МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ ЛІСОТЕХНІЧНИЙ УНІВЕРСИТЕТ УКРАЇНИ

ЛІСОВЕ ГОСПОДАРСТВО, ЛІСОВА, ПАПЕРОВА І ДЕРЕВООБРОБНА ПРОМИСЛОВІСТЬ

Forestry, Forest, Paper and Woodworking Industry

МІЖВІДОМЧИЙ НАУКОВО-ТЕХНІЧНИЙ ЗБІРНИК

Виходить з 1964 р.

ВИПУСК 42

Львів – 2016

УДК 691.11
Лісове господарство, лісова, паперова і деревообробна промисловість : міжвідомчий науково-технічний збірник. – Львів: НЛТУ України. – 2016, вип. 42. – 84 с.

Рекомендовано до друку Вченою Радою НЛТУ України
(протокол №11 від 29.12.16 р.).

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.

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

Збірник підготовлено Національним лісотехнічним університетом України.

Адреса університету :79057, м. Львів-57, вул. Ген. Чупринки, 103
Адреса редакції :79057, м. Львів-57, вул. Залізняка, 11
тел. : (032) 238-44-96, 238-45-04;
моб. : 067-79-12-522;
факс : (032) 238-44-96;
e-mail: serhiy.hayda@nltu.edu.ua
e-mail: vmmax@ukr.net
e-mail: f-wood-ind@nltu.lviv.ua
http: // forest-woodworking.nltu.lviv.ua

Головний редактор: д-р техн. наук, проф. В.М. Максимів;
заступники головного редактора: д-р с.-г. наук, проф. С.І. Миклуш;
д-р екон. наук, проф. І.П. Соловій;
відповідальний секретар: канд. техн. наук, доц. С.В. Гайда, **секретарі:** канд. техн. наук, доц. О.Л. Сторожук, канд. техн. наук, асист. Р.Б. Щупаківський.

Редакційна колегія: д-р екон. наук, проф. Ю.Ю. Туниця; д-р екон. наук, проф. І.М. Синякевич; д-р екон. наук, проф. Г.С. Шевченко; д-р екон. наук, проф. Т.Ю. Туниця; д-р екон. наук, проф. А.М. Дейнека; д-р екон. наук, проф. М.А. Козоріз; д-р екон. наук, проф. Л.С. Гринів; проф. Джек Морріс (США); д-р біол. наук, проф. В.І. Парпан; д-р с.-г. наук, проф. М.М. Гузь; д-р с.-г. наук, проф. В.П. Кучерявий; д-р с.-г. наук, проф. В.П. Рябчук; д-р с.-г. наук, проф. І.Ф. Калуцький; проф. Ервін Гуссендьорфер (Німеччина); д-р техн. наук, проф. П.А. Бехта; д-р техн. наук, проф. О.А. Кійко; д-р техн. наук, проф. Н.І. Библюк; д-р техн. наук, проф. І.М. Озарків; д-р техн. наук, проф. П.В. Білей; проф. Адам Краєвські (Польща); проф. Єва Ратайчак (Польща); проф. Стефан Тобіш (Німеччина); проф. Ян Сідлячік (Словаччина); проф. Ґавріл Будау (Румунія); проф. Александер Пфрім (Німеччина); проф. Андреас Шульте (Німеччина)

© Національний лісотехнічний університет України, 2016

ЗМІСТ

UDC 630*5 ***Stud. V.V. Kysliuk – UNFU, Lviv; director V.O. Kysliuk – Kostopil' State Forestry Enterprise, Kostopil'; assoc. prof. O.M. Hrynyk, PhD – UNFU, Lviv; prof. H.H. Hrynyk, Dr. of Agricultural Sciences – UNFU, Lviv***

THE ANALYSIS OF THE DYNAMICS OF FOREST LAND FUND AND CURRENT CONDITION OF LITHUANIAN FOREST

The article reveals official statistics of the Lithuanian forest sector in 1938-2016 years and trends of the last few decades. For a better research the main trends of the dynamics of forest land fund and current condition of Lithuanian forest there are some figures and tables, which demonstrate up-dated forest data. Also a comparison evaluation, based on the Environmental Performance Index (EPI), between Ukrainian and Lithuanian forestry was made. The Lithuanian land fund was analyzed in accordance with a data of the National Land Service and National Forest Inventories Assessment of Wood Availability and Use, estimated the level of forestry protection strategies and it`s results, given an information about features of the division of categories of the forests lands and biodiversity of the forests. Moreover, considered a governmental strategy of the forests protection.

Keywords: Lithuanian Forestry, forest land, forest coverage, growing stock volume.

Introduction. Every two years the researchers of Yale University (USA) announce the Environmental Performance Index (EPI) for the countries around the world. This index ranks countries' performance on high-priority environmental issues in two areas: protection of human health and protection of ecosystems. According to the Forest Protection Assessment in 2012, Lithuania was recognized as the country, which puts the biggest amount of effort to protect forests comparing to other countries in the world. Taking a look at general statistics, the country takes 17th place [7]. It is worth to follow a positive dynamic of the country's performance and compare it to the actions regarding the forest protection of Ukraine (Fig. 1). In this case, being able to learn a Lithuanian strategy of growing, protecting, and marketing Ukrainian forests may help the country's foresters to improve their performance and to achieve higher results.

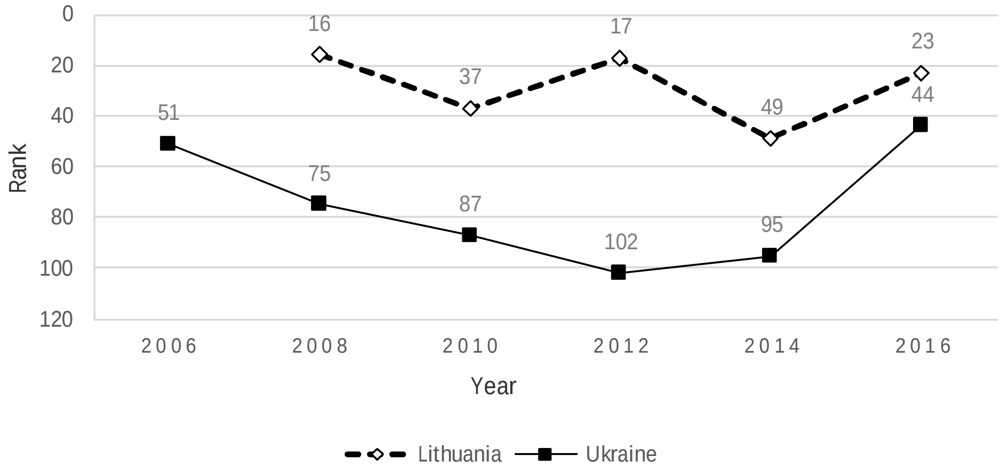


Fig. 1. The comparative rating of Lithuania and Ukraine according to Environmental Performance Index

The aim of the study. The study aims to understand a foreign experience of forestry and learn the features of the climate of Lithuania. In addition, it will also reveal geographical features, amount of species, and volume of tree felling. The study also aims to improve an understanding of forestry with a help of statistical information and to compare a process of forestry in Ukraine and Lithuania. Finally, the study will reveal the key strategies, which should be applied to the forestry of Ukraine.

1.1. Characteristics of Lithuanian Forestry. Lithuania is a country, which is located in the northern part of Europe with the total area nearly 65,300 km^2. The country is one of the three Baltic states and is situated along the southeastern shore of the Baltic Sea. Lithuania is glacially flat, except for morainic hills in the western uplands and eastern highlands, which are not higher than 300 meters. The country has numerous small lakes and swamps; a mixed forest zone covers over 33 % of the country. The growing season of Lithuania lasts 169 days in the east and 202 days in the west and involves mostly sandy- or clay-loam soils [3]. There are 42 forest enterprises in Lithuania, which are managed by the Directorate General (General Directorate) of State Forests under the Ministry of Environment. Enhancing ecological, economic, environmental, recreational, and other socially important values of the state forest and balancing forest sector by rationally using and increasing forest resources are not the only objectives of the Directorate General [1].

Table 1. Land fund republic of Lithuania by land-use categories [6]

Land-use categories	**01.01.2003**		**01.01.2011**		**01.01.2012**	
	Area		**Area**		**Area**	
	1000 ha	**%**	**1000 ha**	**%**	**1000 ha**	**%**
Agricultural land	3487.4	53.4	3463.4	53.0	3465.3	53.1
Forest land	2008.5	30.8	2162.4	32.6	2162.2	32.6
Other wooded land (bushes)	80.1	1.2	84.0	1.2	86.6	1.3
Roads	131.0	2.0	132.1	2.0	131.8	2.0
Urban territory	189.2	2.9	180.5	2.8	181.5	2.8
Water	262.2	4.0	262.6	4.0	262.4	4.0
Swamps (bogs)	146.1	2.2	116.4	1.8	116.2	1.8
Other land	225.5	3.5	164.6	2.6	160.1	2.5
Total	**6530.0**	**100.0**	**6530.0**	**100.0**	**6530.0**	**100.0**

According to the data of National Forestry Inventory (NFI) [5], which presents more reliable data then Land Registry Forestry Inventory (SFI) [6], the total forest land area is 2,162,200 ha covering 32.6 % of the country's territory. It is important to mention that during the 2003-2012 years the coverage increased by 2,4 % as previously it was 30,9 % (Table 1). In the 16th century lands in Lithuania unsuitable for agricultural activities had to be afforested. It is assumed that in the 16th century forest coverage of Lithuania was about 60 %. Later this percentage indicator decreased due to different, mostly economic, reasons; in 1945 it did not reach 17 %. Yet, in the second half of the 20th century, Lithuania's forest coverage increased by 10 per cent (Fig. 2), (Table 2). On 23 May 2012 the National Forestry Sector Development Program was approved by the Government of the Republic of Lithuania, which currently tries to increase an area of forests up to 34,2 % by the year 2020.

1.2. Forestry Protection Control. All forest enterprises in Lithuania are certificated according to the strictest standard in the world – the FSC (Forest Stewardship Council) certificate. The Forest Stewardship Council is an international, non-profit, multi-stakeholder organization established in 1993 with the aim to promote a responsible management of the world's forests. The first two FSC forest management certificates were issued in 2001 to Birzai and Panevezio state forest enterprises. The FSC does this by setting standards on forest products and then if the standards are followed, the council labels them as eco-friendly. The fact that Lithuania is granted with FSC certificate, means that country's state forests are managed especially well. Moreover, this certification is not a one-time action; every five years certificates are renewed and every year an annual inspection is carried out.

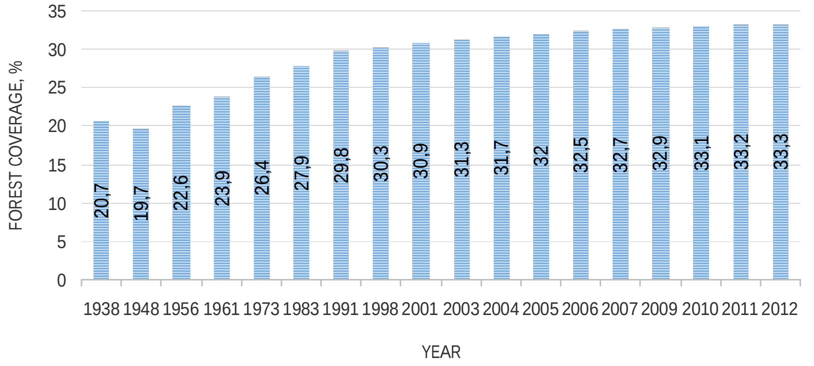


Fig. 2. Forest coverage in Lithuania, 1938-2012 [6]

Table 2. General characteristics of Lithuanian forests [5, 6]

Characteristic	01.01.2003	01.01.2011	01.01.2012
Forest land area according to Forest assessment, 1,000 ha (SFI)	2045	2170	2173
Forest area covered by stands, 1,000 ha (SFI)	1951	2057	2055
Of which planted forest, 1,000 ha (SFI)	459	508	515
Total growing stock volume, mill. m^3 (NFI)	453.4	489.8	501.3
Mean growing stock volume, m^3/ha (NFI)	226	237	240
Total growing stock volume of mature stands, mill. m^3 (NFI)	109.9	123.9	129.1
Mean growing stock volume of mature stands of III-IV groups, m^3/ha (NFI)	301	307	310
Gross annual increment, mill. m^3 (NFI)	16.0	16.6	17.2
Gross annual increment, m^3/ha (NFI)	8.0	8.0	8.2
Accumulation m^3/ha (NFI)	-	2.1	2.5
Forest coverage, % (SFI)	31.3	33.2	33.3
Forest area per capita, ha (SFI)	0.59	0.67	0.68
Growing stock volume per capita, m^3 (NFI)	131	151	157

1.3. Forest land area by land-use categories

According to the data of SFI [6], the total forest land area was 2,173,000 ha, covering 33.3% of the country's territory. Since the 1st January 2003, the forest land area has increased by 128,000 ha corresponding to 2.0% of the total forest cover. During the same period, forest stands expanded by 104,000 ha to 2,055,000 ha. Occupying 1,153,200 ha, coniferous stands prevail in Lithuania, covering 56.1% of the forest area. They are followed by softwood deciduous forests (818,500 ha, 39.8%). Hardwood deciduous forests occupy 83,800 ha (4.1%). The total area of softwood deciduous forest land increased by 120,100 ha over the last nine years. The area of hardwood deciduous has decreased by 8,800 ha and coniferous forest by 6,800 ha. The average forest area per capita increased from 0.57 ha to 0.68 ha (Table 2).

Lithuanian foresters make a hard work with not only reforestation of new areas, but also with creation new nurseries and expanding current ones (1839 ha in 2003, but 2043 ha in 2012), and developing a level of forests protection (making block and technological lines, firebreak belts and forest roads). According to the data of Table 3, the total area of the lands for technological purposes steadily increased from 27676 ha in 2003 to 33810 ha in 2012.

The same situation with the lands for other purposes, the area of which increased in percentage from 0.3% to 0.4% during a period of 2003-2012 (Table 3). All these facts means about a stable progress, positive changes and correct management in the Lithuanian forests enterprises.

Table 3. Forest land area by land-use categories [6]

Land-use category	01.01.2003		01.01.2011		01.01.2012	
	Area		Area		Area	
	ha	%	ha	%	ha	%
Forested land	1950981	95.4	2057462	94.8	2055436	94.6
natural stands	1491497	72.9	1549488	71.4	1540787	70.9
planted forests	459484	22.5	507974	23.4	514649	23.7
Non-forested land	59521	2.9	67499	3.1	72592	3.3
dead stands	1523	0.1	3948	0.2	4546	0.2
clear-cut areas	39652	1.9	44981	2.1	49858	2.3
blanks	15527	0.8	13481	0.6	12855	0.6
land for afforestation	2819	0.1	5089	0.2	5059	0.2
forest land under convertion into other categories	–	–	–	–	275	0.0
Seed orchards, nurseries	1839	0.1	2102	0.1	2043	0.1
seedling nurseries	505		448		391	
seed orchards	704		829		785	
nurseries	630		826		867	
Land for technological purposes	27676	1.4	33938	1.6	33810	1.6
block lines	11860		12366		12587	
technological lines	667		1313		1508	
firebreak belts	469		468		493	
routes, forest roads	14680		19791		19222	
Land for other purposes	5271	0.3	8772	0.4	8975	0.4
plantations of raw materials	339		346		317	
recreational plantations	406		197		199	
wood yards	585		420		418	
feeding places (for game)	2040		3077		2890	
landscape sites	940		4265		4725	
recreation sites	960		467		425	
Total	2045287	100.0	2169722	100.0	2172855	100.0

1.4. Lithuanian Forestry Diversity. Occupying 1,153,200 ha, coniferous plants prevail in Lithuania covering 56.1 % of the forest area. Coniferous plants are followed by softwood deciduous forests (818,500 ha, 39.8 %) and hardwood deciduous forests occupy 83,800 ha (4.1 %). To be precise, scots pine (*Pinus sylvestris*) occupies the biggest share in Lithuanian forests – 722,200 ha. Norway spruce (*Picea abies*) covers 428,400 ha with a reduction of 16,900 ha. Birch (*Betula*) covers the largest area among deciduous trees. Since 2003, it has increased by 66,600 ha and reached 458,800 ha by the 1st January 2012. Areas of black alder (*Alnus glutinosa*) have increased by 22,500 ha to 141,900 ha. The area of grey alder (*Alnus incana*) has expanded by 6,500 ha. The area of aspen (*Populus tremula*) has expanded by 20,900 reaching 78,200 ha. Oak (*Quercus*) forests increased from 35,700 ha to 41,900 ha. The area of ash (*Fraxinus*) has diminished by 30 % decreasing to 35,700 ha (Fig. 3) [2, 4].

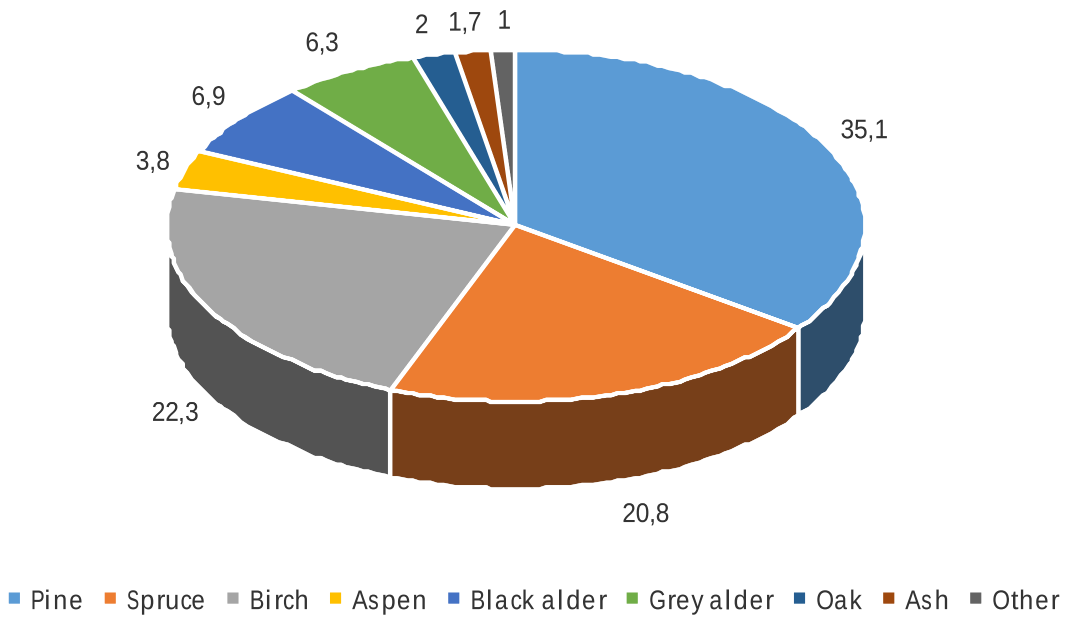


Fig. 3. Forest stands area by dominant tree species 01.01.2012 [6]

According to NFI data, since 2002 total growing stock volume has increased from 453.4 million m³ to 501.3 million m³ [5]. The average growing stock volume in all forests since 2003 has increased by 11 m³/ha up to 240 m³/ha. In the beginning of 2012, the distribution of forests by functional groups was as follows (Table 4):

– Group I (strict nature reserves): 26,300 ha (1.2 %);
– Group II (ecosystem protection and recreational): 266,800 ha (12.3 %);
– Group III (protective): 331,200 ha (15.2 %);
– Group IV (exploitable): 1,548,600 ha (71.3 %) (Table 5) .

The whole county is divided into 10 counties and 60 municipalities. The highest forest coverage was recorded in Alytus (49.1 %) and Vilnius (44.0 %) counties, while the least forested counties were Marijampole (21.7 %) and Klaipeda (26.4 %). The growing stock in Vilnius county (104.0 million m³) makes more than one fifth of the total growing stock in Lithuania [2, 4].

Table 4. Distribution of forest land area by forest groups [6]

Forest groups	01.01.2003		01.01.2011		01.01.2012	
	Area		Area		Area	
	ha	%	ha	%	ha	%
Forest reserves	23929	1.2	26264	1.2	26282	1.2
Special-purpose forests	243592	11.9	264735	12.2	266783	12.3
Protective forests	325889	15.9	330259	15.2	331201	15.2
Exploitable forests	1451877	71.0	1548515	71.4	1548589	71.3
Total	2045287	100.0	2169772	100.0	2172855	100.0

In 2011, 55,000 ha were damaged by different factors such as hunting, diseases, insects, and others. It is also important to mention that damage in previous year was up to 7 % more. The most formidable damage to the forests was caused by Spruce bud scale (*Physokermes piceae*) and Pine-tree Lappet (*Dendrolimus pini*). In addition, Green Oak Tortix (*Tortix viridana*), Gypsy Moth (*Lymantria dispar*), Pine weevil (*Hylobius abietis*), and cockchafer (*Melolontha sp.)*, are also widespread in Lithuania and usually destroy great areas every year as well [4].

Table 5. Forest stand area and growing stock volume per ha by maturity groups in III and IV group forests 01.01.2012 [1000 ha/ m³/ha] [5, 6]

Dominant tree species	Maturity groups				Total
	Young stands	Middle-aged	Premature	Mature	
Pine	100.0 121	390.8 322	52.2 388	47.6 385	590.5 304
Spruce	203.1 83	72.8 277	39.6 312	75.1 354	390.6 209
Birch	88.3 38	116.9 177	88.8 287	121.7 291	415.7 199
Aspen	23.2 42	6.6 193	4.7 262	38.4 346	72.9 245
Black alder	23.9 34	45.4 216	21.5 275	34.7 337	125.5 219
Grey alder	9.2 29	12.0 80	28.7 152	58.0 193	107.9 157
Oak	6.0 63	19.0 251	1.2 -	4.5 329	30.6 220
Ash	4.7 68	23.6 205	1.3 231	1.3 284	30.9 194
Other	2.0 70	3.5 117	1.5 220	3.0 223	10.1 163
Total	460.4 73	690.6 267	239.4 288	384.1 310	1774.6 236
Total 01.01.2003	407.9 93	665.9 242	312.3 269	308.5 301	1694.6 224

1.5. Forestry Protection Strategies in Lithuania. One of the important things that Lithuanian foresters do is that they focus on and care about the way of selection; this is because they believe that this branch can open many opportunities. Therefore, it is important not only to grow big areas of forest, but it is also essential to make sure that they are of high quality ones. In this case, there are a lot of gene reserves (160) on the area of 3,631 ha, seed stands (198) on the area of 1,574 ha and 2,652 selected trees. As the result of this strategy, the main part of the harvest during 2011 was oak acorns (91,9 tons) and the general amount of collected seeds in this year reaches 93,6 tons, which is 3 times more than in 2010. Other popular species for collecting are seeds of Scots pine, spruce, silver birch, black alders, line-trees, and maple.

The area of state nurseries was 1,214 ha at the beginning of 2011. The number of forest seedlings and saplings was counted to be 132 million at the beginning of 2011. The state forest enterprises used 52,7 million plants from their own nurseries in 2011. From this, 32,1 million were planted in their own forests and the remaining 20,6 million were sold. The main share of this amount was sold to private forest owners and to other customers. State forest enterprises purchased 5,4 million plants [2, 4].

Besides the fact that Lithuanian foresters are focused and care about selection, they have also worked on two main strategies of forestry protection. Two types of forest protection, which are considered to be the most serious are forest fire protection and forest protection from illegal felling. In 2012, 81 forest fire accidents in the area of 20,29 ha and 465 cases of illegal forest felling were registered in Lithuania. Because of illegal forest felling, 1,026 m³ of wood were cut. In result, 1506 people were fined for illegal felling and other Forest Law violations. The issued penalties brought for the country EUR 112,275. In 2012, the state forest enterprises spent 1,5 thousand EUR of their own funds on the maintenance of the general state system of anti-fire measures. While taking preventative measures, 12.5 thousand km of fire breaks were made [2, 4].

Interesting fact is that only during one year forest enterprises set up 10,200 new nesting-boxes and repaired 9,200 old nesting-boxes. In addition, 2,400 anthills were fenced and 4,400 hollow trees were marked. Influential various forest protection measures were applied by the state forest enterprises on 95,200 ha of forestland.

The amount of round wood prepared for sale was 7.3 million m³ in 2011; comparing it with 7.4 in 2010, it was considered to be very stable. The amount of round wood prepared in state forests totaled 3.96 million m³ in 2011. According to expert evaluation, the felling rate in private forests decreases by 8 % resulting in 3.3 million m³. Private forest owners received cutting permits for 2.2 million m³. Half of this (1.1 million m³) was issued to cut coniferous stands by 7 %, which in result reached 601,000 m3. Private logging companies performed 35 million EUR worth of wood harvesting and haulage works for state forest enterprises in 2011. Contractors harvested 90 % of timber procured in State forest enterprises. Half of the enterprises contracted out 100 % of harvesting works.

As the annual result of felling, there were provided 582,000 m³ of spruce, 482,000 m³ of pine, 651,000 m³ of birch, 433,000 m³ of aspen, 243,000 m³ of black alder, 41,700 m³ of ash, 47,000 m³ of alder, and only 11,900 m³ of oak.

The annual consumption of round wood in Lithuania decreased to 5.4 million m³ in 2011. Consumption of round wood in the wood industry and in the energy sector was very stable. Prices of round wood continued to increase during 2011. The most significantly (11-14 %) increased prices in State forest enterprises were performed for logs, pulpwood, and firewood [1, 2, 4].

The mean prices of round wood in state forest enterprises increased from 32 EUR/m³ in 2010 up to 40 EUR/m³ in 2011. The export of industrial round wood was 1.84 million m³, i.e. 39 % more to compare with 2010. The main foreign customers are Sweden, Poland, Germany, China, Latvia, UK, and Denmark. EU countries remained the main foreign markets for wood industry products. The total exports from Lithuania increased by 29 % in 2011 (there was a 33 % increase in 2010). Lithuania's main export markets were countries of the European Union, which is in total 61 % (61 % in 2010). Main importers are Belarus and Latvia, Poland, and Sweden. Import from Ukraine decreased from 90,000 m³ to 19,000 m³. This process mainly involved oak logs (18,000 m³) [4].

Conclusions. Lithuania has become independent at the same time with Ukraine. Yet, in fact, until 2016 our northern colleagues have made much better progress in forestry sector. Such strategies as solving environmental problems, rapid raising of forestry areas, exploitation of modern technical equipment, optimization of the process of logging, and working with civil public place Lithuania as one of the countries, which protects forestry in the most efficient way. Therefore, learning foreign experience in forestry and borrowing new technologies and approaches of Lithuanian forestry management, Ukrainian foresters will have an ability to achieve better results in their work. The first step for Ukrainian foresters would be usage of statistical information to compare the forestry management in both countries and then shaping new strategies and steps to reach the same result in the nearest future.

Secondly, the new management of Ukrainian forestry will not work unless several problems influencing the process are eliminated. Such problems are illegal logging, corruption, and old forest machines and equipment. As demonstration, Lithuania has eliminated such problems a decade ago and it has positively influenced forestry situation in long term. Finally, if Ukraine finds a way how to benchmark successful strategies from Lithuania, makes right priorities, learns how to protect and market forests, and helps to improve their performance, the country has all chances to flourish because of prosperous forestry industry in near future.

References

1. Isokas, G., Tervydis, A. (2008). *Traku uredijos miškų istorija*: *X tukst.pr. Kr. – 2007 m*. Vilnius: Mintis. 240 p.: iliustr.
2. Butkus, A., Kuliešis, A., Šakėnaitė, D., & Vižlenskas, D. (2012). *Lietuvos miškų ūkio statistika 2012*. (Lithuanian statistical yearbook of forestry 2012.) Kaunas: Lututė, 184 p.: iliustr.
3. Griguniene, M. (2010). *Lietuvos valstybiniai miškai*. (Lithuanian State Forests). Vilnius: Facililit. 72 p.: iliustr.
4. Lithuanian Forestry Statistics. [Electronic resource]. – Mode of access http://www.gmu.lt/lithuanian_forestry_statistics.
5. Vidal, C., Alberdi, I., Hernandez, L., & Redmond, J. J. (Eds.) (2016) *National Forest Inventories Assessment of Wood Availability and Use*. XXXII, 845 p. 53 illus., 29 illus. in color., Hardcover.
6. National Land Service under the Ministry of Agriculture of the Republic of Lithuania, State Enterprise Centre of Registers. [Electronic resource]. – Mode of access http://www.nzt.lt/go.php/eng/Activities.
7. The Environmental Performance Index . [Electronic resource]. – Mode of access http://epi.yale.edu/downloads.

УДК 630*5 ***Студ. В.В. Кислюк – НЛТУ України; директор В.О. Кислюк – ДП "Костопільське лісове господарство"; доц. О.М. Гриник, канд. с.-г. наук; проф. Г.Г. Гриник, д-р с.-г. наук – НЛТУ України***

Аналіз динаміки лісового фонду і сучасного стану лісів Литви

На основі офіційних статистичних даних щодо литовського лісового сектора впродовж 1938-2016 рр. встановлено та проаналізовано динамічні тенденції останніх десятиліть.

Для унаочнення та дослідження трендів наведено табличні та графічні дані динаміки лісового фонду та сучасного стану литовських лісів.

На основі динаміки екологічного індексу (EPI) здійснено порівняльну оцінку ведення лісового господарства у Литві та на Україні. Проаналізовано земельний фонд Литви за ужитковими категоріями відповідно до даних Національної лісової інвентаризації та Земельного реєстру лісової інвентаризації, оцінено контролювання захисту лісів, наведено особливості розподілу категорій лісових земель та біорізноманіття лісів.

Крім того, розглянуто питання державної стратегії захисту лісів.

Ключові слова: лісове господарство Литви, лісовий фонд, лісистість, запаси деревини.

 Assoc. prof. R.Ya. Orikhovskyy – UNFU

THE INFLUENCE OF EQUIPMENT RELIABILITY ON THE STABILITY OF MANUFACTURING OPERATIONS AND EFFICIENCY OF AUTOMATED PRODUCTION SYSTEMS

The influence of equipment reliability on stability of manufacturing operations and efficiency of automated production systems in the furniture industry is analized. The modern methods of determining reliability to meet the challenges of improving the functioning of the automated industrial systems furniture factories. Reliability of equipment has a significant impact on the stability of the process and on the actual performance of automated lines. Reduced reliability leads to a significant reduction in the actual performance automated lines and reduce the stability of manufacturing operations. Improve the reliability of the automated industrial systems using expedient development schemes equipment layout, structural and parametric optimization, redundancy and structural simulation.

Keywords: reliability of equipment, parameter stability, technological indexes of efficiency, automated production systems, imitation design, structurally and parametric optimization, reservations.

Study features furniture production process shows that it is constantly influenced by various random factors. Therefore, the length transactions furniture production values are random because they depend on such random influences: size-quality characteristics of raw materials, safety equipment, process organization. Furniture parts are characterized by size and physical properties that accept different values in a certain range of changes. Between these values there is no definite constant communication parameters of raw materials have properties of random variables. Elements cycle time manufacturing operations in furniture production include the working pace, duration and idle stroke cycle time losses. Loss of time outside working cycle created especially unreliable technology, shortcomings in the organization of labor and other factors of external influence. To restore the normal functioning of the machine process requires some time. Time spent on the restoration of normal equipment operation intervals increase the duration of release and reduce the actual performance machines. Thus, the operation of the machines there is a consistent alternating two different periods – periods of continuity and recovery periods working condition of the machine. Uptime machine technique called time operating time $\mathbf{t_н}$, and its operability during recovery – recovery time $\mathbf{t_в}$.

The relationship between these parameters determines the level of technical equipment and the efficiency of its use in production. It is estimated fate uptime $\mathbf{t_н}$ or coefficient of readiness. The coefficient of readiness $\boldsymbol{K_г}$ availability index is a comprehensive measure of the reliability and sets the expectation of the time of normal operation of the automated line:

$$K_Г = t_н/(t_н + t_в) \qquad (1)$$

Significantly affect the efficiency of automated production systems in furniture manufacture reliable technical equipment, production equipment, means of control. Unreliable technology, shortcomings in the organization of work, factors outside influence causing loss of time operation of process equipment. Reliability of equipment entails considerable influence on the stability of manufacturing operations and efficiency of automated production systems. According to a number of studies [1, 2] expectancy distributed manufacturing operations by Erlang distribution, used to describe the process operations furniture production:

$$F(t) = p\{\tau < t\} = 1 - e^{-K\cdot\mu\cdot t}\cdot\sum_{i=1}^{k=1}\frac{(K\cdot\mu\cdot t)^i}{i!}, \qquad (2)$$

where: ***F (t)*** – distribution function of the time intervals; p{τ<t} – the probability that the duration of the operation will be less than a certain value ***t***; μ – intensity operations; **K** – Erlang parameter that describes the technological stability operations. Erlang parameter defined as the ratio to the square of the average duration of the operation to its variance:

$$K = t^{-2}/D(t) \tag{3}$$

Depending on the size of the dispersion parameter K may take different values ranging from 1 to ∞. At **K=1** when the variance of length transactions equal to its average value, we get the distribution to describe purely random processes.

In the absence of dispersion when the duration of the operation constant parameter K infinitely large ($K \rightarrow \infty$). Because of this property allows Erlang distribution to describe a wide range of manufacturing operations length with varying degrees of unevenness from a purely accidental to a permanent, inclusive. Dispersion interval release describes stability operations and technology determined by the formula

$$D(t_{IB}) = \frac{\overline{t_H} - \overline{t_Ц}}{\overline{t_H}}\left(D_Ц + \overline{t_Ц}^2\right) + \frac{\overline{t_Ц}}{\overline{t_H}}\left[D_Ц + D_B + \left(\overline{t_Ц} + \overline{t_B}\right)^2\right] - \left(\frac{\overline{t_Ц}}{K_Г}\right)^2 == D_Ц + \frac{\overline{t_Ц}}{\overline{tн}}\left[D_B + \overline{t_B}^2\left(1 - \frac{\overline{t_Ц}}{\overline{t_H}}\right)\right]., \tag{4}$$

where $\mathbf{D_ц}$, $\mathbf{D_в}$ – variance cycle length respectively and recovery time; $\mathbf{t_ц}$ – cycle of technological operations.

Thus dependence (4) defines the dispersion length interval output for specific parameters cycle time, equipment uptime and recovery time its operability. With equipment reliability theory we know that the average time between failure $\mathbf{t_н}$ and recovery time $\mathbf{t_в}$ linked by (1). Therefore, the variance range of output can be expressed in terms of availability factor:

$$D_{IB} = D_Ц + \frac{\overline{t_Ц}}{\overline{t_H}}\left[D_B + \left(1 - \frac{\overline{t_Ц}}{\overline{t_H}}\right)\left(K_Г^{-1} - 1\right)^2 \overline{t_H}^2\right], \tag{5}$$

Parameter Erlang $\mathbf{К_{iв}}$ production interval is calculated using the ratio

$$K_{IB} = \frac{\overline{t_{IB}}^2}{D_{IB}} = \frac{\overline{t_Ц}^2 / K_Г^2}{D_Ц + \overline{t_Ц}^2\left(\frac{1}{K_Г} - 1\right)^2\left(2\frac{\overline{t_H}}{\overline{t_Ц}} - 1\right)} == \left[\frac{K_Г^2}{K_Ц} + \left(2\frac{\overline{t_H}}{\overline{t_Ц}} - 1\right)\left(1 - K_Г\right)^2\right]^{-1}. \tag{6}$$

Stability of technological operations is determined by the Erlang $\mathbf{К_ц}$ cycle time and depends on the readiness coefficient $\mathbf{К_г}$ machines. Only perfect machine ($\mathbf{К_г}$ =1) parameter $\mathbf{К_{iв}}$ remains at its value for the duration of the cycle $\mathbf{К_ц}$. Parameter Stability $\mathbf{К_ц}$ cycle shows a strong influence on the reliability of machines allowed only in the range of $\mathbf{К_ц}$=1 to $\mathbf{К_ц}$=2. This limits availability factor quite high ($\mathbf{К_г}$=0.90-0.98).

To ensure this reliability in terms of furniture production difficult. Further growth cycle stability parameter $\mathbf{К_ц}$ has little effect on the permissible reliability of the machine. Thus appears essential primary stability ordering cycle time. More intensive and broader range of acceptable reliability affects the relative length of time of use.

Completed simulations using statistical research and analysis of the literature **[**1, 2], allows to formulate the following conclusions:

1. Reliability technological equipment creates a significant impact on the stability of manufacturing operations and efficiency of automated production systems in furniture production.
2. Reduce the reliability of equipment leads to a significant increase in the dispersion intervals output.

3. The results of simulation modeling confirms that the average duration of intervals of output is determined by the mean time rate of technological operations and readiness of the machine.

4. A significant increase in the dispersion range output with reduced machine reliability, leading to intense reduction parameter stability for interval output. Especially sharply reduced rate stability equipment with a reduction factor of its readiness.

5. Increasing the reliability of automated production systems appropriate to the use of structural redundancy and structural and parametric optimization of production lines.

The solution to these problems, along with other technical and organizational measures will significantly improve the reliability of automated production systems.

References

1. **Dudyuk D.L., Maksymiv V.M., Soroka L.Ya., Orikhovsky R.Ya. et al.** An imitation design of the flexible automated lines is in a industrial forestry complex. – Kyiv: ISDO, 1996. – 140 p.
2. **Dudyuk D.L., Zagvoyska l.D., Maksymiv V.M., Soroka L.Ya.** Elements of theory of automatic transfer lines. – Kyiv-Lviv: IZMN, 1998. – 192 p.

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

Вплив надійності обладнання на стабільність технологічних операцій та ефективність функціонування автоматизованих виробничих систем

Аналізується вплив надійності обладнання на стабільність технологічних операцій та ефективність функціонування автоматизованих виробничих систем у меблевому виробництві.

Розглядаються сучасні методи визначення надійності для вирішення завдань підвищення ефективності функціонування автоматизованих виробничих систем на меблевих підприємствах. Надійність обладнання має значний вплив на стабільність процесів та фактичну продуктивність автоматизованих ліній. Зниження надійності зумовлює значне зниження фактичної продуктивності автоматизованих ліній і зниження стабільності технологічних операцій.

Підвищувати надійність автоматизованих виробничих систем доцільно за допомогою розроблення схем компонування обладнання, структурно-параметричної оптимізації, структурного резервування та імітаційного моделювання.

Ключові слова: надійність обладнання, параметр стабільності, технологічні показники ефективності, автоматизовані виробничі системи, імітаційне моделювання, структурно-параметрична оптимізація, резервування.

UDC 674.047
Prof. P.V. Biley; post-graduate R.O. Rokun; assist. O.M. Kushpit – UNFU, Lviv

GENERALIZED ANALYSIS OF THE RESULTS OF THEORETICAL AND EXPERIMENTAL STUDIES OF THE CONVECTIVE DRYING PROCESS OF WOOD

Convective drying is the most common method of drying lumber and blanks, veneer and chipped wood, shaped pieces and other wood products. The main equipment for drying veneer are roller dryers. For drying the chipped wood that is used for manufacturing particleboards, powerful drum dryers are mostly used where the drying agent is flue gases generated from the combustion of a mixture of natural gas and sander dust. The use of independent sources of thermal energy in the processes of drying veneer and chipped wood waste is an urgent problem, the solution of which allows recycling a variety of waste wood in woodworking industry, furniture making, sawmilling, plywood manufacturing and other industries, and also used wood which has exhausted its service life (post consumer wood). The received results of theoretical and experimental studies are recommended for use in woodworking and other industries that produce rotary-cut veneer and chipped wood, and enterprises that manufacture products from rotary-cut veneer (plywood, furniture items, musical instrument ,etc.) and also plants that manufacture products from chipped wood (particleboards, fuel briquettes and pellets and other products).

Keywords: humidity, convective drying, lumber, blanks, wood drying, speed of drying, veneer, chipped wood, heating.

Convective drying is the most common method of drying lumber and blanks, veneer and chipped wood, shaped pieces and other wood products. The basis for the characterization of scientific and practical significance of the conducted research are the obtained theoretical and experimental results which are covered in this work.

Wood drying is the most power-intensive process in woodworking industry. In due time, most boiler plants were converted to natural gas or fuel oil, the fuel which has high calorific value. But owing to the rise in prices of energy (natural gas and fuel oil), manufacturers are forced to seek for alternative, cheaper energy sources. One of these resources is a wood raw material as a dependable and renewable source of thermal energy. The scientists of some Western European countries and of Ukraine have developed a number of effective, independent sources of thermal energy, using wood raw materials as fuel , namely: Vynske energie technik NV (Belgium), Politechnik Biomass Energy (Czech Republic), “Hamech”, “Univeks” (Poland), “Krieger”, “Metallist” (Ukraine), which have high efficiency (≥90%).

The main equipment for drying veneer are roller dryers. They have a number of significant advantages over other kind of equipment. Veneer is shaped between the rollers, which prevents the veneer warping. During the movement of the veneer, the rollers further squeeze out of it some moisture without consumption of thermal energy. In a roller dryer, the thermal energy is transferred to the material (veneer) by convection from the drying agent, by conduction from heated rollers and heat radiation from the elements of the dryer.

In roller dryers, the drying agent can be steam-air mixture or flue gases. The steam-air mixture is heated by the heaters, where the heat carrier is water steam with pressure of 0.6-0.8 MPa. As a rule, water steam was produced by large boiler plants of DKVr or DE types. However, such boilers used natural gas or fuel oil as a fuel, which greatly increases the cost of generated thermal energy.

For drying the chipped wood that is used for manufacturing particleboards, powerful drum dryers are mostly used where the drying agent is flue gases generated from the combustion of a mixture of natural gas and sander dust. Besides the production of particleboards, chipped wood has been widely used recently for the manufacture of fuel briquettes and fuel granules (pellets).

When using wood waste, large boiler plants are working inefficiently. Therefore, it is reasonable to use small thermal generating units with a capacity of 1-2 MW of heat energy, which use crushed waste of wood raw material as the fuel .

There is a sufficient supply of wood raw material in Ukraine that can be used as fuel. First, a large amount of logging residues, dead and unfit for economic purposes wood. Secondly, waste from sawmill plants, furniture making, wood panel production and other industries. Thirdly, the use of wood which has exhausted its service life. Fourth, it is the woody biomass which is collected on the green plantations of fast-growing wood species: willow, poplar, aspen, and the like.

Thus, this paper deals with the energy aspects of drying chipped wood, where the drying agent are flue gases derived from the burning of wood raw material in thermal generating units. Among the thermal generating units that are to be used to provide drying plants with heat energy are modern boilers of domestic and foreign manufacturers. For drying chipped wood in the production of fuel briquettes and fuel pellets, it is advisable to use small drum or flash dryers, where the drying agent are flue gases obtained from the combustion of various waste wood.

The use of independent sources of thermal energy in the processes of drying veneer and chipped wood waste is an urgent problem, the solution of which allows recycling a variety of waste wood in woodworking industry, furniture making, sawmilling, plywood manufacturing and other industries, and also used wood which has exhausted its service life (post consumer wood). Western European countries practise cultivating fast-growing wood species (willow, aspen, poplar) which are used as fuel or for generation of synthesis gas. If dryers use flue gases as the drying agent , the gross calorific value of fuel from wood raw material is used then, which significantly increases the energy efficiency of thermal generating units and drying plants.

The process of conducting the studies involved application of the research methodology of heat-mass transfer processes of woodworking, namely, the theoretical and graphoanalytical methods of determining the duration of drying, the kinetic coefficients of the drying process and complex criteria describing the integrated process of heating and drying of wood. To process the experimental results, we used mathematical planning, classical methods of experiment conducting, and mathematical statistics evaluation of physical quantities characterizing the properties of wood (density, moisture content, anisotropy, shrinkage,...) as well as kinetic characteristics of the drying process (rate of drying, factors of moisture conduction and moisture-yielding ability, the gradient of moisture content of wood, drying coefficient). Analysed were the methods of calculating the components of heat balance of power plants in order to improve their operation and increase the effectiveness of heat energy utilization.

Obtained applied scientific results. Modernization of roller dryers SUR-4. The SUR-4 roller dryer is a steam-air dryer with a longitudinal loading of material and transverse circulation of the drying agent which is heated by steam radiators. The drying plants were reconstructed for the experimental studies. Axial fans were replaced with more efficient centrifugal blowers which are placed on the ceiling of the dryer. In this case, the first two fans (from the charging compartment) provided heat and circulation of the gas-air mixture for the first period of drying, and the next two fans provided conditions for the second drying period. That is, it became possible to regulate the speed of circulation and thermal regime in the two equal parts of the drying plant, which is the original aspect of their modernization.

As a result of double purification of products of fuel combustion (waste wood), they are completely cleaned of soot and, at a high temperature, fed into the distribution channel and through adjustable holes to the middle of the drying chamber where they are mixed with the circulating nongaseous mixture. Consequently, all heat energy that is needed in the drying process is the heat energy of flue gases obtained from burning waste wood in the independent sources of thermal energy.

Due to the modernization of the SUR-4 dryer, new results have been obtained which differ significantly from domestic and foreign analogues, namely:

- the drying plant is converted to energy-saving heat supply – flue gases with a high calorific value of fuel;
- the drying process in the drying plant is arranged zonally – for the first period of constant drying rate and for the second period with slowing the rate of drying, with certain temperature modes and circulation rate of the drying agent, which can be changed depending on wood species and thickness of veneer sheets;
- the moisture content of wood is governed by the speed of the conveyor roller drive.

Improvement of drying plants of flash type. In drying plants of drum type (with pneumomechanical movement of material) occurs a process of continuous convective drying of chipped wood. These dryers are simple in design and are of adequate performance. The drying process is regulated by the temperature of the drying agent, its rate of circulation and the rotation speed of the drum and the angle of its slope. The temperature of the environment, usually flue gases, can range from 350 °C up to 730 °C at the inlet to the dryer. Outlet temperature of the drying agent, according to the operating requirements, should be taken from 50 °C up to 90 °C and governed by the circulation rate.

In flash-type dryers, you can create a two-step drying process due to the two-circuit design. In the two-circuit drying plant, the process of chipped wood drying can be divided into two periods: the period of constant (steady) speed of drying from the initial moisture content Wi to the critical value Wcr, and the period of slow drying from the critical value Wcr to final moisture content Wf. This division of the drying process allows to intensify heat-and-mass transfer processes. Due to this improvement of drying plants of flash type, it was possible to obtain new results which differ significantly from domestic and foreign analogues, namely:

- the drying plant uses energy-saving heat supply – flue gases with a high calorific value of fuel;
- the drying process in the dryer is divided into two periods, where the first period is of constant drying rate which occurs in the primary circuit of the dryer and the second period of the slow drying rate in the second circuit of the dryer with individual temperature regimes and circulation rate of the drying agent, depending on particle size of shredded wood, initial and final moisture content of the wood in a separate circuit.

Practical results of theoretical and experimental studies of drying processes. The following new practical results were obtained as a result of studying patterns of heat-and-mass transfer:

- solving the problems of kinetics of the drying process by experimental drying curves, the curves of drying rate and the variation of temperature in the course of time made it possible to develop a methodology for determining the intensity of heat exchange and mass transfer, which gives sufficiently accurate results for practical use;
- solving the system of equations of heat-and-mass transfer according to the corresponding initial and final boundary conditions allows determining the moisture content and temperature fields in the wood, which is of practical use in determining values for humidity and temperature deformations and corresponding stresses characterizing the quality of wood;
- the drying process for rotary-cut veneer and chipped wood is divided into two periods of constant and slow rates of drying for which experimentally were found values for the rate of drying, drying coefficients, moisture conduction, moisture-yielding ability, which allows for synthesizing the calculated dependences of the intensity and duration of drying on wood species, its moisture content and density, temperature and humidity fields of the environment in the drying plants;
- solution of differential equations of drying rate in the periods of constant and slow rates of drying allows defining a list of parameters that need to be found experimentally to transform theoretical equations into design ones in order to determine the duration of drying processes and, accordingly, to determine the performance of installations for wood drying;
- based on the law of conservation and transformation of energy, equations have been synthesized that characterize the heat balance at the interface of phases "environment-the surface of the material" during drying which determine, in one case, the amount of heat energy received from the environment that is used for heating of the material and evaporation of moisture, and, in the second case, characterize the mass flow (moisture) inside the material, that is, practically determine the values for moisture conduction and moisture-yielding ability of wood;
- the possibility has been proved for flue gases, cleared of sparks and subjected to double purification from smoke and soot, to be used in the drying processes not only of veneer and chipped wood, but lumber and blanks as well;
- based on the analysis of the results of experimental investigations on the process of drying rotary-cut veneer in the reconstructed roller-drying systems, the authors derived dependences of the temperature of the drying agent and the speed of circulation in various areas of the dryer on moisture content of the veneer, which makes it possible to divide the drying process into two periods and actually to regulate the intensity of veneer drying process;
- based on the analysis of the results of experimental investigations in the two-circuit flash drying plant, there were developed operating parameters – temperature of the drying agent at the entrance to the first and the second circuits as well as the recommended circulation rate;
- based on the results of experimental studies on rotary-cut veneer and chipped wood, a technique was developed for determining the technical- and-economic performance of reconstructed roller drying plants and pilot plants of drum and flash types, namely their productivity, duration and cost of the drying process;
- Based on the mass of moisture that evaporates during drying of rotary-cut veneer and chipped wood, the dependence of drying rate on the temperature of the drying agent was identified and mathematically described, and, in the end, the desired thermal power of the heat-generating unit was determined.

Conclusions. The above results of theoretical and experimental studies are recommended for use in woodworking and other industries that produce rotary-cut veneer and chipped wood, and enterprises that manufacture products from rotary-cut veneer (plywood, furniture items, musical instrument ,etc.) and also plants that manufacture products from chipped wood (particleboards, fuel briquettes and pellets and other products).

References

1. **Behta P.A.** Technology wood composite materials. Textbook. – K.: Basis, 2003. – 336 p.
2. **Biley P.V., Pavlyust V.M.** Drying and protect wood. Textbook. Lviv:Colored sky,2008. –312 p.

3. **Sterlin D.M.** Drying in the production of plywood and particle boards. – Moscow: Lesnaya promyshlenost, 1977. – 383 p.

4. **Biley P.V.** Heat and mass transfer processes wood. Textbook / Biley P.V., Petryshak I.V., Sokolovskiy I.A., Soroka L.Ya. – Lviv, 2013. – 376 p.

УДК 674.047

Проф. П.В. Білей, д-р техн. наук; аспірант Р.О. Рокунь; асист. О.М. Кушпіт – НЛТУ України

Узагальнений аналіз результатів теоретичних та експериментальних досліджень конвективного процесу сушіння деревини

Конвективне сушіння є найпоширенішим способом сушіння пиломатеріалів і заготовок, шпону та подрібненої деревини, профільних та інших виробів з деревини. Основою для характеристики наукової і практичної значимості проведених досліджень є отримані нові теоретичні та експериментальні результати. Основним обладнанням для сушіння шпону є роликові сушарки. Вони мають ряд істотних переваг в порівнянні з іншим обладнанням. Між роликами фіксується форма шпону, тобто запобігається його деформація-жолоблення. Ролики при рухові шпону додатково вичавлюють з нього частину вологи без витрат теплової енергії. В роликових сушарках теплова енергія до матеріалу (шпону) передається шляхом конвекції від агента сушіння, шляхом кондукції від нагрітих роликів та тепловим випромінюванням від елементів сушарки.

Для сушіння подрібненої деревини, що йде на виробництво деревинностружкових плит, в основному, застосовують потужні барабанні сушарки де агент сушіння – топкові гази, які утворюються від спалювання суміші природного газу та шліфувального пилу. Крім виробництва деревинностружкових плит подрібнену деревину в останній час широко використовують для виготовлення паливних брикетів і паливних гранул (пелетів).

На відходах з деревини великі котельні установки працюють неефективно. Отже, доцільним є застосування невеликих теплових агрегатів потужністю до 1-2 МВт теплової енергії, котрі, як паливо використовують подрібнені відходи з деревної сировини.

Використання автономних джерел теплової енергії в процесах сушіння шпону і подрібненої деревини є актуальною проблемою, вирішення якої дозволяє утилізувати різні відходи деревообробних, меблевих, лісопильних, фанерних та інших виробництв, а також уживану деревину, яка вичерпала свій термін експлуатації.

Якщо в сушарки подаються топкові гази, як агент сушіння, то використовується вища теплотворна здатність палива з деревної сировини, що значно підвищує енергетичний коефіцієнт корисної дії теплових агрегатів і сушильних установок.

В процесі виконання дослідження використано методологію дослідження тепломасообмінних процесів деревообробки, а саме теоретичні та графоаналітичні методи визначення тривалості сушіння, кінетичних коефіцієнтів процесу сушіння та комплексних критеріїв, що інтегровано описують процеси нагрівання та сушіння деревини.

Отримані результати теоретичних та експериментальних досліджень рекомендується використати в деревообробній та інших галузях промисловості та підприємствах, що виробляють лущений шпон та подрібнену деревину та на підприємствах, які виготовляють продукцію з лущеного шпону (фанеру, меблеві вироби, музичні інструменти тощо) і подрібненої деревини (деревинностружкові плити, паливні брикети і пелети та інші вироби).

Ключові слова: вологість, конвективне сушіння, пиломатеріали, заготовки, сушіння деревини, швидкість сушіння шпону, деревинна стружка, процеси нагрівання.

UDC 684.4 ***Assoc. prof. S.A. Grytsak, assoc. prof. G.V. Somar – UNFU, Lviv***

TECHNICAL AND ECONOMIC ANALYSIS METHODS OF MANUFACTURING CURVED BLANKS

In this article are present of the ways to get curved pieces. For comparison selected four variants of the technological process: Cutting out of curved pieces from glued on the smooth surface of panel; Cutting out of curved pieces sections, glued in length on toothed tendons; Bending of solid wood; Bending with simultaneous gluing. The basis of calculations chosen curved work piece, calculated the need for raw materials, developed technological processes, calculated energy needs, calculated the cost-effectiveness of each option. The priority of making curved pieces by bending solid wood on a number criterion was proved.

Keywords: wood, bending, curvilinear workpieces, technology, analysis.

Modern Furniture production observed a wide variety of designs shapes and sizes, high quality of workmanship, original design. To ensure these options in goods are increasingly using parts of curved shape. In our opinion, the most complete classification methods of manufacturing curved pieces presented Voytovych I.G. [1-3]:

- The cutting of massive workpieces (sawing, milling, milling copying, sharpening).
- By bending (solid wood, with simultaneous gluing, sawed pieces, weaving).
- By pressing (solid wood, flat blanks, wood-adhesive composition).
- By burning of laser.

The last two methods are not widely used because it has a number of shortcomings that limit the use of tanbarks. Therefore, they will not analyze.

The raw material for the manufacture of curved blanks obtained by the first and the second method is used, respectively, solid wood and sliced or rotary veneer. The process in each case is different, and for its implementation need specific equipment, certain size of plant, specific power inputs and other factors. No clear data on the efficiency of different methods for curved shape pieces.

The technological process of manufacturing a curved piece from solid wood includes: sawing straight piece; creation of base surfaces; gluing pieces in the panel; technological shutter; calibration of panel; layout and sawing curved piece; primary processing of the workpiece; provide blank forms of detail.

The process manufacturing of bent piece of solid wood includes: making straight piece; plasticizing it before bending; bending; drying; primary processing of the workpiece; provide blank forms of detail. The process of manufacturing the curved pieces by bending thin layers of wood with simultaneous gluing them requires the following operations: manufacture thin layers of required size; applying glue; the formation of the package; bending the package while gluing it in the block; technological exposure of primary processing of curved units; provide blank forms of detail.

Given the above, we can draw the following conclusions:

- modern furniture and other wood products are increasingly use parts curved shape;
- there are some ways to manufacture parts curved shape;
- each method has the special characteristics: raw materials (lumber or piece of solid wood, rotary or sliced veneer); the cost of raw materials per unit of output; technology, tools and equipment; size of shop; auxiliary shops, offices and services; number of employees and their qualifications; power inputs (electricity, steam, water);
- the total for each method is surgery to provide of the workpiece shape of detail;
- as a result – each method has different efficiency (cost) of production;
- definitive data on the efficiency of a method of obtaining blanks curved shape there.

The aim of the development process is the production of finishing pieces curved shape. Shape of pieces is important, because it affects a large extent the structure of the technological process, the content of technological operations, methods of processing workpieces and overall efficiency of the process.

They chose a blank rectangular cross-sectional shape curved in the shape of a semicircle with the internal radius of 200 mm. Work piece dimensions: length – 688 mm, width – 33mm thickness – 19 mm. This blank can be used as a side-bar, or armrest bar or blank of chair seat. In this paper selected four options for making curved shape of the work piece (Table. 1).

Table 1. Methods manufacturing of curved pieces

Version number	Content Works
Variant I	Sawing straight blanks, primary processing, adhesive gluing on the width on the smooth surfaces, technological exposure, sawing curved pieces (Fig. 1), the primary processing of workpieces.
Variant II	Sawing straight blanks, primary processing, milling finger joint, bonding pieces in length on finger jointin form piece, technological exposure, sawing curved pieces (Fig. 2), the primary processing of workpieces.
Variant III	Sawing straight blanks, blanks plasticizing, bending of solid wood, drying preparations, primary processing of workpieces.
Variant IV	Layout of veneer, cutting of veneer, applying adhesive, forming of glue package, pressing, cutting units, primary processing of the workpiece.

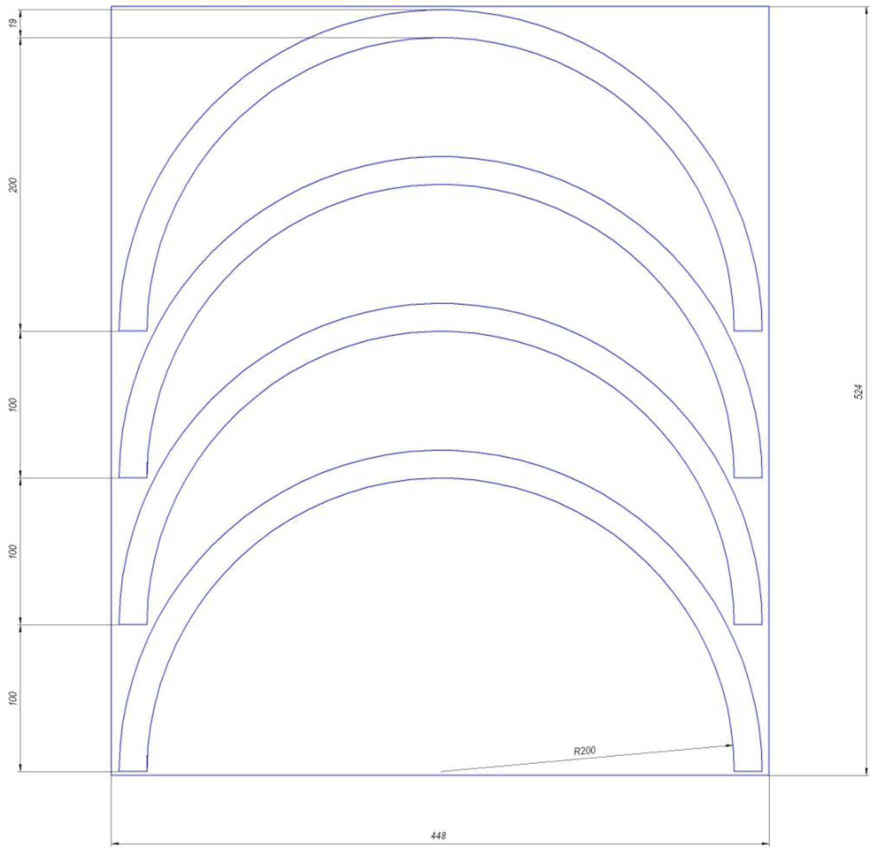


Fig. 1. Scheme obtaining of blank from panel board obtained by gluing bars on the smooth surface at width.

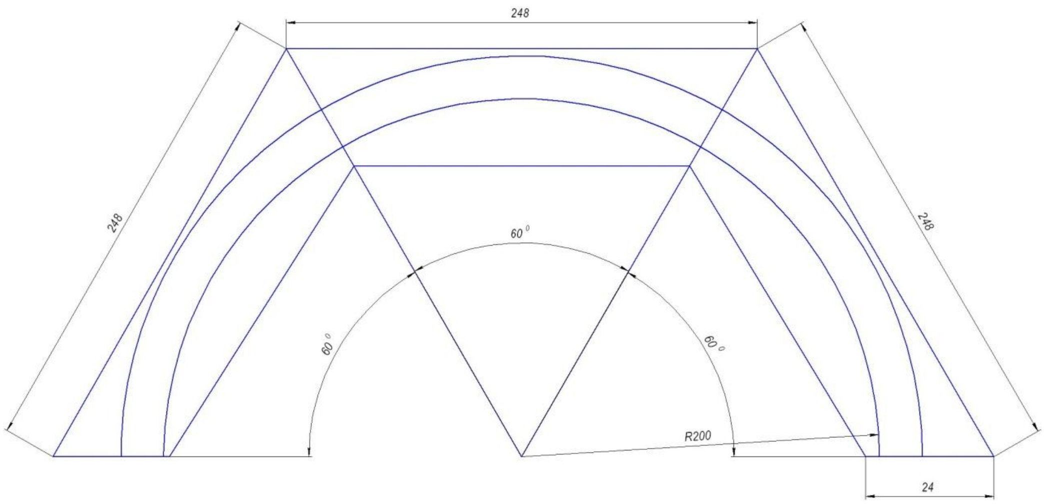


Fig. 2. Scheme obtaining of blank from panel obtained by gluing bars finger joint in length

The comparative analysis should be carried out by comparing the characteristics of the process that uniquely characterize of it. One of the main parameters in our opinion, is the cost of production per unit. For it obtain necessary: to calculate the need for raw materials (Table 2); work out technological process; determine the list of technological equipment and workplaces (Table 3); determine the optimal production program; determine the need for labor (Table 4); determine the size of the building department (Table 5); calculate energy needs (electricity (Table 6), steam (Table 7), water (Table 8)); determine the cost of labor protection, safety and environmental protection.

Table 2. Summary norms of raw materials for productioncurved pieces.

№	Materials name	Unit	Consumption of materials		
			Ontne workpiece	On the program for 100000 pcs	Optimal program
1	2	3	4	5	6
Variant I (cutting)					115000 pcs
1	Hardwood lumber thickness 40 mm	m^3	0,00522	522	600,3
2	Polyvinyl acetate glue	kg	0,031	3100	3565
Variant II (cutting)					110000 pcs
1	Hardwood lumber thickness 25 mm	m^3	0,00484	484	532,4
2	Polyvinyl acetate glue	kg	0,009	900	990
Variant III (bending of solid wood)					180000 pcs
1	Hardwood lumber thickness 25 mm	m^3	0,00128	128	230,4
Variant IV (bending while gluing)					270000 pcs
1	Hardwood slise veneer, 0,8 mm	m^2	0,104	10400	18720
2	Rotary veneers from birch	m^3	0,00090	90	162
3	Urea glue	kg	0,046	4600	8280
4	Glue thread	kg	0,00012	12	21,6

Table 3. Summary list of production equipment

	Variant I		Variant II		Variant III		Variant IV	
№	Name of equip-ment	∑	Name of equip-ment	∑	Name of equipment	∑	Name of equip-ment	∑
1	Hand-operated crosscut off saw	1	Hand-operated crosscutoff saw	1	Hand-operated crosscutoff saw	1	Workplace for mark out	1
2	Quartering saw, trimmer	1	Quartering saw, trimmer	1	Quartering saw, trimmer	1	Guillotine shears	1
3	Hand jointer	1	Universal circular saw	3	Autoclave	1	Veneer composer	1
4	Workplace for ap-plying of glue	1	Molding machine	1	Bender, bending rig	1	Roller glue spreader	1
5	Clamping machine	4	Workplace for ap-plying of glue	1	Drying chamber	1	Workplace for formation of pack-ages	1
6	Hand jointer	1	Clamping machine	8	Handjointer	1	Press (40 pieces – 4 daylight)	1
7	Thicknesses ma-chine	1	Handjointer	1	Thicknesser machine	1	Band mill (resaw)	1
8	Workplace for marking	1	Thicknesser ma-chine	1	Molding ma-chine	2	Universalcircular-saw	2
9	Band mill (resaw)	1	Workplace for marking	1	Universalcircu-larsaw	1	Handjointer	1
10	Springle moulding machine	1	Band mill (resaw)	1			Thicknesser ma-chine	1
11	Universal circular saw	1	Molding machine					

Table 4. Calculating the number of workers

Variantof process	Number of workplace	Number of workers, people
I	13	9
II	20	13
III	10	7
IV	11	6

Table 5. Summary list of production area, m^2

№	Assignment area	VariantI	VariantII	VariantIII	VariantIV
1	Area occupied by facilities and workplaces	191,5	250,8	169,7	131,3
2	Input the storehouse	11,43	10,14	4,39	4,34
3	Storehouse before glueing	1,32	1,18	---	1,55
4	Place the technological exposure	1,32	1,18	---	0,9
5	Production workshop area	333,2	430,5	287,2	225,6
6	Area of sanitary and other offices	72	72	72	72
7	Area (size) of shop	432 (12x36)	504 (12x42)	360 (12x30)	360 (12x30)

Table 6. Summary list of the annual electricity needs, kWh

Variant process	Power electricity	Electricity for lighting and sanitary facili-ties	Total
I	42610,4	8259,0	50869,4
II	58431,2	9603,6	68034,8
III	52215,6	6914,4	59130,0
IV	67619,8	6914,4	74534,2

Table 7. Summary list of the annual consumption of steam

№	Type of consumption	Annual consumption of steam, tons/year			
		I	II	III	IV
1	Technological needs	---	---	631,2	300,8
2	Heating and ventilation	153,9	183,3	122,0	124,6
3	Domestic needs	6,8	9,8	5,3	4,5
	Total:	160,7	193,1	758,5	429,9

Table 8. List of water consumption

Variant process	Technology needs	Domestic needs	Against fire needs	Total
1	2	3		4
I	---	146,3	23	169,3
II	---	211,3	23	234,3
III	---	113,8	23	136,8
IV	9,9	97,5	23	130,4

The subject of research is the formation of the cost of production (production costs) curved wooden pieces under conditions different technological approach to manufacture. Background research is no debate because the enterprise cost as a whole, and individual processes in particular, play a significant role in its activities. They limit profits and thus affect the amount received for the further development of the enterprise resources. The enterprises costs the determine the minimum price of products under the break-even point or an additional request – a variable cost and widely used in pricing if the use of the planned profit and profitability. On the other hand, the costs of the enterprise determine its price competitiveness, the use of price methods of competition and stock financial strength of the available market conditions [4].

Value is not only the total value of the enterprise costs, but also their structure, on the one hand, points out features of the enterprise and its shortcomings, on the other – describes the capabilities of its development and potential risks. The structure of the full cost per unit of output clearly shows their distribution by divisions and functions of the company, and also allows you to identify the reserves to reduce costs.

One of the key issues in the theory of cost are factors that influence on their formation. Recognition of the impact of factors on the cost, they allow accounting costs affect the company. The impact of factors on costs expressed quantitatively and qualitatively. Alone impact can be strictly deterministic or correlation, not always linear character. Among the factors that affect the cost of enterprise, distinguish: prices of resources and their quality, the actual value of resources, employment intensity of labor and machinery and the corresponding level of productivity, organization of production, scale of enterprise, production program, and other.

Analysis of the cost of technological process manufacturing of the curved pieces are an important part of the total production cost management. This manufacturing process can be performed using different technologies, which differ in resource consumption. Selection of the optimal technology options, depending on the price of certain types of resources and the necessary economies of scale may be the manufacturer of that blanks taking into account other limiting factors.

For financial analysis of the costs of production variants of curved pieces should set certain parameters of the source data that are relevant to the settlement date for each of them:

- prices of raw materials;
- transportation and procurement costs for raw materials (12,0 % of their purchase price);
- reverse the price of waste (for remanufacturing , for fuel);
- standard stock of raw materials for the uninterrupted organization of the process (30 days);
- average wages of one production worker;
- average tariffs for energy;
- cost of 1 m^2 production area of shop;
- depreciation deductions (passive of fixed assets – 7,76 % active part of fixed assets (equipment) – 21,93 %);
- equipment cost (average for local dealers of various firms – manufacturers);
- purchase and installation costs for the process equipment (20,0 % of their value);
- repair costs (4,5 % of the assets);
- the cost of labour protection (7,0 % payroll of major workers);
- other expenses (administrative, maintenance and shop equipment, etc. – 15,0 % of the previous costs).

Given the above, it was determined the cost structure of production of curved wooden pieces for different variants of the process (Table 9).

Table 9. The cost structure of manufacturing curved wooden pieces for different variantsof the process (%%)

№	Elements of cost	Project variantstechnology			
		I	II	III	IV
1	Materials (net return of waste)	72,5	66,3	57,1	59,4
2	Energy costs	1,5	2,1	6,8	6,1
3	Wages of production workers with deductions	8,7	13,3	14,5	13,3
4	Depreciation and repair costs	3,8	4,6	7,2	7,8
5	Other expenses	13,5	13,7	14,4	13,4
	Total:	100,0	100,0	100,0	100,0

Financial and economic aspects of comparative analysis can be the key to manufacturers in the decision on the optimal variant of the process for change of certain macroeconomic conditions. Another important, for any investor index is a measure of capital intensity (or the amount of investment costs per unit of output).

Therefore, to ensure the completeness of this comparative analysis it will add two more specific (for 1 blank) parameters: performance (or the efficiency of use of production space) and capital intensity (or the amount of investment costs per unit of output) (Table 10). To calculate this index options for the project took into account the investment costs for the construction of production facilities and the necessary equipment, and the cost of raw materials for the production of billets at the rate of creation of the 30-day reserve (investments in working capital). However, these costs amount to the amount of total investment for each of the variants. Dividing it into optimal program, we get an indicator of capital intensity per unit.

These calculations indicate the undoubted advantage of the last (IV) version of the technology in two given criteria: efficiency of production area and the level of unit production costs.

Table 10. Specific indicators of capital intensity and productivity products

Indexes	Variant I	Variant II	Variant III	Variant IV
Production cost, $/pcs	3,32	3,27	0,99	0,61
Productivity (removing products from 1 m^2 of production area) pcs/m^2	266	218	500	750

Adding to this figure calculated earlier figures material capacity, wages capacity, power capacity and a mort capacity, can present them in the form of graphics for your specific economic indicators (Fig. 3).

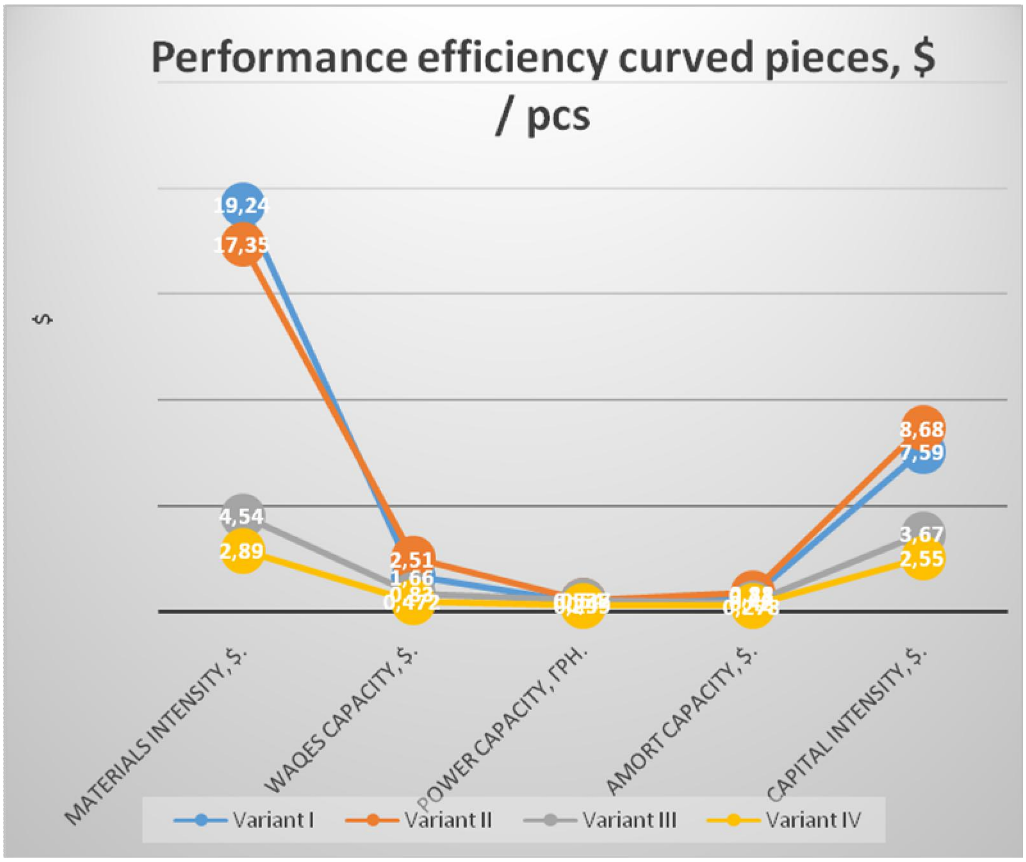


Fig. 3. Specific indicators of production capacity resources for the various versions manufacturing process

Plots demonstrates a significant difference between the options for raw materials intensity (raw materials) and capital intensity (investment property). Changing macroeconomic conditions that may result in increasing the value of these resources will spur the adoption of the manufacturer of the decision on choosing the optimal variant manufacturing technology of curved pieces. From the above graph shows that the most attractive options for process manufacturing curved pieces is an variant III and IV. In terms of appearance and workmanship bending curved pieces of massive wood (variant III) has clear advantages on all levels.

References

1. **Voytovych I.G.** *Osnovi tekhnologiї virobiv z derevini* [The basic technology of wood]. – Textbook. –Lviv: Kraine andeljat, 2010. – 304 p.

2. **Gayda S.V., Voronovich V.V.** (2011): *Porivnyal'niy analiz gnuttya vzhivanoї derevini riznikh porid ta vikovikh kategoriy* [Comparative analysis of bending particularities for various post-consumer wood species and age categories]. *Forestry, Forest, Paper and Woodworking Industry* 37(1): 84-88 (in Ukrainian).

3. **Gayda S.V., Voronovich V.V.** (2011): *Issledovanie osobennostey gnut'ya vtorichno ispol'zuemoy drevesiny* [Investigation of the features of bending of post-consumer wood]. *Scientific progress – creative young: proceedings of the International Scientific Conference, Mari State University*: 190-192 (in Russian).

4. **Kozachenko G.V., Pogorelov Y.S., Hlaponov L.Y., Makuhin G.A.** *Upravlinnya zatratami pidpriєmstva* [Management costs of the company]. – Monograph. – Kyiv: Libra, 2007. – 320 p.

УДК 684.4 ***Доц. С.А .Грицак, канд. техн. наук; доц. Г.В. Сомар, канд. техн. наук – НЛТУ України***

Техніко-економічний аналіз способів виготовлення криволінійних заготовок

Проаналізовано способи отримання криволінійних заготовок. Для порівняння вибрано чотири варіанти технологічного процесу: випилювання криволінійних заготовок із склеєного на гладку фугу щита; випилювання криволінійних заготовок із ділянок, склеєних по довжині на зубчатий шип по формі заготовки; гнуття масивної деревини; гнуття з одночасним склеюванням. За основу розрахунків вибрано криволінійну заготовку, розраховано потребу в сировині і матеріалах, розроблено технологічні процеси, розраховано потребу в енергоносіях, розраховано економічну ефективність кожного варіанта. Доведено пріоритетність виготовлення криволінійних заготовок гнуттям масивної деревини за рядом критеріїв.

Ключові слова: деревина, гнуття, криволінійні заготовки, технологія, аналіз.

UDC 684.4 ***Master's degree V.A. Koryachko; assoc. prof. A.S. Kushpit; assist. O.M. Kushpit; assoc. prof. Yo.V. Andrashek – UNFU, Lviv***

THE STUDY OF THE BLOCKBOARD SHAPE STABILITY DEPENDING ON THE DESIGN

The existing designs of blockboards are analyzed. Experimentally investigated was the influence of the core structure of blockboard and methods of joining its elements on the shape stability and dimensional change after the manufacture.

Keywords: wood, blockboard, core, structure, shape stability.

Relevance of the problem. Currently, manufacturers of panel-form materials are developing new materials for the purpose of obtaining various designs, environment-friendly and with the possibility of expanding the scope of application. However, the ordinary blockboards (coreboards), which are often used, for example, for the manufacture of the door leaf, do not become irrelevant.

One of the problems in the production is to ensure the dimensional stability and shape of the blockboard, which is important during its operation.

The purpose of the study was to determine the characteristics which are important during operation – warping and waviness – depending on the design of the blockboard.

Studies were conducted to determine the shape stability of such boards for various design options, as well as calculations were made to determine the economic feasibility of manufacturing such material. The object of the study was a blockboard – panel of strips (block), sandwiched between two layers of rotary-cut veneer.

Analysis of the research and publications. Despite the variations in colour and texture offered by manufacturers of laminated chipboard, modern furniture design dictates fashion for style solutions. This can be, for example, large working surfaces of a large thickness. There is a growing demand for lightweight construction materials, allowing to significantly reduce the use of wood and logistical costs of the furniture parts and ready-to-use furniture. This encourages the active development of panel-form materials with different types of core [3, 5, 10, 12].The use of "forgotten" panel-form materials of a frame structure with different types of core in the manufacture of cabinet-type furniture allows obtaining the properties of a perfect surface, high surface hardness and impact resistance. With modern adhesive materials and high-precision equipment, you can create panel structures from natural wood of the desired configuration and thickness. In addition, such designs are environment-friendly since they contain significantly less amount of harmful emissions from adhesives as compared to laminated and faced wood particleboards.

Blockboard is a product that has been present in our market for a long time. It is used for the manufacture of furniture, doors, partitions, floors, and sometimes walls in residential buildings, car-building, shipbuilding and other industries. With today's shortage of wood resources, it is important to use post-consumer wood in the production of blockboards [1-10]. A classical blockboard consists of strips glued together (the bulk of blockboard), faced with 3 layers of veneer – two rotary-cut-veneer layers, glued perpendicular to each other, and the outer ply is made of sliced veneer. If the boards are not faced with sliced veneer, then there are only 2 layers of rotary-cut veneer over the bulk.

Blockboard is traditionally considered to be the best material for manufacturing high-quality furniture. It is durable and lightweight structural material. Blockboards are environmentally benign in production and application.

This type of panel-form material was the main substitute for solid wood in the manufacture of furniture products, but with the development of wood particle- board production, its share in furniture making significantly decreased. One of the disadvantages of blockboards is the change in dimensions and shape after fabrication. The indexes of shape stability are different for different designs, but the blockboard of type NR (НР) [14] , with the core composed of strips which are not glued edge-to-edge, shall be considered as having the greatest shape stability. However, the blockboards of this type are the least strong, the strips, during the manufacture of the blockboard, are connected with a twine for fixation, the strength of the blockboard is provided only by adhesive bonding ‘ strip – veneer facing’.

Blockboards of types SR (СР) and BR (БР) have better indexes of strength [13, 14], due to glueing of the core strips by edge to edge. Here the core strips form a solid basis, and in combination with facing – a rugged structure. Warping of such panels is higher than that of panels NR (НР).This is due to the mutual deformation of the core strips, glued to form a blockboard. The warpage rate depends on the relative position of the annual rings in adjacent strips, the slope of grain, the presence of defects, etc.

The problem of shape stability has been solved in various ways, in particular, the methods proposed in the patent by V. Pyatkov, A. Voyakin “A method of manufacturing blockboards“ [11].

The performance of this task is ensured by the fact that, before laying the blockboard, the adjacent strips of the basis are fastenedby brackets on the upper and lower planes. Fig. 1 shows the structure of a blockboard using steel brackets.

The blockboard core is formed from thickness-calibrated strips 1. The adjacent strips in the core are fastened by brackets on the upper and lower planes 2 at a certain distance from the end of the core. Then the core is sandwiched between two layers of sheet wood material 3, for which can be used natural veneer, plywood, synthetic veneer, fibreboard. The core is placed between layers of sheet wood material whose surfaces, adjacent to the core, are coated with adhesive ,with the subsequent retention of the formed blockboard in the press.

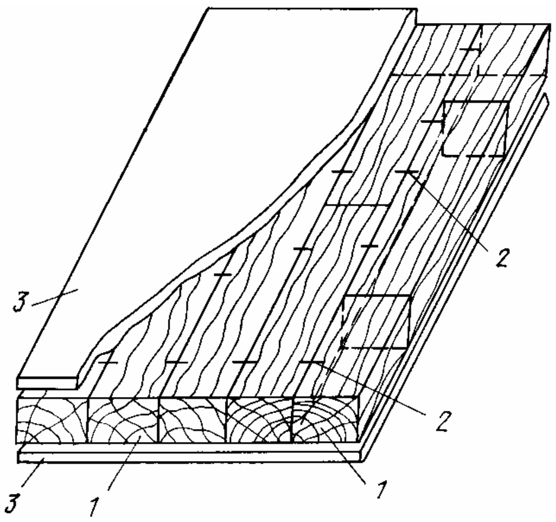


Fig. 1. A method for manufacturing a blockboard by fastening strips with steel brackets: *1 – core strip; 2 – steel bracket; 3 – facing*

This method of manufacturing blockboards, according to the authors [2], allows obtaining a blockboard with greater rigidity, compared to blockboards of type NR (HP), and with the preservation of its shape stability. Jointing of adjacent strips with brackets simplifies the technology of manufacturing a blockboard since there is no gluing operation of strips compared to the production of a blockboard of type NG (НГ).

Methods of the studies. The study of the blockboard shape stability, depending on the design, was carried out according to the following procedure:

Blockboard design. The basis (core) of blockboards was made of softwood strips, 450 mm long, 19 mm thick, and 20, 40 and 60 mm wide.

Facing – rotary-cut veneer, birch, 1.15 mm thick. Adhesive – PVA dispersion, class D3. The glue was applied manually with a glue spread of 150-200 g/m^2.

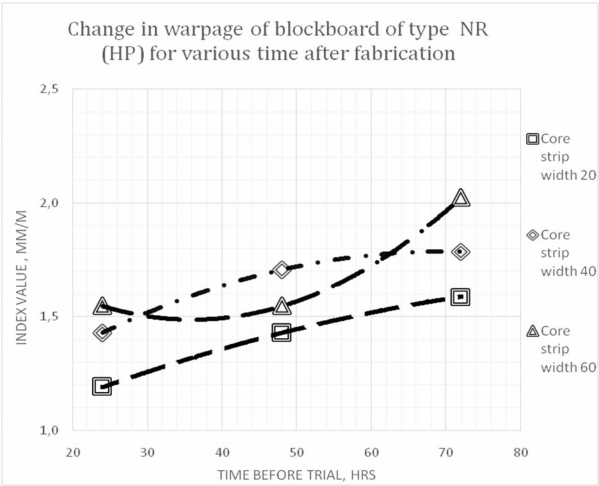
The fabricated specimens of blockboard were 450×450 mm in size, with three widths of core strips for three design types of blockboard. The study was conducted at the training and production workshop of the Department of furniture production techniques and wood products of the UNFU.

The length, width and thickness of the blockboards, waviness and warpage were controlled according to the requirements [13, 14].

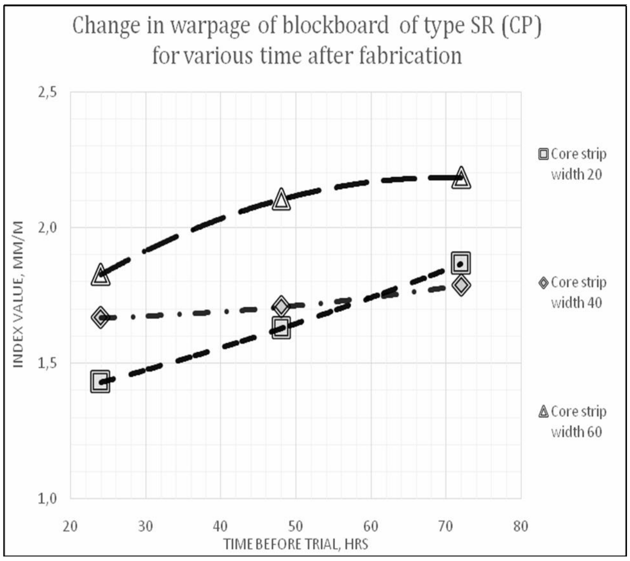
Results of the studies. The research was conducted by monitoring the blockboards' parameters 24, 48 and 72 hours after the blockboards were unloaded from the press. As it turned out, after the processing the experimental data, the deviation in the values for shape stability (waviness and warpage) is observed for different core strip widths and this is influenced by the blockboard designs.

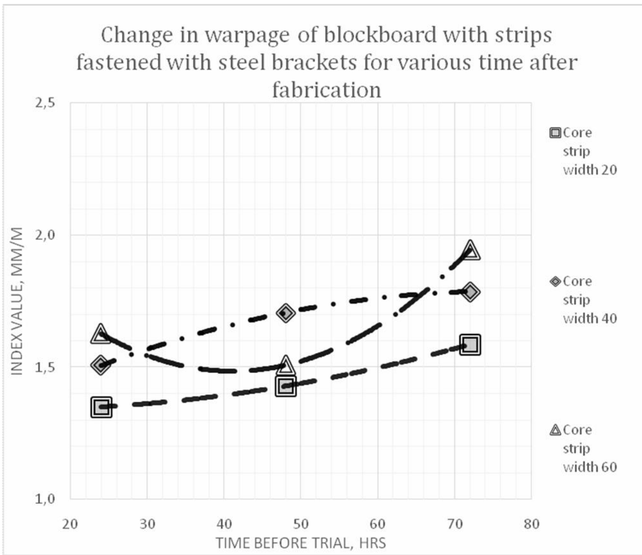
As follows from the experiments, the blockboard of type NR(HP) can be considered the best in terms of shape stability. This blockboard is made of strips that are not glued together and its strength is provided only at the expense of the adhesive jointing: the core strip face–veneer facing. This design, due to the fact that the core strips are free in the transverse direction, enables war page of the blockboards. Such a design is inconvenient in manufacturing as it requires additional effort when pressing the blockboard – the strips need to be fixed in the transverse direction.

The application of adhesive on the side surfaces of core strips improves the strength of the blockboard. However, this leads to an increase in deformation of the blockboard due to stresses, changes in humidity, the presence of defects in strips, incorrect stacking, etc. The third type of blockboard was a design in which the core strips were fast end with one another by using steel brackets as described in [14].



a)





b) ***c)***

Fig. 2. Warpage change in time for different types of blockboard:
a – for blockboard of type NR(HP) , b – for blockboard of type SR (CP),
c – for a blockboard in which the core strips are fastened with brackets

Conclusions:

1. As shown by the experiments, fastening the core strips with steel brackets has a positive impact on the properties of the blockboard. In particular, the core will be sufficiently rigid and does not require transversal clamping when pressing.
2. In terms of shape stability, this blockboard is not inferior to the blockboard of type NR (HP) with non-glued strips.
3. The amount of warpage for the above mentioned blockboard designs is the smallest for blockboards of type NR (HP)and with fastening brackets is 1.78 and 1.79 mm/m, respectively, for the width of core strip 40 mm.
4. Thus, the studies have shown that the design with fixed core strips can be applied to the manufacture of blockboards.

5. Calculations of manufacturing costs to produce one square meter of blockboard for three design options with different core strip widths showed that the largest amount of material costs is for blockboards with brackets and the blockboard of type NR (HP) is the cheapest.

References

1. **Gayda S.V.** (2017): *Tekhnologiya i svoystva mebel'nogo shchita iz vtorichno ispol'zuemoy drevesiny* [A technology and properties of furniture board made of post-consumer wood]. *Actual problems of forest complex* 48:34-38, (in Russian).
2. **Gayda S.V.** (2016): A investigation of form of stability of variously designed blockboards made of post-consumer wood. *ProLigno* 12(1):22-31.
3. **Gayda S.V.** (2016): *Formoustoychivost' stolyarnykh plit iz vtorichno ispol'zuemoy drevesin* [A form of stability of blockboards made of post-consumer wood]. *Actual problems of forest complex* 46:148-153, (in Russian).
4. **Gayda S.V.** (2015): *Issledovanie fiziko-mekhanicheskikh svoystv vtorichno ispol'zuemoy drevesiny* [Investigation of physical and mechanical properties of post-consumer wood]. *Actual problems of forest complex* 43:175-179, (in Russian).
5. **Gayda S.V.** (2015): *Tekhnologiї i fiziko-mekhanichni vlastivosti stolyarnikh plit iz vzhivanoї derevini* [Technology and physical and mechanical properties blockboard made of post-consumer wood]. *Technical service of agriculture, forestry and transport systems* 3(1):145-152, (in Ukrainian).
6. **Gayda S.V.** (2015): *Tekhnologicheskie osnovy pererabotki vtorichno ispol'zuemoy drevesiny* [Technological of processing basics of post-consumer wood]. *Actual directions of Scientific Research XXI century: Theory and Practice, Voronezh State Forestry Engineering University Named after G.F. Morozov* 3(8-2 (19-2)): 82-86, (in Russian).
7. **Gayda S.V.** (2015): Modeling properties of blockboards made of post-consumer wood on the basis of the finite element method. *Forestry, Forest, Paper and Woodworking Industry* 41:39-49.
8. **Gayda S.V.** (2013): *Tekhnologiї ta rekomendatsiї do vikoristannya vzhivanoї derevini v derevoobroblenni* [Technologies and recommendations on the utilization of post-consumer wood in woodworking industry]. *Forestry, Forest, Paper and Woodworking Industry* 39(1):48-67, (in Ukrainian).
9. **Gayda S.V.** (2013): *Resursooshchadni tekhnologiї pereroblennya vzhivanoї derevini* [Resource-saving technologies of recycling of post-consumer wood]. Scientific Bulletin of NULES of Ukraine: *Technology and Energy of agroindustrial complex* 185(2):271-280, (in Ukrainian).
10. **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* 36:81-92.
11. **Goncharov N.A., Voyakin A.S.** (12.08.2002) *Sposob izgotovleniya stolyarnoy plity* [A method of manufacturing blockboards] (19) RU (11) 2214328 (13) C1. Application: 2002121261/13, *Moscow State University of Forestry*, (in Russian).
12. **Kushpit A.S., Mnykh A.Ya., Kushpit O.M.** (2012) *Zastosuvannya shchitiv zi stil'nikovim zapovnennyam u meblevomu virobnitstvi* [Application of blockboards with honeycomb core in furniture production]. *Scientific Bulletin of UNFU* 22(6): 90-96, (in Ukrainian).
13. **DIN 68705-2:2014-10** Plywood – Part 2: Blockboard and laminboard for general use. Germany, (in Deutsch).
14. **GOST 13715:1978** *Plity stolyarnye. Tekhnicheskie usloviya* [Blockboards. Technical specifications]. *Moskow: Publishing house of standards*, (in Russian).

УДК 684.4
Магістр В.А. Корячко; доц. А.С. Кушпіт, канд. техн. наук; асист. О.М. Кушпіт; доц. Й.В. Андрашек, канд. техн. наук – НЛТУ України

Аналіз формостійкості столярної плити залежно від конструкції

Проаналізовано існуючі конструкції столярних плит. Експериментально досліджено вплив будови заповнення столярної плит та способів з'єднання її елементів на стабільність, формостійкість та зміну розмірів після виготовлення.

Ключові слова: деревина, столярна плита, заповнення, конструкція, формостійкість.

UDC 684.4 ***Assoc. prof. S.V. Gayda – UNFU, Lviv***

RESEARCH ON PHYSICAL AND MECHANICAL CHARACTERISTICS OF FRONT BLOCKBOARDS MADE FROM POST-CONSUMER WOOD

The expediency of using post-consumer wood (PCW) for material production is substantiated. It is proposed to process PCW into blockboards (BB). Proposed are new designs of PCW-made blockboards which are suitable for manufacturing furniture fronts. It was experimentally confirmed that the physical and mechanical properties of front PCW-made blockboards meet the requirements of standards. Obtained are patterns of influence of the width of the core strips of the blockboard and the thickness of the facing wood fiberboard (WFB) on dimensional stability, strength at static bending across the strips and strength in shearing along the glue line of front PCW-made blockboards in the dry state. Adequate regression models are obtained that can be used to describe a study object. Practical recommendations are offered for the production and use of front PCW-made blockboards for furniture production.

Keywords: wood, post-consumer wood (PCW), blockboards (BB), wood fiberboard (WFB), recycling, front surfaces, BB designs, technologies, shape stability, strength.

Relevance of the research. At the beginning of the third millennium, the humanity of the planet started seriously thinking about the environmental problems. These challenges also apply to forest resources, woodworking and furniture industries, secondary wood raw material reserves, postproduction wastes, primary production wood residues, solid household waste and so on.

An additional, unused reserve of wood raw materials in Ukraine is post-consumer wood (PCW) [1-19], the annual potential volume of which is about 2 million tons. In most European countries, the problems of PCW utilization have been partially solved. In Ukraine this issue at the Ministerial level has not been seriously discussed yet. Among scientists and manufacturers of furniture and joinery products, as well as producers of electric and thermal energy, sometimes there is a dilemma – whether to burn PCW or give this wood a «second life».

The scientists of UNFU believe that the future of PCW is its material use [1, 2, 6, 7, 10, 12, 13]. PCW will provide woodworking and furniture enterprises with additional raw materials, reduce the amount of waste accumulation in landfills, improve the environment of settlements, reduce carbon dioxide emissions from burning high-quality PCW, preserve the primary forest resources, which is relevant.

Besides, the involvement of PCW in the creation of wood products will force entrepreneurs to create new technological solutions for the processing of this resource, and scientists - to create new innovative non-standard wood products. All this requires conducting research, testing and confidence in their reasoning, as well as environmental and economic feasibility. Only a comprehensive and rational approach to the use of wood material on the basis of economic and environmental considerations will become effective for the implementation and solving of the main tasks of the country in the field of woodworking.

The problem of research. The problem today in this field is to prove to the producer of Ukraine the expediency of using PCW materially, i.e. for the manufacture of wood products. Today, entrepreneurs are mainly engaged in post-production wood waste, which, unlike European ones, does not cover the whole segment of secondary wood resources, one of which is PCW [14].

The solution of this problem is complicated by the diversity of PCW, the lack of technological solutions, practical recommendations, and the like. Scientists of Ukraine in their writings suggest ways of material use of PCW, in particular for the production of particleboards [3, 9, 11, 18], blockboards [2, 4, 6, 8, 19], the manufacture of elements of structural furniture [1, 7, 10, 12, 13], bended workpieces [15, 16] and others.

The results of their research indicate that this problem has not been completely solved, because the scientific basis and practical recommendations for effective production processes with predicting the properties of PCW-made products have not yet been developed in full [1-13, 15-19].

The implementation of this relevant idea in the production process should be based on the substantiated scientific and technical base of the PCW material resources, the development of resource-saving and environmentally friendly technologies, the development of regime parameters, the formulation of practical recommendations and the establishment of the patterns of impact of the PCW use on the physical and mechanical indices of the obtained products, in particular front blockboards (BBs).

The purpose of the work is to study the feasibility and clarify the specifics of PCW usage in the production of structural components of front blockboards (BBs).

The object of research are front PCW-made blockboards that are faced with thickened wood fiberboards (WFB).

The subject of research are physical and mathematical models, patterns and practical recommendations for the use of PCW in the technology of front blockboards.

The objectives of research:

- to collect PCW;
- to clean PCW which is suitable for material use;
- to make front blockboards from PCW;
- to determine the shape stability of PCW-made blockboards;
- to determine the ultimate static bending strength across the strips;
- to determine the ultimate strength in shearing along the glue line;
- to elaborate practical recommendations for the construction of front PCW-made blockboards.

Materials and designs of front PCW-made blockboards. Blockboards are constructional materials that are made by sandwiching a blockboard core between two sheets of veneer, a thin-walled plywood or sheets of fiberboard (2.5 and 3.2 mm thick). To create experimental front blockboards, WFB sheets of increased standard thickness were used – 4-6 mm (Fig. 1). On the faces of the manufactured PCW-made blockboards, it will be possible to perform milling work and, in the future, to make front surfaces (doors), softforming, postforming.

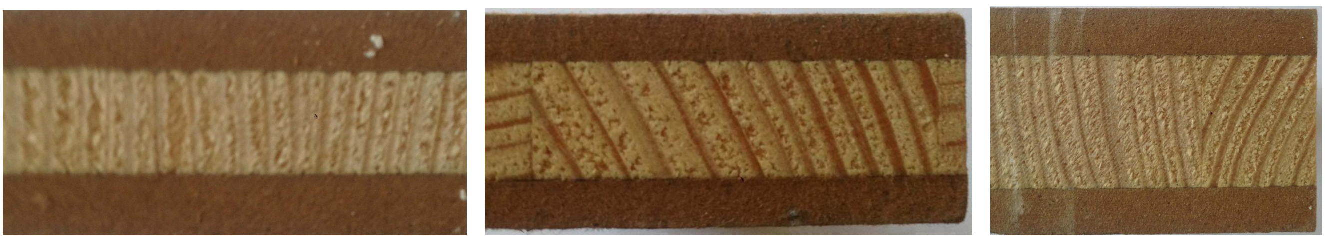


Fig. 1. Cross-section examples of front blockboards for testing

The following materials were used to make new PCW-made blockboards intended to create front surfaces of furniture products:

- wooden strips of softwood species from used wood products (in particular, window and door frames and cases);
- hard fiberboard (hardboard);
- polyvinyl acetate adhesive (PVA) of the brand Jowat 103.05 D3.

To conduct studies, the designs of PCW-made blockboards were developed, which would be used in the manufacture of front surfaces.

Basic characteristics of new structures of front PCW-made blockboards:

- the thickness of the PCW-made blockboard is 19 mm, which complies with the standard GOST 13715-78 [21];
- the width of the core strips is from 20 to 40 mm, which complies with the standard GOST 13715-78;
- gluing strips by straight joints into a blockboard core;
- increased thickness of the fiberboard for facing the blockboard core, in particular 4.0; 5.0; 6.0 mm, the sizes of which comply with the standard GOST 4598-86 [25]. This is determined by the need for milling works for front surfaces on both the faces and the edges of the PCW-made blockboards.

Developed were designs for PCW-made blockboards of 3 groups according to their thickness , and of 9 types according to the width of the core strips:

- the thickness of the fiberboard is 4 mm, the width of the strips is 20; 30; 40 mm (Fig. 2);
- the thickness of the fiberboard is 5 mm, the width of the strips is 20; 30; 40 mm (Fig. 3);
- the thickness of the fiberboard is 6 mm, the width of the strips is 20; 30; 40 mm (Fig. 4).

The laying of strips during the formation of blockboard core was done with consideration for the grain slope, that is, on the principle of alternation, where the main was radial slope with an angle of 60 to 90 degrees.

General methodology of research. To achieve the objectives, a comprehensive methodology was developed that includes the following logical developments:

- methods of manufacturing front PCW-made blockboards;
- methods for determining the shape stability of PCW-made blockboards;
- methods for determining physical and mechanical characteristics of PCW-made blockboards.

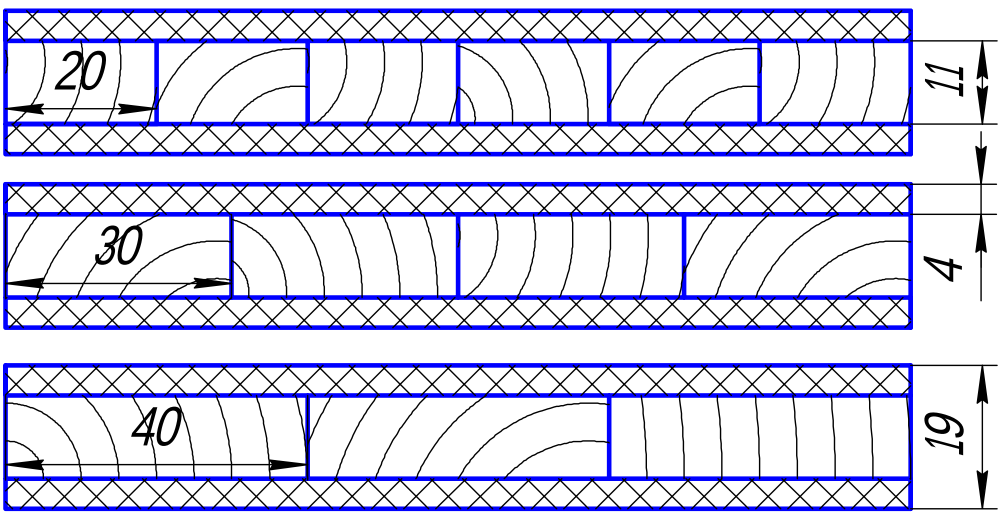


Fig. 2. PCW-made blockboards structures faced with WFB 4 mm thick

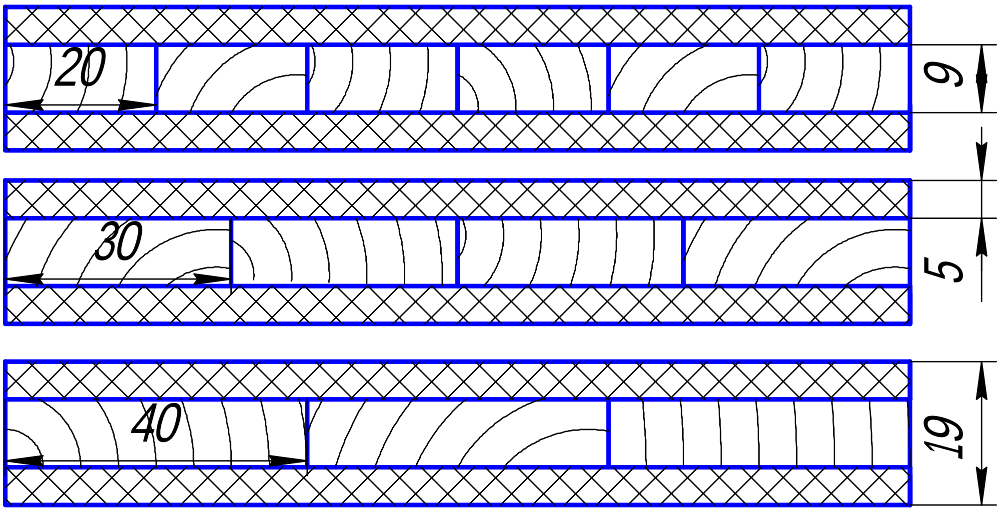


Fig. 3. PCW-made blockboards structures faced with WFB 5 mm thick

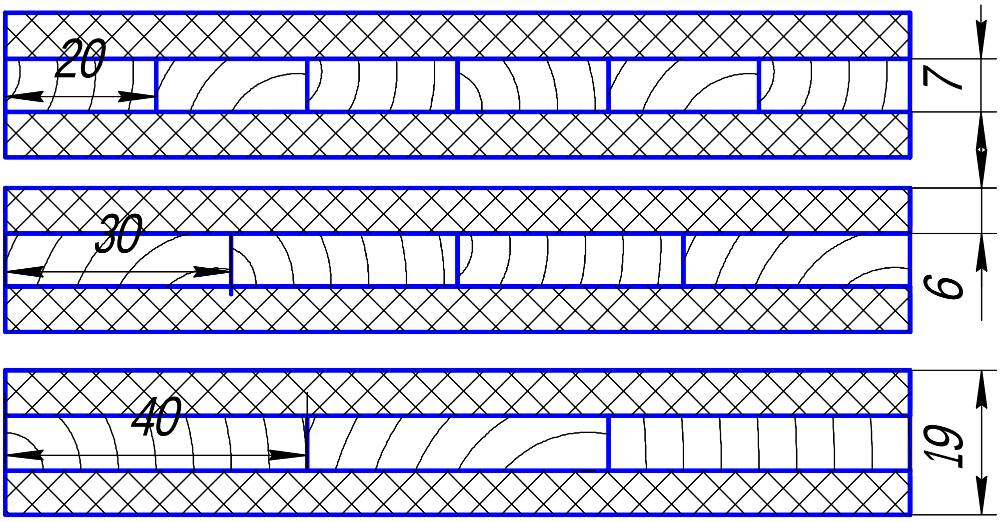


Fig. 4. PCW-made blockboards structures faced with WFB 6 mm thick

Methods of manufacturing front PCW-made blockboards. Since the research was based on the study of the influence of the characteristics of the BB structural components on the shape stability and the physical-and- mechanical characteristics of the blockboards obtained, a B-plan of the second order was implemented (Table 1).

Also, an additional experiment was conducted in the center of the plan. The number of duplicated experiments is 3 for each type of facing: plywood and WFB. A total of 9 types of PCW-made blockboards were fabricated in order to implement the experimental investigations based on the type of facing material (Figs. 2-4).

The prepared strips from solid pine ($B_{PCW)}$ were made 20, 30 and 40 mm wide.

In each blockboard core were presented strips of the same width.

Each of the variant blockboard core was faced fiberboard (H_{WFB}) 4.0, 5.0, and 6.0 mm in thickness.

Constant factors in this study of manufacturing front PCW-made blockboards were as follows: relative humidity – 60-65 %; air temperature – 18-20 ^{o}C; atmospheric pressure – 736 mm Hg; the air circulation velocity – v ≈ 0 m/s; the level of airborne dust; Jowacol 103.05 PVA adhesive; method of application (roll); press temperature; press time; pressure; equipment; volume of the room.

Table. 1. Planning matrix for B-plan with two variables

Experiment No.	Input factors values in the experiment			
	in natural value		in coded value	
	B_{PCW}, mm	H_{WFB}, mm	x_1	x_2
1	20	4	-1	-1
2	40	4	1	-1
3	20	6	-1	1
4	40	6	1	1
5	20	5	-1	0
6	40	5	1	0
7	30	4	0	-1
8	30	6	0	1
9	30	5	0	0

Front PCW-made blockboards technology. The general production process for obtaining PCW-made blockboards can be divided into several stages:

- preparation of the core strips made from PCW;
- cutting of panel woodfiberboard components of blockboards;
- manufacturing the core;
- manufacturing the PCW-made blockboard.

The preparation of wooden strip components of blockboards involves PCW cleaning from fittings and other foreign matter, destruction of finger joints and cutting out defective spots, cleaning wood surfaces from paint and varnish materials, face planing, wood ripping, double-surface milling of edges, trimming to a length of 480 mm.

Preparation of facing decks from WFB involves dimension cutting into a size of 520×520 mm.

Obtaining of blockboard core involves selection of strips according to the strip width, annual rings angle, applying glue to the strips edges with the glue spread of 200-250 g/m^2, clamp bonding (operation parameters: temperature – 85-90 ^{o}C; soaking time – 30-40 min; pressure – 0.5-1.0 MPa), technological conditioning (humidity – 60±5 %; temperature – 20±2 ^{o}C) for 8-12 hours; double-side milling up to 11, 9, 7 mm respectively for WFB with a thickness of 4.0; 5.0; 6.0 mm; dimension cutting into a size of 480×480 mm.

The final stage of blockboard manufacturing comprises the following steps: application of glue to the blockboard core with glue spread of 150-200 g/m^2, the formation of package, facing in a flat press (operation parameters: temperature – 115-120 ^{o}C; press time – 4-6 min; pressure – 1.2-1.3 MPa) technological conditioning (humidity – 60±5%; temperature – 20±2^{o}C) for 4-8 hours; cutting on the perimeter into dimension of 440×440 mm.

Methods for determining shape stability of front PCW-made blockboards.

According to the requirements of the standard GOST 13715-78, warpage of the blockboard can be no more than 1.5-2.5 mm, and rippling – 0.2-0.6 mm

The rippling of boards is determined by the maximum depth of the wave on the surface of the board which is measured with an error of no more than 0.05 mm by indicator of the type ICH-10 (ИЧ-10), according to GOST 577-68, fixed to the ruler slider, it is applied to the board across the core strips at a distance of 200 mm from the edges and in the middle of the length of the board, or by another measuring instrument that provides the required measurement accuracy.

Warping of a blockboard is determined by the amount of the board sag, referred to 1 m of the length of the board diagonal, placed on the verified horizontal surface. The easiest way is to measure the sag with an error of no more than 0.1 mm by using the ICH-10 type indicator, according to GOST 577-68, mounted on a ruler slider, and which is placed along the board diagonal, or by another measuring instrument that provides the required measurement accuracy.

However, having a Computer Numerical Control Unit (CNC) for determining planeness in our laboratory, (Fig. 5), the deflection S, as one of the main characteristics of the shape stability, was measured directly by this unit immediately after the technological conditioning and under the same ambient conditions.

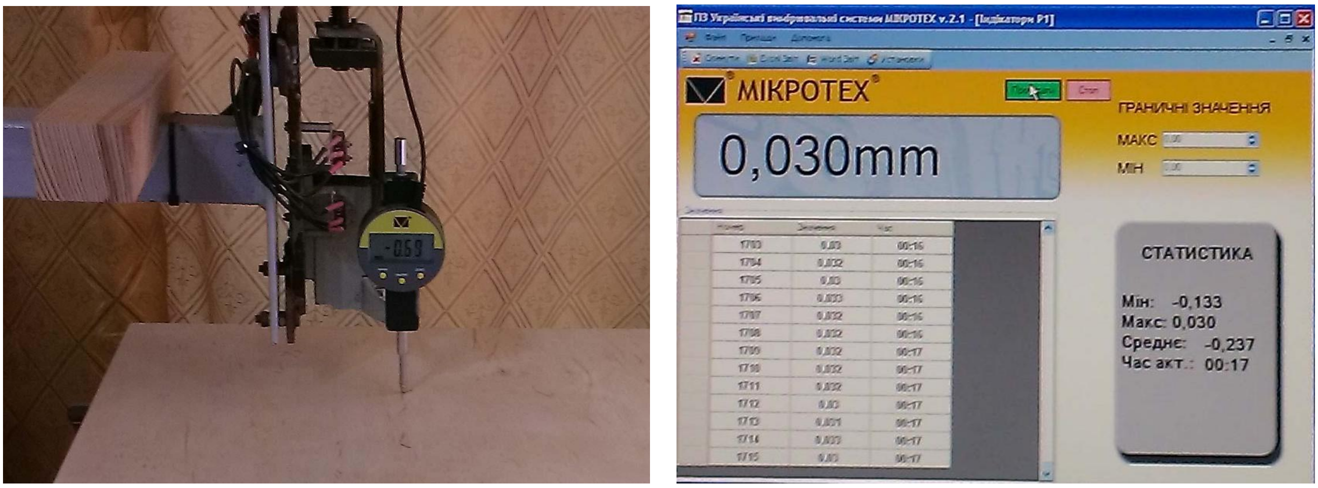


Fig. 5. CNC experimental set-up for determining shape stability of PCW-made blockboards

The numeric readings of the IGC-(3)-25-0.01 indicator (readings are obtained to an accuracy of 0.001 mm) were read with the help of the Microtech Excel company software, type UIC-P1-SOM which was transferred to the Microsoft Excel environment for recording. The readings from BB experimental specimens were taken in two directions: the direction along the grain-direction A, (along the length of BB strips), the direction across the grain-direction B (across the width of the blockboards). The measurements in each direction on the PCW-made blockboards were performed along 10 conventional lines, that is for a total of 20 imaginary lines with a pitch between them being 40 mm (Fig. 6). As a result of measurements, 380 to 440 points were recorded for each line.

Thus, one set of measurements resulted in sampling population of 7.600 to 8.800 (20×(280…440)). The sag value took the average value of this sampling population.

The experimental value of response function was obtained as a difference of the average values of samples obtained in the first and the last measurement (in absolute value). The results are presented in Table 2. The second set of measurements was performed 7 days after the date of the manufacture of experimental specimens of PCW-made blockboards. The measurements were performed once a week. The last set of measurements was taken on the sixth week, the amount of sag for this measurement did not differ from the previous one by more than 5%. Thus, six sets of measurements were performed during the study on shape stability of PCW-made blockboards. The value of the sag was determined as the difference between the first and the sixth experiment.

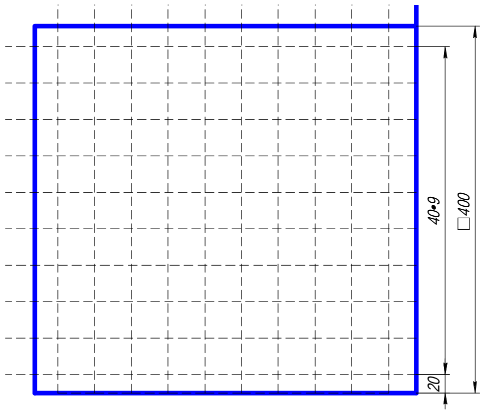


Fig. 6. Scheme of motion trajectory of the numerical indicator on the plane of the blockboard

Methods for determining of physical-and-mechanical properties of front PCW-made blockboards. According to the requirements of GOST 13715-78, the following parameters were subject to control:

- static-bending strength across strips;
- shearing dry strength along the glue line;

Test specimens for determination of static bending strength across strips were made according to GOST 9625-2013 [24], which refers to GOST 13715-78 [21]. Specimens selection, their quantity, making and preparing for testing was done according to GOST 9620-94 [22]. The sprecimen’s thickness is equal to the thickness of the BB h=19 mm, the specimen b=50 mm, and, the length l_1=15h=15·19=285 mm. When testing the specimens whose length l_1=15h, the spacing between supports l is taken equal to l=12h=12·19=228 mm (Fig. 7).

Test specimens for determination of shearing dry strength along glue line were made according to GOST 9624-93 [23]. Selection of models of their manufacturing, their fabrication and preparing for testing is done according to GOST 9620-94 [22]. The shape and dimensions of test specimens for determination of shearing strength along glue line should correspond to the 85×40×19 mm dimensions with the kerf of 5 mm (Fig. 7).

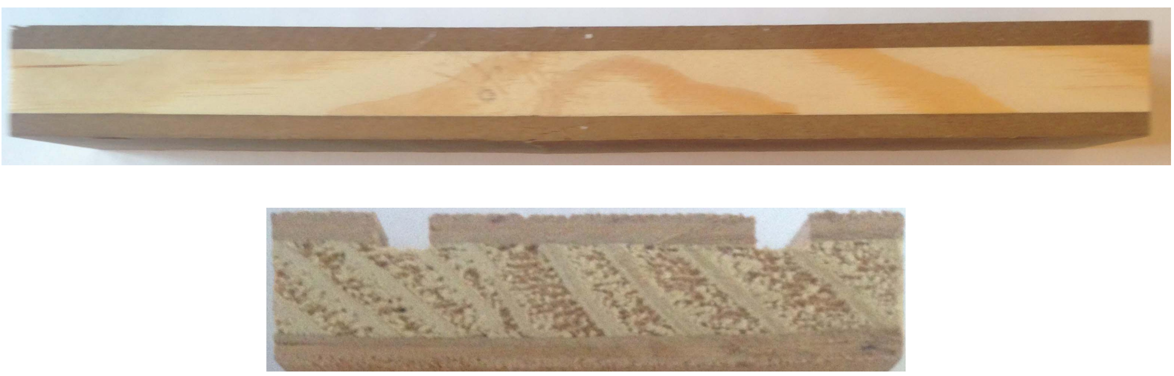


Fig. 7. Examples of front PCW-made blockboards for testing

To suit GOST 9625-2013 [24] for measuring static-bending strength across strips the following guidlines must be followed: in order to determine static bending strength across strips the laboratory test machine UMM-05 (GOST 7855-61) (Fig. 8)was used while the test machine PM-05 (GOST 28840-90) was used to determine shearing strength.

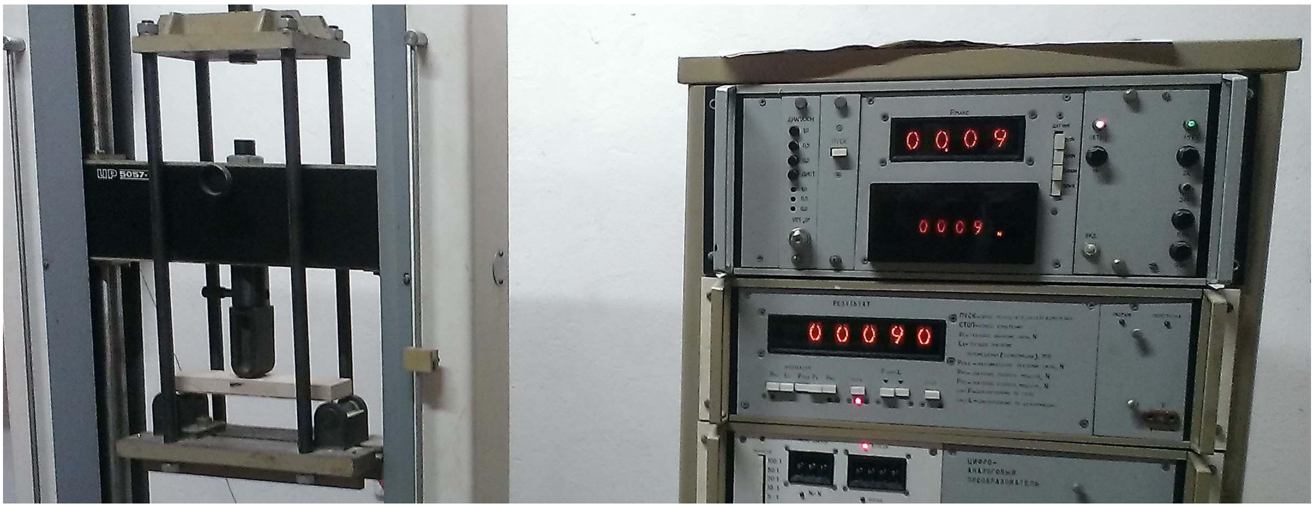


Fig. 8. Test specimen a facades blockboard with a coreboard made from PCW and face decks made from WFB at the moment of breakage

Static bending strength (σ_u) in MPa was calculated by the formula:

$$\boldsymbol{\sigma_u=3P_{max}l/(2bh^2)} \qquad (1)$$

The srtength along glue line $\tau_{ск}$ is determined in MPa by rounding the result to 0.05 MPa by the

$$\boldsymbol{\tau_{ск}=P_{max}/(b_{ск}l_{ск})}\ , \qquad (2)$$

where: P_{max} – maximum load, H; l – spacing between supports, mm; b – the width, mm; h – the specimen thickness, mm; $b_{ск}$, $l_{ск}$ – the width and the length of the shear area, mm.

Results of experimental studies. Complete factorial plan allows obtaining a linear dependence of the function of strength on the factors investiguted. For most part of wood working processes the representation like this would be inadequate. Therefore, other kinds of plan were used, that is plans by means of which one can obtain a mathematical description of objects in the form of polynom of the second order (quadratic model). At these plans, each factorxi varies at three levels, that is it takes one of the three values in every test: the lowest $X_{i\ min}$ the highest $X_{i\ man}$ and the mean $X_{i\ 0}$. At normalized values, these levels are denoted respectively ***-L, +L, 0***.

Generally, the regression model for ***k*** variable factors will read:

$$y = b_0 + \sum_{i=1}^{\kappa} b_i x_i + \sum_{i=1}^{\kappa} b_{ii} x_i^2 + \sum_{i,u=1}^{k} b_{iu} x_i x_u\ , \qquad (3)$$

where: b_o – free term; b_i – linear regression coefficients, ***i=L,k;*** b_{ii} – quadratic regression coefficients; b_{iu} – pairwise coefficients, ***u=L,k (i≠u).***

Results and discussion on shape stability of front PCW-made blockboards.

As a result of the experimental data processing, a second-order regression equation was obtained which describes the dependence of the sag on the width of the structural elements, i.e. the width of PCW-made strips (solid wood) – B_{PCW} (x_1) and the thickness of face decks made from WFB – H_{WFB} (x_2).

Graphical representation of the obtained regression curves is shown in Fig. 9 and Fig. 10. The resulting regression equation in normalized values of variables takes the form:

$$y=0.137+0.016x_1-0.072x_2+0.006x_1^2+0.023x_2^2-0.003x_1x_2, \qquad (4)$$

While in natural values of variables it can be written as:

$$S = 1.033 + 0.0005B_{PCW} - 0.293H_{WFB} + 0.00006B_{PCW}^2 + 0.023H_{WFB}^2 - 0.0003B_{PCW}H_{WFB} \qquad (5)$$

where: B_{PCW} is the width of PCW-made (solid wood) strip of blockboard, in mm; H_{WFB} is the thickness of face decks made from WFB, in mm; S is the averaged deviation from flatness, that is the sag of blockboard, in mm.

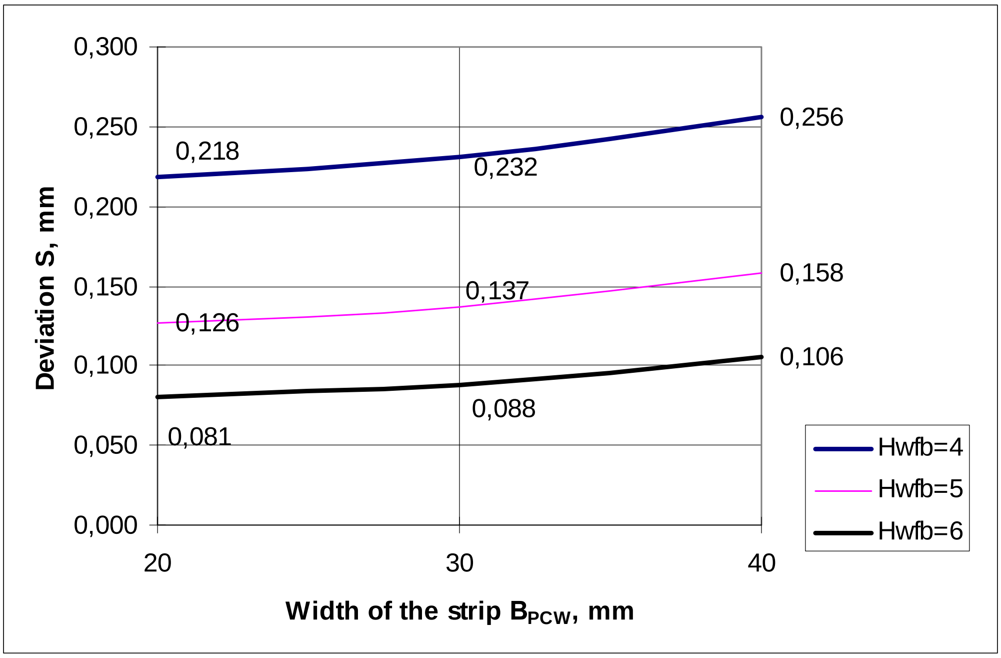


Fig. 9. Dependence of the averaged deviation S from flatness of the blockboards on the width of PCW-made strip (solid wood) – B_{PCW} (x_1).

The deviation from flatness (sag) for accuracy degree 12 for all the experimental specimens meets the requirements of the GOST 6449.3:1982 (Table 2).

Table. 2. Comparison of experimental and calculated values with the standardized values

No.	Input variables, mm			Objective (response) function, mm	
	natural values		flatness tolerance for block-boards size 440×440	experimental value Y_{exp}	calculated value Y_{calc}
	B_{PCW}	H_{WFB}	degree of accuracy 12		
1	20	4	0.3	0.219	0.218
2	40	4	0.3	0.255	0.256
3	20	6	0.3	0.082	0.081
4	40	6	0.3	0.105	0.106
5	20	5	0.3	0.124	0.126
6	40	5	0.3	0.160	0.158
7	30	4	0.3	0.232	0.232
8	30	6	0.3	0.088	0.88
9	30	5	0.3	0.133	0.137

As can be seen from Fig. 9, increasing the width of PCW-made strip (solid wood) leads to increased deviation S (sag). However, the dependence of the blockboard's sag on the thickness of face decks made from WFB is a reverse one (Fig. 10). It should be noted that the nature of the strip width effect on the average deviation S is nonlinear, although it is possible with a certain probability to suggest the presence of tendency for reverse (Fig. 9) and direct proportionality (Fig. 10).

The results of the experiments made it possible to optimize the width of strips using the gradient method, which revealed that the minimum deviation value S_{min} = 0.076 mm, taken in absolute value, can be obtained by establishing dimensional parameters for the width of the PCW-made strips of the blockboards as follows: B_{PCW} = 20 mm; thickness of face decks made from WFB – H_{WFB} = 6 mm (Fig. 11).

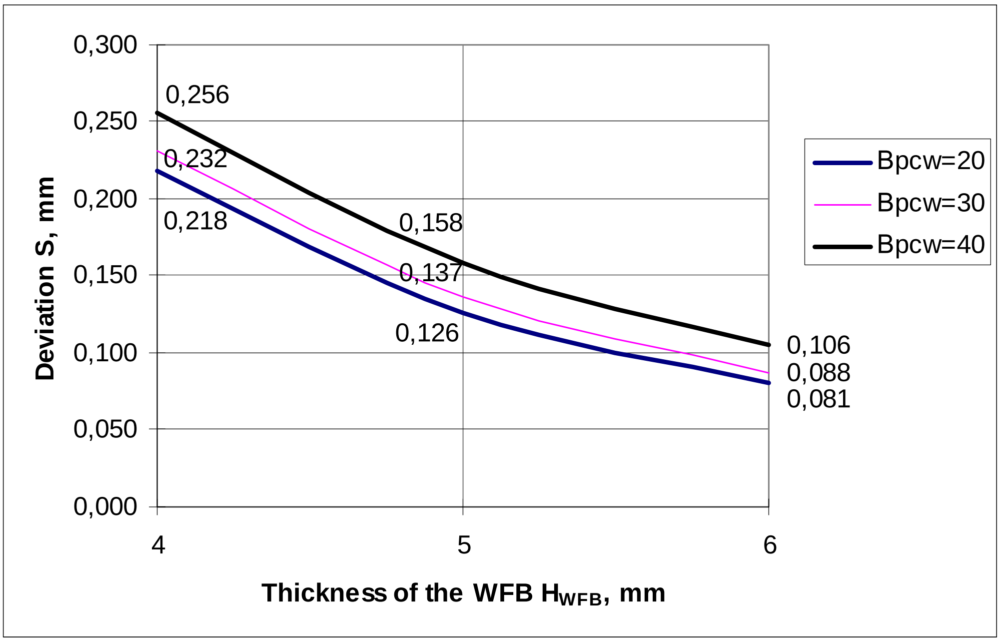


Fig. 10. Dependence of the averaged deviation S from flatness of the blockboards on the thickness of face decks made from WFB – H_{WFB} (x_2)

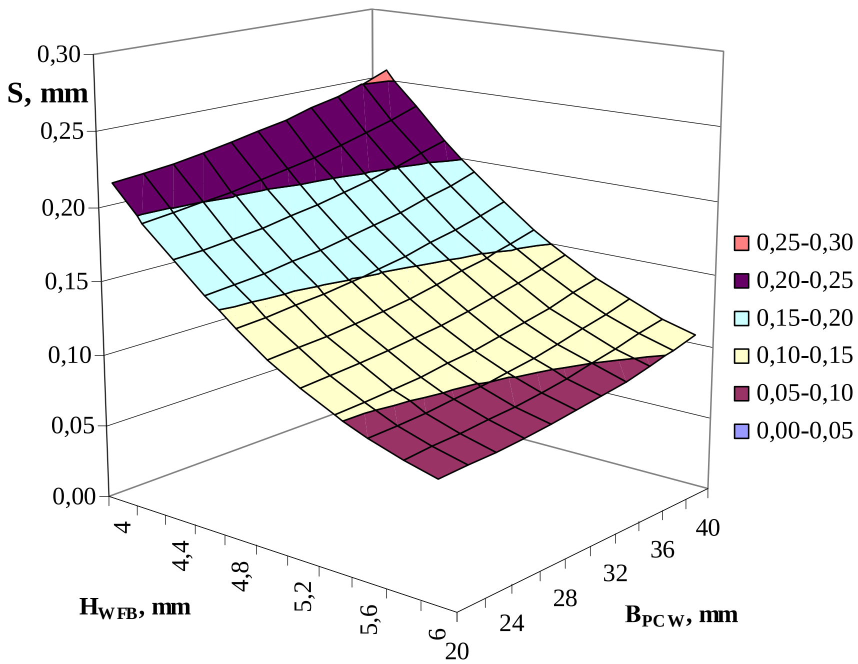


Fig. 11. Dependence of the averaged deviation S from flatness of the blockboards on the width of PCW-made and thickness of face decks made from WFB.

Results and discussion of static-bending strength across strips of front PCW-made blockboards. Having carried out statistical processing of experimenntal data we have the following regression equation:

$$y=22.978-1.73x_1-3.658x_2+0.004x_1^2+1.008x_2^2+0.017x_1x_2, \quad (6)$$

When analysing the regression equation, we can see that the factor x_2, certainly, has the most influence on the output value of the function while factor's x_1 influence is significantly less. Besides, output values to decrease up with an increase in x_1 and x_2 values. In order to determine equation coefficients in natural expression letus make use of factors coding formulas which we insert into the coded equation.

$$\sigma_u = 84{,}044 - 0{,}26B_{PCW} - 13{,}8H_{WFB} + 0{,}00004B_{PCW}^2 + 1{,}008H_{WFB}^2 - 0{,}0017B_{PCW}H_{WFB} \quad (7)$$

The static-bending strength across strips σ_u of front PCW-made blockboards 19 mm thick for all the experimental specimens, except for No.4, meets the requirements of the GOST 13715-78 (Table 3).

Table. 3. Comparison of experimental and calculated values with the standardized values

No.	Input variables, mm			Objective (response) function, mm	
	natural values		static-bending strength across strips σ_u, MPa	experimental value Y_{exp}	calculated value Y_{calc}
	B_{PCW}	H_{WFB}	blockboards 19 mm thick		
1	20	4	20	29.048	29.395
2	40	4	20	25.926	25.901
3	20	6	20	22.020	22.046
4	40	6	20	18.966	18.619
5	20	5	20	25.084	24.712
6	40	5	20	20.880	21.252
7	30	4	20	27.966	27.644
8	30	6	20	20.006	20.328
9	30	5	20	22.755	22.978

Graphical representation of the obtained regression curves is shown in Fig. 12 and Fig. 13.

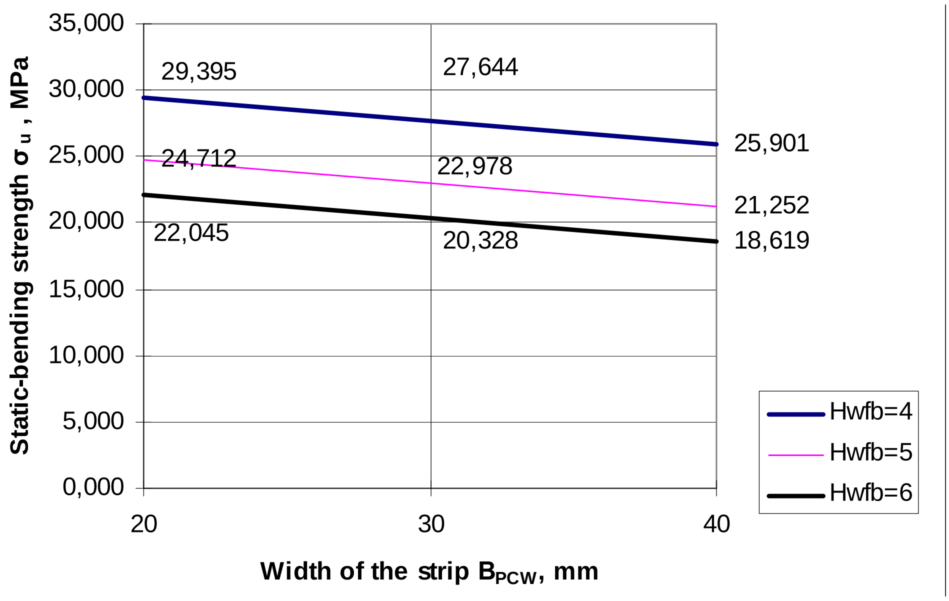


Fig. 12. Dependence of the static-bending strength across strips σ_u of the facades blockboards on the width of PCW-made strip (solid wood) – B_{PCW} (x_1).

As can be seen from Fig. 12, increasing the width of PCW-made strip (solid wood) leads to decrease static-bending strength across strips σ_u. The dependence of the blockboard's sag on the thickness of face decks made from WFB is similar (Fig. 13).

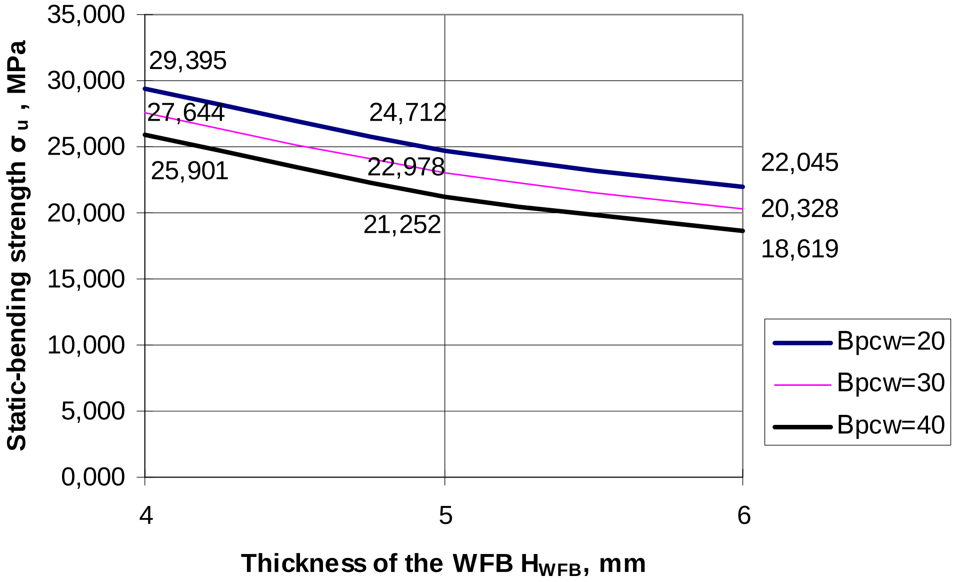


Fig. 13. Dependence of the static-bending strength across strips σ_u of the facades blockboards on the thickness of face decks made from WFB – H_{WFB} (x_2).

Thus, the static-bending strength of BB is influencer the most by the thickness of face decks made from WFB while strip width being of little influence.

The results of the experiments made it possible to optimize the width of strips using the gradient method, which revealed that the maximum deviation value static-bending strength across strips σ_u = 29,395 MPa, taken in absolute value, can be obtained establishing dimensional parameters for the width of the PCW-made strips of the blockboards as follows: B_{PCW} = 20 mm; thickness of face decks made from WFB H_{WFB} = 4 mm (Fig. 14).

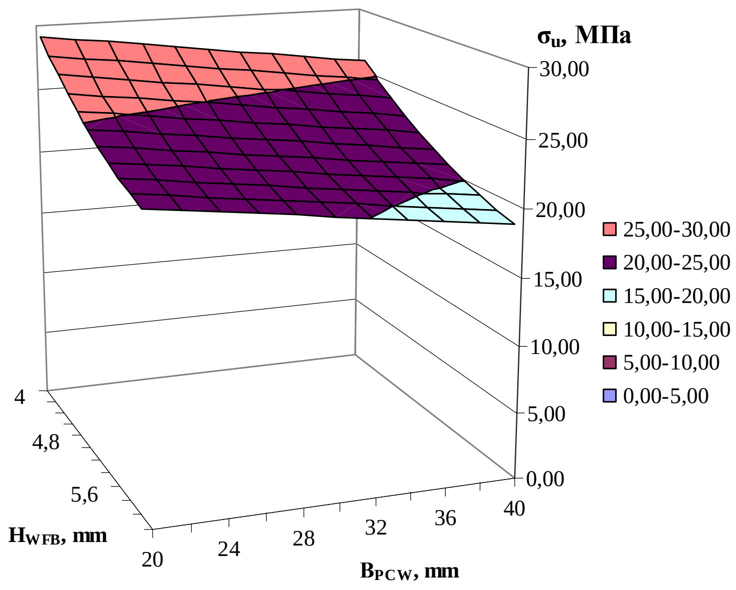


Fig. 14. Dependence of the static-bending strength across strips σ_u of the facades blockboards on the width of PCW-made strips and thickness of face decks made from WFB

Results and discussion of shearing dry strength along the glue line of front PCW-made blockboards. Having carried out statistical processing of experimenntal data we have the following regression equation:

$$y=1.469+0.12x_1-0.08x_2-0.007x_1^2-0.139x_2^2+0.0005x_1x_2, \quad (8)$$

In order to determine equation coefficients in natural expression letus make use of factors coding formulas which we insert into the coded equation.

$$\tau_{c\kappa} = 1{,}116 + 0{,}05375B_{PCW} + 1{,}3085H_{WFB} - 0{,}00007B_{PCW}^{\ 2} - 0{,}139H_{WFB}^{\ 2} - 0{,}00005B_{PCW}H_{WFB} \quad (9)$$

When analysing the regression equation, we can see that the factor $H_{WFB,}$ certainly, has the most influence on the output value of the function while factor's B_{PCW} influence is significantly less. Besides, output values grow up with an increase in B_{PCW} values, output values teng to decrease as factor's H_{WFB} value increases. Graphical representation of the obtained regression curves is shown in Fig. 15 and Fig. 16.

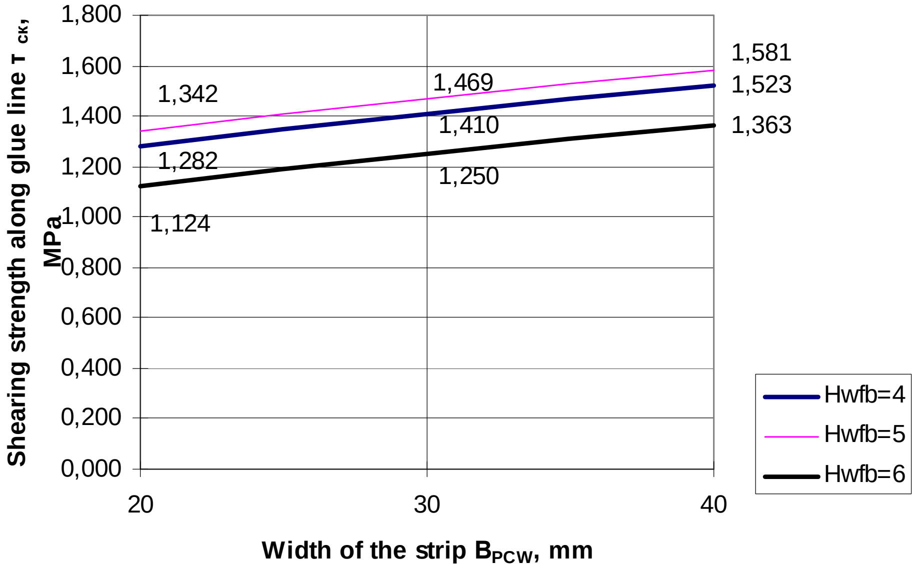


Fig. 15. Dependence of the shearing dry strength along the glue line $\tau_{c\kappa}$ of the facades blockboards on the width of PCW-made strip (solid wood) – B_{PCW} (x_1)

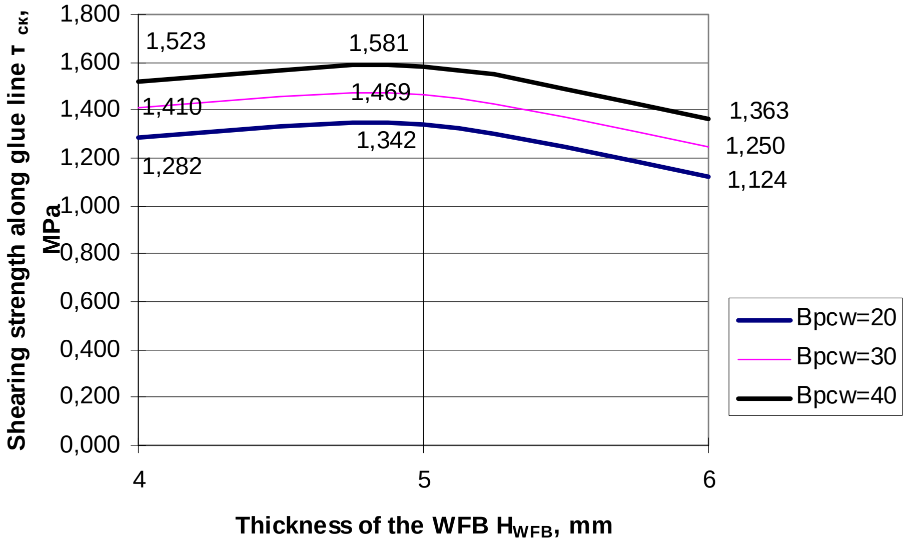


Fig. 16. Dependence of the shearing dry strength along the glue line $\tau_{c\kappa}$ of the facades blockboards on the thickness of face decks made from WFB – H_{WFB} (x_2)

The ***shearing dry strength along the glue line*** $\tau_{ск}$ of front PCW-made blockboards 19 mm thick for all the experimental specimens meets the requirements of the GOST 13715-78 (Table 4).

Table. 4. Comparison of experimental and calculated values with the standardized values

No.	Input variables, mm			Objective (response) function, mm	
	natural values		shearing dry strength $\tau_{ск}$, MPa	experimental value Y_{exp}	calculated value Y_{calc}
	B_{PCW}	H_{WFB}	blockboards 19 mm thick		
1	20	4	1	1.303	1.282
2	40	4	1	1.507	1.523
3	20	6	1	1.140	1.124
4	40	6	1	1.342	1.363
5	20	5	1	1.305	1.342
6	40	5	1	1.618	1.581
7	30	4	1	1.405	1.410
8	30	6	1	1.255	1.250
9	30	5	1	1.457	1.469

The results of the experiments made it possible to optimize the width of strips using the gradient method, which revealed that the maximum deviation value ***shearing dry strength along the glue line*** $\tau_{ск}$ = 1.581 MPa, taken in absolute value, can be obtained establishing dimensional parameters for the width of the PCW-made strips of the blockboards as follows: B_{PCW} = 40 mm; thickness of face decks made from WFB H_{WFB} = 5 mm (Fig. 17).

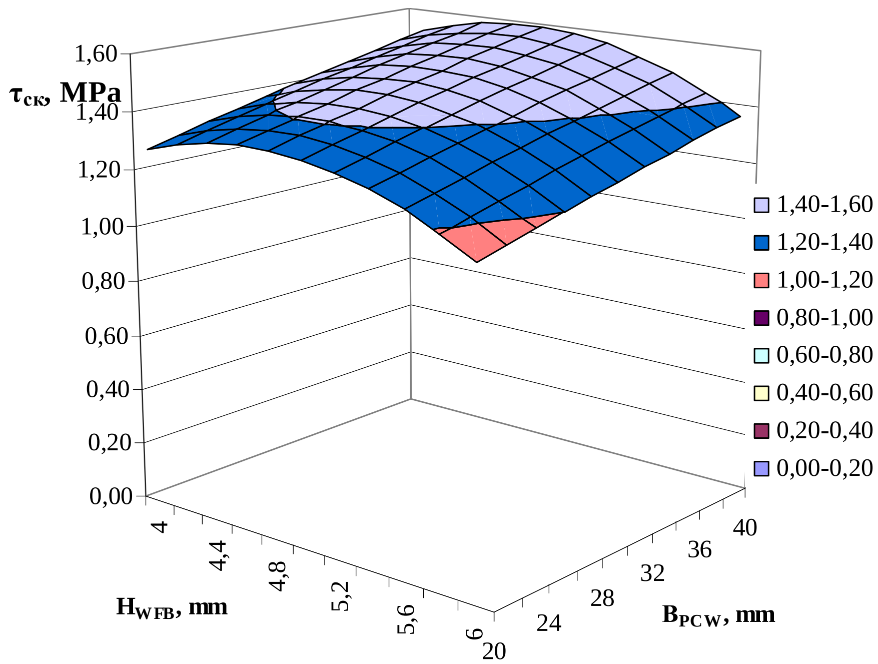


Fig. 17. Dependence of the shearing dry strength along the glue line $\tau_{ск}$ ***of the facades blockboards on the width of PCW-made strips and thickness of face decks made from WFB***

Conclusions:

1. It has been proved that PCW is a suitable secondary raw material resource for manufacturing front blockboards because this wood has a low moisture content (W = 8±3%) and stable internal stresses, which has a positive effect on shape stability – the stress-strain state of the blockboards' construction.
2. PCW-made blockboards' constructions have been proposed which are suitable for the manufacture of front furniture products.
3. Physical-and-mechanical properties of front PCW-made blockboards have rather a high scattered field, nevertheless, they are subordinated to the law of normal distribution, which was confirmed by Pirson's criterion when analyzing the sample of one hundred speciment tested for static bending strength across strips, shearing dry strength along the glue line, shape stability.
4. Physical-mechanical parameters of all front PCW-made blockboards 19 mm in thickness, regardless of their design (thickness of the wood fiberboard) meet GOST 13715-78 requirements.
5. The highest level of physical-and-mechanical properties in front PCW-made blockboards is found in the following conditions: B_{PCW} = 20 mm; H_{WFB} = 6 mm – shape stability will be 0.082 mm; B_{PCW} = 20 mm; H_{WFB} = 4 mm – static-bending strength across strips – 29.395 MPa; B_{PCW} = 40 mm; H_{WFB} = 5 mm – shearing dry strength along the glue line – 1.581 MPa.
6. The patterns of the strip width and the influence of thickness of the woodfiberboard upon shape stability, static-bending strength across strips and shearing dry strength along the glue line of front PCW-made blockboards have been established.
7. The obtained regression models are adequate and, therefore, can be used to describe the object of study.
8. It is shown that in order to ensure high shape stability of PCW-made blockboards, we must use wooden strips of predominantly radial cut with further facing with woodfiberboard 6 mm thick.

Recommendations for use of PCW-made blockboards:

1. To obtain shape stability and maximam static bending strength of BB across strips it is recommended that the width of the strips used for the core of PCW-made blockboard should not exceed its 2.5 – fold thickness.
2. To ensure shape stability of PCW-made blockboards which operate under conditions of varying humidity, it is desirable to apply the 1:3 aspect ratio in the cross-section of strips, while annual rings angle in the ends of the strips shall not be less than 45^o.
3. To obtain front PCW-made blockboards ,whose surfaces meet the requirements of the depth of milling, GOST 13715-78, it is enough to cover the core with woodfiberboard 5-6 mm thick.

Practical advice and guidelines. Recommendations for design and technologies of front PCW-made blockboards 19 mm thick:

- strips moisture content – 8 ± 2%;
- for strips made from solid wood: width = 2.5 thickness,
- (thickness 7 (9), width – 17.5 (22.5) mm);
- strips arrangement – radial or at an angle of 45^o;
- facing – woodfiberboard 5-6 mm thick;

- glue spread for the core – 200-250 g/m^2; glue spread for a blockboard – 150-200 g/m^2;
- clamp temperature for the core –85-90 °C; press temperature for the BB – 115-125 °C;
- press time for the core – 30-40 min; press time for the blockboards – 4-6 min;
- pressure for the core – 0.5-1.0 MPa; pressure for the blockboards – 1.2-1.3 MPa.

References

1. **Gayda S.V.** (2017): *Tekhnologiya i svoystva mebel'nogo shchita iz vtorichno ispol'zuemoy drevesiny* [A technology and properties of furniture board made of post-consumer wood]. *Actual problems of forest complex* 48:34-38, (in Russian).
2. **Gayda S.V.** (2016): A investigation of form of stability of variously designed blockboards made of post-consumer wood. *ProLigno* 12(1):22-31.
3. **Gayda S.V.** (2016): *Ekologo-tekhnologicheskiye aspekty pererabotki vtorichno ispol'zuyemoy drevesiny dlya proizvodstva pressovannykh materialov* [Ecological and technological aspects of recycling post-consumer wood for production compacted materials]. *Lesnoy vestnik / Forestry bulletin of MSFU* 20(3):15-22 (in Russian).
4. **Gayda S.V.** (2016): *Formoustoychivost' stolyarnykh plit iz vtorichno ispol'zuemoy drevesin* [A form of stability of blockboards made of post-consumer wood]. *Actual problems of forest complex* 46:148-153, (in Russian).
5. **Gayda S.V.** (2015): *Issledovanie fiziko-mekhanicheskikh svoystv vtorichno ispol'zuemoy drevesiny* [Investigation of physical and mechanical properties of post-consumer wood]. *Actual problems of forest complex* 43:175-179, (in Russian).
6. **Gayda S.V.** (2015): *Tekhnologiї i fiziko-mekhanichni vlastivosti stolyarnikh plit iz vzhivanoї derevini* [Technology and physical and mechanical properties blockboard made of post-consumer wood]. *Technical service of agriculture, forestry and transport systems* 3(1):145-152, (in Ukrainian).
7. **Gayda S.V.** (2015): *Tekhnologicheskie osnovy pererabotki vtorichno ispol'zuemoy drevesiny* [Technological of processing basics of post-consumer wood]. *Actual directions of Scientific Research XXI century: Theory and Practice, Voronezh State Forestry Engineering University Named after G.F. Morozov* 3(8-2 (19-2)): 82-86, (in Russian).
8. **Gayda S.V.** (2015): Modeling properties of blockboards made of post-consumer wood on the basis of the finite element method. *Forestry, Forest, Paper and Woodworking Industry* 41:39-49.
9. **Gayda S.V.** (2014): Techniques for recycled of post-consumer wood in the production of quality particleboard. *Forestry, Forest, Paper and Woodworking Industry* 40:41-51.
10. **Gayda S.V.** (2014): *Sposoby podgotovki k pererabotke vtorichno ispol'zuyemoy drevesiny iglofrezernymi i shchotochnymi stankami* [Preparation methods for processing of post-consumer wood (PCW) needle-milling and brushing machines]. *Actual problems of forest complex* 40:65-69 (in Russian).
11. **Gayda S.V.** (2014): *Teoreticheskoye obosnovaniye podkhoda po prognozirovaniyu prochnosti drevesnostruzhechnykh plit iz vtorichno ispol'zuyemoy drevesiny* [The theoretical rationale for the approach on the prediction the strength of particleboard from recycled wood]. *Actual problems of forest complex* 38:212-216 (in Russian).
12. **Gayda S.V.** (2013): *Tekhnologiї ta rekomendatsiї do vikoristannya vzhivanoї derevini v derevoobroblenni* [Technologies and recommendations on the utilization of post-consumer wood in woodworking industry]. *Forestry, Forest, Paper and Woodworking Industry* 39(1):48-67, (in Ukrainian).
13. **Gayda S.V.** (2013): *Resursooshchadni tekhnologiї pereroblennya vzhivanoї derevini* [Resource-saving technologies of recycling of post-consumer wood]. Scientific Bulletin of NULES of Ukraine: *Technology and Energy of agroindustrial complex* 185(2):271-280, (in Ukrainian).
14. **Gayda S.V.** (2013): *Osnovy formuvannya klasyfikatora vtorynnykh derevynnykh resursiv* [Bases of secondary wood resources classifier formation]. *Scientific Works of the Forestry Academy of Sciences of Ukraine* 11:208-215 (in Ukrainian).

15. **Gayda S.V., Voronovich V.V.** (2011): *Porivnyal'niy analiz gnuttya vzhivanoï derevini riznikh porid ta vikovikh kategoriy* [Comparative analysis of bending particularities for various post-consumer wood species and age categories]. *Forestry, Forest, Paper and Woodworking Industry* 37(1): 84-88 (in Ukrainian).

16. **Gayda S.V., Voronovich V.V.** (2011): *Issledovanie osobennostey gnut'ya vtorichno ispol'zuemoy drevesiny* [Investigation of the features of bending of post-consumer wood]. *Scientific progress – creative young: proceedings of the International Scientific Conference, Mari State University*: 190-192 (in Russian).

17. **Gayda S.V.** (2011): *Vzhyvana derevyna – dodatkovyy resurs syrovyny* [Recovered wood is additional resource of raw material]. *Forestry, Forest, Paper and Woodworking Industry* 37(1): 238-244 (in Ukrainian).

18. **Gayda S.V.** (2011): The investigation of physical and mechanical properties of wood particleboards made from post-consumer wood. Forestry, Forest, Paper and Woodworking Industry 37(2):95-110.

19. **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* 36:81-92.

20. **DIN 68705-2:2014-10** Plywood – Part 2: Blockboard and laminboard for general use. Germany, (in Deutsch).

21. **GOST 13715-78** *Plity stolyarnye. Tekhnicheskie usloviya* [Blockboards. Technical specifications]. *Moskow: Publishing house of standards,* (in Russian).

22. **GOST 9620-94.** *Drevesyna sloystaya kleenaya. Otbor obraztsov y obshchye trebovanyya pry yspytanyy* [Laminated glued wood. Sampling and general requirements in testing]. *Moskow: Publishing house of standards,* (in Russian).

23. **GOST 9624-2009**. *Drevesyna sloystaya kleenaya. Metod opredelenyya predela prochnosty pry skalyvanyy* [Laminated glued wood. Method for determination of shear strength]. *Moskow: Publishing house of standards,* (in Russian).

24. **GOST 9625-2013** (EN 310:1993, EN 13986:2004). *Drevesyna sloystaya kleenaya. Metody opredelenyya predela prochnosty y modulya upruhosty pry statycheskom yz·hybe* [Laminated glued wood. Methods for determination of ultimate and modulus of elasticity in static bending]. *Moskow: Publishing house of standards,* (in Russian).

25. **GOST 4598-86.** *Plity drevesnovoloknistyye. Tekhnicheskiye usloviya* [Fibre boards. Specifications]. *Moskow: Publishing house of standards,* (in Russian).

УДК 684.4

Доц. С.В. Гайда, канд. техн. наук – НЛТУ України

Дослідження фізико-механічних характеристик фасадних столярних плит із вживаної деревини

Обґрунтовано доцільність використання вживаної деревини (ВЖД) для матеріального виробництва. Запропоновано переробляти ВЖД на столярну плиту (СП). Запропоновано нові конструкції СП із ВЖД, які є придатними для виготовлення фасадів меблевих виробів. Експериментально підтверджено, що фізико-механічні властивості фасадних СП із ВЖД відповідають вимогам стандартів. Одержано закономірності впливу ширини рейок та товщини деревноволокнистої плити (ДВП) на формостійкість, на міцність при статичному згині впоперек рейок та на міцність при сколюванні по клейовому шарі в сухому стані фасадних СП із ВЖД. Отримано адекватні регресійні моделі, які можуть бути використані для опису об’єкта дослідження. Запропоновано практичні рекомендації щодо виготовлення та використання фасадних СП із ВЖД для меблевого виробництва.

Висновки:

1. Обґрунтовано, що ВЖД є придатним вторинним ресурсом для виготовлення фасадних СП, оскільки дана деревина має низьку вологість (W=8±3 %) та стабільні внутрішні напруження, що позитивно впливає на формостійкість – напружено-деформований стан конструкції СП.
2. Запропоновано нові конструкції СП із ВЖД, придатних для виготовлення фасадів меблевих виробів.
3. Фізико-механічні властивості СП із ВЖД мають досить високе поле розсіювання, тим не менше вони піддаються закону нормального розподілу, що було підтверджено критерієм Пірсона при аналізі вибірки із ста взірців, випробуваних на міцність при статичному згині впоперек рейок, на міцність при сколюванні по клейовому шву, формостійкість.
4. Фізико-механічні параметри всіх фасадних СП із ВЖД товщиною 19 мм не залежно від їх конструкції (товщини личківки) задовольняють вимоги стандартів [20, 21].
5. Найвищими фізико-механічними параметрами характеризується фасадні СП із ВЖД за таких умов: $B_{ВЖД}$ = 20 мм; $H_{ДВП}$ = 6 мм – формостійкість буде становити 0,082 мм; $B_{ВЖД}$ = 20 мм; $H_{ДВП}$ = 4 мм – міцність на статичний згин впоперек рейок – 29,395 МПа; $B_{ВЖД}$ = 40 мм; $H_{ДВП}$ = 5 мм – міцність на сколювання по клейовому шарі в сухому стані – 1,581 МПа.
6. Одержано закономірності впливу ширини рейок та товщини ДВП на формостійкість, на міцність на статичний згин впоперек рейок та на міцність на сколювання по клейовому шарі в сухому стані фасадних СП із ВЖД.
7. Отримані регресійні моделі є адекватними, а отже можуть бути використані для опису об’єкта дослідження.
8. Обґрунтовано, що для забезпечення високої формостійкості фасадних СП із ВЖД необхідно використовувати дерев’яні рейки переважно радіального перерізу та личкувати ДВП товщиною 6 мм.

Практичні рекомендації:

1. Для досягнення формостійкості та максимальної міцності СП на статичний згин впоперек рейок, рекомендується ширину рейки СП із ВЖД приймати не більше 2,5 її товщини.
2. Для отримання фасадних СП із ВЖД, поверхня яких відповідала вимогам глибини фрезерування, достатньо личкувати ДВП товщиною 5-6 мм.
3. Для забезпечення формостійкості СП із ВЖД, які експлуатуються в умовах змінної вологості, бажано застосовувати співвідношення сторін у поперечному перерізі рейок 1:3, а кут нахилу річних шарів в торці рейок повинен бути не менше 45^{o}.

Рекомендації до конструкцій і технологій фасадних СП із ВЖД товщиною 19 мм:

- вологість рейок – 8±2 %;
- для рейок з масиву : ширина = 2,5 товщини
  товщина 7 (9), ширина – 17,5 (22,5) мм;
- розташування рейок – радіальне, або під кутом 45^{o};
- личкувати – ДВП товщиною 5-6 мм;
- витрата клею для щита – 200-250 г/$м^2$;
- витрата клею для СП – 150-200 г/$м^2$;
- температура вайми для щита – 85-90 ºС;
- температура преса для СП – 115-125 ºС;
- час витримки під тиском для щита – 30-40 хв;
- час витримки під тиском для СП – 4-6 хв;
- тиск для щита – 0,5-1,0 МПа; для СП – 1,2-1,3 МПа.

Ключові слова: деревина, вживана деревина (ВЖД), столярна плита (СП), деревноволокниста плита (ДВП), пероблення, фасадні поверхні, конструкції СП, технології, формостійкість, міцність.

UDC 684.4.059.4
Assist. O.V. Yarish; assoc. prof. S.A. Grytsak; assist. O.M. Kushpit – UNFU, Lviv

THE POSSIBILITY OF POLYMERIZATION OF THE ACRYLIC PVMOF PHOTOCHEMICAL CURING UNDER THE IMPACTOF UV-RADIATION EMITTED BY SOLID-STATE SOURCES

The possibility of polymerization of acrylic VPMof photochemical curing under the impact of UV radiation emitted by solid-state sources (based on laboratory equipment) was researched; the hardness (as a characteristic of the degree of hardening) of obtained paint and varnish coatings was compared with the hardness of similar coatings, photopolymerization of which was initiated by a high-pressure mercury-quartz lamp.
Keywords: UV-curing, solid-state sources of UV-radiation, LED sources, laboratory unit, hardness of coating.

Actuality. The technologies of photochemical curingare widely used in conjunction with environmentally friendly LFM. In recent years, there has been a tendency towards the gradual replacement of traditional electrovacuum sources of UV radiation by energy-saving solid-state (LED) devices [1]. Their advantages are as follows.

- Long lifetime of LEDs (over 10,000 hours).
- Extremely low energy consumption (5-6 kW - the source of the installation radiation). Specialists from the Bürkles company calculated that the energy consumed by a typical UV-curing device decreases from 22.1 kW to 7.6 kW, which gives a save of 67%. While generating the electricity needed to power one high pressure lamp throughout the year, 25 tonnes of CO_2 are emitted into the atmosphere. In order to compensate for these emissions, about 200 trees must be planted or 10 cars be removed from the freeways annually [2].
- The radiation source enters the mode immediately after switching on and does not require time to cool between the switches. Instant on / off allows to immediately switch on / off the lamp when needed. This working cycle significantly increases the lifetime of the lamp to 6-8 years.
- Deep curingis provided even for pigmented coatings.
- LEDs are suitable for solidifying coatings on all types of wood and other heat-sensitive materials.
- LEDs show the slight decrease of radiative ability during their lifetime.
- Operation of the installation with solid-state sources does not lead to the formation of ozone.
- LED technology is more effective in converting electric energy to the energy of UV radiation, which leads to 25-30% of photopolymerization - compared to less than 10% for a mercury lamp [3].

In 2009, at the LIGNA exhibition in Hanover (Germany), the technological line of photochemical curingbased on the LED technology presented by Bürklescompany, was awarded the 1-st place in the resource efficiency segment.

This technology can be used for both organo-soluble and water-soluble UV materials in an inert environment. The market for UV light-emitting diodes is constantly changing both in the direction of increasing the specific power of radiation, and in the direction of increasing the available wavelengths [4].

One of the main factors limiting the wide usage of technologies with UV-light-emitting diodes is the lack of available VPM that photopolymerize in the range of 320-400 nm (UVA). Therefore, the search for compositions that solidify under solid-state sources and provide acceptable results regarding the physical-mechanical characteristics of the coatings is relevant.

Goal. Study of the possibility of polymerization of acrylic VPM of photochemical curingunder the impact of UV radiation emitted by solid-state sources (based on laboratory equipment); the comparison of hardness as a characteristic of the degree of hardening of the obtained coatings with the hardness of similar coatings, whose photopolymerization was carried out under a mercury-quartz high pressure lamp.

Experimental part. Materials. The experiment used acrylic varnishes for photochemical curing, water-soluble acrylic varnishes for photochemical curing and acrylic enamels for photochemical curing by Sayerlack (Sherwin-Williams Italy S.r.l.). Characteristics of paint and varnish materials are given in the table. 1.

Table 1.Technical characteristics of the acrylic VPM of photochemicalcuring, produced by the Sayerlack firm (Sherwin-Williams Italy S.r.l.)

Indicators	Composition A	Composition B	Composition C
	Acrylic lacquer UV-curing for rolling with rollers	Water soluble acrylic lacquer UV-curing for spray application	White acrylic enamel UV-curing for roller rollers
Volatile matter content,%	99±1	32 ± 2	99 ± 1
Density, kg/l	1.250 ± 0,030	1,050 ± 0,020	1.370 ± 0.030
Viscosity (DIN 4 at 20°C, seconds)	30 ± 2	90±3	38± 2
Number of layers	1-2	2 with intermediate polishing	1-2
Consumption, g/m^2	4-8	80-110	10 –15
Drying	UV-lamp of high power (360nm 80-120W/cm)	20′ - hot air for 30-35˚C High Power UV Lamps (360nm, 80-120 W/cm)	3′-4′ 'High Power UV Lamps gallium/mercury 80-120W/cm

Experiments were conducted at a temperature of 20±2°C and a relative humidity of 65±5%. Paint and varnish materials of photochemical curing were evenly applied on glass substrates of size 100x20mm using a brush. Using electronic weights (accuracy of measurement 0,001 g) the consumption for each type of LFM were observed (Table 1). The coatings were smooth and without defects on the surface.

For water evaporation, the water-soluble UV-composition was pre-stored at 60°C for 15 minutes ina thermal camera prior to polymerization under a UV-LED or high pressure mercury-quartz lamp.

The glass plates with the same VPM were dried under various UV sources (high pressure mercury lamp DRT-375 and laboratory installation with UV LED) for the time interval time necessary for obtaining technological hardness.

For the study of photopolymerization processes, traditional UV sources (high-pressure mercury-quartz lamp DRT-375) and laboratory equipment with UV-light-emitting diodes [5] were used. This installation makes it possible to make the experimental samples harden under the impact of emitted UV-light radiation of different wavelengths and power.

The main technical characteristics of the installation are given in Table. 2.

Tabl. 2. The main technical characteristics of the laboratory installation with UV-light-emitting diodes

The size of the samples under study	50x80 mm
Moving speed of the carriage (variable)	2.5 m/min - 10.0 m/min
Maximum stabilized power supply of LEDs	3A
Variable LED emitters with length radiation, nm:	365 –375 / 380 –390 / 395 –410
Power supply	220 V

Structurally, the laboratory installation of UV LED (Fig. 1) consists of three parts:

- the carriage, moving reciprocally, on which the test sample is installed;
- replaceable illuminator with UV light-emitting diode;
- the power supply unit of the UV radiator and the drive of the carriage.

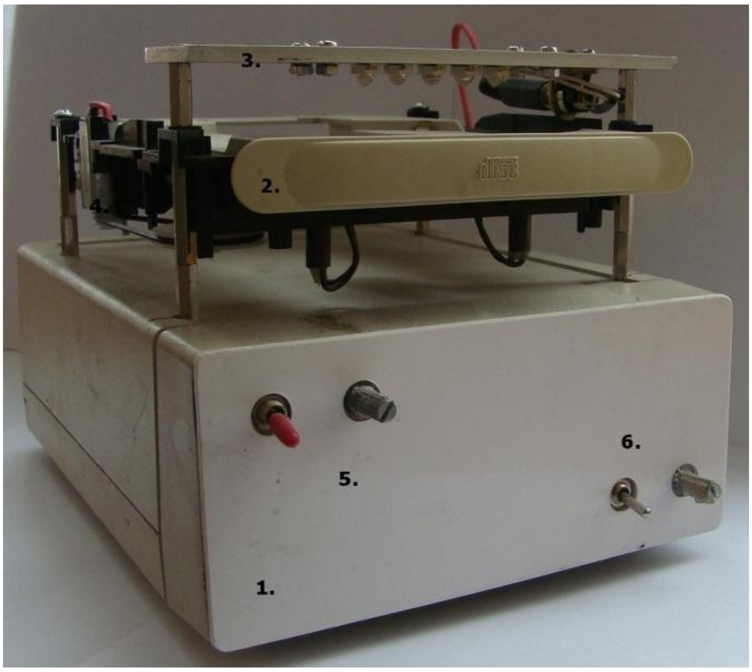


Fig. 1. General view of the laboratory installation with UV light-emitting diodes:
1 –power module; 2 – mobile carriage; 3 – UV illuminator; 4 – electric drive carriage; 5 – UV control bodies; 6 – bodies of control of the electric motor drive carriage

Fig. 2. Ruler with five LEDs:
1 – aluminium radiator plate; 2 – UV-light; 3 – power connector for the UV radiator

Mechanism of reciprocating movement of a carriage – a rail type with a drive from a reversing electric motor. LEDs are located on a massive aluminium bar, which acts as a radiator (Fig. 2). The design of the mechanical fastening of the LED strip and the presence of an electrical connector in the power supply of LEDs provide the ability to quickly replace the LED line. During the study, the radiator with LEDs EDEV-1LA1 (Edison company), whose radiation spectrum is in the range of 395-410 nm, was used.

Research methods. Before the study samples were kept at a temperature of 20±2°C and a relative humidity of 65±5% for not less than 16 hours.

The degree of hardening of the coating can be characterized by hardness, which is a function of the time spent on drying paint and varnish coating. The hardness of the coating was determined by the fading of the oscillations of the pendulum M-3 [6]. Coating was formed on a glass plate to study its hardness, since the hardness of the substrate used may affect the results. Similar coatings were polymerized both under a UV-LED and under a mercury-high pressure lamp.

Research results. The results of determining the hardness of the coatings as the degree of hardening of paint and varnish materials under the influence of UV radiation emitted by a high pressure mercury lamp and solid-state sources are given in Table 3.

Table 3.Hardness of coatings based on VPM, polymerized under high pressure mercury lamp DRT-375 and UV lamp with LEDs EDEV-1LA1

Types of paint and varnish materials of photochemical curing	Hardness of coatings, conventional units	
	photopolymerization under a UV lamp with LEDs EDEV-1LA1	photopolymerization under a high pressure lamp DRT-375
Composition A	0,39	0,54
Composition B	0,48	0,60
Composition C	0,59	The coating does not harden

Conclusions.

In the study of the possibility of polymerization of acrylic VPMof photochemical curingunder the impact of UV radiation emitted by solid-state sources (whose radiation spectrum is in the range 395-410 nm), the laboratory tests discovered the following:

1. The best hardness results can be traced to white acrylic enamel (composition C) under the LED source. Under the mercury-quartz lamp the coating was not formed. This can be explained, probably, by the low transmission of white enamel pigment in the region of maximum emission of a high pressure mercury lamp and, accordingly, by high transmittance of this pigment in the high-wavelength region of UV radiation of LEDs EDEV-1LA1 (range 395-410 nm).
2. Insufficient degree of hardening is observed in the coating with the basis of acrylic varnish (composition C) when using solid-state sources. Photopolymerization under the traditional DRT bulb was successful.
3. A coating with the basis of water-soluble acrylic varnish (composition B) reached a sufficient hardness, and, consequently, a high degree of hardening. Perhaps, this is due to the fact that coalescence occurs after the evaporation of water, resulting in less chemical bonds.

In conclusion, it is necessary to conduct a series of experiments on the study of photochemical curing of coatings based on acrylic varnish of UV-curing applied by rollers under solid-state sources. To conduct this experiment, it is necessary to choose the variable illuminators with UV light-emitting diodes (the laboratory installation is equipped with them) of another radiation length, namely 365-375 nm, 380-390 nm, or to use successive radiation by solid-state sources with the different spectrum of radiation.

References

1. **Adrian Lockwood** (October 2012): UV LED light sources for the curing of wood coatings // PRA`s 8^{th} International Woodcoatings Congress. – Netherlands.
2. **Robert P Karsten** (July 31, 2015): UV Curing for Wood Coatings, Phoseon Technology p.7 Available online: http://www.phoseon.com/ Documentation / UV LED for wood coatings. pdf.
3. **Veronic Landry, Pierre Blanchet, Gabrielle Boivin, Jean-Francois Bouffard and Mirela Vlad** (2015) : UV Curing Efficiency of Wood Coatings // *Coatings* 5:1019-1033.

4. **Jim Raymont, Abhinav Kashyap** (Spring 2011): Measuring the output of Ultraviolet light emitting diodes // Radtech Report Technical Paper.

5. **Yarish O.V.** (2013): *Fotopolimeryzatsiya LFM pid diyeyu emitovanoho tverdotil'nymy dzherelamy UF-vyprominyuvannya v laboratornykh umovakh* [Coatings photopolymerization by the irradiation emitted by solid sources of UV-radiation in the laboratory conditions]. *Forestry, Forest, Paper and Woodworking Industry* 39(1):75-79, (in Ukrainian).

6. **Karyakina M.I.** (1988): *Ispytaniye lakokrasochnykh materialov i pokrytiy* [Испытание лакокрасочных материалов и покрытий]. – Moscow : *Chemistry* : 85-92, (in Russian).

УДК 684.4.059.4 ***Асист. О.В. Яріш, канд. техн. наук; доц. С.А. Грицак, канд. техн. наук; асист. О.М. Кушпіт – НЛТУ України***

Дослідження можливості полімеризації акрилових лакофарбових матеріалів фотохімічного твердіння під дією УФ-випромінювання, емітованого твердотільними джерелами

Досліджено можливість полімеризації акрилових ЛФМ фотохімічного твердіння під дією УФ-випромінювання, емітованого твердотільними джерелами (на базі лабораторної установки); проведено порівняння твердості (як характеристики ступеня затвердіння) отриманих лакофарбових покриттів з твердістю аналогічних покриттів, фотополімеризація яких ініційована ртутно-кварцовою лампою високого тиску.

Ключові слова: УФ-твердіння, твердотільні джерела УФ-опромінення, світлодіодні джерела, лабораторна установка, твердість покриття.

UDC 684.4 ***Director Ye.P. Kunynets – concern "ENO Mebli Ltd", Mukachevo; post-graduate A.A. Mokrytskyy; post-graduate A.A. Yakovenko; post-graduate Yu.V. Maksymiv– UNFU, Lviv***

RESEARCH OF THE WOOD COMPOSITE MATERIAL DEFORMABILITY IN TERMS OF THE HEAT MASS TRANSFER

The analysis of the basic structural states in the technological process of manufacturing of wood composite materials is carried out. The parameters of temperature-humid field and kinetics of structural transformations are determinedand building a mathematical model for the determination of the stress-strain state of wood composite materials under conditions of heat mass transfer.

Keywords: fluidity, viscoplasticity, viscoelasticity, stress-strain.

Introduction. A characteristic trend in modern studies of the wood composite materials (WCM) is a shift towards process problems and formation of a new direction their basis, namely process mechanics of the wood composite materials. The central problem in this respect is to develop the phenomenological interrelated physical and mechanical WCM models, taking into account the structure formation evolution in the process. On their basis, reasonable process parameters for specific materials, basic types of structures and processes of their manufacture may be identified, recommendations may be justified, and special algorithms to control such parameters ensuring the required WCM quality may be developed.

The analysis of theoretical and experimental study findings, as well as the production experience shows that the use of traditional physical mechanics relations to determine the WCM quality indicators does not allow determining their dependence on the influence of process factors during their manufacture unequivocally. In particular, the same hydrobarothermic WCM production modes result in formation of residual process stress fields with varying nature and structure. Besides, the formation of WCM structure as polymer composites in the manufacturing process is related to the evolution of its condition. In the most general case, under the temperature, humidity and mechanical stress, the polymer materials undergo irreversible physical and chemical transformations with phase transitions, and consistently move from one equilibrium state to another, taking into account the fluidity, viscoplasticity, and viscoelasticity.

Synthesis of mathematical model for determination of deformation-relaxation processes in wood composite materials. One can highlight five major structural conditions in the WCM manufacturing process:

- viscous state with viscosity varying during heating;
- formation of molecular and supramolecular structure, the transition of reinforced matrix to highly elastic condition;
- temperature field lowering to T-vitrifaction, slowing down of elastic properties;
- transition to the glassy condition with vigorous increase in relaxation time due to the supramolecular structuring;
- cooling down to the ultimate temperature subject to change of relaxation properties.

To solve the problems related to determination of the process stress fields and strains for each stage, the corresponding physical ratios for temperature and humidity, relaxation and conversion processes shall be recorded.

At all WCM production stages, the thermal and mechanical properties depend on the temperature, humidity and structural condition of composites. Logically, it is first required to consider the problems of thermal and moisture conduction, as well as structural transformationkinetics. The mathematical formulation of the heat conduction problem in view of the structural transformations kinetics is reduced to the following system of equations:

$$\begin{cases} \dfrac{dU}{d\tau} = \dfrac{d}{dx_j}\left(a_{mij}\dfrac{dU}{dx} + \dfrac{d}{dx_j}\left(a_{mij}\delta_{ij}\dfrac{dT}{dx_j}\right)\right) \\ C\rho_0\dfrac{dT}{d\tau} = \dfrac{d}{dx_j}\left(\lambda_{ij}\dfrac{dT}{dx_j}\right) + \varepsilon\rho_0 r_{12}\dfrac{dU}{d\tau} + Z\dfrac{dT}{dx_j} + q_i\dfrac{d\gamma_i}{dt} \end{cases} \qquad (1)$$

where: $C(T_i,U_i,\gamma_i)$ means heat; $\rho(T_i,U_i,\gamma_i)$ means density; r_{12} means vaporization heat; δ_{ij} means thermodynamic factor; ε means the phase transition criterion; γ_i means the structural transformation value.

Note that for anisotropic bodies, the diffusion a_{mij} and thermal conductivity λ_{ij} ratios are the second-rank tensors.

During non-isothermal processes in the manufacturing process, WCM consistently pass through the viscous-flow, highly elastic, and glassy conditions, and are accompanied by sophisticated physical and mechanical transformations. WCM condition evolution is associated with a change in *S* entropy, internal *U* or free energy *F* and activation modes E_k (*k = 1,2,3*). The following processes are the most common for WCM structural transformations: thermal activation, structure formation, and stabilization, each of which features a relevant structure and physical properties. Each component WCM in microscopic terms is a thermodynamic system with an infinite number of molecules in the state of an unstable equilibrium ($\delta U = 0,\ \delta U^2 < 0$). A kinetic equation for the process in general can be written as follows

$$\frac{d\gamma_i}{dt} = \sum_i \frac{E_i \gamma_i}{KT^2} \frac{dT}{dt} \Delta\delta(t_i, t_{i+1}) + \sum_3 \gamma_j (t, T) \Delta\delta_j . \tag{2}$$

where: $i = 1, 3, 5$; $j = 2,\ 4$; $\delta(t_i) = 0,\ t_i < 0$; $\delta(t_i) = 1,\ t_i > 0$

$$\delta(t_i, t_{i+1}) = \delta(t - t_i) - \delta(t - t_{i+1}).$$

Let us specify the ratio (2) for the key process stages. Since no structurally aggregated transformations occur at stages 1, 3, 5, WCM can be regarded as an adiabatic system in a thermodynamically equilibrated state. Parameter γ_i may describe the thermodynamic probability of the condition. From the kinetic theory, we obtain

$$\frac{d\gamma_i}{dT} = \frac{U_i \gamma_i}{RT^2} \tag{3}$$

where R is the gas constant, and U_i is the internal system energy.

At the second stage of the structure formation and transition to the highly elastic state, a dramatic change in the composite properties occurs, and its volume of adhesion bond formation is reduced.

$$\frac{d\gamma_2}{dt} = k_\rho \omega_2 (\gamma_2) \tag{4}$$

$k_\rho = k_2 a_{T2}$ means an effective reaction rate constant; k means a reaction rate constant; $a_{T2} = \exp(\ E_2 / \mathrm{RT})$ means a thermal displacement coefficient; $\omega_2(\gamma_2)$ means a dependence of the chemical reaction rate: $\omega_2 = 1\ \ \gamma_2^2$ means a polycondensation, and $\omega_2 = 1\ \ \gamma_2$ means a polymerization. At the fourth stage, a phase transition from a highly elastic into a vitreous conditions occurs. It corresponds to an extensive increase in stiffness and strength

$$\frac{d\gamma_4}{dt_4} = k_4 a_{T4} \omega_4 (\gamma_4) \tag{5}$$

After determination of temperature and humidity field parameters and structural transformation kinetics, let us proceed to finding the stress-strain WCM condition in the process at all stages of structural aggregate transformations.

Mechanics values take into account the bi-phase nature of the porous environment featuring the thermal viscoelastic properties. The environment permeability, and its filtration properties are described by k_1, k_2 factors. In general, the mechanical load with P_0 intensity on the surface $C(t)$, which occurs, for example, during movement, is described by the function $f(t) = V^{-1}(t) \int_C P_0 dC$

A closed-circuit system of mechanics equations looks as follows.

- WCM equilibrium equation

$$\psi_a div\sigma_a + \psi_M div\sigma_M = \psi_M f(t)\delta(t - t_0); \tag{6}$$

where *a* and *m* indices belong to the reinforced particles and the polymer matrix, respectively; and δ is the delta function.

- equation of solving the velocity fields of the viscous-flow matrix with the field pressure *P* therein

$$V_H = -k_2 gradP \tag{7}$$

- equation of continuity in a strained viscoelastic medium

$$\frac{d}{dt}(\psi_M \rho_M) - div(\phi_M v_M k_M gradP) = 0 \qquad (8)$$

- physical ratios for reinforced particles and a polymer matrix

$$\sigma_M = PI + F_M(\Delta_M); \;\; \rho_M = \varphi_M(\rho); \;\; \sigma_a = F_a(\varepsilon). \qquad (9)$$

where Δ_M means the strain rate tensor; I means the unit tensor; ε means the strain tensor.

In the case of adhesive interaction between WCM components, the mechanics equations take into account non-isothermal nature of the structure. This must be supplemented with the mass conservation equation upon shrinkage strains

$$\frac{1}{\rho}\frac{d\rho}{dt} + (1-\theta_y)^{-1}\frac{d\theta_y}{dt} = 0, \qquad (10)$$

where $\theta_y = \varepsilon_{kk}$ means the volume strain.

In the process, WCM is modeled by anisotropic viscoelastic environment with sophisticated thermal rheology, the properties of which depend on the structural and physical condition, and the boundaries of one condition they are transient, heterogeneous and unstable. Therefore, the formalization of WCM dependencies is a very complex task.

A real way of simplifying the physical equations is to accept the hypotheses on additivity of WCM component properties by the existence of polyfactor-time analogies. Based on experimental studies, the time reduction functions for temperature and humidity-time reduction were determined in a broad range of *T* and *U* variation.

To establish specific dependencies (7) between the stress and strain tensors, the postulates of irreversible process thermodynamics were used. The calculated physical correlations look as follows

$$\frac{d\varepsilon_{ij}}{dt} = (1-\gamma_k(t))\left(a^k_{ijmn}\frac{d\sigma_{mn}}{dt} + \frac{d\theta^k_y}{dt}\delta_{ij} \right) + \gamma_k(t)\left(b^k_{ijmn}\sigma_{mn} + \alpha^k_{ij}\frac{dT}{dt} + \beta^k_{ij}\frac{dU}{dt} \right) \qquad (11)$$

where a^k_{ijmn} means the stiffness tensor components; b^k_{ijmn} – means the viscosity tensor components; and $a^k_{\text{ik}}, b^k_{\text{ij}}$ means the temperature and humidity expansion tensor components.

Conclusion. A mathematical model for studying stress and deformation fields in wood composite materials under heat and mass transfer conditions was constructed.

УДК 684.4 ***Ген. д-р Є.П. Кунинець, канд. техн. наук – ТОВ "Ено-Меблі ЛТД"; аспіранти: А.А. Мокрицький; А.А. Яковенко; Ю.В. Максимів – НЛТУ України***

Дослідження деформативності деревинних композитних матеріалів в умовах тепло масообміну

Проведено аналіз основних структурних станів в технологічному процесі виготовлення деревинних композитних матеріалів. Визначено параметри температурно-вологісного поля і кінетики структурних перетворень та побудовано математичну модель для визначення напружено-деформівного стану деревинних композитних матеріалів в умовах тепломасообміну.

Ключові слова: в'язкопластичність, в'язкопружність, напружено-деформівний стан, текучість.

UDC 674.05.053
Post-graduate V.I. Taras – UNFU; prof. A.S. Kutsyk, Doctor of Technical Sciences – Lviv Polytechnic National University

METHODIC OF RESEARCH OF FACE RUNOUT OF CIRCULAR SAW IN THE PROCESS OF WOOD SAWING

The face runout of the saw is an important parameter of the equipment, which affects in particular the quality of the product and the durability of the tool. The article describes a well-developed technique for researching the face runout of a saw, which differs by the used sensor, the simplified procedure of its calibration and the method of processing the received signals. The use of computer technology ensures a wide range of settings, displaying results in a convenient format, enables automation of signal processing.

Keywords. Face runout, wood sawing, induction sensor, calibration, technological control.

One of the most common types of woodworking machines is round saw for sawing wood [1]. The energy costs, the precision of the product, the surface roughness, the width of the sawdust largely determine the energy consumption and the amount of wood waste in this operation and in the further processing of the workpiece. The face runout of a disk is one of the main factors of the listed indicators.

Meanwhile, the face runout of a saw is also determined by a set of parameters: constructive, which can be considered unchanged for each sample the machine, and depending on the mode of operation of the equipment, in particular the speed of the feed material. Several mechanisms for influencing the velocity of the face runout of the saw are known, in particular the mechanical stresses and uneven heating of the cutting tool [2]. Changes in the value of the face runout of unloaded saw characterize irreversible deformations in the tool during the period of operation. The same changes that occur in the process of cutting wood, is an indicator of the coherence of the operating mode with the properties of the tool and determine the possibility of obtaining the result of processing the product of a given quality. Consequently, for scientific researches, the determination of face runout of a saw will allow a more detailed study of the tool in the process of cutting wood, and for practice – the monitoring of the state of equipment and modes of its use. In the known means for determining the value of axial beats, electromagnetic position sensors [1] are used. The use of other types of movement data in face runout studies is limited by their principle of action or constructive execution. For example, the possibility of using rheostat and condenser sensors is influenced by the necessity of mechanical connection with the moving object of research; Magnetininductive – the need to attach to the object some elements of the sensor [3, 4].

For a more detailed study of axial impacts with the definition of momental values of its value or the nature of the deformation of the disk is important not only the maximum frequency of conducting measurements of the average value, but also the sensor frequency bandwidth range. The lower frequency of this band is determined by the speed of rotation of the saw, and the upper part is also the possible number of nodal radius of deformed saws. If due to deformation on the saw disk five nodal radii have been formed, then, in calculations to determine the range of discrepancies of the disk with an error of 2%, the operating frequency of the sensor should be 32 times higher than Nyquist frequency: 50*5*2*32= 16 kHz. Taking to account the characteristics of real filters, in order to provide such bandwidth, operating time of sensors using alternating voltage should be 5-10 times higher, which excludes the possibility of using low-frequency devices.

In the electromagnetic sensor, an inductor is used which creates a variable magnetic field of high frequency near the surface of the saw. Depending on the distance between the coil and saw, the part of the magnetic flux that is locked through the ferromagnetic material of this tool and changes the electric inductive resistance of the coil. The advantage of this sensor is the lack of mechanical contact with a moving saw.

To increase the sensitivity of a magnetic sensor, two coils are often used by a differential circuit [1]. The output voltage of this sensor characterizes the distance between the coil and dust. To observe the instantaneous values of the output voltage, use an oscilloscope. The width of the face runout of the saw is determined by the difference between the maximum and minimum amplitudes during one turn of the saw (Fig. 1).

The analysis of the oscillogram of the output voltage of the electromagnetic sensor is complicated by the need to compare both the positive and negative values of the stresses distributed in time (Fig. 1) on a moving oscillogram. You can evaluate the nature of the heterogeneity of the saw in the line of contour of oscillogram. In the drawings, the dotted line separates the signal region corresponding to one rotary dust.

Unresolved questions of face runout control. A well-known method requires the operator to work with complex devices and signals (generator of high frequency voltage, differential sensor, oscilloscope), but does not provide a direct estimate of the value of the face runout, which must be calculated for two values of the amplitudes , determined from the moving image on the oscillograph screen.

The boundary of errors of data taken on the oscilloscope's screen is taken as five percent. Thus, the error limit of determining the value of a face runout , as the difference between the two indicators, exceeds ten percent [3]. It is known that the sensitivity of the electromagnetic sensor depends on the distance to the dust, so to compare the size of the face runout of different pollen it is necessary to calibrate it after each sensor installation . The calibration procedure of this sensor requires a considerable amount of time and special equipment. These difficulties and low accuracy of estimates limit the use of known methods for studying face runout of the saw.

Problem statement To use in practice control of face runout of pollen, it is necessary to improve the known technique, to provide more precise definition of the value of the face runout, to simplify the methods of use and calibration of means of research.

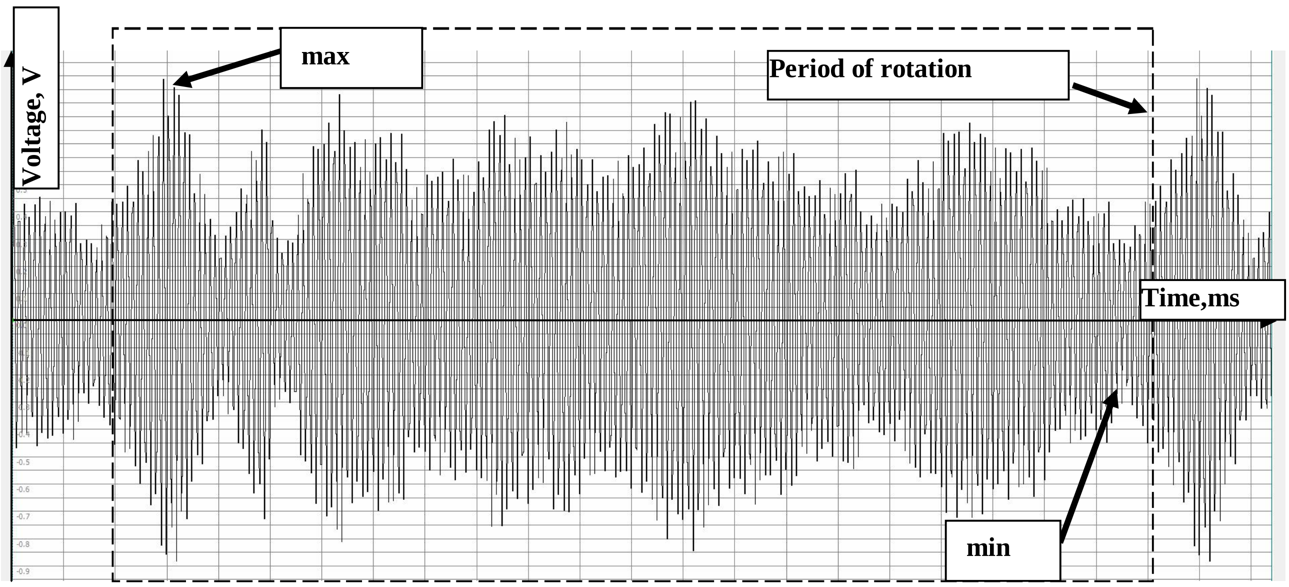


Fig. 1. Voltage at the output of the electromagnetic sensor of position saw

In the method developed by us the principle of electromagnetic induction is used. To form an induction sensor in the vicinity of the saw blade, a permanent magnet is installed, the magnetic field of which partially closes through the saw. The distance between the magnet and the saw is a non-magnetic intermediate, which determines the magnetic flux of a permanent magnet through the saw. Changes of this flow caused by the face runout of the saw are the cause of the electrical voltage in the coil installed in this magnetic flux (Fig. 2). It voltage is proportional to the velocity of flow changes.

The face runout of the saw of the saw is a periodic process and can be represented in the Fourier series:

$$S = \Sigma An \cdot \sin (n \cdot \omega \cdot t + \varphi n), \qquad (1)$$

where: S – instantaneous value of the deviation of the saw from the middle position due to the face runout; ω – angular velocity of the saw; t – time; An is the amplitude of n-th harmony of face runout of the saw, n – harmonic number; φn is the angle of displacement of the initial phase of the n-th harmonic.

The results of the calculations show that, if the average distance from the sensor to the disk saw, which is three times the size of the face runout the maximum error of the linear approximation of the dependence of the magnetic flux on the magnitude of the non-magnetic gap is 1%.

$$Smax - Smin < (Smax + Smin) / 6, \qquad (2)$$

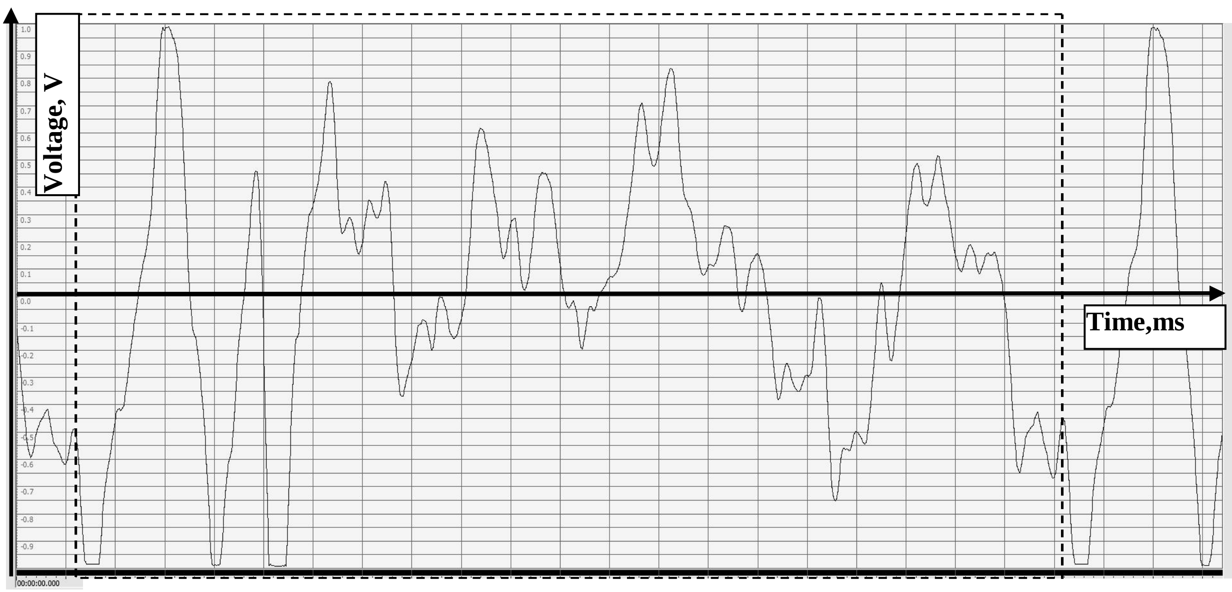


Fig. 2. Signal of the induction sensor from the face runout of the saw

Consequently, voltage of this sensor with high accuracy characterizes the rate of change in the magnitude of the nonmagnetic gap dS / dt:

$$U = k \cdot dS / dt = k \cdot \omega \cdot \Sigma An \cdot n \cdot \sin (n \cdot \omega \cdot t + \varphi n), \qquad (3)$$

where: U – induction voltage induced in the winding; k – coefficient taking into account the parameters of the design of the sensor and the method of its installation, as well as linear approximation of the dependence of the magnetic flux on the magnitude of the non-magnetic gap..

The rolling of the asynchronous motor rotor of a saw relative to the magnetic field for modern machines is 3-5% [3]. Therefore, the speed of rotation of the saw during the work changes slightly and in the first approximation the speed of rotation can be considered as a constant. The instability of the rotational frequency of the saw in this case results in an error of measurement of the axial beat ± 1%, which is significantly less than error of the known method . If necessary of reduction of error, frequency of rotation, equal to the frequency of the first harmonic of the induced signal, can be measured and its value is used to correct the results of determining the value of the face runout. The non-stability of the idle speed and the errors generated by it are still much less than the deviation of the rotational speed of the saw during operation.

As a magnetic system with a winding, it is convenient to use the headphone in the offered device. The membrane system headphone with a fixed coil is used as a sensor, removing the membrane, and in the headphone of the dynamic system, it is necessary to fix the position of the coil relative to the magnetic circuit (for example, with glue) and then remove the diffuser to bring the magnetic system to the saw. The compact magnetic headphone system allows you to control the face runout of the saw at different distances from the axis and thus carry out a kind of scanning of the surface of the saw. The closed construction of the magnetic system helps to reduce sensitivity of the sensor to external fields, which results in a low noise level in the received signal (Fig. 2).

The signal received from the induction sensor contains information, but graphically does not reflect the nature of the fluctuations of the saw, because the instantaneous signal values are proportional to the speed of change the axial position of the stick disk. To get information about the saw profile and its changes during operation, it is necessary to process the signal, namely perform the integration and scaling operations.

To perform the mathematical processing of the signal, we used a computer technology and a specialized program GoldWave for processing signals. This program provides a wide range of reception, processing of signal and graphical visualization of the results of computations and signal formatting. To evaluate the nature of the beating of the saw, we used spectral analysis and filtration of the signal of the induction sensor.

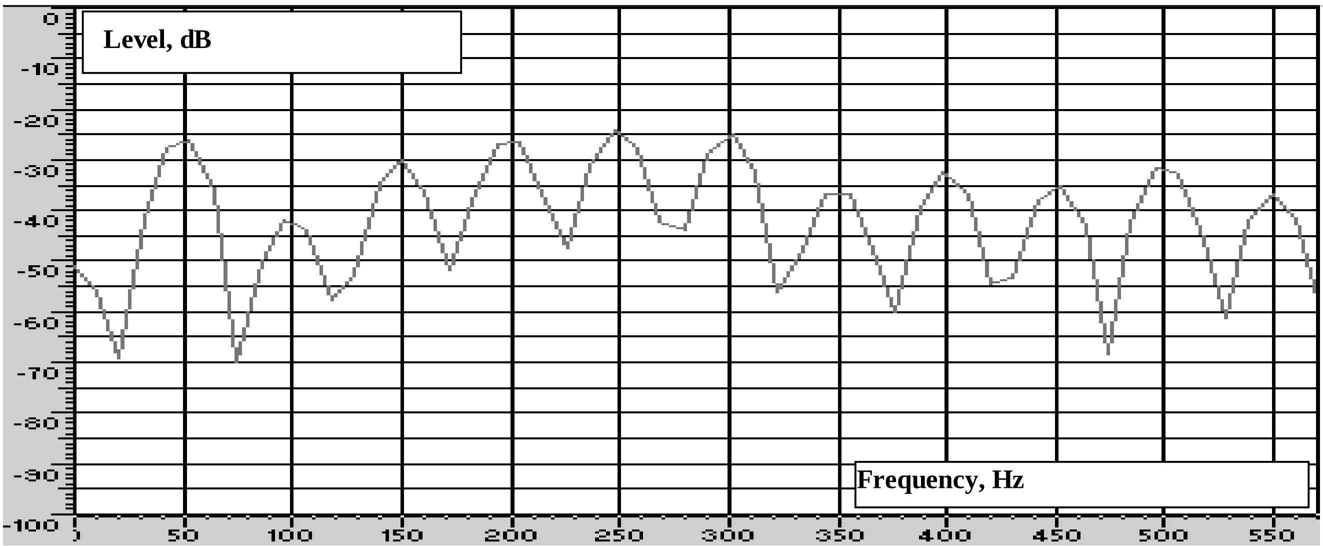


Fig. 3. The spectrum of induction sensor signal

The results of the spectral analysis (Fig. 3) indicate the poliharmonic composition of the received signal and the lawfulness of the Fourier series for its analytical representation. The high level of the fourth, fifth and sixth harmonics, the amplitude of which is practically equal to the amplitude of the first harmonic (the consequence of not the perpendicularity of the saw and the axis of rotation), testify to the multiple bends of the saw disk (nodal radii).

The use of the first-order low frequency filter property to integrate signals in the frequency range higher than the frequency of its cut is used to obtain a deformation profile of a saw disk. Given the uniform rotation of the saw disk in the signal spectrum , generated by this rotation, there are no components with frequencies below the rotational speed. Therefore, the low-pass filter of the first order with the 50Hz frequency limit allows for the integration of the signal of the induction sensor with high accuracy and obtaining a signal corresponding to the instantaneous values of position the saw disk (Fig. 4). The received signal reflects the profile of the saw on the radius of the sensor installation, but without its calibration does not make it possible to determine the value of disk deformation. The standard calibration procedure reduces to setting the dependence of the output voltage of the sensor on the size of the gap between the sensor and the saw blade. To obtain such dependence, multiple measurements of the size of the gap and the voltage level of the transducer are performed by exemplary devices. This method of calibration is burdensome even for scientific research because of the need for exemplary devices and a significant length of procedure.

In the methodic we have developed studying face runout is simplified by the calibration of the sensor. Two measurements of the scale of the filtered signal Ur = U2-U1 (Fig. 4) with the change of the non-magnetic gap to the calibrated value ΔS = S2-S1 are performed for its conducting after the sensor is installed. The value of ΔS in the range of 0.2-1 mm can easily be transmitted using a metal plate, which allows the sensor to be fixed in a position shifted to the thickness of the calibration plate. The relation of difference of the sensor signal in these positions to the thickness of the plate determines the sensitivity of the sensor C in the conditions of use of the sensor:

$$C = (Urs1 - Urs2) / \Delta S \quad (4),$$

where: C – sensitivity of the sensor; Urs1 and Urs2 the sensor signal in the initial and shifted position; ΔS change in the magnitude of the non-magnetic gap.

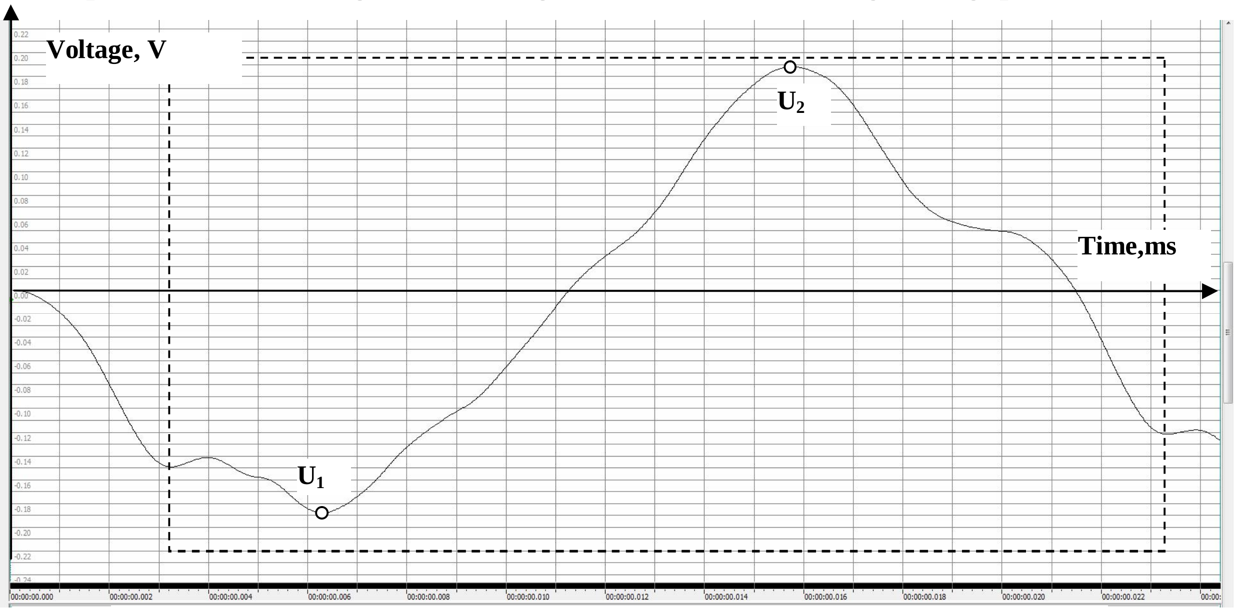


Fig. 4. Filtered signal of the induction sensor

This calibration procedure of sensitivity of the sensor consists of only two measurements made near the working point by working means of computing using the GoldWave program for fixed level of signal. Possibilities of the used means provided a wide range of amplification of the signal processing channel of the sensor and scaling the received results.

In tests conducted as a sensor tested headphones TON-2 and IE 800 S. Conversion of analog signal to digital was carried out sound card of the computer in 16-bit code with a sampling rate of 16kHz, which allowed the value of a signal with an error of tenths of a percent. These tools allowed not only to calibrate sensors with a sensitivity of 1 to 0.01 mm/V, but also to scale the received signals to represent the oscillograms in the form of a convenient to estimate the value of the face runout of the saw (for example, Figure 4 depicts the disc deviation of the saw in the range of ± 0,1mm) The methodological error of determining the value of the beats according to the developed method is determined by the error of quantization of the signal, which is much smaller than the error of reference on the oscilloscope screen. According to the results of the test, it was discovered that a metodic of researching the face runout was developed. It the metodic:

- ses easy-to-use, robust technical means that enables the primary information to be obtained in a contactless manner, which determines their durability and lack of influence on the subject of research,
- provides high accuracy due to the hardware receiving of numerical values of the signal, which excludes the possibility of a subjective error of the operator; Developed metodic allows to simplify and minimize calibration operations of the sensor;
- makes it possible to analyze deformation of complex form due to the wide bandwidth of used devices and the application for analysis of signals by software means of computer technology;
- suitable for use in automated systems of technological control and regulation, creation of effective means of diagnostics of the condition of the equipment (in particular, the implementation of the developed method allows to implement in the system of control the possibilities the controlling of speed of the supply of wood of modern machine tools [1], will promote the quality of products, increase term of service of the tool and increase of profitability of production).

References

1. **Sanyov V.Y.** *Obrabotka drevesyny kruhlymy pylamy* [Wood treatment with round saws]. – M.: Forest industry, 1980. – 232 p.
2. **Stahiev Yu.M.** *Rabotosposobnost ploskykh kruhlykh pyl* [The working capacity of flat round dust]. – M.: Forest industry, 1989. – 384 p.
3. **Polischuk Ye.S., Dorozovets MM, Yatsuk V.O., etc.** *Metrolohiya ta vymiryuvalna tekhnika* [Metrology and measuring technique: a textbook]. – Lviv: Beskid Beat, 2003. – 544 p.
4. **Zhuk A.Ya., Zhelyabin N.K, Malyshev G.P.** *Osnovy naukovykh doslidzhen v sferi praktychnoyi mekhaniky* [Fundamentals of scientific research in the field of practical mechanics]. – K.: Condor Publishing House, 2012. – 224 p.

УДК 674.05.053
Аспір. В.І. Тарас – НДТУ України; проф. А.С. Куцик, д-р техн. наук – Національний університет «Львівська політехніка»

Методика дослідження торцевого биття круглої пилки в процесі пиляння деревини

Торцеве биття пилки є важливим параметром обладнання, що впливає зокрема на якість продукції та довговічність інструменту. Описано розроблену методику дослідження торцевого биття пилки, яка відрізняється використаним датчиком, спрощеною процедурою його калібрування та способом обробки отриманих сигналів. Застосування засобів обчислювальної техніки забезпечує широкий діапазон налаштувань, індикацію результатів у зручній формі, дає змогу автоматизації процедури оброблення сигналів.

Ключові слова. Торцеве биття, пиляння деревини, індукційний датчик, калібрування, технологічний контроль

УДК 647.047 ***Проф. В.М. Максимів, д-р техн. наук; асист. Р.Б. Щупаківський, доц. В.Р. Солонинка, канд-ти техн. наук; аспір. Ю.В. Максимів – НЛТУ України***

СТАН ТА ПЕРСПЕКТИВИ РОЗВИТКУ ДЕРЕВООБРОБНОЇ ОСВІТИ ТА НАУКИ В УКРАЇНІ

Проаналізовано сучасний стан та перспективи розвитку вітчизняної деревообробної освіти і науки, окреслено шляхи взаємодії ЗВО з підприємствами галузі, сформульовано завдання в підготовці висококваліфікованих фахівців-технологів в умовах євроінтеграційних процесів та викликів сучасного суспільства.

Ключові слова: деревообробна освіта і наука, працевлаштування випускників, деревообробне підприємство, економіка транзиту, міжнародна співпраця, євроінтеграційні процеси.

Винятково важливого значення в умовах розбудови лісопромислового комплексу, глибоких динамічних перетворень деревообробної галузі, набуває система впровадження якісних рішень щодо організації і становлення нових та підтримки розвитку існуючих підприємств сектору.

В рамках прийнятого Закону України “Про особливості державного регулювання діяльності суб’єктів підприємницької діяльності, пов’язаної з реалізацією та експортом лісоматеріалів” (щодо мораторію на експорт лісо- та пиломатеріалів у необробленому вигляді) та Закону України “Про внесення змін до розділу XX «Перехідні положення» Податкового кодексу України” (щодо особливостей оподаткування операцій з ввезення на митну територію України та постачання на митній території України деревообробного обладнання для відродження промислового виробництва) перспективи розвитку деревообробної та меблевої промисловості оцінюються експертами у збільшенні об’ємів внутрішньодержавного перероблення лісоматеріалів у 3-4 рази. Це дасть змогу створити умови для значного збільшення кількості деревообробних і меблевих підприємств, а відтак потребуватиме підготовки висококваліфікованих інженерно-технічних кадрів.

Станом на 2013, 2014 і 2015 роки чисельність деревообробних і меблевих підприємств становила 4815, 4350 і 4440 одиниць відповідно. На цих підприємствах зайнято 77.6 тис., 71.2 тис. і 69.4 тис. осіб. Обсяг реалізованої продукції у млрд.грн. у ці роки становив 17.3, 22.8 і 32.3 відповідно. В основному це спеціалізовані підприємства, на яких зайнято приблизно декілька десятків працівників. Більшість підприємств якісно різняться рівнем оснащеності – від обладнанням відомих європейських фірм, до обладнання вік якого сягає декількох десятків років. Практично усіх об’єднує одна проблема – кадрова. Це дефіцит як кваліфікованих робітників, так і інженерно-технічних кадрів.

Якість підготовки кадрів для будь-якої галузі залежить від багатьох чинників. У першу чергу від рівня державного фінансування освіти і науки. На жаль, з кожним роком воно погіршується.

Важливим чинником є також посилення впливу роботодавців на якість підготовки кадрів, зокрема на рівень їх практичної підготовки.

На разі зацікавленість роботодавців зводиться до двох позицій. Перша полягає у запрошенні на роботу декількох хороших випускників. І як тільки цієї мети досягнуто – інтерес до подальшої співпраці із ЗВО зникає. Суть другої полягає у залученні студентів до проходження практик. Є декілька підприємств які готові прийняти від 5 і більше студентів, забезпечивши їх роботою та проживанням:

“Ено Меблі ЛТД” (м. Мукачево), ТОВ “Меблі-ТОКАБО” (м. Чернівці), Меблева фабрика “Ламелла” (м. Тячів), ТзОВ “Брама” (м. Львів) та інші. Певний відсоток студентів бажають проходити практики за місцем проживання. Проте, як правило, ЗВО не може забезпечити контроль за проходженням практик таких поодиноких студентів. Часто студент на практиці – це дешева робоча сила, яка, відтак, не може бути якісною. Внаслідок цього виникають взаємні невдоволення.

Посилення євроінтеграційних процесів в царині освіти і науки є одним із шляхів покращення якості підготовки фахівців для галузі.

Підготовку кадрів для деревообробної галузі в Україні сьогодні здійснюють чотири університети, сім галузевих коледжів, чотири вищих професійно-технічних училища і декілька десятків закладів професійної освіти.

Базовим вітчизняним ЗВО з підготовки фахівців для лісопромислового комплексу є Національний лісотехнічний університет України. Підготовка фахівців-технологів здійснюється навчально-науковим інститутом деревообробних технологій і дизайну. На технологічних кафедрах інституту зосереджено до 80 % науково-педагогічних кадрів, які мають базову освіту і відповідну наукову спеціальність. Тут працюють майже усі доктори наук за технологічною деревообробною спеціальністю. Випуск технологів з деревообробки ведеться з 1946 року. Станом на сьогодні тут готують за усіма рівнями: бакалавр, магістр, доктор філософії і доктор наук.

За період з 1998 р. і по 2015 р. для деревообробної галузі підготовлено майже півтори тисячі фахівців-технологів за стаціонарною формою навчання. Щорічно за технологічними (деревообробними) напрямами/спеціальностями навчалося від 300 до 500 студентів (рис.1).

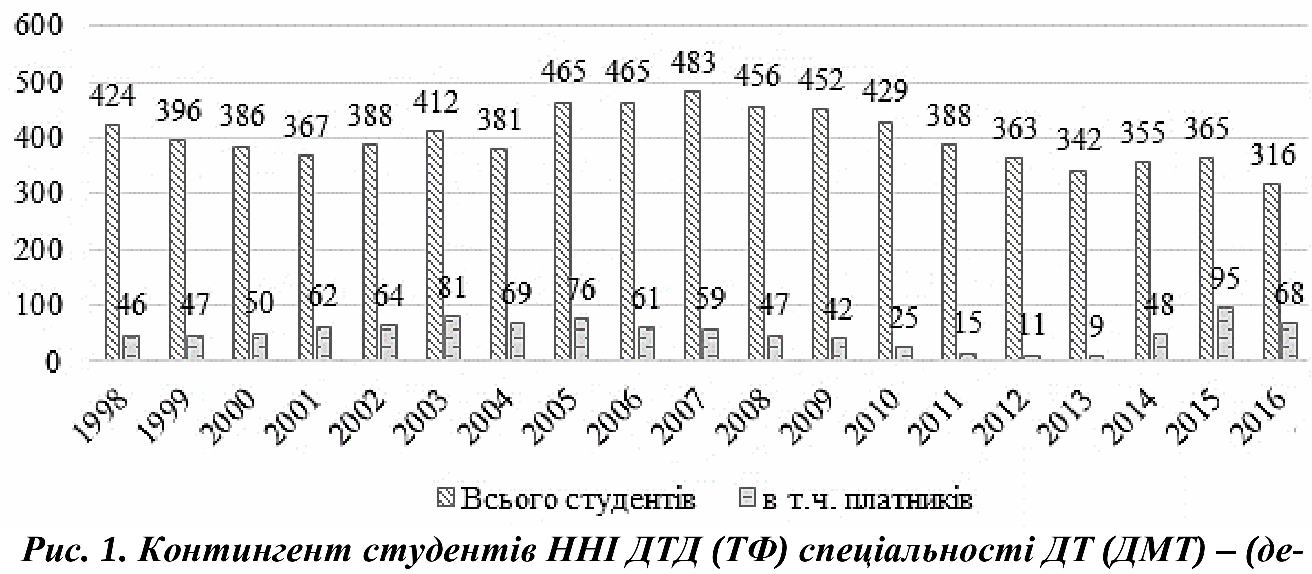


Рис. 1. Контингент студентів ННІ ДТД (ТФ) спеціальності ДТ (ДМТ) – (деревообробні та меблеві технології)

Попри ці та інші досягнення більш важливими є питання перспективи – питання шляхів розвитку вітчизняної деревообробної освіти і науки.

Україна прагне інтегруватись до країн Євросоюзу, маючи при цьому істотне відставання у своєму розвитку, приречена йти слідами передових економік, враховуючи при цьому свої «національні» особливості. Передові економіки прямують до нового економічного порядку (нової економіки) знаходячись на різних стадіях економіки транзиту. Україна знаходиться на її початковій стадії. Економіка транзиту – поступове впровадження заходів з енергозбереження в усіх сферах; поступовий перехід від невідновлювальних джерел енергії до відновлюваних; перехід до маловідходних технологій; розвиток технологій утилізації сміття (відходів) і його вторинного використання; поступове впровадження екологобезпечних технологій (зменшення негативного впливу технологій на довкілля).

До основних принципів нової економіка відносять: значна частина енергії виробляється з відновлюваних джерел енергії; використання безвідходних технологій; виробництво ресурсів внаслідок перероблення сміття побутового та промислового походження, відсутність негативного впливу технологій на довкілля; поступове відновлення біосфери; використання штучного інтелекту; розроблення нових (у т.ч. модифікованих) матеріалів та біотехнологій тощо.

Це найхарактерніші риси що стосуються лише сфер виробництва і енергетики. З огляду на вище наведене перспективи вітчизняної деревообробної технологічної науки і освіти є наступними:

- Формування нових знань і поглядів про деревину, як відновлюване джерело сировини і енергії.
- Модифікування деревини і деревинних матеріалів з метою надання їм кращих експлуатаційних і естетичних характеристик (світовий тренд, який інтенсивно розвивається).
- Розроблення і впровадження екологобезпечних і ресурсоощадних технологій сушіння, склеювання деревини її опорядження(починаючи від етапу виготовлення клеїв і лакофарбових матеріалів, продовжуючи через технології склеювання і опорядження, враховуючи етап експлуатації виробів і завершуючи утилізацією).
- Використання залишків деревообробки для виробництва альтернативних видів палива – гранул і брикет та ін.
- Впровадження малолюдних і безлюдних технологій оброблювання деревини і виготовлення продукції за рахунок впровадження елементів штучного інтелекту.

Вище перелічені завдання для науки та освіти лежать в основі підготовки фахівців-технологів закладами вищої освіти. Якісна ж підготовка кадрів повинна також враховувати сучасні тенденції та особливості розвитку економік в умовах глобалізаційних процесів:

- Європейські економісти прогнозують наступні зміни у різних сферах зайнятості на перспективу до 2025 року. Скорочення зайнятості прогнозується у сферах: видобуток вугілля і розроблення кар’єрів (~20%); сільське господарство, лісівництво і рибальство (~20%); електрика, газ, кондиціонування (~10%); водопостачання, каналізація, управління відходами (~6%); промисловість, мистецтво, рекреація (~5%).Зростання зайнятості у наступних сферах: наука і техніка (~20%); освіта (~10%); інформатика і комунікації (~10%); охорона здоров’я і соціальна робота (~8%).
- Дослідження проведені у ЄС показують, що за набутими спеціальностями у західних країнах ЄС не працює ~ 35 %, у центральних ~ 50 % і ~ 60 % у східних країнах. В Україні понад 60 % мають проблеми з працевлаштуванням за здобутою спеціальністю.

- Згідно з дослідженнями Оксфордського університету до 2025 у розвинених економіках зникнуть 40-50 % професій. Натомість інші отримають розвиток, а ті яких зараз немає стануть звичайним явищем.
- За даними роботодавців «чистий» (100%-ий)інженер-технолог не дуже потрібний виробничим сферам промисловості. Відтак затребуваними є «гібрид» – 50-70% технолог, решта – менеджер, дизайнер, бухгалтер, програміст і інше залежно від ситуації.
- В Україні налічується понад 400 тис. безробітних. З них: понад 40% це люди з вищою освітою, з професійно-технічною освітою ~38%, з середньою освітою ~20%. На загал – це люди передпенсійного віку, яким уже важко переучуватись. Тим паче, що в Україні майже відсутня система перепідготовки крім того вища освіта до цього неготова. Процес перепідготовки характерний тим, що люди прийдуть не за дипломом, а за конкретними знаннями.
- Україна знаходиться у стані системної кризи, яка пронизує усі сфери – як виробництво, так і освіту та науку. Для кризового стану характерним є те, що значна частина робочих місць не є традиційно з повною занятістю і повним соціальним пакетом – короткотермінові контракти, сезонні роботи і часткова занятість. Це необхідно враховувати ворганізації навчального процесу та формуванні складу кафедр.
- Нові технології в українському бізнесі «попадають» спочатку у сферу виробництва, тому бізнес про них знає швидше та краще і повинен активніше долучатися до процесу підготовки кадрів, особливо практичної підготовки.

З огляду на вище наведене необхідно готувати студентів вчитися упродовж життя і вміти пристосовуватись до зміни ситуацій.

В організації навчального процесу необхідно здійснювати організаційну та структурну перебудову кафедр, інститутів та інших структурних підрозділів. Викладацька діяльність не повинна бути єдиним джерелом доходів. Участь у міжнародних проектах, грантах, робота за фахом на фірмах, наукові консультації тощо повинні стати нормою діяльності викладачів. Звичним явищем може бути неповна занятість викладача (0.25-0.5) ставки. Частина колективу обирається терміном на 5 років, частина на 1 рік залежно від навантаження. До цього колектив необхідно готувати і формувати нову генерацію викладачів.

Найважливішими завданнями у міжнародній співпраці на нашу думку є:

1. Продовження роботи з оформлення заявок на участь у міжнародних грантах і програмах.
2. Розроблення системи заходів щодо проходження стажування викладачів у закордонних.
3. Наближення навчальних планів підготовки технологів з деревообробки до кращих закордонних аналогів, а також розроблення спільних освітніх та навчальних програми на магістерському рівні.

Література

1. **Teischinger, Alfred.** (2010). The development of wood technology and technology developments in the wood industries – from history to future. Holzals Roh- und Werkstoff. 68. 281-287 (DOI 10.1007/s00107-010-0458-2).

2. **Ellefson, Paul V.; Kilgore, Michael A.; Skog, Kenneth E.; Risbrudt, Christopher D.** (2007). Organization, governance, and measures of performance in a world widesetting. 57. 6-13.

3. **Sutton, WRJC.** (2000). Wood in the third millenium. Forest Products Journal. 50. 12-21.
4. **Lossack, Ralf-Stefan** (2006): Wissen schafts theoretische Grund lagenfür dierechner unterstützte Konstruktion (DOI 10.1007/3-540-29947-5).

UDC 647.047 ***Prof. V.M. Maksymiv; assist. R.B. Shchupakivskyy; assoc. prof. V.R. Solonynka; post-graduate Yu.V. Maksymiv– UNFU, Lviv***

State of the art and prospects of development of woodworking education and science in Ukraine

The article analyzes currentstate and prospects of national woodworkin geducation and science development, outline ways of interaction of highereducation institution and industry enterprises, formulatetasksinpractical training of highly qualified woodworking technologists in the frame work of integration processes and challenges of modern society.

Keywords: woodworking education and science, graduate employment, woodworking enterprise, transiteconomy, international cooperation, eurointegration processes.

УДК 647.047 ***Доц. С.В. Гайда, канд. техн. наук; ст. викл. Я.М. Білий – НЛТУ України***

ДОСЛІДЖЕННЯ ФОРМОСТІЙКОСТІ КЛЕЄНИХ ЩИТІВ ІЗ ВЖИВАНОЇ ДЕРЕВИНИ

Встановлено, що для впорядкування використання лісових ресурсів України необхідно прискорити прийняття законів щодо ресурсозбереження і використання вторинних відходів. Вживана деревина є додатковим ресурсом, придатним для матеріального використання, зокрема у виробництві щитових елементів. Досліджено, що формостійкість столярних плит та меблевих щитів при використання рейок шириною 20-40 мм , відповідає вимогам стандарту. Формостійкість комбінованих СП із ВЖД є вищою, ніж меблевих щитів за однакових конструкцій, зокрема складальних елементів – рейок. Встановлено, що для забезпечення підприємств вживаною деревиною, можливо, крім звичайних щитових елементів, виготовляти комбіновані. Рекомендовано для підвищення формостійкості щитових складальних одиниць бажано використовувати рейки малих шириною до 40 мм.

Ключові слова: вживана деревина, столярна плита із ВЖД, меблевий щит із ВЖД, клеєні щити, технологія, формостійкість.

Стан питання та актуальність. Деревні відходи утворюються у виробників деревообробної продукції і споживачів дерев'яних виробів. На сьогодні єдиної класифікації деревинних відходів немає. Можна їх поділити на відходи технологічні (утворені в процесі виготовлення виробів) і вживані відходи (утворені внаслідок використання і викидання тих же виробів). Нестача законів і відповідної класифікації деревних відходів згідно з токсичністю і шкідливістю спричинює багато непорозумінь, як у трактуванні самого терміну відходів, так і в підході до їх економічного та екологічного застосування.

Сьогодні фігурує обґрунтування, що відходи – це безповоротні втрати для підприємства, які або спалюються або вивозяться на звалище, а залишки деревини від основної продукції – це деревинний ресурс, який може бути проданим іншому виробнику або перероблений на додаткову продукції і також реалізованою.

Багато непорозумінь виникає ще й тому, що по-одному оцінює відходи виробник, по-іншому – споживач, а ще інакше сприймають їх з огляду на охорону довкілля. Вважають, що деревина як натуральна сировина не може загрожувати довкіллю. Це залежить від їх виду, кількості та способу утилізації. Кількість і якість відходів зумовлена профілем продукції та технологією, впроваджена на даному підприємстві.

Сьогодні актуальною проблемою комплексного використання деревинної ресурсів є економічно та екологічно обґрунтовані заходи з перероблення деревинних відходів, зокрема вживаної деревини (ВЖД). Підставою для оцінки ВЖД з огляду на безпеку довкілля є їх хімічний склад. В НЛТУ України розроблено Класифікатор ВЖД, згідно якого всю ВЖД поділено на чотири категорії. Для матеріального використання придатна ВЖД першої та другої категорії. Із якісної очищеної ВЖД (старих меблевих і столярно-будівельних виробів) можна отримати дошки, бруски, рейки, а також технологічну тріску. Відсортовані та випиляні на відповідні поперечні розміри рейки із ВЖД різних порід можуть бути використані для виготовлення клеєних щитових елементів, зокрема, столярної плити та меблевого щита. Але відсутність технологічних рішень, практичних рекомендацій та перевірених показників, в тому числі, на формостійкість, вимагають експериментальних досліджень.

Мета досліджень – дослідити та виконати порівняльний аналіз формостійкості щитових елементів клеєних конструкцій, зроблених із ВЖД.

Об'єкт досліджень – клеєні щитові елементи із ВЖД : меблевий щит та столярна плита комбінованих конструкцій.

Предмет досліджень – закономірності впливу конструкцій щитів на формостійкість готових виробів із ВЖД

Методика досліджень. Загальна методика досліджень включає: Заготівлю ВЖД. Очищення та сортування ВЖД. Технологічні операції з виготовлення рейок з ВЖД. Виготовлення меблевих щитів із ВЖД. Виготовлення столярних щитів із ВЖД. Виготовлення столярних плит із ВЖД. Перевірка на формостійкість столярних плит та меблевих щитів.

Матеріали для проведення досліджень – це заготовки ВЖД породи дуб та сосна, клей ПВА компанії Jowat, фанера, товщиною 4 мм.

Рейки заготовлялись поперечним розміром 20×20, 20×40, 20×60 мм. Після склеювання одержували калібровані щити розміром 450×450×16. Личковані столярні плити із ВЖД мали товщину 22 мм.

Для вирішення поставлених завдань досліджень було використано план другого порядку, який дозволяє отримати математичний опис об'єкта у вигляді поліному другого порядку (квадратична модель). У загальному випадку для k змінних факторів регресійна модель має вигляд:

$$\boldsymbol{y = b_0 + \sum_{i=1}^{\kappa} b_i x_i + \sum_{i=1}^{\kappa} b_{ii} x_i^2 + \sum_{i,u=1}^{k} b_{iu} x_i x_u}, \tag{1}$$

де: b_o – вільний член; b_i – лінійні коефіцієнти регресії, $\boldsymbol{i = \overline{1,\kappa}}$; b_{ii} – квадратичні коефіцієнти регресії; b_{iu} – коефіцієнти при парних взаємодіях, $\boldsymbol{u = \overline{1,\kappa}}$ (i≠u).

Рівняння регресії, яке можна отримати у результаті реалізації ***B***-плану для двох факторів, має такий вигляд : $y = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2$.

Для двох змінних факторів кількість дослідів В-плану дорівнює $N=2^2+2*2=8$. Оскільки на основі пошукового експерименту визначено, що в кожному досліді було проведено п'ять спостережень, тобто кількість спостережень в експерименті дорівнює 8×5=40. Щоб уникнути систематичних помилок, усі спостереження проводили за генерацією випадкових чисел. У результаті досліджень явища з літературних джерел, практичного досвіду і теоретичного аналізу дослідник було вибрано область експерименту (табл. 1). Змінними факторами для комбінованих плит були ширини рейок із ВЖД 20, 40, 60 мм дуба (Вд) та сосни (Вс).

Вихідним параметром було відхилення S від площинності одержаних комбінованих щитових елементів, столярної плити та меблевого щита.

Таблиця 1. Матриця В-плану для двох змінних факторів

№ досліду		Значення вхідних факторів у досліді			
		У натуральному позначенні		У кодованому позначенні	
		$В_Д$	**$В_С$**	**x_1**	**x_2**
ПФП 2^k	20	20	20	-1	-1
	60	20	20	1	-1
	20	60	60	-1	1
	60	60	60	1	1
Зіркові точки	20	40	40	-1	0
	60	40	40	1	0
	40	20	20	0	-1
	40	60	60	0	1

Вимірювання стріли прогину (відхилення від площинності) як однієї з основних характеристик формостійкості здійснювали після тижневої витримки експериментальних зразків у кімнатних умовах. Вимірювання проводили за допомогою експериментальної установки з ЧПУ (рис. 2).

Рис. 2. Експериментальна установка з ЧПУ для визначення формостійкості

Значення числового індикатора ІГЦ (З)-25-0,01 (точність вимірювання 0,001 мм) зчитували за допомогою програмного забезпечення фірми «Мікротех» типу УІС-Р1-СОМ та передавали у середовище Microsoft Excel для запису та оброблення. Всі значення формостійкості одержаних щитових елементів порівнювали з нормативною величиною (0,3 мм) згідно ГОСТ 6449.3 "Допуски та посадки. Допуски форми та розміщення поверхонь". За результатами порівняння робили висновки та наводили практичні рекомендації.

Результати одержання щитових елементів із ВЖД. За результатами досліджень було виготовлено взірці – меблеві щити та столярні плити із ВЖД для подальшого експериментального дослідження та порівняльного аналізу.

Взірці мають вигляд продукції із ряду напівфабрикатів, а саме комбінованих конструкцій – меблевого щита та столярної плити лицькованої фанерою з розмірами 450х450 мм (рис. 3, 4).

Рис. 3. Загальний вигляд готової столярної плити та МЩ із ВЖД

Рис. 4. Вигляд столярної плити із ВЖД

Склеювання рейок із ВЖД за шириною у щити представлено на рис. 5.

а) *б)* *в)*

Рис. 5. Процес склеювання щитів

Стругання склеєних щитів в розмір за товщиною (рис. 6).

Рис. 6. Виконання операції стругання склеєних щитів за товщиною

Одержані щитові елементи із вживаної деревини різних конструкцій підлягали випробуванню на формостійкість.

Результати випробування щитових елементів із ВЖД на формостійкість. Вплив ширини рейок комбінованих столярних плит на формостійкість. Результати експериментальних досліджень впливу ширини рейок комбінованих столярних плит на формостійкість представлено у табл. 2.

Таблиця 2. Результати експериментальних досліджень СП із ВЖД

№ досліду	Результати $У_{ij}$ міцності на статичний згин, МПа					Середнє значення в j-ій вибірці $\overline{y}$ '
	y_{1j}	y_{2j}	y_{3j}	y_{4j}	y_{5j}	
1	0,154	0,157	0,150	0,156	0,151	0,153
2	0,254	0,257	0,250	0,256	0,251	0,254
3	0,234	0,237	0,230	0,236	0,231	0,233
4	0,326	0,329	0,322	0,328	0,323	0,326
5	0,228	0,231	0,224	0,230	0,225	0,227
6	0,244	0,247	0,240	0,246	0,241	0,244
7	0,221	0,224	0,217	0,223	0,218	0,221
8	0,242	0,245	0,238	0,244	0,239	0,242
Сума						1,90

Графічна інтерпретація отриманої регресійної залежності представлена на рис. 7.

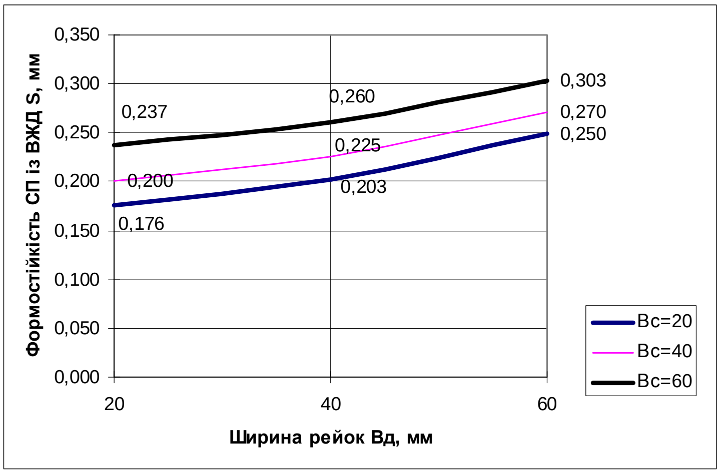


Рис. 7. Залежність усередненого відхилення S (від площинності) столярної плити від ширини рейки з ВЖД (дуб) $В_Д$ (x_1)

Як видно з рис. 7, збільшення ширина рейки з ВЖД (дуб) СП призводить до збільшення відхилення S. А також, тенденція щодо залежності впливу ширини рейки із сосни на відхилення столярної плити від площинності є прямолінійною.

Варто зазначити, що характер впливу ширини рейок на усереднене відхилення S є нелінійним, хоча внаслідок цього можна з певною імовірністю припустити наявність тенденцій прямої пропорційності (рис. 7).

Одержане рівняння регресії в нормалізованих значеннях змінних факторів має вигляд: $y = 0,225 + 0,035x_1 + 0,029x_2 + 0,01x_1^2 + 0,006x_2^2 - 0,002x_1x_2$
де: $B_Д$– ширина рейки з ВЖД (дуб) СП; B_C – ширина рейки з ВЖД (сосна) СП;
S – усереднене відхилення від площинності, тобто стріла прогину СП.

Відхилення від площинності за стрілою прогину для ступеня точності 12 для всіх експериментальних зразків, задовольняють вимоги стандарту ГОСТ 6449.3-82.

За результатами експерименту здійснено оптимізацію ширини рейок за допомогою градієнтного методу, внаслідок якої виявлено, що мінімальне значення відхилення S_{min} = 0,176 мм, взяте за абсолютною величиною можна отримати зафіксувавши розмірні параметри ширини рейок СП із ВЖД(дуб): $B_Д$ = 20 мм; ширина рейки з ВЖД (сосна) B_C = 20 мм (рис. 8).

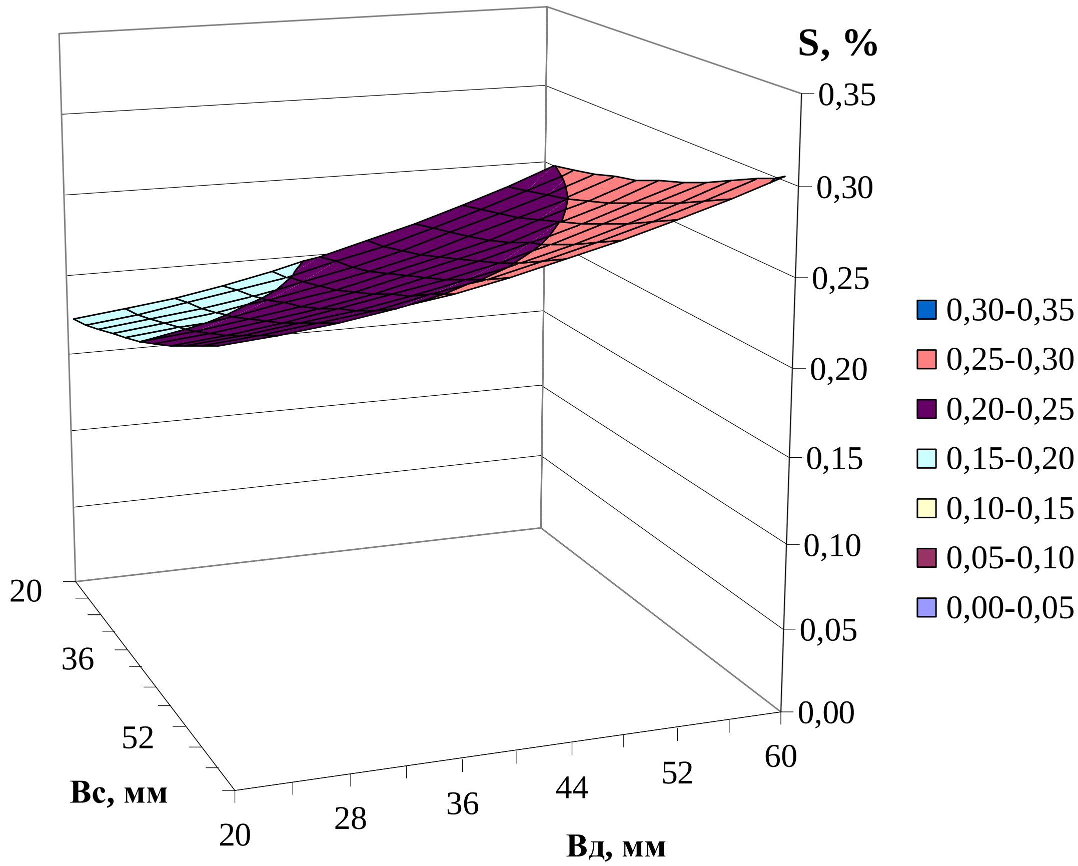


Рис. 8. Залежність усередненого відхилення S (від площинності) столярної плити від ширини рейки з ВЖД (дуб та сосна)

Вплив ширини рейок комбінованих меблевих щитів на формостійкість. Результати експериментальних досліджень впливу ширини рейок комбінованих меблевих щитів на формостійкість представлено у табл. 3.

Таблиця 3. Результати експериментальних досліджень МЩ із ВЖД

№ досліду	Результати $У_{ij}$ міцності на статичний згин, МПа					Середнє значення в j-ій вибірці $\overline{y}'$
	y_{1j}	y_{2j}	y_{3j}	y_{4j}	y_{5j}	
1	0,198	0,202	0,193	0,200	0,195	0,198
2	0,305	0,309	0,300	0,307	0,302	0,305
3	0,305	0,309	0,300	0,307	0,302	0,305
4	0,388	0,392	0,383	0,390	0,385	0,388
5	0,225	0,229	0,220	0,227	0,222	0,225
6	0,311	0,315	0,306	0,313	0,308	0,311
7	0,294	0,298	0,289	0,296	0,291	0,294
8	0,336	0,340	0,331	0,338	0,333	0,336
Сума						2,36

Одержане рівняння регресії в нормалізованих значеннях змінних факторів має вигляд: $y= 0,284 + 0,046x_1 + 0,039x_2 - 0,016x_1^2 + 0,031x_2^2 - 0,006x_1x_2$
де: $В_Д$– ширина рейки з ВЖД (дуб) СП; $В_С$ – ширина рейки з ВЖД (сосна) СП; S – усереднене відхилення від площинності, тобто стріла прогину СП.

Графічна інтерпретація отриманої регресійної залежності представлена на рис. 9.

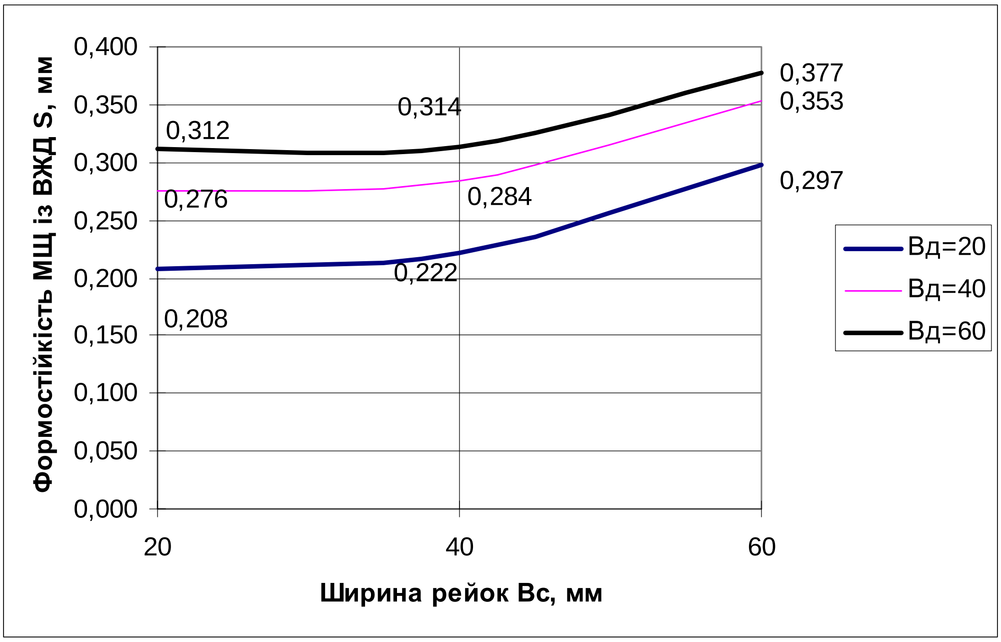


Рис. 9. Залежність усередненого відхилення S (від площинності) столярної плити від ширини рейки з ВЖД (дуб) $B_Д$ (x_1)

Як видно з рис. 9, збільшення ширина рейки з ВЖД (дуб) МЩ призводить до збільшення відхилення S. А також, тенденція щодо залежності впливу ширини рейки із сосни на відхилення МЩ від площинності є прямолінійною. Варто зазначити, що характер впливу ширини рейок на усереднене відхилення S є нелінійним, хоча внаслідок цього можна з певною імовірністю припустити наявність тенденцій прямої пропорційності (рис. 7). Відхилення від площинності за стрілою прогину для ступеня точності 12 для всіх експериментальних зразків, задовольняють вимоги стандарту ГОСТ 6449.3-82.

За результатами експерименту здійснено оптимізацію ширини рейок за допомогою градієнтного методу, внаслідок якої виявлено, що мінімальне значення відхилення S_{min} = 0,208 мм, взяте за абсолютною величиною можна отримати зафіксувавши розмірні параметри ширини рейок СП із ВЖД(дуб): $B_Д$ = 20 мм; ширина рейки з ВЖД (сосна) B_C = 20 мм (рис. 10).

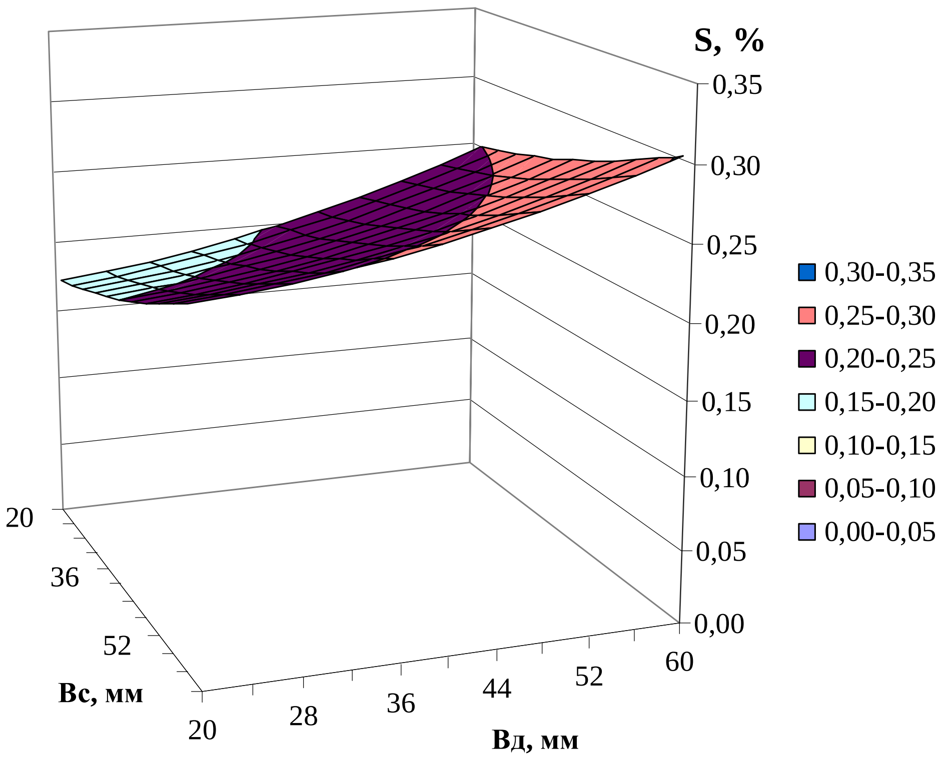


Рис. 10. Залежність усередненого відхилення S (від площинності) меблевого щита від ширини рейки з ВЖД (дуб та сосна)

Порівняльний аналіз формостійкості. В результаті проведення експерименту були отримані дані формостійкості МЩ та СП із ВЖД (табл. 4, рис. 11).

Таблиця 4. Аналіз формостійкості МЩ і СП із ВЖД для рейок різної ширини

Конструкції комб. щитів із ВЖД	Розрахунок	Норма	% норми
СП із ВЖД (20 мм)	0,176	0,3	59
МЩ із ВЖД (20 мм)	0,208	0,3	69
СП із ВЖД (40 мм)	0,226	0,3	75
МЩ із ВЖД (40 мм)	0,284	0,3	95
СП із ВЖД (60 мм)	0,303	0,3	101
МЩ із ВЖД (60 мм)	0,377	0,3	126

Як видно з гістограми рис. 11. найкращу формостійкість має комбінована столярна плита, щит якої виготовлений з рейок шириною 20 мм, відхилення від площинності якої становить:0,178 мм. Комбіновані МЩ з шириною рейки 30 мм мають відхилення від площинності 0,208 мм. Відхилення від площинності комбінованих СП із ВЖД при ширині рейки 60 мм було не значним (1 %) , а для МЩ із ВЖД при ширині рейки 60 мм перевищувало вже на 26 %, що більше за нормативні (0,3 мм) згідно ГОСТ 6449.3 "Допуски та посадки. Допуски форми та розміщення поверхонь".

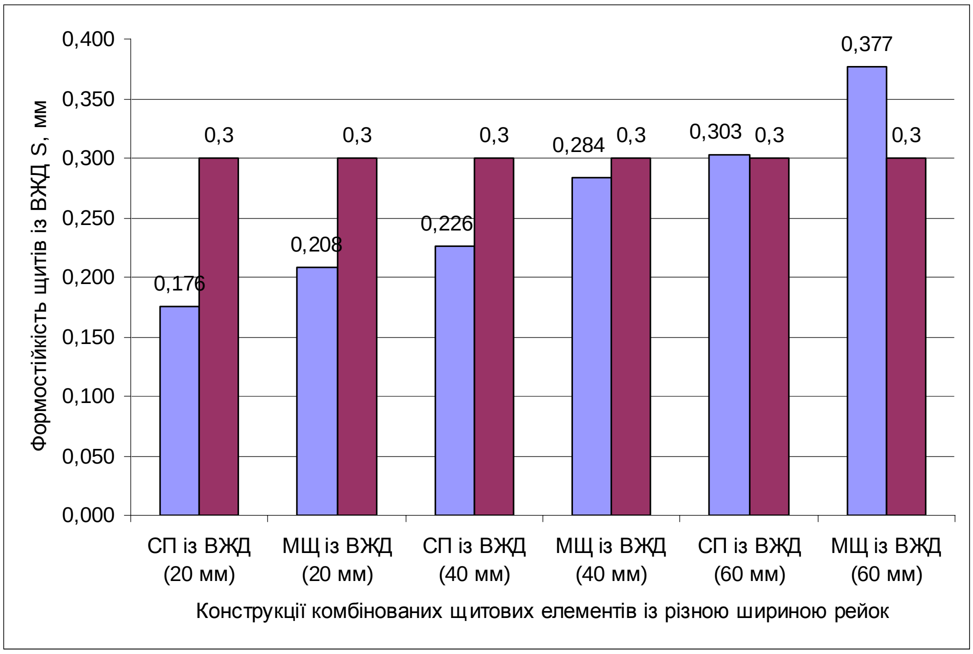


Рис. 11. Гістограма формостійкості комбінованих щитових елементів для рейок різної ширини

Висновки та рекомендації.

1. Встановлено, що для впорядкування використання лісових ресурсів України необхідно прискорити прийняття законів щодо ресурсозбереження і використання вторинних відходів. Ці закони повинні ефективно націлювати підприємства на екологічне та раціональне споживання ресурсів, а значить – на розробку і застосування маловідходних і безвідходних технологій, ресурсозберігаючої і надійної техніки. Для цього в законах необхідно передбачити заходи економічної відповідальності за нераціональне використання ресурсів, а за знищення ділових відходів – штрафи.
2. Обґрунтовано, що вживана деревина є додатковим ресурсом, придатним для матеріального використання, зокрема у виробництві щитових елементів.
3. Досліджено, що формостійкість столярних плит та меблевих щитів при використання рейок шириною 20-40 мм , відповідає вимогам стандарту.
4. Формостійкість комбінованих СП із ВЖД є вищою, ніж меблевих щитів за однакових конструкцій, зокрема складальних елементів – рейок.
5. Встановлено, що для забезпечення підприємств вживаною деревиною, можливо, крім звичайних щитових елементів, виготовляти комбіновані.
6. Рекомендовано для підвищення формостійкості щитових складальних одиниць використовувати рейки малих шириною до 40 мм.

References

1. **Gayda S.V.** (2016): A investigation of form of stability of variously designed blockboards made of post-consumer wood. *ProLigno* 12(1):22-31.

2. **Gayda S.V.** (2016): *Ekologo-tekhnologicheskiye aspekty pererabotki vtorichno ispol'zuyemoy drevesiny dlya proizvodstva pressovannykh materialov* [Ecological and technological aspects of recycling post-consumer wood for production compacted materials]. *Lesnoy vestnik / Forestry bulletin of MSFU* 20(3):15-22 (in Russian).

3. **Gayda S.V.** (2016): *Formoustoychivost' stolyarnykh plit iz vtorichno ispol'zuemoy drevesin* [A form of stability of blockboards made of post-consumer wood]. *Actual problems of forest complex* 46:148-153, (in Russian).

4. **Gayda S.V.** (2015): *Issledovanie fiziko-mekhanicheskikh svoystv vtorichno ispol'zuemoy drevesiny* [Investigation of physical and mechanical properties of post-consumer wood]. *Actual problems of forest complex* 43:175-179, (in Russian).

5. **Gayda S.V.** (2015): *Tekhnologiï i fiziko-mekhanichni vlastivosti stolyarnikh plit iz vzhivanoï derevini* [Technology and physical and mechanical properties blockboard made of post-consumer wood]. *Technical service of agriculture, forestry and transport systems* 3(1):145-152, (in Ukrainian).

6. **Gayda S.V.** (2015): *Tekhnologicheskie osnovy pererabotki vtorichno ispol'zuemoy drevesiny* [Technological of processing basics of post-consumer wood]. *Actual directions of Scientific Research XXI century: Theory and Practice, Voronezh State Forestry Engineering University Named after G.F. Morozov* 3(8-2 (19-2)): 82-86, (in Russian).

7. **Gayda S.V.** (2015): Modeling properties of blockboards made of post-consumer wood on the basis of the finite element method. *Forestry, Forest, Paper and Woodworking Industry* 41:39-49.

8. **Gayda S.V.** (2014): Techniques for recycled of post-consumer wood in the production of quality particleboard. *Forestry, Forest, Paper and Woodworking Industry* 40:41-51.

9. **Gayda S.V.** (2014): *Sposoby podgotovki k pererabotke vtorichno ispol'zuyemoy drevesiny iglofrezernymi i shchotochnymi stankami* [Preparation methods for processing of post-consumer wood (PCW) needle-milling and brushing machines]. *Actual problems of forest complex* 40:65-69 (in Russian).

10. **Gayda S.V.** (2014): *Teoreticheskoye obosnovaniye podkhoda po prognozirovaniyu prochnosti drevesnostruzhechnykh plit iz vtorichno ispol'zuyemoy drevesiny* [The theoretical rationale for the approach on the prediction the strength of particleboard from recycled wood]. *Actual problems of forest complex* 38:212-216 (in Russian).

11. **Gayda S.V.** (2013): *Tekhnologiï ta rekomendatsiï do vikoristannya vzhivanoï derevini v derevoobroblenni* [Technologies and recommendations on the utilization of post-consumer wood in woodworking industry]. *Forestry, Forest, Paper and Woodworking Industry* 39(1):48-67, (in Ukrainian).

12. **Gayda S.V.** (2013): *Resursooshchadni tekhnologiï pereroblennya vzhivanoï derevini* [Resource-saving technologies of recycling of post-consumer wood]. Scientific Bulletin of NULES of Ukraine: *Technology and Energy of agroindustrial complex* 185(2):271-280, (in Ukrainian).

13. **Gayda S.V.** (2013): *Osnovy formuvannya klasyfikatora vtorynnykh derevynnykh resursiv* [Bases of secondary wood resources classifier formation]. *Scientific Works of the Forestry Academy of Sciences of Ukraine* 11:208-215 (in Ukrainian).

14. **Gayda S.V., Voronovich V.V.** (2011): *Porivnyal'niy analiz gnuttya vzhivanoï derevini riznikh porid ta vikovikh kategoriy* [Comparative analysis of bending particularities for various post-consumer wood species and age categories]. *Forestry, Forest, Paper and Woodworking Industry* 37(1): 84-88 (in Ukrainian).

15. **Gayda S.V., Voronovich V.V.** (2011): *Issledovanie osobennostey gnut'ya vtorichno ispol'zuemoy drevesiny* [Investigation of the features of bending of post-consumer wood]. *Scientific progress – creative young: proceedings of the International Scientific Conference, Mari State University*: 190-192 (in Russian).

16. **Gayda S.V.** (2011): *Vzhyvana derevyna – dodatkovyy resurs syrovyny* [Recovered wood is additional resource of raw material]. *Forestry, Forest, Paper and Woodworking Industry* 37(1): 238-244 (in Ukrainian).

17. **Gayda S.V.** (2011): The investigation of physical and mechanical properties of wood particleboards made from post-consumer wood. Forestry, Forest, Paper and Woodworking Industry 37(2):95-110.

18. **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* 36:81-92.

19. **DIN 68705-2:2014-10** Plywood – Part 2: Blockboard and laminboard for general use. Germany, (in Deutsch).

20. **GOST 13715-78** *Plity stolyarnye. Tekhnicheskie usloviya* [Blockboards. Technical specifications]. *Moskow: Publishing house of standards*, (in Russian).

21. **GOST 9625-2013** (EN 310:1993, EN 13986:2004). *Drevesyna sloystaya kleenaya. Metody opredelenyya predela prochnosty y modulya upruhosty pry statycheskom yz·hybe* [Laminated glued wood. Methods for determination of ultimate and modulus of elasticity in static bending]. *Moskow: Publishing house of standards*, (in Russian).

22.**GOST 9620-94.** *Drevesyna sloystaya kleenaya. Otbor obraztsov y obshchye trebovanyya pry yspytanyy* [Laminated glued wood. Sampling and general requirements in testing]. *Moskow: Publishing house of standards*, (in Russian).

23.**GOST 9624-2009**. *Drevesyna sloystaya kleenaya. Metod opredelenyya predela prochnosty pry skalyvanyy* [Laminated glued wood. Method for determination of shear strength]. *Moskow: Publishing house of standards*, (in Russian).

UDC 674 ***Assoc. prof. S.V. Gayda, senior teacher Ya.M. Bilyy – UNFU***

The investigation of the shape stability of glued panels made of post-consumer wood

It has been established that in order to streamline the use of forest resources in Ukraine it is necessary to accelerate the adoption of laws on resource conservation and the use of secondary waste. These laws should effectively target enterprises to the ecological and rational consumption of resources, and hence to the development and application of low-waste and non-waste technologies, resource-saving and reliable technology. To do this, the laws must provide for measures of economic responsibility for the irrational use of resources, and for the destruction of business waste - fines. PCW (Post-Consumer Wood) is an additional resource suitable for material use, in particular in the production of panel elements. It was investigated that the shape stability of the combined PCW-made blockboards and the combined PCW-made furniture panels with the use of rails in the width of 20-40 mm, meets the requirements of the standard. The shape stability of the combined PCW-made blockboards is higher than the the combined PCW-made furniture panels for identical structures, in particular the assembly elements - rails. It has been established that in order to provide enterprises with PCW, it is possible, in addition to ordinary panel elements, to make combined ones. It is recommended to use rails of small widths up to 40 mm to increase the shape stability of shield assembly units.

Keywords: post-consumer wood, shape stability, PCW-made blockboard, PCW-made furniture panels, glued panels, technology.

UDC 674.053:621.02.001/53 ***Post-graduate I.O. Ben, assoc. prof. Y.I. Ozymok – UNFU***

ORBITAL GRINDING TOOL FOR SHARPENING WOODCUTTING KNIVES

On the ground of analysis and evaluation of grinding wheels for sharpening industry-used woodcutting knives, a new design of a grinding tool with an orbital drive is proposed. The use of orbital face grinding makes it possible to change the motion kinematics and realize intermittent grinding simultaneously, thus significantly improving the quality of thick knives deployment.

Keywords: knife, grinding tool, sharpening, orbital drive, intermittent grinding.

The development of the modern economy features an increased competition in markets where science has become a determining factor and a powerful productive force. In the industrial sector, particularly in the woodworking industry, the processing technology appears to be the productive force that determines the enterprise competitiveness. The progress of technology, namely the development and implementation of new materials, tools, methods and processes, as well as intensification of technological conditions, determine the qualitative and quantitative indicators of product and its cost.

Viewing the technology development as a science, one should note that in recent years it has won one of the key roles. One of such key roles in the technological science of materials processing by cutting is reserved by the technological processes of grinding wheel sharpening and whetting of woodcutting tools. Such wheels ensure high accuracy of shapes and sizes, low roughness of the work surfaces, ensuring their durability, and thus the quality of the tool. The complexity of grinding process and its associated phenomena brings a need for in-depth theoretical and exploratory study of the physical nature of the phenomena occurring during the grind processing (sharpening) of the woodcutting tool. The essential academic work of the well-known scientists, P.I. Yashcheritsyn, E.N. Maslov, A.V. Yakimov, Y.N. Polyanchykov, A.N. Reznikov, D.R. Yevseyev, S.A. Popov, J.H. Filimonov, S.L. Khudobin, V.M. Shumyacher et al. allows for creating scientific basis of the grinding process, along with the development of the technological methods of grind processing that are widely and successfully applied in various branches of mechanical engineering, including woodworking. These academic papers and enterprise experience prove the ample opportunities of grinding processes in ensuring the high quality of the tool and machine parts during processing.

However, many factors that change over time compromise the stability of the grinding process. Furthermore, the sharpening method affects the productivity and quality of the woodcutting tool sharpening. Thereby, the development of intensive defect-free grinding processes on the basis of new constructive and technological solutions is a scientific challenge of great importance. Thick knives are sharpened on grinding machines TchN21-5, TchN31-4. To sharpen these tools, solid cup-shaped grinding wheels (GOST 2424-83) are used. Recommended wheel sizes, mm: diameter 150...250, thickness 63...100. The abrasive grains material – synthetic corundum, retinoid or ceramic bond, hardness – L...O, grain size – 16...40.

Typically, these knives are sharpened in two stages. At the first stage, the sharpening angle is formed and a wheel with a grain size of 40 is used to clear the notches. The second stage of sharpening is actually a whetting operation. A wheel with grain size 16 ... 25 on minimal feeds with intense cooling of the knife back surface allows surface roughness $R_a \leq 1{,}25$ microns. Both the sharpening and the replacement of grinding wheels make the process of knives deployment time-taking.

The disadvantages of solid grinding wheels encompass considerable waste load at the end of the wheel's life cycle, along with significant operational heat generation, and poor removal of grinding waste, which leads to smearing of the wheel and deteriorates grinding parameters, reducing the sharpening process productivity. Implementation of segmented grinding wheels did not yield the expected results regarding the improvement of the quality and efficiency of the woodcutting tools sharpening process.

The disadvantages of the segmental grinding wheel design are as follows: the grinding involves the unalterable abrasive segment surface, which leads to uneven wear of their surface. Thereby, there arises a need for frequent whetting of its surface or replacement of segments [1]. Taking into account the revealed drawbacks of known grinding tools and applying the method of morphological analysis (MA), the academic department of woodworking equipment and tools developed a prototype of a new orbital grinding tool. The cutting surface length calculation for various types of grinding wheels shows that the cutting surface length of the multi-cup grinding tool with drive cups is the largest (Fig. 1).

Overall view and a prototype of the orbital grinding tool is shown at Fig. 2.

The orbital grinding tool consists of a steel casing 1, with holes 2, where the bearings 3 are placed. The thread pins 4 are pressed in the bearing bores, being fixed by the thrust plate 5. The grinding cups 7 are placed on the pins between the two collars 6. A gear wheel 9 (a satellite) is key connected 8 at the opposite end of the thread pin.

The casing has a hub 10 with a conical hole for mounting on the grinding machine spindle. Upon the hub there's a press-fitted bearing 11 with a tooth gear 12 (central gear), which is immovable and flange mounted to the machine body.

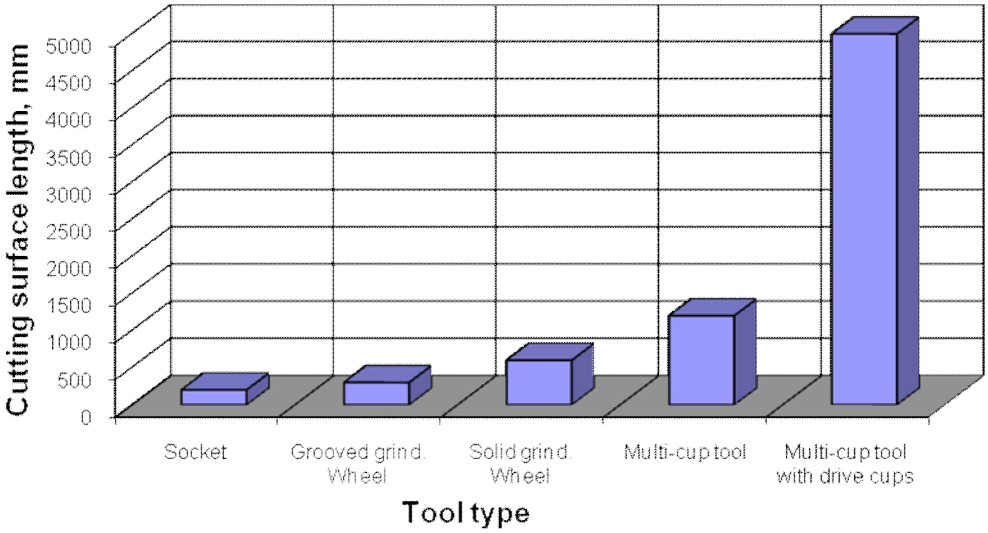


Fig. 1. Dependency graph for the cutting surface length and the grinding wheel type.

The tool has a protective cover 13, which is bolted 14 to the tooth gear 11 [4]. The tool works as follows. While the machine spindle (with the orbital grinding tool mounted on) rotates, the tooth gear 11 (central gear)remains immovable. The gears 8 (satellites) that mate with the tooth gear 11 drive the grinding cups 7. Due to this, the rotational direction of the grinding cups matches the rotational direction of the casing 1. When rotating, the cups' ends remove the allowance for sharpening. That way they wear out evenly and create a ventilation effect that intensively cools the tool being sharpened.

This will intensify the grinding process, increase productivity, improve the quality of the knife blade sharpness during sharpening, increase the operative durability of knives and the stability of the grinding tool.

Intensification of technological conditions for woodcutting tools sharpening determines the quality and quantity of product made, and reduces its cost.

The TTX of the orbital grinding tool are summarized in Table 1.

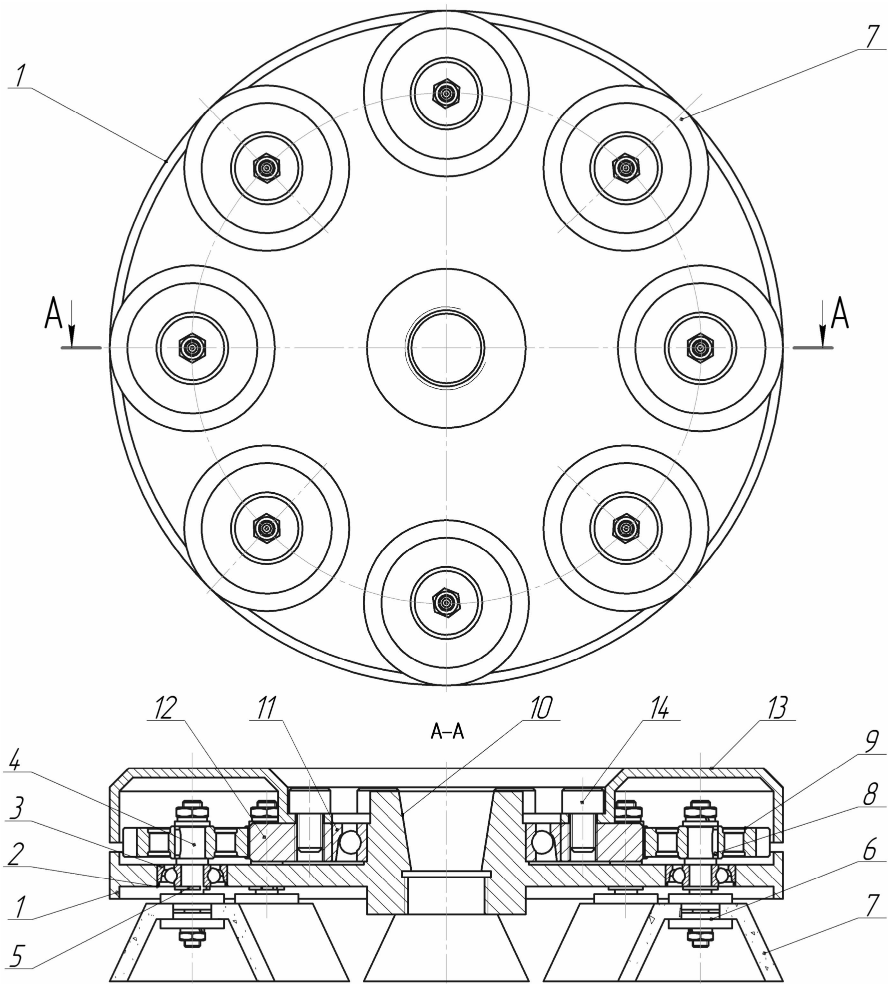
Table 1. TTX of the orbital grinding tool

Parameters	Value
1. Outside wheel diameter, mm	250
2. Wheel height, mm	50
3. Number of grinding cups, n	8
4. TTX of grinding cups: type	11, 6
abrasive grain	synthetic corundum, silicon carbide
bond	ceramic, retinoid
hardness	K
5. Cup sizes, mm : diameter / height	50 / 25
6. Cup drive type	orbital
7. Wheel weight, kg	5.0

The main advantages of the proposed tool design are as follows:

- significant increase in the cutting surface length, which is the largest when compared with other tools. At the same time, the intermittence index is the lowest;

- thermal field intermittence while sharpening;
- maximum use of the grinding cups’ operational height;
- even wear (without trimming) of cups;
- cups of various grain and hardness;
- smooth tool cutting-in during sharpening due to the rotation of the grinding cups.



a)

b)

Fig.2. Orbital grinding tool for sharpening woodcutting planer knives:
a – overall view; b – research prototype

Theoretical and exploratory research is required to select the best conditions for sharpening scoring knives with an orbital grinding tool.

Conclusions.

1. A new design of a an orbital grinding tool for grinding flat surfaces has been developed to ensure the contact intermittence of internal tools abrasive grains with the work surface in the cutting area.

2. Preliminary laboratory tests of an orbital grinding tool have yielded positive results.
3. Intensification of the knives sharpening conditions will provide a significant increase in productivity, improve quality and increase the overall durability of knives.

References

1. **Demyanovskyy K.I., Dunayev V.D.** *Zatochka derevorezhushchykh instrumentov* [Sharpening of the wood-cutting tools]. – Moscow: *Wood Industry*, 1975. – 176 p. (in Russian).
2. **Ivanova T.N.** *Perspektyvnye napravlenyya v sovershenstvovanyy obrabotky ploskykh poverkhnostey shlyfovanyem* [Perspectives for improving the flat surfaces processing by grinding]. *Processing of metals*. 1 (18), 2003. P. 16-18. (in Russian).
3. **Fedulina A.I.** *Teoretychna mekhanika* [Analytical mechanics]. – Kyiv: *Higher School*, 2005 – 319 p. (in Ukrainian).
4. **Ozymok Y.I., Ben I.O.** *Bahatochashkovyy abrazyvnyy instrument z pryvodnymy chashkamy* [Multi-cup grinding tool with drive cups] / *Declarative patent for a utility model* (11) 100679 B23D63 / 12 Pub-ed. 08/10/2015 Bull. №15. – 2 p. (in Ukrainian).

УДК 674.053:621.02.001/53

Аспір. І.О. Бень; доц. Ю.І. Озимок, канд. техн. наук – НЛТУ України

Планетарний абразивний інструмент для загострення дереворізальних ножів

На основі аналізу і оцінки абразивних кругів для загострення дереворізальних ножів, що використовуються на підприємствах галузі, запропонована нова конструкція абразивного інструменту з планетарним приводом. Обгрунтовано, що застосування планетарного торцевого шліфування, дозволяє одночасно змінити кінематику руху, реалізувати перервне шліфування, що значно покращить якість підготовлення товстих ножів до роботи.

Ключові слова: ніж, абразивний інструмент, загострення, планетарний привод, перервне шліфування.

ДО ВІДОМА АВТОРІВ СТАТЕЙ

Під час підготовки статей для міжвідомчого науково-технічного збірника "**Лісове господарство, лісова, паперова і деревообробна промисловість"** радимо авторам дотримуватись таких рекомендацій.

Текст статті обсягом 5-20 сторінок необхідно подавати англійською мовою, друкувати на папері формату А4 за допомогою комп'ютера у редакторі MS Word (шрифт – Times New Roman, розмір – 14 points, рядки – через 1.5 інтервали, поля – 2 см по периметру) без присвоєння жодних стилів і оформляти в такій послідовності. На початку статті **ОБОВ'ЯЗКОВО** проставляється індекс УДК, в заголовку вказуються: вчене звання, ініціали і прізвище автора (або авторів), науковий ступінь, скорочена назва закладу, в якому виконана робота, назва статті, анотація (500 знаків) та ключові слова. Далі – українською мовою: ініціали і прізвище автора (або авторів), скорочена назва закладу, в якому виконана робота, назва статті, анотація та ключові слова.

Статті здавати доц. С.В. Гайді, корп. №2, вул. Залізняка 11, 2 пов., каб. 22а;
тел. роб. 238-45-04; моб. 067-79-12-522;
e-mail: serhiy.hayda@nltu.edu.ua; e-mail: vmmax@ukr.net;
e-mail: f-wood-ind@ukr.net
http:// forest-woodworking.nltu.lviv.ua

Ліс. госп-во, ліс., папер. і деревооб. пром-сть : міжвід. наук.-техн. зб. – Львів: НЛТУ України. – 2016, вип. 42. – 84 с.

Збірник науково-технічних праць

ЛІСОВЕ ГОСПОДАРСТВО,
ЛІСОВА, ПАПЕРОВА І ДЕРЕВООБРОБНА
ПРОМИСЛОВІСТЬ

Міжвідомчий
науково-технічний збірник

виходить з 1964 р.

ВИПУСК 42

Літературний редактор : В.В. Дудок
Редагування іноземних мов : В.В. Лентяков
Комп’ютерне макетування : С.В. Гайда

Електронна версія наукового фахового видання знаходиться на депозитарному зберіганні у Національній бібліотеці України ім. В.І. Вернадського

Підписано до друку 29.12.16. Формат 60×84/16
Папір офсетний. Гарнітура Times. Друк офсетний
Умов. друк. арк. 4,88. Умов. фарб. відб. 5,12
Наклад 250 прим. Зам. № 455/2016

Свідоцтво про державну реєстрацію друкованого засобу масової інформації
(Серія КВ, № 11890-761ПР від 26.10.2006 р.)

Згідно з переліком №19, «Лісове господарство, лісова, паперова і деревообробна промисловість» належить до наукових фахових видань України, в яких можуть публікуватися результати дисертаційних робіт на здобуття наукових ступенів доктора і кандидата технічних наук за такими напрямами:
технічні науки (Додаток до наказу Міністерства освіти і науки України від 21.12.2015 р. № 1328),
сільськогосподарські науки (Додаток до наказу Міністерства освіти і науки України від 07.10.2015 р. № 1021)

Віддруковано з готових оригіналів.
ТзОВ «Графік Стар», вул. Володимира Великого, 2.
Тел.: +38 (032) 244 28 37, 244 46 77