**МІНІСТЕРСТВО ОСВІТИ І НАУКИ, МОЛОДІ ТА СПОРТУ УКРАЇНИ**

**НАЦІОНАЛЬНИЙ ЛІСОТЕХНІЧНИЙ УНІВЕРСИТЕТ УКРАЇНИ**

# ЛІСОВЕ ГОСПОДАРСТВО, ЛІСОВА, ПАПЕРОВА І ДЕРЕВООБРОБНА ПРОМИСЛОВІСТЬ

# Forestry, Forest, Paper and Woodworking Industry

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У статтях збірника містяться матеріали наукових досліджень і проектно-конструкторських робіт, спрямованих на вдосконалення технології та техніки лісового господарства, лісової, паперової, деревообробної промисловості та економіки.

Збірних розрахований на наукових, інженерно-технічних працівників, а також студентів, які виявляють інтерес до наукової діяльності.

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# DESIGN CALCULATIONS OF MAIN COMPONENTS AND PARAMETRIC SUBSTANTIATION OF CABLE YARDING SYSTEMS USED IN GROUP-SELECTION FELLING OPERATIONS

Presented in this work are configurations of cable yarding systems used for timber extraction from the cutting area and mechanization of group-selection felling operations. The relationships between dynamic loads and selection of tightening force for the running skyline have been determined. An analysis of analytical dependences was made, and recommendations were given concerning the selection of main parameters of the system.

**Keywords:** cable rigging, felling, loads, parameters.

A considerable practical experience and the studies done by loggers and foresters have shown that exploitation of montane forests requires the use of special equipment and technologies which would permit to conserve in the fullest measure the ecosystems not only in the mountain regions but also in the adjacent flat country. The recently adopted regulatory acts prohibit clear felling in mountain regions, also they impose more rigid requirements on the machinery and equipment used in logging operations [1, 2, 3]. Many researchers have been engaged in the development of environmentally-sound technologies and equipment for exploitation of montane forests [4, 5, 6]. New types of cable yarding system have been proposed in recent years [7, 8, 9], the introduction of which will allow for meeting the requirements on the exploitation of montane forests, also this will promote the mechanization of group-selection felling operations [10]. Fig. 1 represents the configuration of a cable yarding system for extraction of timber from the cutting area.

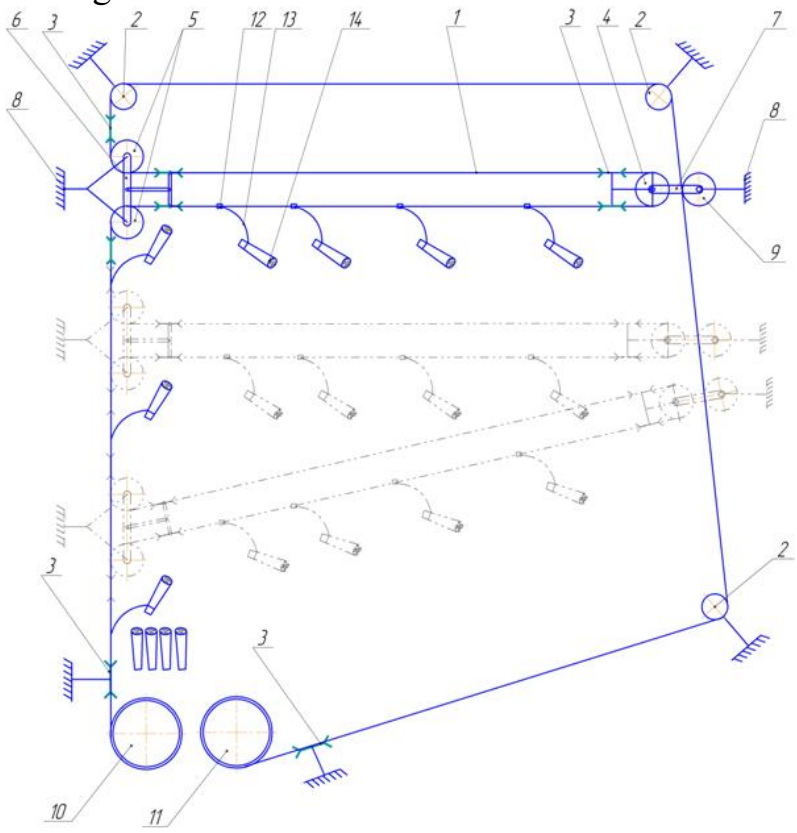


***Fig. 1. Cable yarding system for extraction of timber from the cutting area***

Positions II and III designated by dot-and-dash line, show the variants of relocation of intermediate supports of the cable system when preparing a successive corridor. The cable yarding system consists of the running line 1 that passes over corner-2, bearing-3, and movable blocks 4, 5, and the latter ones, in their turn, are structural elements of corresponding articulated bearing-guide twin-block carriages 6 and 7 which are fixed to detachable intermediate supports 8, the bearing-guide carriage 7 therewith is attached to the detachable intermediate support 8 by means of movable bearing blocks 9.

The transportation of logs is done by means of a driving drum 10 and a haul-back drum 11 with a drive unit (not shown), (also there may be a version with a cable-driving pulley). The tightening and slackening of the cable 1 is done by means of the haul-back drum 11 and the corner blocks 2. The quick-detachable grapple-transporting device 12 is fastened to logs 14 by means of a special choker-equipped cable 13.

Safety transportation of load through the carriage blocks is provided by availability of complementary cable-holding flanges in the corner and bearing blocks, the spacing between the flanges being $b+\delta$ ($\delta = 5...10$ mm – technological clearance). These flanges get in contact with the working bearing part of the grapple-transporting device the width of which being equal to $b$. The configuration of cable yarding system designed for mechanization of group-selection felling operations is shown in Fig. 2.

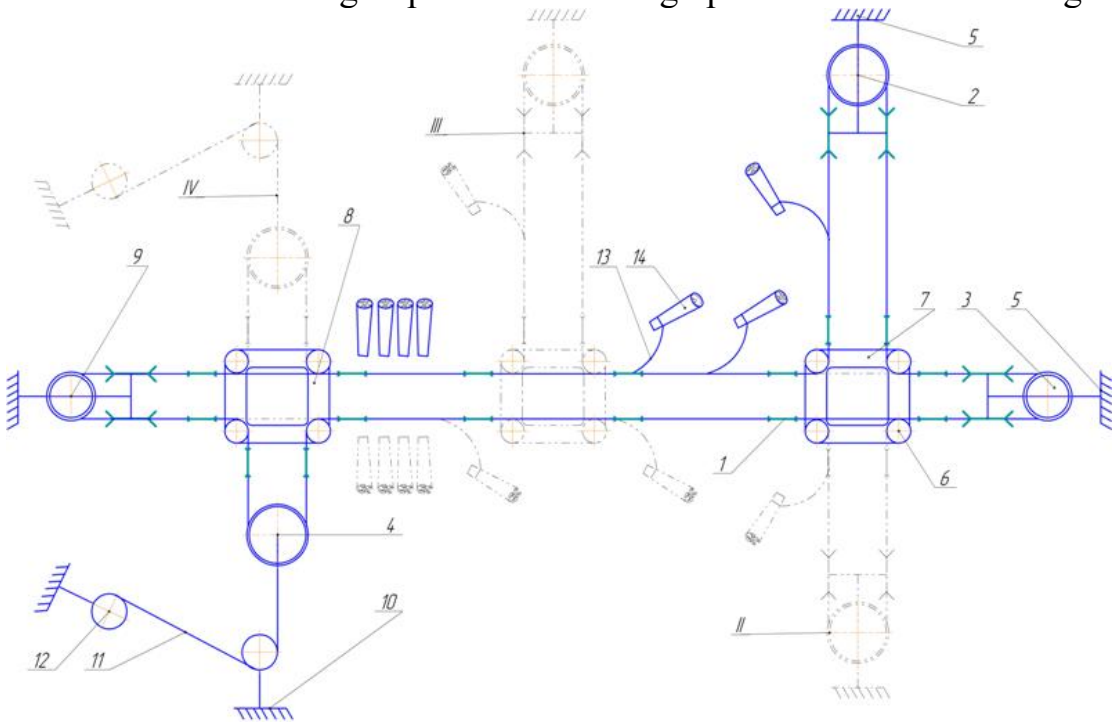


***Fig. 2. Configuration of cable yarding system designed for mechanization of group-selection felling operations***

Positions II and III, depicted by dot-and-dash line, in Fig. 2 show variants of relocation of the intermediate support of the cable yarding system when preparing a successive logging corridor. Position IV shows a location variant of tightening line of the cable system. The cable yarding system consists of the running line 1 which passes over corner blocks 2 and 3; loose block 4, and the latter ones, in their turn, are fastened to detachable intermediate supports 5 through blocks 6 of the guide-bearing carriages 7 and 8, and through a cable-driving pulley 9 with a drive unit (not shown), (there also may be a version with two drums instead of the cable-driving pulley). The tightening and slackening of the cable 1 is done by means of the loose block 4, the corner block 10, the ca-

ble 11, and the driving drum 12 as well as the guide carriage, which constitutes a tensioning device for one line of the running line 1. The grapple device is fastened to logs 14 by means of a special choker cable 13. In order to design systems of this type, it is necessary to work out a procedure for calculating their elements and then to substantiate the main parameters. The main component of the cable yarding system presented here is a running skyline. The calculation scheme for such systems is presented in Fig. 3.

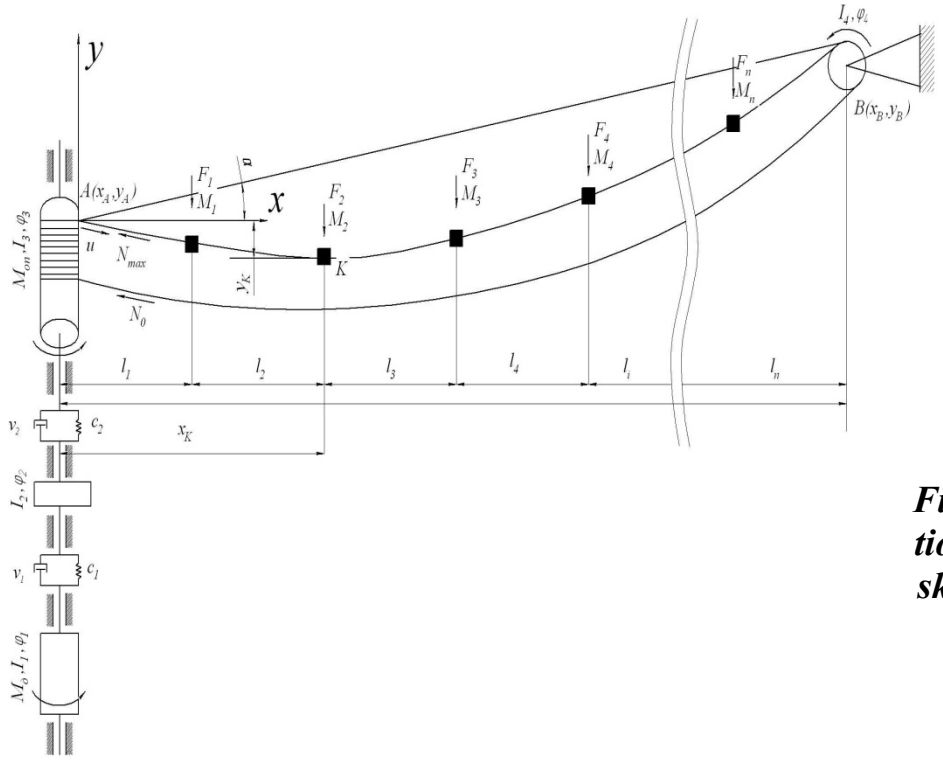


***Fig. 3. Calculation scheme for skyline systems***

The movement pattern of the system presented can be described by the second-order non-homogeneous differential equations [11]

$$\left.\begin{aligned} I_1 \cdot \ddot{\varphi}_1 + C_z(\varphi_1 - \varphi_3) &= M_\partial \\ I_z \cdot \ddot{\varphi}_3 - C_z(\varphi_1 - \varphi_3) &= -M_{on} \end{aligned}\right\}, \tag{1}$$

where: $I_1$ – general moment of the inertia of gyrating mass of the engine; $I_z$ – reduced moment of the inertia of the cable system mass; $\varphi_1, \varphi_3$ – angles of twist of the corresponding masses; $C_z$ – reduced rigidity of transmission lines; $M_\partial$ – engine starting torque; $M_{on}$ – moment of the drive resistance,

$$I_z = I_2 + \frac{I_3}{i_2^2} + \frac{N_k \cdot \vartheta_k^2}{g \cdot \omega_o^2}, \tag{2}$$

where: $I_2, I_3$ – moments of the inertia of gyrating mass of the drive; $i_2$ – gear ratio of the drive; $\omega_o$ – angular speed of the driving drum; $N_k, \vartheta_k$ – respectively, tension and travel speed of the running line.

In series connecting of the system's components, the reduced rigidity can be derived from the equation

$$\frac{1}{C_z} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_k}, \tag{3}$$

where: $C_1, C_2$ – rigidity values of individual components of the drive; $C_k$ – rigidity of the system: running line-support,

$$C_k = \frac{E_k \cdot A_k}{l_k} = \frac{E_k \cdot A_k}{l_{ok} + \varphi_3 \cdot r_3}, \tag{4}$$

where: $E_k$ – elastic modulus of the system: cable-support which depends on the cable tensioning and support's rigidity [12]; $A_k$ – metal cross-sectional area of the cable; $l_k$ – the cable length which is considered to be linear function of rotation angle of the drum; $l_{ok}$ – initial value of the cable length; $r_3$ – the drum radius;

$$E_k = \frac{E}{1 + \frac{E \cdot A_k}{\sum_{i=1}^{n} \frac{l}{\cos\alpha}} \cdot k_o}, \quad (5)$$

where: $E$ – elastic modulus of the cable; $l$ – span length of the system; $\alpha$ – angle of slope of the span chord to the horizon line; $k_o$ – displacement factor of the supports,

$$k_o = \frac{\delta_л + \delta_{np}}{N_{max} - N_o} = \frac{1}{C_{on}}, \quad (6)$$

where: $(\delta_л + \delta_{np})$ – total displacement of the left and right supports, respectively; $C_{on}$ – rigidity of elastic supports; $N_{max}, N_o$ – maximum and installation tensioning of the cable, respectively.

However, the running line and the load in the cable system perform complex motion, which should be taken into consideration when solving the system of equations (1).

In order to solve the system of the given equations and enable practical implementation of the mathematical model, a number of assumptions were made: the cable has a shape of ladder lines that intersect at the point of load attachment; the supports influence on the change in the system's rigidity is taken into account by means of the system's reduced rigidity; gyrating mass of the drive is reduced to the engine shaft; dissipation function is of linear character and is dependent on tractive resistance coefficient of individual components of the system; transverse oscillation of the system cable is considered in vertical plane.

The maximum tensioning of the cable can be determined by method of static calculation by catenary line [13, 14]. By using this method, the system of equations for determining the parameters of the running line can be presented as follows

$$\left.\begin{aligned} y_k &= C_{1i} ch \frac{x_k - C_{2i}}{C_{1i}} - C_{3i}; \\ C_{2i} &= \frac{1}{2}\left( x_м + x_k - 2C_{1i} arth \frac{y_м - y_k}{l} \right); \\ C_{3i} &= C_{1i} ch \left( \frac{\frac{1}{2}\left( x_k - x_м + 2C_{1i} arth \frac{y_k - y_м}{l} \right)}{C_{1i}} \right) - y_A \end{aligned}\right\}, \quad (7)$$

where: $C_{1i}, C_{2i}, C_{3i}$ – parametric coefficients of catenary lines; $i$ – the numbers of the cable lines, $i = 1...n$.

At the beginning of calculations, the interaction force values between the cable lines are given [14]. The maximum tensioning of the cable can be determined by

$$N_{max} = N_o ch \frac{(x_B - x_A)q}{2N_o} + arsh \frac{(y_B - y_A)q}{2N_o sh \frac{(x_B - x_A)q}{2N_o}} + N_o, \quad (8)$$

where: $N_o$ – installation tensioning of unloaded line of the cable; $q$ – weight per linear meter of the cable. In order to provide for safe coupling of the cable with the driving pulley (drum), there should be the following dependence between the maximum and installation tensions [15]

$$1{,}25\frac{N_{max}}{N_o} \le e^{\mu\alpha}, \qquad (9)$$

where: $\mu$ – coefficient of cable-on-pulley friction; $\alpha$ – the angle of contacts of the cable with the driving pulley.

The common solution of the equations (8, 9) will enable to determine the forces that occur in the running line. The moment of resistance, which the drive is overcoming, can be determined by taking into account the total resistance to the system motion

$$\begin{aligned} &\sum M_i \cdot \nu_i + \left(C_k + C_б\right)\cdot\left(x - \varphi_3 \cdot r_3\right) - \nu_k\left(\omega_3 \cdot r_3 - \vartheta_k\right) - \\ &- \nu_б\left(\omega_3 \cdot r_3 - \vartheta_в\right)\cdot r_3 = -\frac{M_{on}}{r_3}; \quad M_{on} = N_{(t)} \cdot r_3 \end{aligned}, \qquad (10)$$

where: $M_i$ – the weight of loads that are being transported; $\nu_i$ – coefficient of linear resistance; $\nu_k, \nu_б$ – coefficient of linear resistance for the cable and drum, respectively; $C_б$ – rigidity of the driving drum; $\omega_3$ – angular speed of the drum in operation; $\vartheta_k, \vartheta_в$ – linear speeds of the cable when approaching the drum, and the loads in the system span; $N_{(t)}$ – the cable tension that occurs at a given point in time.

The common solution of the equations (1, 8, 9, 10) will enable to determine the forces in the running line and select appropriate rigidity values for the system components, the weight of loads, and the speed of their movement depending on the system design features and operational conditions. As an example, let present diagrams of force variation in the running line as a function of the system's length and the weight of loads (Fig. 4). The calculations were performed on PC by means of the "MATKAD-14" program by using a subroutine of the numerical Runge-Kutt method for the following data: $\alpha = 30°$; $F_1 = F_2 = ...F_n = 5\,kH$; $l_1 = l_2 = ...l_n = 20$ m; $\vartheta = 0...3$ m/sec; the cable standard being GOST 2688 – $d_k = 22.5$ mm. The other data were taken in keeping with the recommendations [11, 12, 14] for cable yarding systems and their drives.

In order to determine dynamic load that takes place during operation, the cable longitudinal oscillation should be considered.

The longitudinal oscillation that shows movement of the cable along the axis $A_x$ (Fig. 3). If it is taken that the cross-sections remain flat during operation while the cable is moving along the axis, the cable tension in any cross-section can be expressed as

$$N_д = E_k \cdot A_k \cdot \frac{\partial U}{\partial \zeta}, \qquad (11)$$

where: $N_д$ – dynamic constituent of the cable tension; U – transferring function, $U = U(\zeta, t)$.

The general view of the system's oscillation can be obtained by way of superposition of series of main simple oscillation that corresponds to normal coordinates $\psi_1, \psi_2, ...$ . For any coordinate $\psi_i$, the general solution will be as follows [16]

$$\psi_i + n_i^2 \cdot \psi_i = \frac{1}{a_i}\Phi_i;\ n_i^2 = \frac{C_i}{a_i}, \qquad (12)$$

where: $a_i, C_i$ – are constants that describe the design and properties of the system; $\Phi_i$ – generalized force that corresponds to the coordinate $\psi_i$.

The generalized force can be expressed by the cable tension

$$\Phi_i = N_{(t)} \cdot sin\left(\frac{2n+1}{2} \cdot \pi\right). \quad (13)$$

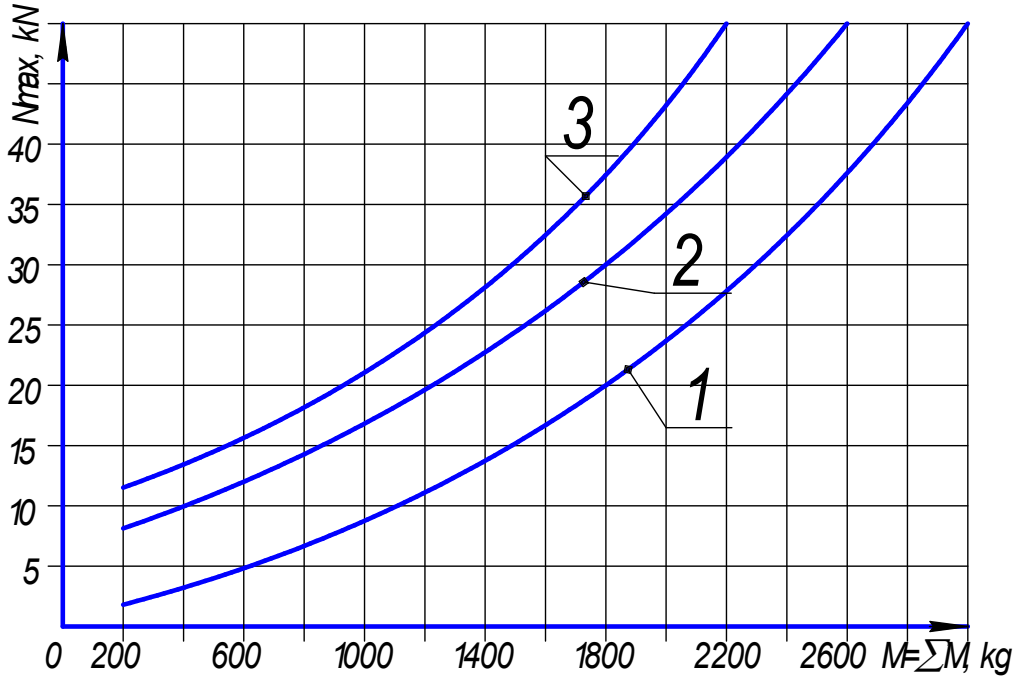


***Fig. 4. Curves of variation of the running line maximum tension as a function of the system parameters:***
*1 – l=100 m;*
*2 – l=200 m;*
*3 – l=300 m*

Provided that the origin of coordinates is point A while the axis is directed along the cable axis (Fig. 4), boundary conditions are found then at points A and B

$$U_{/\zeta=0} = 0; \quad \frac{\partial U}{\partial \zeta_{/\zeta=l}} = 0. \quad (14)$$

Then the general expression for transferring in normal coordinates can be written as follows

$$U = \sum_{n=0}^{\infty} \varphi_n \, sin\left(\frac{2n+1}{2} \cdot \frac{\pi}{l_k} \cdot \zeta\right). \quad (15)$$

From the formula (15) we will find $\frac{\partial U}{\partial \zeta} = \sum_{n=0}^{\infty} \varphi_n \cdot \frac{2n+1}{2} \cdot \frac{\pi}{l_k} \cdot cos\left(\frac{2n+1}{2} \cdot \frac{\pi}{l} \cdot \zeta\right)$ (16)

By substituting the value $\frac{\partial U}{\partial \zeta}$ into the formula (11) we will obtain the expression for determining the dynamic tension of the cable

$$N_{\partial} = E_k \cdot A_k \cdot \sum_{n=0}^{\infty} \varphi_n \frac{2n+1}{2} \cdot \frac{\pi}{l_k} \cdot cos\left(\frac{2n+1}{2} \cdot \frac{\pi}{l_k} \cdot \zeta\right). \quad (17)$$

An analysis of the dependence (17) will allow to obtaining the magnitude and characteristic of dynamic constituent of the cable tension which occurs during operation of cable yarding systems.

The diagram (Fig. 5) shows the mode of change in the tension $N_{\partial}$ for the following data: $l = 300$ m; $\alpha = 30^o$; $m = \sum_{i=1}^{n} M_i = 3000$ kg; $n = 5$; $l_i = 60$ m; $N_{max} = 80$ kH. From these curves, it is obvious that the dynamic tension amounts to 8-15 % of $N_{max}$

depending on the cable travel speed, which should be taken into consideration when selecting individual components for the system. The employment of the above methodology under given operational conditions, boundary and initial conditions as well as known parameters and specifications of individual components, will enable to determine main design and performance parameters of systems of this type, which would make it possible to design reliable and competitive cable systems that will meet the requirements of forest management and logging.

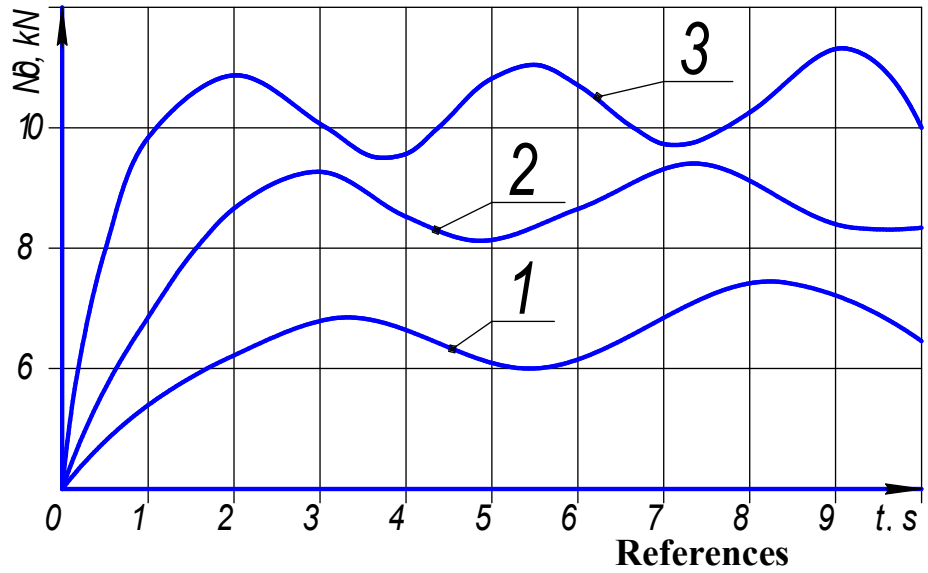


***Fig. 5. Diagrams of dynamic loading change as a function of the cable movement speed:***
*1 – ϑ = 1 m/sec;*
*2 – ϑ = 2 m/sec;*
*3 – ϑ = 3 m/sec*

**References**


1. **Правила рубань** в гірських лісах Українських Карпат. – К.: Держкомлісгосп, 2003. – 24 с.
2. **Закон України** “Про мораторій на проведення суцільних рубок на гірських схилах в ялицево-букових лісах Карпатського регіону” 10.02.2000. № 1436 – III И // Відомості Верховної Ради України, 2000. – № 8. – с. 221-236.
3. **Про затвердження** “Правил рубок головного користування в гірських лісах Карпат”. / Постанова Кабінету Міністрів України від 22.10.08 р. №92911. Урядовий кур’єр. – 12.11.2008.
4. **Мартинців М.П., Бадера Й.С.** Розробка еколого-зберігаючих технологій та механізмів для освоєння гірських лісів. // Наук. вісник. Матеріали Міжн. конф. “Лісотранспорт в Карпатах: традиції, реалії, перспективи розвитку” – Львів: УкрДЛТУ, 1998. – Вип. 9. – с. 121-129.
5. **Бадера Й.С.** Теоретичні основи вибору системи машин для освоєння гірських лісів. // Наук. Вісник : зб. науково-техн. праць.– Львів : НЛТУ України, 2006. – Вип. 16.5. – с. 62-68.
6. **Адамовський М.Г., Мартинців М.П.** Вибір типів та основних параметрів канатних установок для освоєння гірських лісів. // Лісове госп-во, лісова, паперова і деревообр. пром-сть. – Львів: УкрДЛТУ, 2004. – Вип. 29. – с. 69-73.
7. **Бадера Й.С., Мартинців М.П., Сологуб Б.В., Кий А.В.** Канатна установка. // Патент на корисну модель № 37289; B61B12100, зареєстровано 25.11.2008 р. Бюл. № 22.
8. **Бадера Й.С., Бариляк В.В., Боратинський О.В.** Канатна установка. // Деклараційний патент на корисну модель № 17058; B61B12100, зареєстровано 20.02.2006 р., Бюл. № 9.
9. **Бадера Й.С., Бариляк В.В., Боратинський О.В.** Канатна установка. // Деклараційний патент на корисну модель № 17087; B61B12100, зареєстровано 28.02.2006 р., Бюл. № 9.
10. **Криницький Г.Т., Делеган І., Землинський С., Савич І.** Особливості формування лісових фітоценозів на букових зрубах Українських Карпат. // Наук. вісник. Матеріали Міжн. конференції “Лісотранспорт в Карпатах: традиції, реалії, перспективи розвитку”.– Львів: УкрДЛТУ, 1998. – Вип. 9. – с. 26-32.
11. **Мартинців М.П., Сологуб Б.В., Матіїшин М.В.** Динаміка та надійність підвісних канатних систем. Монографія. – Львів: Видавництво Львівської політехніки, 2011. – 188 с.
12. **Адамовський М.Г., Мартинців М.П., Бадера Й.П.** Підвісні канатні лісотранспортні системи. – К.: ІЗМН, 1997. – 156 с.
13. **Качурин В.К.** Теория висячих систем. – М.: Гостехиздат, 1962. – 224 с.

14. **Мартинців М.П.** Розрахунок основних елементів підвісних канатних лісотранспортних установок. Монографія. – К.: Ясмина, 1996. – 175 с.

15. **Энтин Г.Я.** Распределение усилий в гибких растяжимых нитях, охватывающих абсолютно жесткие шкивы // Функциональный привод гибкого тягового органа. – М.: Машгиз, 1963. – 86 с.

16. **Горошко О.А., Савин Г.Н.** Введение в механику деформируемых одномерных тел переменной длины. – К.: Наукова думка, 1971. – 224 с.

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## Розрахунок основних елементів і обгрунтування параметрів канатних лісотранспортних систем для групово-вибіркових рубок

Запропоновано схеми підвісних канатних лісотранспортних систем для збору деревини з площі лісосіки та механізації групово-вибіркових рубок. Отримано залежності для вибору натягу тягово-несучого канату з врахуванням динамічних навантажень. Виконано аналіз аналітичних залежностей і наведено рекомендації для вибору основних параметрів установки.

**Ключові слова:** канатне оснащення, рубки, навантаження, параметри.

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UDC 630*116.28

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## DISTRIBUTION, STRUCTURE AND PRODUCTIVITY OF OAK STANDS IN WEST UKRAINE

Oak forests in the study region cover an area of 461.5 thousand ha, which amounts to nearly 27.1% of Ukraine's oak forests. The age structure of the stands analyzed, is essentially disturbed. A major portion is made up of middle-aged stands (over 57.2%), somewhat less is represented by stands of sapling stage (21.1%), and the smallest part is made up of mature stands (6.3%). It has been found that in the most representative forest type (moist hornbeam oakery) in the western part of the study region, a substantial proportion of the area is occupied by secondary stands. For oak stands of fertile site type forests in the study region, a clear-cut relationship is shown between the increase in the area of secondary stands and periods of improperly conducted silvicultural measures of oak trees tending.

**Keywords:** oak stands, oak forests, structure, productivity.

According to the complex forest management zoning, the forest-steppe region occupies the central part of Ukraine as well as a considerable part of the study region extending from its western to eastern border. The western Forest-steppe includes the districts of the Volyn heights, Male Polissia, Rostochia and Opillia, the Prut-Dnister district and North- Western Podillia [1, 3]. The eastern border of this region coincides with the wastern border of Khmelnytsk region. The relief of the forest management district is broken: there are deep river valleys, gullies and ravines. The most commonly encountered types of soil in this area are Loess grey forest soils and Loess-like clay Loams; also degraded chernozem soils are occasionally found there [1]. The characteristic feature of Forest-steppe is alternation of steppe and forested areas among which an oakery-type of forest is the most widespread (Fig.1).

The forest cover of the study region varies depending on the soil-an-climatic conditions. In particular in the western and the northern parts, predominant are pine-oak, pine and alder stands on soddy podzolic soils. The central part with its prevailing middle-productive soils boasts of beech, oak-beech and oak forests. In the eastern part of the forest management district, hornbeam-oak forests growing on the highly productive neutral and leached chernozem soils, occupy the greatest area [3].

The pre-Carpathian forest management district occupying the southern part of the study region, is located to the south of the Forest-steppe zone and is bordered by the Carpathians along the line that runs from the western border of Ukraine through Borislav, to the north of Bolehiv, to the south of Kolomyia, towards Beregomet and to the border with Romania. The most abundant types of soil in the forest management district involved, are soddy middle-and highly podzolic soils. The most representative stands are oak stands the composition of which gradually changes: from pure oak and hornbeam-oak stands to fir-beech-oak and fir-oak ones in the south-eastern part, and beech-fir in its south-western parts [3].

***Fig.1. The distribution of oak stands in the Forest-steppe part of the study region***

Common oak is one of the most valuable tree species growing on the territory of Ukraine and within the study region in particular. Oak-participating stands in addition to being a valuable raw material source, fulfill most important soil protection, water-regulation, water-conservation and recreational functions. By absorbing a considerable amount of surface water, they substantially diminish the surface, run-off and subsequently, reduce water erosion. The powerful root system of common oak tree helps the formation of drought-resistant stands, which is of great importance for creation favourable microclimatic conditions on the adjaicent area of their distribution [4, 6].

In the past the geographic range of common oak was much wider than the present one, but in response to adverse environmental effects as well as intensive human management activity, its range of distribution has significantly reduced in size. The oak forests suffered the most losses in the study area during the period of $16^{th}$-$19^{th}$ centuries. The intensive forest cutting contributed to a decrease in the area of highly-productive oak forests, in the past war period, beginning in 1950s-1970s, the excessive exploitation resulted in considerable reduction in forest cover percentage in Lviv, Ivano-Frankivsk, Ternopil and other regions. For example, from 1946 through 1956, the forest cover percentage in the above mentioned regions decreased: in Lviv region- by 0.9 %, Ivano-Frankivsk region- by 1.5 % and in Ternopil region- by 0.5 % [3, 5 ].

At the same time, since the mid-20th century, a tendency for an increase in the area occupied by oak-predominant stands has became evident in Ukraine. As of January 01, 1962 oak-predominant stands occupied an area of 1318400 ha, or 19.2 % of the total area while in 1966- 1419000 ha (20.1 %) and as of January 01, 1966 their area increased to 1710300 ha [7]. According to the statistics data on the forest area inventory in 2002, the total oak stands area of the government agency of forest resources in Ukraine,

amounts to over 1.7 mln ha, which corresponds to nearly 27 % of the forested area within the western Forest-steppe and the pre-Carpathians zone, oak-participating stands cover over 461500 ha, that is about 27.1 % of the oak stands total area in this country. The most part of oak-predominant stands within the study region is in Lviv region (over 95600 ha), somewhat less in Ternopil region (81900 ha), and in Khmelnytskyy region (78600 ha). The figures fall far short in Rivne region (58000 ha), Volyn region (58000 ha), Ivano-Frankivsk region (59100 ha) and in Chernivtsi region (30000 ha), the distribution of which being considered for the study region (Table 1). In the above mentioned regional forest management administrations, coppice stands constitute nearly one percent of the oak stands area, the average volume of which in Lviv regional forest management administration amounts to only 118.8 $m^3$ per ha where as the average volume of oak-participating high forests amounts to 189,6 $m^3$ per ha. Similar feature is observed also in other regional forest-and-game management administrations.

In particular, the average volume of coppice oak stands in Ternopil region amounts to 134.9 $m^3$ per ha while the volume of high oak stands is 182.9 $m^3$ per ha in Rivne region- 104.5 $m^3$ per ha and 174.2 $m^3$ per ha, in Ivano-Frankivsk region – 124.0 $m^3$ per ha and 160.7 $m^3$ per ha, respectively. Somewhat higher are the productivity indexes for oak stands in Chernivtsi region where the volume of oak coppice stands averages to 175.5 $m^3$ per ha while 211.5 $m^3$ per ha for highstands and in Khmelnytsk region – 177.9 $m^3$ per ha and 193.1 $m^3$ per ha, respectively.

**Table 1. The dynamics of variation in oak stand area in the Forest-steppe zone and the pre-Carpathians according to year classes**

| Species | The year of inventory | Seedling-stage stands | Sapling-stage stands | Middle-aged stands | Maturing stands | Mature and over mature stands | Total, ha | Percentage of forest cover area |
|---|---|---|---|---|---|---|---|---|
| Lviv regional forest-and-game management administration | | | | | | | | |
| Common oak | 1960 | 18623.0 | 16716.0 | 16566.0 | 4240.0 | 2854.0 | 58999.0 | 13.6 |
| | 1980 | 18520.0 | 20196.0 | 26919.0 | 6178.0 | 4112.0 | 75925.0 | 18.3 |
| | 2002 | 6352.0 | 21048.0 | 54831.0 | 8567.0 | 4863.0 | 95661.0 | 22.2 |
| Ternopil regional forest-and-game management administration | | | | | | | | |
| Common oak | 1960 | 29533.0 | 12447.0 | 14477.0 | 627.0 | 1042.0 | 58126.0 | 39.9 |
| | 1980 | 13756.0 | 33578.0 | 24697.0 | 3566.0 | 1168.0 | 76765.0 | 52.6 |
| | 2002 | 5773.0 | 15769.0 | 53662.0 | 4875.0 | 1832.0 | 81911.0 | 57.3 |
| Khmelnytskyy regional forest-and-game management administration | | | | | | | | |
| Common oak | 1960 | 15398.0 | 12528.0 | 10188.0 | 568.0 | 184.0 | 38866.0 | 23.5 |
| | 1980 | 10442.0 | 16845.0 | 18230.0 | 2615.0 | 335.0 | 48467.0 | 29.9 |
| | 2002 | 8785.0 | 15219.0 | 42540.0 | 7159.0 | 4975.0 | 78678.3 | 46.7 |
| Rivne regional forest-and-game management administration | | | | | | | | |
| Common oak | 2002 | 4237.0 | 11476.0 | 30542.0 | 3032.0 | 8714.0 | 58001.0 | 10.0 |
| Volyn regional forest-and-game management administration | | | | | | | | |
| Common oak | 2002 | 4964.0 | 13009.0 | 32426.0 | 3552.0 | 4130.0 | 58081.0 | 14.1 |
| Ivano-Frankivsk regional forest-and-game management administration | | | | | | | | |
| Common oak | 2002 | 5419.0 | 15067.0 | 34361.0 | 3032.0 | 1312.0 | 59191.0 | 13.5 |
| Chernivtsi regional forest-and-game management administration | | | | | | | | |
| Common oak | 2002 | 2089.0 | 5673.0 | 15813.0 | 3093.0 | 3339.0 | 30007.0 | 18.8 |
| In total for the study region | 2002 | 37619 | 97261.0 | 264175.0 | 33310.0 | 29165.0 | 461530.0 | 19.8 |

Our analysis of the oak stands area dynamics in the western Forest-steppe and the pre-Carpathians has shown a gradual increase in the oak stands-occupied area beginning in 1960. However there is a dangerous tendency for a decrease in the area occupied by oak stands of younger year classes. In particular, an essential decrease in the oak stands area has been seen for a 10-year class. For example, according to the results of a year 2002 forest inventory in Lviv region, the area of oak stands aged up to 10 years amounted to only 1062,1 ha whereas it was equal to 87280 ha in 1960. Similar tendency was revealed in our study for the same year class in other regional forest management administrations. Such variations in the area of oak stands for some year classes will result in disproportions in the stands age structure [7]. The research that we conducted with the use of statistics data, shows that the age structure of oak stands in the study region has been essentially disturbed. In particular, the middle-aged oak-participating stands in Lviv regional forest management administration occupy the largest area (49.4 %) while the amount of mature and over mature stands is much lower (9.7 %) and the least is the amount of seedling-stage stands (6.7 %). Similar tendency of oak stands age distribution is typical of other regions (Fig.2).

As is apparant from the results of our study, the most significant variations in oak stands age structure is characteristic of Ternopil regional forest management administration where the middle-aged stands occupy over 65 % of the oak forest area. It should be pointed out that this year class is represented without exception in all forest management administrations of the study region. The representativeness of middle-aged oak stands varies from 52.7 % in Rivne and Chernivtsi regions to nearly 58.1 % in Ivano-Frankivsk regional forest-and-game management administration. The greatest amount of sapling stage oak stands in the study region is found in Ivano-Frankivsk forest-and-game management administration. The smallest area amond mature stands of the stydy region is occupied by stands in Ternopil (1832.0 ha) and Ivano frankivsk regions, which amount to only 2.2 % of their total area [3, 6].

The thorough analysis of the peculiarities of growth and productivity of oak stands in the study region made it possible to mark some characteristic features of this process. In particular, the highest average increment (from 3.5 to 4.5 $m^3$ per ha) is characteristic of the stands aged 21 to 40 years. The trend has been toward a gradual decrease in the average increment of oak stands aged 10 years and over, it is most evident in Lviv, Rivne, Ternopil, Ivano-Frankivsk, Volyn, and Chernivtsi regional forest-and-game management administrations.

Somewhat different pattern of the variations of the index value for the average annual increment was marked for oak stands in Khmelnytskyy region. For example, the highest index value for the average increment of the middle-aged stands was equal to 3.8 $m^3$ per ha. The highest index value for the average volume is characteristic of mature oak-participating stands in Chernivtsi regional forest management administration (over 328 $m^3$ per ha), Ternopil region (244 $m^3$ per ha) and Khmelnytskyy regional forest management administration (over 237 $m^3$ per ha). This index value is much lower in Ivano-Frankivsk region (222 $m^3$ per ha), Lviv region (217 $m^3$ per ha) and Rivne forest-and-game management administration. The optimum growth conditions have been created for oak-participating stands within the study region, at the same time, the existing site conditions are not exploited to the best advantage. In particular, a considerable amount of heat that comes onto the ground surface in the study region is combined with

appropriate amount of moisture, which creates proper conditions for growing oak stands of the first site class. However, the study that we conducted, points to the fact that environmental potential is not utilized to the full advantage (Fig. 3).

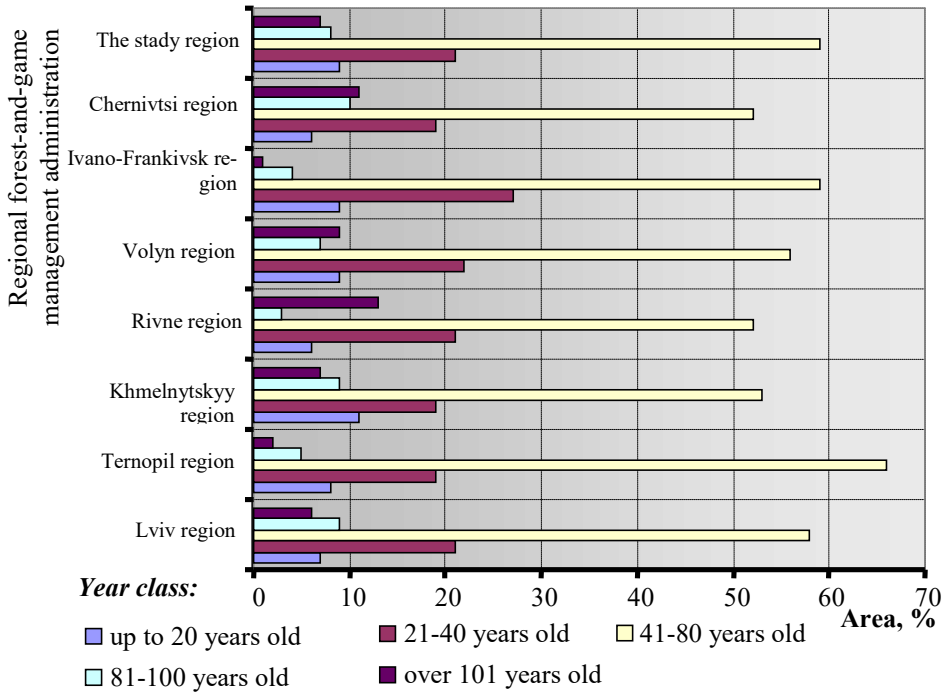


***Fig. 2. The correlation of the oak stands areas of different year classes within the study region***

It has been pointed out that the productivity of oak-participating young-growth stands on the territory of some forest-and-game management administrations, corresponds to the volume of oak stands of the first site class. However, the results of further analysis of the productivity of oak-participating middle-aged stands shows essential reduction in their volume (nearly by 25 %) compared with stands of the first site class. The decrease in the volume is even more striking for the maturing (up to 30 %) oak stands as well as mature and over mature stands (over 70 %) within the study region as compared with stands of the first site class. This is due to to several reasons.

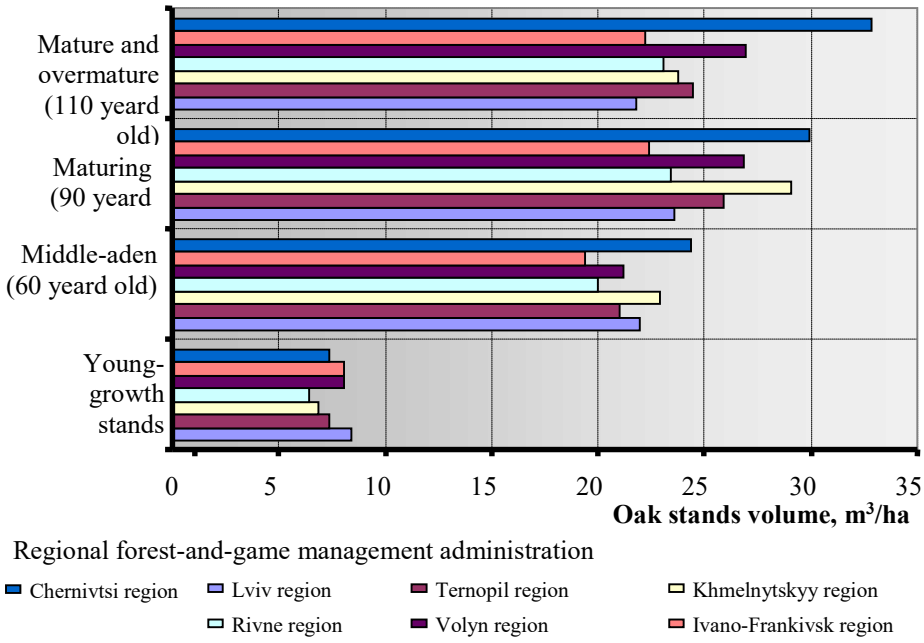


***Fig.3. The average index values for oak stands volume in the forest-and-game management administrations of the study region***

One of them is improvement cuttings that are not conducted timely, which results in overtopping and suppressing common oak trees by associated tree species. Also high

intensity of belated improvement cutting, excessive and unreasonable removal of common oak trees in middle-aged and maturing stands during improvement cutting may contribute to lower final productivity. There is one more reason for this: unsufficient attention is given to natural regeneration of oak stands by seed [3,6,8].

By convention, the study region can be divided into two parts which are distinguished by their differing indexes of average annual precipitation. For example, the central, eastern and southern parts of Lviv region, the west of Ternopil region, the north-western part of Ivano-Frankivsk region differ essentially in their amount of precipitation from the central and southern parts of Ternopil and Khmelnytsk regions. The average annual amount of precipitation in the central part of Lviv region makes up 700 to 742 mm whereas 750 to 800 mm in the pre-Carpathians. The amount of precipitation decreases drastically and makes up 500 to 600 mm in the north-western part of Podillia region which includes the central, southern and north-eastern parts of Ternopil and Khmelnytsk regions, the northern parts of Ivano-Frankivsk and Chernivtsi regions.

The peculiarities like this result in the dominance of moist forest type in the western part of the study region, namely moist hornbeam oakery and fairly moist hornbeam oakery in the east [2,3]. With the aim to make more in-depth study of the peculiarities of oak stands formation under conditions of prevailing forest type in the study region, we analyzed the stands in the subsidiary "Lviv Lisgosp" ( Lviv forest management). The forest area of "Lisgosp" is represented by fairly large tracts of oak, pine and beech forests. The oak forests are formed by common oak and largerly occupy the elevated terrain with claim-loam soils. The most abundant are fairly fertile site type of forest with participations of common oak, common pine as well as associated species such as hornbeam, maple, lime-tree, elm, ash, birch, sycamore maple. The fairly fertile site type of forest is more often found in forest management units situated to the east, west and south of the city of Lviv. The productivity of most forest types is rather high. The age structure is not uniform. The greenspace forests around Lviv tend to have increasing share of mature and maturing stands. In keeping with the results of our studies, it should be noted that percentage of secondary stands is progressively increasing, which has an assentially detrimental effect. According to investigation of many researchers, it is generally taken that naturally-originating stands are the most resistant to adverse environmental effects and anthropogenic impacts, the stands of this type most closely correspond to primary ones in their structure and morphological characteristics. To conduct a typological analysis, we selected a moist hornbeam oakery, one of the most representative (4 185.3 ha) and valuable forest type in the subsidiary "Lviv Lisgosp".

This forest type is common to Krasiv, Lypnyky, Vynnyky, Lapaivka, Borshchovychy and Tovshchiv forest management units. The larges forested area occupied by moist hornbeam oakery is in Lapaivka forest management unit (over 1 330.0 ha), the smallest (255.0 ha) is in Lypnyky forest management unit. The highest percent of forested land occupied by moist hornbeam oakery (over 41 %) is in Tovshchiv forest management unit while the lowest percent is in Lypnyky forest management unit (10.7 %).

The typological analysis made for the given type of forest in the above mentioned forest management units, has revealed essential fluctuation in the rate of typological potential use for different year classes. In particular, the lowest rate of using typological potential is noted for year classes of 11 to 20 years (50.9 %) and 61 to 70 years (32.1 %). The highest rate of using typological potential and the absence of variation in year

classes is characteristic of Lapaivka, Borshchovychy, Krasiv and Vynnyky forest management units. The typological analysis allowed to find that the average age of moist hornbeam oakery stands varies from 50 years in Borshchovychy and up to 65 years in Vynnyky forest management unit. The highest average actual volume of oak stands of this forest type – over 270 $m^3$ per ha – was recorded in Vynnyky forest management unit while the lowest (about 208 $m^3$ per ha) in Lypnyky forest management unit, whereas potential average volume of standard stands is higher in Vynnyky forest management unit by 43 $m^3$ per ha, and almost by 73 $m^3$ per ha in Lypnyky forest management unit. Similar tendency is typical of other forest management units as well.

The division of oak stands into primary and secondary ones made it possible to reveal a sizable proportion of secondary stands, which essentially influences the productivity and resistibility of stands. The percent of secondary stands is especially high in Vynnyky (over 73 %), Borshchovychy (over 71 %) and Krasiv (63.6 %) forest management units (Table 2). A more thorough analysis of the forest type in question in Borshchovychi forest management unit made it possible to reveal the main causes of excessive presence of secondary stands. As a result of our study, it has been found that the percentage of secondary stands aged up to 10 years, amounts to 100 %, which points to the fact that the first cleanings are not given proper attention. The highest percent of secondary stands was established in the period 1983-1993 and from 1963 to 1973. The lowest percent of secondary stands was formed in Borshchovychy forest management unit in the period from 1913 to 1923 (57.8 %) and from 1933 to 1943 (47 %), which testifies to proper attention given to common oak tending at the beginning of the life cycle.

**Table 2. Division of forest management subsidiary " Lviv Lisgosp" stands into primary and secondary according to their density**

| № з\п | Forest management unit | Total area, ha | The distribution of forest covered areas according to density, ha % | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Primary | | | Secondary | | |
| | | | 1.0-0.8 | 0.7-0.5 | < 0.5 | 1.0-0.8 | 0.7-0.5 | < 0.5 |
| 1 | Lypnyky | 255,0 | 46.0/18.0 | 83.2/32.6 | 5.4/2.1 | 57.6/22.6 | 62.8/24.6 | |
| 2 | Vynnyky | 501,0 | 22.6/4.5 | 109.4/21.8 | 2.4/0.4 | 95.7/19.1 | 235.5/47.0 | 35.4/7.0 |
| 3 | Krasiv | 577,2 | 124.2/21.5 | 85.4/14.8 | - | 57.7/10.0 | 309.2/53.6 | |
| 4 | Borshchovychi | 737,2 | 65.9/8.9 | 146.3/19.8 | - | 273.4/37.1 | 252.3/34.2 | |
| 5 | Tovshchiv | 782,6 | 144.4/18.5 | 338.4/43.2 | - | 123.6/15.8 | 176.2/22.5 | |
| 6 | Lapaivka | 1331,6 | 247.8/18.6 | 411.5/30.9 | 21.4/1.6 | 282.6/21.2 | 332.9/25.0 | 35.4/0.3 |
| | Total | 4185,3 | 651.6/15.6 | 1174.2/28.1 | 29.2/0.7 | 890.6/21.3 | 1368.9/32.6 | 70.8/1.7 |

It is of interest to mark a fact that was revealed during the process of making the typological analysis of the forest type prevailing for a given part of the region. In particular, it was found that secondary oak stands in Urmantsi forest management unit subsidiary "Berezhany lisgosp" that were established in the period 1904-1923, from 1944 to 1953, and in the period 1974-1993, dominate over primary oak stands (Fig. 4). It was in these periods when little attention was given to the regeneration of oak stands and especially to timely conducted oak tending. Improvement fellings the aim of which is removing secondary tree species that suppress the growth and development of oak trees, if not done in due time, result in the establishment of secondary stands over a large area (Fig. 5). In Vynnyky forest management unit subsidiary "Yarmolun Lisgosp", the largest part of secondary stands was formed in the period 1902-1941. The regeneration of primary oak stands was not given a proper attention in this period. That period saw intensive removal

of oak stands for the needs of sugar-producing and other industries. Large areas of secondary stands also appeared in 1920s, 1930s and 1940s, which is accounted for by lack of silvicultural practices and targeted activity of forest management for regeneration of primary oak-participating stands. In succeeding decades, the area of primary stands increased considerably and is dominating over the area of secondary stands.

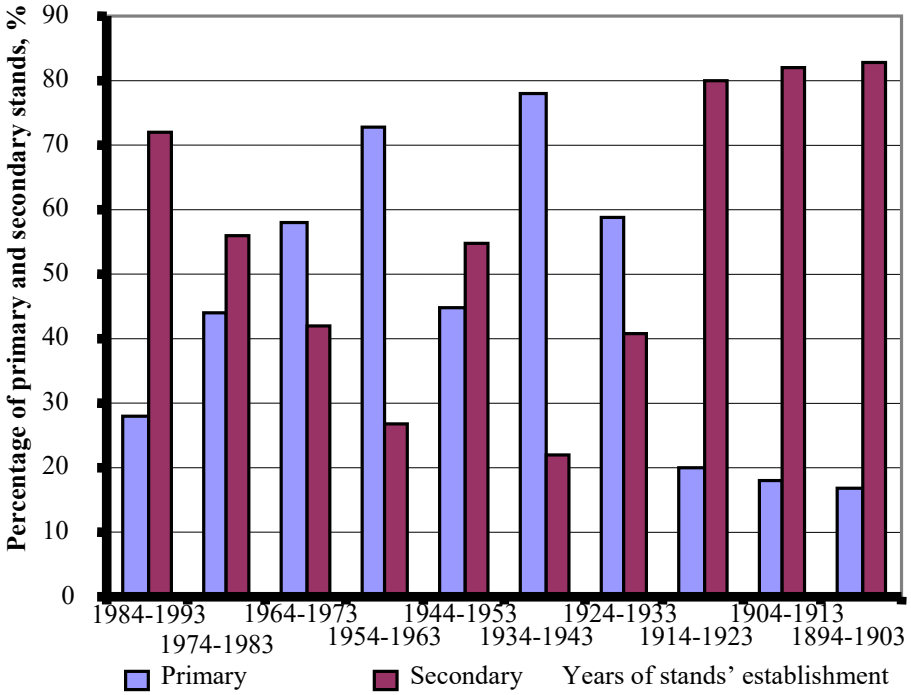


***Fig. 4. The correlation of the primary and secondary stands by age structure in the Urmanci forestry***

The essential dominance of primary stands over secondary oak stands in seedling and sapling stages, points to the efficiently conducted silvicultural measures during the process of regeneration and growing oak stands in the period from 1974 to 1993.

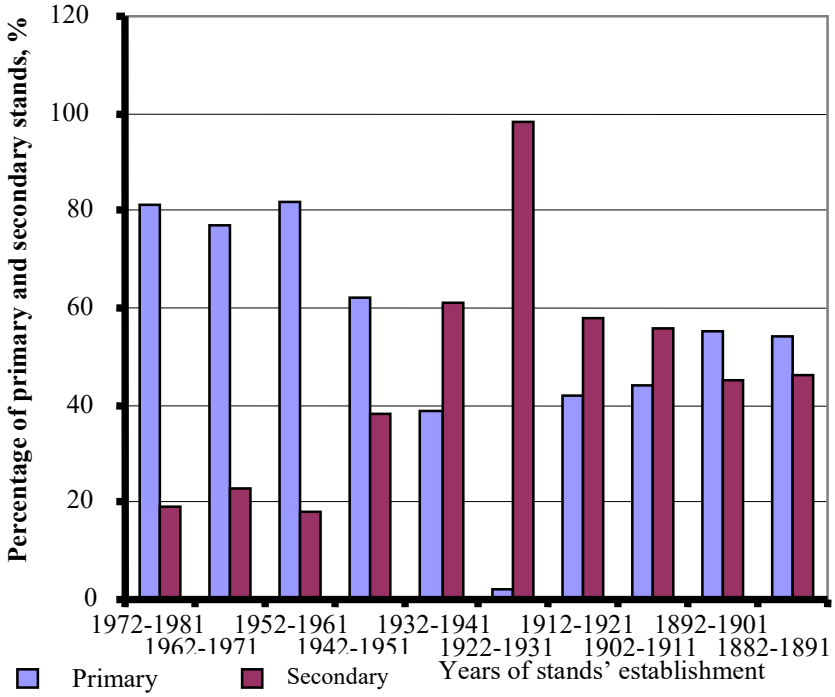


***Fig. 5. The correlation of the primary and secondary stands by age structure in the Vinkivci forestry***

## Conclusions:

- For oak stands of fertile site type forests in the study region, a clear-cut relationship is shown between the increase in the area of secondary stands and periods of improperly conducted silvicultural measures of oak trees tending. The most part of secondary stands in Urmantsi forest management unit subsidiary "Berezhany Lisgosp" was formed in the period 1904-1923, 1944-1953 and from 1974 to 1993. The most part of secondary stands in Vynnyky forest management unit was formed in the period 1902-1941.

- Oak forests in the study region cover an area of 461.5 thousand ha, which amounts to nearly 27.1 % of Ukraine's oak forests. The most part of common oak-participating stands is concentrated in Lviv region (over 95.6 thousand ha), somewhat less amount of oak stands is found in Ternopil region (78.6 thousand ha).
- It has been found that in the most representative forest type (moist hornbeam oakery) in the western part of the study region, a substantial proportion of the area is occupied by secondary stands. Large areas of secondary stands are found in Vynnyky forest management unit (over 73 %), Borshchovychy (over 71 %) and in Krasiv forest management unit subsidiary "Lviv Lisgosp" (over 63.6 %).
- The age structure of the stands analyzed, is essentially disturbed. A major portion is made up of middle-aged stands (over 57.2 %), somewhat less is represented by stands of sapling stage (21.1 %), and the smallest part is made up of mature stands (6.3 %).

## References


1. **Комплексное лесохозяйственное районирование Украины и Молдавии.** / [С.А. Генсирук, С.В. Шевченко, В.С. Бондарь и др.]. – К. : Наукова думка, 1981. – 360 с.
2. **Воробьев Д.В.** Типы лесов европейской части СССР / Д.В. Воробьев. – К.: Изд-во АН УССР, 1963. – 450 с.
3. **Генсірук С.А.** Ліси Західного регіону України / С.А. Генсірук, М.С. Нижник, Л.І. Копій. – Львів : Атлас, 1998. – 408 с.
4. **Дубравы СССР** (Том 1) : В 2 т. / [Всесоюзный научно-исследовательский институт лесного хозяйства]. – М. : Гослесбумиздат, 1949. – 352 с.
5. **Дубравы СССР** (Том 2) : В 2 т. / [Всесоюзный научно-исследовательский институт лесного хозяйства]. – М. : Гослесбумиздат, 1949. – 164 с.
6. **Копій Л.І.** Основні аспекти регіональної програми збільшення лісистості західного регіону України / Л.І. Копій // Наук. вісник УкрДЛТУ. – Львів. – Вип. 9.8. – 1999. – С. 134-140.
7. **Короткий довідник лісового фонду України** / Державний комітет лісового господарства України (За матеріалами обліку лісів на 1 січня 2002 року). – Ірпінь, 2003. – 149 с.
8. **Криницкий Г.Т.** Лесоводственно-экологические аспекты естественного семенного возобновления старовозрастных насаждений грабовых дубрав Украины / Г.Т. Криницкий, Л.И. Копий, Я.П. Целень, С.Л. Копий // Наука о лесе XXШ века: матер. межд. научно-практ. конф., посвященной 80-летию Института леса НАН Беларуси, Гомель, 17-19 ноября 2010 г. / Институт леса НАН Беларуси, 2010. – С. 214-217.



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## Поширення, структура та продуктивність дубових насаджень заходу України


Проведено аналіз поширення дубових лісостанів в межах регіону досліджень. Подано динаміку зміни площі лісових насаджень, особливостей типологічної структури, продуктивності за участю дуба звичайного в західній частині України в межах Західного Лісотепу та Прикарпаття. Досліджено специфіку співвідношення корінних та похідних дубових деревостанів в умовах сфіжих та вологих грабових дібров.



**Ключові слова:** дубові насадження, дубові ліси, структура, продуктивність.


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UDC 639*1



***Assoc. prof. P.B. Khoyetckyy – UNFU***


## THE DYNAMICS OF BEAR POPULATION IN THE EASTERN CARPATIANS


In the dynamics of bear population in the Eastern Carpations, there are two recorded periods of change in the numbers. The first one that lasted over 50 years, started in the late 1940s and ended in the year 2001. The second one has started in the early 21-st century.



**Keywords:** population, hunting, environmental factors, poaching.

The brown bear (*Ursus arctos* L.) numbers in the Eastern Carpathians had been rather considerable up to the mid – 19th century, their number, however, began to decrease dramatically through overhunting, reduction in the forested area; this led to the prohibition against hunting on bears in the 1930 s. After World War II, in the late 1940 s, the bear population counted only several tens of animals (70 to 80 individuals) [18, 21, 23, 24]. In the 1970 s, there was an increase in the number of the species due to protective measures taken as well as improvement of their habitat conditions, as a result bears numbers reached their peak i.e. over 1000 individuals. However, a decrease in the species population in the 1990 s caused a serious concern about the future of this species [2, 7, 8, 25]. On the basis on the fact that the annual reduction in the bear numbers averaged 28 individuals, this species was predicted to extinct in the Eastern Carpathians within a 12-year period [9]. The species was entered into Ukraine's Red Book just on the grounds of the species number reduction without conducting a detailed analysis of the population dynamics and the factors which influence the numbers of the predator etc. [8]. That is why the purpose of this work is to analyze the bear population dynamics in the Eastern Carpathians as well as to reveal the factors causing these changes. This beast of prey is common under mountainous conditions of the Carpathians in four regions: Lviv region, Ivano-Frankivsk region, TransCarpathians, and Chernivtsi region. The dynamics of bear numbers in these regions shows an increase in the population size in the period from the 1940 s to 1968. The years 1968 shows the maximum size of bear population: 1,236 individuals. In the year that followed (1969), the numbers decreased by 305 individuals, which makes up 24.7 % of the total number of the population.

It is impossible to give any reasonable explanation for substantial decline in the numbers during the period 1969-1970 as well as their abrupt increase by 17.8 % in 1971 (Fig. 1). In the early 1970 s, 1,100 individuals were registered in the Eastern Carpathians. According O. Slobodian, the total number of this species amounted to 1,300 individuals at that time. The difference of 18 % is accounted for by inaccuracy of inventory methods (which may produce an error of up to 20 %), inadequate professional training of the record-keepers, non-observance of the inventory methodology etc. O. Slobodian allows for the inaccuracy of inventory results in the early 1970 s [21].

The over-estimate of bear population size was observed not only in Ukraine but also in other European countries (Poland, Slovakia) [27, 28]. The information on the bear numbers in the Eastern Carpathians is contradictory in some research works [3-5, 10, 13, 17, 18, 20-22, 24], sometimes the difference between researchers' studies and the inventory records on animals done by the users of the game lands, amounted to over 250 individuals (25 %) [20]. According to I. Turianyn [24], the species numbers amounted to 70 individuals in 1947; after 10 years the number of bears was already as much as 484 individuals (in 1956). The population size in other European ranges of bear distribution, in particular Kalinin region, Russia, increased only twice as much within a 15-year period. With the total population size being 400 individuals, the annual increase made up 13 individuals [15]. In Belarus, the micropopulation of 20 head increased annually only by 4 individuals of which one or two little bears failed to live more that one year [12]. Therefore, the increase in the bear numbers by 6.5 times in the Carpathians within a 10-year period is unlikely. According to K. Tatarynov [22], the number of this species in the early 1950 s was estimated at 150 to 200 individuals, having increased by 2.1 to 2.8 times as compared with the 1940 s. If the bear numbers amounted to 70 indi-

viduals in 1947, this population could reach over 200 head in number in the 1950 s with the annual increase rate being 17 to 18 % while the numbers of 600 head was reached in 1960 with the annual increase being about 20 %.

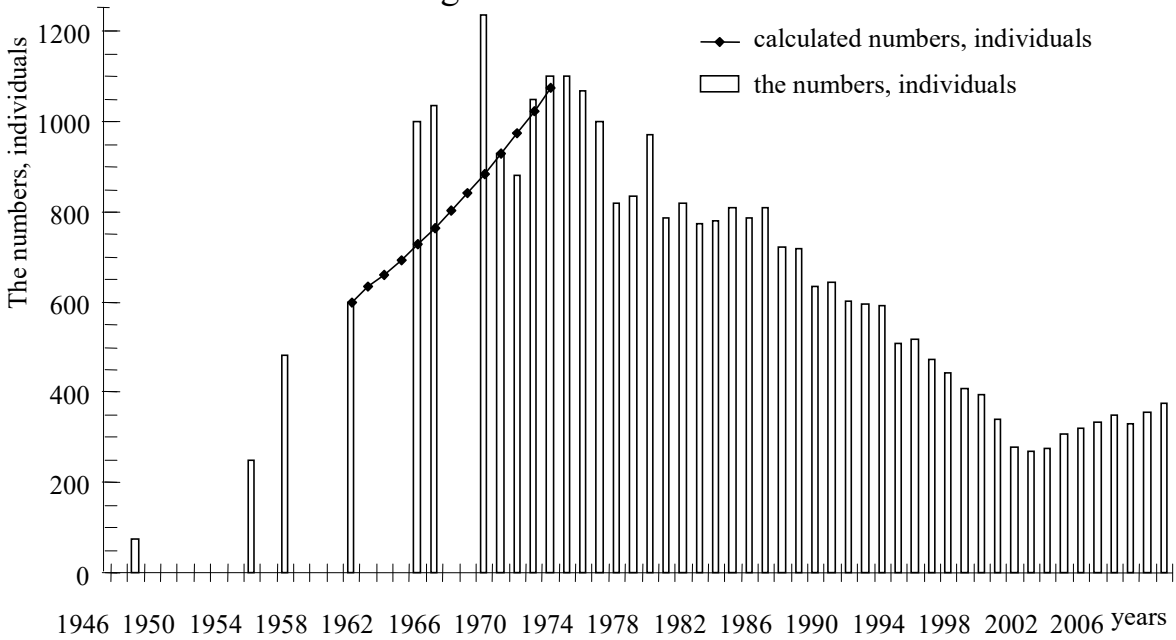


***Fig. 1. Dynamics of the numbers of Ursus arctos in the Ukrainian Carpathians***

Large mammals, in particularly bears, are characterized by a slow rate of reproduction which is accounted for by late maturity, reproduction does not occur every year, and their productive performance is relatively low [19]. That is why the increase in the bear population by 17 to 20 % is essential for the Eastern Carpathians. According to M. Hunchak [7], the increase in some game management units amounted to 19.6 % in the 1990 s. With a knowledge of main parameters of the population (numbers, increase), it is possible to restore the dynamics of the bear population in the Carpathians in the 1960 s. Setting the population size in 1960 at about 600 individuals and the average annual increase rate being 5 %, the bear population size could theoretically reach the numbers of 1000 to 1,100 individuals by the beginning of the 1970 s.

Periodic and regular variations in species numbers are a natural process in the life of any population, which is explained by intrapopulation mechanisms [14]. Two types of numbers dynamics are recognized for wild animals [26]. The first one – labile – is typical of small-sized animals (mouse-like rodentia and others), they have a short life-span and are characterized by high productive performance. The distinctive features of this type are considerable fluctuation amplitudes according to which the population size may vary several–fold, the period duration being 4 to 8 years.

The other type – steady – is typical of large animals that are characterized by big sizes, a long life–span, late maturity, and low productive performance (fecundity). This type is marked by a moderate amplitude and an extended period of the numbers change that may last for several decades [26]. The dynamics pattern of the numbers for each separate species is specific, it results from the interaction of the population with its environment and is a consequence of this species adaptation to specific habitat conditions, which, in its turn, is determined by biological peculiarities of the species. One hypothesis holds that the life-span of a species roughly corresponds to one period of the numbers change [14]. Generally, the life-span of a bear in a zoo makes up 47 years [6], it is shorter under natural conditions and makes up about 20 years [11], sometimes there can

be found individuals aged up to 27-30 years, which gives grounds for researchers to indicate the average age as being within the range of 30 to 50 years [16].

Thus, in the dynamics of bear numbers in the Eastern Carpathians, one may distinguish two periods of the numbers variation. The first one that lasted over 50 years, started in the late 1940 s and ended in 2001. The phase of increasing population lasted over 20 years. The bears numbers reached their peak in the early 1970 s, the population density being about 1.0 individual per 1000 ha. Starting in 1972-1973, a decline in the numbers was registered that lasted up to the beginning of the 21-st century. The smallest numbers (270 individuals) were registered in the year 2001. The duration of the phase of decreasing population was about 30 years. At the beginning of the 21-st century, the population size decreased by four times as compared with the 1970 s, with the fluctuation amplitude of the numbers being nearly 830 individuals.

The second period of the population size change started in 2001 (it is not over yet). During a 8-year period (2001-2009), the number of the species increased by 10.3 %. The average annual increase of the population amounts to 5.4±1.3 % (S=3.1; V=58.0 %). The variation coefficient points to the essential annual variation of increase. Thus, during the study period, the minimum 1.8 % increase of the population was recorded in 2002 while the largest – in 2003 (10.7 %). In general, from 1968 to 2009, the average bear numbers in the Eastern Carpathians amounted to 649.4±28.4 individuals (S=184.4; V=28.4 %), the increase being 5.2±1/1 % and the elimination amounting to 11.1±1.8 %, which is twice as much as the increase.

Direct and indirect human activity, in particular hunting, poaching etc., may be the deciding factor in the change in numbers of game animals, it may influence the dynamics of the population. It should be marked, however, that the effect of hunting on the bear numbers is insignificant and this cannot cause the population number to decrease. In the 1950s, in the Ukrainian Carpathians, approximately 20 animals were hunted according to the issued licenses. In the late 1960s – the early 1970s, the number of hunted animals made up nearly 9 % of the total number of the bear population [5]. From 1991 to 1998, only four individuals were shot in the Carpathians. The maximum permissible Level of hunting on game population is considered to be 15 %, while further escalation of shooting will result in the population decrease [4].

According to the official statistics data, the decline in the population size began in the early 1970 s. At that time, the guarding of game lands was much more efficient that it was in the 1990 s, a period of people's mass impoverishment, weakening of state protection of game animals, the ease of procuring firearms, both smoothbore and rifled. That is why the poaching in the 1970s was not the cause of decrease in the predator numbers while the illegal hunting in the 1990s simply contributed to the depression of the population and prolonged the phase of the numbers decrease. The extent of poaching at the beginning of the 21-st century still remains of sizable proportions, and this may adversely affect the dynamics of the bear population. According to our investigation, poach hunting is responsible for 85 % of registered cases of bear death, of which about 8.7 % of animals are killed by noosing. Totally, anthropogenic factors are responsible for 96.0 % of the registered cases of bear death (Fig. 2). Quite often after the death of a female bear through poaching hunting, the little bears are left to the mercy of fate. Thus, in 1995, in the vicinity of the village of Kozakivka (Ivano-Frankivsk region), a forest guard found two live little bears and the female bear that had been killed by poachers.

The cases like this are not uncommon ones in the Carpathians. There were cases when a female bear left her little bears due to human disturbance. In 1986, in the Bukhtivets forest district (Ivano-Frankivsk region) the foresters were keeping two little bears (female) that had been found in a critical state in the forest without their mother-bear.

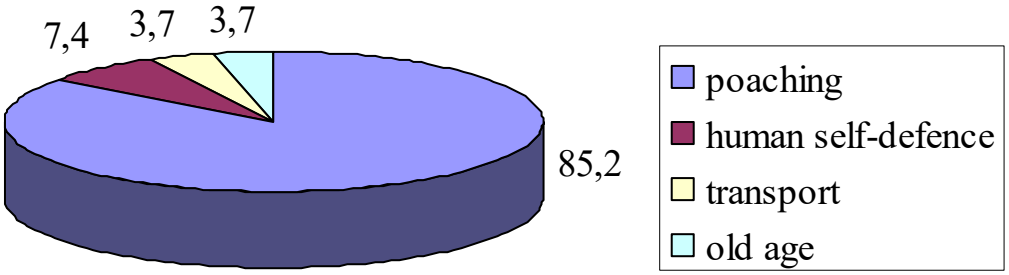


***Fig. 2. Causes of Ursus arctos death in the Ukrainian Carpathians, in %***

At the end of April 2008, a little bear was found in the area of the Bereziv forest district, it was quite exhausted and the female bear was not near-by. Our studies have revealed that no less than 19 bears of various age are being kept in enclosures in three Carpathian regions (Lviv-, Chernivtsi-, and Ivano-Frankivsk regions). The majority of the animals are kept in the enclosures at hotels, motels, restaurants.

**Table 1. Keeping *Ursus arctos* in enclosures (as of 2009)**

| Sex | Age, years | | | | |
|---|---|---|---|---|---|
| | up to 2 | 2-3 | 4-10 | over 10 | not revealed |
| Male | 1 | 1 | 3 | 2 | 1 |
| Female | 1 | 1 | 3 | 1 | 1 |
| Not revealed | - | - | 1 | - | 3 |
| Total | 2 | 2 | 7 | 3 | 5 |

As is seen from Table 1, almost 58 % of the animals are of reproductive age. The ratio of genders is nearly 1: 1. Therefore it is necessary that a rehabilitation centre should be established in one of the natural reserves in the Carpathians (the Skolivski Beskydy National Natural Park, the Carpathian National Natural Park and others) for the purpose of keeping animals there and further introduction of little bears in the wild. The assistance in establishing such centres could be rendered by the International Fund of Animal Welfare (IFAW). A centre of this type has been already organized in Russia. The employees of the centre have managed to rescue and return to the wild over 90 little bears. In particular, the little ones that were kept in the rehabilitation centre and then released to the areas of the Briansky Les Reserve, got accustomed to the place and helped to recover the local bear population that had been degrading due to the prolonged isolation and close-related mating. Direct and indirect human activity may be a determining factor in the change of game animals numbers.

The evidence for human activity impact on the population dynamics could be the bear numbers in the game hunting areas of Ivano-Frankivsk region. In the dynamics of numbers, there are three registered periods of the population decrease: two of them are completed while the third one is still lasting. There is an intimate relationship between the species numbers in the Eastern Carpathians and the population size in the game lands in Ivano-Frankivsk region, which is supported by the correlation coefficient (R = 0.91). The data on the bear inventory is available only from 1965 on, but the above mentioned relationship between the species numbers in the Carpathians and the popula-

tion size within Ivano-Frankivsk region allows for stating the phase of increase in the numbers from the late 1940 s to the early 1970 s. A 1971 bear inventory in the region recorded the maximum number of the animals – 390 individuals. An 8-year period that followed the peak, witnessed a decline in the bear numbers. The first period of the population size change ended in 1978. This period lasted for over 30 years. The numbers of bears decreased by 2.4 times as compared with the early 1970 s (Fig. 3).

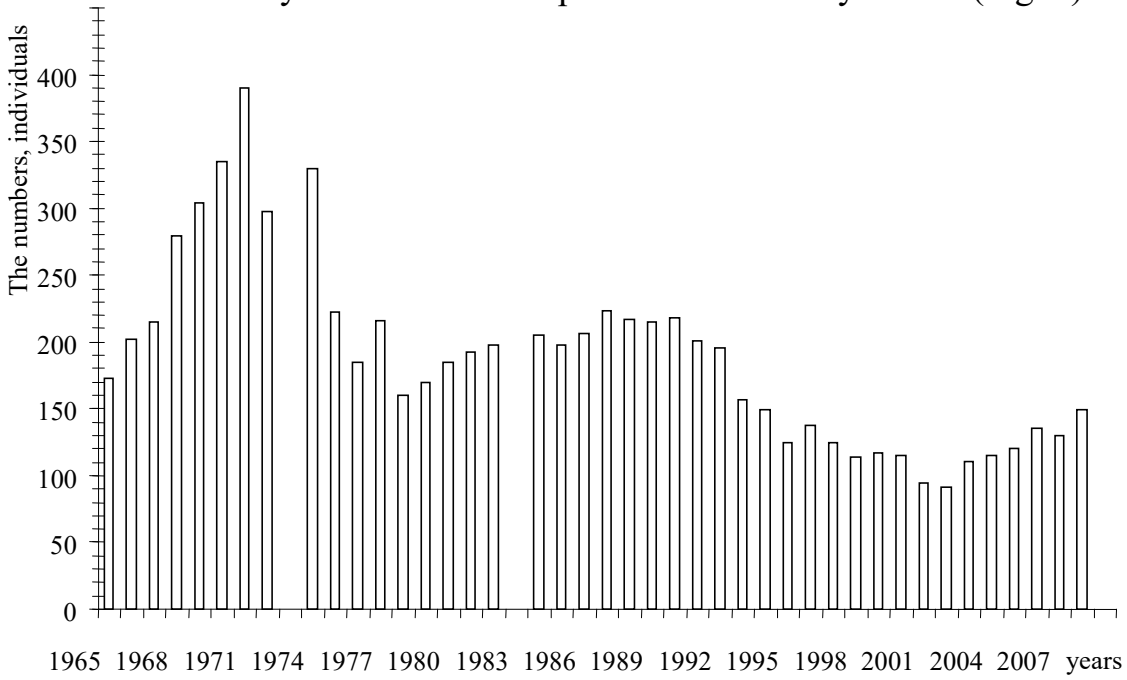


***Fig. 3. Dynamics of the numbers of Ursus arctos in the game lands of Ivano-Frankivsk region***

The second period lasted from 1978 to 2002. An increase in the numbers occurred between 1978 and 1987, the phase duration being 9 years. Bears numbers reached their peak (over 220 individuals) in 1987. During the period from 1984 to 1991, the numbers were steady, over 220 individuals were registered in the region's lands. Starting with 1992, there occurred a decrease in the numbers, illegal hunting being one of the causes. The minimum number of bears (over 90 individuals) was recorded in 2002.

Thus, the second period of the numbers change lasted for 24 years and is shorter than the first one. Most probably, the poaching in the early 1990 s caused the phase of increasing the numbers to change for the phase of decreasing the numbers which lasted for 11 years. The third (incomplete) period is characterized by the average annual increase of 9.9±2.7 % (S=6.1; V=61.5 %) which is higher than in the Carpathians as a whole. The population increased by 1.6 times during a 7-year period (2002-2009).

The numbers of the predators increased also in the game lands of other regions. In particular, the total number of this species increased twice as much in Chernivtsi region. However, the tendency for the population change is influenced by the number of bears in game lands of Ivano-Frankivsk and TransCarpathian regions. There is a very close relationship between the number of this species in the game lands of TransCarpathian region and the Eastern Carpathians (R=0.98) while a slight relationship is registered in the game lands of Chernivtsi region (R=0.16), which is due to the small numbers of bears – about 12 % of the total number of the population.

A slightly negative relationship is registered between the bear population in the lands of Lviv region and the Carpathians which is either due to inaccurate inventory re-

sults or because of considerable fragmentation of the area resulting in the establishment of an isolated bear population that does not have any contact with the main population, thus acquiring the features of a "patch" population. "Patch" population of bears retain their viability even if their population size drops to 35 individuals [1]. The population of bears in the Eastern Carpathians makes an integral part with the bear population in the Southern and Western Carpathians. There is continual migration of bears from Romania to Ukraine's territory, and vice versa. The animals come to the territory of TransCarpathians region during a spring-summer period as disturbance factors increase due to the beginning of sheep-grazing season in the mountain valleys. Thus, migration of bears from the territory of Romania to the adjacent area of the Vyshkiv forest district (State enterprise "Khust forest research centre – SE "Khust FRC") occurs on a regular basis. In particular, a case of coming from Romanian territory of a female bear together with little bears was recorded in march 2005. The lands of SE "Khust FRC" are characterized by favourable conditions for wintering. In 1997, the windfalls in the borderland of SE "Vynogradovo forest management unit" and SE "Khust FRC" threw down a 120 m3 – volume of forest trees, the area was not fully cleared but despite the resulting favourable shelter conditions, the bears did not make their dens there.

In the borderland, on Poland's side, there are no engineering structures, also the fencing on Ukraine's side has been partially dismantled, which furnishes an opportunity for animals to migrate freely from Poland's territory into the interior of Ukraine, and vice versa – to Poland. The translocation of animals across the borderline occurs regularly. Thus, the border guards have registered migration of elk, deer, bison, and bear across the border. In the area of the Bircha gmina (rural council district) that is adjacent to the Poland-Ukraine border. Cases of bear migration from this area to the land of the Dobromyl forest district (SE "Vynogradovo forest management unit") are recorded from time to time. In order to restore the wholeness of bear population within the area of the Eastern Carpathians, it is necessary that ecological corridors should be created. Such corridors need to be created first at the western boundary of the Eastern Carpathians, the area of which is considerably fragmented and heavily populated as compared with other areas of the Ukrainian Carpathians.

Thus, the entering of the brown bear into Ukraine's Red Book was done without due consideration for natural dynamic processes of the species population. Two periods are revealed in the population dynamics in the Eastern Carpathians from the second part of the 20$^{th}$ century to the beginning of the 21-st century. The first period lasted over 50 years, the second one (still lasting) started early in the 21-st century. The periodic and cyclic pattern of the population change may be substantially influenced by human activity, in particular poaching. The illegal hunting prolonged the duration of the phase of decreasing the population number in the 1990 s, and this is the factor which is slowing down the species restoration at the beginning of the 21-st century. That is why the efforts of nature–protection bodies, the huntsmen service of game management units should be directed towards revealing cases of illegal hunting, and preventive measures against poaching should be taken. The restoration of the bear population will be promoted by the establishment of rehabilitation centres and creation of ecological corridors.

**References**

1. **Баскин Л.М.** Бурый медведь в России: есть ли у него будущее // Бюлетень МОИП. Отд. биологии, 1996. – Т. 101. – Вып. 2. – С. 18-28.

2. **Бондаренко В.Д., Хоецкий П.Б.** Проблемы регулирования пространственной структуры популяции бурого медведя // Матер. междунар. научно-техн. конф. “Леса Беларуси и их рациональное использование”. – Минск, 2000. – С. 112-115.

3. **Верещагин Н.** Бурый медведь в СССР // Охота и охотничье хозяйство. – № 3. – 1967. – С. 16-21.

4. **Верещагин Н.** О численности медведей в СССР // Охота и охотничье хозяйство. – № 2. – 1974. – С. 20-21.

5. **Верещагин Н.** Сколько же бурых медведей в СССР // Охота и охотничье хозяйство. – № 11. – 1972. – С. 20-21.

6. **Гептнер В.Г., Наумов Н.П.** Млекопитающие Советского Союза. Парнокопытные и непарнокопытные. – Т. 1. – М.: Высш. шк., 1961.– 776 с.

7. **Гунчак М.** Бурий ведмідь у Карпатах // Лісовий і мисл. журнал. – 1999. – № 5. – С. 25.

8. **Делеган І.В. Делеган І.І.** Обґрунтування необхідності занесення ведмедя бурого до Червоної книги України // Novitates Theriologicae. – 2001. – Pars. 4. – С. 53-56.

9. **Загороднюк І., Слісаренко В.** Загальна характеристика ряду хижих // Ссавці України під охороною Бернської конвенції. – К., 1999. – С. 110-114.

10. **Керечун С.Ф.** Влияние хищников на карпатскую популяцию копытных // Копытные фауны СССР. Экология, морфология, использование и охрана. – М.: Наука, 1975. – С. 197-198.

11. **Кудактин А.Н., Козин Ю.В.** Влияние охоты на популяцию медведей Кавказа // Медведи в СССР. – Новосибирск: Наука, 1991. – С. 79-87.

12. **Лавов М.А.** Бурый медведь в Белоруссии // Экология медведей. – Новосибирск: Наука, 1987. – С. 27-34.

13. **Лобачев В., Честин И., Губарь Ю.** Сколько у нас бурых медведей ? // Охота и охотничье хозяйство. – № 2. – 1989. – С. 28-29.

14. **Лобков В.А.** Крапчатый суслик северо-западного Причерноморья: биология, функционирование популяций. – Одесса: АстроПринт, 1999. – 269 с.

15. **Макаров О., Хохлов А.** К экологии бурого медведя в Калининской области // Экология, морфология, охрана и использования медведей (Материалы совещания). – М.: Наука, 1972. – С. 56-59.

16. **Сиивонен Лаури.** Млекопитающие Северной Европы. – М.: Лесн. пром-сть, 1979. – 232 с.

17. **Слободян А.А.** Влияние ландшафтов Карпат на популяцию бурого медведя // VI Всесоюз. зоогеогр. конф.: Тез. докл. – Кишенев, 1975. – С. 205-206.

18. **Слободян А.А.** Изменения ареала и численность бурого медведя в Украинских Карпатах // Экология медведя. – Новосибирск: Наука, 1987. – С. 12-18.

19. **Слободян А.А.** Некоторые сведения о розмножении и развитии бурого медведя в Карпатах // Экология, морфология и охрана медведей в СССР. Тезисы докл. – М., 1981. – С. 38-39.

20. **Слободян А.А.** Численность бурого медведя в Украинских Карпатах и методика его учета // Медведи в СССР. Сб. нуч. тр. – Новосибирск: Наука, 1991. – С. 73-79.

21. **Слободян О.О.** Бурий ведмідь Українських Карпат. – Івано-Франківськ, 2008. – 159 с.

22. **Татаринов К.А.** Звірі західних областей України. – К.: Вид-во АН УРСР, 1956. – 186 с.

23. **Турянин И.И.** Заметки об экологии, численности и значении бурого медведя в Карпатах // Изучение ресурсов наземных позвоночных фауны Украины. – К.: Наука, 1969. – С. 118-121.

24. **Турянин И.И.** Млекопитающие советских Карпат, их хозяйственное и зоопаразитологическое значение : дис. ... доктора биол. наук : 097. – Ужгород, 1971. – 580 с.

25. **Хоєцький П.Б.** Сучасний стан популяції ведмедя бурого (Ursus arctos L.) в Українських Карпатах // Тематичний збірник. Наукові основи збереження біотичної різноманітності. – Львів: Ліга-Прес, 2000. – С. 64-67.

26. **Яриш В.Л.** Динаміка чисельності благородного оленя та козулі в лісових біоценозах гірського Криму // Заповідна справа в Україні. – Т. 11. – Вип. 1. – 2005. – С. 29-31.

27. **Lehocky Marcel.** Rozmieszczenie, liczebność oraz ochrona niedźwiedzia brunatnego Ursus arctos na Słowacji // Roczniki Bieszczadkie. – 1999 (8). – str. 61-67.

28. **Gula Roman, Frąckowiak Witold.** Niedźwiedź brunatny w Bieszczadach // Monografie Bieszczadkie. – 2000 (9). – str. 103-125.

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## Динаміка чисельності ведмедя у Східних Карпатах

Встановлено, що у динаміці чисельності ведмедя у Східних Карпатах зареєстровано два періоди зміни чисельності. Перший період тривалістю понад 50 років, розпочався у кінці 40-х років XX ст. і завершився у 2001 р. Другий період (триваючий) почався на початку XXI ст. Максимальної чисельності близько 1100 особин поголів'я ведмедя досягнуло на початку 70-х років минулого століття. У понад 85 % виявлених випадків загибелі ведмедя причиною є браконьєрське полювання.

**Ключові слова:** популяція, полювання, чинники середовища, браконьєрство.

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## STATE AND PERSPECTIVES IMPROVEMENT OF FOREST TRANSPORT NETWORK

The state of forest roads network in Ukraine and some countries of Europe is analyzed. The optimum values of forest roads density are substantiated for different geomorphologic conditions on the basis of analysis of forest road planning results.

**Keywords:** forest roads network conditions, model of timber transport development, density of forest roads network.

**Introduction.** Forest roads is a kind of entrance to the forest areas, the possibility of providing its essential functions, rational and ecologically safe use of natural resources, effective functioning of the tourism and recreation industry. Transport routes play a critical role at the forestry production of mountainous area, where forest areas are scattered over a large territory and such territory has the following characteristic features: difficult relief and soil-hydrological conditions, low concentration of harvestable timber per unit area, one-sided cargo traffic and other factors. The development of road networks in forested areas has a positive effect on the intensification and expansion of opportunities for many sectors of the economy and, promote the population with the employment, reduction of staff turnover, improvement of working and living conditions of the population. But so far in Ukraine there is has not been any concept concerning the extension of forest roads network with the recommendations regarding its main parameters and choice of technology of primary timber transportation. The aim of this study is to substantiate the optimal density of forest road network in different geomorphological regions of Ukraine under the conditions of the economically viable use of promising timber transport means.

**The forest road network condition.** It should be noted that the work concerning the investigations of the road network condition of the forest areas in Ukraine, its assessment and inventory are nearly absent. Therefore at first we analyze the data concerning other countries, in particular those that have natural and geomorphological conditions similar to Ukraine. The study [9] provides a detailed analysis of forest access network in neighboring Slovakia, which according to its location, structure and density, should ensure optimal transport accessibility of forestland. Forest access network of this country includes forest road network (Table. 1), intended for the timber hauling by trucks and the

skid road network, intended for the timber skidding by tractor means, and in some cases, and under favorable conditions, for the timber hauling by trucks.

**Table 1. Characteristics of forest transport network in Slovakia**

| Type | Forest roads | | Skid roads |
|---|---|---|---|
| Category | 1L | 2L | Tractor road |
| Purpose | Main hauling | Local hauling | Skidding |
| Peculiarities | - year-round use;<br>- high traffic density | - seasonal use | - unsurfaced road;<br>- constructed acc. to the parameters of the forest roadbed |
| Max. longitudinal slope, % | up to 10 (12) | up to10 (12) | up to 12 |
| Permissible contact pressure, кPa | 650 + | 450-550 | 450 |
| General length*, km | 8534,2/5842, 0 | 11608,3/11092,9 | 13934,1 |
| Density, m/ha | 4,43/3,03 | 6,01/5,74 | 7,23 |

Note: * – as of 1997; in the denominator – road of forestry enterprises.

As seen from the Table 1, the majority of the forest roads (84 %) and all the skid roads are owned by the forestry enterprises. Overall length of forest road network is 34 076.6 km, which determines its density – 17.67 m/ha. However, if one takes into account only forest roads, their density is 10.44 m/ha (that is similar to Ukrainian indicator). According to the recommendations of scientists [9] the optimal density of the forest road network for the geomorphological conditions of Slovakia should be about 20 m/ha, providing the road interval within 400-600 m. Similar recommendations exist for other European countries that basically have been already implemented (Table 2) [8].

**Table 2. The density of forest road network in some European countries**

| Country | Description (name) of the region | Density of the forest road network, m/ha |
|---|---|---|
| Switzerland | Plain | 54 |
| | Jura Mountains | 42 |
| | Foothills | 16 |
| | Alps | 7 |
| Austria | Small areas (up 200 ha) | 37,1 |
| | Forest areas (over 200 ha) | 29,7 |
| | State forests | 22,3 |
| | Mountain forests | 33,3 (8,6) |
| Sweden | Southern part | 20,8 |
| | Central part | 12,0 |
| | Northern part | 7,1 |
| Germany | | up to 55 (from 10) |

Note: in brackets – protected forests.

According to statistics, the total length of roads in the forests of the State Forestry Committee of Ukraine in 2007 was 74.4 thousand km (among them around 17 thousand km (22.8 %) – public roads, which runs through the State Forest Fund) [4]. The density of forest road network is 10.1 m/ha (excluding public roads – 7.8 m/ha). Moreover, this is average index, to which relatively extensive network of roads in low-lying parts of the region significantly affects. In the foothills and in particular the mountain areas this index is much lower and according to our assumptions it varies in the range of 3,5-6 m/ha. This index was obtained by summarizing the data of our own researches (Rozhanka forestry unit of State Enterprise «Slavske forestry») [7], and – researches of Ukrainian Research Institute of Mountain Forestry (State Enterprise «Osmoloda forestry», State Enterprise «Velykyy Bychkiv forestry» and Nyzhniy Bystryy forestry unit of State Enterprise «Khust forestry») [1, 2]. Around 40 % forest areas have the road density less than 4 m/ha. Mountain forest areas, where the density of roads exceeds 10 m/ha

is less than 2 % [3]. Very often, forest roads are in unserviceable condition. In particular, in Nyzhniy Bystryy forestry unit the percentage of the forest roads that need repair or reconstruction is 31.5 %.

To forest transport network it is usually referred unsurfaced or so-called "tractor" roads, which, unlike Slovakia ones, are constructed without complying with the standards of road construction (they are not equipped with the drainage systems, slope of separate parts is more than 30 %, the width of roadbed is mostly less than 4 meters). Even according to these, scattered data, we can conclude that the technical state and main parameters available forest transport network in the Forest Fund of Ukraine does not meet the requirements of sustainable development of forestry, its density is several times lower compared with the European countries with similar geomorphological conditions.

**Modelling of the forest transport development.** In order to provide argumentation of optimum density of road network and means of primary wood transportation we have elaborated a conceptual model of transport development of forest areas, and its algorithm contains the evaluation of all possible expenses for timber skidding, that is a function of roads network density [6] (Fig.1).

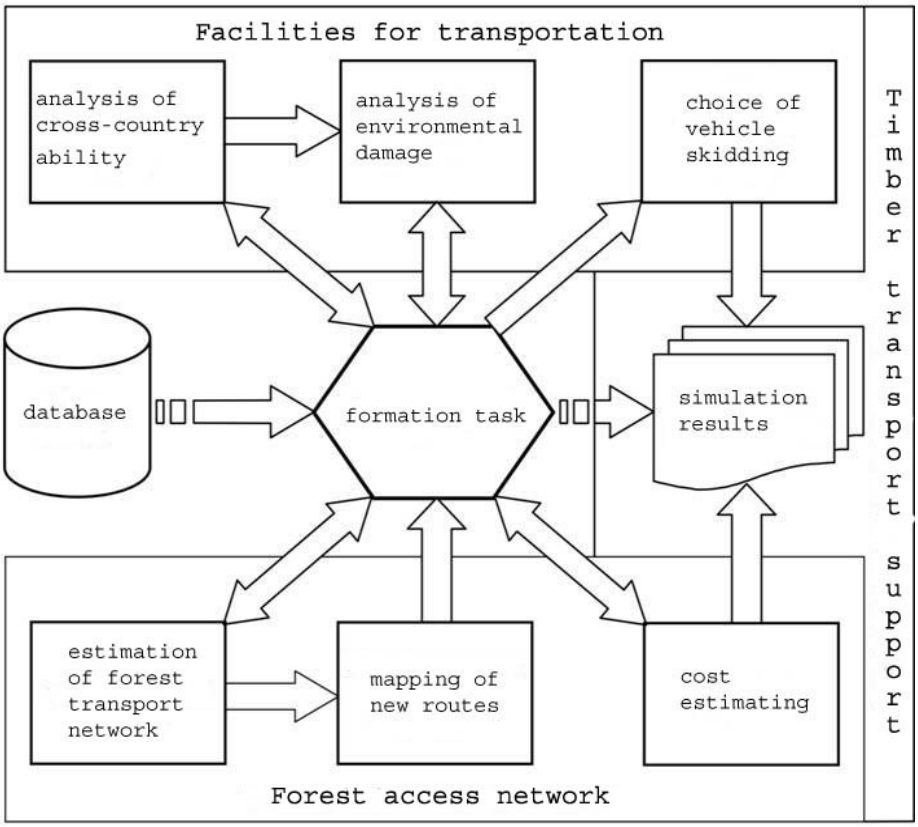


***Fig. 1. Conceptual model of the planning of forest transport development***

One of the blocks of the developed model contains mathematical relations that describe the relationship between the density of the forest road network (DRN) and road interval *s*.

$$s = c_n \cdot c_s / DRN, \quad (1)$$

where: $c_s$ – corrective coefficient of slope $c_S = \cos\nu / \cos\eta$; $c_n$ – corrective coefficient of the forest road network; ν – maximum longitudinal gradient of forest road; η – slope terrain.

Equation (1) can be written for the length of skid roads $l_{sr}$.

$$l_{sr} = c_{sr} \cdot c_n \cdot c_s / DRN, \quad (2)$$

where $c_{sr}$ – corrective coefficient skidding network, which takes into account the angle of contact of skidding lines to the forest automobile road.

The value of **s** is a parameter of transport availability and equals to maximum skidding distance or doubled value under the condition of transportation, respectively, only down the hill (skidder), or up and down the slope (cable system, skidder on the plains). In the a result of the performed modeling of the transport development of forest areas the relations of density of forest transport network from skidding distance were obtained (Fig. 2). These relations relate to wood skidding up and down the slope.

**Research results.** Basing on the performed investigations economically reasonable distance of wood skidding by the means of cableway (350-400 m) and skidder (600-800 m) was determined, as well as the optimal density of the forest roads network for different geomorphological regions of Ukraine that corresponds to this values:

- Carpathian mountainous area (steep hills, slope over 20°), wood skidding by the means of cableway up and down the hill to a distance of 400 m – 17,5-19,0 m/ha;
- Carpathian mountainous area (sloping hills, slope 11°-20°), wood skidding by the means of wheeled skidder down the hill to a distance of 800 m – 16,7-18,0 m/ha;
- flat and hilly terrain (slope up to 10°), wood skidding by the means of skidder up and down the hill to a distance of 600 m – about 11 m/ha.

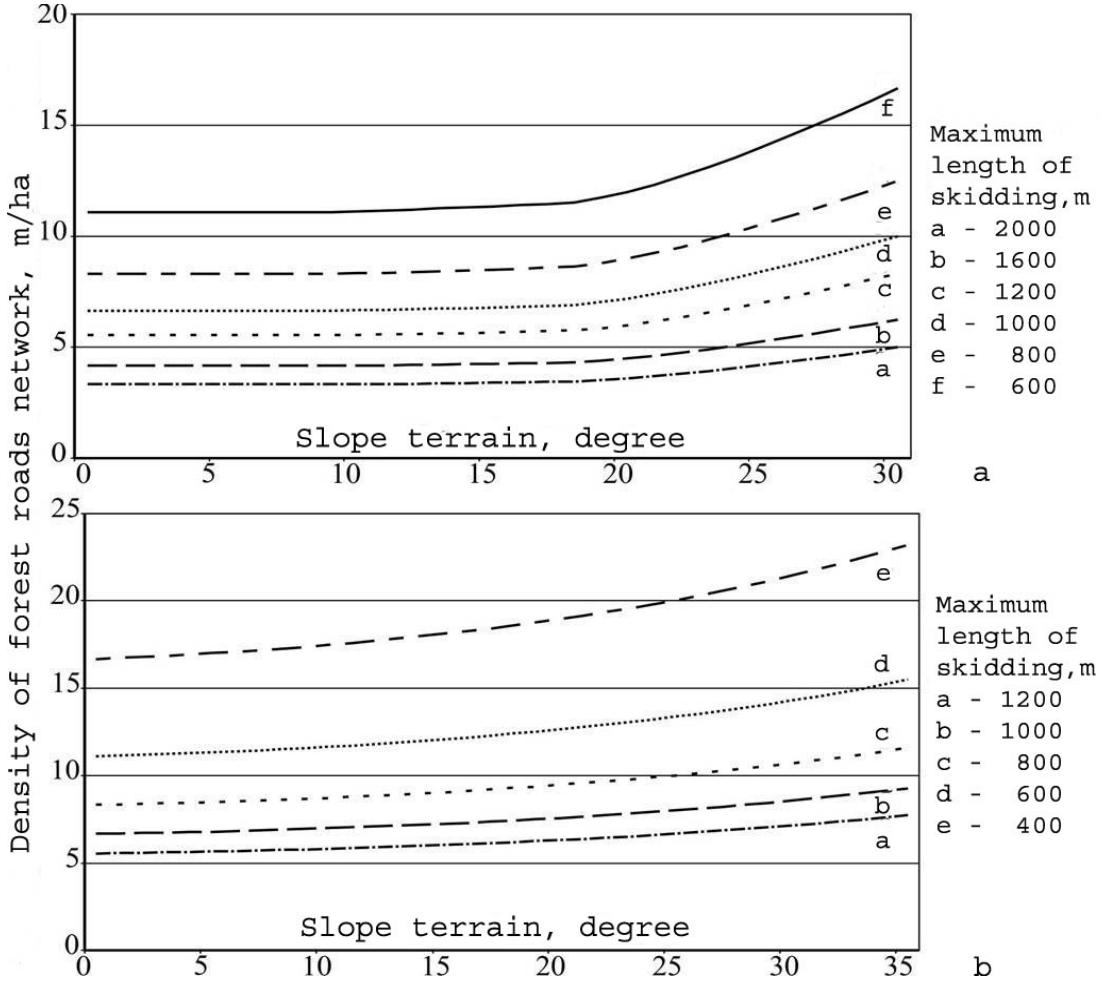


***Fig. 2. Dependence forest road network density from slope terrain, where skidding perform by:*** *a – wheeled skidder; b –cable crane*

According to the recommendation of State Forestry Committee of Ukraine (now – State Forest Resource Agency) forestry companies must construct at their own expense 1 km of forest road for every 25 thousand $m^3$ of final harvest. So, considering that the planned annual volume of final harvest is about 6.4 mil $m^3$, we can determine the annual construction of forest road at expense of forestry companies – more than 250 km.

But the total annual demand in the construction of forest road is about 500 km estimated State Forest Resource Agency [5]. This means that the construction of no less 250 km of forest roads should be financed from State Budget to maintain competitiveness of Ukrainian forestry companies.

**Conclusions.** Conditions forest road network is largely affects the efficiency of forest management in any natural and geomorphological conditions. Forest road network of Ukraine currently doesn't meet the sustainable development of forestry sector, because of it in short term before Ukrainian foresters must be delivered the following urgent tasks:

- to develop a plan of forest access network initially for some model forestry and then for all geomorphological regions;
- to conduct a detailed accounting, inventory and condition inspection, and subsequently to monitor the forest road network with the representation of results in tabular and cartographic form, the most using modern GPS and GIS technology;
- provide increased density of forest road network in mountainous regions, on average to 17 m/ha, and in the plains – at least 11 m/ha, while respecting the annual volume of construction about 500 km of new forest roads, including no less than 250 km at expense of forestry companies.

## References


1. **Бойчук І., Коржов В.** Транспортна мережа // Лісовий і мисливський журнал. – 2005. – №4. – С. 26-27.
2. **Коржов В.Л., Роман Д.І.** Параметри і технічний стан дорожньої мережі в лісфонді Великобичківського ДЛГ // Лісова інженерія: техніка, технологія і довкілля. Науковий вісник : зб. наук.-техн. праць. – Львів: УкрДЛТУ. – 2004, вип. 14.3. – С. 446-452.
3. **Парпан В.І., Коржов В.Л., Корнієнко В.П., Сидорук Ю.К.** До питання екологізації гірських лісозаготівель // Матеріали міжн. наук.-практ. конф. „Наукові основи ведення сталого лісового господарства". – Івано-Франківськ: Екор. – 2005. – С. 203-206.
4. **Пристая О.Д.** Проблема сталого розвитку лісо транспортної інфраструктури та шляхи її вирішення // Автошляховик України . – 2008. – № 5(205). – С. 46-48.
5. **Пристая А.Д.** Спасительный лес // Альтернативное топливо. – 2010. – № 4(32). – С. 32-37.
6. **Стиранівський О.А., Стиранівський Ю.О.** Обґрунтування способу транспортного освоєння гірського лісового масиву // Лісова інженерія: техніка, технологія і довкілля. Науковий вісник : зб. наук.-техн. праць. – Львів: УкрДЛТУ. – 2004, вип. 14.3. – С. 371-380.
7. **Стиранівський О.А., Стиранівський Ю.О.** Природоохоронні засади транспортного освоєння гірських лісових територій: монографія. – Львів: РВВ НЛТУ України, 2010. – 208 с.
8. **Dvorščák P.** Ako dalej vo výstavbe lesných ciest na Slovensku? // Les 7/97. – S. 25-27.
9. **KLČ P.** Sučasný stav a perspektivy realizácie lesných ciest // Lesné cesty – stav a perspektivy ich rozvoja na Slovensku. Zbornik referátov zo seminára. – Zvolen, 1997. – S. 5-20.



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## Стан і перспективи вдосконалення лісотранспортної мережі


Проаналізовано стан лісотранспортної мережі в лісфонді України і деяких країн Європи. На основі аналізу результатів моделювання транспортного освоєння лісового масиву обґрунтовано оптимальні значення густоти мережі лісових доріг для різних геоморфологічних умов .



**Ключові слова:** стан лісотранспортної мережі, моделювання транспортного освоєння, густота мережі лісових доріг.

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# REGRESSION ANALYSIS OF THE REASONS OF EMPLOYEES' OCCUPATIONAL INJURIES OF THE STATE FORESTRY COMMITTEE OF UKRAINE

The analytic dependences for determining the main indices of regression analysis are presented. The correlative dependences of the occupational injury frequency at the plants of the State Forestry Committee of Ukraine in 2000-2009 depending on the volume of the wood logged, costs spent on labour protection, the number of inspections and examinations (instructions) intended per person have been found.

**Keywords:** regression analysis, occupational injuries, coefficient of correlation, coefficient of injury frequency

In the paper [1] the analysis of the occupational injuries at the plants of the State Forestry Committee of Ukraine has been conducted and the main reasons of accidents in the production process have been found. It's obvious that all these values are random and stochastic. Therefore, it's important to establish certain quantitative or functional relations among separate factors. And this is the purpose of our research.

**Main theoretical information.** Suppose two random values *x, y* after conducting *n* independent tests assume the value $(x_1,y_1)$, $(x_2,y_2)$,…, $(x_n,y_n)$. Hence the existence of correlations between these values are found by means of the correlation coefficient *r* determined in the following manner:

$$r = \frac{\overline{xy} - \bar{x} \cdot \bar{y}}{\sigma_x \cdot \sigma_y} \qquad (1)$$

where: $\overline{xy} = \frac{1}{n}\sum_{i=1}^{n} x_i y_i$ – the average value of the product of two correlated quantities; $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$, $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ – the average values of these quantities; $\sigma_x = \sqrt{x^2 - \left(\bar{x}\right)^2}$, $\sigma_y = \sqrt{y^2 - \left(\bar{y}\right)^2}$ – the average square (standard) deviations of the corresponding quantities; $\overline{x^2} = \frac{1}{n}\sum_{i=1}^{n} x_i^{\,2}$, $\overline{y^2} = \frac{1}{n}\sum_{i=1}^{n} y_i^{\,2}$ – the average value of the squares of the correlated quantities.

Let us notice that in the given case $\sigma^2$ is the dispersion of a random quantity (measure of dispersion). The correlation coefficient *r* is a characteristic of density connection between the investigated quantities and it changes within the range of $-1 \le r \le 1$. In case that *r=0,* there is no correlative connection between two random quantities, thus they are independent. In case that $r=\pm 1$, we observe linear functional connection between two random quantities. The direct connection exists when *r* obtains positive values, it means that with increasing of the independent variable *x* the dependent random quantity *y* increases too. If *r* has negative values we observe reciprocal connection, thus with increasing of the independent variable *x* the dependent random quantity y decreases. For conducting the regression analysis a block of statistic data on occupational injuries at the plants of forestry in 2000-2009 was used [1].

Suppose an independent variable *x* stands for the volume of the wood (ths $m^3$) and our aim is to investigate how the reasons of injuries are connected with this factor. For instance, if in the function of an independent variable we choose the frequency coefficient of general injuries or the frequency coefficient of injuries with the lethal out-

come, then usage of the formula (1) yields such values for the correlation coefficient $r_1$=0,01307 (general injuries) and $r_2$=0,4112 (injuries with the lethal outcome).

Besides in both cases the value of the correlation coefficient is rather small. It proves that there is no linear dependence between the investigated quantities. Examining the correlative field in both cases we receive the approaching curves which have three points of extremum (maximum or minimum). If the correlation coefficient $r$ is non-zero, we observe certain functional dependence $y=f(x)$ among the quantities. If the function has three points of extremum using the results of mathematical analysis we receive the equation $f'(x)=0$ having three different solutions, thus the very function can be expressed by the polynomial of the 4-th degree:

$$y = f(x) = a_o + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 \tag{2}$$

For determining the coefficients of the polynomial $a_0$, $a_1$, $a_2$, $a_3$, $a_4$ we apply the method of least squares. The essence of the method is that the most probable value of the parameters gives the minimum of the function:

$$S = \sum_{i=1}^{n} \left[ y_i - f(x_i, a_o, a_1, a_2, a_3, a_4) \right]^2$$

In the case under consideration the function $y = f(x_i, a_o, a_1, a_2, a_3, a_4)$ has continuous derivatives for all unknown parameters $a_\kappa$ ($\kappa = \overline{0,4}$), and if so then the necessary condition of the minimum of the function $S$ has the form of

$$\frac{\partial S}{\partial a_o} = 0; \frac{\partial S}{\partial a_1} = 0; \frac{\partial S}{\partial a_2} = 0; \frac{\partial S}{\partial a_3} = 0; \frac{\partial S}{\partial a_4} = 0;$$

Having done the transformations for determining five unknown polynomial coefficients (2) we receive the system of five linear algebraic equations:

$$\begin{cases} a_o n + a_1 \sum_{i=1}^{n} x_i + a_2 \sum_{i=1}^{n} x_i^2 + a_3 \sum_{i=1}^{n} x_i^3 + a_4 \sum_{i=1}^{n} x_i^4 = \sum_{i=1}^{n} y_i; \\ a_o \sum_{i=1}^{n} x_i + a_1 \sum_{i=1}^{n} x_i^2 + a_2 \sum_{i=1}^{n} x_i^3 + a_3 \sum_{i=1}^{n} x_i^4 + a_4 \sum_{i=1}^{n} x_i^5 = \sum_{i=1}^{n} x_i y_i; \\ a_o \sum_{i=1}^{n} x_i^2 + a_1 \sum_{i=1}^{n} x_i^3 + a_2 \sum_{i=1}^{n} x_i^4 + a_3 \sum_{i=1}^{n} x_i^5 + a_4 \sum_{i=1}^{n} x_i^6 = \sum_{i=1}^{n} x_i^2 y_i;; \\ a_o \sum_{i=1}^{n} x_i^3 + a_1 \sum_{i=1}^{n} x_i^4 + a_2 \sum_{i=1}^{n} x_i^5 + a_3 \sum_{i=1}^{n} x_i^6 + a_4 \sum_{i=1}^{n} x_i^7 = \sum_{i=1}^{n} x_i^3 y_i; \\ a_o \sum_{i=1}^{n} x_i^4 + a_1 \sum_{i=1}^{n} x_i^5 + a_2 \sum_{i=1}^{n} x_i^6 + a_3 \sum_{i=1}^{n} x_i^7 + a_4 \sum_{i=1}^{n} x_i^8 = \sum_{i=1}^{n} x_i^4 y_i \end{cases} \tag{3}$$

The matrix of the linear equations system (3) is symmetric; hence the solution of this system always exists and is a unique one. Having solved the system of the equations (3), we received the estimates $\overline{a_k}\left(k = \overline{0,4}\right)$ of the approximating polynomial coefficients (2). If the values of $x_i$ are exact and the values of $y_i$ are independent and equally accurate then the estimate of the dispersion $\sigma^2$ of the variable y is determined by means of the proportion:

$$\overline{\sigma}^2 = \frac{1}{n-m-1} S_{\min} \tag{4}$$

where: $S_{\min}$ – the value calculated under the assumption that the polynomial coefficient (2) is substituted for the estimates from the equations system (3); $m$ – the degree of the approximating polynomial.

The estimates of $\overline{\sigma}^2_{a_k}$ dispersions of $a_k$ coefficients are expressed in a formulas:

$$\overline{\sigma}^2_{a_k} = \frac{\Delta_{k,k}}{\Delta}\overline{\sigma}^2 \qquad (5)$$

where: $\Delta$ – the determinant of the equations system (3); $\Delta_{k,k}$ – algebraic complement of the element (lying on the principal diagonal) in the determinant $\Delta$.

The confidence intervals for the coefficients $a_k$ in case of the arbitrary specified confidence probability $\beta$ have the following form [2]:

$$\overline{a_k} - t_\beta \overline{\sigma_{ak}} < a_k < \overline{a_k} + t_\beta \overline{\sigma_{ak}} \qquad (6)$$

where $t_\beta$ – is determined from the table of Student's distribution law using the entered values $\beta$ and the number of degrees of freedom $k=n-m-1$, while: $\beta = \int_{-t_\beta}^{t_\beta} S(t,n)dt$

where $S(t,n) = \dfrac{F\left(\frac{n}{2}\right)\left(1+\frac{t^2}{n-1}\right)^{-n/2}}{\sqrt{\pi(n-1)}F\left(\frac{n-1}{2}\right)}$ – Student's distribution law,

$F(x) = \int_0^\infty t^{x-1}e^{-t}dt$, $x>o$ – gamma-function or Euler's interval of the 2-nd kind.

**The results of the numerical analysis.** If y is the frequency coefficient of the general injuries and x is the volume of the wood logged at the plants of the State Forestry Committee of Ukraine in 2000-2009, then the system of the linear equations (2) assumes the form of:

$$\begin{cases} 10a_o+1{,}16\cdot10^5a_1+1{,}36\cdot10^9a_2+1{,}61\cdot10^{13}a_3+1{,}91\cdot10^{17}a_4=16 \\ 1{,}16\cdot10^5a_o+1{,}36\cdot10^9a_1+1{,}61\cdot10^{13}a_2+1{,}91\cdot10^{17}a_3+2{,}3\cdot10^{21}a_4=1{,}85\cdot10^5 \\ 1{,}36\cdot10^9a_o+1{,}61\cdot10^{13}a_1+1{,}91\cdot10^{17}a_2+2{,}3\cdot10^{21}a_3+2{,}78\cdot10^{25}a_4=2{,}17\cdot10^9 \\ 1{,}61\cdot10^{13}a_o+1{,}91\cdot10^{17}a_1+2{,}3\cdot10^{21}a_2+2{,}78\cdot10^{25}a_3+3{,}38\cdot10^{29}a_4=2{,}56\cdot10^{13} \\ 1{,}91\cdot10^{17}a_o+2{,}3\cdot10^{21}a_1+2{,}78\cdot10^{25}a_2+3{,}38\cdot10^{29}a_3+4{,}14\cdot10^{33}a_4=3{,}05\cdot10^{17} \end{cases}$$

Its solution: $a_0$ =-1734,7; $a_1$= 0,611; $a_2$= -8,016·10$^{-5}$; $a_3$= 4,646·10$^{-9}$; $a_4$=-1,0·10$^{-13}$, thus the correlation curve has the form:

$$y=-1734{,}7+0{,}611x-8{,}016\cdot10^{-5}x^2+4{,}646\cdot10^{-9}x^3-1{,}0\cdot10^{-13}x^4.$$

In the case under consideration the dispersion of general injury frequency according to (4) $\overline{\sigma}^2$ =0,0154, the number of the degrees of freedom κ=10-4-1=5; hence, in case that the confidence probability β=0,8 (taken from the tables of Student's distribution law) we determine that β=1,476 and the confidence intervals (6) for the correlative polynomial coefficients are the following ones:

$-2553{,}4<a_0<-916{,}1$; $0{,}611<a_1<0{,}611$; $-8{,}016\cdot10^{-5}<a_2<-4{,}234\cdot10^{-5}$;

$2{,}447\cdot10^{-9}<a_3<6{,}844\cdot10^{-9}$; $-1{,}481\cdot10^{-13}<a_4<-5{,}27\cdot10^{-14}$.

Similarly, we receive the result for the curve of the correlative dependence of the frequency of injuries with the lethal outcome on the volume of the wood logged:

$$y=193{,}94-0{,}069x+9{,}24\cdot10^{-6}x^2-5{,}510^{-10}x^3+1{,}2\cdot10^{-14}x^4.$$

The dependences of the coefficient of injury frequency on costs spent on labour protection per an employee, the number of inspections and examinations (instructions) per a specialist in labour protection have also been researched. The results of the analysis are indicated in figures 1 and 2. The spreadsheet Excel program [3] was used for carrying out the calculations presented above.

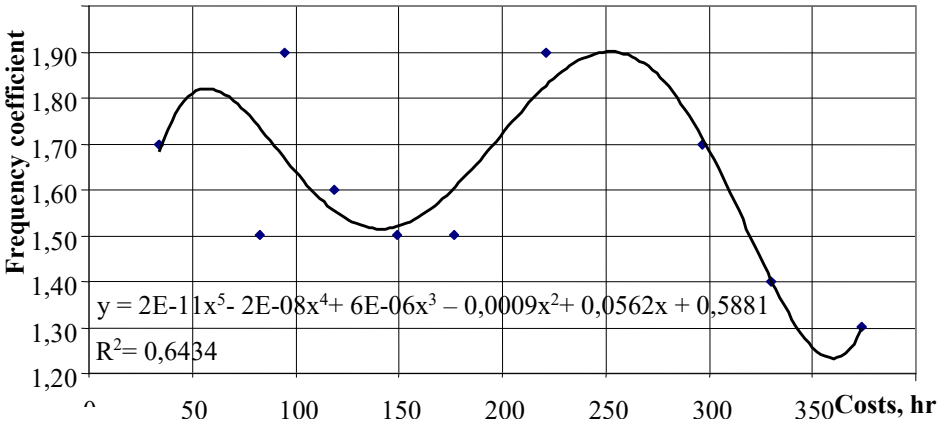


***Fig. 1. Dependence of the coefficient of injury frequency on the costs spent per an employee***

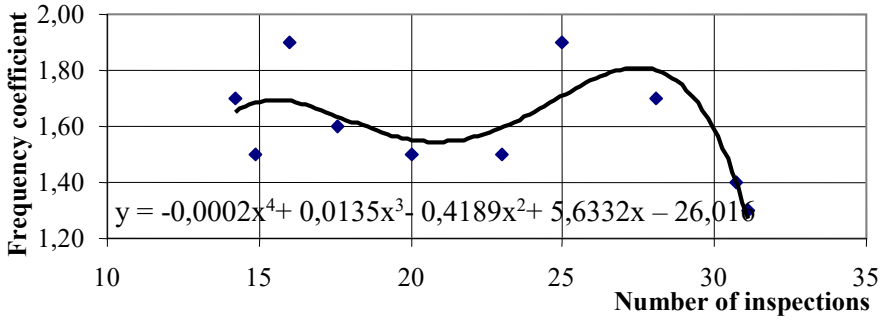


***Fig. 2. Dependence of the coefficient of injury frequency on the number of inspections per a specialist***

**Summary.** In the paper the functional dependence between the frequency coefficients of occupational injuries (namely injuries with the lethal outcome) on the main factors influencing it has been revealed. It is based on the foregoing analysis [1] of the statistic data concerning the reasons and consequences of occupational injuries of employees. The obtained results will lay the foundation for the development of the optimum planning methods of labour protection with the aim of reducing occupational risks to the minimum. We shall notice that the presented calculation dependences are of general character and can be used for the estimate of occupational injuries not only at the plants of forestry.

## References

1. **Гогіташвілі Г.Г., Степанишин В.М., Тисовський Л.О.** Аналіз статистичних даних щодо причин та наслідків виробничого травматизму працівників // Вісник НУ «Львівська політехніка», 2011. – №707, – С.43-46.

2. **Фёрстер Е., Рёнц Б.** Методы корреляционного и регрессионного анализа. – М.: Финансы и статистика, 1983. – 302 с.

3. **Радке Х.О.** Практическое использование Microsoft Excel для обобщения статистических данных и их презентации. – М.: НТ Пресс, 2008. – 272 с.

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## Регресійний аналіз причин виробничого травматизму працівників Держкомлісгоспу України

Приведено аналітичні залежності для визначення основних показників регресійного аналізу: коефіцієнт кореляції, апроксимуючий поліном, оцінки дисперсії залежної величини і дисперсій коефіцієнтів апроксимуючого полінома, довірчі інтервали для коефіцієнтів при довільній заданій довірчій ймовірності. Отримано кореляційні залежності частоти виробничого травматизму на підприємствах Держкомлісгоспу України (2000-2009 рр.) від об'єму заготовленої деревини, витрачених коштів на охорону праці, кількості перевірок, обстежень (приписів) в розрахунку на 1

особу. Отримані результати ляжуть в основу розроблення методики оптимального планування охорони праці з метою зменшення до мінімумів професійних ризиків. Зазначимо, що приведені розрахункові залежності носять загальний характер і можуть бути використані для оцінки виробничого травматизму не лише на підприємствах лісової промисловості.

**Ключові слова:** регресійний аналіз, виробничий травматизм, коефіцієнт кореляції, коефіцієнт частоти травматизму.

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## REALIZATION OF STATISTICAL INVENTORY OF THE VIRGIN BEECH FOREST IN UHOLSKO-SHYROKOLUZHANSKYY MASSIF

This article provides a short overview on the statistical inventory of the virgin beech forest in the "Uholsko-Shyrokoluzhanskyy massif" which was held in July-August 2010 as a result of Swiss-Ukrainian cooperation.

**Keywords:** forestry inventory, virgin beech forest, WSL, CBR, UNFU, method, tree stand characteristics, experience, Ukrainian forestry, Ukrainian state statistical inventory of forest stands.

Carpathian mountain system is one of the biggest biologically diversified systems on the European continent. In XX century an intensive nature usage took place in the Ukrainian Carpathians, but several territories saved the unique forest plantations which have to be explored in the near future. Among all those territories there are such called virgin forests (also known as primary forest, primeval forest or ancient woodland) consisting of European Beech *Fagus sylvatica L.* [1]. Since 2007 these virgin forests belong to the UNESCO natural heritage.

Currently these unique areas are under the state protection and belong to the Carpathian biosphere reserve. The largest beech virgin forests grow on the 15580 ha territory in the "Uholsko-Shyrokoluzhanskyy massif". It is located in the beech forests zone, with the prevailing zonal beech forests, and forming the upper forest line at an altitude of 1200-1300 m. The fragments of forest with *Duschekia viridis* are found higher, mainly in hollows. In the optimum ecological conditions, the species of beech is marked by the high vitality and form highly productive plantations with a stock of timber, which is more than 600 $m^3$/ha. The communities of *Taxeto-Fagetum* and *Juniperetum sabinae*, which are unique for the Carpathians, are preserved in the limestone ledges. Such relict phytocenosises as *Quercetum petreae*, *Fageto-Tilietum platiphyllae*, *Piceetum abietis* and *Betuletum pendulae* are also represented here [5]. Plantation is characterized with the great biodiversity of flora and fauna, but the greatest interest represent beech natural plantations, which are not influenced with the human activity [4]. The exploration and monitoring of these territories will make it possible to gain new knowledge about the structure of forests, which develop without economic intervention [6-15].

For the purpose of statistical inventory of Uholsko-Shyrokoluzhanskyy massif the cooperation between Swiss Federal Institute for Forest, Snow and Landscape, Birmensdorf (Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL, Birmensdorf), Carpathian Biosphere Reserve (Rakhiv, Ukraine) and Ukrainian National Forestry University (Lviv, Ukraine) took place during July-August 2010. Ukrainian and Swiss scientists and students participated in the research.

The method of research was based on the document "Statistical inventory of Swiss national reserves – method of establishing sample plots, 03.02.2010 version"

(Tinner et al. 2010), which was based on the method of realization the third Swiss state statistical forest inventory (LFI 3, Keller 2005) [3].

All working groups (each group consisted of 2 persons: Swiss and Ukrainian) were well equipped with the modern equipment and gadgets, such as: SUUNTO clinometers and compasses for angle and exposition measurements; Vertex IV for the height measurements; Meridian 400 gon compass for measurements of azimuth from the center of sample plot to each tree; Garmin eTrex Summit HC GPS and orthorectification images of territory for the orientation and reaching sample plots; software of Trimble Juno SB for the accurate coordinates measurements; electronic basal area factor-scope and dendrometer Criterion RD 1000 for the diameter on 7 m height measurements; Hagloff /Mantax 80 cm/calipers; knives, poles, tripods, measure tapes, etc.

According to that method, the 445×1235 m raster grid was designed for the whole inventory area.

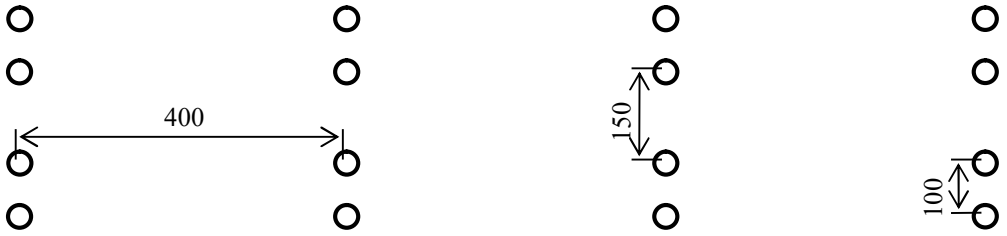


***Fig. 1. The scheme of the raster grid***

As it shown on the Fig. 1, distance between two nearby sample plots (territory of each SP equals 500 $m^2$) was ~100 m, and distance between two rows was approximately 1,5 km [2]. Besides, working groups were given the orthorectification aircraft images with sample plots and coordinate system (World Geodetic System (WGS84) was chosen as main coordinate system, because 2 different kinds of GPS-receivers were used for founding the sample plots – Trimble and Garmin). These images were used as additional materials for orientation and founding sample plots. The SCSP (south center of sample plot) was found with the help of GPS-receiver, then 20 m distance from that point to north was measured and new point was fixed with pole as center of sample plot. Besides that, center of sample plot was fixed to the 3 nearest trees and its coordinates were marked from GPS-receivers. Azimuth from center of sample plot to each tree was measured with the help of Meridian 400 gon compass. This will allow finding center of sample plots and measured trees easily in future.

All researches had a list of tasks to do during the inventory, f.e.: to reach the sample plot; to mark and identify the sample plot; to identify and sum up the anthropogenic influence on the sample plot; to receive the forest and inventory indicators of tree stands, regeneration and dead wood (breast height diameter, tree height, diameter on 7 m height, dead wood taxation, tree status, tree species, growth form, crown length, etc.).

All data from sample plots was written to 6 different forms [3]:

*Form 1. Navigation and sampling decision.* Sample plot number, date, starting point for navigation, declination and compass deviation, remarks concerning navigation, sampling decision and other basic information was written in this form. *Form 2. Sample plot.* Information about sample plot (its altitude, inclination and radius), Trimble measuring point, sketch of sample plot, photos of sample plot, boundary lines, eye-catching objects and remarks were mentioned here.

*Form 3. Sample trees.* Tree stand inventory with mentioning of such characteristics as tree number, BHD, tree status, species, azimuth, distance and inclination from sample plot center, crown layer, growth habit, crown length, crown breakage, dead wood in crown, bark lesion, cracks, holes in stem, polypore's on stem, tree height, height of crown base, diameter on 7 m height and others. *Form*

*4. Regeneration.* Information regarding regeneration survey, f.e. position of regeneration subplot, distance from sample plot center, inclination of subplot, stone/rock %, humus layer, shade, amount of regeneration on 3 radiuses (horizontal 1,26 m, 1,78 m, 2,52 m) etc. *Form 5. Dead wood transects.* Direction of dead wood transects, inclination of transect, length of transect, information about trees, which cross the transect (its number, 2 diameters, angle, species and degree of decay) were written in this form. *Form 6. Assessment of interpretation area.* Site characteristics (slope aspect, relief) traces of anthropogenic use, root plates, identifiability of former root plates, gaps, structural characteristics, stand density and other features were mentioned in this form.

Schematic view of the sample plot is shown on picture 2. Real radius of sample plot was corrected according to the inclination of each area, which was measured during filling Fig. 2. All received data was soon digitized and saved in the data bases by appropriate workers. The use of this method on 400 sample plots provided receiving of such characteristics as: main forest and inventory indicators of tree stands (density of stand, absolute fullness, volume, diameter distribution, composition etc.). stock and degree of decay of dead standing and lying wood; structural indicators of tree stands, which are especially valuable for the biodiversity rating; vertical and horizontal structure of tree stand (tree storey and placement); density and structure of regeneration, its viability, main biometrical indicators); impact of natural disasters on the dynamical processes in beech primary forest; level of the anthropogenic influence on beech primary forest; influence, which can threaten the integrity of primary forest in the future.

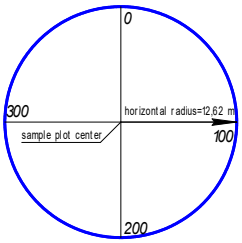


***Fig. 2. The schematic view of the sample plot***

So, in 2010 results of statistical inventory of Uholsko-Shyrokoluzhanskyy massif's virgin forest were received for the first time. Inventory was held according to the method, which was developed by Swiss Federal Institute for Forest, Snow and Landscape. These results accurately reflect the present-day condition of the biggest virgin forest massif in Europe – the Uholsko-Shyrokoluzhanskyy massif.

Nowadays results of statistical inventory are the base for:

- monitoring of the beech virgin forest's development and it's dynamics of existence;
- comparison of growth processes and overall development with man-held forests, European natural reserves, apart forest massif "Sihlwald" near Zurich (Switzerland);
- investigation of the natural structure, biological diversity, genetic structure and natural processes in undisturbed forests which can benefit the nearnatural management of exploited forests.

Experience, which was gained during the statistical inventory, is extremely valuable; it can be used for realization of the first Ukrainian state statistical inventory of forest stands.

## References

1. **Old-growth forest** http://en.wikipedia.org/wiki/Old-growth_forest.
2. **Stichprobeninventur Uholka-Schyrokyj Luh** http://www.wsl.ch/fe/walddynamik/projekte/uholka/index_DE.
3. **Stichprobeninventur im Buchen-Urwald Uholka-Schyrokyj Luh** – Anleitung für die Inventur 2010 http://www.wsl.ch/fe/walddynamik/projekte/uholka/aufnahmenaleitung_de.pdf.
4. **Uholsko-Shyrokoluzhanskyi protected massif** http://cbr.nature.org.ua/new_e.htm.
5. **Virgin forest of Uholka.** Nature Guide to the Largest Virgin Beech Forest of Europe. A UNESCO World Heritage Site http://www.wsl.ch/dienstleistungen/publikationen/pdf/9126.pdf.
6. **Gayda S.V.** Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:238-244. (in Ukr.).

7. **Gayda S.V.** A problem of wood raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2007, 33:55-63. (in Ukr.).

8. **Gayda S.V.** Research of concentration of operations is in modern furniture Productsion // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2007, 33:73-79. (in Ukr.).

9. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2008, 34:55-68. (in Ukr.).

10. **Gayda S.V.** Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood / Forestry, Forest, Paper and Woodworking Industry, 2008, 34:68-79. (in Ukr.).

11. **Gayda S.V.** Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2009, 35:63-83.

12. **Gayda S.V., Maksymiv V.M.** From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. – Lviv: 2010, 36:57-77.

13. **Gayda S.V.** A comparative analysis of physical-and mechanical parameters of variously-designed Glued Boards made of post-consumer Recovered Wood / Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2010, 36:81-91.

14. **Gayda S.V.** Comparative analysis of bending particularities for various post-consumer wood species and age categories // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:84-88. (in Ukr.).

15. **Gayda S.V.** The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. – Lviv: UNFU. – 2009, 19.14:72-89. (in Ukr.).

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## Статистична інвентаризація букових пралісів угольсько-широколужанського масиву

Наведено характеристику статистичної інвентаризації букових пралісів Угольсько-Широколужанського масиву Карпатського біосферного заповідника, що проходила у липні-серпні 2010 року у рамках співпраці між Швейцарським федеральним інститутом досліджень лісу, снігу і ландшафтів, Бірменсдорф (Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL, Birmensdorf), Карпатським біосферним заповідником (м. Рахів) та Національним лісотехнічним університетом України (м. Львів). Проведено короткий огляд методики, що використовувалась інвентаризаторами для збору даних у польових умовах та їх подальшого зберігання і обробки. Оскільки ,на даний час загальнодержавна інвентаризація лісів України не проводилась ще з радянських часів, пропонується звернути увагу на досвід, отриманий у співпраці із кваліфікованими швейцарськими лісівниками та підготувати методику, яка може покласти початок загальнодержавній інвентаризації лісів незалежної України, що, у свою чергу, приведе до більш якісного та оптимізованого ведення лісового господарства.

**Ключові слова:** лісова інвентаризація, букові праліси, WSL, КБЗ, НЛТУ, методика, характеристики деревостану, досвід, українське лісове господарство, загальнодержавна інвентаризація.

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## THE PROSPECTS FOR THE ADVANCEMENT OF THE PROCESS OF ELECTRO-SPARK TREATMENT

The article describes the main lines of the advancement of electro-spark treatment (EST) process: development of new electrode materials and devising new methods for producing the known materials, additional treatment of electro-spark coatings (ESC) by various methods, the application of the EST method in combination with other methods of treatment, feeding surface-active materials to interelectrode space, physical- and mechanical action on the electrodes, design upgrading of the EST plants and improvement of their electrical characteristics.

**Keywords:** electro-spark treatment, electrode material, wear resistance, mass transfer, temperature gradient.

The technology of electro-spark treatment (EST) is a promising method for surface hardening of metals and alloys. It is used to enhance wear resistance of cutting tools and machine parts, for the application of silver coatings to the surface of electric contacts, etc. The main advantages of this technique lie in the feasibility of transferring any current-conducting materials onto the surface being treated, high degree of cohesion of the hardened layer with its substratum, the feasibility of local application of coating, relatively moderate cost of the equipment as well as the ease of maintenance. At present, the work on the advancement of the EST process is being done in the following lines:

1. Development of new electrode materials (based on carbides, nitrides and borides of transition metals of groups IV through VI; natural titanium magnetites; iron-based multicomponent alloys) and devising new methods of obtaining the known materials (with the employment of powder metallurgy techniques, by way of coreduction of metal oxides).
2. Additional treatment of ESC by various methods: laser or plasma partial melting, hydroabrasive jet processing [1].
3. Employment of the EST method in combination with other methods of treatment such as ultrasonic treatment, laser treatment, diamond smoothing [2].
4. Feeding to the interelectrode space of efficacy-enhancing materials such as powdered materials of Ti-N and Cu-Sn systems [3].
5. Physical- and mechanical action on the electrodes: preliminary hardening with subsequent drawing of substratum metal; the application of methods of single-axial static load on the main electrode [4].
6. Perfecting the design of the EST plants and improvement of their electrical characteristics: development of multielectrode plants, enhancement of the condensers capacity and power.

Research institutions have been deeply involved in the study of external impacts on the characteristics of the electric erosion process. In particular, G.Kurdiumov Institute of Physics of metals, the National Academy of Sciences of Ukraine, has been recently engaged in the study of external physical fields impact on the characteristics of mass transfer in metals under conditions of impulsive deformation. The aim of this study is to find the pattern of mass transfer processes, to reveal structure- and phase formation, which take place in the surface layer and throughout the volume of metals in the process of hardening them under conditions of temperature gradients. The results of the theoretical and experimental research have shown that the occurrence of temperature gradients in electro-spark treatment of the substratum influences the characteristics of mass transfer, this influence being exerted up to the depth of penetration of $^{63}$Ni radioactive isotope into the substratum. It has been demonstrated that the coating formation occurs more efficiently if it is applied onto a copper substratum in liquid nitrogen. One of the most promising ways of improvement of the EST process is developing new electrode materials for the purpose of replacing scarce and expensive tungsten compounds in the alloy composition, however, preserving or enhancing in doing so erosion characteristics and properties of the coating (Fe-Mn-C-B) – based alloys and alloys containing Ni, Cr, Si, Al, V, Ti, Cu, Li [5]. The investigation done enabled to enhance the wear resistance of coating by 2 to 5 times.

Another promising method involves designing multielectrode machines with portioned feeding powdered materials of Ti-N and Cu-Sn systems to electrodes. This enables to maximize the process efficiency without high financial costs. By way of example, a metal sheet of size 2 $m^2$ can be coated within four minutes taking into account all service operations, thus in mass production, one machine alone is able to process the ar-

ea of 720 $m^2$ a day. Fig. 1 depicts a section of a multielectrode machine with portioned feed of powdered material to the electrodes.

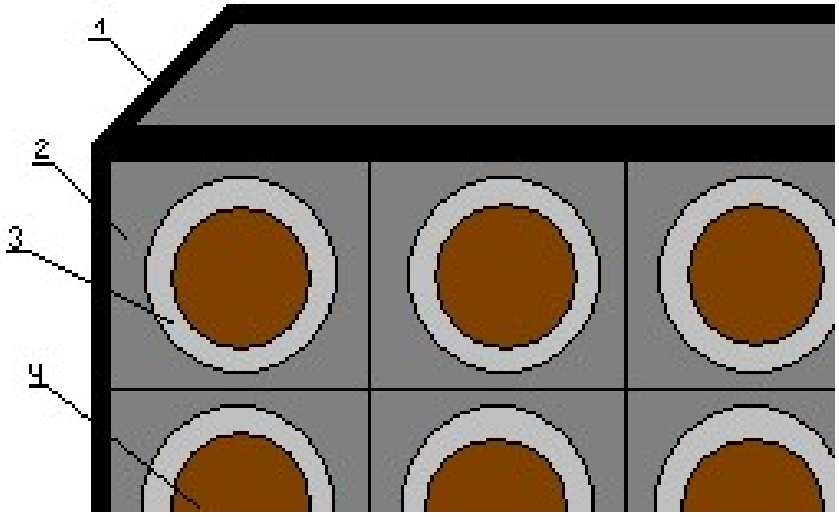


***Fig. 1. Section of multielectrode machine:*** *1 – casing, 2 – individual electrode area, 3 – port for powdered material feeding, 4 – electrode*

The dimensions of one section are 6×4 mm. The plant is made up of about 800 sections that are easy to replace when they are worn out. All the sections are connected to controllers which are responsible for proper operation of the sections. In case of failure, the operator is informed by the control desk. The given system of control allows for reducing the amount of rejects by 15 %. The sections are combined in a common unit by method of lap joint in order to increase the total area of hardening in a single pass.

Thus, the tendencies of advancing the electro-spark treatment technique are directed towards the intensification of the process of obtaining coating for enhancement of competitiveness of this method as compared with other methods of surface hardening.

## References

1. **Проволоцкий А.Е.** Повышение качества поверхностей, обработанных электроискровым способом // Электронная обработка материалов. – 1988. – № 2. – С. 83-84.

2. **Ковальченко М.С., О.В. Паустовський, С.М. Кириленко та ін.** Вплив вигладжування на властивості електроіскрових покриттів // Фізико-хімічна механіка матеріалів. – 1990. – № 5. С. 119-120.

3. **Мещеряков Н.Т., Чаругин Н.В.** Интенсификация процесса электроискрового легирования в среде поверхностно-активных металлов // Электронная обработка материалов. – 1987. – № 1. – С. 33-38.

4. **Михайлов В.В., Перетятку П.В.** Интенсификация электроискрового легирования путем прямого действия тока на рабочие электроды // Электронная обработка материалов. – 1987. – № 2. – С. 90-92.

5. **Білоус О.В., В.М. Голубець, В.В. Широков, О.Б. Гасій.** Розробка багатокомпонентного електродного сплаву на основі системи Fe-Mn-B-C. Наукові нотатки. Міжвуз. зб. (за напрямом «Інженерна механіка»). Луцький ДТУ. – 2007. – Вип. 20. – С. 30-32.

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### Перспективи розвитку технології електроіскрового легування

Технологія електроіскрового легування (ЕІЛ) – перспективний метод поверхневого зміцнення металів і сплавів. Він використовується для підвищення зносостійкості різального інструменту та вузлів деталей машин, нанесення срібла на електричні контакти тощо. У даний час роботи з вдосконалення технології ЕІЛ ведуться за напрямами: 1. Створення нових електродних

матеріалів (на основі карбідів, нітридів і боридів перехідних металів IV-VI груп; природних титаномагнетитів; багатокомпонентних сплавів на основі заліза) і розробка нових методів одержання відомих матеріалів (із застосуванням технології порошкової металургії; шляхом спільного відновлення оксидів металів). 2. Додаткова обробка електроіскрових покриттів (ЕІП) різними методами: лазерним або плазмовим оплавленням, гідроабразивною струменевою обробкою. 3. Застосування методу ЕІЛ в сукупності з іншими методами обробки, такими як накладання ультразвуку, лазерна обробка, алмазне вигладжування. 4. Подача в міжелектродний простір матеріалів, які підвищують ефективність процесу, зокрема, порошкові матеріали систем Ti-N та Cu-Sn. 5. Фізико-механічний вплив на електроди: попереднє гартування і відпуск металу основи; застосування методів одноосного статичного навантаження на робочий електрод. 6. Вдосконалення конструкції установок для ЕІЛ та їх електричних характеристик: розробка багатоелектродних установок, збільшення ємності конденсаторів і потужності.

**Ключові слова:** електроіскрового легування, електродний матеріал, зносостійкість, масоперенесення, температурний градієнт.

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## SELECTION OF STANDARD TEST SPECIMENS FOR MICROMECHANICAL INVESTIGATION OF METALS AND ALLOYS

The article deals with the problems of test specimen selection for mechanical investigations of refractory metal alloys with diffusion coatings under conditions of combined action of high temperatures, mechanical loads, and chemically active medium.

**Keywords:** refractory metal, mechanical investigations, diffusion coating.

The main problem that limits the application of refractory metal alloys in present-day production, in spite of their unique set of physical and mechanical properties, is their ability to actively react with gaseous oxygen-containing media at elevated temperatures. Heat resistance of these metals is so low that a practical usage of niobium, vanadium, molybdenum, and tungsten in oxidizing media at temperatures above 500 °C, is impossible without protection [1]. At the same time, high specific strength, technological effectiveness, high-temperature strength, and a number of other properties make it possible to produce refractory metal-based alloys that will have optimum combination of strength and plasticity. Thus, long-term service of articles made of refractory metals as well as refractory metal-based alloys in aggressive media including exposure to the atmosphere, is impossible without special protective coating.

This generates a need for large-scale laboratory investigations of protection-coated materials for the purpose of optimization of their properties, chemical composition, and structure. This, in its turn requires the use of a great number of test microspecimens. That is why, when deciding on the particular kind and type of specimen, we should take into consideration economic factors as well, which accounts for the necessity of savings in valuable materials, precious metals, and alloys.

The shape and size of specimens for micromechanical investigations are dependent on the following: the degree of required accuracy, the material under investigation, test machines and equipment used as well as a number of other factors. To apply protective coating to the complex-shaped articles, the method of diffusion saturation with liquid melt of alkaline earth metals is employed [2].

Economically, obtaining diffusion coating from the elements that are more resistant to a chemically active medium is rather a costly process. Therefore, it is neces-

sary that test specimens used in the exploration of mechanical characteristics of metals and alloys with diffusion coating applied, should be of small size. Also, it is necessary to give proper attention to the techniques and accuracy of their fabrication, which is essential for obtaining accurate results of investigation. It is important to determine mechanical properties that are characteristic of polycrystal structure, that is the properties of material which consists of many variously-oriented grains. If the cross-sectional area is close to the grain size, the investigation results will depict the properties of individual crystallites rather than properties of polycrystal metal as a whole. With the aim to reduce the number of possible errors conditioned by the test equipment (readings at the beginning or at the end of the scale of any test equipment are relatively less accurate than those in the middle), it is advisable to have a small cross-sectional diametre (d=0.8 mm) for high-strength materials; for medium-strength materials d=1.0 mm; and for low-strength materials d=1.2 mm. One of the main criteria for determining the length of microspecimen, is thought to be its stiffness.

In order to determine the relative lengthening (δ) which is commonly determined on standardized specimens as their five- or ten-fold length in relation to the cross-sectional diametre, we will take the five-fold value (l=5d) as the optimum length of the working (effective) part without taking into account the length of their fillets.

The radius of the fillets is determined by the effect of stress concentration as well as by dependence of the material strength on three-dimensionally stressed state that develops in the fillet zone. Normally, it should be recommended (as in the case of ordinary size) that the radius of the fillet in tensile test is to make up about half the working part diametre while in torsion test – approximately one diametre. The radius of the fillets should be considerably increased in the investigation of metal-plastic materials. The shape and size of the heads depend on the method of fastening the specimens in the clamp of the test machine. Special attention should be given to exclude the development of any additional stresses in the working part due to probable misalignment. A comprehensive review of the specimens of all existing shapes and types [3] allowed to dwell on the following variant (Fig. 1).

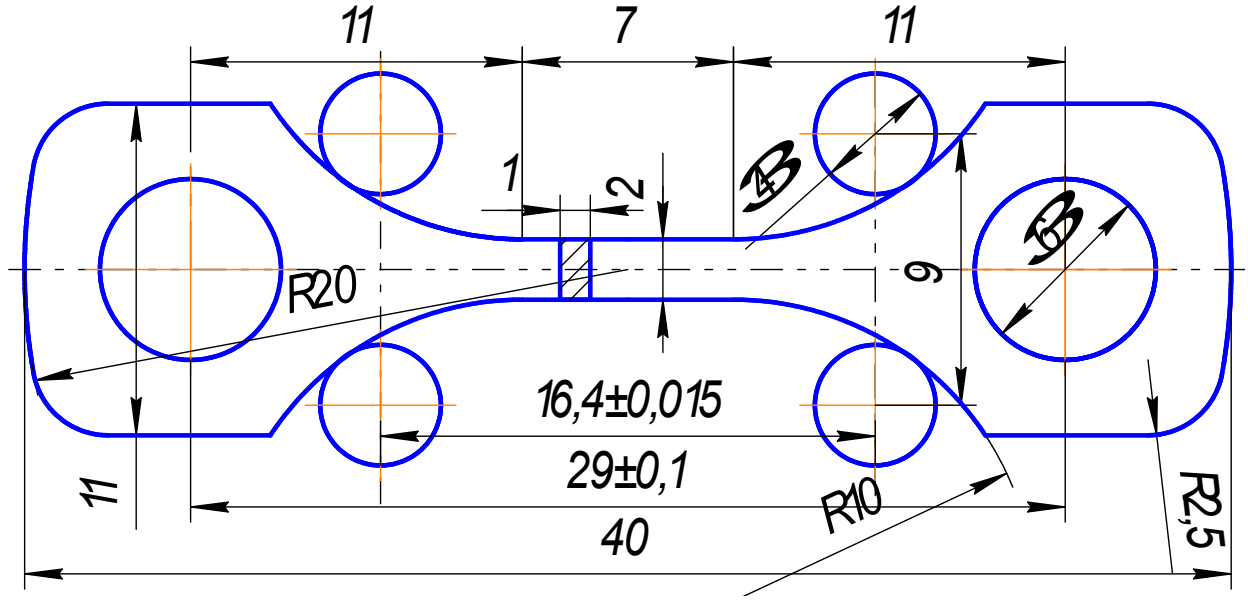


***Fig. 1. Standard specimen for micromechanical investigation of protection-coated metals and alloys***

The size of the given specimen is the most effective as its fabrication requires a small amount of material which could be fairly expensive. Due to the fact that the size and surface area are small, there is no need for using much material for coatings. With the size like this, the diffusion coating can be applied under laboratory conditions where large electric furnaces are simply not used. Also, small-sized specimens make it possible to reduce the size of test machines and, consequently, to reduce energy consumption. Because the size of specimens is small, the probability of machining defects is not so high. When fabricating microspecimens, the emphasis should be made on the accuracy of their shape (freedom from taper, barrel-shape, concavity and other shape defects), the working part should be kept clean, there should not be any cold hardening on the surface. Such defects can result in premature failure of the specimen. Thus, from the above discussion it follows that the given microspecimen would be best appropriate for use in conducting physical and mechanical investigations of refractory metals and their alloys. The given specimen is cost-saving, its fabrication enables savings in material, the application of various protective coatings can be done under laboratory conditions because the specimen's size allows for doing so. The area of the surface being machined, is small, which reduces the probability of defects. The proposed specimen meets all the requirements for mechanical investigation of metals and alloys.

## References


1. **Кофстад П.** Высокотемпературное окисление металлов. – М.: Мир, 1969. – 390 с.
2. **Шатинский В.Ф., Збожная О.М., Максимович Г.Г.** Получение диффузионных покрытий в среде легкоплавких металлов. – К.: Наукова думка, 1977. – 97 с.
3. **Максимович Г.Г.** Микромеханические методы испытания металлов и сплавов. – К.: Наукова думка, 1976. – 244 с.



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## Вибір типових зразків для мікромеханічних досліджень металів і сплавів


Розглянуто проблему вибору зразків для механічних досліджень сплавів тугоплавких металів з дифузійними покриттями в умовах одночасної дії високих температур, механічних навантажень і хімічно активних середовищ. В зв'язку з цим постає необхідність широкомасштабних лабораторних досліджень матеріалів з покриттями з метою оптимізації їх властивостей, хімічного складу та структури. Це в свою чергу вимагає використання великої кількості мікрозразків. Тому при виборі виду і типу зразка, в сучасних умовах слід враховувати також і економічні фактори, пов'язані з необхідністю економії дорогоцінних матеріалів, металів і сплавів. Форма і розміри зразків для мікромеханічних досліджень залежать: від виду потрібної точності, від матеріалу, що досліджується, від експериментальних машин та установок, які використовуються, а також ряду інших факторів. Одним із основних критеріїв при визначенні довжини мікрозразка, вважається його жорсткість. Необхідність визначити відносне видовження (δ), яке здебільшого визначається на типових гостованих зразках при п'ятикратній чи десятикратній їх довжині відносно діаметру поперечного перерізу дозволяє вважати оптимальною довжиною робочої частини п'ятикратну (l=5d), не рахуючи довжини галтелей. Таким чином, використання пропонованого мікрозразка для проведення фізико-механічних досліджень тугоплавких металів та їх сплавів є найбільш доцільним. Даний зразок є економічно вигідний, для його виготовлення не потрібно багато матеріалу, нанесення різних захисних покрить можна робити в лабораторних умовах, оскільки його розміри це дозволяють. Мала площа обробки при виготовленні зразка зменшує можливість дефекту. Запропонований зразок відповідає усім вимогам механічних досліджень металів та сплавів.



**Ключові слова:** тугоплавкі метали, механічні дослідження, дифузійні покриття.

UDC 630*5:630*811.2 *Assoc. prof. I.M. Sopushynskyy – UNFU*

# DECORATIVE WOOD OF VALUABLE BROADLEAVED TREE SPECIES GROWING IN UKRAINE

The wood structure of valuable broadleaved tree species determines the surface features of sawn or cut wood which supply the fine or decorative appearance of wood products. Wood anomalies often display fine textures which have quite a high value. They are typical for sycamore birdseye, sycamore, European beech and ash with wave grain wood. These valuable broadleaved tree species deliver high-value decorative wood and also special acoustical wood for the musical instruments production.

**Keywords:** decorative wood, wave grain, beech, sycamore, ash.

**Introduction.** Wood structure of valuable broadleaved tree species determines the texture or the drawing of sawed or cut wood surfaces which supply the fine or decorative appearance of wood products [10]. Wood anomalies and its varieties often display fine textures which have quite a high value [6, 8, 9]. An interspecific variability of sycamore (*Acer pseudoplatonus* L.), European beech (*Fagus sylvatica* L.) and ash (*Fraxinus excelsior* L.) are special wood anomalies like birdseye and wave grain. In the Ukraine such wood anomalies are typical for sycamore, European beech and ash [1, 5]. These valuable broadleaved tree species deliver decorative wood and also special acoustic wood of sycamore with wave grain [7].

While traditional decorative wood surfaces face big challenges and veneer manufacturer complain about difficulties on markets and declining market shares, digital printing technology for wood and wood based panels with improved reproductions of natural wood surfaces shows a rapid market share growth [12]. The discussion about natural and synthetic surfaces can be read in the various supplements of the journals "Holz-Zentralblatt" and "HK-Holz Kunststoffverarbeitung". On the other hand there is an evidence that the final consumers are ready to pay a higher price for individual and customized products (e.g. furniture, interior design, floors with highly decorative wood surfaces). There are some established plantations of curly birch in Finland to produce the high quality decorative wood oriented on getting economical value [9]. In addition, on the socio-economic point of view of sycamore, beech and ash with a decorative wood has a beautiful texture and a higher economic value than other trees. It contributes to biodiversity conservation and very profitable forest management with present wood prices [3]. These challenges are described in works of Rober Walser: "Die Natur braucht sich nicht anzustrengen, bedeutend zu sein, sie ist es" (nature does not have to put emphasis on showing its importance, it is important).

**Decorative value of wood.** The appearance and properties of individual tree are strongly affected by annual growth, which, in turn depends on variations of adverse environmental factors [2, 4, 6, 8, 11]. The quality reflects the utility of the wood and therefore is defined by the end user. Quality criteria can only be applied for the specific purpose for which the wood is used. The main characteristics that define the timber quality classes of sycamore, beech and ash according to current European norms [2, 8] include average diameter, knots, wood growth, slope of grain, wane, colour, spiral grain, sweep of the wood etc. The study of decorative value of wood is important in the context of its classification by quantifiable or explicable characteristics.

The size, type, and arrangement of the wood cells affect the appearance of the grain or the texture. Figured grain is known as unusual patterns, many of which are strikingly

beautiful. Oak wood has especially prominent rays in the quartersawn, these produce silver grain (Fig. 1a), wave grain (Fig. 1b) and bird's eyes (Fig. 1c) are especially striking in beech and sycamore. The last one is thought to be caused by a fungus that affects the growth of the longitudinal cells. Larger dimples are the result of a fungus and are characterized for maple (Fig. 1d). Some trees (elm, beech, maple etc.) produce bur (burl) wood, which may be caused by an injury, virus or fungus (Fig. 1e).

The review of the literature [1, 2, 3, 4, 5, 8, 9] shows that the criteria of the assessment of tree species with a decorative wood are not studied enough, and not developed the processes for selection, rational and complex use of decorative valuable wood of broadleaved tree species growing in Ukraine have not been developed.

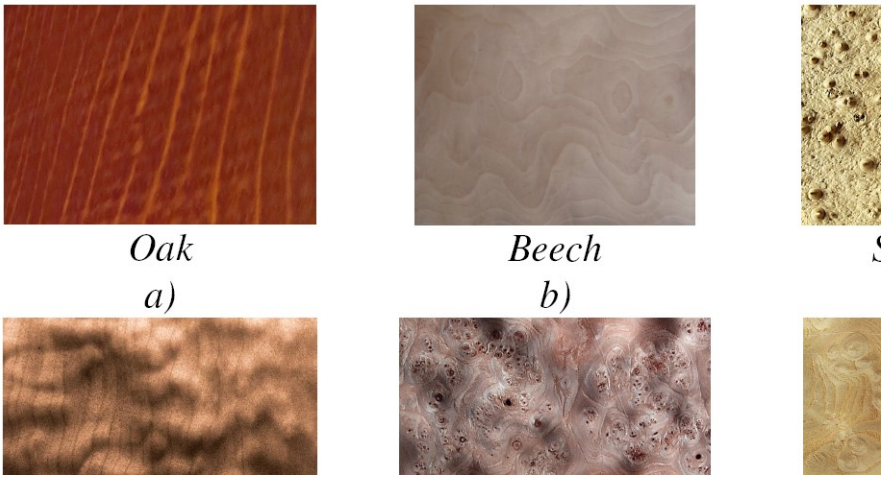


***Fig. 1. Decorative wood of some broadleaves tree species growing in Ukraine***

**Classification of decorative wood.** While foresters think of tree size and form, and lumber manufacturers see large, straight and clear logs, customers associate wood quality with aesthetic characteristics. Special figures add value to solid wood products. Decorative wood is a combination of fine arts and aesthetical features of wood surface that are highlighted by the color and pattern of anatomical elements (tracheids, vessels, rays etc.) and wood anomalies formations, their micro and macro dimensions, a variety of anatomical tissue, density, annual rings, spring and summer wood. A diversity of wood texture caused by the natural variability, environmental and biological factors, and the forest management and in the technological context – the sawing angle, drying and finishing of wood products. The criteria of the wood pattern evaluation are aesthetic characteristics and dimensions of anatomical elements. The wood texture classification is an important tool for the wood resource evaluation and management and also for improving the economic evaluation of natural resources of forests (Fig. 2).

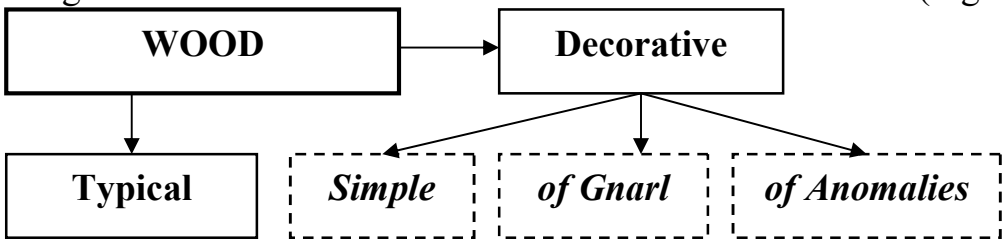


***Fig. 2. Classification of decorative value of wood***

Typical wood texture is native to the wood with straight-fiber structure of conifers, diffuse and ring porous round timber. Simple decorative value of wood is the result of radially or plain-sawn logs, which underlines the dimensions of one or a group of anatomical elements (silver grain of oak, the growth cone formed annual ring of coniferous and ring porous wood, etc.) (Fig. 3a). Decorative wood of gnarl (woodknob) is specified by stems, roots and branches that they produce a large growth (Fig. 3b). It is caused by bacteria and fungi, and has sharp local protuberance on a tree.

Decorative wood of anomalies (irregularity or deviation from the general patterns) is specified by parts or the whole trunk of one tree or group of trees (Fig. 3c).

***Fig. 3. Wood examples with decorative value***

**Conclusions.** In Ukraine, there are defined five types of valuable decorative wood that are typical for indigenous tree species and are important for forestry and woodworking industries. Wood anomalies are typical for sycamore birdseye, sycamore, European beech and ash with wave grain wood. The article demonstrates that the decorative value of wood requires the classification in such categories as simple, gnarl and anomalies. The diagnostic criteria of growing trees, round timber and sawn timber with high-value decorative wood have to be investigated.

## References


1. **Винтонив И.С., Сопушинский И.Н., Винтонив Р.В.** Некоторые особенности строения явора с декоративно – резонансной древесиной (*Acer pseudoplatanus* L.) // Структурные и функциональные отклонения от нормального роста и развития растений под воздействием факторов среды: межд. науч.-техн. конф., 20-24.06.11. – Петрозаводск: КарНЦ РАН, 2011. – С. 368-372.
2. **Сопушинський І.М., Маєвський В.О., Тайшінгер А. та ін.** Зв'язок властивостей деревини та якості виробів з деревини // Науковий вісник : зб. наук.-техн. праць. – Львів : НЛТУ України. – 2007. – Вип. №17.4. – С. 101-108.
3. **Сопушинський І.М., Вінтонів І.С., Гриник Г.Г.** Лісова сертифікація одна з передумов для сталого ведення лісового господарства // Науковий вісник НЛТУ України : зб. наук.-техн. праць. – Львів : УкрДЛТУ. – 2002. – Вип. №12.8. – С. 9-13.
4. **Сопушинський І.М.** Методичні аспекти структуроутворення декоративної деревини // Науковий вісник НЛТУ України : зб. наук.-техн. праць. – Львів : РВВ НЛТУ України. – 2011. – Вип. №21.10. – С. 41-46.
5. **Сопушинський І.М., Вінтонів І.С., Рябчук В.П.** Особливості внутрішньовидової диференціації листяних деревних видів // Науковий вісник НЛТУ України : зб. наук.-техн. праць. – Львів : РВВ НЛТУ України. – 2008. – Вип. №19.13. – С. 8-12.
6. **Beals H.O.** Figure in Wood: An Illustrated Review / H. O. Beals T. C. Davis // Alabama Agricultural Experiment Station. – Alabama: Auburn University. – 1977. – Bulletin 486. – 79 p.
7. **Bucur V.** Acoustics of Wood. – [2nd edition]. – Berlin: Springer Verlag, 2006. – 393 p.
8. **Contribution to the fine anatomy and histochemistry of birdseye sugar maple** / D. Rioux, T. Yamada, M. Simard [et al.] // Canadian Journal of Forest Research. – NRC Research Press. – 2003. – Volume 33, Number 5. – P. 946- 958.
9. **Growing valuable broadleaved tree species**: COST E42 [Final Report] / Edited by G. Hemery, H. Spiecker, E. Aldinger etc. – Freiburg im Br.: Uni-Freiburg, 2008. – 40 p.
10. **Mayevskyy V.** The effect of a sawing angle on wood texture / V. Mayevskyy, V. Maksymiv, I.Sopushynskyy [et al.] // Folia Forestalia Polonica. – Poznań: Series B. – 2008. – Issue 39. – P. 45-54.
11. **Quality Control for Wood and Wood Products:** The first conference COST E53, 15th -17th

October 2007, Warsaw / Edited by M. Grześkiewicz. – Warsaw: Warsaw University of Life Sciences, Faculty of Wood Technology, 2007. – 173 p.
12. **Kohl F.** Furnier – Tradition mir Netzwerk und Perspektiven // Furnier Magazin. – 2009. – P. 32-49.

УДК 630*5:630*811.2 ***Доц. І.М. Сопушинський, канд.с.-г.наук – НЛТУ України***

## Декоративна деревина цінних листяних деревних порід, що зростають в України

Структура деревини цінних листяних деревних видів визначає особливості поверхонь пиляної та колотої деревини, які надають декоративний вигляд виробам із деревини. Декоративна деревина аномалій демонструє дуже часто неповторну текстуру і має досить високу вартість. Вони характерні для клена-явора форми "пташине око" та клена-явора, бука лісового та ясена звичайного із завилькуватою деревиною. Деревина цих цінних листяних деревних порід має велике значення як декоративна сировина, так і акустична сировина для виробництва музичних інструментів.

**Ключові слова:** декоративна деревина, завилькувата деревина, клен-явір, бук, ясен.

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UDC 658.527.011.56 ***Assoc. prof. R.Ya. Orikhovskyy – UNFU***

## PROBLEMS OF RELIABILITY OF HARDWARES IN COMPUTER-AIDED SYSTEMS OF TECHNOLOGICAL PROCESSES CONTROL

The questions of application of modern methods of determination of reliability of automated control the system technological processes are examined for the decision of tasks of increase efficiency of functioning of the automated production systems on the enterprises of industrial forestry complex. Influence of reliability of equipment on the actual productivity of the automated production systems is probed. Diminishing of reliability of equipment results in the considerable decline of the actual productivity of the automated production systems and decline of stability of technological operations. It is expedient to conduct the increase of reliability of the automated production systems by the structural backuping, development of charts of arrangement of equipment, structurally self-reactance optimization, imitation design.

**Keywords:** problems of reliability, automated control the system by technological processes, instability of duration of operations, imitation design is automated.

One of basic properties of hardwares of automation of production processes, which substantially influences there is reliability on efficiency of functioning of automated control the system by technological processes. The considerable losses of time of functioning of technological equipment are drawn above all things the unreliability of technique, failings in organization of labour and other factors of external influence. Reliability of hardwares of automated control the system by technological processes is determined such constituents: faultlessness, suitability to repair, by longevity, by property to keep the set descriptions during the set term.

Faultlessness, determines property of hardware to keep a capacity during some time is the most essential constituent of reliability of hardwares and determined reliability of elements, chart of their connection, functional, structural and algorithmic features, external environments. Suitability to repair, characterizes adjusted of hardware to warning, finding and removal of consequences of refuses by implementation of technical service and repairs, predefined structural properties of hardware, presence of control-diagnostic apparatus, properties of the utillized elements, and also qualification of auxiliary personnel, organization of exploitation et cetera. Longevity characterizes property of hardware to keep a capacity with necessary interruptions for technical service and repairs to some certain state. Sometimes the moral senescence of majority of hardware often comes before, than physical. Important is property of hardware to keep the set operating descriptions during shelf-life and transporting.

Important the factor of violation of the set terms of co-operation between mechanisms, instruments and purveyances in a technological line there are not only harmful influences on equipments which appears in the process of his protracted exploitation, but also cyclic instability of parameters of work which shows up from the beginning of exploitation of technological line. Therefore interpretation of the phenomena of reliability of the automated production systems from positions only a wear and accumulation of damages is insufficient. In technological lines refuses influence on technological reliability through casual character of sizes and certain descriptions of purveyances, parameters of machine-tools and their knots, instruments. On proceeding in the normal process of functioning of the automated production system required set time. The charges of time on proceeding in normal work of equipment increase duration of intervals of issue and reduce the actual productivity of basic and auxiliary equipment [1-13].

The necessity of increase of reliability of hardware at automated control the system by technological processes is predefined the substantial consequences of refuses of hardwares, which result in diminishing of amount of products which is made, decline of its quality, to the groundless charges of energy, materials of raw material, fuel. These undesirable consequences grow with the increase of power of equipment and rev-up flowing of technological processes. As a result of insufficient reliability of hardwares and considerable growth of their amount the quantity of necessity of operative operating personnel of automated control the system by technological processes is increased, and also to the personnel which is engaged in repair of automatic control the system.

Therefore for the decision of problem of reliability of automated control the system by technological processes it is suggested to decide such essential tasks:

1. To develop the methods of forming of the scientifically grounded requirements to reliability of industrial hardwares of different types recognition possibility of their backuping, use of these facilities at different automated control the system by technological processes which differ after the level of necessary reliability.
2. To develop the methods of optimization of technical maintenance of hardwares of automated control the system by technological processes and microprocessors, to utillize facilities of computer technique, with the study of rational level of centralization of service and warehousing of awaiting-parts.
3. To develop scientific and technical principles and organizational methods of providing of reliability of hardwares for especially responsible automated control the system by technological processes, which must engulf all of the stages of development, mass production and exploitation of such hardwares.
4. To analyse possibilities and wideuse of vehicle and programmatic methods of control and diagnostics of good condition of hardwares of automated control the system by technological processes.
5. To create scientific and engineerings bases of reliable computer-aided of difficult facilities and control the system design. To execute a supervision and calculations of actual reliability of mechanisms indexes and built on in the conditions of exploitation together with analogical researches of the productivity and stability. It is expedient to conduct the increase of reliability of the automated production systems with the use of the structural backuping, development of charts of arrangement of technological lines, structurally self-reactance optimization, imitation design.

The decision of the indicated tasks, next to upgrading stuff wares, improvement of their external environments, upgrading preparation of operating personnel and other technical and organizational measures, will enable considerably to improve reliability of hardwares of automation of automated control the system by technological processes on the whole.

## References

1. **Dudyuk D.L., Zagvoyska L.D., Maksimiv V.M., Soroka L.M.** Elements of theory of automatic transfer lines: – Kyiv-Lviv: IZMN, 1998. – 192 c.

2. **Dudyuk D.L., Maksimiv V.M., Soroka L.Ya., Orikhovsky R.Ya. et al.** An imitation design of the flexible automated lines is in a industrial forestry complex. – K.: ISDO, 1996. – 140 c.

3. **Gayda S.V.** A comparative analysis of physical-and mechanical parameters of variously-designed Glued Boards made of post-consumer Recovered Wood / Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2010, 36:81-91.

4. **Gayda S.V.** A problem of wood raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2007, 33:55-63. (in Ukr.).
5. **Gayda S.V.** Research of concentration of operations is in modern furniture Productsion // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2007, 33:73-79. (in Ukr.).
6. **Gayda S.V.** Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:238-244. (in Ukr.).
7. **Gayda S.V.** Comparative analysis of bending particularities for various post-consumer wood species and age categories // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:84-88. (in Ukr.).
8. **Gayda S.V., Voronovich V.V.** Investigation of the features of bending of post-consumer wood // Proceedings of the Conference, Mari State University, – 2011, 190-192 (in Russian).
9. **Gayda S.V.** The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. – Lviv: UNFU. – 2009, 19.14:72-89. (in Ukr.).
10. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2008, 34:55-68. (in Ukr.).
11. **Gayda S.V.** Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood / Forestry, Forest, Paper and Woodworking Industry, 2008, 34:68-79. (in Ukr.).
12. **Gayda S.V.** Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2009, 35:63-83.
13. **Gayda S.V., Maksymiv V.M.** From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. – Lviv: 2010, 36:57-77.

УДК 658.527.011.56 ***Доц. Р.Я. Оріховський, канд. техн. наук – НЛТУ України***

## Проблеми надійності технічних засобів в автоматизованих системах керування технологічними процессами

Розглянуто питання застосування сучасних методів визначення надійності автоматизованих систем керування технологічних процесів для вирішення завдань підвищення ефективності функціонування автоматизованих виробничих систем на підприємствах лісопромислового комплексу. Досліджено вплив надійності обладнання на фактичну продуктивність автоматизованих виробничих систем. Зменшення надійності обладнання призводить до значного зниження фактичної продуктивності автоматизованих виробничих систем і зниження стабільності технологічних операцій. Підвищення надійності автоматизованих виробничих систем доцільно проводити за допомогою структурного резервування, розроблення схем компонування обладнання, структурно-параметричної оптимізації, імітаційного моделювання.

**Ключові слова:** проблеми надійності, автоматизовані системи керування технологічними процесами, нестабільність тривалості операцій, імітаційне моделюванняю

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## DETERMINATION OF LOADING IN THE MANIPULATOR TYPE MOBILE LOADING MACHINES BY THE ACCELERATIONS

The casual oscillations of loading machine during motion, on the basis of model of the spatial oscillating system of loader are considered. Indignation of oscillations in a loading machine is caused by different sources, namely: by the oscillations of the suspended log grab and load, manipulator, aggregates and knots of transmission, vibrations and inequalities of road. The theoretical bases are executed and determination of loading is offered by determination of vertical reactions by the oscillations.

**Keywords:** mobile loading machine, oscillations, accelerations, vertical reactions.

**Introduction.** Work of manipulator type mobile loading machines in the conditions of log sort yard is accompanied by the continuous by a change of loading which

operates on it [1]. Frame of upper carriage, an undercarriage frame, construction of manipulator of loading machine are details, which test the considerable variables loadings and intermittent shock loadings, that causing a fatigue fracture of local character. The development of construction of such loading machine is impossible without a lead through experimentally researches. Such researches are especially needed because of the complication of executable by the machines functions during the transportation of the round commercial timbers, trapped by a radial log grab that is freely suspended on dipper stick. The structural features of such machines must provide firmness during the motion, optimal dirigibility and safety of motion, and also avoid the loading machine from a vibration [2, 3].

All the knots and parts of the machines were always tested thoroughly, but in the last few years the requirements to the volume and quality of all gained results grew considerably and the methods of tests became more complicated. At this time, statistical estimations require the thorough approach to the experiment, special equipment and apparatus. It is related with requirements that behave to quality of steel construction of weight-lifting machines and their knots. As it has been noted, the calculative method doesn't allow us to determine the character of the oscillating system of loading machines with the wanted accuracy [3]. It is because the calculation models usually substantially simplify the real system. Therefore complication of calculation model itself does not justify practically, as it requires introduction to the model of many coefficients and nonlinear dependences unknown on the stage of constructing.

According to this, it is possible just to estimate all the indexes of operational attributes of the knots and parts on the planning stage. More actual descriptions and sizes of those indexes are being determined only during the tests of pre-production model and they can substantially differ from the calculated ones.

**Methodology.** Indignation of oscillations in a loading machine is caused by different sources, namely: oscillations of the suspended log grab and load, manipulator, aggregates and knots of transmission, vibrations and inequalities of road. But not all oscillations of loading machine influence her firmness during motion. In this regard, the changes of reaction of the wheels of the loading machine are only caused by oscillations that are stipulated by operating of oscillations of manipulator under the suspended loads and by the inequalities of road. These oscillations of the basic masses of the oscillating system cause substantial inertia overloads in the support points of a loading machine, that can be fixed by determination of vertical reactions according to accelerations.

The oscillating system of loading machine can be presented by a dynamic model that consists of a row of swaying links, connected together. Those are manipulator with the suspended load, the springless masses on tires, the spring mass on it suspension, spring suspension cab, engine on resilient supports, operator on a seat and others.

Determination of vertical reactions on the wheels of loader by registration of accelerations in the different points of spring suspension and unsprung parts is most expedient, as establishment of transducer for determination of accelerations requires minimum preparation, and the method of registration is well exhausted. First of all it allows to analyse the features of the system on the whole in more depth, second - to estimate the role of separate parts in the general system of oscillations.

**Ground of theoretical bases.** Structurally a loading machine is developed in the way to ensure its stable forward longitudinal motion and avoid the oscillation. It is also

important to avoid any transversal linear oscillations while the machine is in motion [2]. In order to do that the loading machine is designed in the special way, where the manipulator set swing-type differs from existent weight-handling and grapple dredger machines. Its framework has to assure stable rectilineal motion, in the way to prevent any occasional turns in a horizontal plane, that "yaw". Thus, the springing undercarriage and upper carriage of loading machine during motion carries out only vertical, longitudinally angular and transversal-angular oscillation [4].

Let's analyse the occasional oscillations of loading machine during motion, on the basis of the simplified model of the spatial oscillating system of loader (fig. 1). Vertical dynamic reactions on wheels are marked $N_{1Л}$, $N_{1П}$, $N_{2Л}$ and $N_{2П}$.

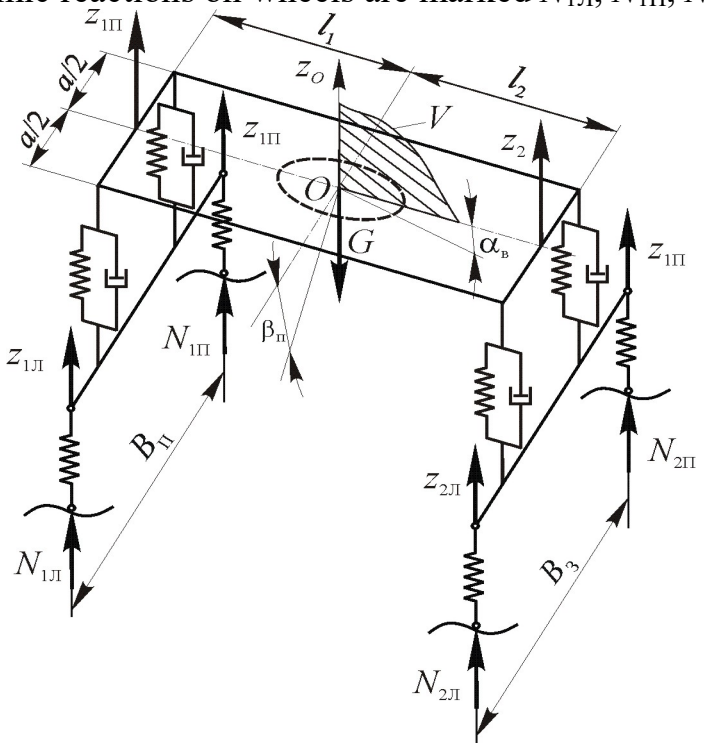


***Fig. 1. Simplest spatial model of loader***

The horizontal constituents of dynamic reactions will consider insignificant [4]. Then for all system which includes spring suspension and unsprung the masses, it is possible to write down the followings equalizations which link dynamic reactions and inertia forces:

$$N_{1Л} + N_{1П} + N_{2Л} + N_{2П} = M \cdot \ddot{z}_o + \frac{(\ddot{z}_{1Л} + \ddot{z}_{1П}) \cdot m_1}{2} + \frac{(\ddot{z}_{2Л} + \ddot{z}_{2П}) \cdot m_2}{2}, \quad (1)$$

$$(N_{1Л} + N_{1П}) \cdot l_1 - (N_{2Л} + N_{2П}) \cdot l_2 = J_\alpha \cdot \ddot{\alpha}_В + \frac{(\ddot{z}_{1Л} + \ddot{z}_{1П}) \cdot m_1}{2} \cdot l_1 + \frac{(\ddot{z}_{2Л} + \ddot{z}_{2П}) \cdot m_2}{2} \cdot l_2, \quad (2)$$

$$\frac{B_П \cdot (N_{1Л} - N_{1П})}{2} + \frac{B_З \cdot (N_{2Л} - N_{2П})}{2} = J_\beta \cdot \ddot{\beta}_{ПП} + J_{Н1} \cdot \ddot{\beta}_{Н1} + J_{Н2} \cdot \ddot{\beta}_{Н2}, \quad (3)$$

where: $l_1$, $l_2$ – are distances of centre of gravity $O$ of spring suspension the masses from front to the back axis; $B_П$, $B_З$ – track of front and back wheels; $M$ – spring suspension the masses; $m_1$, $m_2$ – front and back unsprung the masses; $J_\alpha = M\rho_\alpha^2$ – moment of inertia of spring suspension the masses in relation to a transverse axis which passes through the centre of gravity; $J_\beta$ – moment of inertia of spring suspension the masses in relation to a longitudinal axis which passes through the centre of gravity; $J_{Н1}$, $J_{Н2}$ – moments of inertia of front and back unsprung the masses are in relation to horizontal axes which pass through their centres of gravity parallel the longitudinal plane of loading machine; $z_o$ –

vertical moving of centre of gravity of spring suspension the masses; $z_{1Л}$, $z_{1П}$, $z_{2Л}$, і $z_{2П}$ – vertical moving of supports; $\alpha_в$, $\beta_п$ – angular moving of spring suspension mass in longitudinal and transversal planes; $\beta_{Н1}$, $\beta_{Н2}$ – angular moving in the transversal plane of front and back axes, that lines which connect the centers of right and left supports.

Sum of vertical reactions on the forewheels of $N_{1Л} + N_{1П}$ and sum of vertical reactions on the back wheels of $N_{2Л} + N_{2П}$ it is possible to define from equalizations (1) and (2).

After simple transformations will get the followings expressions:

$$N_{1Л} + N_{1П} = M_1 \cdot \ddot{z}_1 \cdot \left( \frac{l_2 + \varepsilon l_1}{L} \right) + M_2 \cdot \ddot{z}_2 \cdot \left( \frac{l_2 + \varepsilon l_2}{L} \right) + \frac{m_1 \cdot (\ddot{z}_{1Л} + \ddot{z}_{1П})}{2}, \quad (4)$$

$$N_{2Л} + N_{2П} = M_2 \cdot \ddot{z}_2 \cdot \left( \frac{l_1 + \varepsilon l_2}{L} \right) + M_1 \cdot \ddot{z}_1 \cdot \left( \frac{l_1 + \varepsilon l_1}{L} \right) + \frac{m_2 \cdot (\ddot{z}_{2Л} + \ddot{z}_{2П})}{2}, \quad (5)$$

where: $z_1$, $z_2$ – vertical moving of spring suspension the mass in the longitudinal plane of symmetry above a front and back axis; $L$ – length of wheelbase of loader; $M_1 = Ml_2/L$ and $M_2 = Ml_1/L$ – spring suspension the masses of front and back axis; $\varepsilon$ – coefficient of distributing of the masses, which taking into account mass of $M$ and moment of inertia of $J_\alpha$ loading machine it is determined after a formula $\varepsilon = \dfrac{J_\alpha}{M \cdot a \cdot L}$, (6)

where $\rho$ – radius of gyration.

The results of researches show that for the values $\varepsilon = 0{,}8 \div 1{,}2$ of oscillation of spring suspension the masses above front and back suspension is practically unrelated, and for values $\varepsilon = 0{,}7 \div 0{,}8$ and $\varepsilon = 1{,}2 \div 1{,}4$ intercommunication of these oscillations shows up poorly enough. The condition of independent oscillations is a case $\varepsilon = \rho^2 / (a \cdot L) = 1$. Then for a case $\varepsilon \cong 1$.

$$N_{1Л} + N_{1П} = M_1 \cdot \ddot{z}_1 + \frac{(\ddot{z}_{1Л} + \ddot{z}_{1П}) \cdot m_1}{2}, \quad (7)$$

$$N_{2Л} + N_{2П} = M_2 \cdot \ddot{z}_2 + \frac{(\ddot{z}_{2Л} + \ddot{z}_{2П}) \cdot m_2}{2}. \quad (8)$$

According to the presentations described above, a loading machine is examined as a conditional equivalent oscillating system, which includes separate masses, connected by resilient elements with snubbers. Analysing such mechanical system, mathematical copulas set foremost between the laws of moving of separate the masses, descriptions of resilient and snubbers elements, and external actions which are put.

**Conclusions.** Thus, it is possible to define the sum of vertical dynamic reactions on right and left wheels by measuring accelerations of spring suspension and unsprung the masses of a loading machine.

In order to define every reaction separately, present three equalizations (1) – (3) not enough. Differences in reactions on the left and right wheels of $N_{1Л} - N_{1П}$ and $N_{2Л} - N_{2П}$ from equalization (3) are determined for both of them only. Correlation between $N_{1Л} - N_{1П}$ and $N_{2Л} - N_{2П}$ even for the very simplified model, presented on fig. 1, does depend on internal forces of the system, which arise up between spring suspension and unsprung parts, that from the difference of corners $\beta_п$ and $\beta_н$, angular inflexibilities and angular unsprung resistances of front and back suspensions. In actual fact this correlation depends also on the kinematics of sending device of suspension and from turning inflexibility of frame of loading machine under the action of oscillations of load.

While determining of sum of vertical reactions after equalizations (4) and (5) or (7) and (8) all the operations with measuring of accelerations should be conducted according to special measuring system, from which a signal, proportional the size of total reaction, acts at once. All the proper coefficients should also be taken into the account.

There is other method which is more accurate but less practical, where accelerations $\ddot{z}_1$ and $\ddot{z}_2$ is separately registered. In this case, to find the quadratic average of reaction, it is necessary yet to define mutual cross-correlation functions, which write down accelerations which at the same time makes the processing of data much more complicated. Transducers for measuring of acceleration $\ddot{z}_1$ and $\ddot{z}_2$, set symmetries of loader in plane. Transducers for measuring of accelerations $\ddot{z}_{1Л}$, $\ddot{z}_{1П}$, $\ddot{z}_{2Л}$, $\ddot{z}_{2П}$, set on wheels. Since both front and back axes of the loading machines are structurally executed as solid beams, that is why two transducers on the right and left wheels of one axis can be substituted with one in the vertical plane of symmetry, which will write down the mean value of acceleration directly $(\ddot{z}_Л + \ddot{z}_П)/2$.

## References


1. **Бакай Б.Я.** Погрузочные машины: надежность, скорость, качество / Б.Я. Бакай // Оборудование и инструмент для профессионалов. – Харьков : ИИФ ЦентрИнформ, 2007. – Вып. 5 (93). – С. 102–107.
2. **Jörnsen Reimpell.** The automotive chassis: engineering principles / Reimpell Jörnsen , Stoll Helmut, W. Betzler Jürgen. – [2nd edition]. – Oxford : Butterworth-Heinemann Elsevier Science, 2001. – 460 p. – ISBN 0-7506-5054-0.
3. **Monismith C.L.** Truck pavement interaction: requisite research / C.L. Monismith, J. Lysmer, J. Sousa, J.K. Hedrick // SAE Technical Paper Series, UCTC. – 1988. – № 48. – P. 87–96.
4. **Певзнер Я.М.** Колебания автомобиля / Я. М. Певзнер, Г. Г. Гридасов, А. Д. Конев и др. – М. : Машиностроение, 1979. – 208 с.
5. **Корчагин П.А.** Развитие научных основ проектирования виброзащитных систем землеройных машин : автореф. дис. на соиск. учен. степ. д-ра техн. наук : спец. 05.05.04 “Дорожные, строительные и подъемно-транспортные машины” / П.А. Корчагин. – Омск, 2011. – 36 с.



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## Визначення навантаження в мобільних навантажувальних машин маніпуляторного типу за пришвидшеннями


Розглянуто випадкові коливання навантажувальної машини під час руху, на основі моделі просторової коливальної системи навантажувальної машини. Збурення коливань у навантажувальній машині спричинено різними джерелами, а саме: коливаннями підвішеного грейфера і вантажу, маніпулятора, агрегатів та вузлів трансмісії, вібраціями і нерівностями дороги. Виконано обґрунтування теоретичних основ та запропоновано визначення навантаження шляхом визначення вертикальних реакцій за пришвидшеннями.



**Ключові слова:** навантажувач, коливання, пришвидшення, вертикальні реакції.

UDC 674.

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# METHODOLOGICAL PRINCIPLES OF ENERGY MANAGEMENT IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT OF WOODWORKING INDUSTRY ENTERPRISES

In this article, we consider the issue of working out energy efficiency strategy at woodworking enterprises as a constituent part of energy management. The role it plays and the place it occupies in the global strategy of sustainable development of enterprises have been defined; also characterized here are the main stages of shaping energy conservation policy as well as energy management in terms of integrated approach to environmental management.

**Keywords:** energy management, sustainable development, wood waste, energy efficiency, wood-fired energy, heat energy balance.

For many decades, the main task of the department of energy in the woodworking companies was provision of reliable and uninterrupted power supply. Costprice, quality and environmental performance of energy were considered of minor importance and were settled only in the case of special aggravation. The first were the necessary resources of energy and generating capacity. Today, the state seeks to provide primarily high social standards and safe environment for its citizens. Therefore, in the foreground is reliable and environmentally friendly meeting the needs of energy products at reasonable, economically reasonable and balanced cost. Clearly enough, that using in the production morally and physically obsolete equipment, conducting passive policy of modernization, makes impossible and contrary to the main preconditions of the concept of energy management, sustainable development at wood processing enterprises as a whole [1-15].

The development of energy strategy has prominent place in the energy management system. Unfortunately, researching of the energy strategy formation in the woodworking industry, despite its importancis, at the in fant stage of development. Until now, we have not had even terminology that applies to this problem, have not resolved issues related to the definition of its place in the overall development strategy, principles of construction, development stages, etc.

The problems of energy strategy of woodworking enterprises should be considered based on the fact that wood waste, generated in the production of any wood products is a raw material for heat and, in the future, electric power for meeting their energy needs. Of course, the energy strategy of woodworking enterprises must meet specific key areas of energy policy at the state level, due to primarily monopolistic nature of all power and lack of competition in the electricity market. Under these conditions, becouse of limited measures woodworking enterprice, usually try to find additional cost savings to reduce the energy costs. The process of developing the energy strategy of woodworking companies can be divided into several stages. In the first stage, which premised on technological analysis (waste balance), should be assessed wood waste, generated during the production as wel as it distribution. On the basis of the analysis, the ability of wood waste in annual heat energy should be calculated. In the second stage we have to prove the needs of the enterprise for thermal and electric energy. It is reasonable to classify heat energy needs according to in the areas of its using: – drying

department; – technological needs; – heating and ventilation needs; – household needs, and then to develop a schedule of consumption during the year, given the overall strategy of the enterprise. In the third stage the enterprise directly or through third-party experts conducts an energy audit to reveal internal reserves to reducing energy costs. The main purpose of this is to evaluate the efficiency of all types of energy resources, heat and electric energy, compressed air, water to determine the energy saving potential, to make a choice of boiler, ventilation equipment for own using of thermal energy.

The fourth stage involves identifying areas of wood waste using, which generated after the enterprise satisfying in heat energy needs. The number of it is based on heat balance as the results of calculations of thermal energy in the first and second stages. The selection of direction is based on impact assessment of macro environment and the enterprise location. Analysis of macro environment requires using information on forecasts of the country's and region economy, including the development prospects of the energy sector. To analyze the immediate environment and evaluate its impact on the formation of production costs of certain products may be involved information obtained through the studying of actual and potential market demand, expert opinions on various aspects of the competitors' works, and so on. In the fifth stage a system of indicators should be formed for economic evaluation of the effectiveness of and justification for selecting the most appropriate options for energy saving measures.

An economic assessment of expected effectiveness of the proposed measures should be carried out. The final sixth stage provides the implementation of actions under enterprise energy strategy, it monitoring and adjustment. Theoretical research of energy capacity of woodworking enterprises, using the above methodology, allowed the authors to develop the nomogram of heat energy balance, which depend on the company specialization. For example, (Fig. 1) presents the nomogram to define thermal balance of glulam beams manufacturing enterprise. To use this nomogram should be asked specific volume value of roundwood processing now (year or quarter), and type of waste that will be burnt to obtain thermal energy (including their fractional status and humidity). However, the use of nomogram helps us to determine not only the necessary amount of heat energy for the operation of enterprises, the volume of wastes that must be taken (for burning) to receive it, but also the number of "surplus" of wood waste – in this order of the above operations should be carried out in the opposite direction.

The results obtained by using the graph method of nomogram shows, that direct combustion of wood waste generated during the manufacture of products, fully enables the production of thermal energy for technological purposes (drying lumber),for heating production and administrative and domestic premises during the heating period and other requirements. In addition, during the burning of the entire volume of waste for a year, excess of thermal energy will be about 20-65%, depending on specialization, which enables to realize the surplus of dry wood waste in many ways – to organize production line for fuel pellets or briquettes, or to supply thermal energy to other consumers in the area range of economic efficiency. Using proposed methodological approach to the energy management problem of woodworking companies, as the process of control of using primary resource and energy: planning, organization, coordination, accounting and control for consumption of all types and forms of energy with minimal environmental impact, optimal use of capacities, including level of current costs and future costs, – is an objective for building sustainable development strategy of woodworking enterprises,

guidelines for each of which are reorganization of the power supply system and rethinking the principles of immense squandering, that generally promote providing competitive advantages for domestic woodworking enterprises, enhance their competitiveness and improve state's economic and energy security as a whole.

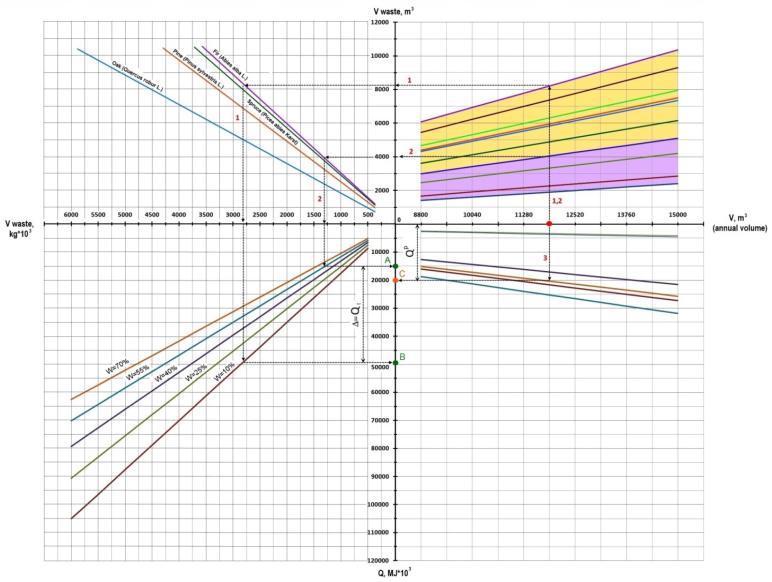

***Fig. 1. Nomogram of definition heat energy balance***

Fig. 1 – shows a method of using the nomogram; "1" – curve to determine the maximum amount of heat (point A), when burning the entire volume of wood waste with moisture adopted by 10 %; "2" – curve to determine the amount of heat (point B), which is released during combustion of the entire volume of raw wood waste. Value Δ (Δ = $Q_t$) shows the maximum of heat energy formed during the combustion of total volume of wood waste with regard to their moisture, factionalism and wood species. The curve "3" is used to determine the total heat capacity of the enterprise (point C).

**Conclusions.** The article discusses the formation of energy strategy of woodworking enterprises, as part of energy management. Defines its role and place in the overall strategy of the company, described the main stages of development of energy conservation and energy management.

## References


1. **Klaus Dieter E. Pawlik** – Solutions manual for guide to energy management, Fourth edition – Special publication, Vancouer, 2008.
2. **Michael F. Hordeski** – Dictionary of energy efficiency technologies. The Fairmount press, Indian trail, Lilburn. – 2005.
3. **Wayne C.** Turner – Energy management handbook, fifth edition – The Fairmont Press, 2004 – 812 p.
4. **Головков С.И.** Энергетическое использование древесинных отходов / С.И. Головков, И.Ф. Коперин, В.И. Найденов. – М.: Изд-во "Лесн. пром-сть", 1987. – 224 с.
5. **Енергетична стратегія України** на період до 2030 року. Розпорядження, стратегія від 15.03.2006 р., № 145-Р.
6. **Закон України** "Про енергозбереження". – № 74/94-ВР від 1.07.1994 р.
7. **Gayda S.V.** A problem of wood raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2007, 33:55-63. (in Ukr.).
8. **Gayda S.V.** Research of concentration of operations is in modern furniture Productsion // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2007, 33:73-79. (in Ukr.).
9. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2008, 34:55-68. (in Ukr.).
10. **Gayda S.V.** Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood / Forestry, Forest, Paper and Woodworking Industry, 2008, 34:68-79. (in Ukr.).
11. **Gayda S.V.** Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2009, 35:63-83.
12. **Gayda S.V., Maksymiv V.M.** From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. – Lviv: 2010, 36:57-77.
13. **Gayda S.V.** A comparative analysis of physical-and mechanical parameters of variously-designed Glued Boards made of post-consumer Recovered Wood / Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2010, 36:81-91.

14. **Gayda S.V.** Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:238-244. (in Ukr.).
15. **Gayda S.V.** The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. – Lviv: UNFU. – 2009, 19.14:72-89. (in Ukr.).

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## Методологічні принципи енергоменеджменту в аспекті проблем сталого розвитку підприємств деревообробної галузі

Розглянуто питання формування енергетичної стратегії деревообробного підприємства як складової частини системи енергетичного менеджменту. Визначено її роль і місце в загальній стратегії сталого розвитку підприємства, охарактеризовано основні етапи розробки енергозбереження та енергетичного менеджменту з точки зору комплексного підходу до природокористування.

**Ключові слова:** енергоменеджмент, сталий розвиток, відходи деревини, енергоефективність, баланс теплової енергії.

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## METHOD OF CALCULATION OF DRYING TIME IN SOLAR PLANTS

Provided analytical equation calculation of the drying in the 1st and 2nd periods of drying.
**Ключові слова:** solar plant, grafically-criterial methods, nusselt criterion.

It is known [1, 2] that in engineering practice, to calculate the duration of drying grafically-criterial and analytical (tabular) methods are used. Thus the total duration of drying includes drying time in the periods of constant and slowing drying rates [3-7].

Note that the grafically-criterial method is based on analytical formulas that are derived from studies of the kinetics and dynamics of the drying process, as well as principles of the general theory of drying. For the analytical calculations of the drying time Initial data should be known or taken into account: species *($\rho_b$)*; thickness of material *$S_1(R=S_1/2)$* which is dried, width of lumber stacks, direction of moisture flow(tangential, radial), operating conditions *($t_s$, $t_m$, $\Delta t$, $\varphi$)* i and air circulation speed (drying agent) on stacks *v*. The sequence of calculating the duration of drying is. Depending on operating conditions, species and average humidity of wood with appropriate diagrams define the coefficients of specific heat and thermal conductivity of wood at the actual humidity of the material and define the magnitude of the coefficient of thermal diffusivity a ($a = \frac{\lambda}{\rho \cdot c}$, $m^2/s$).

According to the formulas given below [3] set the value of the coefficients of thermal conductivity of air (drying agent) $\lambda$ and kinematic viscosity $\upsilon$, that is

$$\lambda = [4{,}67-(4{,}16+2{,}45\cdot\varphi)]\ 10^{-2}+[7{,}14+4{,}46\ \varphi]\ T_1\cdot 10^{-5}, \quad (1)$$

where $T_1$ – absolute temperature of the dry thermometer, K; $\varphi$ – relative humidity.

$$\upsilon = [0{,}113\cdot T_1-(18{,}24+7\cdot\varphi)]\ 10^{-6} m^2/s \quad (2)$$

Set mode of heat motion (drying agent) with the Reynolds criterion, that is

$$\mathrm{Re}_f = \frac{v\cdot b}{\upsilon} \text{ for air} \quad (3)$$

and several stacks of boards $\mathrm{Re}_{\text{air}} = \frac{v \cdot S_1}{\upsilon}$ (4)

Nusselt criterion, as demonstrated by our study [1], should be determined by the formula type $Nu_f = 0{,}0641 \cdot \mathrm{Re}_f^{\,0.80} \cdot \left(\frac{T_1}{T_2}\right)^2 \mathrm{Pr}_f^{\,0.33} \left(1 - \frac{1}{\mathrm{Re}_{\text{air}}} \cdot \frac{b}{S_1}\right)^4$, (5)

where $Pr_f (Pr_f = v_c/d)$ – Prandtl criterion, which for air can be taken equal $Pr_f$=0,72 for solar plant conditions.

Finding the value of Nusselt criterion, we can calculate the coefficient of heat transfer, that is $\alpha_к = \frac{Nu_f \cdot \lambda}{b}$, *W/(m°C).* (6)

At a given temperature regime of drying wet thermometer $t_2$ specific heat of vaporization will be $r = r_0(1 - 0{,}001 \cdot t_2)$ *kJ/kg.* (7)

Speed of drying in the first period, period of constant drying rate, determined by the formula [1] $N = \frac{100 \cdot \lambda_k \cdot (t_1 - t_2)}{r \cdot \rho_{\text{b}} \cdot R}$ *%/s.* (8)

As shown by our study, the value of humidity on the surface of material (drying matter) at the critical point can be determined by the formula $W_{\text{ex}} = 32{,}5 - 0{,}135 \cdot t_2$, *%.* (9)

To determine the coefficient of moisture conductivity at it is necessary to know the direction of moisture motion (radial, tangential) in wood during drying. Particularly, if solar plant chamber loaded with tangentially cut boards, the basic direction of water movement in the material should be taken radial and vice versa. When placing the boards in a mixed stack should be taken tangential direction of moisture in the material should be taken.

Mathematical treatment of our experimental studies [1] showed that the coefficient of moisture conductivity with sufficient accuracy can be calculated by the formula type $a'_m = 23{,}5 \cdot 10^{-8} \left(\frac{T_2}{273}\right)^{23} \left(\frac{\rho}{400}\right)^{-3{,}9} \left(1 + \frac{2 \cdot V_{\text{w}}}{100} + \frac{\sin\beta}{\sin 90^0}\right)$ *sm²/s,* (10)

where: $V_w$ – the amount of volume pith, %; $\beta$ – the angle formed by the tangent to the annual rings and the normal drawn to the outer layer in the middle of the board (for radial flow of water β=90°, and for tangential β=0°).

Then, the duration of wood drying in a period of constant drying rate will be

$\tau_1 = \frac{W_{\text{in}} - W_{\text{ev}}}{N}$, *s.* (11)

Duration of wood drying in the period of slowing down rate of drying can be found by the formula $\tau_2 = 2{,}31 \cdot \frac{4 \cdot R^2}{\pi \cdot d'_m} + \frac{R}{\alpha'_v} \cdot \lg \frac{W_{\text{ex}} - W_r}{W_{\text{ev}} - W_r}$, *s,* (12)

where $\alpha'_{\text{v}}$ – moistre-change coefficient ($\alpha'_v = \frac{N \cdot R}{0{,}25}$) *m/s;* $W_r$,$W_{ev}$ – accordingly equilibrium and the fime moisture content of wood, *%.*

The intensity of evaporation of moisture in the first period is determined

$q'_m = \frac{\rho \cdot R \cdot N}{100}$, *kg / m²s.* (13)

For the second period of drying (at the beginning), when $Re > \lambda_0^5$, heat transfer coefficient is determined by the formula $\alpha_c = 0{,}032 K y_a^{0{,}80} \cdot \frac{\lambda}{b}$, *W/(m²°C).* (14)

Value of the criterion of phase transition will be $\varepsilon' = \frac{2 \cdot \lambda \cdot \Delta t}{r \cdot q'_m \cdot R}$. (15)

Thus, the total drying time will be equal to $\tau = \tau_1 + \tau_2$.

## References


1. **Ozarkiv I.M.** Scientific and technical bases of convective-radiative drying of wood / Manuscript. Doctor of Technical Sciences Thesis, speciality 05.05.07. – Lviv: UNFU, 2006.
2. **Ozarkiv I.M., Misaki L.S., Kopynets Z.P.** Using solar energy industry: Teach. Manual. – Lviv: RPC "Ukrainian Technologies", 2008. – 276 p.
3. **Ozarkiv I.M., Soroka L.Y., Hrytsiuk Y.I.** Fundamentals of aerodynamics and heat mass transfer: Teach. Manual. – K.: IZMN, 1997. – 280 p.
4. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2008, 34:55-68. (in Ukr.).
5. **Gayda S.V.** Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2009, 35:63-83.
6. **Gayda S.V.** Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:238-244. (in Ukr.).
7. **Gayda S.V.** The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. – Lviv: UNFU. – 2009, 19.14:72-89. (in Ukr.).



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## Методика розрахунку тривалості сушіння в геліоустановці


Виведено аналітичні рівняння розрахунку часу сушіння в 1-му та 2-му періодах сушіння. Застосовано графокритеріальний метод визначення тривалості сушіння в періодах постійної та заповільнюючої швидкостей. Графокритеріальний метод базується на аналітичних формулах, які отримані в результаті досліджень кінетики та динаміки процесу сушіння, а також виразах загальної теорії сушіння. Наведено рівняння для визначення коефіцієнта вологопровідності в залежності від напряму руху вологи в матеріалі. Застосовано критерій Нусельта для розрахунку значення коефіцієнта теплообміну.



**Ключові слова:** геліоустановка, графокритеріальний метод, критерій Нусельта.


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UDC 630.824.83.



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## WOOD INFILTRATION WITH WATER-SOLUBLE DYES


In order to obtain the necessary colour while infiltrating wood using the vacuum, we carried out an investigation to determine the optimal concentration of water-soluble dyes.



**Keywords:** wood, dye, infiltration, vacuum.


**Applicability of the problem.** With the development of industry the high cost and deficit of the valuable species of wood urge to produce their imitations from a cheaper material by way of dyeing and proper processing. The process of dyeing is carried out in different ways: by means of pneumatic spray, rollers, immersion, etc. all of them are simple to use, however, the depth of paint does not exceed 0.08 mm and that excludes any further mechanical processing.

One of the most famous methods of infiltration is using vacuum – method “vacuum – atmospheric pressure”. As the research shows, this method allows to evenly infiltrate samples of hardwood up to 10mm thick in two sets (cycles) with 5-7 minutes of duration each. The tone color is rather smooth, however the colour on the billet surface is more saturated. It should be said that homogeneity and saturation of the colour depends upon the duration of the cycle as well as on the nature and concentration of the dye. In order to find out the optimal conditions of depth infiltration of wood to obtain the necessary colour and its saturation we investigated the dependence of the nature and concentration of dye solutions, correlation of dyes in a solution, the sequence of infiltration with dyeing solutions, etc.

**Methods of investigation.** The investigation was carried out on the samples of beech (size: 20×20×30 mm.) cut out of sap-wood (humidity 8-10 %). The infiltration solutions were made of water-soluble dyes – brown and red #3, concentration 1-3 %, resorcinol $Fe(NO_3)_3$, $FeSO_4$, $(NH_4)HPO_4$, potassium dichromate with concentration 2-6%. The infiltration was conducted according to the following scheme: a) keeping of dry wood samples in an autoclave in vacuum for 10 minutes; b) keeping of the samples in dye solutions in vacuum – 10 minutes; c) keeping the samples in the dye solutions without vacuum – 10 minutes. In case of a consequent infiltration with two different solutions after drying the samples were infiltrated with the first solution during one hour at the temperature of 40-60 °C another infiltration with a mordant solution was carried out in order to obtain the final colour of the sample. As a result of the research we obtained beech samples with brown and red tones: "bog oak", "mahogany", etc. It was found out that bright and saturated colours are obtained from brown and red dyes with the concentration of 2.5-3 %. Good results were obtained by combination of brown and red dyes. Thus, for example, to have the effect of "mahogany" the optimal is the combination of 4 % solutions of the above-mentioned dyes in the ratio 1:1.

2-6 % solutions of $K_2Cr_2O_7$, $Fe(NO_3)_3$, $FeSO_4$ paint beech in grey colour. The adequate concentration in the infiltrating solution for $K_2Cr_2O_7$ is 4 %, for $Fe(NO_3)_3$, $FeSO_4$ is 2 %. These concentrations provide smooth colouring of wood. The best infiltrating quality for this group of dyes is achieved with a 2 % solution of $FeSO_4$.

To determine the effect of "development" a consequent infiltration with two solutions was conducted as well: firstly with the solution of resorcinol (concentration 2-4 %) and then with 2-6 % solutions of $K_2Cr_2O_7$, $Fe(NO_3)_3$, $FeSO_4$, $(NH_4)HPO_4$. The results are in given in Table 1.

**Table 1. Change of beech colour while infiltrating with two solutions**

| Infiltrating solution #1 | "Development" solution #2 | Resulting colour | Tone homogeneity |
|---|---|---|---|
| Resorcinol | $K_2Cr_2O_7$ | Light brown | Average |
| Resorcinol | $FeSO_4$ | Grey with a brown tone | High |
| Resorcinol | $Fe(NO_3)_3$ | Brown | Average |
| Resorcinol | $(NH_4)HPO_4$ | The colour does not change | – |

**Conclusions.** When infiltrating with a 2-6 % solution of resorcinol and a 2-6 % solution of $K_2Cr_2O_7$, we get light brown samples of average quality. The maximal saturation of wood with a dye takes place with the utilization of a 6 % solution of resorcinol and a 6 % solution of $K_2Cr_2O_7$. With the consequent usage of resorcinol and $FeSO_4$ solutions the wood colour is changed from grey (when infiltrating just with $FeSO_4$) to grey-brown. For the infiltration it is enough to use the solutions of resorcinol and $FeSO_4$ with the 2 % concentration. With the consequent usage of resorcinol and $Fe(NO_3)_3$ solutions the samples are brown. The best quality is achieved when using a 2 % solution of resorcinol and a 6 % solution of $Fe(NO_3)_3$. If the resorcinol concentration is increased in the infiltrating solution #1 up to 6 % the colour saturation increases but the tone becomes less smooth, especially closer to the edges of the sample.

## Reference

1. **Суханов В.А.** Исследования процесса и разработка технологии пропитки древесины способом "вакуум – атмосферное давление – вакуум". Автореф. дис... канд. техн. наук. М., 1977.

2. **Хунт М., Геррат А.** Консервирование древесины. М, 1961.

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## Просочування деревини водорозчинниими барвниками

Проведено дослідження з визначення оптимальних концентрацій водорозчинних барвників для забезпечення заданого кольору під час просочування деревини із застосуванням вакууму.

**Ключові слова**: деревина, барвник, просочування, вакуум.

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## THE STUDY OF MODIFIERS IMPACT ON THE PROCESS OF PELLETIZING HARDWOOD WASTE

A process for pelletizing hardwood wherein the particulated wood is treated with a starch, wax emulsion and lignosulfonate prior to pelleting is disclosed.

**Keywords:** pelleting press, hardwood pellet, hardwood particulate materials.

With the increase in cost of energy, greater efforts are presently being made to utilize hardwood waste for heating. Generally the hardwood waste which is not in particulate form is reduced to particulate form and pelleted to obtain the waste in a uniform particle size which can be conveniently handled. In pelleting the hardwood, pellet mill with stationary die and rotating rollers is used wherein the particulated wood is compressed and forced through orifices in the die. These types of mills have high capacity for pelleting the large quantity of hardwood waste [1, 2]. It is, therefore, an object of this investigation to provide an improved process for pelleting of hardwood.

A further objective is to provide a process characterized by the production of hardwood pellets of improved durability. A still further objective is to provide a process wherein an increase in production rates may be obtained with a decrease in power costs.

The above and other objectives are attained by this research which comprises drying the particulate wood to a moisture content less than about 16 % and treating the particulate wood prior to pelleting with starch, an aqueous wax emulsion and lignosulfonate [3].

The particulate wood is treated with the starch, wax emulsion and lignosulfonate in an amount about 0.25 to about 2.5 weight percent of the wood, that permitted by EU standards. The amount of the starch, wax emulsion and lignosulfonate used in treating the wood and the ratio of wax to lignosulfonate solids used may be varied depending upon the species of wood being pelleted to obtain optimum results.

With some of the woods, the durability of the pellets may be one of the main concerns while with others, such as oak, the pellets obtained without the additive may be acceptable but the power requirements for the pelleting operation are excessive and the life of the die is relatively limited. Thus, for the latter higher wax content is desirable while for the former, such as beech, lower wax content may be used.

The extent of enhancement obtained by use of the additive will also vary with the species used, with some improvement being generally obtained for most soft and hardwoods and mixtures of waste woods which may contain many different species, bark and other lignocellulosic constituents.

The starch, mixture or emulsion of wax and lignosulfonate is usually applied to the particulate wood after it has been dried to a moisture content of less than about 16

%, preferably dried to a moisture content ranging of from about 12 to about 14 % or less. Usually the mixture of the wax and lignosulfonate is sprayed upon the dried products at the conditioning chamber prior to being fed into the pelleting machine.

The pelleting mills often use paddle conveyors or other means to feed the particulate wood into the pelleting die so that the treated wood particles are mixed prior to pelleting to obtain a sufficiently uniform mixture. The wax and lignosulfonate mixture or emlusion may also be applied to the wood particles prior to drying.

However, when this procedure is used the conditions and methods used in the drying operation are limited. Thus, it is generally preferred to dry the particles prior to the application of the starch, mixture of wax and lignosulfonate taking into account during the drying operation of the additions of water which will be made by the treatment of the particles with the mixture. In addition to for the treating step discussed above, other procedures normally used in pelleting of wood may be followed.

A production scale test was made using a production pellet mill which was driven by a 125 kWt motor. A die contained orifices of 8mm in diameter and had a thickness of 35mm through which the hardwood was forced. The pellet mill had a conditioning chamber. The starch was fed by conveyor, wax-lignosulfonate emulsion was sprayed on the wood particles in the conditioning chamber. The moisture content of the ground hardwood and product pellets was measured by a bench type moisture meter.

In making the test runs, the operator set the pellet machine at a maximum power load of 200 amperes. The machine was operated using beech particulated wood without any additive at this setting and the durability and rate of production determined. After this determination was made, the particulated wood was treated with a starch, wax-lignosulfonate emulsion in an amount of 1-3 weight percent of the particulated wood.

The wax-lignosulfonate emulsion was prepared by mixing the wax emulsion in an amount of 20 weight percent with 80 % of the 50 % lignosulfonate solution. Upon treatment of the particulated wood with the starch or wax-lignosulfonate emulsion, the power demand dropped and the operator increased the feed to the mill until a power demand of 200 amperes was being used by the machine.

The production rate on particulated wood without the additive was 600 kg per hour utilizing a power demand of 200 amperes. Upon addition of the additive, the production rate increased to 800 kg per hour and the power demand was 200 amperes.

The durability of the pellets without the additive was 94.5 % while that with the additive was 96.8 %. The moisture content for the wood during the first test run and with starch treated was 9 weight percent and at the time the pellets were treated with the wax-lignosulfonate emulsion the moisture content was 8 %. In pelleting oak, without the additive the production rate was 800 kg per hour at power demand of 200 amperes.

With additive added in an amount of 1 weight percent of the wood, the production rate increased to 880 kg per hour on a power demand of 150 amperes. The durability of the pellets without the additive was 92 % and 92.6 % with the additive.

After the treatment of the particulate wood with the wax-lignosulfonate mixture or emulsion was discontinued, the amperage on the pelleting mill after about 5 minutes began to increase and was up to 200 amperes about 6 minutes later.

The durability of the pellets was tested by screening the pellets on a 5 mesh screen and then taking a 100 gram sample of pellets remaining on the screen and shaking the sample in a can on a paint mixer for 4 minutes. After shaking, the sample was

again screened on a 5 mesh screen and the percentage of the sample retained on the screen was reported as the durability of the sample. The material which passed through the screen on the first screening was weighed and the amount of fines thus obtained was expressed in grams of fines obtained per 100 grams of pellets.

In the tests made on the pellet mill, the beech wood was pelleted without any additive and also where the particulated wood was treated with a wax emulsion alone and also with a lignosulfonate solution by itself.

The results obtained above were compared to the results obtained where a wax-lignosul-fonate emulsion was used. In the run where wax emulsion was used, the wax content of the emulsion was about 47 weight percent. The lignosulfonate solution contained about 50 % solids.

In preparation of the wax-lignosulfonate emulsion the wax emulsion used above and the lignosulfonate solution described above were used. It was prepared by mixing 20 % by weight of the wax emulsion with 80 % of the lignosulfonate solution.

Since the solids of the lignosulfonate solution (a fermented calcium base spent sulfite liquor) contained about 80 % lignosulfonate, the wax content of the mixture was about 24 weight percent of the total wax and lignosulfonate solids in the mixture. Tests were also made using oak with and without the above additive (Table 1).

**Table 1. The results obtained in the test runs**

| Run, # | Hard-wood type | Average moisture content, % | Additive | Amount additive, % | Average production rate, kg/hour | Average durability, % |
|---|---|---|---|---|---|---|
| 1 | Beech | 14.1 | - | - | 600 | 94.5 |
| 1.1 | Beech | 13.8 | starch | 1 | 690 | 95.5 |
| 1.2 | Beech | 14.2 | lignosulfonate solution | 1 | 760 | 96.5 |
| 1.3 | Beech | 14.5 | wax-lignosulfonate emulsion | 1 | 800 | 93.8 |
| 2 | Beech | 12.5 | - | - | 480 | 90.5 |
| 2.1 | Beech | 12.4 | starch | 3 | 560 | 93.5 |
| 2.2 | Beech | 12.8 | lignosulfonate solution | 3 | 620 | 94.5 |
| 2.3 | Beech | 12.3 | wax-lignosulfonate emulsion | 3 | 650 | 92.8 |
| 3 | Oak | 13.8 | - | - | 800 | 92.5 |
| 3.1 | Oak | 14.2 | starch | 1 | 850 | 93.5 |
| 3.2 | Oak | 13.9 | lignosulfonate solution | 1 | 860 | 94.5 |
| 3.3 | Oak | 13.6 | wax-lignosulfonate emulsion | 1 | 880 | 92.6 |

## Conclusions.

Treating the particulate hardwood with a starch, wax and lignosulfonate, increase the production capacity of the pelleting mill with a reduction in power costs, as well as obtaining an improvement in the durability of the pellets and reduces production costs.

## References


1. **Курка Р.Р.** Особливості технології формування паливних гранул з подрібненої деревини листяних порід / Науковий вісник НЛТУ України: зб. наук.-техн. праць. – Львів : РВВ НЛТУ України. – 2011. – Вип. 21.13. – С. 132-136.
2. **Облагораживание твердых материалов** путем прессования на прессах с плоской матрицей. – [Електронний ресурс]. – Режим доступу: http://www.amandus-kahl-group.de/kahl_ gruppe /ru/home.
3. **Pelletizing wood.** Lindell. Courtney D. [Електронний ресурс]. – Режим доступу: http:// www. patentgenius.com/patent/4612017.html.

УДК 674.8 *Ст. викл. Р.Р. Курка – НЛТУ України*

## Дослідження впливу модифікаторів на процес гранулювання відходів деревини листяних порід

Досліджено вплив модифікаторів – крохмалю, воску та лінгосульфонатів на процес гранулювання подрібненої деревини листяних порід.

**Ключові слова**: прес-гранулятор, дерев'яні гранули, частинки твердих листяних порід.

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UDK 674.023: 51-7 + 004.942 *Assist. Ya.V Matsyshyn; assoc. prof. V.O. Mayevskyy; senior teacher M.M. Mysyk; prof. V.M. Maksymiv – UNFU*

## FUZZY INFERENCE SYSTEM FOR LUMBER CROSS CUTTING PROCESS MODELING

The hierarchic structure of factors, which influence on the scheme selection of cross cutting of lumbers into blanks, is provided. The model of the cross cutting process of lumbers is developed on the basis of fuzzy expert system. The possibility of using methods of fuzzy set theory for the solution of rational cross cutting is shown.

**Keywords**: lumber cross cutting, blank, defectless sections, cross cutting scheme, fuzzy expert system, linguistic variable.

**Introduction.** The cross cutting of lumbers into blanks is the important technologic operation, which has a considerable influence on the efficiency of wood working industry. The problem solution of products output (on the value and volumetric basis) with minimal raw material expenses may be the topical criteria of the efficiency of cut-out process of lumbers into blanks. It is appropriate to implement the searching of rational version of cross cutting process with account taken of main factors: measured and qualitative characteristics of lumbers and blanks, methods, ways and schemes of lumbers cross cutting, available type of equipment, parameters of workshop and importance of valuable indices in the products output – ways of wood waste usage.

The limitedness of wood stocks and its high value that forms 70 % of production costs impels to the immediate solution of tasks which will give an opportunity to secure the rational usage of wood. It is appropriate to consider the searching of rational version (method, way, scheme) of lumbers cross cutting into blanks one of the immediate tasks since output of blanks from lumbers may range mainly from 10 % to 90 %.

Thus, problem of searching the rational version of lumbers cross cutting into blanks is topical and for its solution it is important to develop effective ways of acceptance of current, efficient decision immediately in the process of real cross cutting.

**Literature Review.** Significant research work which concerns the problem solution of rational cross cutting of lumbers into blanks is conducted in the sawmilling technology. The research work of cross cutting of lumbers into blanks are mainly aimed at determination of blanks output, optimization of cross cutting and establishment of the effective usage of that or other version of cross cutting process for specific conditions of production according to their results [1-7]. Aiming at prognostication of blanks output the scientists use three main trends of research.

The first trend envisages conducting of theoretic research, the results of which permit to prognosticate only volumetric output of blanks [1]. The second trend envisag-

es conducting of great number of experimental researches and establishment of regression dependency of volumetric and qualitative blanks output from accepted factors, which are variable and stochastic by nature [2, 3]. The third trend envisages the prognostication of volumetric and qualitative blank output according to the results of imitational modeling of lumbers cross cutting. Measured and qualitative characteristics of these blanks are determined with the help of special scanning devices [4].

The first trend has exceptionally theoretic sense and it does not take into account qualitative output of blanks. The second trend reflects the results that depend on accepted stochastic factors and which exceptionally characterize conditions of their production. Because of this reason, they cannot interpret results received on other conditions. However, the third trend provides efficient prognostication of volumetric and qualitative output of blanks, but it needs the availability of high-technology scanning equipment with proper software for the interpretation of results received from scanning and modeling different versions of lumbers cross cutting into blanks.

It is not enough to use only reliable prognostication of blanks output for the efficient problem solution of cross cutting of lumbers into blanks, because in such case the main criterion of efficiency is fulfilment of blanks specification with minimal raw material expenses. The effective way of providing the blank specification fulfilment is cross cutting of lumbers into blanks according to the results of its optimization. Traditional consideration of optimization planning task of lumbers cross cutting into blanks in the form of linear programming task is inefficient [2, 5].

It is caused by the fact that given task can be solved in the presence of all initial data (quantitative, measured and qualitative characteristics of lumbers and blanks). Thought, the usage of task solution of linear programming in the real industrial process is extremely complicated. For the variant selection of current cross cutting it is important to take into account previously received results. Some scientists for the solution of this problem suggest using heuristic optimization algorithms [6], especially genetic ones, but they do not give mathematic model for the implementation of algorithms in case of planning of lumbers cross cutting into blanks. Instead, individual manufacturer of woodworking equipment, especially of optimization lines of lumbers cross cutting (laths and fragments) declare the possibility of optimization of cross cutting process [8]. However, on the one hand they do not give laid mathematic models of cross cutting and it does not allow them to examine the adequacy of these models. On the other hand, the scientists envisage the cross cutting of lumbers into the boards or blanks with minimal outputs (with or without the priority of certain lengths).

Thus, the selection of rational versions of lumbers cross cutting into blanks which are received on the basis of results of cross cutting optimization and procedure of acceptance of current solution as regards variants of cross cutting is important and at the same time little-researched problem. Consequently, this problem needs additional researches for the efficient solution. The usage of conventional methods for the tasks solution of optimal (rational) variants searching, especially in form of optimization tasks of linear programming is inefficient.

Tasks of such type are characterized by insufficient information and vague features of initial factors. Therefore, for their solution it is appropriate to use methods, which take into account this feature and in particular the methods of fuzzy set theory. Methods of fuzzy set theory (fuzzy logic) are successfully used while controlling tech-

nological processes, transport, staff, in medical and technical diagnostic, financial management, image identification or other types of human activity [9-13].

**Problem Statement of the Research.** The selection of rational versions of lumbers cross cutting into blanks is difficult multicriterion task with a great number of stochastic factors which are characterized by insufficient information and vague features. The solution of formulated task needs realization of difficult calculation and increase of time expenses on acceptance of rational decision. For the solution of selection of rational variant of lumbers cross cutting into blanks it is possible to develop fuzzy expert system (FES). Developed system should imitate the procedure of acceptance of current decision as regards the cross cutting version (cross cutting schemes according to accepted methods or ways of cross cutting). It will give the possibility to decrease the expenses on efficient decision in real industrial conditions.

**Fuzzy Inference System: the Main Factors.** The development of fuzzy inference system (FIS) for the selection of rational variant of board cross cutting into blanks first of all envisages the separation of main factors, which influence on functioning of the system. The hierarchical structure of factors that influence on the selection of rational scheme of lumbers cross cutting into blanks is shown on the Fig.1.

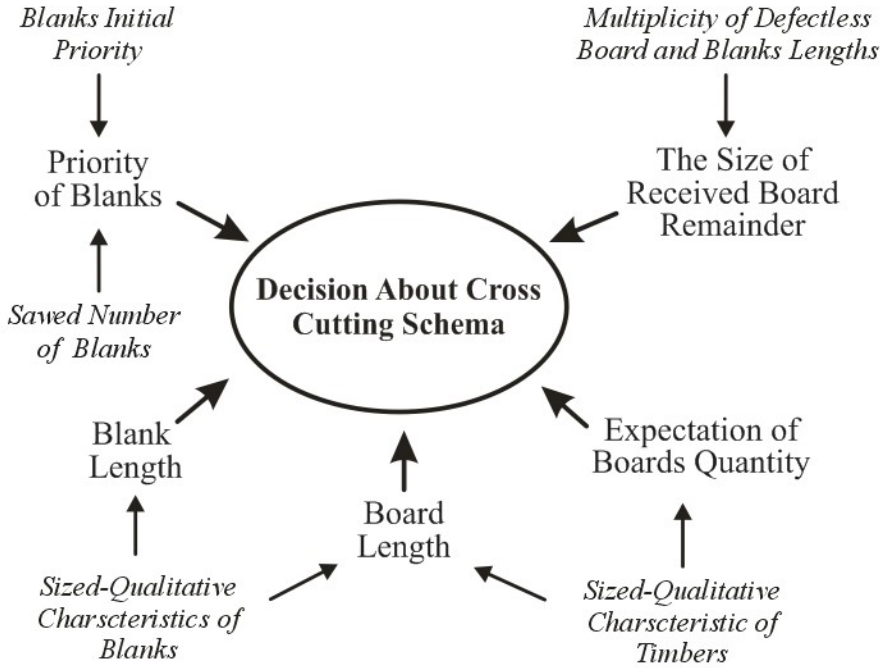


***Fig.1. The hierarchical structure of factors that influence on the selection of rational scheme of lumber cross cutting into blanks***

*Priority of blanks.* Initial priority that would determine the immediate sawing of blanks should be attributed to each measured and qualitative group of blanks. First of all, it is necessary to saw out blanks with the highest priority. The highest priority is usually attributed to blanks with higher quality and bigger sizes and which are the most valuable. In the process of cross cutting the priority would be controlled depending on a number of practically sawed blanks of certain group. However, with the increase of quantity of sawed blanks of certain group the priority on sawing should decrease.

*Expectation of boards quantity.* Since the appearance of boards of different length is the stochastic phenomenon, then it is necessary to saw long blanks from long boards, despite of the fact that total output may be less than output of short blanks. It is caused by the fact that on the further stages of cross cutting process the appearance of long boards, from which long blanks can be sawn may be less probable. Thus, if there are few long boards, then it is necessary to saw only long blanks. On the other hand, if there are many boards or few long blanks, then it is possible to saw shorter blanks.

*Board length.* The longer board is the greater percent of blanks and possible schemes of board cross cutting may be received from it. Obviously, it is impossible to saw the blank, the length of which is bigger than the length of a board. It also should be taken into account that depending on measured and qualitative characteristics of sawed blanks, different board length may be received.

*Blank length.* The increase of blank length mainly causes the increase of its priority as in the cross cutting process it is more difficult to saw the blanks. On the one hand, such situation is caused by natural stochastic factors that make the sawing of great percent of long boards impossible, especially because of high standards to the blank quality. On the other hand, in the process of board cross cutting there is the possibility to lose valuable wood because great part of received remainders from board after cross cutting may be shorter than minimal blank length.

*The size of received board remainder.* The board remainder is usually received in the process of board cross cutting into blanks. This is the result of aliquancy of board length to the blank length. The size of this board remainder characterizes the loss of valuable wood and it consequently has direct influence on the selection of cross cutting scheme. In particular, the increase of the size of board remainder mainly causes the decrease of priority and the size decrease causes the increase of priority.

Aiming at developing fuzzy expert system of selection of rational variant of lumbers cross cutting into blanks in given work (on the first stage of research) only the most general input factors are taken into account: board length and percent of sawed blanks of each size. For the modeling of the cross cutting process of lumbers into blanks, the regime of line work is chosen. With the help of it, only the cross cutting into given dimensions (lengths) of blanks with given beforehand percent of each size.

Besides, the following assumptions are made:

- Used in the case of cross cutting, second stage of cross-longitudinal or third stage of cross-longitudinal-cross ways of cross cutting.
- Lumbers (laths) with the board lengths identified by scanner come to the cross cutting machine-tool of lines (according to given demands to the quality).
- Demands to the quality of all blanks are the same.
- Board length is always bigger or equal to the length of the shortest blank.
- The line works in established regime – lumbers (laths) are always on entry, but appropriate forehearths always have space for the next blanks on the outlet of line.
- In the process of line work the quantity calculation of received blanks of each size is realized.

Consequently, **the aim of the research** is the development of FIS for the acceptance of rational decision as regards necessary blank length, which should be cut according to received information about the board length of each lath. One more important condition is the information about the quantity of sawed blanks of each size.

**Fuzzy model of the cross cutting process.** ***The method of fuzzy systems synthesis.*** According to the fuzzy systems creation traditional method [9-13], to achieve the stated goal must perform the following procedures:

- select the linguistic terms for qualitative assessment of the levels of input and output factors;
- to form a fuzzy knowledge base (rules of inference) (IF… – THEN ...);
- generate the membership function for fuzzy sets, which are used to describe the input and output factors;
- select the scalarization method.

This is followed by a process model of the FIS, which you need to calculate the values of membership functions for crisp input data to compile all of the rules of infer-

ence and implement scalarization of the result to make a clear decision. To configure the FIS to solve a specific task used scalarization method change, the type and parameters of membership function and clarify the fuzzy knowledge base [9-13].

***The fuzzy system structure.*** Typical structure of the FIS, detailed on this problem, are shown in Fig. 2. The input to the system receives information from the scanner to the length of the defect less section of **L** and the number had already sawed blanks of each size, $n_{l1}$, $n_{l2}$, …,$n_{lk}$. The output of the system we decide on the procurement of any size should be cut out at any given moment.

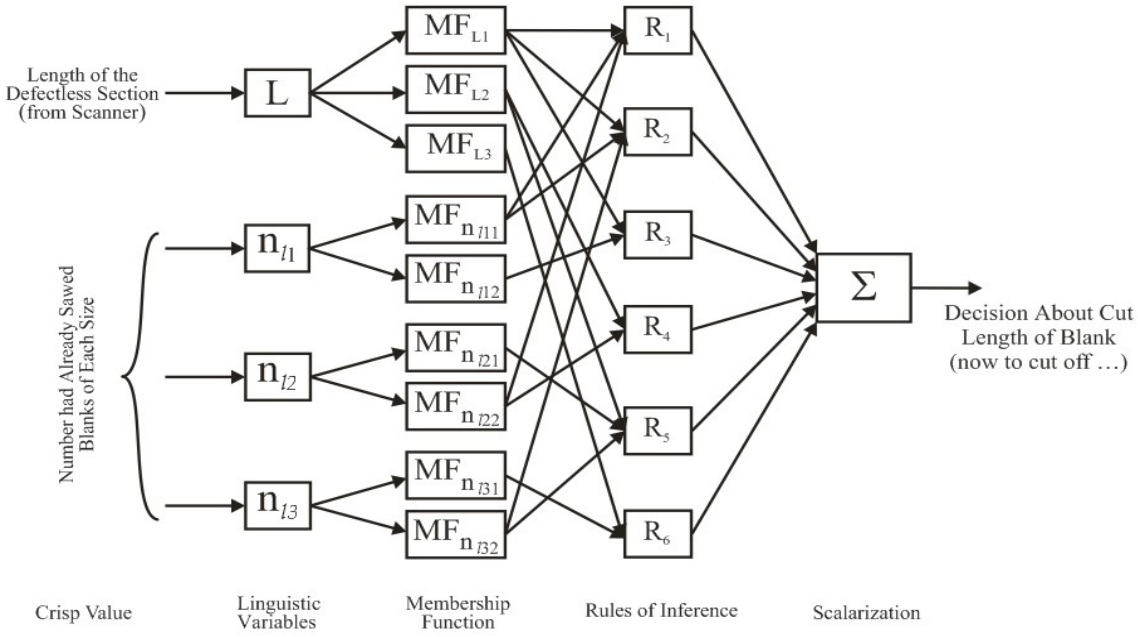


***Fig. 2. FIS structure, that imitates procedure of decision making about cut length of blank***

For description of the input and output factors the following linguistic variables are used (Fig. 3):

- *Board_Length* – length of the defectless section;
- *Percent_of_Long_blanks* – sawed number of "long" blanks;
- *Percent_of_Average_blanks* – the number of sawed "average" blanks;
- *Percent_of_Short_blanks* – the number of sawed "short" pieces;
- *Now_to_cut_off* – now to cut off "long", "medium" or "short" blank.

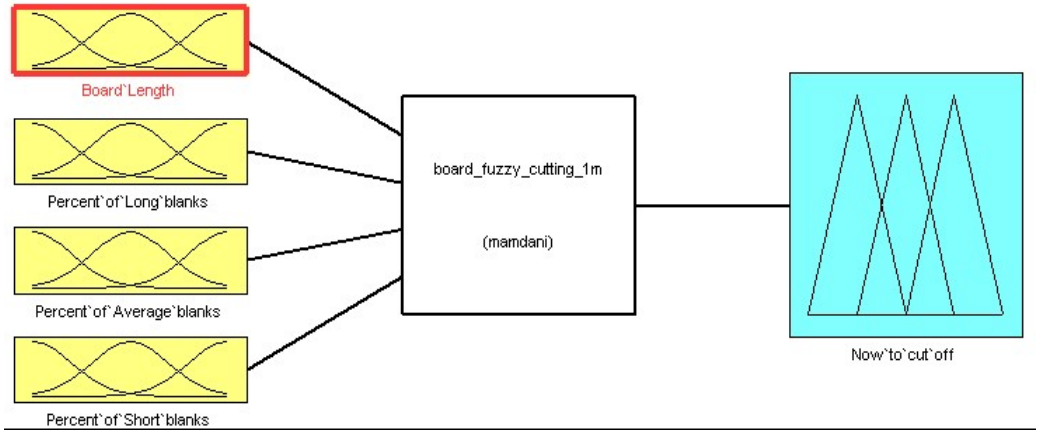


***Fig. 3. The structure of the FIS in the MatLab***

Before forming of membership functions, input and output factors are reflected in a uniform universal set [0, 1], that essentially will simplify evaluations and will make possible customization of a developed system to specific features of concrete technological process. In particular, the board length is defined as a 0 on the universal set corresponds to the minimum board length, defined as 1 – the maximum board length. Input

linguistic variable *Board Length* we shall describe by three terms (Fig. 4): “short”, “average” and “long”.

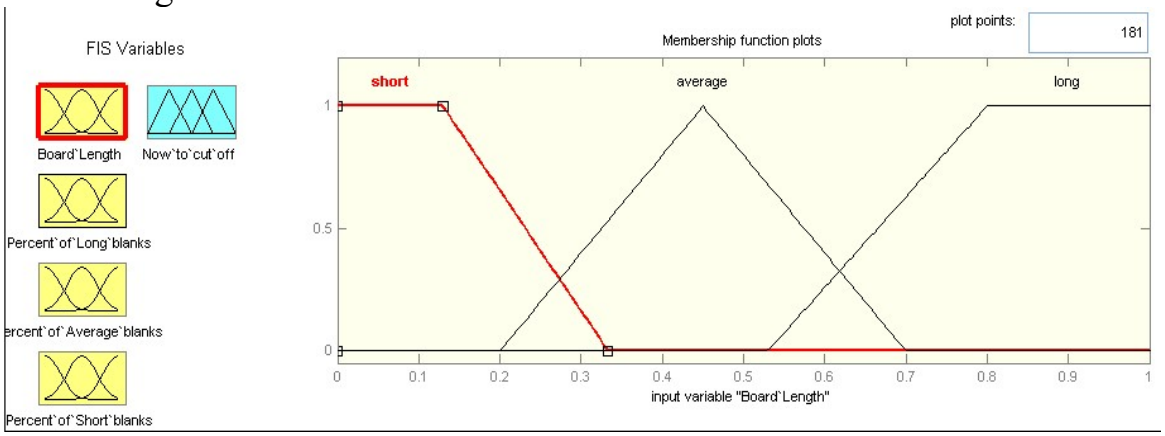


***Fig. 4. Membership functions of linguistic variable Board_Length in the MatLab***

On the abscissa is the board length in arbitrary units [0, 1], and the y-axis – the degree of membership corresponding to the board length to a specific term-set. Degree of membership appropriate board length to a specific term-set taken in the form of:

$$\mu_{short} = \begin{cases} 1, & 0 \le x \le 0{,}2; \\ \dfrac{0{,}45 - x}{0{,}45 - 0{,}2}, & 0{,}2 \le x \le 0{,}45; \\ 0, & x > 0{,}45. \end{cases} \quad \mu_{average} = \begin{cases} 0, & x < 0{,}25; \\ \dfrac{x - 0{,}25}{0{,}5 - 0{,}25}, & 0{,}25 \le x \le 0{,}5; \\ \dfrac{0{,}75 - x}{0{,}75 - 0{,}5}, & 0{,}5 \le x \le 0{,}75; \\ 0, & x > 0{,}75. \end{cases}$$

$$\mu_{long} = \begin{cases} 0, & x < 0{,}55; \\ \dfrac{x - 0{,}55}{0{,}8 - 0{,}55}, & 0{,}55 \le x \le 0{,}8; \\ 1, & x > 0{,}8. \end{cases}$$

Input linguistic variable *Percent_of_Long_blanks* we shall describe by two terms (Fig. 5): “not_enough” and “enough”.

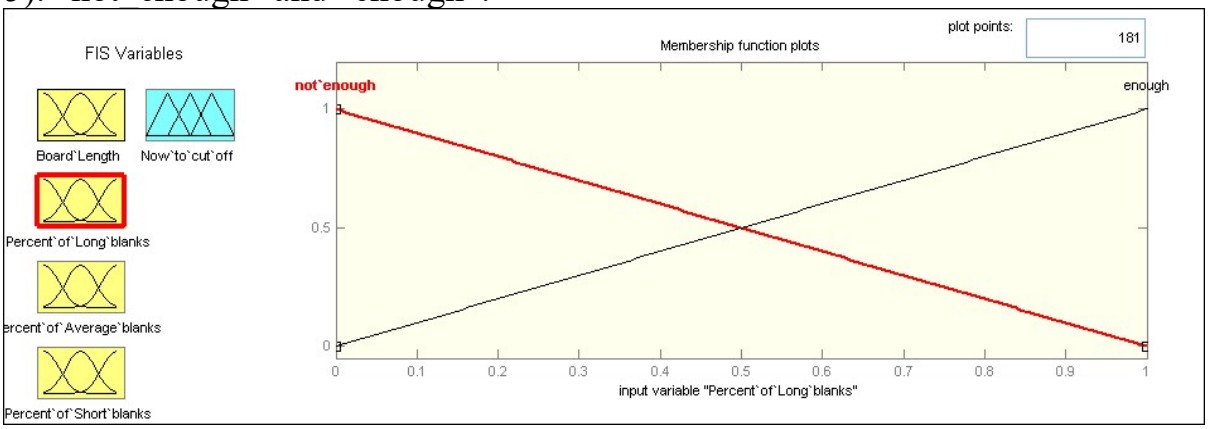


***Fig. 5. Membership functions of linguistic variable Percent_of_Long_blanks in the MatLab***

On the abscissa is the number of sawed "long" blanks in arbitrary units [0, 1], and the y-axis is the degree of membership corresponding to the number of blanks to a particular term-set. Degree of membership appropriate number of blanks received to a particular term-set taken in the form: $\mu_{not\ enough} = 1 - x,\ 0 \le x \le 1;$

$$\mu_{enough} = x,\ 0 \le x \le 1.$$

Similar terms describe the linguistic variables *Percent_of_Average_blanks* and *Percent_of_Short_blanks*. Output linguistic variable *Now_to_cut_off* we shall describe by three terms (Fig. 6):

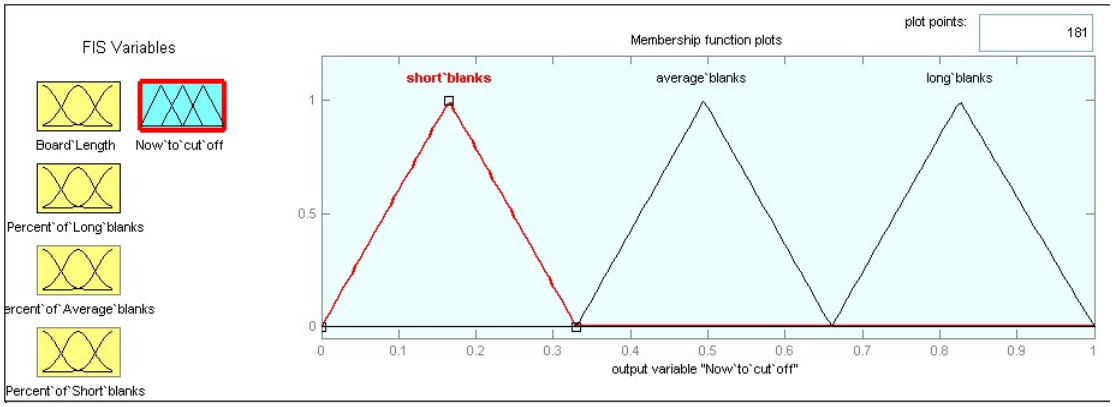


***Fig. 6. Membership functions of linguistic variable Now_to_cut_off in MatLab***

On the abscissa is the blank length in standard units [0, 1], and the y-axis – the degree of membership corresponding to the blank length to a defined term-set. It should be noted that each term in the decision making process corresponds to one specific length of the blank. Based on the assumptions made and in the absence of requirements for optimal decision making, fuzzy knowledge base can be formed by synthesizing the results of observations of the human operator actions and optimization line in the mode of cutting to the specified dimensions and guided by "common sense" or "elementary logic" like statement "long blank can not be obtained with a short board ", but expressed in the imperative form:" if the length of the board is small, it is necessary to cut out a short blank. "The minimum number of rules of fuzzy inference, in which the system behaves quite adequately (taking decisions that in a similar situation could have been taken a human operator or control system optimizing cross-cut line) is shown in Fig. 7.

1. If (Board`Length is long) and (Percent`of`Long`blanks is enough) and (Percent`of`Average`blanks is not`enough) then (Now`to`cut`off is average`blanks) (1)
2. If (Board`Length is long) and (Percent`of`Long`blanks is enough) and (Percent`of`Short`blanks is not`enough) then (Now`to`cut`off is short`blanks) (1)
3. If (Board`Length is long) and (Percent`of`Long`blanks is not`enough) then (Now`to`cut`off is long`blanks) (1)
4. If (Board`Length is average) and (Percent`of`Average`blanks is not`enough) then (Now`to`cut`off is average`blanks) (1)
5. If (Board`Length is average) and (Percent`of`Average`blanks is enough) and (Percent`of`Short`blanks is not`enough) then (Now`to`cut`off is short`blanks) (1)
6. If (Board`Length is short) then (Now`to`cut`off is short`blanks) (1)

***Fig. 7. The fuzzy knowledge base about cross cutting process***

**Modeling of the FIS functioning in the MatLab environment.** Taking into account lack of formal "precise" mathematical model of investigated process, it is possible to realize only "behavioural" verification, which is usually applied during testing simulation models, designed a fuzzy system – to check up her response on different input situations and to compare them to solutions, which the human operator or a line control system would accept in these cases.

We assume that the lengths of the separation of defectless parts and pieces on the "long", "medium" and "short" conducted in a way that from the "long" defectless areas can be drank all kinds of blank, from "average" – "medium" and "short" and on the "short" – "short." Then, when you receive a "long" defectless area, provided that all sizes of sawn blanks a little, the system decides to cut out a long piece (Fig. 8). When the "long" procurement has already drunk " enough "(Tab. 1), the system decides sawing "average" or "short" blanks (depending on what blanks sawn less). When the system receives an "average" defectless area, first the decision to sawing "average" pieces (Table 1), further increases in their number would be cut out "short" blank. If receive a "short" defectless parts, they will cut out only the "short" blank, regardless of whether how many pieces of other sizes are already sawn (Table 1).

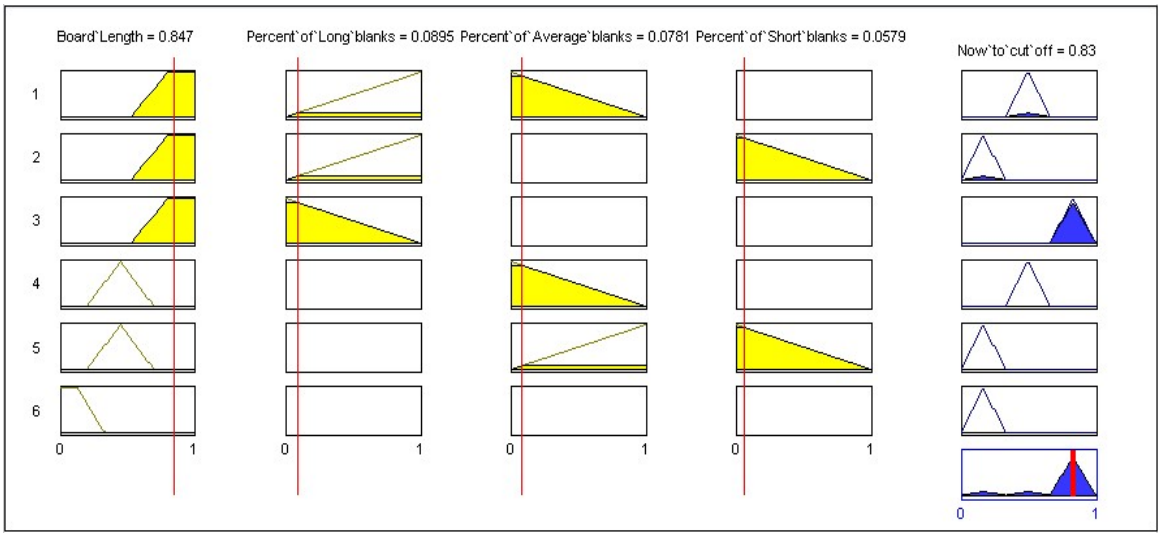


***Fig. 8. Modeling the the FIS depending on a parameters of the input factors changing***

**Table 1. FIS behavior depending on a parameters of the input factors changing**

| Input linguistic variables | | | | Output linguistic variable | Interpretation (now to cut off ...) |
|---|---|---|---|---|---|
| *Board_Length* | *Percent_of_ Long_blanks* | *Percent_of_ Average_blanks* | *Percent_of_ Short_blanks* | *Now_to_cut_off* | |
| 0,847 | 0,0895 | 0,0781 | 0,0579 | 0,83 | Long blanks |
| 0,847 | 0,62 | 0,0891 | 0,12 | 0,5 | Average blanks |
| 0,847 | 0,62 | 0,247 | 0,12 | 0,16 | Short blanks |
| 0,393 | 0,29 | 0,197 | 0,139 | 0,5 | Average blanks |
| 0,393 | 0,29 | 0,716 | 0,142 | 0,16 | Short blanks |
| 0,131 | 0,25 | 0,189 | 0,673 | 0,16 | Short blanks |

Thus, even a simple system designed using the theory of fuzzy sets, can adequately carry out the procedure for making decisions about sawing blanks of a certain length depending on the length of the board and the number of defect less already sawed blanks.

**Conclusions and Further Research.** Application of fuzzy set theory is an effective approach to modeling the process of cutting lumber into blanks, so it should be used for building complex, including the optimization models of this process.

Preliminary studies the authors provide a basis for building hierarchical fuzzy "predictive" models to take into account the elements of experience and intuition of the human operator, and to solve the most complex and poorly formalized problems arising in this area – the choice of optimal (or efficient) version of the method of cutting.

## References

1. **Песоцкий А.Н.** Рациональное использование древесины в лесопилении / А.Н. Песоцкий, В.С. Ясинский. – М.: Лесн. пром-сть, 1977. – 128 с.

2. **Пижурин А.А.** Оптимизация раскроя хлыстов пиловочных брёвен и пиломатериалов на заготовки для деревяного домостроения: Дис... канд. техн. наук: 05.21.07. – Львов, 1989. – 197 с.

3. **Маєвський В.О.** Вдосконалення розкрою букової пиловочної сировини на пилопродукцію: Дис. ... канд. техн. наук: 05.05.07. – Львів, 2000. – 284 с.

4. **Szymani R.** Scanning technology & process optimization: Advances in the wood industry. – San Francisco: Miller Freeman, 1999. – 252 p.

5. **Маєвський В.О.** Аналіз способів оцінювання розмірно-якісної характеристики колод. Ліс. госп-во, ліс., папер. і деревооб. пром-сть // Міжвід. наук.-техн. зб. – Львів: УкрДЛТУ. – Вип. 29. – 2004. – С. 149-156.

6. **Koch S.** Linear programming for a cutting problem in the wood processing industry – a case study / Koch S., König S., Wäscher G. – Magdeburg: FEMM Working paper №14, 2008. – 17p.
7. **Fritz van Zyl.** Determining the optimal log position during primary breakdown using internal wood scanning techniques and meta-heuristic algorithms // Thesis submitted in Engineering at the University of Stellenbosch. – 2011. – 116p.
8. **Линия оптимизации ОПТИМА 8М** [Электронный ресурс] // Главная: Продукция – линии сращивания по длине прессы сращивание древесины: Деревообрабатывающее оборудование производства «БАКАУТ»: Оборудование для торцевого раскроя: [сайт] /«БАКАУТ»; Разработка и производство деревообрабатывающего оборудования. – Режим доступа: http://www.bakaut-vn.ru/catalog/bakaut/tor/74.html (10.10.12). – Загл. с экрана.
9. . **Штовба С.** Проектирование нечетких систем средствами MATLAB. – М.: Горячая линия, 2007. – 288 с.
10. **Леоненков А.** Нечеткое моделирование в среде MATLAB и fuzzy TECH. – СПб. : БХВ-Петербург, 2003. – 736 с.
11. **Сигеру О.** Нейроуправления и его приложения. / Омату Сигеру, Халид Марзуки, Юсоф Рубия. – М.: ИПРЖ, 2000. – 272с.
12. **Ротштейн О.** Інтелектуальні технології. Нечіткі множини, генетичні алгоритми, нейтронні мережі. – Вінниця: Універсам, 1996. – 320 с.
13. **Гостев В.** Проектирование нечетких регуляторов для систем автоматического управления. – СПб.: БХВ-Петербург, 2011. – 416 с.

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## Система нечіткого логічного виведення для моделювання процессу поперечного розкрою пиломатеріалів

Наведено ієрархічну структуру чинників, що впливають на вибір схеми розкрою пиломатеріалів на заготовки. Розроблено модель процесу розкрою пиломатеріалів на основі нечіткої експертної системи. Показано можливість застосування методів теорії нечітких множин для розв'язування задачі раціонального розкрою.
**Ключові слова***:* розкрій пиломатеріалів, заготовка, бездефектна ділянка, схема розкрою, нечітка система, лінгвістична змінна.

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## MODELING OF THE INFLUENCE OF ATMOSPHERIC MOISTURE CYCLIC ACTION ON THE DURABILITY OF THERMOPLASTIC ADHESIVE WOOD JOINT

Considered in the article is the mathematical calculation of moisture transfer in adhesive wood jointing for boundary, initial, steady conditions. The process of the environmental effect on adhesive wood joint has been modeled, which changes according to harmonic law.
**Keywords:** Adhesive joint, moisture, moisture transfer, steady and variable conditions, stressed-and-strained state.

The durability of thermoplastic adhesive wood joint is influenced by two main factors: moisture and temperature. Because wood makes up the major volume portion in the adhesive wood joint, the moisture effect on the wood as a capillary-porous and hygroscopical body, will be more significant than on the glue line.

The glue line is in the interior of the structure between the two layers of wood, which lowers the possibility of direct penetration of moisture into the very glue line. The moisture penetrates the glue line mainly through the pores and capillaries of the

wood. The more porous wood is, the more readily moisture can reach into the glue line. Also, the amount of moisture that reaches into the glue line through the wood is sufficient to change physical and mechanical properties of the thermoplastic glue film and affect the strength and durability of the adhesive joint. The extent of moisture effect on the wood in service will depend on the atmospheric moisture, its cyclic changes (daily, weekly, monthly etc.) and the temperature. The higher moisture content of air, the higher degree of sorbing it by the wood, and the more frequently the moisture content changes, the higher stressed-and-strained condition of the wood is due to the impossibility for deformation processes to relax during a short period of time. This is why the wood moisture content needs to be considered as volume mass that is dependent on the environment and which changes according to the harmonic law.

The effect of moisture on wood can be partially described by means of the phenomenological methods or theological models which are currently used. The mechanism for moisture transfer in the adhesive joint under operating conditions is quite similar to that of moisture transfer in drying processes which is described by existing mathematical relationships [2, 4-6]. However, the cyclic action of moisture on the adhesive joint as well as stresses and strains, which take place under non-standard operating condition, are not taken into consideration in wood drying,. Therefore, the mathematical calculation of moisture transfer in wood as capillary-porous material will be considered by the author just for non-standard operation conditions.

Wood or glued wood is defined as a body that occupies a space $\Omega$ with the boundary S. The process of moisture transfer is being studied within a time interval of $\tau$ is [0, t]. Taking into consideration the fact that the convection component of water object is negligible in comparison with the conduction component for the colloid capillary-porous body, it is possible to resort to the approaches described in the works [1, 3].

The severity of the investigation into moisture-induced effects consists in the fact that water absorption is a long-lasting process and moisture distribution in the material varies non-uniformly during a long period of time. To determine the change in moisture conditions of the material at arbitrary point of time, it is necessary to describe the kinetics of the sorption process under steady moisture conditions. Under storage and operation conditions, wood material undergoes variable moisture loads. These are periodical change or seasonal air moisture variations which can be considered as harmonic or jump-type variables. To take into account the peculiarities of this sort, it is necessary to allow for appropriate solutions for non-standard water absorption.

Therefore, let us consider the problem of moisture transfer for wood in the form of a plate of h thickness. The diffusion coefficients are taken as constant. Let us integrate the problem solution for moisture transfer in the case of steady and balanced boundary conditions

$$\frac{\partial U\ (x,\tau)}{\partial \tau} = a\ \frac{\partial^2 U\ (x,\tau)}{\partial x^2} \qquad (1)$$

where: x – coordinates, o – initial instant.

$$U\ (x,o) = U_0; U\ (o,h,\tau) = U_p, \qquad (2)$$

where $U_0$, $U_p$ – are initial and balanced wood moisture contents, respectively.

Let us present the problem solution (2) with given boundary conditions:

$$U\ (x,t) = U_p - 2 \cdot \frac{U_p - U_0}{\pi} \sum_{n=1}^{\infty} \frac{1-(-1)^n}{n} \cdot \sin\left(\frac{\pi \cdot n}{h} x\right) \cdot \exp\left(\left(-\frac{\pi \cdot n}{h}\right)^2 \cdot at\right) \qquad (3)$$

Use them to briefly write the expression for determining

$$W(t) = W_p - 2\frac{W_p - W_0}{\delta^2}\sum_{n=1}^{\infty}\frac{(1-(-1)^n)^2}{n^2}\exp\left(\left(\frac{\pi\cdot n}{h}\right)^2\cdot a\cdot t\right) \quad (4)$$

where: $W_0$ and $W_p$ – are moisture content of the wooden plate at the initial instant and balanced moisture, respectively.

The sorption characteristics a (coefficient of moisture conductivity) $W_p$ can be obtained by way of approximation of the experimental data.

Now let us consider the dependence of moisture distribution for the case of steady change in the atmosphere. Depending on the initial moisture conditions of the material and the air humidity, there may be various cases of moisture penetration or its removal. Let us consider the case of the sorption – sorption process. If the process of moisture removal begins at the time point $t_o$ when the balanced state is reached, we can use the regularities (3), (4). If actual geometric configuration and various periods of saturation are taken into account, non-uniform moisture distribution over the cross-section of the material can be observed. In this case the saturation of wood is accompanied by non-uniform moisture transfer.

Therefore, to model moisture transfer with consideration for steady change and the above obtained conditions, it is necessary to find the solution of the equation (5) for these initial conditions. $U(x,\tau = 0) = U_{0t}(x_1 t_0)$. (5)

And boundary conditions $U(x = 0, x > h, t \geq t_0) = U_{0l}$, (6)

where $\tau = t\text{-}t_0$ – is current time.

The initial distribution of moisture $U_{0t}(x,t_0) = U(x_1 t_0)$ is obtained from the expression (4) for the values $t = t_0$.

Now we will obtain the solution to the problem of water absorption under non-uniform boundary condition on the cross-section of the wooden plate:

$$U(x,\tau) = U\cdot\alpha + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{1-(-1)^n}{k}\left(\left(U_p - U_{o\varphi}\right)\exp\left(-\lambda_n^2 a\tau\right) - \left(U_p - U_o\right)\exp\left(-\lambda_n^2 a(\tau + t_0)\right)\cdot\sin(\lambda_n\cdot x)\right) \quad (7)$$

The expression (7) indicates that for the case when desorption reaches the state of water absorption ($t_0 \to \infty$), we will obtain the moisture distribution found in the expression (5). On integration the expression (7) over the area of deformation we obtain the expression for the relative moisture content,

$$W(\tau) = W_{0\alpha} + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{(1-(1)^n)^2}{n^2}\left((W_p - W_{0\alpha})\cdot\exp(-\lambda_n^2 a t) - (W_p - W_0)\exp(-\lambda_n^2 a(\tau + t_0))\right) \quad (8)$$

The value $\lambda_n$ is the root of the characteristic equation $tg\,\lambda_n = \lambda_n / B_i$,

where $B_i$ is the criterion Bio.

Thus, by using the expression (6) and (8), we will model the process of change in the removal of absorbed water on the single scale.

$$W(t) = W_p - 2\cdot\frac{W_p - W_0}{\pi^2}\sum_{n=1}^{\infty}\frac{1-(-\gamma)^n/2}{n^2}\cdot\exp(-\lambda_n^2 a t), \quad t < t_0 \quad (9)$$

$$W_1(t) = W_1 + \frac{2}{\pi^2}\sum_{n=1}^{\infty}\frac{(1-(-\alpha)^n/2}{n^2}(W_p - W_\alpha)$$
$$\exp(-\lambda_n(t-t_0)) - (W_p - W_0)\exp(-\lambda_n{}^2 at))), \quad (10)$$
$$t > t_0$$

By means of the relation (7) we obtain the moisture distribution in the wooden plate for desorption from unbalanced values.

Now let us consider the study results of the process of atmospheric moisture effect that varies according to the harmonic periodical law. This makes it possible to model the process of daily , annual and other long-lasting environmental time-variable fluctuations. The broad outline of such process can be described by means of three-dimension function $\varphi(t) = A\sin(\omega t + \varphi) + B$ (11)

where: A – is amplitude of fluctuations, B is steady component of moisture, ω – is fluctuation frequency, $\omega = 2\pi / T$ , T is period of fluctuations, φ is initial phase shift.

It is necessary now to write the solution to the equation (11) for one-dimensional moisture transfer for initial $U(x_1 t = 0) = U_0$ and boundary conditions which now take the form: $U(x = 0, x = h, t) = A^{!}\sin(\omega t + \varphi) + B^{!}$, (12)

where: A', B' – are values for moisture concentration that are determined on the basis of the values A, B that appear in (11). To obtain this value, let us assume that the proposed change in the atmospheric moisture is equal to the change in moisture distribution on the surface of the wooden plate also according to the harmonic law.

According to [2,7] the solution to the equation (9) with boundary condition (11) will be represented in the form $U(x,t) = U_1(x_1 t) + U_2(x,t)$ (13)

where: $U_1(x_1 t)$ describes the relation of the problem to non-uniform boundary conditions while $U_2(x_1 t)$, accordingly, to uniform boundary condition.

In compliance with the accepted assumption, the function $U_1(x_1 t)$ takes the form:

$$U_1(x_1, t) = A^{!}\sin(\omega t + \varphi) + B^{!} \quad (14)$$

In its turn, finding the function $U_1(x_1\gamma)$ reduces to the solution of the non-homogeneous equation for moisture transfer with uniform boundary conditions as the sum of solutions $U_1(x_1, t) = U_1^{!}(x_1 t) + U^{!!}(x_1 t)$ (15)

where $U_1^{!}(x_1 t)$ -is the solution of the non-homogeneous equation (4) with uniform boundary and initial conditions, while $U^{!!}(x_1 t)$ is the solution of uniform value for moisture transfer with uniform boundary and initial

$$U_1(x_1, t = 0) = U_{10} = C_0 - (A^{!}\sin\varphi + B^{!}) \quad (16)$$

By using the method of solution to such equation [], we will obtain the general solution of the non-homogeneous equation

$$U^{!}{}_1(x_1, t) = \sum_{n=1}^{\infty}\left(\frac{-\frac{2}{n\pi}\left(1-(-1)^n\right)}{1 + a^2\lambda_n{}^2/\omega^2}\right)\left(\frac{1}{\omega}\sin(\omega t + \varphi) + \right. \quad (17)$$
$$\left.\frac{a\lambda^2{}_n}{\omega^2}\cos(\omega t + \varphi) + \frac{\frac{2}{n\pi}(1-(-1)^n)}{1 + a^2\lambda_n{}^2/\omega^2}\left(\frac{1}{\omega}\sin\varphi + \frac{a\lambda^2{}_n}{\omega^2}\cos\varphi\right)\exp\left(-a\lambda^2{}_n t\right)\right.$$

The solution of the non-homogeneous equation for moisture absorption with uniform boundary conditions is the special case (5). Thus, $U^{!!}(x_1 t)$ can be written in the form

$$U^{!!}(x_1 t) = \frac{2U_0}{\pi}\sum_{n=1}^{\infty}\frac{1-(-1)^n}{n}\sin(\lambda_n x)\exp(-\lambda^2{}_n \alpha t) \qquad (18)$$

Now let us substitute (14), (15) info (16), and then (17) info (18), we will obtain the general solution to the problem with variable boundary atmospheric moisture conditions which vary according to the harmonic law.

$$U(x_1 t) = A\sin(\omega t+\varphi) + B^{!} - \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{1-(-1)^n}{n}\left(\frac{A_c}{1+\frac{\lambda_n{}^4 a^2}{\omega^2}}\right)$$
$$(\sin(\omega t+\varphi)) + \frac{\lambda_n{}^2 a}{\omega}\cos(\omega t+\varphi) - \left(\sin\varphi + \frac{\lambda_n{}^2 a}{\omega}\cos\varphi\right) \qquad (19)$$
$$\exp(-\lambda_n{}^2 at) + (U_o - A^{!}\sin\varphi - B^{!})\exp(-\lambda_n{}^2 at)\sin(\lambda_n x)$$

By integration the expression (19) we will obtain the equation for moisture content.

$$W(x_1 t) = A_\omega\sin(\omega t+\varphi) + B\omega - \frac{2}{\pi^2}\sum_{n=1}^{\infty}\frac{\left(1-(-1)^4\right)^2}{n^2}\cdot$$
$$\left(\frac{A\omega}{1+\frac{\lambda_n{}^4 a^2}{\omega^2}}\left(\sin(\omega t+\varphi)+\frac{\lambda_n{}^2 a}{\omega}\cos(\omega t+\varphi)-\left(\sin\psi+\frac{\lambda_n{}^2 a}{\omega}\cos\psi\right)\right)\right) \qquad (20)$$
$$\exp(-\lambda_n{}^2 a\gamma) + (w_o - A\omega\sin\psi - B\omega)\exp(-\lambda^2{}_n a\gamma)$$

where: $A_\omega$, $B_\omega$ – are values for moisture contents that corresponds to he values A and B.

However, the relation (3) and (4) indicate that we will obtain the dependence (5) and (6) for steady conditions (w=0). The expression $A\omega\sin(\omega\gamma+\varphi)$, which appears in (3) characterizes the cyclic change in the material moisture content for a very rapid process of changing. The first and second items characterize the kinetics of the process of moisture content drop for cyclic change in boundary conditions. The presence of the function $\cos(\omega t+\varphi)$ is responsible for the shift under the atmospheric and wood moisture contents changes. The third item determines the duration of transition of moisture exchange process to conditions fluctuations. The last item characterizes the process of moisture absorption for steady conditions.

In conclusion, it should be noted that the author has proposed mathematical modeling of moisture transfer in wood under conditions of cyclic action of moisture content variation with consideration for the harmonic law in non-standard conditions. The mathematical relations obtained make it possible to hold that moisture content variation in wood under initial, variable and harmonic conditions will depend on the specimen dimensions, wood moisture conductivity and change in the atmospheric moisture.

## References


1. **Соколовський Я.І.** Деформативність деревини й деревинно-стружкових плит зі змінними потенціалами тепломасоперенесення. Дис… д-ра техн. наук. – Львів, 2001. – 372 с.
2. **Тюленева Е.М.** Экспериментальное уточнение реологической модели древесины / Е.М. Тюленева// Дисс… канд. техн. наук: 05.21.05. – Красноярск, 2009. – 157 с.
3. **Лыков А.В.** Тепломассообмен: справочник / А.В. Лыков. – М.: Энергия, 1971. – 560 с.
4. **Kuffner M.** Elastizitätsmodul und Zugfestigreit von Holz verschiedenen Rohdichte in Abhängigkeit vom Feuchtigkeitgehalt. – Holz als Roh- und Werkstoff, 1978. – №11. – S. 435-440.

5. **Уголев Б.Н.** Деформативность древесины и напряжения при сушке/ Б.Н. Уголев. – М.: Лесн. пром-сть, 1971. – 176 с.
6. **Уголев Б.Н.** Контроль напряжений при сушке древесины / Б.Н. Уголев, Ю.Г. Лапшин, Е.В. Кротов. – М.: Лесн. пром-сть, 1980. – 205 с.

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## Моделювання впливу циклічної дії вологості навколишнього середовища на довговічність термопластичних клейових з'єднань деревини

Наведено математичний розрахунок вологоперенесення в клейовому з'єднанні деревини для граничних, початкових та стаціонарних умов. Змоделювано процес впливу циклічної дії вологості навколишнього середовища на клейові з'єднання деревини під час експлуатації.
**Ключові слова:** клейове з'єднання, вологість, вологоперенесення, стаціонарні і змінні умови, пружно-деформаційний стан.

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UDC 674.815.
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## THE STUDY OF METHODS OF WOOD BENDING

Existing methods for bending wood. The basic perspective directions of manufacturing curved details and examples of finished products. The analysis of technology, given the advantages and disadvantages of each. Using new methods of bending is one way to save wood resources.
**Keywords:** bending, kerfing, laminated bending, vacuum, compression bending, internal heating.

Wood bending is one of the techniques used in the wood processing from a long time ago. Nowadays, there are various designs for chair with a value-added element, and to make it as a product, the need to learn the manufacturing technique and its application becomes very important. From now on, wood bending is one of the techniques that is necessary in the furniture making and also in its design strategy, make us able to make and design furniture accompanied with a new value-added elements. Bending process such as a heating method, depends on the different of the method used, could be classified as below. These are simple explanation for every bending process [1-14].

<table>
<tr><td rowspan="12">Wood Bending</td><td colspan="6">Laminated Bending</td></tr>
<tr><td rowspan="11">Solid Wood Bending</td><td colspan="5">Kerfing</td></tr>
<tr><td colspan="3" rowspan="2">Bending process using a chemical treatment</td><td colspan="2">Ammonia treatment</td></tr>
<tr><td colspan="2">Alkali treatment</td></tr>
<tr><td colspan="5">Compression bending</td></tr>
<tr><td colspan="5">Cold bending</td></tr>
<tr><td rowspan="6">Hot bending</td><td colspan="4">Internal heating (microwave heating)</td></tr>
<tr><td rowspan="5">External bending</td><td colspan="3">Direct heating method</td></tr>
<tr><td colspan="3">Hotplate method</td></tr>
<tr><td colspan="3">Boiling method</td></tr>
<tr><td rowspan="2">Steaming method</td><td colspan="2">High pressure method</td></tr>
<tr><td colspan="2">Low pressure method</td></tr>
</table>

***Fig. 1. Type of bending process***

**Laminated Bending.** The method used in laminated bending is to press the lamination of veneers glued at the former made from metal, plywood etc. With the former, this method is comparatively easy to make the bend component. It is widely used in the making of chair component for the mass production. In laminated bending the thin layer is chosen so that it would be easy to bend (between 1mm to 5mm) depends on its curvature. For the mass produc-

tion, the ready-made veneer is widely used. Regarding the former, it is better to make both the male former and the female former, but for a trial making or a partial component making, we can make only the one side former and do the clamping. In America, we can see the laminated bending technique using a vacuum type mold device. Here, the molding range is limited, but of course one side mold is already enough. Different from a pure bending technique, the laminated bending technique keeps the 'R' shape of the product from straightening out when it is removed from the mold. It has the strength. One of the merit is there is almost no spring back occurred to the material. Keeping a fixed shape of the 'R', and to get a same quality of the components means a big merit for the maker side. Moreover, since the laminated bending using a large quantity of adhesive material causes a rise in the moisture content, it is important to fully dry it before removing it from the former. Basically, if the drying process is done carefully after applying the adhesive to the material, there should be no spring back problem.

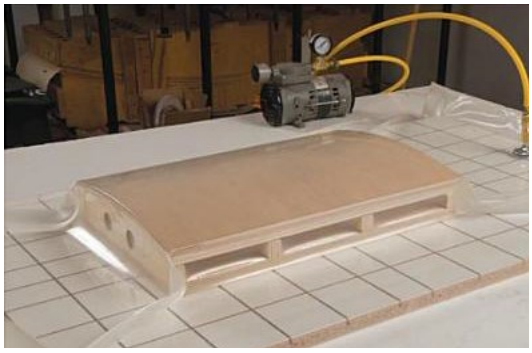

***Fig. 2. Vacuum type mold device***

But, if it is removed from the mold too quickly, spring back will occur. Moreover, the problem in the manufacturing of the veneer, small crack along the grain of the material after the molding caused by its moisture content are some of the things that might occur. In the case where a gap occurs between the veneer layers, wood dust is applied to the place and super glue is used to fix it (use a low adhesive type used for metal use, high adhesive type for wood material use is not good enough to be used). More, the efficiency would increase if we use a spray type primer.

***Fig. 3. Prototypeat thelaminatedbending***

The reference figures show the bending process work and prototype. Figure at the previous page shows the laminated veneers with a thickness of 1.5mm. Since it is just for modeling, only one side mold is made.

**Kerfing.** Generally, the method used is to make a saw kerf (cut) on the inner surface of the material. The formula for this kerf bending is the relation between the thickness of the material, the curve 'R' (outer side) and the quantity of the saw cut. Here we figure out how many saw cut can be made with in the R/4 of the circle. Quantity of saw cut = 1.75 x thickness of wood / thickness of saw blade. In the above formula, the quantity of the saw cut has no relation with the value of 'R'. For example, for the cuts with the thickness of 2mm, to get a 300mm radius of the outer 'R', we need to make 15.7 (about 16 cuts) to the material with the length 471 mm (1.57×300). Here, make about 1 ~ 2 mm of the outer side of the material remain uncut. Since the

'R' is not included in the formula, even the quantity of the cuts made decided from the formula, there will be a case where we could not get the desired 'R'. Here we need to make a little adjustment, by adding more cuts or by crushing the angle of the saw cut.

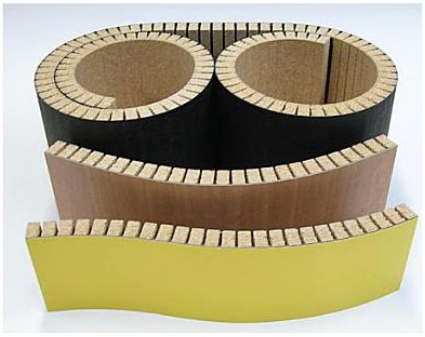

***Fig. 4. Sample-kerf bending details***

**Compression bending.** This is a new technique in bending process. Firstly, the material is pressed along its length direction (along the grain) before it is bended. Means, the structure of the fiber becomes like a bellow, making it easier to bend. However, compare to other method that usually use a heat (Tohnet's method: will be discussed later), it is weaker in term of the strength. The method used is to use a device that hold both the ends of the material firmly, then it is inserted into a casing (like a pipe etc) that just fit its size, and using a hydraulic cylinder the material is pressed along its length for about 10 %, and then it is returned back to about 5 %.The material used is the one with moisture content of about 20-30 %. After it is pressed, it is bended using a former and dried. During the bending, it is better to use the strap so that the material sticks to the former properly.

This method is same as Tohnet's except for the pressing process. After the material is processed, if we could maintain the content of the moisture, then we do not have to do the bending process right away. This is the merit of this method. Even it seems very simple in term of the theory, this method is still not a common thing. 'Compwood' Machine Company from Denmark is one of the little companies involves in the making and sale of the machinery equipment used for cold bending. In this patent system, material that already dried naturally to 20-25 % moisture content and processed using a planer is put to the autoclave and heated using a steam. Next, the process is complete when the steamed material is pressed along its grain with the hydraulic pressing device. By applying a pressure, a pleat occurs at the wall surface of the fiber (cellulose), and leaving it in several minutes would make it easy to bend even in the cold condition. Then, by dry it in its bended condition, the material would harden. Since, the material that is processed using this compressing method is suitable for storage, it is possible for an effective production control in the making of partial component.

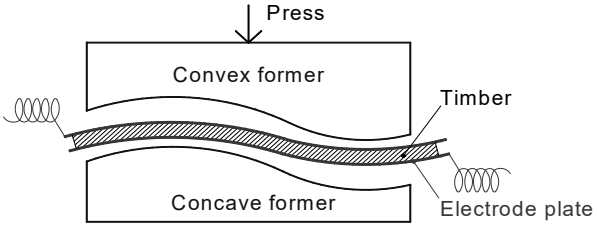


***Fig. 5. High frequency heating***

**Internal heating / Microwave heating.** This is a method of using a microwave to do the heating. Microwave is a wave with a frequency about 300 Hz to 300 kMHz, wavelength of about 1 m to 1 mm range. In this range we have UHF (Ultra-high Frequency, wavelength 10-1 cm), SHF (Super-high Frequency, wavelength 10-1 cm) and EHF (Extremely-high Frequency, wavelength 1-0.1 cm). The heating process is done using these waves. Microwave, like an AC current repeatedly irradiates a plus and minus charge to the material. At the other side, the molecules constructing the material itself, has a plus and minus characteristic. These molecules respond to the direction of the electric field comes from the external source, but when the fre-

quency becomes higher, they become more independent resulting a friction between the vibrating and rotating molecules. The friction generates heat to the material.

Moreover, water is very ideal substance in term of heating, because its absorption and loss of energy is big (generates heat easily). At the frequency of 10 GHz, 915 MHz and 2450 MHz, it shows a big loss of energy. For that reason, material contains water (moisture) generates heat more easily. The frequency of microwave in the microwave oven used at home is about 2450 MHz (245 millions cycles per seconds). By the way, microwave permeates through a ceramic, and reflected by a metal. For that reason, this method of bending is widely used during softening process, or during a molding process where the heat is applied at the same time (above figure), and the use scope is expanding. The device itself is simple, where the heating part consists of the microwave oscillator, heating room, wave guide assembly, antenna etc. Moreover, since it is possible to bring the microwave to some distance, it is possible to use it for a partial heating (there is a noise problem and there is a case of a maker using it for partial bonding).

## References


1. **Jonathan Benson.** – Bending Wood, Woodworkers Guide, China 2008.
2. **Kohji Katsuragi-Tai-Workshop** / 1608-2, Nishizato, Oguni-Cho, Aso-Gun, Kumamoto. 867-2504 Japan, Copyright(c), 2004.
3. **Edward C.** Peck – Bending Solid Wood to Form, Agriculture Handbook. –No. 125, U.S. Department of Agriculture, 1957.
4. **Gayda S.V.** A problem of wood raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2007, 33:55-63. (in Ukr.).
5. **Gayda S.V.** Research of concentration of operations is in modern furniture Productsion // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2007, 33:73-79. (in Ukr.).
6. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2008, 34:55-68. (in Ukr.).
7. **Gayda S.V.** Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood / Forestry, Forest, Paper and Woodworking Industry, 2008, 34:68-79. (in Ukr.).
8. **Gayda S.V.** Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2009, 35:63-83.
9. **Gayda S.V., Maksymiv V.M.** From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. – Lviv: 2010, 36:57-77.
10. **Gayda S.V.** A comparative analysis of physical-and mechanical parameters of variously-designed Glued Boards made of post-consumer Recovered Wood / Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2010, 36:81-91.
11. **Gayda S.V.** Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:238-244. (in Ukr.).
12. **Gayda S.V.** Comparative analysis of bending particularities for various post-consumer wood species and age categories // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:84-88. (in Ukr.).
13. **Gayda S.V., Voronovich V.V.** Investigation of the features of bending of post-consumer wood // Proceedings of the Conference, Mari State University, – 2011, 190-192 (in Russian).
14. **Gayda S.V.** The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. – Lviv: UNFU. – 2009, 19.14:72-89. (in Ukr.).



УДК 674.815



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## Дослідження методів гнуття деревини


Розглянуто існуючі методи гнуття деревини. Досліджено основні перспективні напрямки виготовлення криволінійних деталей. Наведено приклади готових виробів. Проведено аналіз технологій, подані переваги та недоліки кожної з них. Використання нових методів гнуття є одним із шляхів економії деревинних ресурсів.



**Ключові слова:** гнуття, ламіноване гнуття, вакуум, гнуття тиском, внутрішнє напруження.

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# INVESTIGATION OF SOUND VELOCITY IN WOOD BY NON-CONTACT METHOD

This article is dedicated to development of resonance methods for the study of properties of wood and other materials, as well as to improvement of methods for determination of acoustic waves propagation velocity (AWPV) and to methodology of research and analysis of experimentally obtained results. There was proposed a non-contact method for determination of phase velocity of sound and there was described a device for implementation of the method. The measuring method used is notable for the considerable decrease in sound velocity measurement error and it may be applied with small samples. There were presented the developed methods of conducting research in climate chamber equipped by oil gate for weighing sample in course of experiment. There are shown the results (experimentally obtained for a sample of pine-wood) for the values of sound velocity in a wide range of moisture content and temperature.

**Keywords**: acoustic wave, wood, temperature, moisture content, statistical processing.

Relevance of research. It is known that the velocity of acoustic waves propagation in materials depends on their structure, moisture content, density, elasticity modulus, temperature, direction of propagation and other factors [1-5]. Therefore, this parameter is often used in non-destructive methods of materials quality control. Development of new means and methods for determination of the speed of sound is a high-priority task on the way of increasing the accuracy and trustworthiness of monitoring over the important operational parameters of materials and articles manufactured from them.

**Analysis of the known results** For the studies of wood by acoustic methods there can be used variety of ultrasonic devices, including: [6]. As a basis for measuring in those devices there is laid an ultrasonic pulse method (UPM). This method is based on the technique of determination of (ultra)sound velocity in materials by means of dividing the distance between the emitting and receiving devices for the sound wave (base of insonification) by the time of sound pulse passage of the specified distance. The countdown of passage time starts from the moment of excitation of sound wave emitting device and ends at the moment of fulfillment of the condition, by means of which the fact of receiving this pulse by the receiver is determined. In UPM devices it is (as a rule) piezoelectric ceramic plate with pronounced resonance properties, which takes the role of sound wave emitting and receiving device. In real devices to excite oscillations of the emitter there is used a periodic short pulse, from which the time-count starts.

Even in case of low-quality devices the emission and reception of sound wave significantly narrows the width of the signal spectrum and thus reduces the steepness of the signal front and the accuracy of pulse arrival moment selection. It also makes measurements results susceptible to noise-level in the channel of measurements [9].

Another drawback of the above devices is direct contact of vibrations excitation and reception devices with the sample. The devices, pressed-up to the faces of the sample, form with it the mechanical system, in which the conditions of acoustic oscillations differ from the conditions in the very sample. Besides of parameters of the material under studies, the obtained values of sound velocity also depend on the weight and position of acoustic instruments on the sample. Exclusively large influence is on the part of heavy devices, such as, for instance, piezoelectric ceramics or ferromagnetics, which also have their natural expressed resonant frequencies. Limitation of this effect leads to the need for large sample sizes and masses and thus increases the measurement error due to irregularity of the struc-

ture, while in some cases (for instance, for wood) it is unacceptable. Thus, the known UPM-devices introduce (in different ways) methodological error into the measurement process, while it limits from below the absolute error for determination of the speed of sound (for instance, for wood) – by the rate of several tens of meters per second [9].

Another common practice is resonance method for determination of wood properties, which involves attaching the tested sample by two supporting needles inserted in two blind holes, drilled in the sample against each other at the intersection of the diagonals of the side surfaces of the sample. For excitation of oscillations the ferromagnetic plates are glued to the sample. By means of electromagnets the oscillations are excited in the sample and its resonance characteristics in the range of sound frequencies are determined. This is followed by calculation of mechanical parameters of the material.

This method for sample fixation, as well as for excitation and reception of oscillations in the sample (associated with changes in mass and geometry of the sample, holes for fixation and magnetic plates) also leads to distortion of the self resonance frequency of the sample and requires additional sample preparation time. This article is dedicated to application of means and methods of measurement, which would allow determining parameters of the sample without distortion of its properties. Such means and methods can significantly increase the accuracy of materials parameters, increase reliability and accuracy of non-destructive acoustic control and, therefore, expand its application scope.

**Means of experimental studies.** To provide for experimental studies, set free from the above-mentioned disadvantages, there was designed the device for non-contact measuring of the sound velocity in the material sample. On (Fig. 1) there is shown the axonometric structural diagram of the experimental acoustic research device, which consists of a shock mechanism, fasteners in the form of suspension, microphone, spectrum analyzer, filter and frequency-meter.

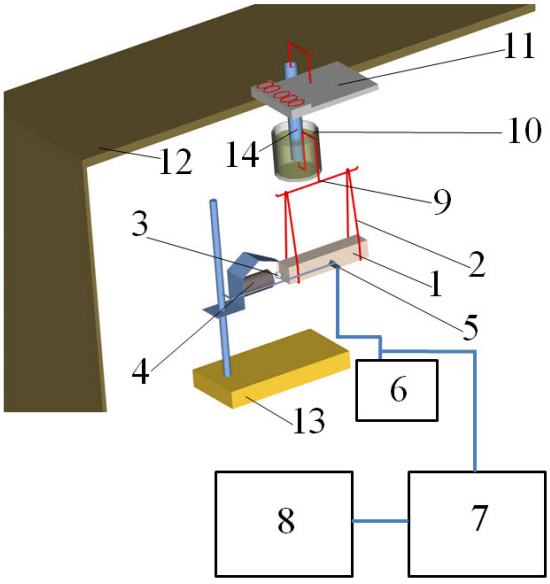


***Fig. 1. Axonometric block diagram of the experimental acoustic research unit:***
*1 – a sample that is shaped as a parallelepiped, 2 – suspension, 3 – pendulum mechanism, 4 – electromagnet, 5 – microphone, 6 – spectrum analyzer,7 – filter, 8 – frequency-meter, 9 – tie-rod of oil gate for weighing samples in the climate chamber, 10 – bath with oil, 11 – electronic balance, 12 – climate chamber wall, 13 – supporting stand, 14 – oil gate tube*

The basis of the shock mechanism is holder, upon which there is mounted the electromagnet with damper diode and pendulum mechanism. Electromagnet deflects pendulum iron ball from the equilibrium position in the direction opposite to the sample. After clearing the ball on the pendulum passes state of equilibrium by inertia, hits the sample and excites in it the natural acoustic oscillations. Damper diode allows preventing interference with electromagnet self-induction towards the measuring electric circuits. The disadvantage of oscillations excitation shock method is due to uneven spectral density of the signal and, consequently, due to low amplitude of excited oscillations at high frequen-

cies. The lower the duration of the pulse signal (with the same energy) is, the wider its spectrum is [11] and the larger high-frequency oscillation it can excite.

Reducing the size of the sample leads to increase in the resonant frequencies of natural oscillations and requires a shorter shock excitation pulse. The value of material hardness limits the force of shock and leads to limitation of the frequency range for application of the shock method. In Fig. 2 there is shown the experimentally obtained dependence of the interaction force changes during the shock of the pendulum iron ball against a sample of pine-wood in the longitudinal direction. The spectrum, corresponding to this pulse excitation, is calculated and presented in the same figure. In the spectrum presented there are no frequencies with zero spectral density. Thus, shock method is suitable for excitation of resonance oscillations in a broad continuous range of frequencies in samples of arbitrary size. [9]. In [9] one can see that even at a frequency of 25 kHz the level of oscillation, excited in the sample of pine-wood is by 30 dB above the noise level.

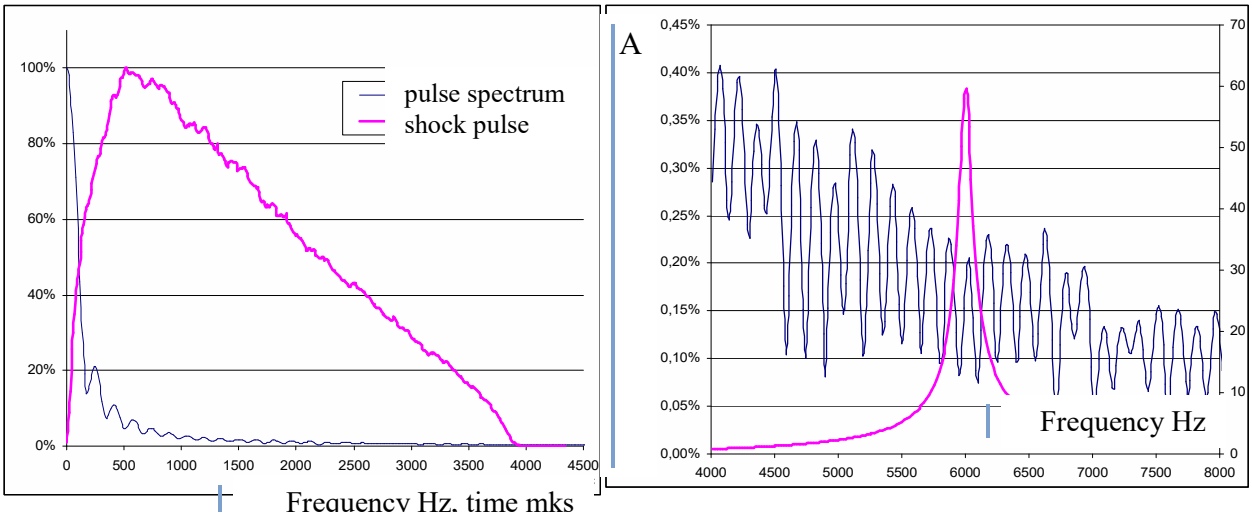


***Fig. 2. Substantiation of possibility for shock excitation of natural vibrations of the sample:*** *a – pulse shape and spectrum for shock excitation; b – pulse spectrum for shock excitation and amplitude-frequency characteristics of the sample*

In order to obtain the more exactly specified physical and mechanical characteristics of wood by resonance method there was implemented a sample fixation (suspension) in the form of loops, which in turn were fixed to a stationary support and did not interfere the natural oscillations of the sample. This design maintains integrity of the sample and provides for its quick installation and removal [9].

To fix the standard sample sized 20×20×300 mm [10] assume the length of the loop thread equal to 0.18 m. This loop provides a suspension of mass-center for the sample at a distance of 0.05 m from support. Under this condition, the resonance frequency of the pendulum, formed from the loops and the sample, will be about 2,2 Hz. That is more than for three decimal signs lower than the testing frequency and it does not hinder the measurement of natural resonance frequency of the sample.

Using data on high strength and density of kapron (density of loop's material $d_2 = 1{,}14 g/sm^3$, limit load $\sigma = (74-86) kg/mm^2$), provided that each loop can withstand three times the weight of standard-size sample with the most heavy on the Earth black-snake-wood (density of the material sample $d_1 = 1{,}49 g/sm^3$), it is possible to calculate the mass of two thread-loops, which constitutes 0.0015 g.

Thus, one can neglect the influence of mass of the two loops on the frequency of oscillation of the sample, suspended on them and weighing 180 g – if to compare it with the influence of magnetic plates' mass, which constitutes 1 g according to GOST. Estimates of mass for thread loops from other materials: pure silk, steel, nylon, spider's web give similar results. In addition, loops can be placed not on the edges of the sample, but closer to the middle (Fig. 1), where the amplitude of sample oscillation is much smaller, which further reduces the influence of loops upon the natural resonant frequencies of the sample. It is also possible to mention that it is not the entire loop which participates in the oscillations, as its upper part is immovable together with the holder.

For perception of natural acoustic oscillations of the sample there is used (in non-contact sound velocity measuring device) the broadband microphone MF5, installed near one of the faces of the sample, but without mechanical contact with it.

In the developed device the pendulum mechanism of acoustic wave excitation has (in the moment of shock) a brief, with duration of 5,2 milliseconds, contact with the sample, while after the shock it is thrown away from the sample by forces of elasticity and gravity. The natural oscillations of the sample are perceived by sensitive microphone remotely. So, the device has no structural elements, mechanically connected with the sample and capable to change the resonance frequency. The frequency of vibration of the sample itself is transferred to the medium that surrounds the sample (air), and it is perceived there by the microphone. Information parameter (frequency) does not change during such transformations and does not cause an additional measurement error.

The spectrum of short pulse of mechanical oscillations excitation is sufficiently broad and it promotes a perturbation of oscillations in the sample – in several of its natural resonant frequencies. These frequencies depend on the geometrical dimensions of the sample and the speed of sound in the material. Speed of sound in the material depends on the oscillations polarization and anisotropic material properties. Thus, for such orthotropic material as wood, there are nine different types of acoustic waves, propagating along the principal axes of symmetry with their speeds, and there are types of acoustic waves, propagating in directions that do not coincide with the axes of symmetry. Selection of natural oscillations of the necessary type was carried out according to the developed methods, based on the dependence of resonance frequency upon the geometrical dimensions of the sample.

To isolate the resonance frequency oscillations there were used possibilities of PC to receive, register and process the acoustic signals, transformed by microphone. In the studies undertaken for the implementation of functions of spectrum analyzer, filter and frequency-meter there was used program medium of GoldWave audio-redactor.

After the shock excitation, depending upon the elastic and plastic properties of the material, as well as upon the parallelism of the sample faces and cleanness of the surface, the oscillations in the natural resonance frequencies of the sample last for few tenths of a second. Digital processing of signal record allows to select the necessary oscillations, determine with high accuracy their frequency and calculate the velocity of acoustic waves propagation:

$$C = 2 \cdot l \cdot f \qquad (1)$$

where: $C$ – the velocity of oscillations propagation; $l$ – the size of sample in the direction of oscillations propagation.

From the expression (1) it follows that the relative error of the speed of sound is made up of relative errors of determination of sample size and resonance frequency. Usage of sliding calipers with point value of 0,05 mm and implementation of signal quan-

tification with a frequency of 192 kHz allowed measuring the velocity of propagation for longitudinal wave of tangential polarization in pine-wood sample with the length of xx cm with an accuracy of ± 1 m/s. By means of the experimental unit there was performed the study of dependence of the speed of sound in pine-wood upon the moisture content and temperature of the material. To create the necessary temperature and moisture conditions there was used the climate chamber [7].

**The technique of conducting experiment** While planning the experiment it is expedient to use the fact that alignment of the temperature field in the sample occurs faster than alignment of the moisture content. Therefore, to reduce the time of experiment conducting, the testing was first carried out throughout the entire temperature range for maximum preservation of the sample moisture content at the same level, while after that there was implemented the transition to the sample testing at the other moisture content.

To maintain the equilibrium moisture content of the sample at a specified level with changing temperature of the working area of chamber – there shall be also arranged a simultaneous change of the relative moisture content of the medium. In case of the range of free moisture content of the sample, the climatic conditions in the chamber (as a result of technical limitations) can not completely stop the loss of sample moisture. Under the conditions of maximum achievable in camera relative humidity of the air (92-98 %) it is possible to significantly slow down drying of the sample. This makes it possible to achieve sufficiently uniform distribution of moisture in the sample and provides time to carry out these studies. Measurements were done by described technical means according to the developed methods in the following sequence of operations:

- dry the samples in the chamber till completely dry state and determine their dry weight;
- to place samples in a chamber zone in measurement devices:
- to determine the frequency of resonant oscillation it is necessary (tentatively, with reference to [12] and the sample size) to calculate the frequency range for the possible location of resonance;
- in the written down file the program of spectrum analyzer Goldwave to survey this range of frequencies and to choose the necessary resonant fluctuation;
- conduct periodic weighing of the sample and determine the time when the sample achieve the desired moisture content;
- after achievement of uniform distribution of humidity and temperature of the sample to make record of fluctuations in a sound file of the personal computer;
- on requirement to change temperature and humidity in the chamber;
- during an establishment in the sample of uniform distribution of temperature to execute operations of processing of a sound file;
- to allocate with the filter resonant fluctuations, and to define their frequency.

The experimental measurements were conducted by series of five shocks for each sample. The results were averaged, and the deviation from the mean was determined. Deviation of the speed of sound in a series constituted several tenths of meter / second.

**Discussion on the results of experimental investigation** The data obtained allowed to clarify the nature of the functional dependencies of AWPV from moisture content within the limits from 0 to 90% and temperature from 15 º C to 65 º C. Graphical representation of functional dependencies is presented in Fig. 3.

For approximation of experimental data there was used multiple regression calculation module of STATISTICA 6.1 program medium [8]. By using STATISTICA module with regression coefficients estimation procedure (stepwise with inclusion) for pine-wood in the specified ranges of climatic conditions there was obtained the regression dependence of the second order: $C = b_o + b_1T^2 + b_2W + b_3W^2 + b_4TW,$ (2)

where: $b_o = 1251{,}751$; $b_1 = -0/029$; $b_2 = -10{,}447$; $b_3 = 0{,}059$; $b_4 = 0{,}017$; $T$, $W$ – temperature and moisture content of pine-wood.

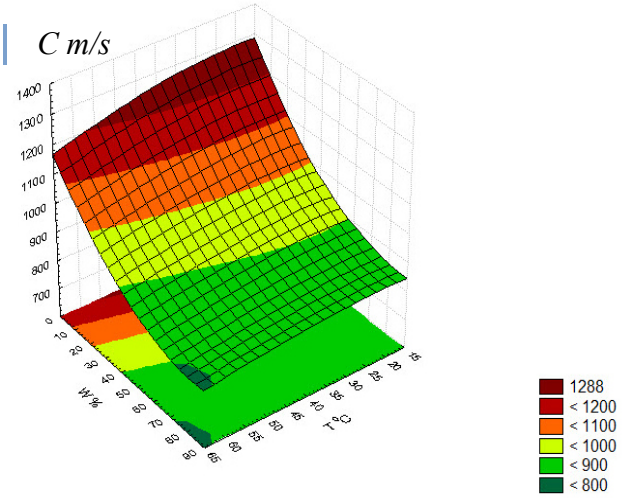


***Fig. 3. Dependence of acoustic waves $C_{LT}$ propagation velocity upon the temperature and moisture content in pine-wood***

The coefficient of multiple determination (R-squared) from equation (2) with the natural coefficients is equal to $R^2 = 0{,}9978$ . Such a high value for the coefficient of multiple determination indicates the practical identity of results of the experiment and results of measurement of sound velocity. Analysis of the data shows that the dependence of sound velocity in wood upon the temperature is significantly nonlinear, as evidenced by the absence (in equation 2) of component with a temperature in the first degree. With increasing of wood temperature the AWPV decreases proportionally to the square of the temperature value (coefficient $b_1<0$). The negative sign of this coefficient provides (with increase of temperature) more rapid dependence. The higher the temperature is, the stronger the influence of its changes becomes.

Nonlinear dependence of sound velocity upon the moisture content is much stronger than upon the temperature. The regression coefficient (at a square value of moisture index $b_3$) is in absolute value higher than $b_1$ for more than twice. But the general type of dependence of AWPV upon the humidity is determined by a large value of negative coefficient $b_2$ at the moisture rate in the first degree. It is just this coefficient which determines the decrease of speed of sound with increasing of moisture content. The positive value of coefficient $b_3$ reduces sensitivity of AWPV to changes in moisture content in conditions of its growth. In case of the simultaneous increase in moisture content and temperature – the positive value of coefficient $b_4$ additionally provides a relatively small ($b_4 = 0{,}017$) slow down of decrease of the speed of sound in the area of the vertical diagonal of the depicted surface in relation to areas with high value of just moisture content or just temperature. But due to small value of $b_4$ the influence of this component is very limited and almost imperceptible in Fig. 3.

**Conclusions** The authors carried out the analysis for the known methods of measuring AWPV, developed a method and created a device for measuring the phase speed of sound without contact of measuring devices with the sample. The described device has allowed achieving higher accuracy of data for smaller-in-size samples. Based on experimental data, there was obtained an analytical non-linear function of dependence of AWPV upon the moisture content and temperature for pine-wood. Development of research by this method will allow creating the technology of non-destructive testing of moisture distribution in wood, which is particularly important for large wood assortments.

## References


1. **Александров К.С.** Измерение упругих постоянных древесины импульсным ультразвуковым методом // Труды института леса и древесины. Сиб.отд. АНСССР, 1962, 51, – С. 81-85.
2. **Берзон А.В.** О механизме распространения продольных ультразвуковых волн во влажной древесине // Неразрушающие методы испытаний строительных материалов и конструкций. – Рига: РПИ, Вып.1, 1974. – С. 85-99.
3. **Ефимов А.А.** Измерение скорости ультразвука по радиусу ствола // Современные наукоемкие технологии. – М: Российская Академия Естествознания. – 2009, №8. – С. 23-27
4. **Неразрушающий контроль:** Справочник: В 7 т. Под общ. ред. В.В.Клюева. Т.3: Ультразвуковой контроль / И.Н.Ермолов, Ю.В. Ланге.-М.:Машиностроение, 2004. – 864 с.
5. **Reinprecht L., Panek M.** Detection of rot in wood beams by ultrasound method – model and practical studies / Technical Uneversity of Zvolen, Slovakia // International Conference on Wooden Cultural Heritage: Evaluation of Deterioration and Management of Change, (Hamburg, Germany; October 7-10, 2009).
6. **Каталог приборов** неразрушающего контроля качества бетона. – К.: НИИСК Госстроя СССР, 1986. – 24 с.
7. **Сторожук О.Л., Соколовський Я.І.** Математичне моделювання та експериментальне визначення закономірностей поширення акустичних хвиль в деревині // Інтелектуальні системи прийняття рішень і проблеми обчислювального інтелекту: Матеріали міжнародної наукової конференції. Том 1. – Херсон: ХНТУ, 2011. – 472 с.
8. **Сторожук А.Л., Соколовський Я.И.** “Statistical simulation for influence of wood characteristies on propagation speed of ultrasonic waves” // Ліс. госп-во, ліс., папер. і деревооб. пром-сть : міжвід. наук.-техн. зб. – Львів: НЛТУ України. – 2009, вип. 35. – С. 108-114.
9. **Соколовський Я.И., Кенс И.Р., Сторожук О.Л., Борисов В.М.** Экспериментальное исследование влияния температуры и влажности на распостранение акустических волн в древесине // Сб. научных трудов Брянской государственной инженерно-технической академии “Актуальные проблемы лесного комплекса”. – Брянск, 2011. – Вып. 30.
10. **ГОСТ16483.31-74** Древесина. Резонансный метод определения модулей упругости и сдвига и декремента колебаний – М.: ИПК Изд-во стандартов, 1999.
11. **Теория электрической связи:** учебное пособие / К.К. Васильев, В.А. Глушков, А.В. Дормидонтов, А.Г. Нестеренко;под общ. ред. К.К. Васильева. – Ульяновск: УлГТУ, 2008.
12. **Сергиенко Ю.К.** Исследование ультразвукового метода обнаружения гнили в круглых лесоматериалах. – М.: Дисс. на соиск. ученой степени канд.техн.наук, 1968. – 179с.



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## Дослідження безконтактним способом швидкості звуку в деревині


Стаття присвячена розвитку резонансних методів дослідження властивостей деревини та інших матеріалів, удосконаленню способів визначення швидкості поширення акустичних хвиль (ШПАХ), методиці проведення дослідження та аналізу експериментально отриманих результатів. Запропоновано безконтактний спосіб визначення фазової швидкості звуку та прилад для його реалізації. Використаний спосіб вимірювання відзначається суттєвим зменшенням похибки вимірювання швидкості звуку і придатний для зразків малих розмірів. Дослідження проведені у кліматичній камері, спорядженій масляним затвором для зважування зразка в ході експерименту. Наведені результати експериментально отриманих для зразка сосни значень швидкості звуку у широкому діапазоні вологості та температури.



**Ключові слова**: акустична хвиля, деревина, температура, вологість, статистична обробка.

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# THE PHYSICAL-AND-MECHANICAL MODEL OF WOOD DEFORMATION IN THE PROCESS OF BENDING AND PRESSING

Various techniques for obtaining curved wood members from solid wood were analyzed, also the influence of wood properties on its deformity in the processes of bending and pressing was investigated, obtained were the dependences for calculating the degree of wood compaction as well as relationships between a test bar thickness and its length in bending.

**Keywords.** Bending, pressing, compressive strain, tensile strain, steaming, cooking, solid wood.

Curved members from solid wood can be produced by two radically different ways:

- by way of carving (sawing out) shaped blanks during which a great amount of residue is produced and the fibers cutting occurs, which considerably lowers the wood strength;
- by way of bending a straight bar into shape by using a special template and allowing it to dry in its new shape.

Both of these methods are of practical use, they have their advantages and disadvantages. Obtaining curved members by method of bending requires more complicated techniques and equipment compared to carving. However, the material subjected to bending fully retains its strength or, in some instances, the strength tends to increase. The bent wood can be worked like any normal unbent wooden parts. The nature of physical processes that take place during bending is as follows: the process of bending any body involves the production of transverse stresses (normal-to-cross section stresses) within the limits of elasticity: tension on the convex surface and compression on the concave surface. Between the zones of tension and compression, there is a neutral layer the normal stresses in which are equal to zero. Since the values of normal stresses vary over the cross-section, there develop shear stresses that tend to cause adjacent layers of the body to slide parallel in opposite directions, but such slide is impossible, therefore the bending is inevitably accompanied by tension on the convex surface and compression on the concave surface of the woodwork [1-13].

The amount of tensile and compressive strains is dependent on the bar thickness and the bending radius. Let us assume that a bar of rectangular cross-section is bent in an arc of the circle, then the amount of deformation in the bar is in direct proportion to the stresses with the neutral layer being in the interior of the bar.

Let us denote the bar thickness by $S$, the initial length by $L_0$, the bending radius along the neutral line by $R$. The bar length along the neutral line during bending remains constant. It is equal to

$$L_0 = \pi R(\varphi / 180), \qquad (1)$$

where φ is the bending angle expressed in degrees.

The face layer will show an increase in its length, this elongation being ΔL. The total length of the stretched portion of the bar is determined by expression

$$L_0 + \Delta L = \pi(R + h/2)\varphi / 180. \qquad (2)$$

On deducting the preceding equation (1) from this one (2) we obtain the absolute elongation value:

$$\Delta L = \pi(h/2)(\varphi / 180). \qquad (3)$$

The relative elongation $\varepsilon_\rho$ is equal to $\Delta L/L_o = S/2R$, that is, the relative elongation $\Delta L/L_o$ in bending is dependent on the ratio of the bar thickness to the bending radius. The higher this ratio, the greater thickness of the bar $S$ and, accordingly, the smaller bending radius $R$. Similar ratio for the relative compression value in bending process can be obtained in the same way.

If a bar of initial length $L_o$ is bent round a radius $R$, in this case the maximum compressive and tensile strains are achieved. By denoting the amount of allowable compressive strain along the grain by $\varepsilon_{cm}$ and the amount of allowable tensile strain along the grain $\varepsilon_{розт}$, we can write the ratio for the stretched side of the bar

$$L_1 = L_0(1 + \varepsilon_{розт}) = \pi(\mathrm{R}' + S)\,\varphi/180. \quad (4)$$

Yelding, $$R' + S = [L_0(1 + \varepsilon_{розт})]/\pi\,(\varphi/180). \quad (5)$$

For the compressed (concave) side

$$L_2 = L_0(1 - \varepsilon_{cm}) = \pi\ \mathrm{R}'\,(\varphi/180), \quad (6)$$

or $$R' = [\mathrm{L}_0(1 - \varepsilon_{cm})]/\pi\,(\varphi/180). \quad (7)$$

By deducting the second equation from the first one, we obtain

$$S = [L_0(\varepsilon_{розт} + \varepsilon_{cm})]/\pi\,(\varphi/180). \quad (8)$$

By using the ratio *S/R* that characterizes the bending limit of wood for this case, we obtain $$S/R' = (\varepsilon_{розт} + \varepsilon_{cm})/(1 - \varepsilon_{cm}). \quad (9)$$

By substituting the values of allowable compressive and tensile strains ($\varepsilon_{розт}$ and $\varepsilon_{cm}$), into the expressions obtained, we can determine the greatest possible values of S/R′ for various wood species. This ratio limiting values are obtained experimentally: for beech – 1/2.5; for oak – 1/4; for birch – 1/5.7; for spruce – 1/10; for pine – 1/11.

The common practice is that wood needs to be bent at the ratio greater than 1/3. From the data presented, one can see that coniferous species and part of soft broadleaved species are not suitable for bending to small curvature radii even if full advantages are taken of possible compressive and tensile strains. Rejects that occur in the process of bending coniferous and soft broadleaved wood species, result from ripple formation on the concave side due to nonuniform compression along the grain and low resistance to compression perpendicular to the grain. A perfect bend of a bar is only possible to the point where the amount of relative elongation of stretched layers or the amount of relative compression of compressed layers do not exceed the limit values for a given material. The above obtained ratio holds true for the materials whose tensile and compression strengths are equal. If the compression strength of the material is higher than the tensile strength, the neutral line will shift to the concave side. If the tensile strength is higher than the compressive strength, the neutral line will shift to the convex side, which is the case in the wood. In the example of an uncontrolled bending, the wood failure occurs due to rupture of the surface stretched layers. This is attributable to the fact that the allowable amount of tensile strain in wood is very small, no more than 1…2%, whereas the limit value for the compressive strain makes up 15…25 %.

The bending property of wood can be enhanced by cooking or steaming. Such treatment adds plasticity to wood. Wood cooking lowers the compressive resistance by a factor of two or more while the amount of shrinkage is increased. The tensile strength and deformity of wood are affected but slightly. For example, in steam-seasoned beech wood at moderate compressive resistance level (about 23 MPa) and the allowable compressive strain of 30%, the amount of possible tensile strain remains insignificant even with high amount of stresses (2% at 130 MPa). This is a limiting factor to bending properties of steam-seasoned wood and does not allow for taking full advantage of its ability to take considerable amounts of compressive strain. The bending properties of steamed wood are restricted by small amount of allowable tensile strain, the bend being limited to the ratio of approximately S/R ≤ 1/30. The bending properties of wood can be significantly enhanced when the property of steamed wood such as the ability to fully take a considerable amount of compressive strain, is taken into account.

Pressing is one of the currently used method of mechanical processing of wood. It is based on the application of force to wood using its plastic properties, wood is subjected to pressing for the purpose of obtaining complex shapes or compaction. Pressing is widly used to produce decorative wooden profiles for application in furniture making instead of non-ferrous metals thus saving them for machine engineering and electric power industry. Physical and mechanical characteristics of pressed wood are higher compared to genuine wood. Pressing is

characterized by the degree of compaction which is determined by the ratio of woodwork dimensions prior to pressing and after pressing. The degree of compaction is calculated by the formulas: $$\varepsilon = (h_n - h_к) / h_n, \quad (10)$$

$$\varepsilon_0 = (h_n - h_к) / h_к, \quad (11)$$

where: $\varepsilon$ and $\varepsilon_0$ – the degrees of compaction that are determined for initial or final dimensions; $h_п$, $h_к$ – the woodwork dimensions prior to and after pressing.

The given characteristics of the degree of compaction are related to one another by the ratio $$\varepsilon_0 = \varepsilon / (1 - \varepsilon) \quad \text{i} \quad \varepsilon = \varepsilon_0 / (1 + \varepsilon_0). \quad (12)$$

Since the mass of the woodwork during the pressing process and the mass of the woodwork obtained after pressing remain practically the same, the degree of compaction can be defined as a ratio of the wood density after pressing to the density prior to pressing

$$\varepsilon = (\rho_к - \rho_n) / \rho_к, \quad (13)$$

where $\rho_к$ and $\rho_п$ – final and initial values of density.

Sometimes the degree of compaction is expressed in percent. Commonly, wood pressing is done to a 40 % degree of compaction. Wood is more amenable to across-the-grain pressing after steaming which enhances its plasticity. Wood's plasticity increases at moisture content of about 30 % and elevated temperature up to 160 ºC. Higher temperatures cause wood pyrolysis. The stabilization of the shape obtained during the process of pressing is provided by cooling followed by drying when the moisture content is higher than 12 %. Pressing of wood involves deformation of its cells. Three phases of deformation can be observed here. Initially, the wood is in the stage of elastic deformation, the cells compression, $\varepsilon$, being equal to about 6 %. In the second stage of pressing, the thin walls of cells are destroyed - this is the stage of plastic deformation with $\varepsilon$ being equal to 6 to 30 %; in the third stage, with $\varepsilon$ ranging from 30 to 40 %, thicker walls of the cells are being destroyed that were deformed in the second stage. The types of pressing are distinguished by the direction of the acting forces: flat-uniaxial, profile, and volume-hydrostatic. The dependence of deformation on stresses during the process of pressing is analytically expressed by the formula: $$\varepsilon_{cm} = \sigma / E + (1/\eta)(\sigma^2 / \upsilon), \quad (14)$$

where: $\varepsilon_{ст}$ – compressive strain; $\sigma$ – stress; E – modulus; $\eta$ – coefficient of toughness; $\upsilon$ – loading rate.

By analyzing the above dependence, one can note that the degree of compaction tends to increase with increase in stresses, and decreases with increasing modulus of elasticity, toughness and loading rate. Flat and profile pressing are the most frequently used types of pressing today. The flat pressing can be done with the use of a mould that confines the shape of the woodwork being pressed or without it. The amount of pressing force is determined by the size of the woodwork as well as by the required degree of compaction. The force required for pressing without a mould is calculated by the formula $$P = b \cdot l \cdot \sigma_x, \quad (15)$$

where: $P$ – required pressing force; b is the woodwork width; $l$ – the woodwork length; $\sigma_x$ – the resistance of wood to pressing, it is dependent on the degree of compaction and wood species. The value of $\sigma_x$ is determined by empirical equation $$\sigma_x = k \cdot e^{m\varepsilon}, \quad (16)$$

where: k, m – coefficients which are dependent on wood species (for pine – k = 1.6, m = 0.007; for spruce − 1.19 and 0.07 respectively; for aspen – 0,45 and 0,09); e – base of natural logarithms; $\varepsilon$ – degree of compaction.

If pressing is carried out with the use of a mould, it is necessary, when calculating the force, to take into account additional force required to overcome wood-to-metal friction. In the case of profile pressing, account must be taken of the pressing force and force for moving the woodwork in the receiver. The force required to move the woodwork into the receiver is defined as frictional force with consideration for compressive pressure and coefficient of friction.

**Conclusions.** The study presented in this paper indicates that wood deformity in bending and pressing is influenced by the following factors: wood species (its micro- and macrostructure), the direction of force action in relation to the grain, the age and moisture content of the wood, the methods of cooking or steaming to impart plasticity, and other physical and mechanical properties of wood.

## References


1. **Білей П.В.** Теоретичні основи теплової обробки і сушіння деревини. (Монографія). – Коломия: Вік, 2005. – 364 с.
2. **Буглай Б.М., Гончаров Н.А.** Технология изделий из древесины. Учебник для вузов.– М.: Лесн. пром-сть, 1985. – 408 с.
3. **Gayda S.V.** A problem of wood raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2007, 33:55-63. (in Ukr.).
4. **Gayda S.V.** Research of concentration of operations is in modern furniture Productsion // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2007, 33:73-79. (in Ukr.).
5. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2008, 34:55-68. (in Ukr.).
6. **Gayda S.V.** Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood / Forestry, Forest, Paper and Woodworking Industry, 2008, 34:68-79. (in Ukr.).
7. **Gayda S.V.** Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2009, 35:63-83.
8. **Gayda S.V., Maksymiv V.M.** From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. – Lviv: 2010, 36:57-77.
9. **Gayda S.V.** A comparative analysis of physical-and mechanical parameters of variously-designed Glued Boards made of post-consumer Recovered Wood / Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2010, 36:81-91.
10. **Gayda S.V.** Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:238-244. (in Ukr.).
11. **Gayda S.V.** Comparative analysis of bending particularities for various post-consumer wood species and age categories // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:84-88. (in Ukr.).
12. **Gayda S.V., Voronovich V.V.** Investigation of the features of bending of post-consumer wood // Proceedings of the Conference, Mari State University, – 2011, 190-192 (in Russian).
13. **Gayda S.V.** The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. – Lviv: UNFU. – 2009, 19.14:72-89. (in Ukr.).



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## Фізико-механічна модель деформації деревини в процесах гнуття і пресування


Встановлено, що в процесі гнуття будь-якого тіла в межах пружних деформацій виникають нормальні до поперечного перерізу напруження: розтягу на випуклій поверхні і стиску на ввігнутій стороні. Оскільки величина нормальних напружень змінюється по перерізу, то виникають напруження сколювання, які стараються зсунути одні шари деталей відносно інших. Для підвищення здатності деревини до гнуття застосовують гідротермічну обробку: проварювання в гарячій воді або пропарювання. Така обробка робить деревину більш пластичною. Пресування засноване на силовій дії на деревину з використанням її пластичних властивостей. Пресують деревину для отримання: декоративних деталей в меблевій промисловості; матеріалів, які заміняють кольорові метали в машинобудуванні; ізоляційних матеріалів в електротехнічній промисловості. Деревина піддається пресуванню легше поперек волокон після гідротермічної обробки, яка підвищує її пластичність. Деревина стає більш пластичною за вологості біля 30 % і підвищеною температурою – до 160 °С.



**Ключові слова:** гнуття, пресування, теплова обробка, нагрівання, масивна деревина.

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# THE INVESTIGATION OF PHYSICAL AND MECHANICAL PROPERTIES OF WOOD PARTICLEBOARDS MADE FROM POST-CONSUMER WOOD

It is found that post-consumer wood (PCW) is as yet non utilized resource of wood waste that is suitable for manufacturing wood particleboards (WPB). It is found that graded chips from PCW (solid wood) of categories I and II are characterized by a standard fraction content (no less than 80 %) and meet the requirements for chips, PS GOST 15815-83. The shreds from clean: PCW when obtained on the standard equipment similar to that which is used for processing primary raw material do not differ essentially by geometrical configuration, size as well as fraction composition from shreds obtained from conventional wood. The high anisotropy factor of the wood particles gives grounds to expect high strength values for WPB made from PCW.

Investigated was the influence of the PCW and binder contents in each of the layers on physical and mechanical properties of three-layer particleboards: bending strength, tensile strength perpendicular to plane, and thickness swelling. Obtained were adequate mathematical models of dependence of WPB physical and mechanical properties on the PCW contents in each layer and the binder.

Production techniques for PCW-containing three-layer particleboards were developed. It was established that optimal production conditions for standard quality panels (DSTU 10632:2009) should correspond to: for panels of PA type (13 MPa) – PCW content in the core and the face layers of the panels may amount to up to 60 % with the average glue consumption of 11.5 %; for panels of PB type (11.5 MPa) – PCW content may amount to 100 % in the core, and 80 to 100 % in the face layers with glue consumption of 7 to 8 % in the core and 10 to 11 % in the face layers. The resulting effect of using PCW in WPB manufacture was estimated for Swisspan Ltd. enterprise, which lies in the fact that, due to PCW utilization, conventional wood expenditures are reduced by 9.4 %.

**Keywords:** wood, post-consumer wood, wood particleboard, chips, shreds, fractional composition analysis, physical and mechanical properties of panels, bending strength, tensile strength perpendicular to plane, thickness swelling, eco-economic effect.

**Topicality of the subject matter.** Large-scale cutting down of forests and the resulting environmental impacts, wood resource scarcity – all these force the woodworking industry to seek for alternative sources of raw material. The prospective resource that could be used as the raw material base for wood particleboard manufacture, is PCW [1]. This category of wood waste has been making successfully a sort of «career» over the last several decades, especially in West European countries. PCW includes all kinds of wooden material that is available at the end of its use as a wooden product. Such wood mainly comprises demolition wood, packaging material, used furniture [2].

PCW may contain fire retardant material, wood preservatives, paints, varnishes, glues, artificial films, metal, and even glass (windows) [3].

Because of its very different composition, the presence of various kinds of impurity as well as the lack of appropriate machines for its conversion into valuable raw material, the industries of many countries do not always display great interest in this promising source of wood raw material. That is why, PCW, like other industrial wood waste is mainly landfilled. Millions of tons of wood waste have accumulated on the long-standing refuse dumps [4]. The amount of the accumulated waste is too large to be naturally decomposed [5-10].

Thus, the present study is devoted to solving the problem which is important and pressing both for industry and the environment: replenishment of the raw material base.

**The aim of the paper.** The present scientific work is aimed at developing resource-saving technology and scientifically based recommendations concerning utilization of PCW to manufacture WPB.

**The object of study.** Development of resource-saving production methods for the use of PCW to manufacture wood-based panels.

**The subject of study.** Regular effects of technological parameters on the quality of PCW-containing WPB.

**Methods of study.** A number of methods were used in the study, namely, experiments, measuring and comparison. The wood particles from conventional wood and PCW were obtained by way of cutting and chipping. The test specimens of panels from PCW were made by way of flat pressing in the hydraulic press. In order to reduce the number of systematic errors during the experiments, the method of randomization was used. During the determination of wood particles from green wood and PCW, the following research methods were applied: physical research methods to determine fractional composition of the particle, the particles moisture content, density, and thickness swelling; mechanical methods to determine the bending strength and tensile strength perpendicular to plane. The experimental data were processed by method of statistical analysis. Also, a comparison was made between the panels made from PCW and the panels made from conventional wood to check the conformity to the standards [11-16].

**Scientific novelty of the findings.** On the basis of the experimental results obtained, the feasibility of PCW utilization for manufacturing flat-pressed particleboards with adequate physical and mechanical qualities was substantiated.

The optimal ratio of the components of the chips-glue furnish with the addition of PCW was developed, which ensures the production of P-A type of WPB according to DSTU 10632:2009 [11]. Regression dependences were obtained for bending strength, tensile strength perpendicular to plane, thickness swelling versus PCW content in the face layers and the core, various glue consumption as well as pressing parameters (temperature, pressing time, and pressure); these can be used for calculating technological parameters of particleboard manufacture.

**The technique for obtaining wood particles from PCW.** During the studies, demolition wood was used as raw material (Fig. 1), this wood was not dissimilar in outward appearance to primary wood, although it was about 40 years old [7].

The raw material was chipped into small particles at the enterprise of “Hemmel-Ukraine” company. The chipping was done on the mobile RM-800.4 chipper. The RM-800.4 chipper is fitted with a 30 kWatt electric motor which allows the use of the machine under condition of the enterprise or nearby a source of electric power. This type of chipper is designed for chipping wood waste into chips of 10 sm long, 10 to 25 mm wide, 3 to 5 mm thick. The diameter of the cutter disk (which is fitted with ant jamming system) amounts to 795 mm, the arrangement of disks is favourable for optimal feed of wood, and also it reduces the disk wear. The speed of disk rotation is 1000 rpm, the output of the equipment of this type is about 10 to 15 $m^3$/hour.

The resulting chips were further converted into shreds (Fig. 2) in the RM 800.7 shredder. The plant is equipped with a dosing bin from which the material is fed through the charging opening into the mill. The grinding is executed due to the high speed of the core rotation – 1480 rpm. The ground material is then sifted through the screen the mesh openings of the which are 10×10 mm, this determining the output fraction size. This type of machine ensures the finest possible grinding of chips to the size of 0 to 10 mm owing to its cutters the number of which is 40 pcs. The productivity of such machine is 8 $m^3$ per hour. The plant is driven by a 30 kWatt electric motor. The

moisture content of the wood particles prior to chipping amounted to 12 %. The wood particles obtained are first subjected to drying and screening, then they are moved further for forming various layers of mat. The drying operation was performed in the drying oven to reach the oven-dry weight at the initial temperature of 200ºC. The screening operation was performed on the laboratory-type screen where the wood particles were separated into two fractions: core particles and particles for forming face layers.

*Fig. 1. Post-consumer wood*

*Fig. 2. Chips obtained from PCW*

**Comparative analysis of chips.** Depending on the factor of cutting and the degree of its effect, the process of wood chipping is characterized by the quality of chips obtained and the operating parameters of chipping. The shape of PCW particles should be characterized above all qualitatively (pin-shaped, twisted, cube-shaped, fibrous particles) rather than quantitatively (PCW species, density, bulk density, size distribution curve, etc). There are methods of screen analysis for measuring sample particle size and calculation of arithmetical mean length, width and thickness. However, in actual practice, the methods of qualitative estimate of wood particles are dominant.

The parameters that provide quantitative characteristics (particles size, their ratio, specific surface, “ends area”) are not controlled accurately and are not related to each other, the methods of measuring them do not allow for accurate quantitative values that could be used to calculate composite material composition and to develop techniques for manufacturing panels with prescribed qualities with a minimum of glue and energy consumption. Therefore, the critical characteristics of PCW particles are the chips fractional size and composition. In order to compare the geometry and fractional composition of chips, we used primary conventional wood and PCW (Fig. 3, Fig. 4).

In order to measure the moisture content of wood particles, a s 200 hygrometer was used. The principle of the instrument operation is based on measuring dielectric constant and loss tangent of the controlled material in the electromagnetic field created by ring contacts of the instrument transducer. The depth of the field penetration into the interior of the material is 30 to 50 mm, which allows the moisture content of the study material to be measured without impairing its outward appearance.

The selection of measurement mode according to wood species or the type of material is done by means of momentary pressing the button, this is followed by sequential appearance of symbols H1,…H6, E1,…E5 on the liquid crystal indicator. On selection the mode of measurement one should wait until the automatic tuning is completed outdoors and then to continue working. The measurement mode is selected by using the tabulated data in the instrument certificate or on the back cover of the instrument.

**Fig. 3. Primary wood chips**

**Fig. 4. PCW chips**

The process of moisture content measurement consists in direct touching the study material with the three-ring contacts (Fig. 5).

Geometrical dimensions of the chips were determined by measuring separate particles thickness, width and length along the wood fiber direction. The number of measurements in the study amounted to no less than 100. The average size of chips was determined from the data obtained by measuring a definite number of particles. The measurements of geometrical dimensions indicates the quality of a separate chip, while the fractional analysis allows for determining the shares of coarse, standard, and fine fractions in the total weight.

The dimensions of chip fractional form: –/10; 10/7; 7/5; 5/3; 3/2; 2/1; 1/0,5; 0,5/0. The sifting of the chip batch was done by means of a 71-GP screen analyzer (Fig. 6).

***Fig. 5 Moisture content of PCW chips***

***Fig. 6. Determination of PCW chip fraction***

In the process of the fractionating screen analysis, the weight of each traction was determined by means of analytical balance to an accuracy of 0,01 g. The amount of each fraction is expressed as a percentage to the total weight of the batch. The number of particles for the fractionating analysis was taken so that the whole quantity of the selected particles was used with nothing left over. When selecting a portion of particles from a large quantity, the method of quartering was used since finer fraction in the bulk of par-

ticles tends to fall down. The selected portion of particles weighing as much as 50 to 100 g was sifted by means of screen analyzer, fitted with a set of round screen 200 mm in diameter, five of them possessed circular holes of diameter 10, 7, 5, 3, 2, 1 mm, and two ones possessed wire net with meshes measuring 0,5×0,5 and 0,25×0,25 mm.

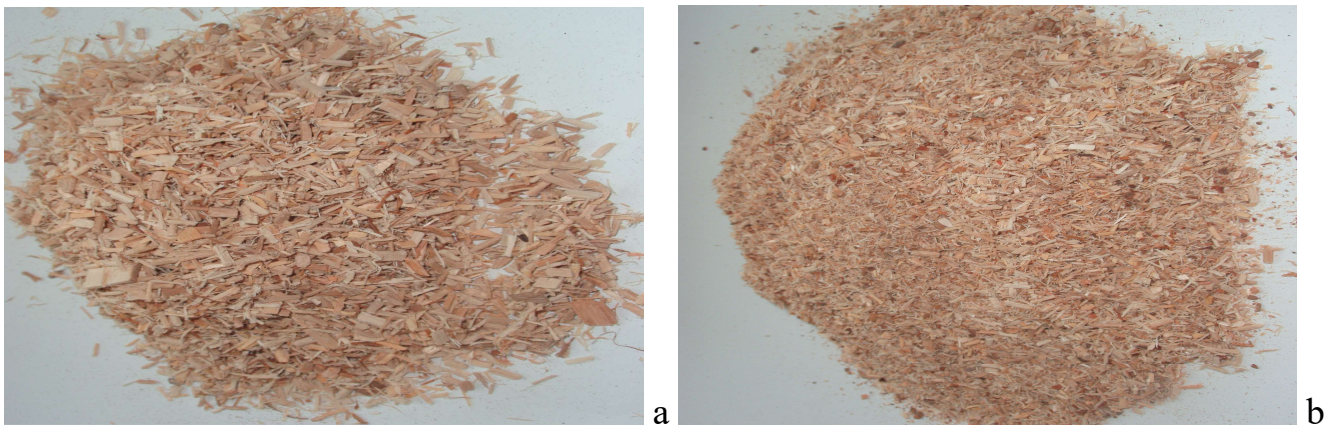
On a 5-minute sifting, the material obtained was divided into eight fractions (Fig.7): –/10, 10/7, 7/5, 5/3, 3/2, 2/1, 1/0.5, 0.5/0. The results of the study of wood particles geometric dimensions show that fraction content practically does not vary with respect to wood particles from conventional wood (Table 1), although the amount of fine fraction (fraction content 1/0) is two time as much.

**Table 1.Comparative analysis of chip fractional composition**

| Type of wood | Fraction content, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | –/10 | 10/7 | 7/5 | 5/3 | 3/2 | 2/1 | 1/0,5 | 0,5/0 |
| Conventional wood | 0,5 | 2,3 | 2,6 | 32,1 | 28,9 | 20,6 | 10,6 | 2,4 |
| PCW | 0,4 | 1,0 | 1,8 | 28,3 | 25,2 | 19,3 | 19,1 | 4,9 |

The length, width, and thickness of particle fractions 2/1, 1/0.5, 0.5/0 were determined by way of measuring the particles projection magnified by means of slide projector. The statistical processing of the comparative experiments results was done according to GOST 16483.0-89.

The mean dimensions of chips in a batch involved were determined on the basis of the mean dimensions of an individual chip (length, width, and thickness) in each fraction.



a b

***Fig. 7. Wood particles for:*** *a) the core b) the face layers*

The impact of structural and technological parameters on panels' strength values is demonstrated through the mediation of dimension less geometrical characteristic of chip formation: degree of contact area. It was foundthat the degree of contact area is dependent on the size of wood particles, namely, the values of bending strength and tensile strength perpendicular to plane as chip fractional composition changes from fraction 5/3 to fraction 10/7. Wood particles from conventional wood and PCW do not have a significant deviation of the fractional content.

One of the main factors which is absent in PCW is bark. The values of physical and mechanical properties of bark are considerably lower than those of sound wood. The bonding between bark particles as well as between bark particles and wood particles is less strong than that between purely wood particles. Therefore, the addition of bark particles into chips lowers the strength of panels made from conventional wood.

**The study of the process of manufacturing particleboard from PCW.** ***Selection of the evaluation criterion.*** WPB as a structural material is characterized by a number of factors on the basis of which we can discuss the material quality and its suitability for a specific purpose. In turn, physical and mechanical qualities of particleboard are influenced to a great extent by the very structure of the panel, the formation of which is also influenced by a number of factors: the raw material and the equipment used as well as production conditions. The majority of panel parameters are regulated by relevant standards.

When determining the evaluation criteria for the resulting panels, it is necessary to take into account both technological and economic components of the process. This is dictated by the fact that panels made from PCW must meet the requirements for panels of P-A DSTU 10632:2009 [11] while their production cost should not exceed the production cost of the panels made from trunk wood. An important characteristic of physical and mechanical properties of particleboard is their bending strength which is responsible for panel optimal applications. By means of this parameter, it is possible to determine the optimum manufacturing conditions, PCW chip content and the least binder consumption in order to obtain high-quality panels (strength, roughness and toxicity).

The above said considered, bending strength is taken as the criterion for evaluation of the results of panel manufacture. Besides, there are other parameters which can serve as criteria for the evaluation of panel quality. These are tensile strength perpendicular to plane and thickness swelling.

**Investigation planning.** Since the process of manufacturing and testing WPB made from PCW was investigated under laboratory conditions, multifactor planning was applied: full-factorial plan. During the experiments, the following factors were taken as variable factors: the contents of the binder and PCW particles both in the core and the face layers. The values for PCW chips content for each layer varied from 20 to 100 % – the rest were standard technological chips; the binder content in each layer was within the average consumption norm ranging from 7 to 16 %.

The levels of factors and factor-change intervals as well as planning matrix in coded values (CV) and actual values (AV) are given in Tables 2-3.

**Table. 2. The levels of factors-change interval under investigation**

| № | Name | Value denotation | | Change in interval | Factor level | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | AV | CV | | lower | | datum level | | upper | |
| | | | | | AV | CV | AV | CV | AV | CV |
| 1 | PCW content in the core, % | $P_c$ | $X_1$ | 40 | 20 | -1 | 60 | 0 | 100 | 1 |
| 2 | PCW content in the face layers, % | $P_f$ | $X_2$ | 40 | 20 | -1 | 60 | 0 | 100 | 1 |
| 3 | binder content, % | K | $X_3$ | 4,5 | 7 | -1 | 11,5 | 0 | 16 | 1 |

For the purpose of reducing the number of systematic errors, the method of randomization was applied which allowed for establishing random sequence of the experiments conducting. The following factors characteristic of panel manufacture, were noted at the fixed levels: density – 700 kg/m; specific pressure – 2.5 MPa; press temperature – 200 °C; pressing time – 0.35 min/mm moistures content of the particles for the core – 2 %; moistures content for the face layers – 4 %; the ratio of the layers – 50/50; three-layer panels of 16 mm thick.

**Table. 3. Matrix of planning of full-factorial plan – $2^3$**

| № | Values of input factors in the experiment | | | | | | Serial number | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | AV | | | CV | | | | | | | |
| | $P_c$ | $P_f$ | K | $x_1$ | $x_2$ | $x_3$ | 1 | 2 | 3 | 4 | 5 |
| 1 | 20 | 20 | 7 | -1 | -1 | -1 | 20 | 2 | 5 | 13 | 23 |
| 2 | 100 | 20 | 7 | 1 | -1 | -1 | 35 | 6 | 16 | 32 | 9 |
| 3 | 20 | 100 | 7 | -1 | 1 | -1 | 28 | 19 | 22 | 10 | 11 |
| 4 | 100 | 100 | 7 | 1 | 1 | -1 | 1 | 33 | 24 | 4 | 12 |
| 5 | 20 | 20 | 16 | -1 | -1 | 1 | 36 | 25 | 8 | 7 | 26 |
| 6 | 100 | 20 | 16 | 1 | -1 | 1 | 15 | 40 | 34 | 31 | 38 |
| 7 | 20 | 100 | 16 | -1 | 1 | 1 | 14 | 17 | 27 | 18 | 29 |
| 8 | 100 | 100 | 16 | 1 | 1 | 1 | 37 | 39 | 3 | 21 | 30 |

**Board manufacturing process.** The process of fabricating specimens consists of four steps: preparation of the binder, resin-treatment of the particles, mat formation (Fig. 8) and pressing. A UF-WT-15 urea-formaldehyde resin was the basis for the binder, the resin concentration was reduced by adding water: 64.7 to 62 % for the core and up to 58 % for the face layers. The resulting board is presented in Fig. 9.

***Fig. 8. Forming of mat***

***Fig. 9. Particleboard pressed from PCW***

Thus prepared adhesive solution was used for the cores and the face layers. In the process of particleboard manufacture, ammonium chloride (20 % solution) is used in the fallowing amounts: for the core – 1.5 %, for the face layers – 0.5 %, which was mixed with the resin prior to applying it the chips.

The calculation of required proportions of wood particles, resin, curing agent for obtaining specimens of required density as well as the relationship between face layers, the core, and the particleboard thickness, was performed according to the recommendations of the enterprise. The blending of the wood particles, binder and curing agent was done by hand and in a slow manner with the help of electric drill. The chips and the binder were fed in a three-step process by using a compressor to achieve a uniform soak of the wood particles. The process of blending was done separately for each layer according to the prepared quantity of batch.

The forming of mats was also done by hand. The following accessories were used: two metal sheets (pallets), wooden box of 0.5×0.5 m, two metal stops of 0.016 m to control panel thickness. The forming of the panel was done in the wooden box by

even distribution of the wood particles on the pallet to form three layers in the 25:50:25 ration. The loss of resined chips made up no more then 7 %. The formed mat was pressed in the single-platen batch press into a panel all required parameters of pressing being observed in doing so. The temperature of the press platen was controlled by thermometer the error of which did not exceed 5 °C. The panel thickness was controlled by the stops the deviation of which made up ±0,05 mm from the preset thickness.

The press cycle $\tau_c$ consisted of: the time $\tau_{con}$ needed to charge the press, the time $\tau_{cl}$ needed for the platens to close up to the preset thickness, reaching the preset pressure, pressing time $\tau_p$ which includes compression time $\tau_{com}$ as well as the time $\tau_o$ needed to lower the pressure and open the press. The press time $\tau_{pr}$ is counted from the moment of reaching a maximum of preset pressure to the moment when the press platens begin to open.

In order to ensure a maximum of strength, to reduce warpage ("spring up") and free formaldehyde release, the panels were conditioned separately from one another. This is accounted for by the fact that the elevated temperatures that may persist in closed stacks of panels up to 5 days (this is especially true for the central part of the stack) cause the destruction of cured glue, which, in turn, results in deterioration of the outward appearance of particleboards, increasing the content of free formaldehyde as well as degradation of their physical and mechanical properties.

**Physical and mechanical testing.** The determination of the WPB physical and mechanical properties was carried out 5 days after the panels were pressed. The PCW-made panels were cut on the circular saw bench to size specified for specimens testing according to GOST 10633-78; GOST 10634-88; GOST 10635-88; GOST 10636-90 [12-15].

The tests for the bending strength $\delta_b$ and the tensile strength perpendicular to plane $\delta_t$ were conducted on the WOLPERT machine according to GOST 7855-84 (Fig. 10, a). The motion speed of the load-carrying head – 60 mm/min, the scale division – 1 kg/sm$^2$; deviation from the actual value made up – 1%.


***Fig. 10. Determination of test specimens' strength:***
*a) bending strength* *b) thickness swelling*

To conduct the tensile strength perpendicular to plane test, wooden plates were sticked to the test specimens on both sides; thus prepared specimens were subjected to loading for 24 hours. The specimens for determining thickness swelling were placed in water medium of this plant (Fig. 10, b) which houses 40 pieces of specimens, they stood vertically for 24 hours at the constant temperature of 20±1 °C. The swellings can be calculated by the phormula [12]:

$$\Delta h=(h_1-h)/h*100\ \% \quad (1)$$

where: h is the panel's dimensions (length, width, thickness) after conditioning, m; $h_1$ is the panel's dimensions after water soaking or keeping in humid environment, m.

**The results of experimental investigation.** The data obtained from physical and mechanical testing of pilot PCW-containing particleboard for bending strength, tensile strength perpendicular to plane, and thickness swelling are shown in Tables 4-6.

**Table 4. The results of testing PCW-containing WPB for beading strength**

| No | Factor value in the experiment | | | | | | Bending strength measurements, MPa | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | actual values | | | coaded values | | | | | | | |
| | $P_c$ | $P_f$ | K | $x_1$ | $x_2$ | $x_3$ | $y_{1j}$ | $y_{2j}$ | $y_{3j}$ | $y_{4j}$ | $y_{5j}$ |
| 1 | 20 | 20 | 7 | -1 | -1 | -1 | 13,20 | 13,00 | 12,90 | 13,10 | 12,80 |
| 2 | 100 | 20 | 7 | 1 | -1 | -1 | 12,70 | 13,20 | 12,80 | 13,20 | 12,80 |
| 3 | 20 | 100 | 7 | -1 | 1 | -1 | 12,31 | 12,50 | 12,30 | 12,24 | 12,10 |
| 4 | 100 | 100 | 7 | 1 | 1 | -1 | 11,80 | 11,20 | 12,75 | 12,00 | 12,24 |
| 5 | 20 | 20 | 16 | -1 | -1 | 1 | 19,50 | 19,80 | 19,10 | 19,90 | 19,20 |
| 6 | 100 | 20 | 16 | 1 | -1 | 1 | 19,23 | 19,32 | 19,28 | 19,21 | 19,11 |
| 7 | 20 | 100 | 16 | -1 | 1 | 1 | 18,13 | 18,22 | 18,40 | 18,20 | 18,30 |
| 8 | 100 | 100 | 16 | 1 | 1 | 1 | 18,80 | 17,50 | 17,40 | 18,10 | 18,20 |

**Table 5. The results of testing PCW-containing WPB for beading strength perpendicular to plane**

| No | Factor value in the experiment | | | | | | Tensile strength perpehdicular to plane measurement, MPa | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | actual values | | | coaded values | | | | | | | |
| | $P_c$ | $P_f$ | K | $x_1$ | $x_2$ | $x_3$ | $y_{1j}$ | $y_{2j}$ | $y_{3j}$ | $y_{4j}$ | $y_{5j}$ |
| 1 | 20 | 20 | 7 | -1 | -1 | -1 | 0,489 | 0,51 | 0,502 | 0,505 | 0,495 |
| 2 | 100 | 20 | 7 | 1 | -1 | -1 | 0,459 | 0,465 | 0,457 | 0,395 | 0,457 |
| 3 | 20 | 100 | 7 | -1 | 1 | -1 | 0,421 | 0,431 | 0,428 | 0,442 | 0,436 |
| 4 | 100 | 100 | 7 | 1 | 1 | -1 | 0,326 | 0,345 | 0,344 | 0,341 | 0,346 |
| 5 | 20 | 20 | 16 | -1 | -1 | 1 | 0,658 | 0,658 | 0,647 | 0,645 | 0,642 |
| 6 | 100 | 20 | 16 | 1 | -1 | 1 | 0,611 | 0,595 | 0,601 | 0,611 | 0,589 |
| 7 | 20 | 100 | 16 | -1 | 1 | 1 | 0,605 | 0,623 | 0,621 | 0,643 | 0,637 |
| 8 | 100 | 100 | 16 | 1 | 1 | 1 | 0,585 | 0,592 | 0,567 | 0,549 | 0,558 |

**Table 6. The results of testing PCW-containing WPB for thickness swelling**

| No | Factor value in the experiment | | | | | | Thickness swelling measurements, % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | actual values | | | actual values | | | | | | | |
| | $P_c$ | $P_f$ | K | $x_1$ | $x_2$ | $x_3$ | $y_{1j}$ | $y_{2j}$ | $y_{3j}$ | $y_{4j}$ | $y_{5j}$ |
| 1 | 20 | 20 | 7 | -1 | -1 | -1 | 17,29 | 17,13 | 16,97 | 17,51 | 17,34 |
| 2 | 100 | 20 | 7 | 1 | -1 | -1 | 17,12 | 16,94 | 16,89 | 16,87 | 17,20 |
| 3 | 20 | 100 | 7 | -1 | 1 | -1 | 16,24 | 17,69 | 16,97 | 16,47 | 16,87 |
| 4 | 100 | 100 | 7 | 1 | 1 | -1 | 16,81 | 16,95 | 16,93 | 16,56 | 16,84 |
| 5 | 20 | 20 | 16 | -1 | -1 | 1 | 14,89 | 14,47 | 14,28 | 14,75 | 14,33 |
| 6 | 100 | 20 | 16 | 1 | -1 | 1 | 14,29 | 14,21 | 14,58 | 14,17 | 14,55 |
| 7 | 20 | 100 | 16 | -1 | 1 | 1 | 14,08 | 14,08 | 14,00 | 14,15 | 14,21 |
| 8 | 100 | 100 | 16 | 1 | 1 | 1 | 13,94 | 13,88 | 13,96 | 13,79 | 13,95 |

On calculating mean values and sample variances, the check on variance homogeneity in the experiments by means of Kohren G-criterion indicated that all the variances were homogeneous. By using similar procedure, the variances of reproducibility of measurements of physical and mechanical properties were calculated: for bending strength: $\mathbf{S_{re}^2}$ = 0.112; for tensile strength perpendicular to plane: $\mathbf{S_{re}^2}$ = 0.0003; for

swelling: $S_{re}^2$ = 0.0646. The root-mean-square deviation for calculated coefficients of regression equations made up: for bend strength: $S\{b_i\}$ = 0.05; for tensile strength perpendicular to plane: $S\{b_i\}$ = 0.0025; for thickness swelling: $S\{b_i\}$ = 0.0402.

On checking regression equations coefficients for meaningfulness and establishing their confidence intervals, the calculations showed that the regression equations coefficients are meaningful except for eight ones (Tables 7-9), but we do not ignore them in consideration of system approach.

**Table 7. Checking regression equation coefficients for meaningfulness, their confidence intervals for bending strength**

| Coefficient | Coefficient value | $t(q,f_y)S\{b_i\}$ | Conclusion | Confidence interval boundaries | |
|---|---|---|---|---|---|
| | | | | $b_i-t_{tab}*S\{b_i\}$ | $b_i+t_{tab}*S\{b_i\}$ |
| $b_o$ | 15,651 | 0,11 | Meaningful | 15,54 | 15,76 |
| $b_1$ | -0,119 | 0,11 | Meaningful | -0,22 | 0,01 |
| $b_2$ | -0,517 | 0,11 | Meaningful | -0,62 | -0,41 |
| $b_3$ | 3,094 | 0,11 | Meaningful | 2,99 | 3,20 |
| $b_{12}$ | -0,026 | 0,11 | No meaningful | -0,13 | 0,08 |
| $b_{13}$ | -0,021 | 0,11 | No meaningful | -0,13 | 0,09 |
| $b_{23}$ | -0,104 | 0,11 | No meaningful | -0,21 | 0,00 |

**Table 8. Checking regression equation coefficients for meaningfulness, their confidence intervals for tensile strength perpendicular to plane**

| Coefficient | Coefficient value | $t(q,f_y)S\{b_i\}$ | Conclusion | Confidence interval boundaries | |
|---|---|---|---|---|---|
| | | | | $b_i-t_{tab}*S\{b_i\}$ | $b_i+t_{tab}*S\{b_i\}$ |
| $b_o$ | 0,521 | 0,01 | Meaningful | 0,52 | 0,53 |
| $b_1$ | -0,031 | 0,01 | Meaningful | -0,04 | -0,03 |
| $b_2$ | -0,029 | 0,01 | Meaningful | -0,03 | -0,02 |
| $b_3$ | 0,091 | 0,01 | Meaningful | 0,09 | 0,10 |
| $b_{12}$ | -0,006 | 0,01 | No meaningful | -0,01 | 0,01 |
| $b_{13}$ | 0,005 | 0,01 | No meaningful | 0,00 | 0,01 |
| $b_{23}$ | 0,015 | 0,01 | Meaningful | 0,01 | 0,02 |

**Table 9. Checking regression equation coefficients for meaningfulness, their confidence intervals for thickness swelling**

| Coefficient | Coefficient value | $t(q,f_y)S\{b_i\}$ | Conclusion | Confidence interval boundaries | |
|---|---|---|---|---|---|
| | | | | $b_i-t_{tab}*S\{b_i\}$ | $b_i+t_{tab}*S\{b_i\}$ |
| $b_o$ | 15,604 | 0,08 | Meaningful | 15,52 | 15,69 |
| $b_1$ | -0,082 | 0,08 | Meaningful | -0,16 | 0,01 |
| $b_2$ | -0,185 | 0,08 | Meaningful | -0,27 | -0,10 |
| $b_3$ | -1,376 | 0,08 | Meaningful | -1,46 | -1,29 |
| $b_{12}$ | 0,025 | 0,08 | No meaningful | -0,06 | 0,11 |
| $b_{13}$ | -0,014 | 0,08 | No meaningful | -0,10 | 0,07 |
| $b_{23}$ | -0,039 | 0,08 | No meaningful | -0,12 | 0,04 |

The regression equation coefficients obtained as a result of the full-factorial plan realization possess a clean physical meaning. The coefficient $\mathbf{b_o}$ is equal to the output value and of all factors are fixed at the basic level. The sigh of the coefficient $\mathbf{b_i}$ points to the nature of corresponding factor influence: if $\mathbf{b_i>0}$, the output value tends to increase with an increase of the factor $\mathbf{x_i}$ value, and vice versa. The absolute value of the regression coefficient in the model points to the extent to which the response function is affected by the corresponding factor. The higher absolute value of the coefficient, the stronger influence on the output parameter change has the factor to which the given coefficient corresponds.

Thus, the extent of the factors effect on the output values can be compared by means of linear regression model and so revealing the most important factors.

In order to evaluate the ability of the obtained models to describe output values with the same degree of accuracy as the experimental results, the mathematical models were checked for their adequacy by Fisher F-criterion by means of which the variances of adequacy $\mathbf{S_{ad}^2}$ and reproducibility $\mathbf{S_{re}^2}$ are compared.

The calculated adequacy variances for physical and mechanical properties of PCW-containing particleboards made up: for bend strength $\mathbf{S_{ad}^2}$ = 0.040; for tensile strength perpendicular to plane $\mathbf{S_{ad}^2}$ = 0.00059; for thickness swelling $\mathbf{S_{ad}^2}$ = 0.0306.

The calculated values for Fisher criterion for physical and mechanical properties of PCW-containing particleboards made up: for bending strength $\mathbf{F_{cal}}$ = 2.821; for tensile strength perpendicular to plane $\mathbf{F_{cal}}$ = 0.437; for thickness swelling $\mathbf{F_{cal}}$ = 0.512.

The tabulated value for Fisher criterion is equal to 250. By comparing the calculated values for Fisher criteria with the tabulated ones, we can see that the inequality $\mathbf{F_{cal} < F_{tab}}$ is accomplished for physical and mechanical properties of PCW-containing particleboards. That is, the mathematical models obtained are considered adequate and can be used to describe objects. Thus, the calculations done made it possible to obtain the following regression equations of the full-factorial plan with actual factor values for physical and mechanical properties.

$$\sigma_b = 8{,}145 - 0{,}00043 \cdot P_c - 0{,}0053 \cdot P_f + 0{,}729 \cdot K + 0{,}000016 \cdot P_c \cdot P_f + 0{,}00011 \cdot P_c \cdot K - 0{,}00057 \cdot P_f \cdot K;$$

$$\sigma_t = 0{,}442 - 0{,}00088 \cdot P_c - 0{,}0015 \cdot P_f + 0{,}0136 \cdot K + 0{,}0000035 \cdot P_c \cdot P_f + 0{,}000028 \cdot P_c \cdot K - 0{,}000083 \cdot P_f \cdot K;$$

$$\Delta h = 19{,}37 - 0{,}0021 \cdot P_c - 0{,}0031 \cdot P_f + 0{,}288 \cdot K + 0{,}000016 \cdot P_c \cdot P_f + 0{,}000076 \cdot P_c \cdot K - 0{,}00022 \cdot P_f \cdot K;$$

The data of regression equations describe the physical and mechanical properties of PCW-containing particleboards and allow output values to be calculated for any point of the experiment zone provided that $\mathbf{x_i = [-1;+1]}$, where $\mathbf{i = 1, k.}$

Since the influence of factors and their interaction on the response function is best analyzed graphically, three groups of diagrams were constructed by regression equations: the relationship between output value (bending strength, tensile strength, and thickness swelling) and PCW content both in the face layers and core at the constant values for the binder at the minimum, mean, and maximum levels (Fig. 11-13).

Graphical representation of the relationships obtained allows for revealing character of variable factors influence on the properties of the resulting particleboards, since the full-factorial plan was realized here, all the dependences have linear character. As is seen from the diagrams, the PCW content in the particleboards behaves equally at different binder content levels that is the bending strength is decreasing within from 19.469 to 12.030 MPa range, the tensile strength is decreasing within the range of 0.646 to 0.344 MPa, while the thickness swelling is also decreasing from 17.22 to 13.93 %. The diagrams also show that the lines do not run parallel to one another, and the angle of their slope varies as certain variable factors change. This points to the fact that the influence of factors interaction is just as significant as the influence of the individual factors.

Our study has demonstrated that for a given 700 kg/m$^3$ particleboard density and an average glue consumption of 11.5 %, an increase in PCW chips content in the face layers from 20 to 100 % results in decreased bending strength by 6 % while the same increase in PCW content in the core makes up only 1 %. The use of a 100 % PCW particles content and glue consumption of 11.5 % both in the core and the face layers results in the bending strength of 15 MPa, which is 8 % smaller than for the case of a 20 % PCW content. The conditions being the same, it was found that the tensile strength is

essentially influenced by the increased content of PCW particles in the core an decrease in the tensile strength amounted to 9 %. The physical and mechanical properties of the particleboard are most influenced by the glue content. With increasing the glue content, the strength is also increasing (by 30 %) while the thickness swelling is decreasing (by 15 %). The reason for this lies in the fact that there is a greater amount of adhesive spread per unit surface area of the wood particles, and this glue film prevents the water from penetration into the interior of wood particles. Also, due to the absence of bark from PCW particles, there is an increase in the strength by 2 to 5 % in the PCW-containing particleboard compared to panels made from conventional wood.

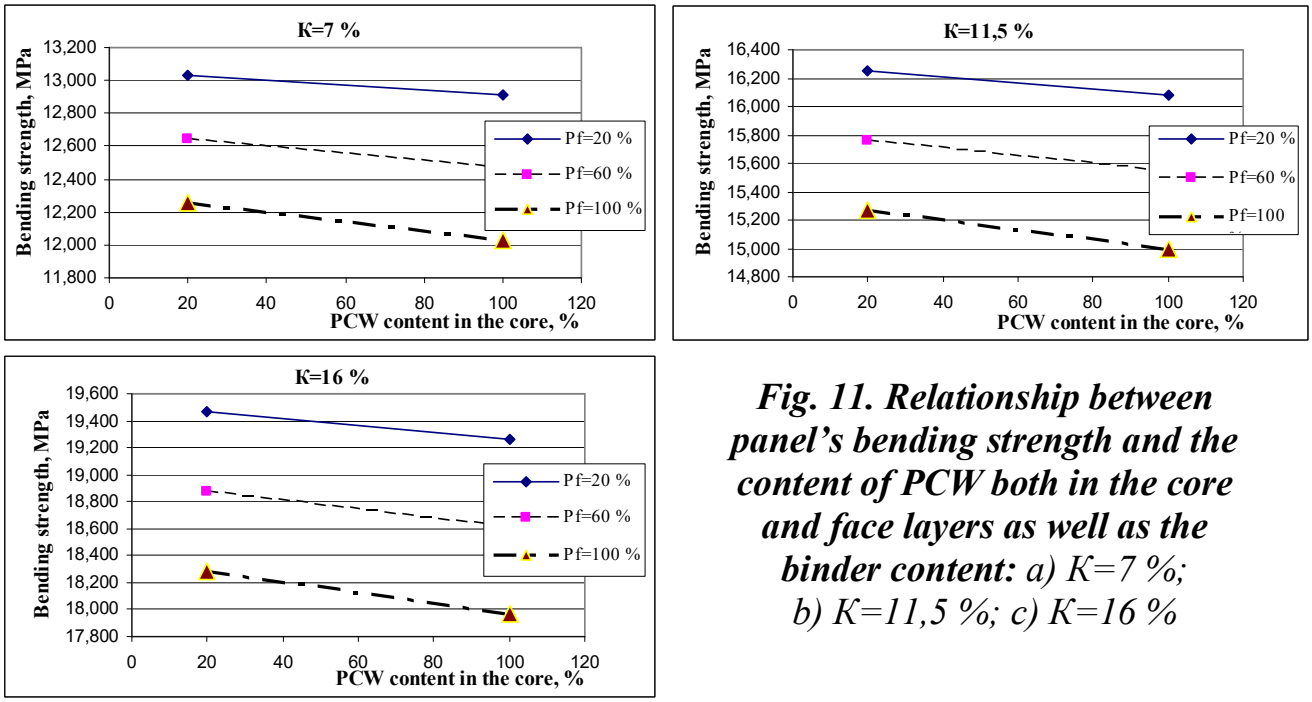



***Fig. 11. Relationship between panel's bending strength and the content of PCW both in the core and face layers as well as the binder content:*** *a) K=7 %; b) K=11,5 %; c) K=16 %*

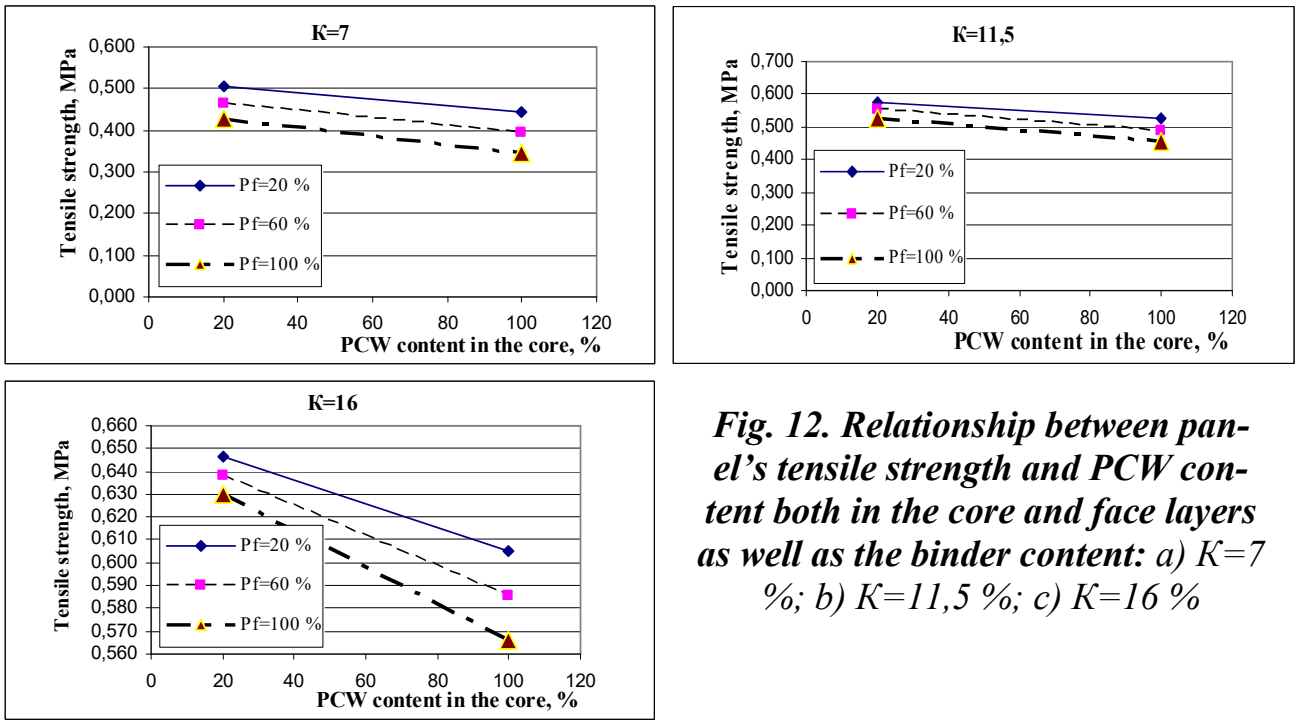
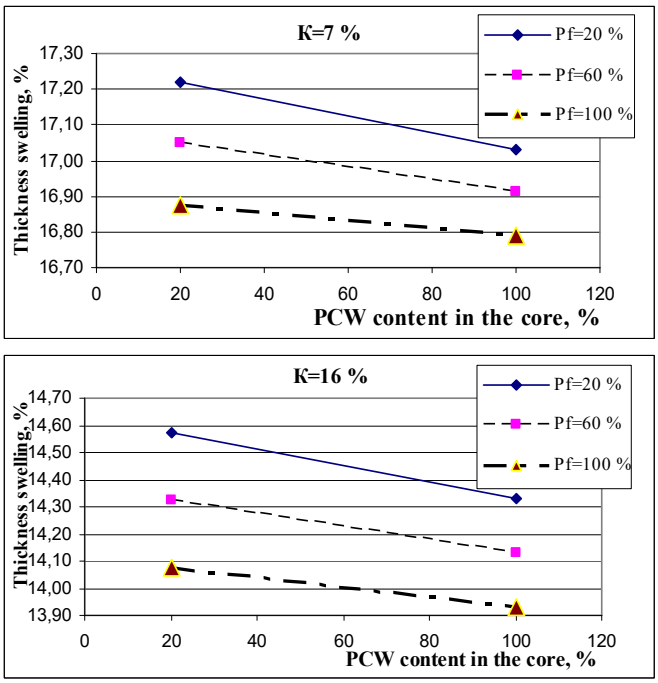



***Fig. 12. Relationship between panel's tensile strength and PCW content both in the core and face layers as well as the binder content:*** *a) K=7 %; b) K=11,5 %; c) K=16 %*

Thus, WPB that has a 60 % PCW particles content and the glue consumption of 11.5 % produces composite materials that meet the requirements for the P-A type of particleboards according to DSTU 10632:2009 «Wood particleboards. Specifications» [11].



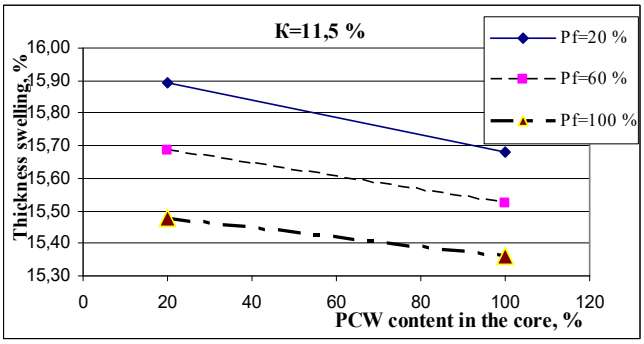







***Fig. 13. Relationship between panel's strength at swelling and PCW content both in the core and the face layers as well as the binder content:*** *a) K=7 %; b) K=11,5 %; c) K=16 %*

## Conclusions and recommendations:

1. It has been found that PCW of categories I and II (30 to 50 % of the total volume) is an important wood resource and can essentially expand the raw material base for WPB manufacture.

2. Processing procedures for WPB manufacturing have been developed with the use of PCW as raw material. By using Full-factorial, Plan-$2^3$, a multyfactor experiment was conducted and the planning matrix has been elaborated. It has been found that graded PCW chips (solid wood) of categories I and II are characterized by a standard fraction (no less than 80 %) and meet the requirements for chips PS GOST 15815-83 [16]. The chips prepared from clean PCW, provided that they are obtained on the standard equipment, do not differ essentially by geometry, shape, and fraction composition from those obtained from conventional wood. Investigations have been carried out to assess the influence of PCW and binder contents in each of the layers on physical and mechanical properties of tree-layer particleboard: bending strength and tensile strength perpendicular to plane, and thickness swelling.

3. Adequate mathematical models were obtained for physical-and-mechanical parameters of WPB versus the PCW and binder contents in each later. It has been revealed that for a given 700 kg/m$^3$ density, the boards made from PCW, depending on the PCW category (quality) and glue consumption, hat a 8 to 10 % decrease in the bending strength and 12 to 32 % decrease in tensile strength compared to boards made from conventional wood, they also meet the requirements for P-A type of particleboards, DSTU 10632:2009 «Wood particleboards. Specification». It has been revealed that thickness swelling for PCW-made particleboards with an average glue consumption of 11.5 % is 3 to 5 % less compared to boards made from conventional wood, also, the glue consumption increase from 7 to 16 % results in the thickness swelling reduction by 18 % under the same manufacturing process conditions. This is accounted for by the fact that PCW particles lose bound moisture after long-lasting usage (20 to 40 years) that is, they become more porous and this, in turn, is responsible for greater amount of these particles per unit volume, thus promoting their greater compactness, which prevents the penetration of moisture. It has been found that the optimum conditions for manufacturing boards of standard quality (DSTU 10632:2009) are as follows: for P-A type (13 MPa) – PCW particles content in the core and the face layers may amount to 60 % with an average glue consumption of 11.5 %; for P-B type of boards (11.5 MPa) – PCW particles content in the core amounts to 100 % and 80 to 100 % in the face layers with glue consumption in the core being 7 to 8 % and 10 to 11 % in the face layers.

4. Estimated was the effect of introducing the results obtained in practice at the Swisspan Ltd. Enterprise, which lies in the fact that the use of PCW in the particleboard manufacture leads' to the reduction of costs for conventional wood by 9.4 % [10].

## References

1. **Gayda S.V.** (1999). Проблеми та перспективи роботизації меблевої промисловості [Problems and prospects of robotics in the furniture industry]. Scientific Bulletin of UNFU 9.5:192-195. (in Ukrainian).

2. **Gayda S.V.** (2000). Визначення стійкості та міцності вертикальних стінок корпусних меблевих виробів [Determination of stability and strength of vertical walls of case furniture products]. Scientific Bulletin of UNFU 10.3:127-129. (in Ukrainian).

3. **Gayda S.V.** (2000). Особливості розрахунку корпусних виробів на міцність [Peculiarities of strength calculation of hull products]. Scientific Bulletin of UNFU 10.2:150-154. (in Ukrainian).

4. **Gayda S.V.** (2000): Матеріали для виготовлення виробів з деревини / Materials for the Productsion of wood Productss. Lviv: BMC. – 160 p. (in Ukr.).

5. **Gayda S.V.** (2001): Раціональне конструювання виробів з деревини / Rational constructing of wood Productss. Lviv: BMC. – 93 p. (in Ukr.).

6. **Gayda S.V.** (2002). Особливості та перспективи роботизації меблевої промисловості України [Peculiarities and prospects of robotization of the furniture industry of Ukraine]. Scientific Bulletin of UNFU 12.5:38-40. (in Ukrainian).

7. **Gayda S.V.** (2003). Гнучкі виробничі модулі для виготовлення ґратчастих меблевих виробів [Flexible production modules for the production of lattice furniture products]. Scientific Bulletin of UNFU 13.2:120-122. (in Ukrainian).

8. **Gayda S.V.** (2004). Інтегровані технології меблевого виробництва [Integrated technologies of furniture production]. Scientific Bulletin of UNFU 14.4:118-121. (in Ukrainian).

9. **Gayda S.V.** (2007): A problem of wood raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2007, pub. 33. – P. 55-63. (in Ukr.).

10. **Gayda S.V.** (2008): Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2008, pub. 34. – P. 68-80. (in Ukr.).

11. **Gayda S.V.** (2009): Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2009, pub. 35. – P. 63-84.

12. **Gayda S.V.** (2009): The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. Collection of scientific and technical works. – Lviv: UNFU. – 2009, pub. 19.14. – P. 72-89. (in Ukr.).

13. **Gayda S.V.** (2010). A comparative analysis of physical and mechanical parameters of variously designed glued boards made of post-consumer recovered wood. Forestry, Forest, Paper and Woodworking Industry 36:81-91.

14. **Gayda S.V.** (2010): From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2010, pub. 36. – P. 57-77.

15. **Gayda S.V.** (2011): Ecological and economic aspects of the wood reuse // Ecological, Economic and Social Problems of Ineffective and Unsustainable Methods of Forest Management and Illegal Logging in Ukraine. Conference Proceedings, Lviv, Dec. 2-3. 2010. – Lviv: Green Cross Society, Liga Press. – 2011. – P. 147-151. (in Ukr.).

16. **Gayda S.V.** (2011): Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2011, pub. 37.1. – P. 238-244. (in Ukr.).

17. **Gayda S.V.** (2011): The analysis of economic efficiency of post-consumer wood use for particleboard manufacture for LLC Swisspan Limited // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2011, pub. 37.2. – P. 129-136.

18. **Gayda S.V., Kshyvetskyy B.Ya.** (1999). Техніко-економічні характеристики деревообробної фабрики майбутнього [Technical and economic characteristics of the woodworking factory of the future]. Scientific Bulletin of UNFU 9.3:83-85. (in Ukrainian).

19. **Gayda S.V., Maksymiv V.M.** (2010). From recycled post-consumer wood towards prime quality particleboard / Ліс. госп-во, ліс., папер. та деревооб. пром-сть // міжвід. наук.-техн. зб. – Львів: НЛТУ України. – 2010, вип. 36. – С. 57-77.

20. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** (2008): Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2008, pub. 34. – P. 55-68. (in Ukr.).

21. **Vintoniv I.S., Sopushynskyy I.M., Teishinger A.** (2007). *Derevynoznavstvo* [Wood-science]. – Lviv: Apriori. – 312 p., (in Ukrainian).

22. **Voytovych I.G.** (2010). *Osnovi tekhnologiï virobiv z derevini* [The basic technology of wood]. – Textbook. –Lviv: Kraine andeljat. – 304 p. (in Ukrainian).

23. **Gayda S.V., Nikityuk L.O.** (1998). До питання застосування екстрагованої деревини для плитного виробництв [On the issue of using extracted wood for slab production]. Scientific Bulletin of UNFU 8:75-77. (in Ukrainian).

24. **Koval L.I., Gayda S.V.** (2011): Recycling waste from sawing MDF // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2011, pub. 37.1. – P. 49-53. (in Ukr.).

25. **Voronovich V.V., Gayda S.V.** (2011): Comparative analysis of bending particularities for various post-consumer wood species and age categories // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2011, pub. 37.1. – P. 84-88. (in Ukr.).

26. **ГОСТ 10633-78.** Плиты древесностружечные. Общие правила подготовки и проведения физико-механических испытаний. – М.: Изд. стандартов. – 1981. – 4 с.

27. **ГОСТ 10634-88.** Плиты древесностружечные. Методы определения физических свойств. –М.: Изд. стандартов. – 1990. – 4 с.

28. **ГОСТ 10635-88.** Плиты древесностружечные. Методы определения предела прочности и модуля упругости при изгибе. – М.: Изд. стандартов. – 1990. – 4 с.

29. **ГОСТ 10636-90.** Плиты древесностружечные. Методы определения предела прочности при растяжении перпендикулярно пласти плиты. – М.: Изд. стандартов. – 1992. – 4 с.

30. **ГОСТ 15815-83.** Щепа технологическая. – М.: Изд. стандартов. – 1985. – 16 с.

31. **ДСТУ 10632:2009.** Плити деревинно-стружкові. Технічні умови. – [Чинний від 2010-04-01]. – К.: Держспоживстандарт України. – 2009. – 17 с.

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## Дослідження фізико-механічних властивостей деревинно-стружкових плит із вживаної деревини

Встановлено, що вживана деревина (ВЖД) є незадіяним ресурсом деревних відходів, придатним для виробництва деревинно-стружкових плит (ДСП). Встановлено, що відсортована тріска з ВЖД (масивної деревини) першої та другої категорії характеризується вмістом кондиційної фракції і відповідає вимогам до тріски ПС згідно ГОСТ 15815-83. Стружка із чистої ВЖД, якщо вона одержана на аналогічному обладнанні, яке використовують для перероблення первинної сировини, за геометричними розмірами, формою та фракційним складом не суттєво відрізняється від стружки з традиційної деревини. Досліджено вплив вмісту ВЖД у кожному із шарів та в'яжучого на фізико-механічні властивості тришарових ДСП – міцність при статичному згині, розтягу перпендикулярно до площини плити та набрякання за товщиною.

Графічна інтерпретація одержаних залежностей дозволила обґрунтувати характер впливу змінних факторів на властивості одержаних плит. Оскільки був реалізований повнофакторний план, то всі залежності носять лінійний характер. З графіків добре видно, що вміст ВЖД в діапазоні 20-100 % в ДСП веде себе однаково при різному вмісті в'яжучого. Зокрема, при витраті клею 11,5 % міцність при статичному згині спадає з 16,25 до 15,0 МПа., при розтягу перпендикулярно до площини плити – від 0,575 до 0,455 МПа, а набрякання за товщиною – з 15,90 до 15,36 %. На графічних залежностях також чітко видно, що лінії між собою не є паралельними і кут їх нахилу зі зміною певних змінних факторів різний. Це свідчить про те, що вплив взаємодій факторів є також значним у порівнянні з впливом самих факторів.

Дослідженнями встановлено, що при щільності плити 700 м$^3$/кг та середній витраті клею 11,5 %, збільшення вмісту стружки із ВЖД у зовнішніх шарах від 20 до 100 % зменшує міцність при статичному згині на 6 %, а таке ж збільшення у внутрішньому шарі приводить до зменшення тільки на 1 %. При 100 % виготовленні плит із ВЖД та середній витраті клею для двох шарів 11,5 % міцність при статичному згині становила 15 МПа, що на 8 % менше, ніж при наповненні деревостружкового килиму на 20 % стружкою із ВЖД. Аналогічно при тих же умовах виявлено, що на міцність при розтягу перпендикулярно до площини плити суттєво вливає збільшення вмісту стружки ВЖД (з 20 до 100 %) у внутрішньому шарі, ніж у зовнішніх. Величина міцності зменшується на 9 %, але відповідає вимогам до плит марки П-А за ДСТУ 10632:2009.

Найбільший вплив на фізико-механічні показники плит має вміст клею. При збільшенні вмісту клею міцніть збільшується, а набрякання за товщиною зменшується. Це зумовлено більшим покриванням деревних частинок плівкою клею, яка перешкоджає проникнення води у се-

редину деревних частинок, а також відсутністю кори в складі ВЖД, яка негативно впливає на процеси склеювання, тобто на фізико-механічні властивості плит ДСП. Крім того, експериментально доведено, що контрольні експериментальні зразки із 100 % використанням традиційної сировини при однаковій витраті клею, мали менші фізико-механічні властивості, ніж плити із 20 % наповненням із ВЖД: межа міцності останніх при статичному згині була більшою на 15 %, при розтягу перпендикулярно до площини плити також більшою на 22 %, а набрякання за товщиною було меншим на 17 %. По-перше, зростання показників у діапазоні вмісту стружки з ВЖД від 0 % до 20 % зумовлене збільшеним вмістом (у два рази) дрібної фракції (1/0) у стружці з ВЖД (табл. 1); по-друге, дрібні частинки заповнюють пустоти і тим самим збільшують площу склеювання, що впливає на показники міцності; по-третє, при добавлянні її до зовнішніх шарів – покращується структура поверхні (шорсткість) одержаних плит, а при добавлянні до внутрішнього шару – неплоска стружка (скручена, кубикоподібна) частково розташовується не в площині плити, а під кутом, що зумовлює більший опір розтягу перпендикулярно площині плити, оскільки на це вливають не тільки клеєві шви, але й волокна деревини.

Таким чином, експериментально встановлено, що при вмісті 60 % ВЖД та середній витраті клею 11,5 % у ДСП, одержані композиційні матеріали відповідають вимогам до плит марки П-А згідно ДСТУ 10632:2009 «Плити деревинно-стружкові. Технічні умови».

## Висновки та рекомендації:

1. Встановлено, що ВЖД першої та другої категорій (30-50 % від усього об'єму збирання) є значним ресурсом деревини та суттєвим додатком до основної сировини у виробництві ДСП.

2. Розроблено технологію виготовлення ДСП з використанням в якості сировини ВЖД. За використання ПФП-$2^3$ проведено багатофакторний експеримент та реалізовано матрицю планувань згідно методики досліджень. Встановлено, що відсортована тріска з ВЖД (масивної деревини) першої та другої категорії характеризується вмістом кондиційної фракції (не менше 80 %) і відповідає вимогам до тріски ПС за ГОСТ 15815-83. Стружка із чистої ВЖД, якщо вона одержана на аналогічному обладнанні, яке використовують для перероблення первинної сировини, за геометричними розмірами, формою та фракційним складом не суттєво відрізняється від стружки з традиційної деревини. Збільшений вміст дрібної фракції (1/0) у стружці з ВЖД у діапазоні вмісту стружки з ВЖД від 0 % до 20 % у плиті зумовлює зростання показників фізико-механічних показників ДСП. Коефіцієнт анізотропії стружок дає можливість передбачати показники міцності плит із ВЖД. 6. Одержано адекватні математичні моделі залежності фізико-механічних показників ДСП від вмісту ВЖД і в'яжучого в кожному із шарів. Встановлено, що при щільності 700 кг/м$^3$ плити із ВЖД (100 %) мали, в залежності від вмісту ВЖД (20-100 %) та витрати клею, на 8-10 % меншу міцність при статичному згині та на 12-32 % меншу – при розтягу перпендикулярно до площини плити, ніж із вмістом ВЖД 20 %, і, при цьому, відповідали вимогам до плит марки П-А ДСТУ 10632:2009 «Плити деревинно-стружкові. Технічні умови».

7. З'ясовано, що набрякання за товщиною для ДСП із ВЖД (100 % ) при середній витраті клею 11,5 % є на 3-5 % меншим, ніж у плит із 20 % вмістом ВЖД, крім того при зміні кількості клею від 7 % до 16 % для тих же умов виготовлення набрякання за товщиною зменшується на 18 %. Причина – деревні частинки із ВЖД після тривалого використання (20-40 років) втрачають зв'язану вологу, тобто є більш пористими, а ще зумовлює їх більшу кількість в одиниці об'єму, що сприяє підвищеному ущільненню їх між собою, тобто зменшує проникнення вологи.

8. Встановлено, що раціональним умовами виготовлення плит стандартної якості (ДСТУ 10632:2009) відповідають: для плит марки П-А (13 МПа) – вміст ВЖД у плиті у внутрішньому та зовнішніх шарах може становити до 60 % при середній витраті клею 11,5 %; для плит марки П-Б (11,5 МПа) – вміст ВЖД у внутрішньому до 100 % та зовнішніх шарах може становити 80-100 % при витраті клею у внутрішньому шарі – 7-8 % та зовнішніх шарах – 10-11 %.

9. Розраховано ефективність від впровадження отриманих результатів виготовлення ДСП з використанням ВЖД на підприємстві ТОВ «Свиспан Лімітед», які полягають в тому, що завдяки залученню ВЖД, зменшаться витрати на традиційну деревину на 9,4 %.

**Ключові слова:** деревина, вживана деревина, деревинно-стружкова плита, тріска, стружка, аналіз фракційного складу, фізико-механічні властивості плит, міцність при статичному згині, міцність при розтягу перпендикулярно площині, набрякання, еколого-економічна ефективність.

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# MOUNTAIN FORESTRY POLICY AND STRATEGIES IN RESPONSE TO CLIMATE CHANGE CHALLENGES: THE CASE OF THE UKRAINIAN CARPATHIANS

This article describes the contribution of mountain forests to climate change adaptation and mitigation. The Ukrainian Carpathians are used as a case study to analyse the challenges for forests and forestry under global climate change impacts. Policies and strategic measures should be combined to work efficiently towards a forest sector response to climate change challenges and take into account the specific features of mountain territories. Results of a field study on the attitudes of forest-dependent communities towards implementation of climate policy and sustainable forest management (SFM) strategies are presented.

**Keywords:** climate change, carbon sequestration, mountain policy, adaptation and mitigation strategies, Ukrainian Carpathians.

**Introduction.** Mountains are among the region's most sensitive to climate change. Mountain areas have a marked and complex topography and so their climates vary considerably over short distances. Thus, climate change projections are difficult to make. In the mountains temperature changes with altitude; therefore, the impacts of a warmer climate are different for different elevations. But mountains themselves play a major role in influencing regional and global climates (Kohler & Maselli, 2008).

Climate changes are going to transform the mountain forest, both directly through the effect of the climate on vegetation and indirectly through changes in the socio-economic context and the demand for forest services **(**Courbaud et al 2011). European mountainous areas, in contrast to many other mountain regions of the world, have high population densities and consequently many potentially conflicting demands on the environment. Forest ecosystems are key elements in the land-use matrix of these areas, providing a variety of goods and services to human livelihoods. Expected climate change could place these ecosystem services at risk (Maroschek et al 2009). This article discusses the potential forest policies and strategies towards climate change impacts adaptation and mitigation in mountain conditions. .

**Ukrainian Carpathian forests and potential impacts of climate change.** The Ukrainian Carpathians cover 4 % of the territory of Ukraine, but they produce one-third of the forest resources of this country, with forests in this region occupying 53.5 % of the land (MoE, 2003; Gamor, 2003). Forests are primarily publicly owned and managed by state, with the forestland divided into protected forests managed for environmental needs and forests managed for commercial purposes. There are 70 species of trees, 110 species of bushes and 1500 species of herbaceous plants in the Ukrainian Carpathians.This is (outside Russia) Europe's last great wilderness area that supports large carnivores, with over half of the continent's population of bears, wolves and lynx.

The Carpathians belong to the country's most unique and biologically diverse region in terms of species richness, the presence of rare and endemic species, and their unique habitats. The mountain range hosts natural and semi-natural forests and many species, including Europe's largest populations of brown bears, wolves and imperial eagles, a globally threatened species. Human influence on forest ecosystems in the Carpa-

thians, during the 18-20th century, has led to deforestation and forest degradation that still challenges the environment and landscape's stability. In 1956-1960, annual volumes of timber harvest exceeded the average increment by almost double (Gensiruk, 2002). This resulted in the decrease of water-protective functions of the Carpathian forests, intensified erosion processes, decreased endurance of spruce stands and contributed to the occurrence of floods and windfalls in the mountains (Nijnik et al 2009).

Today the tendency is to decrease logging in the Carpathians. However, these forests are threatened by poor timber harvesting practices, over-harvesting in the past, overgrazing, and other anthropogenic pressures resulting in the decline of forest health and vitality, soil erosion, destruction of native vegetation, degradation of wildlife habitat and the subsequent loss of biodiversity. Moreover, forest use in recent years has been strongly driven by short-term financial considerations, whereas long-term economic reasoning to sustain and enlarge forest resources and ecosystem services have often been overlooked (Nijnik et al 2009). Environmental requirements and the needs of local people urgently call for new forest management practices that would put emphasis on the sustainable, multipurpose use of forests, and their proper integration with other land uses into an overall landscape context.

Previous studies of plant communities' reactions to climate warming in the Carpathians have shown that it is expressed differently, depending on the vertical location of the forest zone, biological peculiarities of dominant plant species, and the nature of their interrelrelationss and directions of succession processes.

In practical forestry plan there are two aspects of environmental impacts of climate change on forestry – positive and negative impacts. The positive environmental impacts include: possible spontaneous spreading in mountainous areas of hemophilic tree species and increase of biodiversity; possibility of raising high-altitude zone of oak forests and oak-beech forests with Sessile Oak and enriching their species composition (chestnut, Eastern Black walnut, Eastern White Pine et al); increase in growth and productivity of tree species stands due to increased vegetation season; reduction in the frequency of fruiting of trees and increase of these species' fruitfulness; penetration in the mountainous areas of thermophilic species of fauna and an increase of its biodiversity; improvement of ecological processes in the soils of mountainous areas; accelerattion of spontaneous renaturalization of the upper border of forests and improvement in their water regulation and soil protection functions; expansion of recreational potential of mountain forests and an increase in their social value. Adverse environmental effects include: increase in rainfall, water content of mountain rivers and increased risk of floods; increased frequency of dangerous natural phenomena – avalanches, erosion processes, landslides, mud flows, karsts creation processes; freguency of winds and increased risk of forest windfalls; increased danger of forest fires; favourable conditions for forest pests and microflora, which can be dangerous for forests (Stoyko 2009). Thus, climate change poses great risks, but also some opportunities.

The relatively long rotations currently required under Ukrainian forest code offer significant carbon storage benefits. On-going research suggests that structurally complex temperate forests, such as old-growth Carpathian beech and mixed conifer-hardwood forests, store very large amounts of carbon. Conservation of these systems can contribute to climate change mitigation efforts. Active silvicultural management for structurally complex, high biomass forests offers additional benefits (Keeton and Crow

2009). The Carpathian forests may offer a low-cost opportunity for carbon sequestration. The region has the potential to contribute to global carbon uptake, primarily because of the availability of land suitable for tree planting, good forest-growing conditions and relatively low afforestation costs.

**Attitudes of forest-dependent communities to climate policy and SFM strategy implementation.** The contribution of forests to climate change mitigation and adaptation depends on the sustainability of forest management. An adaptive approach to SFM will be essential due to the anticipated effects of climate change on Carpathian flora and fauna. Market based incentives for sustainable forestry, such as green certification and carbon markets, provide significant opportunities for the Carpathian region (Keeton and Crow 2009). The consideration of forest sector stakeholders' attitudes is important in the context of implementing a SFM paradigm and developing strategic responses from the sector towards climate change. The motivational context of the decision making process in the forest sector is not a sufficiently developed research field. Only a few studies have focused directly on the forest sector stakeholders' attitudes, perceptions, and values. Most of these studies have been carried out in the United States, Canada, Sweden, Finland, Germany, Great Britain, and Austria. These studies focus mainly on forest landowners' motivations, and less on the forestry professionals' values, attitudes and perceptions that regulate their professional behavior.

Based on a survey among all forest stakeholders in the rural mountain areas of Ukrainian Carpathians initiated by atelier "Ecological Economics and Sustainable Forest Management" (Lviv, 2007) we can sketch a generalized picture of attitudes towards SFM principles. In total, 735 respondents were involved in the survey, with 74 % of respondents working for the public sector; 10 % – for the private sector (non forest related); 8 % – private entrepreneurs who specialize in harvesting, wood processing or non-wood forest products processing; 4 % – temporarily unemployed; and 1 % – students. The results of this study identify a low level of awareness of SFM ideas.

Only 12.7 % gave an answer that they are know precisely what the term "sustainable forest management" means. The main share of respondents (63.5 %) knows the general terms concerning this concept, and 23.8 % of respondents never heard of it. The authors suggest that there is a lack of understanding of the forest mangers' attitudes towards the SFM paradigm. This lack of specific knowledge is a serious obstacle for new forest policy implementation. More than half of respondents recognized an economic (57.3 %) or an ecological role (60.7 %) of forests as a very important factor of regional development. A considerable portion of respondents recognized both the economic and ecological role of forests as important – 33.2 % and 38.1 % as very important.

In the context of the growing importance of climate change issues, respondents were asked whether climate change will become a globally significant factor for forestry in the near future. A positive response to this question was given by 81 % of respondents indicating a high level of public awareness of climate change and the realization that it is a challenge for the forestry sector.

While 81 % of respondents stressed the need for further reforms in the forest sector, the rest of respondents are satisfied with the present state of this sector and the current model of its development. The high percent of respondents with positive attitudes towards the process of the sector reforming (81 %) confirms the favourable preconditions for further reforms and its potential support. First of all, respondents would like to

reform the system of financing (45 % of respondents), the system of governance (33 % of respondents), and economic relations (20 % of respondents). 13 % of respondents emphasize that it is necessary to reform human resource policy. 18 % of respondents called for regulatory and legal framework reforming. Respondents stressed the importance of the following activities of adaptation in the course of reforms: improvement of felling system, tree-planting system, decision making in forest management, harvesting technique, development of forest roads network, and improvement of nature protected areas. In the opinion of 29 % of respondents an improvement in Ukraine's economic situation is a precondition for the successful development of forestry.

Currently, forest certification is one of the most popular successful instruments of forest policy, but only 48.4 % of respondents have a positive attitude towards forest certification, 45.9 % have a neutral attitude, and 5.7 % are rather afraid of negative consequences of certification. The results show that positive attitudes towards the development of reforms in the forest sector are determined by the cumulative influence of such factors as level of knowledge about SFM, level of knowledge about the Forest Act and educational level (48.7 %). Increased knowledge of SFM on one level (it is framed from statement "first time I hear about it" to statement "I know very well what SFM is") correlates to the respondent's positive attitude towards reforms in the sector (53.4 %).

An increase of knowledge about the content of the Forest Act correlates with the respondents' positive attitude towards reforms on 7.3 %, and correspondingly, an increase of educational level will increase it by 7.0 %.

The way to sustainability in remote mountain areas lies through internalization of the most important externalities in using and managing ecosystem services (Nijnik 2002), and through the changing of institutions towards capacity building and active involvement of local communities in decision-making and sustainable policy implementation. The development of highlands requires mountain-focused strategies, based on mountain-specific research and on deep local and traditional knowledge of the problems related to remote rural areas.

**Silvicultural and management approaches towards climate change mitigation and adaptation.** Typical forest management practices that increase carbon sequestration include: activities which increase forest cover (afforestation, reforestation and forest restoration); increase of tree cover through agroforestry, urban forestry and tree planting in rural landscapes; enhancement of forest carbon stocks (in both biomass and soils) and sequestration capacity through the modification of forestry management practices. Some forest management activities can conserve carbon stocks in forests.

Possible silvicultural and management approaches that conserve carbon stocks include: sustainable silvicultural practices; integrated fire management; management of forest health and vitality; management of forest biodiversity; and management and extension of protected areas. Different forest management adaptation actions can be implemented at different levels of governance, inside or ouside the forest sector (Table 1).

The following climate change adaptation strategies are recommended for the forest sector by the Ukrainian Scientific-Research Institute for Forest Management and Agricultural Melioration (Buksha 2010):

*Forestry-based:* The improvement of forest protection methods against wildfires; the application of more advanced measures aimed at forest protection against pests; the introduction of resistant tree species, supporting the highest productivity in the forecast climatic conditions.

*Scientific and technical*: The development of forest condition diagnostic and forecasting methods; modernization of the information support system to be used for making forest management decisions; the development of the scientific and methodological knowledge base for forest protection against pests and diseases; increased scientific research work dealing with the selection and introduction of new forest species, resistant to the forecast climate changes.

*Legal and administrative*: Development of regulatory mechanisms that establish the principles of the forest management system and which take into account the effects of climate change; increase in forest user responsibility for forest preservation; creation of a stimulus system aimed at supporting forest management activity directed at supporting social and ecologically important functions of the forests.

*Financial*: Establishment of insurance and reserve funds to be used for compensation of forest management activity expenses under the conditions of climate change.

**Table 1. Types of forest management adaptation actions, by implementing actor (based on Carina & Keskitalo 2011, with changes)**

| Measures at higher governance level | Measures at forest management level | Large-scale measures | Additional options |
|---|---|---|---|
| Improved monitoring and research<br>Policy advice and information<br>Improved disturbance management<br>Legal basis for land allocation for afforestation<br>Market based instruments (Payments for ecosystem services etc).<br>Community engagement in forest carbon projects | Changes in forest structure to increase diversity<br>Change tree species/diversity (increase resistance)<br>Regeneration/ natural regeneration<br>Rotation length<br>General (improved) management/ silviculture<br>Increase afforestation and reforestation<br>Continuous cover/ selective cutting in a system of close to nature forestry<br>Forest management in response to additional stresses<br>Protection of forests from illegal logging<br>Fire protection<br>Pest management<br>Watershed management | Forest management on ecosystem level<br>Nature protected area in forests<br>Forest carbon accounting<br>Longer term (genetic variety)<br>Infrastructure and transport | Passive adaptation<br>Other |

The transition plan for the Carpathian forests needs to be viewed as an adaptive management strategy, one that builds on experience a decade at a time. It needs to begin by explicitly testing a range of management prescriptions at the outset as a hedge against climate change impacts. It is impossible to specify what changes in the future climate regime must be anticipated, or even at what pace those changes may be experienced. Further, ecosystem and forest health and productivity effects may only become evident with long lags. Choices of species mixes suited to different soils or elevation belts will necessarily be tentative ones. More complete documentation and analysis of past climate regime changes in the Carpathians, as it may affect forests and water resources, would be most helpful (Irland and Kremenetska 2009).

In the strategy of forestry development in the Carpathians it is necessary to keep in mind both positive and negative consequences of global climate change impacts on forest formations that affect their dynamic trends. S. Stoyko concluded an analysis of potential impacts of climate change in Carpathian forests (Stoyko 2009) with the recommendation that an investigation of the Carpathian forest ecosystem's reaction to climate change is important not only in the overall ecological and biogeographical aspects,

but it is also needed for the development of a mountain forestry strategy, which must focus on forming stable plant communities in each of the elevation belts. In our opinion, this task of forming stable plant communities should be considered as part of the more comprehensive task of forming sustainable forest mountain ecosystems. It has become commonly accepted that a successful climate strategy should combine mitigation and adaptation. The accurate combination between adaptation and mitigation that can best address climate change is still an open question. The strategic complementarity between mitigation and adaptation implies also an economic trade-off. The framework which proposes to integrate mitigation, adaptation, and climate change residual damages into an optimisation model (Carraro et al 2010) can be further developed for specific sectors (forestry) and territories (mountains). It is necessary to promote synergy in planning and implementation of forestry mitigation and adaptation projects to derive maximum benefit to the global environment as well as to local communities or economies, for example by promoting adaptive forest management (McGinley & Finegan, 2003). It should also be taken into account that activities to address mitigation and adaptation in the forestry sector be planned and implemented locally (Nabuurs et al 2007).

**Policies, institutions and governance.** Unfortunately, at present Ukraine has no comprehensive study of adaptation to climate change impacts. At the time of this issue's publication, no attention has been paid to it at all. Therefore, to develop the necessary strategy of adaptation in Ukraine it is necessary to conduct a comprehensive scientific study on the likely effects of climate change, adaptation measures, and the cost of implementing these measures. Based on the relevant data, it is necessary to develop a National Action Plan on Adaptation to Climate Change and regional plans, including a plan for the Carpathian region. An assessment of the necessary costs for adaptation to climate change for different sectors is needed. It is important to explore the potential costs for insurance and other financial instruments that can be used for risk sharing. The government should have to intensify efforts to reduce the negative impact and the destructive consequences of floods in Western Ukraine and forest fires in the South of Ukraine as resulting from climate change and human activities. At the same time, except for measures of adaptation, it is necessary to introduce mitigation measures to reduce greenhouse gas emissions to prevent irreversible catastrophic changes to which society and the ecosystem will not be able to adapt.

In March 2008 a governmental decree regulating Green Investment Schemes (GIS) in Ukraine (Decree No. 221) was adopted. According to this decree, the government assigned the National Environmental Investment Agency (NEIA), which was established in May 2007, as the main institution for both JI and GIS management and for the country's compliance with the Kyoto Protocol. With regard to GIS, NEIA is responsible for negotiations with buyers as well as for the design of the GIS under the government's supervision. A specific GIS law embedded in the country's legal system was so far not seen as necessary; the AAU sales and revenue disbursement processes operate through governmental decisions. Each of Ukraine's AAUPAs specifies that the disbursement of funds is due prior to 2012, provides for an annual reporting and periodic site-visits and regulates details on international technical and financial inspection. There is no overall GIS architecture in Ukraine. The current domestic legislation (Law on State Budget), however, includes a clause that provides for the use of GIS funds only for projects directly leading to emissions reductions (Tuerk et al 2011).

At the Third Meeting of the Conference of the Parties (COP 3) to the Framework Convention on the Protection and Sustainable Development of the Carpathians (Bratislava, Slovakia, from 25-27 May 2011), environment ministers and experts from Central and Eastern Europe discussed sustainable development of the Carpathian mountain region, and adopted a protocol on sustainable forest management. The Protocol seeks to identify, protect and maintain or enlarge forest cover, as well as improve protective forest functions, such as preventing floods and landslides, water cycle regulation and carbon sequestration. Absolute annual volume of absorption of greenhouse gases in forestry at the national scale is proportional to the amount of emissions due to agricultural activities. In Ukraine, Joint Implementation Mechamism projects on afforestation are not carried out.The project on the creation of protective forest plantations on contaminated lands in Polissya, prepared with the assistance of the World Bank, was not implemented due to lack (at that time) of legislative and regulatory framework for the implementation of WB projects and an inadequate mechanism for carbon pricing.

The prospect of implementing these projects remains uncertain. During their preparation, the following key issues to be considered during implementation of such projects in Ukraine was revealed (Marchuk 2009):

- Forestry projects in the framework of the KyotoProtocol mechanisms may include only afforestation, improvement of measures for forest protection from fires and improvement of forestry practices to reduce greenhouse gas emissions.
- When considering the feasibility of launching a joint implementation project of afforestation it should be taken into account the fact that the first 4-5 years after the establishment of forest plantations the result of carbon sequestration are negative.
- Plantations that are established in accordance with the requirements of joint implementation projects need other planting and tending technologies which are not regulated by the existing forestry regulatory framework. They should be included in the existing regulations.
- During the launching of joint implementation projects, it is necessary for the recipient to prove the principle of subsidiarity, i.e. to prove the fact that without this project the proposed measures in this sector would not be carried out.
- One of the determining factors for successful implementation of such projects is the allocation of land under a forests targeted on "Kyoto Protocol " implementation.

During the last 20 years as a result of post-socialist reforms in agriculture a large-scale reforestation of abandoned land has occurred in the Carpathian region (Kummerle et al 2011). The hayfields and pastures are now the place of broad leaf trees of such species as *Betula sp., Alnus ,Incana, Salix* and shrubs are becoming a new forest cover. The young plantations are characterized by high growth energy and are highly productive and, starting from 3 – 5 years old, are actively involved in the absorption of carbon dioxide from the atmosphere. After 20-30 years, from the forestry point of view, reconstruction of such stands will be needed. This can be achieved by planting and sowing in cut corridors of rows of shade-resistant and valuable species (spruce, oak), or through conversion (especially of birch stands) to productive forests.

Agricultural lands are often covered first with such pioneer species as *Betula, Pinus, Alnus* and *Salix and Populus* (less favourable fortimber production).These species are fast-growing, undemanding to soil and hydrological conditions and dominate over more valuable for timber production – tree species. Gradually, under natural conditions these reforested areas may become semi-natural forests, but this process can take centuries.

Foresters can intervene in such processes through optimizing stand composition with the help of reconstructive cuttings or cuttings of reorganization. Such actions can

be carried out only after the conversion of land, which requires the legal transfer from agricultural lands to the forest fund or private property (Fig. 1).

Fig. 1 presents a version of the algorithm of transformed lands conversion in the region. Two ways of converting abandoned lands are considered: a) to the forests in private property; b) to the forest lands of neighboring forestry enterprises in public (state or communal) ownership. In both cases, after the transfer it is necessary to complete a full forest inventory of these areas, which will provide complete and accurate information for the needs of land use and forest planning and estimates of carbon absorption potential. Based on the information from the forest inventory, it is necessary to determine which viable plantations would most promote the growth of carbon fixation and correspond to the regional forest features. Depending on the existing tree species composition, through tending and thinning the desirable stand can be achieved, which will require additional expenses. One of the options is establishing energy plantations that periodically would give a positive economic effect (Soloviy & Ilkiv 2011).

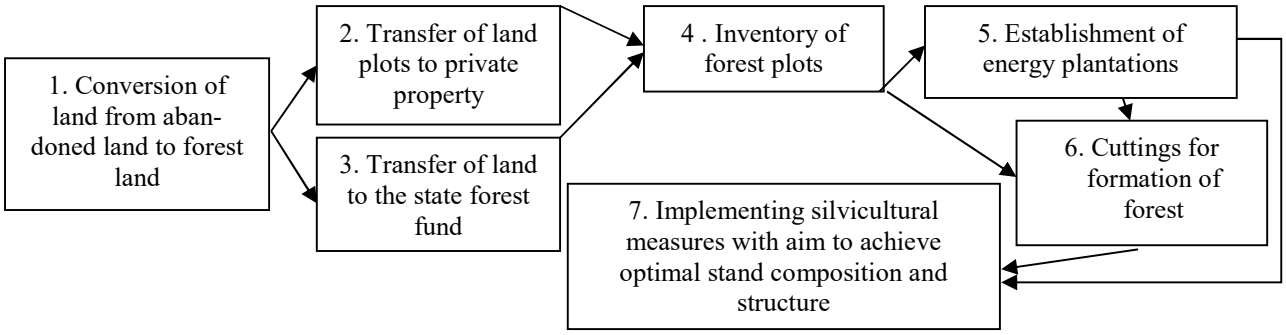


***Fig. 1. The scheme of abandoned land controlled conversion to forest land***

In both cases it will be necessary to gradually tend the forest using different types of planting materials of indigenous species, which will increase the resource potential of transformed lands. It is possible that these land transformations would be applied sequentially, not simultaneously. This primarily applies to devastated lands of various levels of degradation. On such lands, it will first be necessary to stimulate afforestation of the species that are suitable to energy plantations, and then, after the formation of more sustainable forest environment, they should be gradually replaced by more valuable indigenous forest species. Such a scenario would not only have a maximum ecological effect but also economic and social effects towards well-being of local communities.

**Conclusions.** Climate change mitigation and adaptation policy should be combined in an integrated policy framework for the forest sector. The mountain forest policy should cover both aspects of adaptation – adaptation of forest ecosystems and adaptation of mountain forest dependent communities. This means taking the ecosystem resilience, disaster risk reduction and flow of ecosystem services into account, as well as the social and economic aspects which shape local livelihoods and communities' well-being.

Strategies of forest management adaptation to climate change should be supported by appropriate policy tools. Policies will have to ensure flexibility for forest managers to respond adequately to the regional socio-economic conditions, the specific natural conditions of the forest site, to accommodate local knowledge and to consider the needs of local communities regarding the provision of multiple forest goods and services. These demands challenge the application of the traditional set of regulatory policy tools (command and control) and call for additional new models of forest governance based

on negotiations between all stakeholders. Study results call for enrichment and diversification of the mountain forest policy instrument set, first of all for diversification of the informational instruments by introducing new stimulating climate-friendly activities aimed at efficient communication, learning and trust building among the forestry professionals, local communities, authorities and business.

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## References

1. **Benoît Courbaud, G. Kunstler, X. Morin, T. Cordonnier** (2011). What is the future of the ecosystem services of the Alpine forest against a backdrop of climate change?, Revue de géographie alpine [En ligne] , 98-4 | 2010 , mis en ligne le 27 janvier 2011, Consulté le 07 mai 2011. URL : http://rga.revues.org/index1317.html
2. **Bernier P., D. Schoene (**2009). Adapting forests and their management to climate change: an overview. Unasylva No. 231/232, Vol. 60, /1-2 : 5-11
3. Carina E. , H. Keskitalo (2011). How Can Forest Management Adapt to Climate Change? Possibilities in Different Forestry Systems. Forests, 2, 415-430; doi:10.3390/f2010415.- www.mdpi.com/journal/forests
4. **Buksha I. F.** (2010). Ukraine. Study of climate change impact on forest ecosystems, and the development of adaptation strategies in forestry. Forests and Climate in Eastern Europe and Central Asia. Dr. Csaba Matyas, Editor. Forests and Climate Change Working Paper N 8, FAO, Rome, 2010. – Assessed at: http://www.fao.org/docrep/014/k9589e/k9589e16.pdf
5. **Carraro, C., Bosello F. and De Cian E**. (2011). Climate Policy and the Optimal Balance between Mitigation, Adaptation and Unavoided Damage. Climate Change Economics (CCE), Vol. 1, Issue 2, 2010. Available at SSRN: http://ssrn.com/abstract=1854065
6. **Gensiruk S.** (2002). Forests of Ukraine. Scientific Society, Lviv, Ukraine.
7. **Gamor F.** (2003). Carpathian Biosphere Reserve: conservation and sustainable utilization, 30-37. In: Commarmot and Hamor (eds) *Natural forests in the temperate zone of Europe–values and utilization*, Swiss Federal Research Institute Publication.
8. **Keskitalo, E. Carina H.** 2011. "How Can Forest Management Adapt to Climate Change? Possibilities in Different Forestry Systems." *Forests* 2, no. 1: 415-430.
9. **Keeton W.S. and S.M. Crow** (2009). Sustainable forest management alternatives for the Carpathian Mountain region: providing a broad array of ecosystem service. in: I. Soloviy and W.S. Keeton (eds.). Ecological Economics and Sustainable Forest Management: Developing a Trans-disciplinary Approach for the Carpathian Mountains. UNFU Press, Lviv, Ukraine, p. 109-126.
10. **Kohler T. and Maselli D**. (eds) 2009. Mountains and Climate Change – From Understanding to Action. Published by Geographica Bernensia with the support of the Swiss Agency for Development and Cooperation (SDC), and an international team of contributors. Bern.
11. **Kuemmerle, T., P. Olofsson, O. Chaskovskyy,** M. Baumann, K. Ostapowicz, C. Woodcock, R. A. Hougton, P. Hostert, W. Keeton, and V. C. Radeloff. (2011). Post-Soviet farmland abandonment, forest recovery, and carbon sequestration in western Ukraine. Global Change Biology, 17(3): 1335-1349.
12. **Irland, L.C. , E. Kremenetska** (2009). Practical Economics of Forest Ecosystem Management: the Case of the Ukrainian Carpathians. I.P. Soloviy and W.S. Keeton (eds.), Ecological Economics and Sustainable Forest Management, UNFU Press: 180 – 200.
13. **Marchuk Yu.M** *(*2009).Implementing features of Kyoto Protocol in Ukraine forestry mechanisms.-Scientific Journal of UNFU. –− Vol. 19.11: 53-57.
14. **Maroschek M., R. Seidl, S. Netherer and M.J. Lexer** (2009). Climate change impacts on goods and services of European mountain forests . Unasylva No. 231/232, Vol. 60, /1-2 : 76-80.
15. **McGinley, K. and B. Finegan** (2003). The ecological sustainability of tropical forest management: evaluation of the national forest management standards of Costa Rica and Nicaragua, with emphasison the need for adaptive management. Forest Policy and Economics, 5(2003), pp. 421-431.

16. **Ministry of Environment of Ukraine** (2003). The resolution on biodiversity. Fifth Ministerial Conference. 'Environment for Europe', Kyiv, Ukraine, 21–23 May 2003. UN/ECE (2003).- www.ieep.eu/20CAP%20and%20Biodiversity%20(2007)%20Report.pdf

17. **Nabuurs, G.J., O. Masera, K. Andrasko,** P. Benitez-Ponce, R. Boer, M. Dutschke, E. Elsiddig, J. Ford-Robertson, P. Frumhoff, T. Karjalainen, O. Krankina, W.A. Kurz, M. Matsumoto, W. Oyhantcabal, N.H. Ravindranath, M.J. Sanz Sanchez, X. Zhang (2007). Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

18. **Nijnik, M.** (2002). To Sustainability in Forestry. Wageningen University press, The Netherlands.

19. **Nijnik, M., Soloviy, I., Nijnik, A., Deyneka, A**. (2007). Challenges and potential policy responses towards sustainable mountain areas development and nature conservation in Ukrainian Carpathian. In Chmielewski, T., (ed.): *Nature Conservation Management: from idea to practical results.* Poland, PWZN, 133-149.

20. **Nijnik, A., Nijnik M., Soloviy, I.** (2009)**.** Challenges and opportunities for sustainable development in the Ukrainian Carpathians. *Mountain Research Initiative*, Switzerland 22-25.

21. **Soloviy I., Ilkiv H.** Alternative scenarios of naturally forested abandoned land use in the Carpathian Region // Ecological, Economic and Social Problems of Ineffective and Unsustainable Methods of Forest Management and Illegal Logging in Ukraine. Proceedings of the International Scientific Conference, Lviv, Dec 2-3, 2010. – Lviv: Green Cross Society, Liga – Press, 2011: 224-229

22. **Stoyko S.M.** (2009). Potential ecological consequences of global climate warming in forest ecosystems of Ukrainian Carpathians/ Global Climate Change – Threat to humankind and mechanism of prevention. Special issue of Scientific Journal of UNFU, Vol. 19.15 : 214-223

23. **Tuerk A., D. Frieden, M. Sharmina, H. Schreiber, D. Ürge-Vorsatz** (2010). Green Investment Schemes: First experiences and lessons learned. Working Paper, Center for Climate Change and Sustainable Energy Policy, Central European University, April 2010.

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## Гірська лісова політика і стратегії як відповідь на виклики зміни клімату: приклад Українських Карпат

Розкрито потенціал гірських лісів стосовно адаптації до зміни клімату та пом'якшенню її наслідків. Українські Карпати використано як приклад для аналізу еколого-економічних проблем лісів, лісокористування та ведення лісового господарства в умовах впливу глобальних змін клімату. Обговорюються питання інтеграції політичних інструментів лісової політики і стратегічних заходів у сфері лісового господарства, які повинні бути впроваджені у відповідь на виклики зміни клімату, з урахуванням особливостей гірських територій. Зокрема аналізуються можливості здійснювати регулювання величин вигоди від функції депонування вуглецю насадженнями шляхом впорядкування процесу заліснення і контролю використання ресурсного потенціалу земель. Розглянуті питанні раціонального використання самозаліснених земель. Зміни у землекористуванні є питаннями державного характеру, оскільки сам землевласника, не маючи змоги утримувати угіддя сільськогосподарського призначення, не зможе здійснити перепрофілювання земель до лісового фонду. З економічних міркувань зворотній процес самозаліснених земель до ріллі, де вже зростають насадження, є збитковим для пересічного сільського мешканця України. Еколого-економічну ефективність землекористування таких територій можна збільшити шляхом використання таких земель під вирощування енергетичних плантацій, або насаджень, створених в рамках реалізації «вуглецевих» проектів. Це вимагатиме організації державою процесу перепрофілювання земель.

**Ключові слова:** зміна клімату, зв'язування вуглецю, гірська політика, стратегії адаптації та подолання наслідків, Українські Карпати.

UDC 567.6:504
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# INSTRUMENTS OF ENVIRONMENTAL AUDIT IN SEKTORAL ENVIRONMENTAL MANAGEMENT SYSTEM

The importance of introduction of environmental audit into sectoral system of ekomanagement is emphasized. The set of developed instruments for introducing environmental audit was characterized and described by the example of forest sector of Ukraine.

**Keywords:** environmental audit, audit agreement, environmental passport, audit report, forest sector, model of environmental passport.

**Introduction.** According the we research conducte by us, whose results appear in [1], an environmental audit is an external complement to sectoral environmental management system and an integral part of the system at the enterprise level. Environmental audit is an integral part of the Eco provides the desired level of reliability. So for our country is a legitimate approach to international practice of nature to solve environmental and economic problems in a single system of environmental management and audit.

**Statement of the problem.** The purpose of this paper is to display the results of special research tools in the implementation of environmental auditing branch Eco businesses conducted using systemic, cybernetic approach to the problem, using the methods of induction and deduction, analysis and synthesis, abstraction and modeling study of processes.

**Results.** The study was conducted by the example of the forest sector of Ukraine.

According to Art. 12 of the Law of Ukraine "On Ecological Audit" [2] for the forest sector enterprises environmental audit is optional. However, concerned authorities, ie the customers of environmental audit, in our view, there may be central and local executive bodies, local governments that are interested not only in the stability of ecological situations, but also in improving ekolohorekreatsiynyh functions of forests. Interest in environmental audit enterprises as a stabilizing factor, which increases the reliability of environmental management system must identify their owners, the management of the forest sector of Ukraine. Moreover, increased system reliability is improving and environmental, competitiveness, increase the quota in the market of products, etc., that provide and improve the financial situation of enterprises. In addition, under the existing criteria for distribution of businesses by the risk of their business to the environment, forest sector enterprises belong to the group of subjects with high risk, for which action plans of state supervision shall be held annually [3]. The above, in our opinion, gives grounds to propose to make amendments to Article 12 of the Act [2] regarding mandatory for companies environmental audit forestry sector.

As noted in [see 1] at branch level should be carried out external environmental audit firms. Customers can be both authorities and, especially, sectoral leadership. Environmental audit may exercise a legal entity, the statute which provides this type of activity [2 Article 14]. Therefore, in our opinion, at the sectoral level should organize a powerful ekoaudytorsku firm with branches in places that would specialized in environmental auditing sector enterprises, while remaining independent and not subordinate to his superiors. Environmental audit conducted under a contract between the customer and ekoaudytorskoyu firm [2 Article 19]. Thus performers are defined by law and treaty responsibilities to the customer for the implementation of certain contract obligations for the accuracy of the conclusions of an environmental audit. Dates environmental audit determined by the contract.

We offer regular environmental audit commissioned by industry leaders. We believe that it should use the standard contract, a draft of which we have developed for the forestry sector enterprises. By contract offer Protocol (list of) an environmental audit, a draft of which we have developed as a typical also for these companies. Note that the list of necessary applications and tables we have included ecological passport business. The presence of environmental passport requirements provided environmental audit facility in Russia, and experience in conducting environmental audits in Ukraine. However, ecological passports of the former Soviet Union filled only industrial enterprises [4]. The company proved to be short term. Many companies have not finalized this passport Enterprises forestry sector of Ukraine left without such certification.

There fore, we believe that preparation for the implementation of environmental audits in the field of environmental management should start with the environmental certification of all businesses. For this purpose under the direction of the author have developed environmental passports separately for forestry and timber companies that have already passed the practical testing [1-15].

The regulation of EC number 1836193 first review the concept of environment – the first full study of issues related to environmental businesses, the impact on him and his protection in conjunction with the activities in the area. However, for the same time, the goal of environmental certification is [4, 6-15]:

- identification of quantitative and qualitative characteristics of environmental pollution emissions, effluents, waste, radiation;
- acquisition of specific indicators of nature and environmental pollution now that allow you to analyze the use of technology and equipment now compared with the best domestic and foreign models, and information about losses zavdayutsya now.

As a result of ecological passport system [5-12]:

- assess the impact of waste, pollutant emissions on the environment and public health;
- determine the fee for natural resources and for pollution;
- establish the company limit is waste, emissions, discharges of pollutants, environmental planning measures and assess their effectiveness;
- make an examination of reconstruction projects of enterprises;
- monitor and evaluate the level of compliance now law, rules and regulations of environmental protection;
- implement measures to improve the efficiency of utilization of natural resources, energy and secondary resources.

In our view, the above shows that in essence the first test of the environment and environmental certification companies are identical. Therefore, the process environmental audit the business should begin with ekopasportyzatsiyi that, in our opinion, appropriate to this model (Fig. 1). Working Group, which provides an environmental certification, must be specifically established by the company manager. In its composition, think, should include the heads of all functional services companies and to attract to its work of environmental auditors. In our view, it is appropriate that led a group of certified ekoaudytor, acting verifayer – officially accredited, independent of the company and its activities disinterested person who checks and certifies the likelihood and related amount of current legislation documents on environmental policy of the enterprise, programs, management systems, procedures preparatory environmental review and audit, and environmental applications [1]. Manager develops a plan of the group and division of functions between group members and linear units with drafting environmental passport. Approve the plan managers.

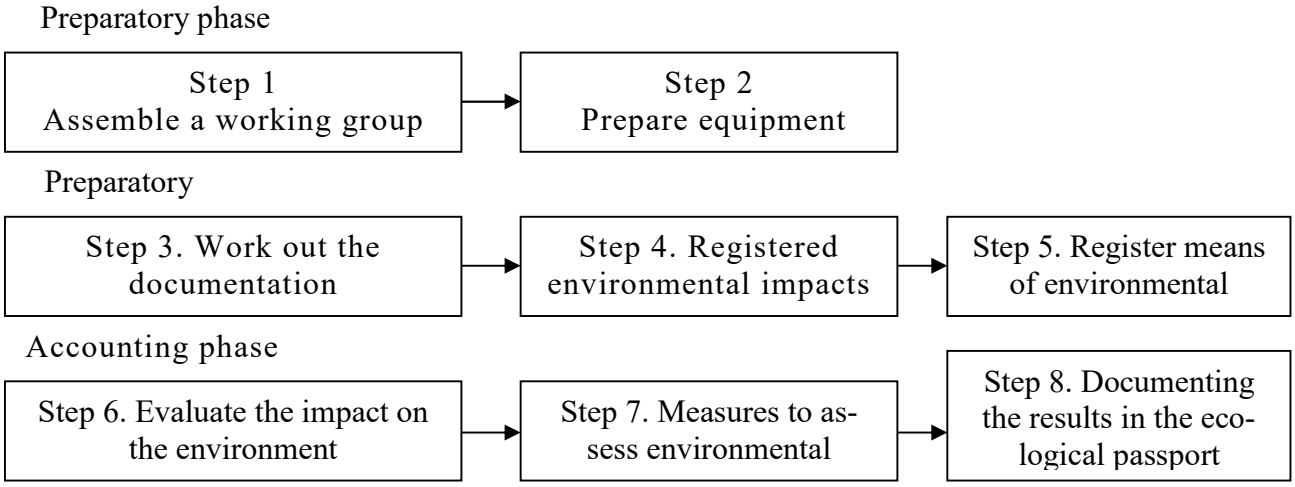


***Fig. 1. Model of the environmental certification company***

The second step is the preparation of all necessary means. First, at the disposal of the group should provide all the general documents, so you can make a preliminary review of the company. It should take care of office space and technical facilities, including computer, software, instruments for measuring environmental parameters, etc., as well as organizational support, including existing legislative and regulatory acts. We must consider all the details, including the involvement of external agencies and experts.

On the accounting phase (Step 3), above all, learn that the documentation was not provided the working group on the 2nd step. It is appropriate mapping schema enterprise applying to it the sources of pollution and purification of the atmosphere and surface water, waste stockpiles, vodozabyrachiv, the boundaries of sanitary protection, highway, recreation areas, monuments of architecture, post monitoring air pollution and wastewater discharges. Also, please make a brief description of the development schemes of material flows from all sources mic selection and treatment of pollution and their control points. It is necessary to process the many documents, including: applicable laws, statutes, regulations, instructions, departmental standards; general plan of the enterprise; plans vodovidnyh buildings, wells; reports on research work; plans warehouses; register of buildings and structures that require permission to use; register of materials hazardous to the environment and documentation for their preparation, storage, use, disposal; documents on basic environmental facilities; documentation of studies of wastewater; an initial permit for wastewater in accordance with applicable law; documentation of the measurements of the environment; documents on waste research, recommendations for their utilization, contracts for disposal; documentation on the use of resources (energy, fuel, materials); measures for environment; selection of methods to control the environment; work instructions for hazardous materials; directory extraordinary cases; plans for safety and protection against accidents; documentation of the fire; a list of companies with activities and special environmental ekolohorekreatsiynyh works; description of the job; existing records and reports on the environment.

At the 4th step includes: getting in the bodies of the nature of meteorological characteristics and coefficients of dispersion of pollutants in the atmosphere of the city (factor stratification of substances in the atmosphere, the coefficient of the terrain, outside air temperature, wind roses, wind speed); getting in organs Derzhhidrometu or local environmental protection characteristics of the environment on background concentrations of pollutants; in a local water management or water conservation characteristics of water quality and sewage receivers; identifying data on the use of land resources as a result of inventory. Characteristics of land use defined separately (buildings and constructions, auxiliary production, administrative office buildings and grounds, storage, landfills, sewage, landscaping, reclamation, sanitary-protective zone and other needs); identify the general and specific consumption of raw materials for each type of product, of forestry, and special lisovidnovlyuvalnyh ekolohorekreatsiynyh

work, based on material flows schemes; compilation of data on general and specific energy consumption by type of product and work on inventory data.

Annexes to this step is calculation of maximum permissible emission standards (HDV) or temporarily agreed emissions standards (MSW) in the atmosphere of harmful substances. It organized sources of pollution assign numbers from 0001 through 5999, and unorganized – from 6001 to 9999. Also, add water and sewerage schemes with reference to the costs and loss of water at each production within the hour. Along with indicators calculated specific consumption norms of water consumption and water per unit of output (work). Are given parameters and properties of the waste water, temperature, biological and chemical oxygen demand, pH value, suspended solids, salinity, toxicity. Indicate the characteristics of treatment facilities and vodooborotnyh systems, and characteristics of waste generated in the enterprise according to the inventory. This annex ecological passport business. At the 5th step should make an inventory of already implemented measures to protect the environment. There are organizational and technical measures. Registering technical measures, separate measures in specific areas and technical measures to reduce the negative impact on the environment in general. Registering arrangements should be mentioned tasks, place of deployment, units, functions and methods. It is important to note the existing arrangements for training and retraining for environmental protection. In the evaluation phase at the 6th step, to implement measures to improve the environment needs to be attached to the inventory data from assessment indicators. To do this, first of all, you should set criteria for assessment which should include: requirements of environmental legislation; potential risk; compliance with environmental policies of the enterprise; social acceptability.

In our opinion, they should consider, if possible, all or individually, giving preference first. At the 7th step should be to evaluate measures to protect the environment. In our view, technical and organizational measures should be evaluated with ABC / XYZ-analysis. At the 8th step should document everything done in 7.1 steps, ie fill ecological passport of all enterprise applications. This separate application must be a plan of organizational and technical measures businesses with nature. The model ekopasportyzatsiyi company tailored the current national regulatory framework, makes it possible to effectively conduct an environmental audit of enterprises, providing them with the system input, control points and basis of comparative analysis.

**Conclusions.** Thus, developed a number of implementation tools in industry-wide environmental audit system on the example of Eco Forestry sector of Ukraine. Thus, provided the necessary conditions for such implementation. The results of this research is the basis for further development towards the formation of an environmental audit methodology within industry environmental management system based on the modeling process environmental audit.

## References

1. **Лебедевич С.І.** Теоретико-методичні засади формування галузевої системи екологічного менеджменту підприємств: [монографія] С.І Лебедевич. – Львів: Ліга-Прес, 2008. – 340 с.

2. **Про екологічний аудит:** Закон України від 24 червня 2004 р. №1862-IV // Урядовий кур'єр, 2004. – №150. – С. 5-9.

3. **Критерії розподілу** суб'єктів господарювання за ступенем ризику їх господарської діяльності для навколишнього природного середовища та періодичності здійснення державного нагляду (контролю)/ Затв. постановою Кабінету Міністрів України від 19 березня 2008 р. №212 // Урядовий кур'єр, 2008. – №76. – С.7.

4. **Охрана природы.** Экологический паспорт промышленного предприятия. Основные положения: ГОСТ 17.0.04-90 – [Действующий 1990-10-15]. – М.: Изд-во стандартов, 1990. – 21 с.

5. **Джигирей В.С.** Основи екології та охорона навколишнього природного середовища (Екологія та охорона природи):[навч. посіб.] / В.С. Джигирей, В.М. Сторожук, Р.А. Яцюк. – [2-ге вид., допов.]. – Львів: Афіша, 2004. – 272 с.

6. **Гайда С.В.** Матеріали для виготовлення виробів з деревини.– Львів:ВМС.– 2000.– 160 с.

7. **Гайда С.В.** Раціональне конструювання виробів з деревини. – Львів:ВМС. – 2001. – 93 с.

8. **Гайда С.В., Кшивецький Б.Я., Войтович І.Г. Прокопович Б.В.** Тлумачний словник з деревооброблення. – Львів: НЛТУ України. – 2002. – 280 р.

9. **Гайда С.В.** Гнучкі автоматизовані виробництва та робототехніка в деревообробці: Основи створення ГАВ. – Львів: ВМС. – 1998, – 149 с.

10. **Гайда С.В.** Гнучкі автоматизовані виробництва та робототехніка в деревообробці: Основи робототехніки. – Львів: ВМС. – 1998, – 145 с.

11. **Гайда С.В.** Особливості та перспективи роботизації меблевої промисловості України / Науковий вісник УкрДЛТУ / наук.-техн. зб. – Львів: УкрДЛТУ. – 2002, 12.5:38-40.

12. **Гайда С.В.** Проблема деревної сировини у Європі та Україні / Ліс. госп-во, ліс., папер. та деревооб. пром-сть / наук.-техн. зб. – Львів: НЛТУ України. – 2007, 33:55-63.

13. **Гайда С.В., Максимів В.М.** Аналіз, особливості, проблеми та досвід використання додаткових ресурсів сировини – відходів та вживаної деревини / Ліс. госп-во, ліс., папер. та деревооб. пром-сть / наук.-техн. зб. – Львів: НЛТУ України. – 2007, 33:63-72.

14. **Гайда С.В.** Дослідження концентрації операцій у сучасному меблевому виробництві / Ліс. госп-во, ліс., папер. та деревооб. пром-сть. – Львів: НЛТУУ. – 2007, 33:73-79.

15. **Гайда С.В.** Хімічний склад та ступінь забруднення – основа систематизації ВЖД / Ліс. госп-во, ліс., папер. та деревооб. пром-сть, – Львів: НЛТУ України. – 2008, 34:68-79.

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## Інструменти екологічного аудиту в галузевій системі екологічного менеджменту

Зазначено актуальність впровадження екологічного аудиту в галузеву систему екологічного менеджменту. Зазначено особливості визначення договірних зобов'язань аудитора, необхідність включення в перелік додатків і таблиць до договору на проведення екоаудиту екологічного паспорту підприємства. Охарактеризовано необхідність і суть екопаспортизації підприємств. Зазначено, що дозволяють забезпечити результати екопаспортизації підприємства. Надано розроблену модель процесу екологічної паспортизації підприємства, її характеристика. Зазначено перелік документів, які підлягають опрацюванню під час екопаспортизації. Зазначено критерії оцінювання показників у процесі екопаспортизації. Зазначена модель екопаспортизації підприємства враховує структуру чинної національної нормативно-правової бази, дає можливість ефективно проводити екологічний аудит підприємств, забезпечуючи його системою вхідних даних, контрольних моментів і базою порівняльного аналізу. Таким чином, охарактеризовано ряд розроблених інструментів впровадження екологіного аудиту в галузеву систему екоменеджменту на прикладі лісового сектору економіки України. Тим самим, забезпечено необхідні умови такого впровадження.

**Ключові слова:** екологічний аудит, система екоменеджменту, проект, договір на проведення екоаудиту, протокол екоаудиту, екологічний паспорт, лісовий сектор економіки, модель екологічної паспортизації.

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UDC 582.288.4

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## THE STUDY OF MYCOTROPHY OF SOME HERBACEOUS PLANTS GROWING ON THE SOILS OF PODOROZHNE SULPHUR MINE

Presented in this work are the results of a 3-year study of mycotrophy of Tussilago farfara L., Trifolium pretense L., Platanthera bifolia Rchb. – the plants that form pioneer successions on the dev-

astated lands of Podorozhne mine. It has been found that the isolated endophytes are obligate symbionts that are of great genetic importance for plant species conservation. Further investigation of this sort will allow to trace the pattern of self-recovery of soil biota on devastated lands.
**Keywords:** plant mycotrophy, species conservation, sulphur-rich soil.

In recent years, a major portion of land has degraded and has been devastated due to intensive human economic activity. This is especially true for the lands where mineral resources were extracted. The presence of sulphur mine in Zhydachiv district, Lviv region, has been a pressing problem for this district.

On July 21,1995, resolution No.442 was adopted by Ukraine's Cabinet which provided for step-by-step removal from service of the sulphur mine in the settlement of Podorozhne and, accordingly, the sulphur mine ceased to operate in 1997. A many-year operation of this mine resulted in originating a pit of about 100m deep and a volume of 135mln cubic metres. The pit has begun to be filled by atmospheric precipitations and underground waters since 2000. The waste rock of Podorozhne pit had been piled in dumps outside the pit. The dumps cover an area of 600.7ha which corresponds to the volume of 138.3mln cubic metres of rock.

The territory of Podorozhne pit is unbalanced natural-and technogenic systems where active geodynamic, hydrochemical and biological processes are taking place. It is of great importance to find the pattern of self-recovering various components of the environment, that is the revival of biota and formation of biocoenoses. Of great importance and topical is the study of symbiosis of herbaceous plants with fungi on the lands devastated as a result of sulphur extraction. By studying these links, it is possible to follow the mechanism of self-recovery of soil biota in the devastated lands [1-5].

**Obtaining pure culture of symbiotic fungi.** The isolation of pure culture of endophytes was accomplished from the plants that grow on the territory of Podorozhne field. To do this, the procedure developed and described in 1990 by F. Geltser was employed [2,4]. Thin rootlets of plants were treated with mercuric chloride with concentration of 1:1000 for 2 to 3 minutes followed by repeated (10 times) rinsing with distilled water in order to ensure sterility of the rootlet surface without disturbing the vitality of the endophytes; in addition, the rootlets were sterilized with 30% hydrogen peroxide to achieve the necessary effect. Endophytes make an active growth in liquid nutrient medium, this is why we used a medium of the following composition (gram per liter): glucose-8; $K_2HPO_4$-0.3; $KH_2PO_4$ -0.9; $MgSO_4$ -0.2; $K_2SO_4$ -0.1; $FeSO_4$ and $MnSO_4$ – traces, asparahin 0.01. The main peculiarity of symbiotrophic fungi of plants is that they require growth hormones during the short period of germination from the plant tissue into the nutrient medium as well as in the process of germination from the seed into the root. According to the author of the procedure, fungi, as a rule, do not germinate without hormonal influence from outside. In some instances, endophytes do germinate without addition of growth hormones on condition that the plant mycotrophy is very potent, the concentration of nutrient medium remains high and evidently, with a sufficient quantity of hormonal agent available in the root tissue.

Extracts from hymenomycetes, in particular actinomycete Actinomycetes Lavendulae, were used as growth hormones; these had been obtained at Kholodniy Research Laboratory of the National Academy of Sciences of Ukraine ( city of Kyiv). Also the author compound Symbiont 1, patented by F. Geltser in 1982, was used [3,4]. The amount of growth hormone added to the medium, makes up 0.5 to 1 ml per litre of me-

dium depending on the compound used. As energy-consuming agents, endophytes are to assimilate glucose, saccharose and starch but they are not able to assimilate organic acids (except for succinic acid), cellulose and lignin. On germination of the endophyte mycelium that occurred in 5 to 12 days, in order to get the mycelium free from the roots, it was re-sawn into retorts containing the above mentioned nutrient medium without adding growth hormones which the fungi synthesize on their own. The above described procedure of isolating endophytes will ensure obtaining pure culture from any plants both highly and slightly mycotrophic as well as from plants that are considered non-mycotrophic because they failed to be observed visually [2,3,4].

**Results and discussion.** Over three years we have isolated endophytes from plants that grow on the territory of Podorozhne field. They were obtained from the roots of coltsfoot plant (Tussilago farfara L.). We obtained clearly septate multicellular mycelium filled with granular plasm and which never sporulates. As it grows older, mycelium forms globular vesicular blisters that are readily coloured with aniline stains. Being placed into liquid medium, mycelium makes a good growth to form a jelly-like mass of dark-green color at first which becomes black in color later.

The pigment is not blended with the medium. The endophytes that are isolated from the young ovary of this plant are of golden-yellow color.

Endophytes were also isolated from clover Trifolium pretense L. The endophytes of this plant are characterized by the mycelium that is very easy to break off. As this takes place, a certain amount of hyphae tips accumulates at the bottom of the retort. Such particles of hyphae can form mycelium with detachable outgrowths in a fresh nutrient medium. Multicellular mycelium of clover plant synthesizes a red pigment. It does not have fruiting organs. The endophytes from Lesser butterfly or-child (Platanthera bifolia Rchb.) form thin, slightly septate hyphae which, as they grow older, form clearly septate mycelium, a characteristic feature of which is white colour. All the pure endophyte cultures obtained, had the following features in common:

- Absence of sporulation organs of reproduction;
- Multicellular mycelium which, as it grows older, takes a clear-cut septate shape with vesicular widening;
- Granular plasm which gets disintegrated when a cellular wall is broken;
- Depth growth in liquid medium in the absence of surface mycelium;
- The ability to synthesize pigments of various colour.

The absence of sporulation organs allows to assign the endophytes obtained to the class of fungi imperfect within which they can be placed into a special order symbiophytum. Some types of fungi have a very wide range of relationship with plants: the same species can exist in rhizosphere or in rhizoplane; it may acquire pathogenic characteristics, forms mycorrhiza [2, 5]. The formation of natural endotrophic mycorrhiza also involves an active participation of symbiotrophic bacteria when, as the seeds germinate, the number of epiphytic bacteria increases considerably followed by their settlement on the surface of young roots where these microorganisms are regarded as rhizospheric bacteria.

The biologically active agents that produce these microorganisms, make the symbiontic fungi leave the aleuronic layer of the seed to germinate into the roots. The sterilization of seeds excludes the possibility of bacteria growth on their surface and thereby production of hormonal agents needed for endophytes to germinate. The application of hormonal agents to the surface of sterilized seeds will ensure the development of vesicular-arbuscular mycorrhiza in the roots.

Any artificial application of fungal or bacterial “infection” to a sterilized seed or plant will build up an additional amount of hormonal agent needed to activate germination of endophytes typical for the given plant. Thus, endophytes are obligate symbionts which are of great genetic importance for plant species conservation [1-5].

**From the above discussion, it may be concluded:**

1. Symbiontic fungi are strongly dependent on growth hormones without which they are unable to accomplish transfer from the seed where they are in the dormant state, to the plant roots. In the process of their vital activity in the plant roots, they synthesize growth hormones on their own and in doing so they promote the plant growth.

2. To accomplish the transfer from the seed to the roots under natural conditions, endophytes are supplied by hormonal agents that produce epiphytic and rhizospheric bacteria which reproduce themselves on the surface of seed during its germination. The studies were conducted to find that endophytes are present not only in the plant roots but also in the above-ground parts of plants including pollen, ovary and seeds, which confirms the fact of cyclic heredity in the transmission of endophytes [1,2,4]. This concept enhances the genetic importance of fungal symbiont and suggests a possibility of the improvement from one generation to another and its transmission in the process of double fertilization discovered by S.Navashyn as early as 1951. In vegetative reproduction, the rate of transferring endophytes from bulbs, tubers and shoots slows down noticeably due to less strong hormonal influence of these fungi.

3. The fungus reaches into the roots of a plant not from the soil but from some zones of the plant roots, which is confirmed by non-injured cover of the root hairs. Endophytes cannot use the soil as their habitat because they are readily lysed [4].

4. The hormonal impact on plant seeds both under natural conditions and in the application of hormonal agents, not only stimulates the activity of symbiotic fungi but also favours the development of extensive root system of plants, which markedly affects mycrotrophy of plants and their productivity.

5. Thus, the resistibility of some plants that form pioneer successions on devastated lands, to toxic environment is accounted for by their high-level mycotrophy and the ability of fungi to adapt themselves to various kinds of pollution due to the availability of powerful hormonal systems. The symbiosis between fungi and plants is favourable to genetic conservation of the species, brings into operation the mechanism of survival under extreme conditions for germination, provides favourable conditions for growth and development of demanding plants.

## References


1. **Гельцер Ф.Ю.** Микробиологическая теория иммунитета // Защита растений. – 1981. – №9, – С.22-24.

2. **Гельцер Ф.Ю., Кузнецова Г.В.** Получение чистых культур ендофитов из растений // Микология и фитопатология. – 1977. – Т.11, вип. 3, – С.182-188.

3. **Гельцер Ф.Ю., Телухин А.Ф.** Симбионт 1 и укоренение черенков // Цветоводство. – 1976. – №3. – С.10.

4. **Гельцер Ф.Ю.** Симбиоз с микроорганизмами – основа жизни растений. – М.: Изд-во МСХА. – 1990. – 134 с.

5. **Orovwska E., Zubek Sz., Mesjasc-Przybolowich J., Przybolowich W., Turnau K.** Nuklear microbe studies of heavy metal distribution in mycorrhizal and nonmycorrhizal roots of Plantago lanceolata. In Proceedings of the 15th International Congres on Electron Microscopy (ICEM-15), Durban, South Africa, 1-6 September 2002, Vol.2. – P. 697-698.

УДК 582.288.4 *Доц. В.П. Оліферчук, канд. біол. наук;*
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## Вивчення мікотрофності деяких трав'янистих рослин на грунтах Подорожненського сірчаного рудника

Представлено результати трирічних досліджень вивчення мікотрофності Tussilago tarfara L, Trifolium pretense L, Platanthera bifolia Rchb., рослин, які створюють піонерні сукцесії на девастованих землях Подорожненського рудника. Досліджено, що виділені ендофіти – це облігатні симбіонти, які мають величезне генетичне значення у збереженні виду рослин. Продовження такого роду досліджень дасть можливість прослідкувати закономірності самовідновлення грунтової біоти девастованих земель.

**Ключові слова**: мікотрофність рослин, збереження виду, ґрунти з високим вмістом сірки.

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UDC 674.815. *Assoc. prof. S.V. Gayda; senior teacher T.P. Dyak – UNFU*

## THE ANALYSIS OF ECONOMIC EFFICIENCY OF POST-CONSUMER WOOD USE FOR PARTICLEBOARD MANUFACTURE FOR LLC SWISSPAN LIMITED

Economic and ecological benefit from post-consumer wood use (PCW) is analyzed. The state of a regional system of PCW management of Rivne region and also a local system of PCW use at LLC SWISSPAN LIMITED are characterized. The importance of their reforming is determined as well.

The PCW potential depending on the amount of solid domestic waste (SDW) on the example of its procurement in Rivne region is calculated. The necessity of PCW buying from population at a price 37.14 UAH/$m^3$ is proved. PCW use introducing in order to produce particleboards, especially at LLC SWISSPAN LIMITED, is suggested. It is also calculated that the enterprise's expenses for buying 1 $m^3$ of traditional timber are 97.97 UAH more than for buying PCW. Prepared PCW use within 100 km area of the region is estimated to provide 9.4 percent of a yearly capacity of the enterprise.

PCW use in a necessary amount as addition to the main raw material for particleboard manufacture (60 percent) is demonstrated to represent 1408.76 UAH/year saving on the resource. An average annual income for one employee will be 32.54 thousand UAH. The amount of a yearly deduction made by the enterprise to the off-budget social funds will attain 150 thousand UAH. 1st and 2nd categories PCW use calculated for this region in amount of 10.07 thousand ton/year and suitable for particleboards is determined to save 32 thousand trees from cutting.

**Keywords:** wood, post-consumer wood, particleboards, solid domestic waste, PCW use analysis, waste recycling, waste management, ecological and economic efficiency.

**State of question.** At the end of the 20th century and in the beginning of the 21th century the problem of solid domestic and industrial waste became acute almost all over the world [8]. It is caused by the rapid increase of the amount of wastes. The rate of waste increasing is 3-4 times higher than the population growth rate. Thus the amount of solid domestic and industrial waste directly depends on the level of population welfare and solvency. The amount of solid domestic and industrial waste was predicted to increase 4-5 times in the case of consumer ability increasing of the developing countries population to the level of the developed countries population (countries of Europe, the USA, and Japan etc.). Solid domestic waste (SDW) is a certain waste of the consumption sphere that is produced in residential areas, organizations and institutions, trade establishments, waste of heating settings in dwelling houses, garbage from streets, construction sites etc. Though a better definition for HDW is foodstuffs unsuitable for further use, and domestic appliances thrown away by people [10-14].

**Method of research.** Human industrial and domestic activity is inevitably connected with solid waste producing. Assimilation of solid waste lasts from tens to hundreds of years, although liquid and gaseous waste is absorbed by the environment comparatively faster. For example, every year 1.5-1.7 billion tons of solid waste are accumulated every year in Ukraine [11, 14]. The total amount of solid waste approximates 30 billion tons occupying more than 165,000 hectares (about 40 kg per each $m^2$ of the area). It means that about 4 percent of the territory of Ukraine (that equals the territory of the Ukrainian Carpathians) is occupied with trashcans, mining wastelands, landfills, and dumps poisoning the environment and sapping the health of our country's citizens [6, 7]. 19,406 tons of unacceptable waste have already been stored in Ukraine [14]. These substances are of greater danger as a source of contamination for soils, groundwater, and people poisoning if being stored in a wrong way.

According to the research, there is about 300-400 kg of SDW per person per year [11]. The structure of SDW content is given in Table 1.

**Table1. The structure and content of SDW [13]**

| Components | Share, % | Components | Share, % |
|---|---|---|---|
| Paper | 40 | Wood [1, 2, 4, 9] | 5 |
| Food wastes | 21 | Rubber and leather | 3 |
| Glass | 12 | Textiles | 2 |
| Iron and its alloys | 10 | Aluminium | 1.3 |
| Plastics | 5 | Other materials | 0.7 |

Rivne region is located in the Northwest of Ukraine, between 50°01' and 51°58' north latitude and between 25°01' and 27°38' east longitude (Fig. 1).


***Fig. 1. The diagram of PCW collecting from the districts of Rivne region for the LLC SWISSPAN LIMITED***

It occupies an area of 20.1 thousand square kilometers that is 3.3 percent of the total territory of the country. The extent of the region from the north to the south is 215 kilometers; from the west to the east is 186 kilometers. The region borders on Byelorussia in the north, Zhytomyr region in the east, Khmelnytskyi region in the south-east, Ternopil region in the south, Lviv region in the south-west and Volyn region in the west of Ukraine. The population of Rivne region is 1,151.7 million people (as of January 1, 2011). The city of Rivne is the centre of the region.

The enterprise is situated in the central part of Kostopil district of Rivne region (western part of right-bank Polissya). It specializes in producing of wood particleboards (WPB), laminated WPB, and table boards. It is one of the leading producers of laminated WPB in Ukraine and the CIS. It produces the widest range of decors (more than 115) and thicknesses (10, 16, 18, 22, 25, 28 mm). All the products are produced under the trade mark Swisspan by Sorbes. A share of the brand SWISSPAN® is about a half of the Ukranian market of laminated WPB. Holding leading positions in the market conditions that grows 15-20 percent each year requires increasing of production and sale volume.

**Results of research.** We calculate the quantity of SDW in Rivne region per year from the data provided: $Q_{SDW} = H*K$ , (1)

where: $Q_{SDW}$ – the quantity of SDW per year, ton; H – size of population thousand people; K – the quantity of SDW per person, ton.

$Q_{SDW}$ = 1,151.7*0.35 = 403.09 thousand tons.

According to the data calculated there is 403.09 thousand tons of SDW per year in Rivne region.

***The calculation of the quantity of raw material that belongs to* PCW.**

$$Q_{PCW} = Q_{SDW}*P/100 , \quad (2)$$

where: $Q_{PCW}$ – quantity of PCW per year, ton; $Q_{SDW}$ – quantity of SDW per year, ton; P – content of wood in the structure of SDW, percent (Table 1).

$Q_{PCW}$ = 403.09*5/100 = 20.15 thousand tons.

***The calculation of the quantity of raw material that belongs to* I (PCW-I) and II (PCW-II)** [1-9]**.** The first category: post-consumer wood I (PCW-I). This is natural and mechanically processed wood with insignificant contaminations by natural struts (paraffin, ceresin, petrolatum, wax, mastic etc.), as well wood from natural calamities. It presents 30 percent. The second category: post-consumer wood II (PCW-II). This is processed wood and timber without any wood protecting substances and halogen organic links in coating. It presents 20 percent.

$$Q_{PCW\ (I,II)} = Q_{PCW} *P_{I,II}/100 , \quad (3)$$

where: $Q_{PCW\ (I,II)}$ – quantity of PCW of the first and second categories per year, ton; $Q_{PCW}$ – quantity of PCW per year, ton; $P_{I,II}$ – percent of I (PCW-I) and II (PCW-II), percent. $Q_{PCW\ (I,II)}$ =20.15*50/100 = 10.07 thousand tons/year.

***Correlation of available and necessary quantity of PCW per year.***

Available PCW presents: $Q_{PCW\ (A)} = Q_{PCW\ (I,II)}/q$ , (4)

where: $Q_{PCW\ (A)}$ – quantity of available PCW per year, $m^3$; $Q_{PCW(I,II)}$ – quantity of PCW of the first and second categories per year, ton; q – average density of PCW, ton.

$Q_{PCW\ (A)}$ = 10.07/0.7 = 14.38 thousand $m^3$ /year.

We calculate the necessary quantity of traditional and PCW [3, 4] for the enterprise LLC SWISSPAN LIMITED concerning the yearly program (548,666.6 thousand UAH): $A_{yearly\ (PCW)} = (S/P)*C*K_n$ , (5)

$$A_{yearly(t)} = (S/P)*K_n , \quad (6)$$

where: $A_{yearly\ (PCW)}$ – quantity of available PCW per year, $m^3$; S – amount of product sold per year, thousand UAH; P – price for WPB per 1 $m^3$, thousand UAH; C – content of PCW in a board (60 percent); $K_n$ – coefficient concerning the amount of necessary raw material when producing 1 $m^3$ of WPB (1.6-1.7).

$A_{yearly\ (PCW)}$ = (548,666.6 / 3.68)*0.6*1.7 = 152.07 thousand $m^3$,

$A_{yearly(t)}$ = (548,666.6 / 3.68)*1.7 = 253.46 thousand $m^3$.

***The calculation of the WPB price per 1 m³***

$$P = P_b * N , \quad (7)$$

where: $P_b$ – an average price of a board 2750×1830×16 (295 UAH/item), UAH; N – number of boards in 1 $m^3$ (12.5 items).

P = 295*12.5 = 3 687.5 UAH.

The necessary quantity of PCW for a yearly program is 152.07 thousand $m^3$/year, available 14.38 thousand $m^3$/year.

***The calculation of the cost of traditional raw material according to the project variant.*** The price of the traditional raw material is 190-227 UAH/$m^3$. Let's take the average meaning – 200 UAH.

The cost of the traditional raw material for the program is

(253,460.1*200= 50,692.02 thousand UAH/year).

***PCW sorting and delivery to the enterprise.***

*The calculation of expenses for PCW delivery to the enterprise.*

$$A = Q_{PCW} * P_d , \quad (8)$$

where $P_d$ – price for PCW delivery 1 $m^3$, UAH.

A = 14.38*37.14 = 534.2 thousand UAH.

Concerning the average tariff on export of SDW to be 26 UAH/$m^3$ in 2011 [11], we suggest cooperation to the communal enterprise in the PCW delivery, increasing the tariff to 70 percent (26*1.7 = 37.14 UAH/$m^3$) taking into account the technological losses at transportation. *Calculation of the yearly salary.*

$$Z = C_{month.sal.} * W * M * X , \quad (9)$$

where: $C_{month.sal.}$ – average monthly salary (2,712 UAH); W – number of workplaces, person; M – number of months in a year; X – norm of deduction for social measures, percent.

Z = 2,712*12*12*1.384 = 540.47 thousand UAH.

*The calculation of expenses for export of III (PCW-III) and IV (PCW-IV) from the enterprise.*

$$E = Q_{PCW(III, IV)} * T , \quad (10)$$

where: $Q_{PCW(III, IV)}$ – quantity of PCW of the third and fourth categories, $m^3$; T – tariff on export of PCW of the third and fourth categories, UAH/$m^3$.

E = 14.38* 26.00 = 373.88 thousand UAH.

The calculation of the other expenses that are accepted 5 percent of labour payment fund including deduction: B = 540.47*0.05 = 18.69 thousand UAH.

Price on 1 $m^3$ of PCW for the enterprise:

$$P_{1\ m3\ (PCW)} = (A + Z + E + B) / Q_{PCW\ (A)} . \quad (11)$$

$P_{1\ m3\ (PCW)}$ = (534.2 + 540.47 + 373.88 + 18.69)/14.38 = 102.03 UAH.

Saving on raw material per year:

$$D = (P_{1\ m3\ (PCW)} - 200) * Q_{PCW\ (A)} , \quad (12)$$

D = (102.03 -200)*14.38 = – 1,408.76 thousand UAH.

Histogram of prices on traditional raw material and PCW (Fig. 2).

*The calculation of the number of trees saved from cutting.*

An average volume of a tree – 0.45 $m^3$.

$$T = Q_{PCW\ (A)} / 0.45 . \quad (13)$$

T = 14.38 / 0.45 = 31,956 items.

The number of trees saved from cutting is 31,956.

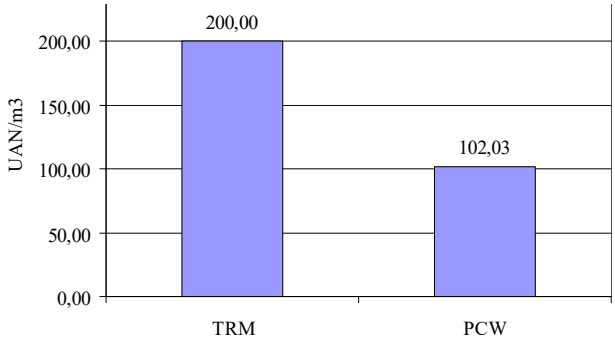


***Fig. 2. Cost of traditional raw material (TRM) and post-consumer wood (PCW) per 1m³***

**Conclusions:** The PCW use in order to produce wood-particleboards is suggested to inculcate after having analyzed in details the development of board materials, supplies of raw material sources in Ukraine, and especially at LLC SWISSPAN LIMITED. The PCW use is calculated to provide 9.4 percent of the yearly capacity of the enterprise. PCW is decided to buy from population at a price of 37.14 UAH/m$^3$ considering technological losses at transportation. It is also suggested to work according to the principle of points of metal and used glass reception.

The PCW use is calculated to be economically efficient. The enterprise spends 97.97 UAH for buying 1m$^3$ of traditional wood comparatively to PCW. The enterprise is proved to save 1,408,760 UAH per year when using PCW. The number of trees saved from cutting is 31,956, and 12 workplaces are also created. An average yearly income for 1 employee is 32,540 UAH. The amount of the yearly deduction made by the enterprise to the off-budget social funds is 150,000 UAH. Economic indexes concerning PCW use for LLC SWISSPAN LIMITED are provided in Table 2.

**Table 2. Economic indexes concerning PCW use for LLC Swisspan Limited**

| № | Indexes | Value of units |
|---|---|---|
| 1. | Saving on raw material per year | 1,408,760 UAH |
| 2. | Number of trees saved from cutting | 31,956 trees |
| 3. | Number of workplaces created | 12 people |
| 4. | Average yearly income for 1 employee | 32,540 UAH |
| 5. | Amount of yearly deduction made by the enterprise to the off-budget social funds | 150,000 UAH |

Thus, PCW use for producing WPB guarantees either economic or ecological indexes. The PCW use is of the great importance for protecting the natural environment, and at the same time it ensures a significant decrease of incoming raw material cost.

**Conclusions and suggestions:**

1. The problems of PCW management attract attention in modern conditions of ecological and economic crisis. The problem of supplying woodworking enterprises with raw material, especially for the particleboard manufacture, is becoming essential on the background of new recycling and utilization technologies development of particular resource-valuable waste. Research reveals that PCW is first of all domestic waste in solid modular condition, and PCW management is a combination of operations that can be carried out toward it. The term 'system of PCW management' is coined in order to study the process of PCW management and prove its functioning. The purpose of this system existence is maximum recycling of produced and suitable for particular production amount of PCW, i.e. supporting a proper level of ecological safety within its measures.
2. Systems of PCW management are determined to be either technological or economic ones. Considering this we suggest to classify them according to technological and economic characteristics, taking into account organizational and ecological characteristics as well. The researches have shown that the method of PCW burial constituting 5 percent of SDW is dominant in Ukraine and world practice as well. Payment for PCW neutralizing is made at the place of its providing. Payment at the place of goods buying that is used for post-consumer packaging has been started since 2001.
3. PCW rated capacity on the example of Rivne region enables to make a conclusion concerning existing great possibilities for raising of the level of post-consumer resources use through involvement of the amount of generated PCW into recycling. Factors of ecological, organizational and technical, financial and economic stability, which tendencies to change allow to determine the type of develop-

ment of a system, are suggested to apply in order to characterize the level of development of PCW management system. The analysis of level of development of the local PCW management system for particleboards producing at LLC SWISSPAN LIMITED that is made according to the techniques suggested shows a progressive type of its development, and the necessity to spread over other regions.

4. The concept for choice of variant of regional PCW management system forming that includes algorithm of decision making concerning a choice of a variant of such system forming and methodological criteria for implementing its separate stages, and also conceptual approaches to necessary resources involvement is suggested on grounds of research results. They are recommended to use for both individual subjects of PCW management, and local and regional bodies of self-government, and state authorities during strategy development. The ground of the investment strategy for creating regional PCW management system for Rivne region is carried out in order to recycle resource-valuable PCW categories. PCW recycling projects are commercially advantageous and can be carried out through drawing in enterprises' own money and credit resources. The priority of investment variants within each direction isn't changed with a transition from individual subject's level to the system level in general, but their system efficiency compared to subject one increases because of additional economic and ecological effects rising. The use of suggested organizational economic mechanism of investment activity stimulation for PCW management subjects on the regional level will promote effective realization of the elaborated investment strategy. Financing with support of local authorities, placing orders for their carrying out by means of tender, and realizing of pilot schemes are suggested to apply for large scale projects. Projects for recycling and utilization of resource-valuable PCW categories can be proved by means of improved strategy – an informational model, and carried out by commercial institutions – wood-working enterprises.

## References


1. **Gayda S.V.** (1999). Проблеми та перспективи роботизації меблевої промисловості [Problems and prospects of robotics in the furniture industry]. Scientific Bulletin of UNFU 9.5:192-195. (in Ukrainian).

2. **Gayda S.V.** (2000). Визначення стійкості та міцності вертикальних стінок корпусних меблевих виробів [Determination of stability and strength of vertical walls of case furniture products]. Scientific Bulletin of UNFU 10.3:127-129. (in Ukrainian).

3. **Gayda S.V.** (2000). Особливості розрахунку корпусних виробів на міцність [Peculiarities of strength calculation of hull products]. Scientific Bulletin of UNFU 10.2:150-154. (in Ukrainian).

4. **Gayda S.V.** (2000): Матеріали для виготовлення виробів з деревини / Materials for the Productsion of wood Productss. Lviv: BMC. – 160 p. (in Ukr.).

5. **Gayda S.V.** (2001): Раціональне конструювання виробів з деревини / Rational constructing of wood Productss. Lviv: BMC. – 93 p. (in Ukr.).

6. **Gayda S.V.** (2002). Особливості та перспективи роботизації меблевої промисловості України [Peculiarities and prospects of robotization of the furniture industry of Ukraine]. Scientific Bulletin of UNFU 12.5:38-40. (in Ukrainian).

7. **Gayda S.V.** (2003). Гнучкі виробничі модулі для виготовлення гратчастих меблевих виробів [Flexible production modules for the production of lattice furniture products]. Scientific Bulletin of UNFU 13.2:120-122. (in Ukrainian).

8. **Gayda S.V.** (2004). Інтегровані технології меблевого виробництва [Integrated technologies of furniture production]. Scientific Bulletin of UNFU 14.4:118-121. (in Ukrainian).

9. **Gayda S.V.** (2007): A problem of arboreal raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2007, pub. 33. – P. 55-63. (in Ukr.).

10. **Gayda S.V.** (2008): Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2008, pub. 34. – P. 68-80. (in Ukr.).

11. **Gayda S.V.** (2009): Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2009, pub. 35. – P. 63-84.

**12. Gayda S.V.** (2009): The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. Collection of scientific and technical works. – Lviv: UNFU. – 2009, pub. 19.14. – P. 72-89. (in Ukr.).

**13.Gayda S.V.** (2011): The investigation of physical and mechanical properties of wood parti-cleboards made from post-consumer wood. Forestry, Forest, Paper and Woodworking Industry 37(2):95-110.

14.**Gayda S.V.** (2010): A comparative analysis of physical and mechanical parameters of variously designed glued boards made of post-consumer recovered wood. Forestry, Forest, Paper and Woodworking Industry 36:81-91.

15. **Gayda S.V.** (2010): From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2010, pub. 36. – P. 57-77.

16. **Gayda S.V.** (2011): Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2011, pub. 37.1. – P. 238-244. (in Ukr.).

17. **Gayda S.V.** (2011): Ecological and economic aspects of the wood reuse // Ecological, Economic and Social Problems of Ineffective and Unsustainable Methods of Forest Management and Illegal Logging in Ukraine. Conference Proceedings, Lviv, Dec. 2-3. 2010. – Lviv: Green Cross Society, Liga Press. – 2011. – P. 147-151. (in Ukr.).

18.**Gayda S.V., Kshyvetskyy B.Ya.** (1999). Техніко-економічні характеристики деревообробної фабрики майбутнього [Technical and economic characteristics of the woodworking factory of the future]. Scientific Bulletin of UNFU 9.3:83-85. (in Ukrainian).

**19.Gayda S.V., Maksymiv V.M.** (2010). From recycled post-consumer wood towards prime quality particleboard / Ліс. госп-во, ліс., папер. та деревооб. пром-сть // міжвід. наук.-техн. зб. – Львів: НЛТУ України. – 2010, вип. 36. – С. 57-77.

20. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** (2008): Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2008, pub. 34. – P. 55-68. (in Ukr.).

21.**Gayda S.V., Nikityuk L.O.** (1998). До питання застосування екстрагованої деревини для плитного виробництв [On the issue of using extracted wood for slab production]. Scientific Bulletin of UNFU 8:75-77. (in Ukrainian).

22. **Koval L.I., Gayda S.V.** (2011): Recycling waste from sawing MDF // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2011, pub. 37.1. – P. 49-53. (in Ukr.).

23.**Vintoniv I.S., Sopushynskyy I.M., Teishinger A.** (2007). *Derevynoznavstvo* [Wood-science]. – Lviv: Apriori. – 312 p., (in Ukrainian).

24. **Voronovich V.V., Gayda S.V.** (2011): Comparative analysis of bending particularities for various post-consumer wood species and age categories // Forestry, Forest, Paper and Woodworking Industry. Collection of scientific and technical works. – Lviv: UNFU. – 2011, pub. 37.1. – P. 84-88. (in Ukr.).

25.**Voytovych I.G.** (2010). *Osnovi tekhnologiï virobiv z derevini* [The basic technology of wood]. – Textbook. –Lviv: Kraine andeljat. – 304 p. (in Ukrainian).

26. **Закон України** «Про відходи» ВВР, 1998, № 36-37. – 20 с.

27. **Національна стратегія поводження з ТПВ в Україні**: Звіт про існуючу ситуацію в секторі та стратегічні питання / Державний комітет України з питань житлово-комунального господарства; № 59219 R1. – К., 2004. – 220 с.

28. **Постанова Кабінету Міністрів України** від 4 березня 2004 року № 265 “Про затвердження Програми поводження з твердими побутовими відходами”. – 126 с.

29. **Регіональна програма поводження з відходами** на 2004-2010 роки / Рішення виконавчого комітету Рівненської міської ради від 9 березня 2006 року. – № 1985. – 14 с.

30. **Системи поводження з ТПВ** в українських містах, роль міського населення в роздільному збиранні сміття та рекомендації для органів місцевого самоврядування. – К.: ПРООН/МПВСР, 2011. – 47 с.

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## Аналіз економічної ефективності використання вживаної деревини для виробництва деревинно-стружкових плит для ТОВ «Свиспан Лімітед»

Проаналізовано економічну та еколого-економічну вигоду від використання вживаної деревини (ВЖД). Дано характеристику стану регіональної системи поводження з ВЖД Рівненської області та локальної системи можливого використання ВЖД на ТОВ «Свиспан Лімітед», встановлено необхідність їх формування. Розраховано потенціал ВЖД у залежності від кількості твердих побутових відходів (ТПВ) на прикладі заготівлі її у Рівненській області. Обґрун-

товано, що ВЖД необхідно закупляти у населення за ціною 37,14 грн/м$^3$. Запропоновано упровадити використання ВЖД для виготовлення деревинно-стружкових плит (ДСП), зокрема, на ТОВ «Свиспан Лімітед». Розраховано, що на закупівлю 1 м$^3$ традиційної деревини підприємство несе витрати на 97,97 грн. більші, ніж на ВЖД. Підраховано, що використання підготовленої ВЖД із 100 км зони даної області забезпечить 9,4 % річної потужності підприємства. Доведено, що використання ВЖД у необхідній кількості, як додатка до основної сировини для виробництва ДСП (60 %), дасть економію на ресурсі 1408,76 тис. грн. в рік. Середньорічний дохід на одного найнятого робітника становитиме 32,54 тис. грн. Сума річних відрахувань, зроблених підприємством до позабюджетних соціальних фондів, сягне 150 тис. грн. Встановлено, що використання ВЖД першої та другої категорії, розрахованої для даного регіону у кількості 10,07 тис. т/рік та придатної для ДСП, збереже від вирубування 32 тис. дерев.

**Висновки та пропозиції:**

1. У сучасних умовах еколого-економічної кризи привертають до себе увагу проблеми поводження з ВЖД. На фоні розвитку нових технологій перероблення та утилізації окремих ресурсно-цінних відходів і ВЖД, в цілому, набуває актуальності проблема сировинного забезпечення деревообробних підприємств, зокрема, для виробництва плит. Дослідженнями встановлено, що ВЖД – це, в першу чергу, відходи побутового споживання у твердому агрегатному стані, а поводження з ВЖД – це сукупність операцій, які можна здійснювати стосовно них.
2. Для з'ясування процесу поводження з ВЖД та обґрунтування його функціонування запропоновано поняття „система поводження з ВЖД". Метою існування такої системи є максимальне перероблення утвореного та придатного для певних виробництв обсягу ВЖД, тобто підтримання належного рівня екологічної безпеки у її межах.
3. Виявлено, що системи поводження з ВЖД є одночасно технологічними та економічними системами, у зв'язку з чим пропонується здійснювати їх класифікацію за технологічними та економічними характеристиками, враховуючи також організаційні та екологічні характеристики.
4. Дослідження показали, що в Україні, як і у світовій практиці, домінує метод захоронення ВЖД, яка становить 5 % від ТПВ. Оплата послуг із знешкодження ВЖД здійснюється передусім за місцем їх надання, а з 2001 року впроваджено схему оплати за місцем придбання товарів, що застосовується для використаної тари та упаковки. Розрахунковий потенціал ВЖД на прикладі Рівненської області дозволяє зробити висновок про наявність значних можливостей підвищення рівня використання вторинних ресурсів через залучення до перероблення обсягів утворених ВЖД. Для характеристики рівня розвитку системи поводження з ВЖД пропонується застосовувати показники екологічної, організаційно-технічної та фінансово-економічної стійкості, тенденції зміни яких дозволяють встановити тип розвитку системи. Аналіз рівня розвитку локальної системи поводження з ВЖД для плитного виробництва на ТОВ «Свиспан Лімітед», виконаний за пропонованою методикою, свідчить про прогресивний тип її розвитку та необхідність її розповсюдження на інші регіони.
5. На основі результатів досліджень пропонується концепція вибору варіанту формування регіональної системи поводження з ВЖД, що включає алгоритм прийняття рішення щодо вибору варіанту формування такої системи та методичні засади щодо виконання його окремих етапів, а також концептуальні підходи до залучення необхідних для цього інвестиційних ресурсів. Вони рекомендуються для використання як окремим суб'єктам системи поводження з ВЖД, так і місцевим та регіональним органам самоврядування і державної влади під час розроблення своєї інвестиційної стратегії. Обґрунтування інвестиційної стратегії формування регіональної системи поводження з ВЖД Рівненської області, виконане для перероблення ресурсно-цінних категорій ВЖД. Проекти перероблення ВЖД є комерційно вигідними і можуть реалізуватися із залученням власних коштів підприємств та кредитних ресурсів. Пріоритетність варіантів інвестування у межах кожного напрямку не змінюється з переходом від рівня окремого суб'єкта до рівня системи в цілому, але їх системна ефективність порівняно із суб'єктною зростає через виникнення додаткових економічного та екологічного ефектів.

**Ключові слова:** деревина, вживана деревина, ДСП, тверді побутові відходи, аналіз використання ВЖД, перероблення відходів, поводження з відходами, еколого-економічна ефективність.

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# ENVIRONMENTAL-AND-ECONOMIC ANALYSIS OF THE LIFE CYCLE OF GAS-SUPPLY SERVICE AT NATIONAL UKRAINIAN FORESTRY UNIVERSITY, MADE BY MEANS OF SIMAPRO SOFTWARE

An environmental-and-economic analysis of the life cycle of gas-supply service was made. The degree of environmental impact of gas supply at National Ukrainian Forestry University (UNFU) was determined. Identified here is the ecological index of the gas-supply life cycle, and on the basis of which conclusions were made in regard with environmental footprints occurring in the given process.
**Keywords:** life cycle, of gas supply, SimaPro software, environmental-and-economic analysis.

**Topicality of the subject matter.** Every product or service covers a series of stages in its development, the totality of which constituents a life cycle of this product or service. Human activity when engaged in the process of manufacturing products or providing services, inevitably involves environmental impacts [9]. Depending on the nature of the product or service, the environmental impact may be manifested in different ways, e.g. ozone layer depletion, greenhouse effect, soil acidification, biodiversity loss etc. The planet of Earth is a closed system of material flows (unlike energy flows) [5]. By moving from one product into another and changing in so doing the form of its state, matter is cycling in an economic system [7]. It is because of this that the total mass of matter remains constant irrespective of the type of product or service humans produce.

In modern socio-economic environment, the material flows and processes are occurring according to a linear manner. But in their moving through time, the materials that have passed through the technosphere, are coming back to the environment as raw materials [1]. The concept of life cycle considers products/ services from the beginning of their origin to the moment when they cease their functioning. The life cycle (Fig. 1) includes the constituents such as raw material extraction, power production, transportation, primary processing operations, direct product manufacturing, packing, distribution, utilization [2].

It should be noted that the life cycle of one product / service becomes more complicated because many of their components are connected with the systems of other products / services [6]. Thus, in order to choose the best environmentally acceptable way of product manufacturing or service rendering, a number of socio-economic factors which embrace the whole life cycle, should be taken into account. This means involving a systemic approach to planning and designing processes.

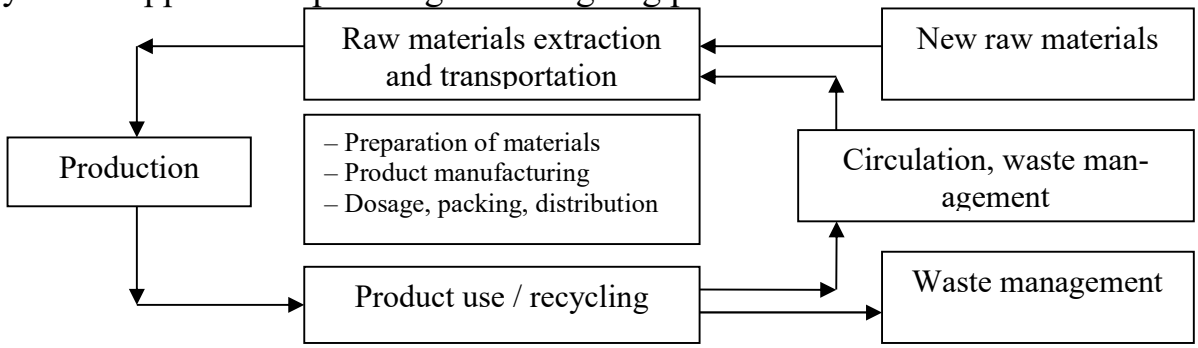


***Fig. 1. Life cycle stages of the product with partial recycling of raw materials and materials*** [3]

**Problem formulation.** The objective of the investigation is determining environmental-and-economic impacts of the gas-supply service life cycle at UNFU.

**Presentation of the basic facts.** SimaPro software is a professional tool for collecting, analysing, and monitoring ecological characteristics of products and services. With such a tool, it is easy to simulate and analyse complex life cycles in a systemized and clear way [8]. In order to analyse environmental impacts of the gas supply during its "life cycle" (Fig. 2), necessary data were grouped, namely, main materials that are needed to accomplish gas supply to the buildings and hostels of the University, the completing parts for every constituent of raw materials and materials which are considered as input, and the processes such as transportation, direct heating – everything that accompanies the life cycle of the product (output). For the sake of convenience, all the constituents of the gas-supply process were grouped into two groups: needed natural resources (gas, mineral resources), and technical and technological equipment.

Little by little the program was further enriched by data on some separate parts of the gas-supply process with indication of constituent materials, components and processes involved. The SimaPro software enables to analyse products including scenarios of waste management which can be modeled independently according to the product / service chosen. The life cycle may contain only one scenario of wastes management or one scenario of wastes burial. In our case, the scenarios were not chosen since the wastes were greenhouse gases whose physical nature does not allow for modeling scenarios of management them. However, we have predicted measures to be taken for energy conservation, which will reduce gas consumption and, consequently, will result in the reduction of the greenhouse gases emission. After completing data input, the tree of processes is built in order to reveal weak points of the analysis (Fig. 2). The red lines (or thermometres) indicate the loading on the environment that takes place in every process.

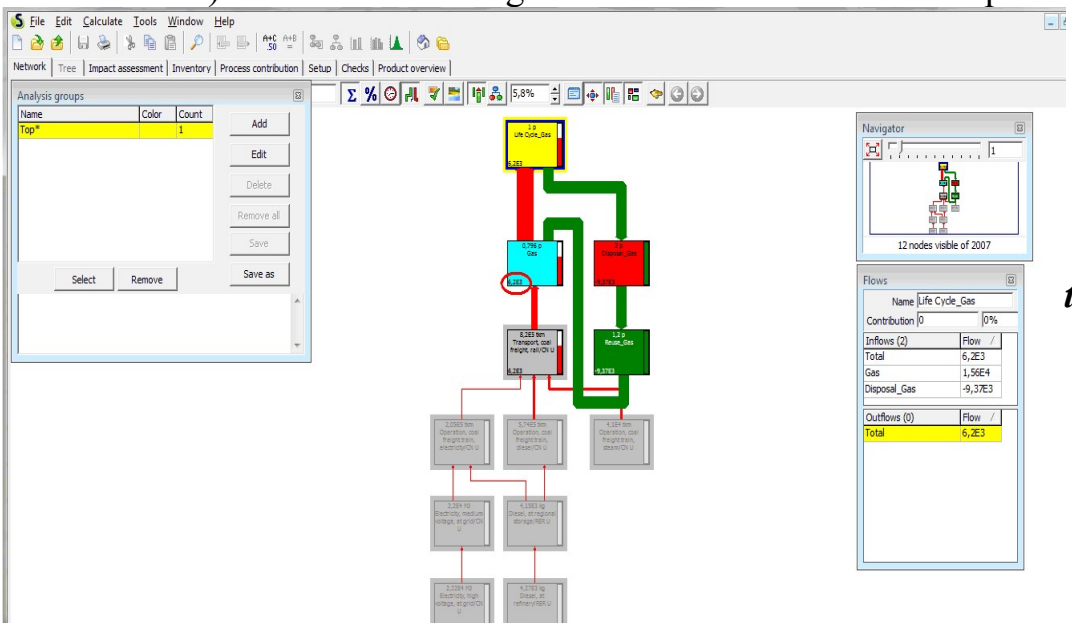


***Fig. 2. Tree of processes of the gas supply to the buildings and hostels of UNFU***

This is a very useful feature of the program that makes it possible to distinguish between important and less important processes (to reveal "hot points"). In our case the "hot points" are heat losses due to poor compactness of the window and door frames, lack of the wall heat insulation, and other factors that are associated with heat loss, also long distance transportation of gas from the source to the consumer leads to gas losses. A considerable amount of energy is lost on the way to the consumer which results from lack of heat insulation. Fig. 2 enables to trace also clear positive tendency – a reasona-

ble use of heating energy and proper heat insulation of the structural materials, which results in a positive ecological effect, that is economical use of natural resources.

In the above Fig. 2, the thickness of the line reflects the process loading on the environment according to the Eco-indicator 99 system. The figure also contains the integrated index: ecological index (it is circled in red). It is possible to turn on or turn off the function by using appropriate buttons, and express it in percentage or eco-points.

Thus, we have obtained a comprehensive Life-cycle picture of the gas-supply process and by pressing the button of the tree or network, we will be able to see the scenarios of the service life cycle completion. The tree is too branched to see all the processes on the screen simultaneously. However, by using context menu, we will be able, due to different colouration, to trace clearly: separate constituents of the service (blue colour), life cycle (yellow colour), and the part assigned for wastes: their spreading or treating (red colour). The tree construction having been completed, we made an analysis of the environmental impact assessment. The analysis procedure consisted of five elements: characterization; damage assessment; normalization; weighting; ecological index determination. The next step was an extension of the life-cycle analysis on the basis of characterization. These are groups of inputs and outputs which are distributed amongst eleven categories of impact in accordance with the Eco-indicator 99 methodology. The characterization points to the intensity of undesirable impacts of the gas-supply life cycle, the contribution of which is to be identified as specific share of: carcinogens, respiratory substances, climate change, radiation, impact on the ozone layer, eco-toxicity, fossil fuels, land-use changes, minerals, acidification / eutrophication (Fig. 3). All the negative values represent preventive measures against hazardous waste discharge, therefore the given values point to positive and environmentally friendly processes, that is, they indicate that the pollutants are trapped or not discharged in great amounts.

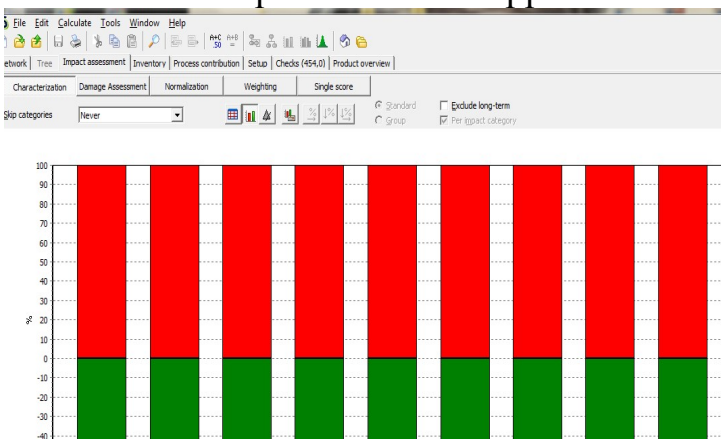


***Fig. 3. Assessment of the life cycle of gas-supply process***

The aggregation of category data is used in environmental models for comparing different contributions to the same environmental problems. This task can be performed by means of factors equivalency provided by models (Fig. 4). Fig. 4 shows characteristic features of the gas-supply service specificity as well as scenarios of formation and spread of wastes generated by this service. This points to the fact that in some impact categories, the dominant factor is transportation while at the end of the life cycle, dominant are other factors, all the impacts are presented on a 100%-scale. The colours indicate the contribution of the service and associated wastes. As is seen from the above diagrams, the most negative environmental impacts result from the wastes, that is greenhouse gases emission, accordingly we can observe eco-toxicity and climate change. This is conditioned by the fact that harmfull greenhouse gases emission is accompanied

by accumulation of harmfull substances which eventually reach into the soils, ground and surface waters also causing a considerable pollution of the atmosphere and making a corresponding negative contribution to climate change.

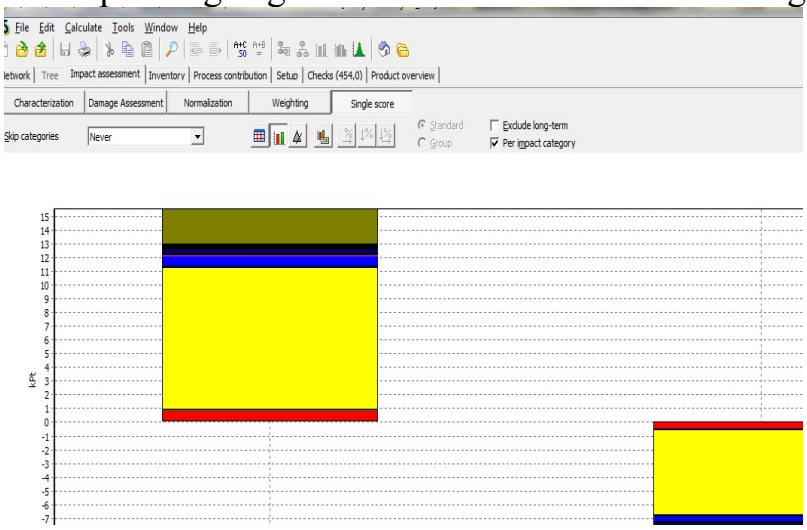


***Fig. 4. Assessment of the life cycle of gas-supply process based on the determination of the ecological index***

In the same fashion, environmental impacts can be assessed at subsequent stages of the analysis: damage assessment; normalization; weighing; ecological index determination. In order to obtain more clear results of the analysis, all the impacts can be grouped into three categories, namely:

- human health: carcinogens; respiratory substances; climate change; radiation; ozone layer; eco-toxicity;
- ecosystem quality: acidification/eutrophication; land use;
- natural resources: minerals; fossil fuels.

As is evident from Fig. 5, the most considerable impact of the gas supply including air pollution, is exerted on natural resources and human health.

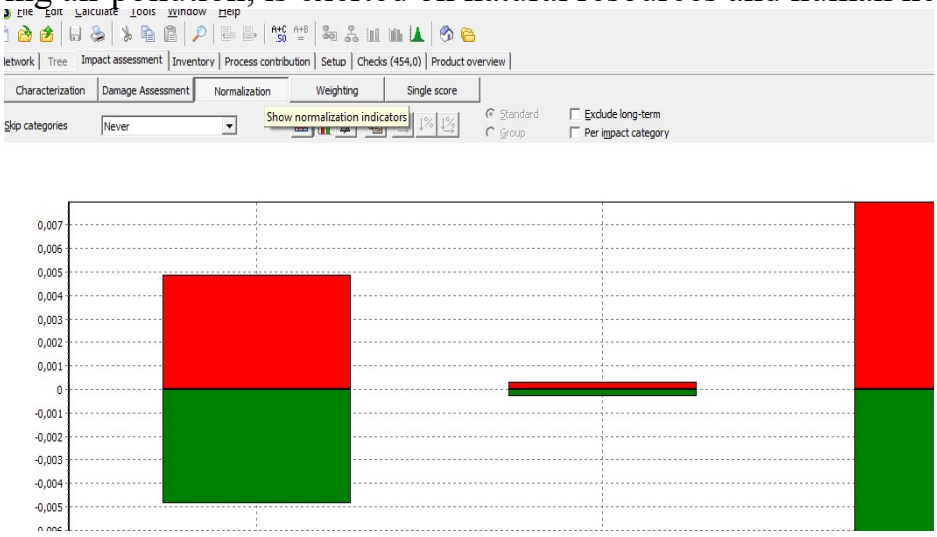


***Fig. 5. Assessment of the life cycle of the gas-supply process according to three combined categories of the environmental impacts***

**Conclusions.** Eco-indicator 99 is one of the methods that allows the use of unified assessment approach for the whole life cycle – the so-called ecological index. This is the sum of all individual eco-points, or partial indexes, for all processes of the life cycle. The calculations are done by way of summing up the results of weighting life-cycle phases. Final results of the whole life cycle impact of the gas-supply process are presented by means of ecological index in Fig. 6.

As is clear from Fig. 6, it is humans who suffer most from the misuse of power resources and greenhouse gases emission, this is evidenced by the yellow and red parts of the diagram that are responsible for carcinogens and other harmfull substances. In this case, the ecological index value makes up 6.7.

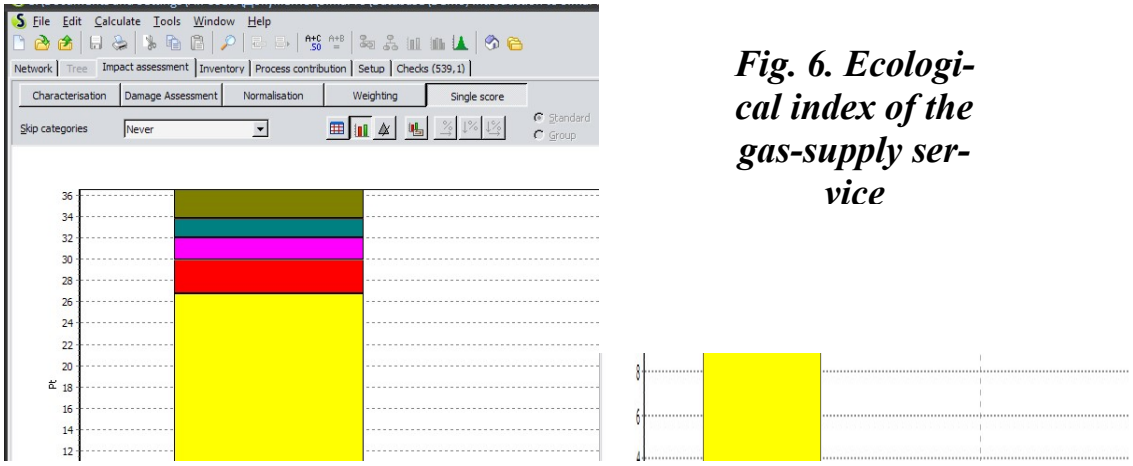


*Fig. 6. Ecological index of the gas-supply service*

In addition, we have made an analysis of the gas-supply process life cycle without regard for the effects of this gas transportation to the consumer as well as energy losses on its way from the supplier to the consumer, the given analysis involved the same categories as for the whole life cycle; the results are presented in Fig. 7. As Fig. 7 shows, the above mentioned process has the most dramatic impact on the spread of respiratory non-organics, the use of fossil fuel, and pertains equally to the climate change and spread of carcinogens.

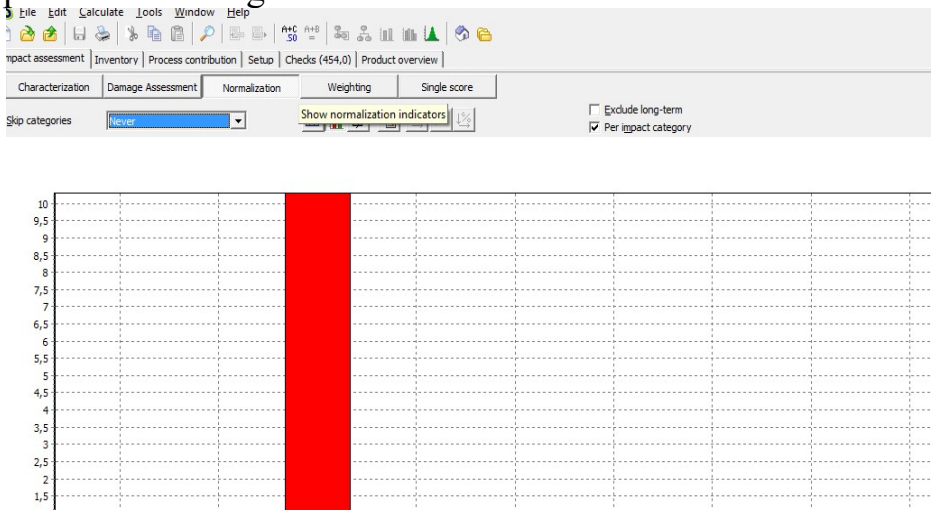


*Fig. 7. Assessment of the impact of the gas-supply process life cycle*

According to the Eco-indicator 99 method, we took the unified assessment approach (as we did for the whole life cycle) to assess part of the life cycle without regard for energy conservation and rational use of natural resources as well as hazardous emission into the atmosphere; the results are presented in Fig. 8.

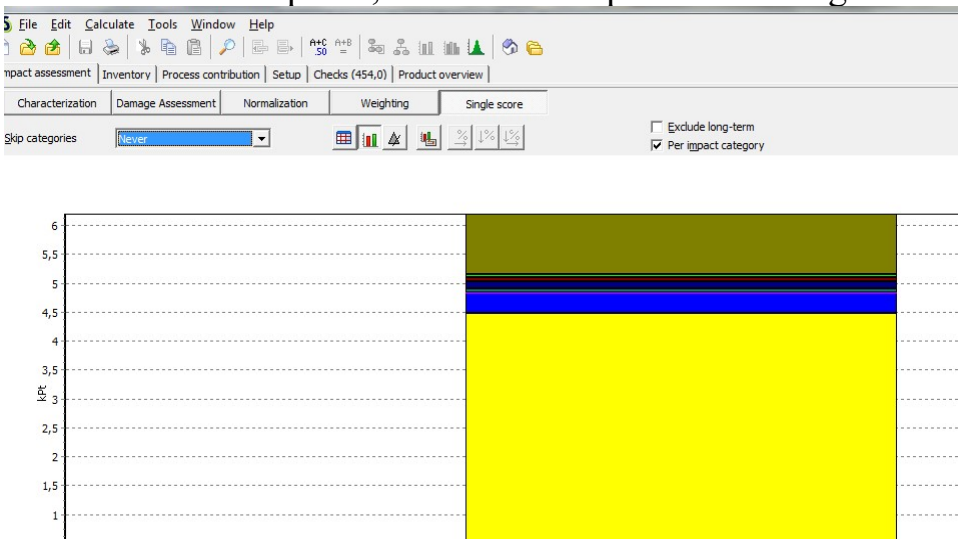


*Fig. 8. Ecological index of the gas-supply service excluding externalities*

Final results including all factors of the gas-supply process with regard for externalities at the input and output of the system are presented in Fig. 9.

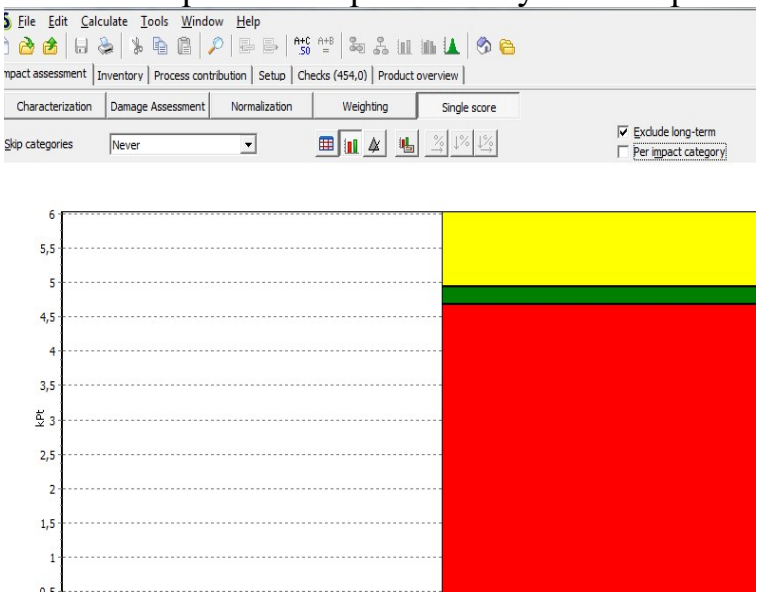


***Fig. 9. Ecological index of the gas-supply service including all externalities***

For this process, environmental footprints that might occur in future, were also taken into account. On the basis of data obtained, we may make conclusions as to further usage of the service in the form as is done today (Fig. 10).

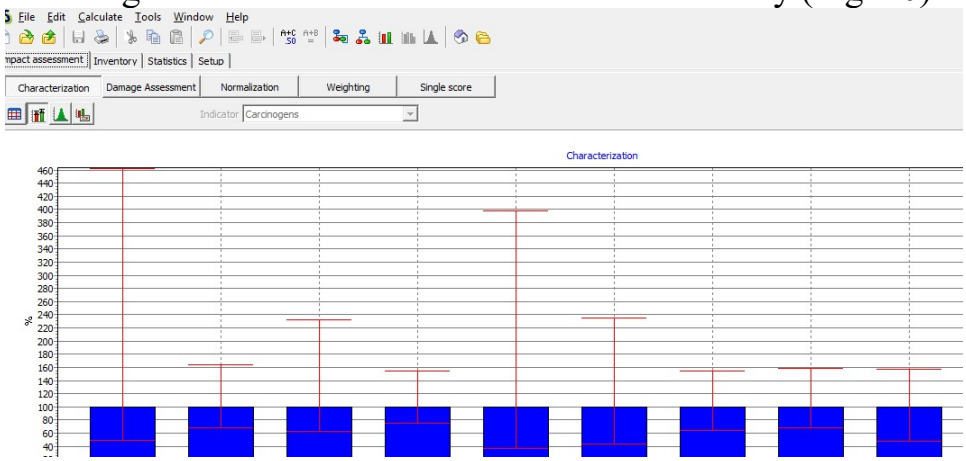


***Fig. 10. Determination of the environmental footprint of the gas-supply service***

The analysis of the environmental impact assessment for the gas-supply service at UNFU during its life cycle was done by means of SimaPro software. The results of the study are presented in the form of environmental impact diagrams, and by determination of the integrated index – ecological index that is measured in eco-points. The index value for the object of the given analysis makes up 6.7.

Evidently, services with lower index value will have less environmental impact. The means for tackling these questions could be provided by considering the processes of energy conservation and proper use of natural resources [4]. The issue of service life cycle has been neglected so far, although it is the research of this kind that could provide efficient tools for solving the problems of energy conservation and sustainable use of natural resources.

## References

1. **Белмане И., Далхаммар К.** Система экологического менеджмента: от теории к практике. – Швеция: Лундский університет, а/я 196, S-221 00 ЛУНД, 2002.

2. **Загвойська Л.Д.** Превентивні стратегії економічного зростання // Стратегія забезпечення сталого розвитку України // Матеріали міжнародної науково-практичної конференції. – К.: НАН України, РВПС України, 2008. – Т1. – С. 73-78.

3. **Максимів Л.І., Дзяма М.В.** Екологічний менеджмент (конспект лекцій). – Львів: НЛТУ України, 2008. – 150 с.
4. **Плепис А., Монт О., Дуркин М.** Экологическое Управление и Более Чистое Производство // Международный Институт Индустриальной Экологической Экономики, Лундский Университет Швеция, 2001.
5. **Скрипчук П.М.** Менеджмент якості довкілля: Монографія. – Рівне: НУВГП, 2006 – 350 с.
6. **Ireneusz Zbicinski, John Stavenuiter, Barbara Kozlowska, Hennie van de Coevering.** Product design and Life Cycle Assessment, The Baltic University Press, Uppsala 2006.
7. **Lindfors L.G., Christianted K., Hoffman L., Virtanen Y., Hanssent O.-J., Roenning A., Ekvall T., Finnveden G.** (eds.) "Nordic Gudelines on Life – Cycle Assement", Nordic Council of Ministers, 1995.
8. **Manual for SimaPro.** [Електронний ресурс] – Доступний з http://www.pre.nl/simapro /simapro_lca-software.htm.
9. **Society of Environmental Toxicology and Chemistry** (SETAC), "A Framework for Life Cycle Assesment", by J.A. Fara, R. Denison, B. Jones, M.A. Curran, B.Vigon, S. Seleke, and J. Barnum, (eds.). Published by SETAC Foundation for Environmental Education, Inc., 1991.

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## Еколого-економічний аналіз життєвого циклу надання послуги газопостачання в НЛТУ України за допомогою програмного забезпечення SimaPro

Здійснено еколого-економічний аналіз життєвого циклу надання послуг газопостачання. Встановлено рівень впливу процесу газопостачання в Національному лісотехнічному університеті України на стан навколишнього природного середовища. Визначено екологічний індекс життєвого циклу газопостачання і на його підставі зроблені висновки щодо екологічних слідів, які мають місце в даному процесі.

**Ключові слова:** життєвий цикл, газопостачання, програмне забезпечення SimaPro, еколого-економічний аналіз.

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UDC 504.03:330.101

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## TAKING INTO ACCOUNT STOCHASTIC FACTORS IN THE GLOBAL ENVIRONMENTAL ECONOMIC MATHEMATICAL MODELS

The necessity of analysis of environmental economic factors for modeling of global processes is motivated. On the basis of improvement of J. Forrester's model, feasibility of taking into account stochastic factors during mathematical modeling of such processes is proposed.

**Keywords:** mathematical model, environmental economics, stochastic factors, system of differential equations.

**Introduction.** The necessity for changing the conventional economic mentality and the need for framing a new environmentally-benign economic conception of the world were first mentioned at the Soviet-American symposium "Economic aspects of the Environmental Protection" (the city of Tsakhkadzor, October 19, 1997) in the report by Yu. Tunytsya "Environmental-and-Economic Assessment of the Production Process as a Factor of the Environmental Protection" There was substantiated the advisability of employing market approach to solving the problem of the Environmental protection and sustainable use of natural resources. The then presented problem of overcoming environmental-and-economic contradictions of the market economy by means of harmonization of interrelations between the human society and nature, has re-

mained up till now a problem of great importance, and the study of inherent basic contradictions between merely economic and environmental requirements is an all-important task to do [5].

**Pre-conditions for problem formulation.** It is well-known that human environment and natural resources constitute physical basis both for economic and environmental systems. But the classic economic system considers natural resources to be the only factor that forms the raw material basis for various sectors of economy whereas the environmental economics of nature use treats this issue as a triune process of use, protection, and reproduction of integrated components of the environmental−and−economic system−the Environment and natural resources. Nature use as well as the whole process of production of material goods is accompanied not only by financial costs but also by environmental impacts: time-and-spatial alterations of the

Environmental quality as well as the quantity and quality of natural resources. These changes may be either of positive or negative character: deterioration of environmental conditions, increase or decrease in the quantity and quality of natural resources. The environmental changes can influence the economic results of material production and non-material sphere; therefore environmental costs (aggregate expenditures and losses both in the sphere of nature use and nature conservation as well as economic activity in general) need to be taken into consideration, these costs are inevitably to be growing up. Appropriate compensation costs for recovering high-quality environmental conditions should be in keeping with the intensity level of natural resources use and the Environmental pollution. The understanding and realization of this fact will make it possible to keep balance between the ecological and economic systems as well as to ensure a steady socio-economic progress of the human society; on the other hand, disregard for these facts may result in degraded quality of the Environment, natural resources depletion, needs for additional environmental costs, possible environmental losses and in the long run to the slowdown of socio-economic development if it does not cease at all [6-18]. Thus, the severity of the problem is in the fact that market economy ruins Nature while Nature destruction ruins the economy itself. The absence of the environmental component in the classic economic system can be explained by the fact that the considerable part of environmental impacts from economic activity is not subject to accurate economic assessment [1].

**Mathematical model.** Hence, further socio-economic advance of the society is impossible without solving the present-day environmental problems. The existing natural systems are rather resilient and robust, however, these qualities of theirs may not be long lasting. At the early stages of the society's development, effects of human activity on the Environment were insignificant and did not produce any marked changes to the Environment, but today's anthropogenic pressure is so intense that humans cannot afford to neglect (as it was before) its adverse effects. The extent of human impact on various components of the biosphere is increasing year after year, and these results in changes of vitally important parameters of the Environment. Accordingly, the construction of environmental-and-economic mathematical models of the global development of the modern world is a pressing task to do [2]. The difficulties of such modeling involve an adequate reflection of environmental and economic laws, a full set of statistics data, the resolution of the issues of allowing for functional extrapolation and other similar problems [3].

One of the first attempts of such economic-and-environmental modeling was Forrester model [7] that contains five time-variable parameters: P – Earth's population size, V – productive capital (capital assets), S – share of agricultural capital in the total productive capital, R – non-renewable natural resources, Z – environmental pollution. These parameters determine 20 specific functions that describe the interaction of the most important economic-and environmental factors of the society's development.

1) Change in the population size. Reflects the balance between birth-rate B and death-rate (with consideration for the main demographic characteristics)

$$\frac{dP}{dt} = B - D = f_1(B, D). \quad (1)$$

2) Differential equation for a decrease in non-renewable natural resources

$$\frac{dR}{dt} = -PR_M = f_2(P,V,S,M_S,E_R). \quad (2)$$

It is believed that natural resources are depleted at the rate which is proportional to population size growth and to a certain factor $R_M$ that takes into account the slowdown of resources extraction rates with a rise of living standards' $M_S$. This dependence is related to natural resources use, namely for manufacturing consumer goods the demand for which is asymptotically approaching saturation as the population's standard of living $M_S$ rises. In its turn, Ms is expressed through the parameters $P$, $V$, $S$ and the function $E_R(R_R)$ which reflects the increase in the cost of mineral resources extraction as their supplies decrease.

3) The dynamics of capital investment is described by the equation

$$\frac{dV}{dt} = PC_V V_M(M_S) - \frac{V}{T_V} = f_3(P,M_S,C_V,T_V). \quad (3)$$

The function $V_M(M_S)$ describes the growth of the population's financial resources investments into production as a result of rising living standards $M_S$; constants $C_V$ and $T_V$ are the coefficients identified on the basis of study of investment processes and the processes of capital consumption (depreciation).

4) The dynamics of agricultural capital

$$\frac{dS}{dt} = \frac{S_F S_Q - S}{T_S} = f_4(S_F,F_R,S_Q,Z,T_S) \quad (4)$$

is described by the functions: $S_F$ – impact of nourishment level $F_R$ on the amount of agricultural capital; $T_S$ – the length of time required for reallocation of capital; $S_Q$ – relationship between agricultural capital and quality of life. In its turn, the quality of life is determined by the living standards $M_S$, the amount of food stuff per capita, population density, and the environmental pollution level *Z*.

5) The dynamics of population is modeled by the equation

$$\frac{dZ}{dt} = PZ_N Z_V - \frac{Z}{T_Z} = f_5(P,Z_N,V_R,T_Z). \quad (5)$$

The first item describes generation of pollution and is proportional to the population size *P*, constant $Z_N$ which refers to normal pollution level, and the function $Z_V(V_R)$ – the rate of the environmental pollution with an increase of marginal capital. The second item characterizes the process of natural decomposition of pollutants $T_Z$, and identifies the length of time required for an n-fold decrease of the pollution index providing no fresh portion of pollutants is added.

**Consideration for stochasticity in mathematical modeling.** Since time change in the major portion of parameters that appear in the differential equations (1)-(5), is of random character, this mathematical model can be improved. Enter the stochastic coefficients $\gamma_i$, that express the probability for corresponding phenomena (processes) to appear. In so doing we assume that $0 \le \gamma_i \le 1$, $(i = \overline{1,5})$. The boundary value $\gamma_i$=0 corresponds to the unfeasibility of the process while $\gamma_i$=1 – shows the certainty of its occurrence. The relations so modified produce a system of differential equations, which is the stochastic model of global development ……

$$\ldots \begin{cases} \frac{dP}{dt} = \gamma_1 f_1(B,D) \\ \frac{dR}{dt} = \gamma_2 f_2(P,V,S,M_S,E_R) \\ \frac{dV}{dt} = \gamma_3 f_3(P,M_S,C_V,T_V) \\ \frac{dS}{dt} = \gamma_4 f_4(S_F,F_R,S_Q,Z,T_S) \\ \frac{dZ}{dt} = \gamma_5 f_5(P,Z_N,V_R,T_Z) \end{cases} \ldots\ldots\ldots \quad (6)$$

Changes in Forrester function's behavior at different values of stochastic coefficients are presented in Fig. 1.

The data to determine functional relations between the system's parameters are averaged data of the world's statistics. For boundary values $\gamma_i = 1, \left(i = \overline{1,5}\right)$ we obtain (Fig. 2) the analog of Forrester model curves [7]. All the curves have well-defined peaks (the living standards curve approximately in 1960, the population size curve – in 2020, capital investments – in 2040, the environmental pollution level – 2050).

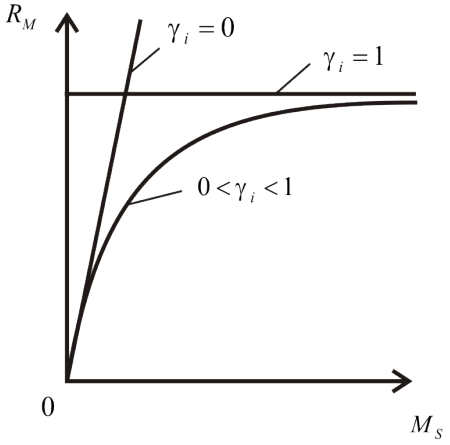


***Fig. 1. Forrester function with consideration for stochasticity***

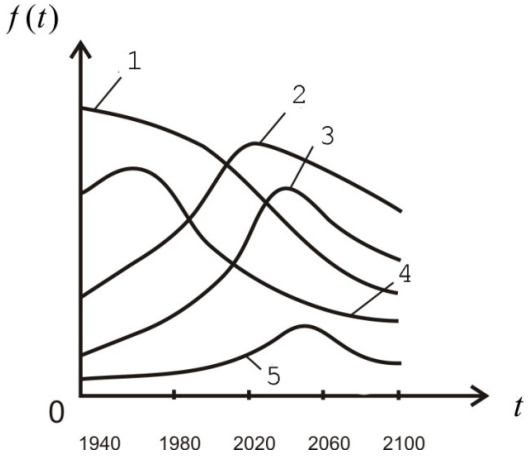


***Fig. 2. Predicted trends of the world's development*** *(1 – natural resources, 2 – population, 3 – capital investments, 4 – living standards level, 5 – pollution level)*

**Conclusions.** The decrease in the amount of natural resources supplies causes industrial decline: an increase in the cost of raw materials, due to the depletion of their supplies, slows down the growth of capital investments and results in contraction of production. This has an effect on the living standards level, the impairment of which first leads to slower rates of its growth, and later on to a decrease in the population size. Thus, the society with market economy is facing the necessity of changing its mode of life and to adapt itself to the reproductive capacity of natural ecosystems. Important though the economic goals may seem, they are leveled by environmental problems. The contemporary society for the sake of its health and life must have a new goal – environmental standard with economic restrictions [4].

## References


1. **Burkynskyi B.V.** Environmental imperative of market economics. Preface to the book «Yu.Tunytsya. Ecoeconomics and market: overcome of contradictions». Kyiv, 2006. P. 9-19. (in Ukr.).
2. **Lyashenko I.M., Korobova M.V., Stolyar A.M.** The base of mathematical modeling of economic, environmental and social processes. –Navchal'na knyha – Bogdan, 2006. – 304 pp. (in Ukr.).
3. **Onyshkevych V.M., Holyavka V.Z., Gapalyak Ch.O.** Mathematical modeling of ecological processes by means of system of linear differential equations. Scientific herald of UNFU: Collection of scientific technical works. – L'viv: UNFU. – 2011. – Vol. 21.6. – P. 330-334. (in Ukr.).
4. **Reymers N.F.** Ecology: theories, laws, rules, principles and hypotheses. – M.: Rossiya molodaya, 1994. – 367 pp**.** (in Russ.).
5. **Tunytsya Yu.Yu.** Ecoeconomics and market: overcome of contradictions. – K.: Znannya, 2006. – 314 pp. (in Ukr.).
6. Success – in balance of environmental and economic systems. Editor's article // Herald of National academy of science of Ukraine, 2003. – № 12. – P. 3-6. (in Ukr.).
7. **Forrester Jay W.** World dynamics, 1973. Waltham, MA: Pegasus Communications. – 144.
8. **Gayda S.V.** A problem of wood raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2007, 33:55-63. (in Ukr.).
9. **Gayda S.V.** Research of concentration of operations is in modern furniture Productsion // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2007, 33:73-79. (in Ukr.).

10. **Gayda S.V., Maksymiv V.M.** From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. – Lviv: 2010, 36:57-77.

11. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2008, 34:55-68. (in Ukr.).

12. **Gayda S.V.** Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood / Forestry, Forest, Paper and Woodworking Industry, 2008, 34:68-79. (in Ukr.).

13. **Gayda S.V.** Comparative analysis of bending particularities for various post-consumer wood species and age categories // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:84-88. (in Ukr.).

14. **Gayda S.V., Voronovich V.V.** Investigation of the features of bending of post-consumer wood // Proceedings of the Conference, Mari State University, – 2011, 190-192 (in Russian).

15. **Gayda S.V.** Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2009, 35:63-83.

16. **Gayda S.V.** A comparative analysis of physical-and mechanical parameters of variously-designed Glued Boards made of post-consumer Recovered Wood / Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2010, 36:81-91.

17. **Gayda S.V.** The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. – Lviv: UNFU. – 2009, 19.14:72-89. (in Ukr.).

18. **Gayda S.V.** Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:238-244. (in Ukr.).

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## Урахування стохастичності в глобальних еколого-економічних математичних моделях

Проаналізовано передумови врахування еколого-економічних суперечностей при математичному моделюванні глобальних процесів. З'ясовано потребу в прогнозуванні впливу екологічного ефекту на економічні результати матеріального виробництва і невиробничої сфери. Оскільки закони зміни функцій, що відображають взаємозв'язок найважливіших економіко-екологічних чинників розвитку суспільства, мають випадковий характер, запропоновано враховувати фактор стохастичності при математичному моделюванні таких процесів. На основі моделі Дж. Форрестера введено у відповідні диференціальні рівняння деякі стохастичні коефіцієнти, які характеризують імовірності проходження певних процесів та явищ. Модифіковані таким чином співвідношення утворюють систему лінійних диференціальних рівнянь першого порядку, яку запропоновано вважати стохастичною моделлю глобального розвитку. В часткових випадках при граничних значеннях стохастичних коефіцієнтів отримано аналог кривих моделі Дж. Форрестера. Зроблено висновки щодо прогнозованих тенденцій розвитку світу, наведено відповідні графіки.

**Ключові слова:** математична модель, екологічна економіка, стохастичні фактори, система диференціальних рівнянь.

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## THE ASSESSMENT OF PROSPECTIVE APPLICATION OF MODERN LOGGING TECHNOLOGIES AND MACHINERY, BASED ON THE TECHNIQUES OF CALCULATING OPERATING COSTS

Successful development of Ukraine's forest sector is intimately associated with the improvement of logging operations efficiency. The current logging technologies and machinery, however, cannot be taken as being satisfactory in the field. The world's modern practice is ever increasing focus on the short-log method of logging which has a number of advantages. The proposed methodological approach to calculating operational costs when using promissing logging techniques and machinery in the short-log method, may find wide use under conditions of Ukrainian forest management units.

**Keywords:** technological process, machinery, operating costs, calculation, production efficiency.

The last few years have witnessed an intensive search for the proper ways of Ukraine's forest sector development as well as looking for means for overcoming crisis processes of its functioning. The majority of professionals are of the opinion that one of the lines for enhancing the efficiency of logging operations is the improvement of their technologies. Ukraine's forest sector is characterized by a variety of logging techniques and machinery but none of these can be definitely considered as being optimum. Although the tree-length method of logging prevailed in the recent past, its present-day share is rapidly decreasing.

The choice of a logging method and appropriate machinery depends on many various factors, namely, on the natural and climatic conditions, availability of skilled manpower, the level of working environment organization, safety at work (accident prevention), and the environmental conditions, but primarily on the efficiency of the machinery used and the level of operating costs. Generally, mechanized systems of logging operations provide for a high productivity but this requires high capital expenditures. This is why the calculation of operating costs for logging machinery is one of the key constituents of the procedure for comparison of how efficient are different logging methods and types of machinery [1-14]. Amongst the environmental and production factors that influence the choice of logging methods and logging machinery, the operating conditions of the cutting area as well as ground-and-terrain conditions should be considered first. In particular, the operating conditions of a cutting area include the species and age composition of the forest stands, merchantable timber output, standing volume per hectar, the average stem volume, the average felling area, the distance between cutting areas, the distance to consumer destination. The research we have done, was based on the elaborated methodological approach, the core of which is the calculation of costs when employing prospective logging machinery in the short-log method, which could have a considerable practical implementation under Ukrainian conditions of logging operations [2, 3, 4].

The production process of a logging operation consists of the core production process and the process of handling and support of the core production process.

The core production process contains a number of stages: felling operations; hauling operations; terminal operations. The handling-support process (preparatory and handling operations) includes: repair and maintenance of the machinery and equipment; building of main logging roads, branch roads, and spur roads; reforestation activities. Recent trends are toward increasing transfer of production functions to legal contracting companies. In addition to providing services such as logging operations (e.g. State Enterprise (SE) "Stryi forest management unit"), a common practice is involving contractors for performing operations such as silvicultural practices, timber extraction, building and reconstruction of logging roads, equipment repair (e.g. SE "Skoliv forest management unit", SE "Brody forest management unit").

The short-log method of logging makes it possible to sell roundwood on franko-upper landing terms (that is directly from the cutblock), in this case the number of operations performed by the loggers themselves can be reduced to one operation: tree felling. It shoud be noted that the development of the contracting system in the area of logging (namely, dealing with small mechanized teams that were registered according to the simplified taxation system) is not favoured because of changes in the tax legislation.

All these changes in the technologies, organizational and operational structure of logging activity call for the necessity of improving managerial prime costs accounting and, in particular, preparing a calculation of costs in the framework of a separate stage of logging operations, for a certain type of logging machinery and equipment.

The order of calculating operating costs for a piece of logging machinery is done in accordance with the following procedure:

**Step 1.** Calculating start-up technical-and-economic indicators of the machinery operation:

- general evaluation of usage potential of one or other type of machinery with consideration for the annual cut and specific environmental-and-operating conditions (done in case of planned purchase of new machinery).

- making a choice of the machine versions and/or machine system for the comparison purpose. This may be comparison of the basic version and new versions or just the comparison of various new versions.
- estimation of expenses needed for purchasing machinery of various types.
- calculating effective working time of the machines. determination of performance of basic and new machinery or various versions of new machinery per machine-hour, per machine-shift, per year.

**Step 2.** Calculating machinery operating expenses and making-up costing, comparison of versions, making a choice of the optimum version:

- calculating production costs in terms of cost types for machine-hour, and for the annual output;
- comparison of basic version of machinery with new ones (collection and generalization of data on actual costs for the operation of basic version machinery in terms of cost types);
- production costs estimation according to various versions of new machinery;
- comparison of machinery basic versions with new ones (calculating production actual costs);
- summary tabulation of costs according to various versions of logging machines.

**Step 3.** Comparison of costs according to various models of machinery or logging methods, factor analysis of them – tabulation of costs according to various versions of machinery (methods) (tables 1 and 2).

**Table 1. Calculation of actual costs for harvesters under conditions of final clear cutting in Ukraine**

| Indicators | John Deere 1270D | Kobelco SK 135 | Kobelco SK 170 | Timberjack 1270 | Timberjack 1270 | Volvo EC 210 |
|---|---|---|---|---|---|---|
| Annual fund of working time, days | 249 | 249 | 249 | 249 | 249 | 249 |
| Coefficient of time shift work | 3 | 2 | 4 | 4 | 4 | 4 |
| Annual fund of working time, hours | 3600 | 2499 | 4800 | 4800 | 4800 | 4800 |
| Planned fund of effective working time, hours | 3240 | 2280 | 4560 | 4560 | 4560 | 4560 |
| **Actual effective working time, hours** | **3204** | **1301** | **3245** | **3385** | **2354** | **2272** |
| Planned coefficient of machine use | 0,9 | 0,9 | 1,0 | 1,0 | 1,0 | 1,0 |
| Actual coefficient of machine use | 0,8 | 0,5 | 0,8 | 0,8 | 0,4 | 0,5 |
| Acquisition cost of machinery, thousand of UAH | 2972 | 1485 | 1441 | 2834 | 2979 | 2404 |
| Lease term, years | - | - | - | - | - | 3 |
| **Actual production per machine a year, m³** | **31066** | **18600** | **29714** | **36901** | **40714** | **36007** |
| Actual productivity of machinery, m³ per year | 9,7 | 14,3 | 9,2 | 10,9 | 17,3 | 15,9 |
| Lease payments, thousand UAH/year | 0 | 0 | 0 | 0 | 0 | 801,6 |
| Fixed costs (depreciation etc.) thousand UAH/year | 823,9 | 547,9 | 535,8 | 1051,6 | 1084,3 | 875,0 |
| Variable costs (fuel and lubricants, repair, spare parts etc) including costs for fuel and lubricants | 835,6<br>229,6 | 562,7<br>185,9 | 622,9<br>195,9 | 1190,1<br>189,5 | 828,2<br>174,5 | 666,8<br>237,5 |
| **Total costs, thousand UAH/year** | **1659,6** | **1110,7** | **1158,7** | **2241,7** | **1912,5** | **1541,8** |
| **Costs per m³, UAH** | **53,4** | **59,7** | **38,9** | **60,8** | **46,9** | **42,8** |
| **Costs per machine-year, UAH** | **517,9** | **853,7** | **357,1** | **662,2** | **812,4** | **678,6** |

Reference data for performing the calculations of actual costs and their comparison were based on the statistics data for operation of harvesters (John Deere 1270 D, Kobelco SK 135, Kobelco SK 170, Timberjack 1270, Volvo EC 210) and forwarders (John Deere 1010 D, Timberjack 1010 D, Timberjack 1110, Deere John 1410 D) in final clear cutting in Finland, Sweden, and Russia [2, 3, 4].

**Table 2. Calculation of actual costs for forwarders under conditions of final clear cuttings in Ukraine**

| Indicators | John Deere 1270D | Kobelco SK 135 | Kobelco SK 170 | Timberjack 1270 | Timberjack 1270 | Volvo EC 210 |
|---|---|---|---|---|---|---|
| Annual fund of working time, days | 249 | 249 | 249 | 249 | 249 | 249 |
| Coefficient of time shift work | 3 | 3 | 3 | 4 | 3 | 3 |
| Annual fund of working time, hours | 3600 | 3600 | 3600 | 4800 | 3600 | 3600 |
| Planned fund of effective working time, hours | 3240 | 3240 | 3240 | 4560 | 3240 | 3240 |
| **Actual effective working time, hours** | **2723** | **2468** | **2482** | **4577** | **3272** | **2277** |
| Planned coefficient of machine use | 0,90 | 0,90 | 0,90 | 0,95 | 0,90 | 0,90 |
| Actual coefficient of machine use | 0,84 | 0,86 | 0,67 | 0,51 | 0,72 | 0,67 |
| Acquisition cost of machinery, thousand of UAH | 1934,7 | 1818,5 | 1858,9 | 1755,6 | 2064,3 | 2261,3 |
| Lease term, years | - | - | - | - | 3 | 3 |
| **Actual production per machine a year, m³** | **21839** | **19280** | **29658** | **59551** | **40714** | **36007** |
| Actual productivity of machinery, m³ per year | 8,0 | 7,8 | 12,0 | 13,0 | 12,4 | 15,8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lease payments, thousand UAH/year | 0 | 0 | 0 | 0 | 688,1 | 753,8 |
| Fixed costs (depreciation etc.) thousand UAH/year | 532,5 | 413,5 | 512,8 | 512,0 | 799,2 | 825,2 |
| Variable costs (fuel and lubricants, repair, spare parts etc) including costs for fuel and lubricants | 419,9<br>154,5 | 632,4<br>169,6 | 497,4<br>171,2 | 1022,1<br>189,2 | 1532,9<br>348,7 | 676,5<br>270,3 |
| **Total costs, thousand UAH/year** | **1024,4** | **1045,9** | **1010,2** | **1534,1** | **2332,1** | **1501,7** |
| **Costs per m³, UAH** | **46,9** | **54,2** | **34,1** | **25,8** | **57,2** | **41,7** |
| **Costs per machine-year, UAH** | **376,2** | **423,8** | **407,0** | **335,2** | **712,7** | **659,5** |

The research we have done, shows that modern logging technologies and machinery used in the short-log method, hold much promise for final cuttings of available timber volumes of Ukraine's State Agency of Forest Resources/

## References


1. **Сюнёв В.С. и др.** Опыт сравнительных исследований различных технологий лесосечных работ в условиях лесозаготовительных компаний Карелии // Лес и бизнес. – 2008, 5(45):50-56.
2. **Сюнёв В.С. и др.** Сравнение технологий лесосечных работ в лесозаготовительных компаниях Республики Карелия : монография. – Йоэнсуу : НИИ леса Финляндии, 2008. – 127 с.
3. **Герасимов Ю.Ю. и др.** Расчет эксплуатационных затрат лесосечных работ. – Йоєнсуу : НИИ леса Финляндии, 2009. – 46 с.
4. **Шкіря Т.М.** Технологія і машини лісосічних робіт. – Львів : Тріада плюс, 2003. – 352 с.
5. **Гайда С.В., Максимів В.М.** Аналіз, особливості, проблеми та досвід використання додаткових ресурсів сировини – відходів та вживаної деревини / Ліс. госп-во, ліс., папер. та деревооб. пром-сть / наук.-техн. зб. – Львів: НЛТУ України. – 2007, 33:63-72.
6. **Гайда С.В.** Дослідження концентрації операцій у сучасному меблевому виробництві / Ліс. госп-во, ліс., папер. та деревооб. пром-сть. – Львів: НЛТУУ. – 2007, 33:73-79.
7. **Гайда С.В.** Гнучкі автоматизовані виробництва та робототехніка в деревообробці: Основи створення ГАВ. – Львів: ВМС. – 1998, – 149 с.
8. **Гайда С.В.** Матеріали для виготовлення виробів з деревини.– Львів:ВМС.– 2000.– 160 с.
9. **Гайда С.В.** Раціональне конструювання виробів з деревини. – Львів:ВМС. – 2001. – 93 с.
10. **Гайда С.В., Кшивецький Б.Я., Войтович І.Г. Прокопович Б.В.** Тлумачний словник з деревооброблення. – Львів: НЛТУ України. – 2002. – 280 р.
11. **Гайда С.В.** Особливості та перспективи роботизації меблевої промисловості України / Науковий вісник УкрДЛТУ / наук.-техн. зб. – Львів: УкрДЛТУ. – 2002, 12.5:38-40.
12. **Гайда С.В.** Гнучкі автоматизовані виробництва та робототехніка в деревообробці: Основи робототехніки. – Львів: ВМС. – 1998, – 145 с.
13. **Гайда С.В.** Проблема деревної сировини у Європі та Україні / Ліс. госп-во, ліс., папер. та деревооб. пром-сть / наук.-техн. зб. – Львів: НЛТУ України. – 2007, 33:55-63.
14. **Гайда С.В.** Хімічний склад та ступінь забруднення – основа систематизації ВЖД / Ліс. госп-во, ліс., папер. та деревооб. пром-сть, – Львів: НЛТУ України. – 2008, 34:68-79.



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## Методологічний підхід розрахунку експлуатаційних витрат при використанні перспективної лісозаготівельної техніки для сортиментної заготівлі


Встановлено, що успішний розвиток лісопромислового комплексу України нерозривно пов'язаний з підвищенням ефективності лісозаготівель. Обґрунтовано, що технологічні схеми і системи машин, які зараз застосовуються на лісозаготівлі, не можна вважати такими, що відповідають зрослим вимогам у цій царині. Виявлено, що світова практика останніх років все більше зосереджується на сортиментній технології лісозаготівель, що має ряд переваг. Запропоновано, що методологічний підхід розрахунку експлуатаційних витрат при використанні перспективної лісозаготівельної техніки для сортиментної заготівлі може мати широке практичне застосування в умовах українських лісових господарств.



**Ключові слова**: технологічний процес, система машин, експлуатаційні витрати, калькуляція, ефективність виробництва.

UDC 504.064.3 *Competitor M.M. Paslavskyy; assoc. prof. G.G. Grynyk – UNFU*

# THEORETICAL PRINCIPLES OF MONITORING ASSIMILATION APPARATUS CHEMISTRY OF FOREST STANDS

Compared are the limits of maximum permissible concentration (MPC) levels of heavy metals in plants in different countries and proposed program and methodology for determination of heavy metals in forest woody plants. Used and adapted to local conditions relevant European research methodology.

**Keywords:** heavy metals, forest tree species, clark, maximum permissible concentration.

In the early nineteenth century in human history machine-industrial stage of development began, accompanied by the intensification of production, increasing the extraction of minerals, and thus increasing anthropogenic pressure on the environment. Sharply increased pollution by heavy metals (HM), which on the one are hand necessary for the development of plants (if they are called – trace) and on the other hand – in excess of the maximum permissible levels act as toxicants. All elements of natural ecosystems contain a certain number of HM. In the natural (background) a concentration of heavy metals bound in the soil, inaccessible to plants and therefore does not carry the negative impact, moreover, are directly and actively involved in all processes of life.

Balanced chemical composition of living organisms – the main condition for their normal growth and development, and is essential as the shortage and surplus chemicals, including salts HM. Areas of contamination by HM are determined by meteorological, terrain, morfostrukturne and technological conditions. Often anomalies of heavy metal band long axis oriented in submerydial and merydial directions. Concentrations of elements that do not exert direct or indirect impact on the health and hygienic conditions and do not worsen residence, are called maximum permissible concentration.

It should be noted that the MPC pollutants norms in different countries often differ, albeit slightly. In table 1. a value of MPC adopted in the former USSR, Russia, Ukraine, USA and the Netherlands are compared.

In Ukraine, engineering and survey station of agricultural chemicals have data on only six toxic elements – Zn, Cd, Pb, Cu, Cr, Hg, defined as moving their forms in the soil and gross content in vegetable samples. The U.S. Office for quality control of food and medicines (USA-FDA) in 1979 began developing a standard GLP, which has become international and is now widely used around the world.

Russia took almost the same MAC as the former USSR.

In the Netherlands a regulatory framework of concentrations of heavy metals has been developed. Three levels of their content in the soil are established: A – background concentrations, C – concentration, indicating the need for additional research and action, C – threshold concentration, indicating the need for urgent action on cleaning soils.

**Aim:** determination of heavy metals in woody plants, pine, spruce, oak and beech – the main forest species of West Ukraine. To achieve this goal the following tasks are set:

- Organization of a network of permanent test areas of plant communities given the distance and direction from the industrial center, physical, geographical and environmental characteristics and features of human impact;
- The definition of the generic features of some heavy metal accumulation in plants of forest plant communities according to the level of anthropogenic impact;
- The assessment of environmental transformation of vegetation plant communities under the influence of anthropogenic stress.

## Table 1. Comparison of MPC values adopted in the various countries

| Country | Form | Heavy metal | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Va | Mn | Cr | Co | Ni | Cu | Zn | Se | Cd | Hg | Pb | Sc | As |
| № CAS | | 7440-62-2 | 7439-96-5 | 18540-29-9 | 7440-48-2 | 7440-02-0 | 7440-50-8 | 7440-66-6 | | | 7439-97-6 | 7439-92-1 | | 7440-32-2 |
| Clarks of heavy metals in soil, mg/kg by Chernych N.A., Ladonin V.F., 1995 [1] | | 100,0 | 850,0 | 75,0 | 8,0 | 40,0 | 20,0 | 50,0 | 0,01 | 0,5 | 0,02 | 10,0 | 300 | |
| MAC of heavy metals in soil, mg/kg by Chernych N.A., Ladonin V.F., 1995 [1] | | – | 1400,0 | 100,0 | 50,0 | 50,0 | 100,0 | 300,0 | 10,0 | 3,0 | 2,0 | 32,0 | 1000 | |
| Ukraine MAC of heavy metals in soil and plant production, by Kysil' V.I., 1997 [4] | moveable form in soil, mg/kg | | | ≤6 | | | ≤3 | ≤23 | | ≤0,7 | 0 | ≤2 | | |
| | gross contain in plant production, mg/kg dry substance | | | ≤0,3 | | | ≤5 | ≤10 | | ≤0,003 | ≤0,02 | ≤0,5 | | |
| MAC of pollutants in soil, mg/kg [7] | moveble form | – | – | – | | 4,0 | 3,0 | 23,0 | | – | – | 20,0 | | – |
| | gross contain | 150,0 | 1500,0 | 0,05 | | Trace +45,0 | Trace +35,0 | Trace +50,0 | | 3,0 | 2,1 | Trace +20,0 | | 2,0 |
| Typical and unsafe heavy metal soil levels(USA) [2] | Typical Background Levels for Non-Contaminated Soil | | | | | 0,5 to 50 ppm | 1 to 50 ppm | 9 to 125 ppm | 0,1 to 3,9 ppm | 0,1 to 1,0 ppm | | 10 to 70 ppm | | 3 to 12 ppm |
| | Unsafe for Leafy or Root Vegetables** | | | | | >200 ppm | >200 ppm | >200 ppm | >50 ppm | >10 ppm | | >500 ppm | | >50 ppm |
| | Unsafe for Gardens and Children Contact* | | | | | >500 ppm | >500 ppm | >500 ppm | >200 ppm | >50 ppm | | >1,000 ppm | | >200 ppm |
| MPC of pollutants in soil, mg/kg (GOST ГОСТ 3034-84, 3210-85, 42-128-4433-87) [9] | | 150,0 | 1500,0 | 0,05*** | 5,0 | 4,0 | 3,0 | 23,0 | | 1,0 | 2,1 | 20,0 | | |
| Russian Federation MPC in soil [3] | gross contain | 150,0 | 1500,0 | 0,05*** | | | | | | | 2,1 | 32,0 | | 2,0 |
| | moveable form | | | | 5,0 | 4,0 | 3,0 | 23,0 | | | | 6,0 | | |
| The Netherlands Consentration of heavy metals (mg/kg) [6] | Background (A) | | | 100,0 | 20,0 | 50,0 | 50,0 | 200,0 | | 1,0 | 0,3 | 50,0 | | |
| | Adranced (B) | | | 250,0 | 50,0 | 100,0 | 100,0 | 500,0 | | 5,0 | 2,0 | 150,0 | | |
| | Threshold (C) | | | 800,0 | 300,0 | 500,0 | 500,0 | 3000,0 | | 20,0 | 10,0 | 600,0 | | |

* Unsafe levels are general guidelines; actual toxicity will be affected by soil texture, organic matter, and pH; ** $Cr^{+6}$.

**Methods of measurements and observations.** In order to integrate into the European Research Area in the study we are planning to use the methods recommended by the European scientific institutions – namely, the methods of monitoring forest ecosystems recommended by ICP-Forests (International Coordination Program, "Assessment and Monitoring of Air Pollution Effects on Forests") [5].

Forest Monitoring System based on creating a network of permanent test areas (PTA) with the predominant species of pine, spruce, oak and beech (a major forest species of the western region of Ukraine) over a periog of 20 years. Distribution and choice of study reflects the surface structure, species, age and condition of forest ecosystems in accordance with the inventory of forest resources.

PTA is a group of at least 20 trees selected from the managed stands. Central area is designated and trees are numbered. For each surface of the circular area defined variable size: 0.005 hectares of woodlands in the age 21-30 years, 0.01 hectares of plantations in the age 31-40 years, 0.02 hectares of plantations in the age 41-60 years and 0.04 hectares in plantations older 60 years. [8]

In each region than five samples will be selected with predominant stands of trees with an average for PTA defoliation. Trees are numbered. Samples will be taken from the four corners of crown from branches at the top (5-7 rpm) and the outer part. The minimum sample weight – 50 g. In coniferous plantations samples of needles will be taken from each tree representing increments of current and past years.

Chemical analysis of samples will be conducted in the environmental laboratory of the Department of Ecology UNFU. After drying at 105 ° C, samples of leaves will be milled, and then make mineralization "wet" in a mixture of concentrated acids $HNO_3$ and $HClO_4$ by volume 4:1. Tests should include determination of: N, P, K, Ca, Mg and S and B, Fe, Mn, Zn, Al, Pb and Cu. Determination of elements will be performed by emission spectroscopy on the spectrophotometer. Nitrogen will be determined by Kiejdahla method [8].

**Conclusion**. The study of features of the accumulation of HM by forest tree species associated with the need of assessment of biosphere environment and stabilizing features trees that serve as phytofilters to the flow of pollutants into the environment was conducted. Woody plants absorb and truss of atmospheric pollutants, dust particles are trapped, preventing the surrounding area from harmful ekotoksykants.

When selecting trees to create a health-protective plantations and for reclamation of disturbed lands (preference will begiven to) especially those species that are indigenous to the intended place of planting differ by undemanding to growth conditions, highly drought-and frost resistance, characterized by rapid growth, decorative (in the case recreational), resistance to industrial pollutants and their ability to accumulate the maximum salt of HM. However, the ability of plants to accumulate a large number of metals can not act as the sole criterion in (selecting) the assortment of species.

Interaction "HM – plant" complex and multifaceted phenomenon, in which should be considered the peculiarities of penetration of toxicants into the environment, phytotoksyc of pollutant, the corresponding reactions of ingress of toxic ingredients in the environment and plants, as well as many other aspects. The main purpose of the proposed work is study of morphophysiological changes in bioaccumulation of chemical elements in woody plants, identifying features of adaptation and resistance of woody plants in case of polymetallic pollution.

## References

1. **Chernych H.A., Ladonin V.F.** Questions of regulation of heavy metals in soil // Chemistry for agriculture, 1995. – № 10. – P. 10-13.
2. **Electrical resource.** Mode of access : www.al-labs-eastern.com.
3. **Hygiene regulations GN** 2.1.7.2041-06 "Maximum permissible concentration (MPC) of chemicals in the soil", approved by the Chief State Sanitary Doctor of the Russian Federation January 19, 2006.
4. **Kisel' V.I.** Soil contamination with heavy metals // Agroecological assessment of land in Ukraine and placement of crops / ed. V.V. Medvedev. – K.: Agricultural Science, 1997. – P. 114-125.
5. **Manual on Methodologies and criteria for harmonized sampling**, assessment, monitoring and analysis of the effects of air pollution on forest, International Cooperative Programme Effects on Forests, Programme Coordinating Centres, Hamburg and Prague, 1994. – 254 p.
6. **Nevolin V.A.** The reaction of higher plants on the chemical pollution of the environment "// Master's thesis. Ekaterinburg, 2010. – 172 p.
7. **Scientific support for sustainable agricultural development.** Steppes. Kyiv, 2004. 2 vol.
8. **Stan uszkodzenia lasow w Polsce w 2002 roku** na podstawie badan monitoringowych. Redakcja merytoryczna: Jerzy Wawrzoniak, Jadwiga Małachowska. Instytut Badawczy Leśnictwa. Warszawa, 2003. – P. 7-9, 45-51.
9. **Zhelibo Є.P., Chmir A.I., Troyan, VS, Savinov Є.O.** Bezpeka zhyttediyalnosti: Course lektsiy. – Irpin: Akademiya DPS Ukraine, 2001. – 356 p.


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## Теоретичні засади здійснення моніторингу хімізму асиміляційного апарату лісових деревостанів

Порівняно межі ГДК рівня важких металів у рослинах у різних країнах й запропоновано програму та методику визначення важких металів у лісових деревних рослинах. Використано і адаптовано до місцевих умов актуальну європейську методику досліджень.

**Ключові слова:** важкі метали, лісові деревні породи, кларки, гранично допустимі концентрації.

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UDC 658.567

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## MONITORING OF HEAVY METALS POLLUTION OF THE MALEKHIVKA RIVER WATERS

The results of analytical investigation of heavy metals Zn, Cd, Co, Ni, Fe, Mn, Pb, Cu content in waters of the Malekhivka during 2011 year summer period are presented in current paper. The pollutions sources, major elements-pollutants and the features of the pollutants income to the river are determined.

**Keywords:** heavy metals, municipal solid wastes landfill, leachate, acid tars.

The small rivers form water resources, hydro-chemical regime and water quality in middle and great rivers. Also, they create conditions for the landscapes formation of their watershed areas. The resulting action of natural and anthropogenic factors In the conditions of the same landscape reflects faster and more sharply on small rivers. Therefore, the small rivers are especially sensitive to the technogeneous pollution [1].

The Malekhivka river is a typical small river. It is the left tributary of the Poltva river and belongs to the Zahidnyi Bug watershed. The Maleknivka springs from South-

Eastern slopes of the small local watershed Roztochchya [2], where Lviv municipal solid wastes landfill works more then fifty years. From the beginning the river flow through deep flat-bottomed ravine of the oblong in South-Eastern direction ellipse [2]. The ravine is intersected by the parallel channels athwart to Malekhivka course. The river is included to the this channel net and together they are the united reclamation system for the landfill leachate surface flow retention (Fig. 1). Further Malekhivka flows trough Malekhiv and Murovane villages. Finally it flows into Poltva river.


***Fig. 1. Research area map-scheme***

At the beginning of Malekhiv village the nameless stream fall into Malekhivka. Its sourse is located to South from the landfill in deeply incited gullies. At the head of one of them near the edge of the landfill two storage reservoirs of Lviv Oil Refinery acid tars are created. The vicinity of these potentially dangerous technogeneous objects attracts especial attention of mass-media, local population and researchers [2, 3].

In order to estimate the current ecological state of Malekhivka river the analytical determination of the heavy metals concentration in river water, are undertaken in the 2011 year summer period. The heavy metals are the most toxic components of landfill leachate and tars. They are highly conservative in natural environment. The heavy metals interact with living organisms trough the circulation and accumulation in ecosystem components causing negative consequences [4]. The water samples are taken according with [5]. Along whole river coarse from the source up to falling into Poltva river the 13 samples are taken (Fig. 1). Before analysis the water samples are treated by filtration, conservation by concentrated nitric acid (1 % from sample volume) and concentration by evaporation method. The concentration of the heavy metals are determined by atomic-absorption method on spectrophotometer S115M1 in propane-butane flame with ap-

plying of deuterium corrector of nonselective absorption. Determinations were performed in triple replication. At P = 95 % relative error do not exceed 7 %. The results of investigation are presented in Table 1.

**Table 1. Heavy metals content in water of the Malekhivka river**

| Sample nunber | pH | Element concentration, мг/л | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Zn | Cd | Co | Ni | Fe | Mn | Pb | Cu |
| Source from landfill reclamation system | | | | | | | | | |
| 1 | 7,33 | 0,013 | 0,0001 | 0,0007 | 0,0403 | 0,62 | 0,22 | 0,015 | 0,028 |
| 2 | 7,90 | 0,018 | 0,0002 | 0,0010 | 0,0563 | 0,92 | 0,23 | 0,021 | 0,038 |
| 3 | 7,86 | 0,014 | 0,0001 | 0,0007 | 0,0309 | 0,62 | 0,18 | 0,012 | 0,018 |
| Right tributary (Nameless stream) | | | | | | | | | |
| 4 | 6,65 | 0,015 | <0,0003 | 0,008 | 0,007 | 0,027 | 6,3 | 0,004 | 0,003 |
| 5 | 7,58 | 0,007 | <0,0003 | <0, 001 | 0,005 | 0,034 | 0,27 | 0,002 | 0,002 |
| 6 | 8,17 | 0,006 | 0,0001 | 0,0003 | 0,0021 | 0,04 | 0,07 | 0,004 | 0,009 |
| Malekhivka river (Malekhive village) | | | | | | | | | |
| 7 | 7,72 | 0,009 | 0,0001 | 0,0004 | 0,0179 | 0,15 | 0,11 | 0,006 | 0,012 |
| 8 | 7,73 | 0,015 | <0,0003 | <0,001 | 0,005 | 0,048 | 0,068 | 0,003 | 0,006 |
| 9 | 7,85 | 0,015 | <0,0003 | <0,001 | 0,006 | 0,054 | 0,078 | 0,004 | 0,006 |
| Malekhivka river (Murovane village) | | | | | | | | | |
| 10 | 7,79 | 0,009 | <0,0003 | <0,001 | 0,006 | 0,095 | 0,164 | 0,010 | 0,002 |
| 11 | 7,38 | 0,028 | <0,0003 | 0,002 | 0,004 | 0,109 | 0,23 | 0,004 | 0,003 |
| Poltva river | | | | | | | | | |
| 12 | 7,53 | 0,016 | <0,0003 | <0,001 | 0,010 | 0,081 | 0,088 | 0,021 | 0,005 |
| 13 | 7,03 | 0,017 | <0,0003 | 0,002 | 0,009 | 0,072 | 0,11 | 0,002 | 0,005 |
| MPC | | 0,01 | 0,005 | 0,01 | 0,01 | 0,1 | 0,01 | 0,01 | Background + 0,001 |

The common Malekhivka river feature is the significant influence of landfill leachate on formation of river runoff. The leachate may have low pH or in the range from 6.5 to 7.5 depending in which phase is landfill: acid phase of decomposition or methane fermentation respectively. As one can see in current case pH on the source from landfill reclamation system is higher then 7. The acid tars outlet from storage reservoirs has significant influence on right Malekhivka tributary runoff formation. Which causes pH value lowering in water stream. The pH value influences in different ways on the different heavy metals state, but in common at pH lowering their solubility growths. Under these circumstance the heavy metals incoming with leachate and tars may undergo transition from soluble into insoluble form, or otherwise. Their content variation in river waters is caused by processes of sorption on organic compounds and colloids incoming in surface waters as a result of erosion, also [6]. The presence of phyto- and zoo-barrier has significant influence in heavy metals content lowering.

The Malekhivka river is not used for fishery purpose or for water supply source, but it belongs to the watershed of Zakhidnyi Bug ,which is an object of fishery category of use. Hence, in current work the water quality is estimated from the point of view of standards of fishery category of use.

The results of investigation show that the content of such elements as Co, Cd, Pb, and Cu is lower then maximum permissible concentration, In some cases as for Co and Cd it is under the limit of determination by atomic-absorption method. The highest concentration of heavy metals are observed at heads of Malekhivka river and nameless spring. The major source of pollution by Zn, Ni, Fe and Mn is the landfill leachate.

Their contents overcome the corresponding maximum permissible concentrations in 1.5, 4, 7 and in 21 times respectively. The same case regarding to the Zn content is observed at the head of nameless spring (1.5 times higher then maximum permissible concentration). An especial attention one should pay to the Mn content which is 630 time is higher then maximum permissible concentration. But its concentration sharply drops (23 times and then 90 times) as a sequence of natural processes outlined earlier.

In Malekhiv village after falling point of right tributary in Malekhiv river the concentration of the most metals lowers al least under waters mixing-diluting. The heavy metals contents decreasing one can observe further up to the Murovane village. But from the middle of Murovane the concentration of Mn growths up to 16.4-23 times and Zn concentration up to 2.8 times of maximum permission level. Obviously, it is caused by the activity of small private enterprises on village area.

The content of Mn in Malekhivka waters is in 2.6 times higher then in Poltva. After Malekhivka falling point Poltva river carries water into Zahidnyi Bug with Mn content of 11 times higher then maximum permission concentration. At the expense of low Pb content in Malekhivka its limit exceeding concentration in Poltva decreases in 8 times. By the Zn content Malekhivka river practically does not influent the water quality in Poltva. In such circumstances one can conclude that Malekhivka river is ander significant stress of the landfill leachate as well as the acid tars.

The major elements-pollutants are Ni, Fe and Mn, the highest exceed maximum permission concentration is observed in Mn content. Due to the processes of diluting, physical, chemical and biological sorption the pollutant concentrations down to the stream decrease. The rapid increasing of Zn and Mn concentration at the end of Murovane village is caused by secondary technogeneous pollution.

## References


1. **Khimko R.V.** Small Rivers – Investigation, Protection, Restoration / R.V. Khimko, O.I. Merezhko, R.V. Babko. – K.: Institute of Ecology, 2003. – 380 p.
2. **Report** about Investigation on Estimation of Ecological and Sanitary State of the Areas at the vicinity of Lviv Municipal Solid Wastes (Ist stage). – Lviv: Geotechnical Institute, 2005. – 93 p.
3. **Conclusion** on the Results of Hydrochemical Investigation of the Underground waters in Village Water Supply Sources Situated in the Lviv Landfill Region. – Lviv, 1990. – 71 p.
4. **Golod D.S., Krasovskiy E.L.** Biochemical Features of Heavy Metals Accumulation in Plant Cover and the Questions of Environment Protection // Materials of 2nd Conference. "The heavy metals in Environment and Nature Protection" (Moscow 1987). – P.1. – M., 1988. – P. 78 – 82.
5. **Nature Protection.** Hydrosphere. Common Rrequirements of Surface and Sea Water, Ice, Atmosphere Precipitations Sampling: State Standard 17.1.5.05-85. – [Approved 25-03-1985]. – M.: Standards Press, 2004. – 86 p.
6. **Bezuglova O.S.** Biogeochemistry. Students Textbook / O.S. Bezuglova, D.S. Orlov. – Rostov-na-Donu: Feniks, 2000. – 320 p.



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### Моніторинг забруднення вод річки Малехівки важкими металами


Викладено результати аналітичних визначень вмісту важких металів Zn, Cd, Co, Ni, Fe, Mn, Pb, Cu у р. Малехівка протягом літнього періоду 2011 р., встановлено джерела та особливості надходження

забруднювачів у річку та визначені основні елементи-забрудники. Загальною особливістю річки є те, що її стік формується під значним впливом фільтратів полігону ТПВ та хвостосховищ кислих гудронів, що зумовлює зміну кислотно-лужного балансу поверхневих вод і розчинності важких металів. Найвищі концентрації мікроелементів спостерігаються на витоках Малехівки і безіменного потічка, що є її правою притокою. Основним джерелом забруднення річки Цинком, Нікелем, Ферумом і Манганом є фільтрати полігону ТПВ, а головним джерелом забруднення безіменного потічка Цинком є гудронові озера. За рахунок процесів розведення, фізичної, хімічної та біологічної сорбції концентрації забруднювачів вниз по течії зменшуються. Наднормативний вміст Цинку і Мангану вкінці с. Муроване спричинене вторинним техногенним забрудненням.

**Ключові слова:** важкі метали, полігони твердих побутових відходів, фільтрат, гудрони.

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UDC 504:338.45

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## THE INTRODUCTION OF ENVIRONMENTALLY – SOUND TECHNOLOGIES AT WOODWORKING ENTERPRISES OF UKRAINE

An analysis of environmental impact caused by industrial enterprise economic activity has been made. It has been found that the anthropogenic pressure on the environment tends to decrease over the last few years. Yet its level remains fairly high. Measures to be taken for improvement nature conservation activity have been proposed.

**Keywords*:*** enterprise, innovations, environmental impact, environmentally sound approach, analysis.

The harmonization of relationships between the economic development and the Environment is currently a top-priority task to be carried out both by the government and the public. The close and proper attention focused on the existing environment is a pre-condition for ensuring adequate living conditions for future generations.

The character of interrelationships between the national economy (production sector) and the Environment assume specific features during the period of transition to the market economy. The acute resource and ecological crisis, the necessity for a substantial improvement of the Environment, the costs for elimination of ecological catastrophe consequences, misuse of natural resources in all sectors of production – all these have an impact on the economic development rate, the populations living conditions as well as the volume of financial funds accumulation necessary for solving the existing and other arising socio-economic and environmental problems. All these issues need urgent consideration in the context of transition to the model of sustainable development and rehabilitation of the Environment. The last few years have seen the trend towards a decrease in the level of technogenic burden on the Environment, yet it remains fairly high. Per 1 $km^2$ of the country's area, about 7.5 ton of harmful substances is emitted into the atmosphere [1, 3, 5-13] by point sources of pollution, the amount of hazardous industrial waste makes up about 3.8 ton [1, 4] while the amount of return polluted water in the open waters is 4.5 thousand $m^3$ [1, 4-13], which amounts to 0.16 ton, 0.08 ton, and 0.10 thousand $m^3$ per one person, respectively. For comparison purpose, Russia's industrial sector discharges 19.5 mln ton of pollutants per year, which amounts to 342 kg per capita.

The analysis made for determining the extent of industrial enterprises impact on the Environment, allows for making the following statement:

An enterprise is the key link in the process of the environmentally-sound development of the country. The control of the environmental component of safe economic activity at the level of the industrial enterprises production system, creates the necessary basis for environmentally sound functioning of the whole economic system of Ukraine.

The introduction of environmentally clean technologies at woodworking and wood products manufacturing enterprises in Ukraine is taking place in the context of the general

trend for environmentally sound approach in the industrial sector. The processes that occurred at separate enterprises reflected the general tendencies for the development of some branches of the industry and economic activity as a whole. As compared with other sectors of industrial activity, woodworking and wood products manufacturing enterprises pollute the atmosphere to a lesser extent (Fig. 1). The share of pollution for these enterprises is 0.1 % of all industrial waste amount. It should be noted that the industrial emissions of harmful pollutants into the atmosphere amount to over 90% of the total amount of waste discharge in Ukraine. The biggest polluters are the following production sectors: production of electric power and distribution of gas and water; mining industry; iron and steel works; nonmetallic mineral products manufacturing; coke production; oil manufacturing industry; chemical industry [1, 4].

The differences in the amount of waste emissions into the atmosphere by various industrial sectors are accounted for by specific structural features of each type of activity as well as their output volumes.

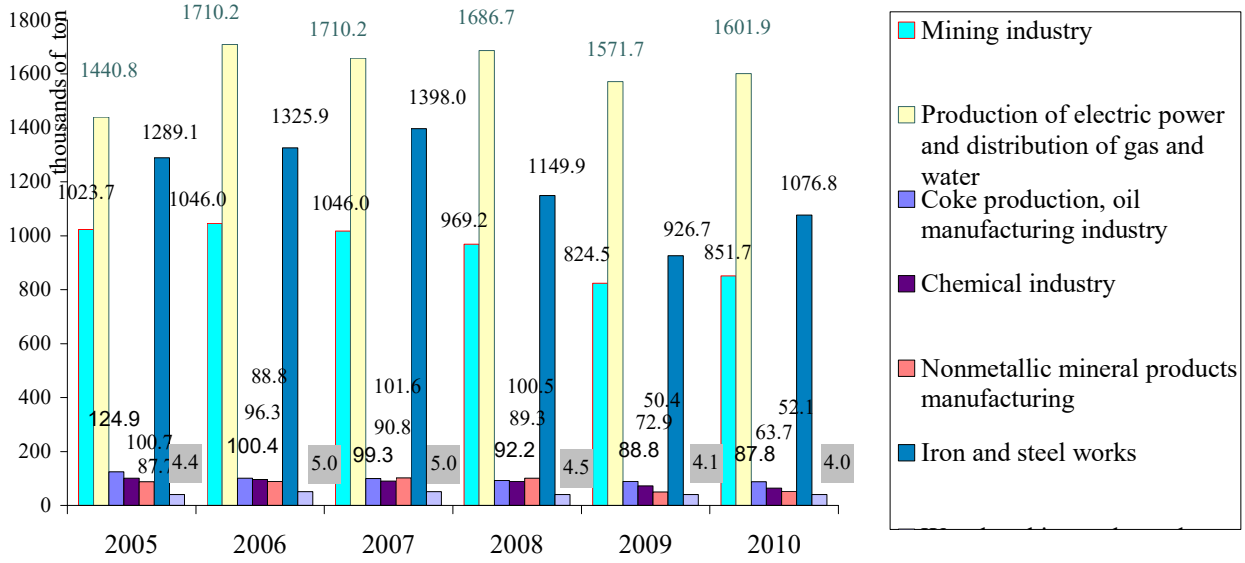


***Fig. 1. Harmful waste emissions into the air according to industrial sectors activity***

It is worth noting that the environmental footprint of woodworking and manufacturing of wood products has a tendency for a decrease in harmful emission into the atmosphere from point sources. At the same time, one can observe a reduction in the amount of atmospheric emissions for each individual enterprise.

Although the level of waste discharge from woodworking enterprises is of minor amounts as compared with other industrial sectors, their total effect is fairly perceptible.

It should be pointed out that all pollutant emissions are classified into emissions of various-type chemicals in the form of fumes, gaseous mixtures and solid particles in the form of dust. The most part of waste treatment plants at our enterprises are designed for trapping solid particles while the compounds such as aceton, xylene, styrol, toluene and others are discharged without any treatment. The main source of the air pollution by woodworking enterprises are workshops for finishing, veneer laying, laying-up, drying, wood machining, wood particle boards and fiberboards manufacturing, wood flour as well as boiler rooms, maintenance shops and various vehicles. The important factors that can have determining effect on the environmental parameters of economic activity, are innovations and technological improvement of the production processes. It is the innovative component that will be able to optimize the production processes and natural resources use, to mitigate environmental impacts from economic production activity with a minimum of negative outcome for manufacturing enterprises.

Fig. 2-5 represent the innovative factors influencing the environmental parameters of woodworking enterprises on the backgrounds of industrial enterprises [2, 4].

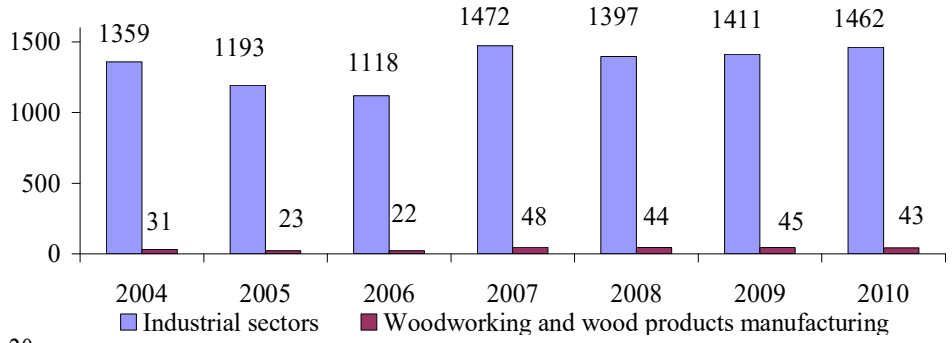


***Fig. 2. The number of innovative-active enterprises***

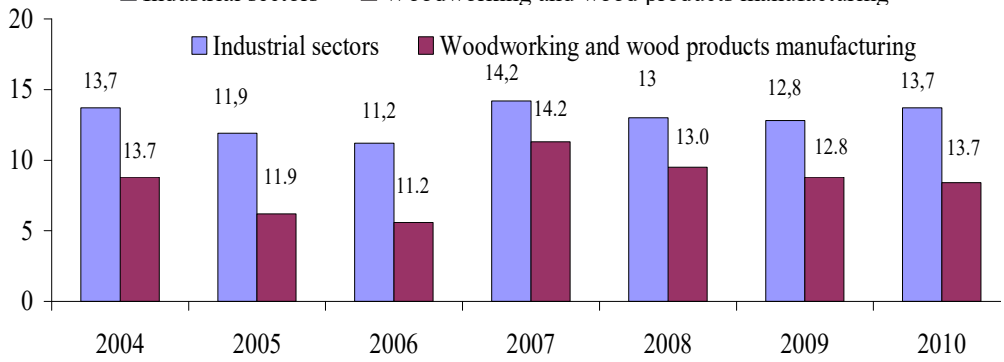


***Fig. 3. Dynamics of innovative-active enterprises share, in % of the total number of enterprises***


***Fig. 4. The number of enterprises that introduced innovations***

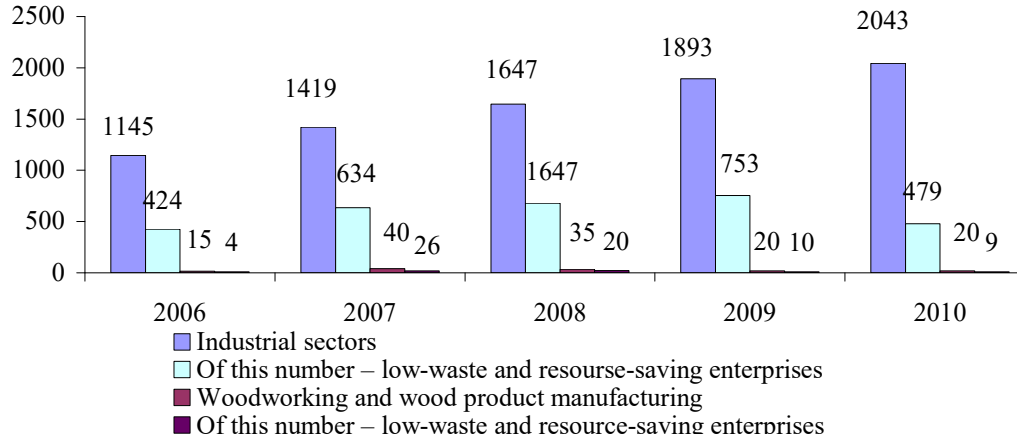


***Fig. 5. The number of new technological processes***

The share of innovative-active enterprises in the world's developed countries amounts to 60-70 %. The data (Fig. 2-5) point to the increasing number of woodworking and wood products manufacturing enterprises that have introduced innovative technologies for the last few years. It should be stressed that the woodworking enterprises introduced 35 innovative kinds of product in 2008, one of them being quite new for the market, in 2009 – 9, in 2010 – 14 kinds [2]. Also, there was some animation as to introducing new technological processes, including low-waste and resource-saving ones, both at industrial enterprises as a whole and woodworking enterprises in particular. However, a negative tendency is being observed today: while the total output is increasing one can observe the general tendency for a decrease in the share of innovative-active enterprises in the industrial sector as a whole and in its branch – woodworking industry in particular. Besides, a considerable gap is seen between the rate of change in the industrial output and the dynamics of the share of enterprises that are introducing new technologies; this is a negative fact because the gap is becoming wider against the back-

grounds of the general fall of the rate of industrial output growth. Thus, the availability of innovative potential as such is not enough for sustained development in the innovative activity to occur at the country's scale. The most favourable way of financing enterprise development is the attraction of foreign investments. However, foreign investors are not willing to invest their capital in Ukrainian woodworking and wood products manufacturing enterprises as this sector does not seem to be of primary importance to them.

The share of direct foreign investments into woodworking and wood products manufacturing enterprises amounts to 3 % of the total volume of direct foreign investments made into the industrial sector, and only 0.7 % of the general state index.

The dynamics of direct foreign investments into woodworking and wood products manufacturing enterprises (mln $ US as of the beginning of a corresponding year, is shown in Fig. 6) [1, 3].

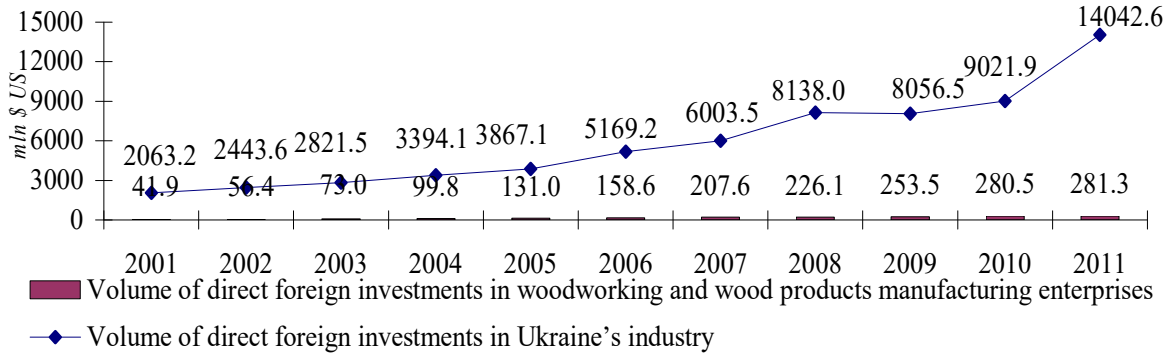


***Fig. 6. Dynamics of foreign investments into woodworking and wood products manufacturing enterprises as of the beginning of a corresponding year***

With the participation of foreign capital, the following production sectors have been set going in Ukraine: sawing and planing industry; production of rotary-cut veneer; glued plywood; laminated and woodparticle boards; manufacturing of various kinds of millwork and carpentry (beams, roof, trusses, window and buck frames, molded pieces etc.).

**Conclusions.** The analysis we have given, shows that in spite of the fact that there exists a tendency for general decrease in anthropogenic burden on the Environment, nonetheless the level of this load remains fairly high. The total industrial output is continually growing, the population numbers are decreasing, and disease incidence is going up. Thus, the current state of the Environment in Ukraine needs improving and calls for solving the environmental and economic problems of domestic enterprises in all sectors of economic activity.

## References

1. **Статистичний щорічник України за 2010 р.** / Державна служба статистики України. – К.: ТОВ "Август Трейд", 2011. – 559 с.

2. **Статистичний збірник "Наукова та інноваційна діяльність в Україні"** / Державна служба статистики України. – К.: ДП "Держкомстат України", 2011. – 282 с.

3. **Статистичний збірник "Інвестиції зовнішньоекономічної діяльності України"** / Державна служба статистики України. – К.: ДП "Держкомстат України", 2011. – 67 с.

4. **Державна** служба статистики України. – Доступний з: <http://www.ukrstat.gov.ua/>.

5. **Gayda S.V.** A problem of wood raw material is in Europe and Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2007, 33:55-63. (in Ukr.).

6. **Gayda S.V.** Research of concentration of operations is in modern furniture Productsion // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2007, 33:73-79. (in Ukr.).

7. **Gayda S.V., Maksymiv V.M., Tunytsya T.Yu.** Elaboration of post-consumer wood classifier // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2008, 34:55-68. (in Ukr.).

8. **Gayda S.V.** Chemical compound and degree of its contamination as the basis to systematization of post-consumer wood / Forestry, Forest, Paper and Woodworking Industry, 2008, 34:68-79. (in Ukr.).

9. **Gayda S.V.** Potential of post-consumer recovered wood and possible ways of it using in Ukraine // Forestry, Forest, Paper and Woodworking Industry. – Lviv. – 2009, 35:63-83.

10. **Gayda S.V., Maksymiv V.M.** From recycled post-consumer wood towards prime quality particleboard // Forestry, Forest, Paper and Woodworking Industry. – Lviv: 2010, 36:57-77.

11. **Gayda S.V.** A comparative analysis of physical-and mechanical parameters of variously-designed Glued Boards made of post-consumer Recovered Wood / Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2010, 36:81-91.

12. **Gayda S.V.** Recovered wood is additional resource of raw material // Forestry, Forest, Paper and Woodworking Industry. – Lviv: UNFU. – 2011, 37.1:238-244. (in Ukr.).

13. **Gayda S.V.** The effective use of post-consumer wood is basis for diminishing of $CO_2$-emission // Scientific Herald. – Lviv: UNFU. – 2009, 19.14:72-89. (in Ukr.).

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## Екологізація деревообробних підприємств України

Проведено аналіз екологодеструктивного впливу економічної діяльності промислових підприємств на довкілля. Встановлено, що упродовж останніх років спостерігається тенденція до зменшення антропогенного навантаження на навколишнє природне середовище, проте рівень цього навантаження є досить високим. Загальний обсяг промислового виробництва постійно зростає, кількість населення скорочується, зростає захворюваність. Рівень впливу на довкілля підприємств з оброблення деревини та виробництва виробів з деревини порівняно з іншими видами діяльності промислових підприємств є значно нижчим, хоча у загальному посилює негативні наслідки впливу господарської діяльності на довкілля. Екологізація деревообробних підприємств в Україні проходить на тлі загальної екологізації промисловості. Процеси, що відбувалися на окремих підприємствах, визначили загальні тенденції розвитку окремих видів промислової діяльності та видів економічної діяльності загалом. Для зменшення негативного впливу господарської діяльності підприємств на довкілля потрібно активізувати інноваційну діяльність; збільшити інвестиції, зокрема іноземні, на природоохоронні заходи; посилити моніторинг техногенного впливу підприємств на навколишнє природне середовище.

**Ключові слова:** підприємство, екологомісткість, екологізація, аналіз.

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## ENVIRONMENTAL ASSESSMENT OF PUBLIC TRANSPORT SITUATION IN THE CITY OF LVIV: FACTS AND PROSPECTS

Urban electric transport is part of a city's public utilities. The degree of transport network development and the quality of its function are responsible for transportation service level and, consequently, proper operation of the city's enterprises and organizations. The issues of public transportation in big cities have always been of importance. This is especially true today because a transportation service is viewed as one of the most socially meaningful component of national economy.

**Keywords:** urban transport, reforming, environment, public utilities.

Urban passenger transport is an important component of national economy. A modern city is simply impossible to exist without proper functioning of city's transportation network. Urban electric transport in many cities of Ukraine plays an important role amongst various kinds of service rendered to the population. Its share makes up 42 % to 56 % of all public transportation. The share of passenger transportation by urban electric transport in the city of Lviv made up 24,3 % of all the city's passenger transpor-

tation in the year 2011 [1]. Urban electric transport network is a constituent part of the unified transport system designed for passenger routing transportation in accordance with the requirements for life-support system of the populated area.

The existing level of transportation service influences human living and working conditions. This is why the problems of problems of providing an adequate public transportation service is of social and economic importance, and the activity for transport infrastructure development is eventually aimed at achieving the global economic goal.

To describe the performance scoring of urban passenger transportation service, the following characteristics are used: traffic punctuality, vehicle service speed, the degree of ride comfortableness etc. For passengers, the main qualitative characteristic of how efficiently transportation service functions, is the speed of travelling. It is this characteristic that should be taken into consideration when organizing a passenger transportation system.

Lviv is quite willing to follow examples of the leading European cities as it is of the opinion that clean, environmentally friendly public transport is of paramount importance both today and in future. The environmentally sound transport is to replace the transport that pollutes the environment. Lviv is a unigue city where an area of 120 ha is under protection of UNESCO, and 95% of the heritage which UNESCO protects in Ukraine, is here, in Lviv. Therefore, the preservation of our architectural monuments is the most important and vital task, the fulfillment of which involves simultaneous addressing and tackling the environmental problems as well.

With its more than a century-long history of electric transport, and having many large industrial enterprises and educational institutions, Lviv has always found it difficult to resolve transportation problem. The electric transport, an environmentally friendly means of transportation, has always been of top priority, and it was fairly successful in dealing with rush-hour stresses under specific infrastructural conditions of the city.

At present, in Lviv there are 74 routes with buses of medium-sized capacity, 4 routes with buses of large-size capacity, 9 tramway and 10 trolleybus routes; however, even with such abundance of public transport routes, the transportation system shows poor performance [2]. The protection of the environment against technogenic factors, the protection of human against adverse effects of this environment, may be both passive and active. In the former case, these are measures taken to protect influenced object against imminent influencing factors, in the latter case – the measures that make it possible to reduce quantitative characteristic of the influence or to eliminate it altogether at the expense of radical changes associated directly with the source.

As to the public transport, there can be used measures e.g. noise-suppressing shields, shelterbelts, etc. (passive measures); changes in the design of road and tracks devices, installation of cleaning filters in automobiles etc, (active measures). Yet, the most efficient appear to be radical solutions-changes in the source of influence, the application of the principle of priority development of environmentally most sound kinds of transport, stated differently, when selecting types of transportation to be used within the context of urban and municipal development as well as assessing public transport performance, it would be appropriate to take into account environmental characteristics including comparison indexes of traffic safety and, consequently, to give recommendation as to the priorities in the development of electric transport.

The tramway and trolleybus that use electricity as the source of their driving power, are in full accordance with environmental standards. The tramway stands first on the

list of the most popular means of transportation and it is no mere chance. Its main advantage is that the tramway practically does not cause pollution of the environment. However, it has some disadvantages. The tramway has low maneuvering power, the construction of new tram lines needs significant costs, also it is hard to call the tramway "silent" means of transportation. Tramway noise is produced by its running traction motor, brake system, box body vibration, the rolling wheels. The noise level is also dependent on the condition of tram tracks and contact power line. The reduction of the noise level can be achieved by using special rubber package under tram tracks, the usage of antivibration pads between the wheel rim and disk or application of graphite grease.

The trolleybus is the most economical and non-polluting means of transportation. It consumes less power than the bus does, and is more reliable and simple in operation, does not use oxygen and does not cause air pollution by exhaust fumes. As compared to the bus, the trolleybus general arrangement is more simple, its maintenance is less laborious, and to start up the trolleybus in cold weather does not present a problem. The noise level produced by the trolleybus is comparable to that produced by cars. In spectrum, it has a low-frequency character, and the noise like this is easier for human to endure as compared to the type of noise produced by the tram, whose level is much higher and is similar to that of cargo transport.

The noise produced by the trolleybus is due to the running motor, the wheels rolling along the road and the operation of accessory electric mechanisms. The noise is also produced by vibration of various enclosure structures and loosely mating windows and doors during the trolleybus movement. To reduce the noise, various rubber-ring absorbers can be used as well as sealing of the window glass and balancing of the mechanism of motor and transmission can be applied. At present, the public transportation system in Lviv is being restructured. This complex matter is attended by the French consulting company Louis Berger as well as by professionals from the National University "Lvivska polytechnika". The company Louis Berger is collaborating with the city within the framework of the project of European Bank for Reconstruction and Development. It this new transport system, the priority will be given to electric transport [3].

From the analysis of the existing electric transport routes, it may be concluded that structurally they are patterned fairly correctly because they are aimed at passengers transportation from the suburbs to the city centre.

But their performance is not satisfactory: in total, the trolleybus and trams do not carry enough passengers because of low-speed movement, they are not very punctual, and are duplicated by buses of middle-sized capacity; also paying the fare takes much of the driver's time, the rolling stock is outdated and considerably worn out, which, by and large, have adverse effects on the environment and human health.

It should be noted, however, that while developing the new public transport system of the city, the professionals have taken into account all these things, in particular, they have eliminated duplication of the electric transport routes, which is to increase the number of passengers by getting relieved the city center from congestion of buses; this is to make the traffic faster-moving. Also, the introduction of the rover-ticket system will make the ride on the city electric transport still more comfortable and convenient.

In restructuring the electric transport system. Lviv is on the right track. Today, most European countries are turning back to the usage to electric transport that was actually destroyed in the 1950s-1970s. The future may lie with electric vehicles since these are environmentally friendly and economical type of transportation.

## References

1. **Львівський трамвай:** [Електрон. ресурс]. – Режим доступу: http://uk.wikipedia.org/wiki/% D0%9B%D1.

2. **Львівський транспорт:** зміна радикальна, рух – радіальний: [Електрон. ресурс]. – Режим доступа: http://neruxomist-lviv.at.ua/publ/lvivskij_transport_zmina_radikalna_rukh_radialnij/1-1-027.

3. **У Львові розвиватимуть електротранспорт:** [Електрон. ресурс]. – Режим доступа: http://188.95.48.87/news/33098.



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## Екологічний стан міського електротранспорту у Львові: реальність і перспектива


Відомо, що міський електричний транспорт є частиною комунального господарства міста. Доведено, що від ступеню розвитку та якості роботи міського електротранспорту залежить не тільки рівень транспортного обслуговування населення, але й нормальна робота підприємств, організацій. Питання організації обслуговування населення міським пасажирським транспортом завжди були актуальними. Сьогодні їхня актуальність ще більше посилюється, що зумовлено насамперед соціальною значущістю транспортної послуги як такої і важливістю збереження міст у відповідному екологічному стані.



**Ключові слова:** міський транспорт, реформування, довкілля, комунальне господарства.


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## PORTRAIT PAINTING IN UKRAINIAN AVANGARDE – VISUAL IMAGE AND MIND REFLECTION


This paper mares an attempt to spotlight topical questions regarding the nature of portraiture thin ring of avant-gardism artists. Cubistic and futuristic portraits are the basis of the analysis. The portraits helped to investigate the logic of deformations that toor place in the art of first quarter of 20th century. The study underlines that attention of Ukrainian cubistic futurists was concentrated on discovery of new possibilities in human conscious and psychogenic. It is re marked that such ideas as representation of invisible, new artistic sensitivity, harmony consisting of dissonances had a positive aftersound in avant-gardism works. It is noticed that cubofuturistic experience of recreation of internal images in portrait that available only for contemplative observation of internal images in portrait that available only for contemplative observation has become a significant phase in formation of suprematic concept of Malevich.



**Keywords:** portrait painting, visual image, abstract composition, alogism.


Portraiture occupies a significant place in art. It is known that development of the portrait genre-painting was always thoroughly studied by art critics and theorists. However, this development could not be equally intensive in all periods. With time passing, the problems have arisen and new ideas have emerged. They included a wide range of new topics and questions. Therefore, a portrait could be a genre-painting more or less attractive for a painter, and its content could be changed and really changed. The portrait was the essential part of the heritage of the avant-garde artists such as Olexandr Bogomazov, Anatol Petrytsky. The works in this genre-painting have been created by Volodymyr Burlyuk, David Burlyuk, Vasyl Yermilov, Victor Palmov and Kazimir Malevich. At the beginning of the XX-th century, the portrait became a problematic, profoundly philosophical genre-painting which combined the most contradictory tendencies, bright realistic individual characteristics, and abstract and expressive deformations

of models. In a new code of art formulae, a "real-objectless" opposition was one of the central. Early in the XX-th century, the trends such as Cubism, Futurism and Suprematism stopped to copy real objects. Their tasks were in another plane associating real with the perception of the intuitive, and that was the core from which a true and modern, for that time, work of art developed.

In the Cubo-Futurism art there dominated two problems: search for the essence and the effective application of the human spirit in art. The reality, which was so much spoken of, frequently, but not always, was metaphysical. The avant-garde artists considered that the imperceptible essence was associated with a dynamic or vitalistic comprehension of the cosmos, and from this point of view the artists were not idealists, but they attempted to represent in the canvas those definite energies, forces, potentialities and rhythms which, as they thought, were beyond the visible world. The artist's interest in an individuality, personality was expressed in search for the essence reality, since the process of perception of the vitality, characteristic of the object, and further conveying it to a viewer through the work of art could be exclusively personal and subconscious; feelings represented only the surface world of the things we see, and this world in many aspects is identical for all people. The differences occurred from the "unconscious", "inner necessity", "intuition" [1,4]. Referring to the aesthetics of the avant-garde, dating back to 1910-1915, we can speak about formation of concepts of a special sight, that is an inner sight, which is realized without eyes. Scientific investigations of the sight physiology, but to a greater extent "new mystique" [2], philosophy and psychology were the context of such conceptions. The avant-garde artists focused their attention on opening of new possibilites of the human conscience and psyche. Enthusiasm from opening the new psyche, new sight, new organs of sense and conscience was the basis of the Futurist myth. It formed many bases of aesthetics, namely alogism and absurdism, accenting of the unconscious mechanics of the creation, passion for infantilism and primitive, interest in different techniques of psychic transformations.

The "psychic evolution" conception was developed in Cubo-Futurist portraits, where a special role was played by the means for revealing the unknown, unconscious sources of a new meaning and new perception. K. Malevich wrote, "To see the world does not mean to see it with the eyes, but one can see the world with knowledge and the whole being,… in our psychic world there is fixed a new real concept of a modern state of our world perception or in the psychic world our brain images, like in a mirror, its real state" [3, 6]. "The brain extract of impressions" is the unique aspect that gives us another modern perception of the world and the sense of a new reality [4].

A similar "extract of impressions" is discovered in the classic Cubo-Futurist work by A.Petrytsky, *Portrait of Olga* (1920). Peculiar features of the compositional structure of the portrait conditioned a special reproduction of the appearance of the model interpreted in a generalized form. In the face there is emphasized its volume, the shape of the nose and plump lips is interpreted completely in a plane manner. The shape of the eyes is slightly enlarged, but at the same time the feeling of the fixed look is not lost. In such interpretation of the face, particularly of the cone-shaped nose, shadows around the head, we see the similarity with the Cubist portraits by P. Picasso. However, in the face of the model there is represented tenderness which is completely absent in the faces painted by P. Picasso. The model, painted in the picture, is playing music. It is difficult to define the kind of the instrument the model is playing, because it is absent in the composition. Meanwhile, in a line-plane rhythm, there are guessed the contours similar to the shape of the piano cover [5]. The musical instrument is transformed into a speculative category, relative object, from which some details are taken out: sign, indication of the existence. Such a speculative existence is sufficient for a compositional and game intrigue which is inherent in the Cubo-Futurism.

In theoretical constructions by a number of Ukrainian artists, new painting from the space of real sight images and the world of physical laws is as if transferred to the sphere of conscience, psyche, and material forms of a picture give only impulses, outer

elements for one's own inner contemplations. "… Sensation is based on rhythmical features (movement), on their some action on our nerve-centres which transfer the sensation of conscience . and what does the conscience do with the received sensation? It perceives the sensation, but judges of it only on the base of memories" [6]. Such bases of a new principle of perception were developed by O.Bogomazov. The representation acquired the form that the traces of the images have, with the objects seen in the artist's brain possessing "a great amount of memories" [6]. (Evidently, O.Bogomazov was influenced by A. Bergson's work "*Matter and Memory*"). Prior to transferring such "traces" to the canvas of the picture, the author had to see them in his conscience. Such a visionary element, "thinking by eyes", the artist described in his theoretical treatise "Painting and Elements".

In this position we particularly appreciate the words of the Ukrainian artists (O.Bogomazov, O.Exter, K.Vasylyeva and others), the "eye-witnesses of the invisible", who declared in the preface to the "Ring" Exhibition Catalogue the conception as set forth, " … Beauty is not in things seen, but in the perceptible emotional experience. There is no object, no thing, but there is some other thing, hidden, and this some other thing is the world of mutual relations,… the world perceived by the soul…" [7]. With such a perception, a purely speculative sphere, conscience or a sphere of unconscious psychical senses, was the mediated "mechanism". David Burlyuk advocated much the eyes of the thoughts of the artist who had to write the analysis of his knowledge. Thus, new Futurist poetry searched for the "words, by which one can see, words-eyes, words-hands, by which one can create", as well as the avant-garde painting searched for the "eyes-conscience", by which one can think, or "eyes-hands", by which one can perceive by touching. A tactile function of sight, hidden deeply in the human psyche, required a special attention to the texture of the painting work.

Such a tactile "texture" component in new painting occupied an essential place. Almost all artists and poets, without exception, attempt to create "texture works". N.Tarabukin, a noted art-theorist, called the representatives of new pictorial trends as "texturists" [8]. D.Burlyuk was one of the first who attempted to give the "single possible" classification of painting works in the article "Texture", understanding by the texture the character of the surface of the picture, features of its plane [9]. The emphasized, thickened, hypertrophied texture of the picture surface referred the viewer not to the eye sight, but rather to perception by touching.

Another painting work by D. Burlyuk, "*Siberian Flotilla*" (1911), belongs to the educational Cubo-Futurist portrait. The peculiar feature of this work is quite a different deforming interpretation of the space. In this picture there is depicted a sailor divided into fragments and separate elements (similar to words in the Futurist poetry which were frequently divided into separate letters), and again gathered together, but not according to the laws of reality. A distinctive special effect in the portrait is "fragmentation" of the image – the representation is broken up by broken lines into acute and open angles with well-defined geometrical contours as if broken off from ice. The sailor's face is represented by the reporting fixing, simultaneously at several visual angles, in three and four revolutions, that is solving the problem of the artist's sight movement about the model. The artist accentuates the attention to the movement, combining the Cubistic laying out of the form on the plane with the Futuristic technique of successive representation of separate phases of the head movement. The Cubo-Futurists attempted to represent the movement of the object or figure and different foreshortening by plastic means. The Futurists spread the dynamic sensations not only on the mechanical movement or the movement we see, but the "movement" of the psyche, inner dynamism. The artists attempted to perceive the plastic movement of the modern spirit state and represent the ephemeral state of the psychical reality, which was developed in the peculiar "inner landscapes" on the base of plastic equivalents. Such are, for example, the paintings by A. Petrytsky, *Portrait of V.Chystyakova, an Actress*, and *Self-Portrait*.

In the context of our analysis, the Cubo-Futurist portraits by O. Bogomazov are of interest. *Portrait of the Daughter* (1928) is Bogomazov's masterpiece. The image in

the portrait has a striking likeness and differs little from the main stream of the Cubo-Futurist painting. The artist as if introduces his model into the space of his own art, where everything is subject to a single plastic ritual-transformation in the given rhythmics. The face of the daughter is presented as seen through special optics which generalizes and individualizes simultaneously. The attempt to reproduce in the canvas the new world, that combines the inner and outer, became the basis of a number of Cubo-Futurist portraits created in another style. Such portraits represent the human appearance consisting of different tactile and sight sensations, associated chains, in which object and texture combinations are constructed. In these portraits, the "face" is represented as a projection of psychic sensations and individual perceptions, where the artist attempts to perceive peculiar configurations. They demonstrate the attempt to deepen, sharpen the portrait conception, not to reproduce the outer surface of the face with the inner content, but to create a special artistic construction, which expresses a complex of sensations in the face, that are always woven from a number of impressions, which are scattered and are almost beyond logical description.

The brilliant examples of the above are the Cubo-Futurist portraits by N.Goncharova, *The Lady with a Hat on* (1913), by L.Popova, *The Sketch to the Portrait* (1915), *The Traveller* (1915), by V.Mayakovsky, *Self-Portrait* (1918), which display the transformation of the content, principles of comprehension and perception. In this situation, the artist demonstrates a qualitatively new level of consciousness. His abstract thinking becomes more flexible and stronger, the change to a sensitively psychological associative vision becomes more noticeable. All these "portraits" are games of memories, where one image is revealed in the other like surprises in the Easter egg. This is a "parade of associations", which occurs from the fantastic intersection of various geometric planes and lines, in which "there are no down and up, it lives only in the human brain, the home of illusions" [10].

In all the portraits analysed, there is observed, to a greater or smaller degree, the evolution of art from the Cubo-Futurism to the infinite reason, which K. Malevich in 1913-1914 named as "alogism". For K. Malevich alogism became an important impulse at the time when the artist created his first Suprematist compositions. The very alogism, which is a component of the Cubo-Futurism, to be more exact, its tint, led to a logical end, to creation of a monochrome quadrangle known as *Black Square*.

Thus, the Cubo-Futurist portrait demonstrates a number of problematic relationships between reality and techniques for its representation, between a visual fact and mental image. The Cubo-Futurist portrait image is represented in the categories of a new associative perception. This means that the artist is still associated with imaging the reality, but only associative, which transforms chaos of absurdity into new imaging forms, that creates a precedent for discovery.

## References


1. **Charlotte Douglas.** Swans of other worlds. Kazimir Malevich and the origin of Abstraction in Russia. – Michigan: Ann Arbor, 1976.
2. **Кравченко Я.О., Прокопчук І.Ю.** Дама на зупинці трамваю № 8 (Наукова лабораторія та художній метод) // Мистецтвознавчий автограф. – Львів: ЛНАМ, 2006. – Вип. 1. – С. 22-39.
3. **Малевич К.** О нових системах в искусстве // Сарабьянов Д.В., Шатских А.С. Казимир Малевич: Живопись. Теория. – М., 1993. – 226 с.
4. **Силлart.** Выставка футуристической скульптуры Боччони // Аполлон. 1913. – № 7. – С. 63.
5. **Анатоль Петрицький:** Портрети сучасників: Альбом / Авт.-упоряд. В.В.Рубан. – К.: Мистецтво, 1991. – 128 с.
6. **Богомазов О.** Живопис та елементи (фрагмент трактату картина-глядач) // Хроніка 2000. – К., 1992. – С. 140-145.
7. **Нога О.** Малярство українського авангарду (1905-1918). – Львів: Українські технології, 2000. – 318 с.
8. **Тарабукин Н.** Опыт теории живописи. – М., 1923. – 180 с.

9. **Русский футуризм:** Теория. Практика. Критика. Воспоминания / Сост. В.Н. Терехина, А.П. Зименков. – М.: Наследие, 2000. – 480 с.
10. **Гессе Г.** Игра в бисер / Пер. с нем. – М.: Олимп; Астрель; АСТ, 2000. – 688 с.

УДК 7.038.15:7.041.5: 75.01 ***Аспір. І.Ю. Прокопчук – ЛНАМ; інж. – НЛТУ України***

## Портретне малярство в мистецтві українського авангарду: між візуальним образом і мисленим відображенням

Проаналіззовано проблеми портретного малярства українських художників-авангардистів О. Богомазова, А. Петрицького, братів Бурлюків, В. Єрмилова. Аналізуються такі модерністичні напрями в мистецтві першої чверті ХХ ст. – як кубізм, футуризм, супрематизм. Окреслені напрями перестали копіювати реальні предмети, вони звели себе до іншої площини, що пов'язувала реальне із осягненням інтуїтивного. Художник, через особисте перетворення зримого висував поняття творчого розрахунку, поєднання художніх засобів з художньою метою для абстрактної творчості. Митці намагалися вловити пластику стану душі та передати ефемерний стан психічної реальності, що отримало розвиток у створенні на основі пластичних еквівалентів своєрідних «внутрішніх пейзажів».

Звернення художників до цієї теми пов'язано з впливом філософських робіт А. Бергсона. Поняття «тривалості», запропоноване Бергсоном, припускає постійну мінливість, становлення, взаємопроникнення різних часових пластів – минулого, сьогодення і майбутнього, – давало основу для подібних експериментів у живописі, заснованих на сугестії різноманітних форм і кольорів, на «психологізації» геометричних фігур і барвистих комбінацій.

Запропоновані до аналізу портрети допомогли простежити логіку деформацій, що відбувалися у мистецтві першої чверті ХХ ст. Кубофутуризм дав єдине в мистецтві за силою, гостротою вираження злиття двох світів – суб'єктивного і об'єктивного, тобто перетвореного і реального. Проаналізувавши низку творів, автор зазначає, що абстрактні портрети відтворюють вигляд людини, який складається з різних тактильних і зорових відчуттів, з асоціативних ланцюжків, з яких вибудовуються фактурні і предметні комбінації. «Обличчя» у таких портретах представлено як проекція психічних відчуттів і особистих сприймань, у яких митці намагалися вловити індивідуальні конфігурації, які демонструють спробу поглибити, загострити портретну концепцію. Художники прагнули подати не зовнішню оболонку обличчя з внутрішнім змістом, а створити особливу художню конструкцію, що передає комплекс відчуттів образу, які завжди виткані з низки вражень, що розбігаються і майже не піддаються логічним описам. Відзначено, що увага українських авангардистів була сконцентрована на відкритті нових можливостей у свідомості та психіці людини. Кубофутуристичний досвід відтворення у портретах образів внутрішнього, доступних лише для умоглядного споглядання, став суттєвим етапом у формуванні супрематичної концепції К.Малевича.

**Ключові слова:** портретний живопис, візуальний образ, абстрактна композиція, алогізм.

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