

## **POSSIBLE USE OF PARALLEL AND PERPENDICULAR SCHEMES OF STRUCTURAL ELEMENTS PLACEMENT OF THE FURNITURE BOARDS MADE OF SOLID WOOD WASTES FOR FURNITURE FACADES CREATION**

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### **Abstract**

*There are a lot of advantages of the furniture boards' usage for the furniture and woodworking industries. Among them are the following: material savings due to the presence of defects in solid wood (knots, resin pockets, cracks, blue stain etc.), the glued details have better durability, give less shrinkage, less crack, are less warped in the process of treatment and exploitation, the glued elements can be made practically of all sizes.*

*Making furniture boards of wood wastes, in its turn, can additionally save timber. Furniture boards made of wood wastes have a number of significant economic and environmental benefits in relation to their use in furniture and woodworking industries in comparison to the usual furniture boards made of timber which are bound into furniture boards in size of length using finger jointing and in size of the width - using adhesive on the straight joint.*

*Among the possible disadvantages of the furniture boards made of structural elements of small size (wood wastes) are: a) deviation from flatness that sometimes exceeds the permissible value and b) certain complexity in regards to usage of the furniture boards made of wood wastes in modern furniture design.*

*In order to avoid the above mentioned disadvantages in the process of the research a comparison of deviation from flatness of furniture boards with directions along and across the fibres for two different schemes for placement of structural elements (parallel and perpendicular) was done. Some very important conclusion was reached, according to which furniture boards made of wood wastes with perpendicular scheme of the structural elements' location differ by better shape stability. Design for some furniture pieces made of wood wastes was elaborated.*

**Key words:** *furniture boards made of wood wastes; deviation from flatness; parallel and perpendicular schemes of structural elements placement; design of furniture pieces made of wood wastes.*

### **INTRODUCTION**

Author of this research suggested the design and manufacturing process of furniture boards made of wood wastes accumulated during the woodworking process (Kiyko 2013, 2014). Previous studies have also found (Kiyko 2014) that the change in the linear dimensions of the structural elements of furniture boards has a significant impact on the deviation from flatness of such boards.

It is likely that the structural placement of the wooden items in the furniture boards made of wood wastes determines the impact on the shape stability of furniture boards.

Therefore, the objectives of the research presented in this paper are the following.

1. Comparison of the absolute value of deviations from flatness defined in direction A (along the fibres) and direction B (across the fibres) for experimental samples of the furniture boards produced by parallel and perpendicular schemes (Fig. 1 and Fig. 2).

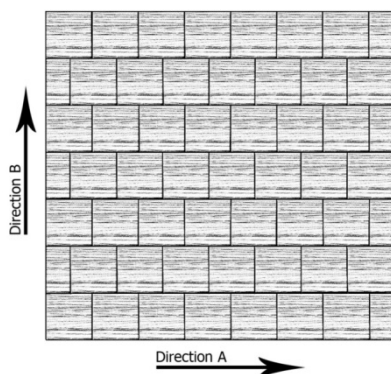
2. Comparison of the deviations from flatness defined in longitudinal and transverse directions for experimental samples of the furniture boards produced by parallel and perpendicular schemes by testing statistical hypotheses: about the homogeneity of its dispersions; homogeneity of the medium values; establishment of the presence for correlation dependence between them.

3. Conclusions regarding the shape stability of the furniture boards produced by parallel and perpendicular schemes.

4. Furniture design with usage of the furniture boards made of wood wastes.

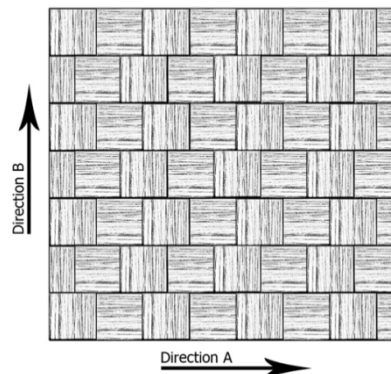
### **RESEARCH METHODS**

During the research, furniture boards with various schemes of placing the structural elements were produced according to the technology (Kiyko 2014) with respect to the direction of the fibres (Fig. 1 and Fig. 2).



**Fig. 1.**

**General view of the furniture board sample №1 with parallel scheme of structural elements placement (dimensions of structural elements:  $L = 40$  mm;  $B = 40$  mm;  $H = 18$  mm)**



**Fig. 2.**

**General view of the furniture board sample №2 with perpendicular scheme of structural elements placement (dimensions of structural elements:  $L = 40$  mm;  $B = 40$  mm;  $H = 18$  mm)**

In order to conduct experimental studies three samples for each of two kinds of experimental models of furniture boards were made of wood wastes of alder (Fig. 1 and Fig. 2) using glue based on polyvinyl acetate (PVAD). The size of the samples was: (L (length) $\times$ B (width) $\times$ H (thickness)) 300  $\times$  300  $\times$  18mm. Deviation from flatness was measured using a numerical indicator ICHTS(3)-25-0,01 (measurement accuracy - 0.001mm). This data was processed by Microtech (Ukraine) company software (type UYS-P1-COM) and transferred to Microsoft Excel environment for recording and processing. Measurements for the experimental sample of the furniture boards were made in two directions (along the fibres - direction A, across the fibres - direction B). In each of the directions of furniture board measurements were carried out along 6-th conditional lines. As a result, number of all measurements along one conditional line made up from 300 to 360 points and finally overall (along six conditional lines) measurements included from 1800 to 2160 points (6  $\times$  (300 ... 360)). The experimental deviation from flatness was estimated using a mean value of the sample. All tests were performed according to the existing norms (EN 13353, EN 318, EN 324-1, ГOCT 13715-78, ГOCT 6449.3 – 82).

Experimental values of the output value (table 1) were obtained as the difference between the mean values of samples obtained for the first and last measurement (in absolute value), moreover the first measurement was made after two weeks from the date when the experimental sample furniture board have been manufactured and the last measurement was determined by invariance of the deflection (deflection measurement is not continued if the value of the last deflection measurement differs from the previous one by no more than 5%). Four series of measurements were made in the experiment and deflection value is defined as the difference between the first and the fourth experiments (time between two successive measurements was made up one month).

Statistical hypothesis about homogeneity of the dispersion and sample averages was tested during the research for two samples - a deviation from flatness that was defined in the direction along the fibres (sample 1) and across the fibres (sample 2). The samples were obtained by averaging the results for each of the six conditional lines for each of the direction of furniture boards with parallel and perpendicular arrangement scheme of structural elements.

Testing of the statistical hypotheses about the homogeneity of two dispersions was performed in the following order.

1. Dispersions for two samples  $S_1^2$  and  $S_2^2$  with volumes  $N_1$  and  $N_2$  was calculated ( $N_1 = N_2 = 355$ ).

2. The calculated value of the Fisher's criterion was obtained as the ratio of bigger dispersion to less one:

$$F_{cal} = \frac{S_1^2}{S_2^2}, \text{ if } S_1^2 > S_2^2. \quad (1)$$

3. The tabulated values of the Fisher's criterion  $F_{tabl}$  were selected using distribution tables for the selected significance level  $q$  and the number of freedom degrees  $f_1$  and  $f_2$ .

4. Values of the calculated and tabulated criteria were compared. If  $F_{cal} < F_{tabl}$ , then the sample dispersions  $S_1^2$  and  $S_2^2$  were considered as homogeneous and otherwise - it was concluded that the difference between them was significant.

Test of the statistical hypotheses about the homogeneity of average values was performed as following.

1. Mean values  $\bar{y}_1$  and  $\bar{y}_2$  for two samples and their dispersion  $S_1^2$  and  $S_2^2$  were calculated.
2. Estimated value of Student's criteria was calculated:

$$t_{cal} = \frac{|\bar{y}_1 - \bar{y}_2|}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}}, \quad (2)$$

3. Value of the tabulated criteria  $t_{tabl}$  from Student's distribution tables was selected using the accepted significance level  $q$  and the number of the freedom degrees  $f=N_1+N_2-2$ .

4. Values of the calculated and the tabulated criteria were compared. If  $t_{pop} < t_{tabl}$ , the hypothesis of homogeneity of the medium was assumed. Otherwise – conclusion was made that there is a significant difference between the averages values for two samples.

Also the presence of correlation between the values of the deviation from flatness defined in two directions was established: along and across the fibres using correlation coefficient. Selective correlation coefficient was calculated from the expression (3) after calculating the average values  $\bar{y}_1$  and  $\bar{y}_2$ , their dispersion  $S_1^2$  and  $S_2^2$  and standard deviation  $S_1$  and  $S_2$ .

$$r = \frac{\sum_{i=1}^N (y_{1i} - \bar{y}_1) \cdot (y_{2i} - \bar{y}_2)}{(N-1) \cdot S_1 \cdot S_2}. \quad (3)$$

In order to determine existence of the correlation relation, value of the calculated Student's criteria was calculated:

$$t_{cal} = |r| \cdot \sqrt{\frac{N-2}{1-r^2}}, \quad (4)$$

The calculated value  $t_{cal}$  was compared with the tabulated value of the Student's criteria  $t_{tabl}$ , which was chosen due to level of the significance  $q$  and the number of the freedom degrees of  $f = N - 2$ . If  $t_{cal} < t_{tabl}$ , the hypothesis about absence of the correlation between two random variables was assumed. If  $t_{cal} > t_{tabl}$ , it was considered that a sample correlation coefficient is significantly different from zero or in other words, there is a linear statistical relationship between two random variables.

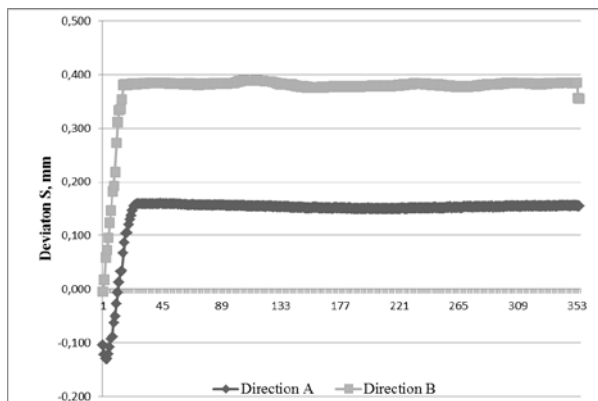
Finally it was designed some set of the furniture pieces made of suggested furniture boards. This design was made with the help of 3Ds Max computer programme.

## RESULTS OF RESEARCH

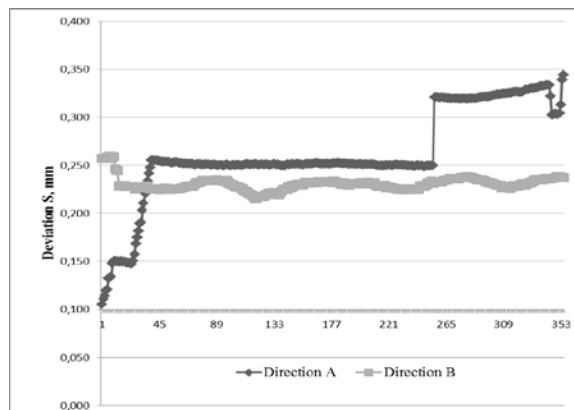
Research results of samples of furniture boards with parallel and perpendicular placement schemes are presented in Fig. 3 and Fig. 4.

The results of the statistical test of the hypothesis of homogeneity of the medium of two random variables (deviation from flatness defined in direction A and direction B) received for two samples are presented in Table 1. As it is shown in the Table 1, in two cases, for various schemes of the structural elements placing the calculated value of Student's criterion is bigger than the tabular value of this criterion and therefore we concluded that the differences between the means of the random deviations from flatness in the directions along and across the fibres is significant and these average values cannot be considered as homogeneous. It should also be noted that the relative difference between the deviations in the directions A and B for furniture boards of the perpendicular

placement (sample number 2, Fig. 2) is substantially less than the same difference for furniture boards of the perpendicular placement (sample number 1, Figure 1.) - 12 and 160%, respectively.



**Fig. 3.**  
**Value of the deflection (deviation S) for the experimental sample number 1 (the length of the structural element L = 40 mm, width of the structural element B = 40 mm; placement scheme of the structural elements – parallel in such directions: along (direction A) and across (direction B) fibres).**



**Fig. 4.**  
**Value of the deflection (deviation S) for the experimental sample number 2 (the length of the structural element L = 40 mm, width of the structural element B = 40 mm; placement scheme of the structural elements – perpendicular in such directions: along (direction A) and across (direction B) fibres)**

**Table 1**  
**Test results of the hypothesis for homogeneity of average for two samples ( $S_i$  deviation in the longitudinal and transverse directions  $S_b$ )**

№ of the experimental sample of the furniture board	Dimensions of the structural elements of the furniture board		Average value of the deviation from flatness S, mm		The relative difference between the values of the deviations in the direction A and direction B, %	Testing of the hypothesis about the homogeneity of the means for two samples ( $S_i$ deviation in the longitudinal and transverse directions $S_b$ )		
	L, mm	B, mm	In the direction along fibres (dir. A), $S_i$ , mm	In the direction across fibres (dir. B), $S_b$ , mm		Calculated and tabulated value of Student criteria		Conclusion about homog. of two means
						$t_{cal}$	$t_{tabl}$	
1	2	3	4	5	6	7	8	9
1	40	40	0,144	0,373	160	65,5	1,96	difference between the averages is significant
2	40	40	0,261	0,230	12	12,03	1,96	difference between the averages is significant

The results of the statistical test of the hypothesis of homogeneity of the dispersions (Table 2) showed that the difference between the sample means of two random variables deviations from flatness in different directions is significant for both: for furniture board with parallel arrangement

scheme of structural elements and for furniture board with a perpendicular arrangement scheme of these elements.

**Table 2**

**Test results in regard to the hypothesis of homogeneity of variances of the two samples ( $S_l$  deviation in the longitudinal and transverse directions  $S_b$ )**

No of the experimental sample of the furniture board	Dimensions of the structural elements of the furniture board		The average value of the dispersion for deviation from flatness		Testing of the hypothesis about the homogeneity of the dispersions for the two samples (deviation in the longitudinal and transverse directions)		
	L, mm	B, mm	In the direction along fibres (dir. A), $S_l$ , mm	In the direction across fibres (dir. B), $S_b$ , mm	Calculated and tabulated values of the Fisher criteria		Conclusion about the homogeneity of the two dispersions
					$F_{cal}$	$F_{tabl}$	
1	2	3	4	5	6	7	8
1	40	40	0,0021	0,0022	1,06	1,00	heterogeneous
2	40	40	0,0023	0,00005	51,1	1,00	heterogeneous

It should be noted that the relative difference between the average values of the deviations from flatness in different directions in the case of parallel placement makes up 160 %, while similar difference for perpendicular arrangements of the structural elements makes up only 12 % (Table 1). However, as a result, we concluded that two samples (for deviation  $S_l$  and for deviation  $S_b$ ) are not the members of the same total population and the difference between two sample means and sample dispersions cannot be explained by random errors. Obviously, the above described difference is related to the influence of certain non-random factors. Therefore it is logical to assume that the deviation from flatness in the direction along the fibres and the deviation from flatness in the direction across the fibres for furniture boards with different placement schemes - are two different random variables, characterized by different nature and causes.

As shown in Table 3, for the pilot sample furniture board with parallel in regard to the direction of fibres placement of structural elements (sample number 1) there is a statistical relationship between two random variables (deviation from flatness toward the direction A and B), or in other words changing of such random variable as  $S_l$  will change the distribution of the other one -  $S_b$ . Also for the experimental sample number 1, it is likely to assume that there is a presence of direct linear dependence, since the sample correlation coefficient value is greater than zero (Table 3).

**Table 3**

**Test results of the hypothesis about the presence of the statistical (correlation) connection between two random variables ( $S_l$  deviation in the longitudinal and transverse directions  $S_b$ )**

No of the experimental sample of the furniture board	Dimensions of the structural elements of the furniture board		Value of the selective correlation coefficient $r$ for two random values: $S_l$ deviation in the longitudinal and transverse directions $S_b$	Testing hypothesis about the correlation connection for the two values (deviation in the longitudinal and transverse directions)		
	L, mm	B, mm		Calculated and tabulated value of Student criteria		Decision about a statistical (correlation) connection
				$t_{cal}$	$t_{tabl}$	
1	2	3	4	5	6	7
1	40	40	0,94	53,2	1,96	there is linear statistical connection
2	40	40	-0,11	2,05	1,96	there is linear statistical connection

The presence of a linear inverse statistical relation (negative sample correlation coefficient) between the value of the deviation from flatness specified in the direction along the fibres and the

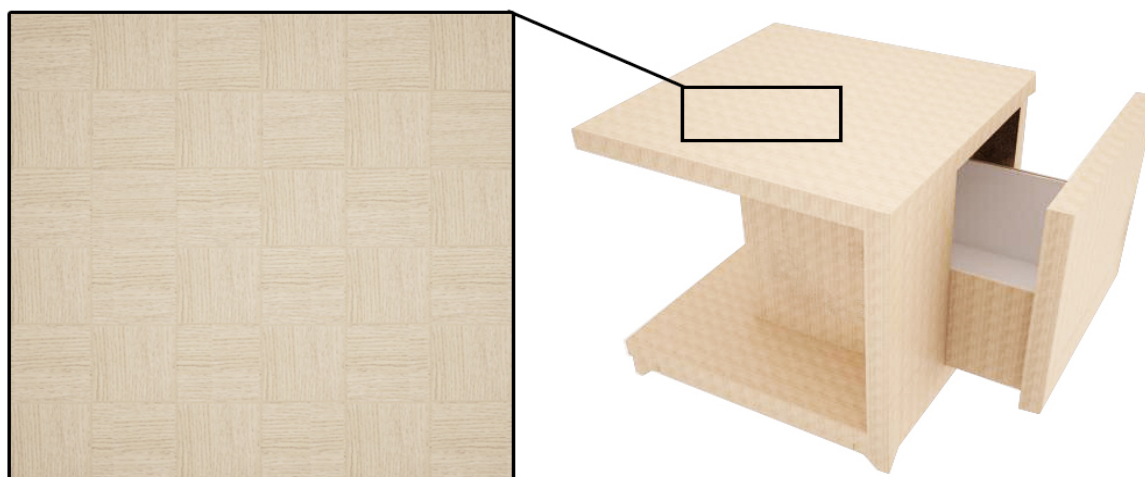
corresponding deflection specified in the direction across the fibres it can observe for the experimental sample of the furniture board number 2 (perpendicular to the placement of structural elements).

For sample of the furniture board with perpendicular placement of structural elements (Table 2), the calculated value of Student criterion makes up  $t_{cal} = 2,05$  which is more than the tabular value of the Student criterion ( $t_{tabl.}=1,96$ ), which is defined for level of significance  $q = 0,05$  (on the basis of this comparison it was concluded that there is a correlation). It is interestingly, if we take  $q = 0,01$  (to increase uncertainty in the case of statistical hypotheses - from 5 to 10%), the value of the tabular value of the Student criterion will increase and will make up  $t_{table.} = 2,58$ . In this case, it will allow to conclude that there is no statistical relationship between deviations from flatness of the furniture boards specified in the directions along and across the fibres (it means that there is considerable dependence regarding the waste placement scheme only and there is not one regarding the direction).

Taking into account mentioned above researches it is possible to conclude that such wood board made of lumpy waste can be considered as a very appropriate material for furniture creation. Feasibility of such board usage in the manufacturing of furniture facades, furniture and interior as a whole is unlimited. In addition, it will improve the situation with the supply of forest materials, and most importantly, would reduce the volume of annual logging

There is some contradiction in regard to usage of the furniture boards made of wood wastes in contemporary furniture design since we can consider the surface of such board as maybe very "specific" or maybe very "simple" due to structural elements of wood wastes presence. In our point of view specific appearance of suggested furniture board we should consider rather as unique advantage instead of seeming simplicity.

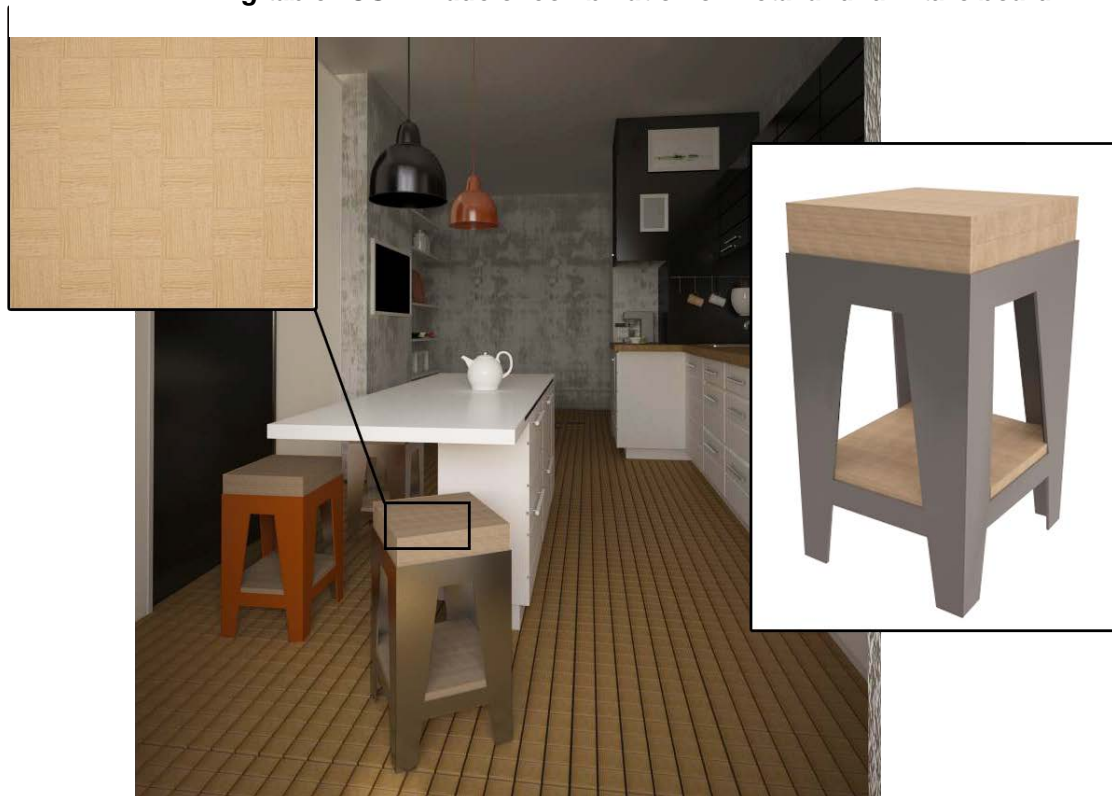
Range of products was designed including the following: a dining table (Fig. 6) made of combination of metal and furniture board, a bedside table (Fig. 5), bar stool (Fig. 7) made of combination of metal and furniture board. Minimalistic design and simple geometric forms are caused by the use of wooden boards as the main material. We think that such simple forms will emphasize the rich texture of furniture boards without distracting attention from the very form of the product. Possibility of usage of the furniture board with lumpy waste in furniture design is very appropriate, since the material is strong, sustainable and aesthetically appealing. One of the best and functional options is a usage of such furniture board in kitchen facades (Fig. 8.), as kitchen countertops and floor as well (Fig. 9).



**Fig. 5.**  
**Bedside table "T1"**



**Fig. 6.**  
*Dining table "OS1" made of combination of metal and furniture board*



**Fig. 7.**  
*Bar Stool "S1" made of combination of metal and furniture board*



**Fig. 8.**  
**Kitchen facades made of furniture board**



**Fig. 9.**  
**Floor and kitchen countertops made of furniture board**

Due to variability combination of colors and textures of different wood species and the possibility of their combining with other materials number of unique design products that can be made of this material are innumerable. The combination of furniture board made of wood wastes with the metal emphasizes warmth and uniqueness of wood, allows to combine different thickness of the different materials. Range of products was designed and material (wood wastes) for furniture boards creating is essential, it dictates the form and not vice versa.

## CONCLUSIONS

Thus, as a result of the comparison of the deviations from flatness for furniture boards for parallel and perpendicular placement of the structural elements (Fig. 1), the following conclusions were made:

1. Two samples (deviation from flatness of the furniture board in direction along the fibres  $S_1$  and deviation from flatness across the fibres  $S_b$ ), the two placing schemes of the structural elements (parallel and perpendicular) do not belong to the same total population and the difference between two sample means and two selective variances of these variables cannot be explained by random errors.
2. Relative difference between the average values of the deviations from flatness in different directions (A and B) in the case of parallel placement makes up 160 %, while a similar difference for perpendicular arrangements of the structural elements makes up only 12%.
3. For the experimental samples of the furniture boards with perpendicular arrangement scheme of structural elements, with a significance level  $q = 0,01$ , we can accept the hypothesis that there is no statistical correlation between these two values of the deviations from flatness in the direction A and direction B, that together with conclusion 2 may indicate a better shape stability of furniture boards with perpendicular placement of structural elements in comparison to similar furniture boards that are made by the parallel scheme.
4. Furniture boards made of wood wastes are very appropriate design material for furniture samples and different kind of interior pieces creation.

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