3D COMPRESSION MOLDING OF WOOD SURFACE IN RELATION TO ITS PLASTICIZNING TREATMENT

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This paper deals with pressing problem – embossing of wood surface. We investigated a following influences i.e. tool shape, depth of pressing, grain direction and type of plasticizing for dimensional change and quality of embossed surface. The best results were obtained for 45˚ wedge point oriented parallel with grain direction, depth of pressing 2 mm with pre-treated wood surface by IR heating.
Keywords: *pressing, embossing, surface quality, shape of wedge, shape stability*

Данная работа посвящена актуальной проблеме - тиснение поверхности древесины. Мы исследовали влияние следующие т.е. инструмент форма, глубина нажатия, направление волокон и типа пластификатора для изменения размеров и качества рельефной поверхностью.Наилучшие результаты были получены для 45 ˚ клин точки ориентированы параллельно с зерном направление, глубина нажатия 2 мм с предварительно обработанной поверхности древесины при нагревании ИК.
Ключевые слова: *прессование, тиснение, качество поверхности, формы клина, формоустойчивость*

Wood pressing is method for wood shaping which belongs to group of chipless – machining operations [1]. Aim of our research is wood shaping by pressing for achievement a decorative treatment referred to as embossing. Nowadays, we know only stationary process of wood surface shaping (embossing). In this process, change of surface shape is created by pressing profiled and heated plates on material – wood. Embossing plates contains styluses locally or continue created on surface.

Pressing process of surface shaping has 3 phases – plasticizing, pressing and conditioning. Plasticizing includes an effect of plasticizing medium, generally steam or chemical agent [2]. Pressing process creates embossment on wood surface (pressing - embossing phase), which is stabilized by effect of heat and pressure (stabilization phase). During conditioning process the moisture and temperature of wood are equalized, or chemical agent evaporates to air. Disadvantage of discontinuous process is long time running [4,5].

The main concept of our research is creation continuous process of pressing (embossing) and provide for required depth of embossment and best possible quality of treated wood surface. We suppose suitable application for unpretentious embossing, for decorative treatment wood species with inexpressive structure.

Methodics of experiments. Basis of objective accomplishment were experimental tests. That is investigation of influencing factors (method of plasticizing, shape of device, wood grain direction, embossing depth and initial moisture) on dimensional changes and quality of treated wood surface [3].

Wood was plasticized by IR and resistance heating for improvement of shaping. Effect of plasticizing was monitored with comparison plasticized and unplasticized experimental samples. Three types of heated wedges (temperature 140 ± 5˚C) were pressed to surfaces of samples. The wedges had a three different peaks 15˚, 45˚and 90˚. Wedges were pressed to tangential area of samples in three different directions (parallel with grain, perpendicular to grain and angle-wise 45˚), to three different depths (2, 4 and 6 mm). For this purpose were used an original pressing plates with mountable wedge device, where is possible to change a random wedge. This mountable wedge device is illustrated at Fig.1.

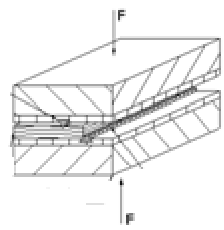

Fig.1 scheme of experimental equipment

Plates, fixed on experimental shredder machine, were heated by resistance heating during experimental tests. To upper pressing plated can be inserted by different embossing wedges. To lower pressing plate is inserted so-called stop bar, which fixing a samples in required position.

Experimental samples were made up aspen wood with dimensions 105 x 105 x 15 mm so that the larger surfaces were tangential. Samples were conditioned to moisture 8% and 16% before tests. These suitable moistures were reached by wettability principle which is based on wood ability to become adapted with surrounding conditions. Required moisture was reached by conditioning determined from Čulickeho diagram. Experimental samples were conditioned for 8% moisture in environs with air temperature approximately t = 20˚C and with relative humidity of air approximately ρ = 40 - 45% (room conditions) and for 16% moisture in environs with approximately t = 20˚C and relative humidity of air approximately ρ = 75%. Moisture was verified with moisture meter and controlled by gravimetric method.

Dimensional changes were evaluated by so-called residual depth of embossment determined from measurement of samples thicknesses. General scheme represented the thickness change curve of compressed material in selected time periods at uni-axial pressing during after 48 hours from press releasing (Fig.2).

Thickness values of samples [mm] in time period t_p a t_8 were measured by timing gauge with dimensional change device (Fig.3). From measured values we calculated residual depth of embossment by equation (1).

$$h_z = h_p - h_8 \text{ [mm]} \quad (1)$$

where: h_z – residual depth of embossment [mm]; h_p – thickness of conditioned sample before pressing [mm]; h_8 – thickness of sample after 48 hours from wedge releasing [mm]

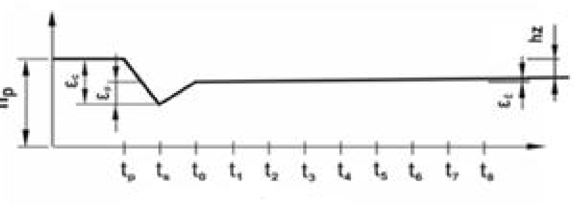

Fig.2 The curve change of embossment depth in uni-axial process of pressing and stabilization and residual depth of embossment after 48 hour from releasing (ε_c – total deformation, $\varepsilon_{\check{c}}$ – elastic deformation in time, ε_p – plastic deformation (permanent), h_P – initial thickness of sample**)**

Fig.3 Fixing device wit so-called stop bar with timing gauge for measurement of dimensional changes

For determination of device influence to residual depth of embossment and quality of embossed area we selected three shapes of wedges (Fig.3):

- Wedge No.1 with cutting-wedge angle 15°,
- Wedge No.2 with cutting-wedge angle 45°,
- Wedge No.3 with cutting-wedge angle 90°.

Experiments were realized at influence of wedge on tangential surface with 3 basic directions of wedges – parallel, perpendicular and angle-wise 45˚to grain direction, this is illustrated in Fig.6.

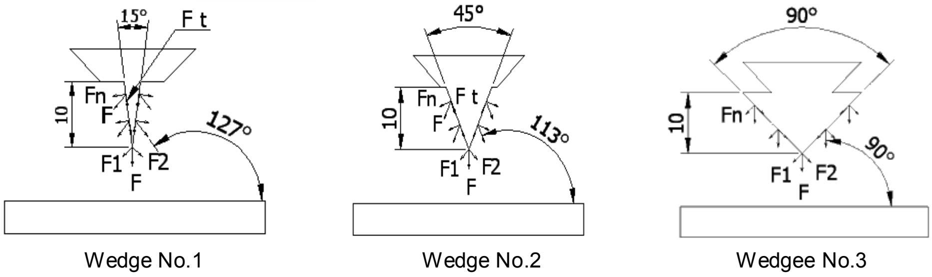

Fig.5 Types of embossing wedges

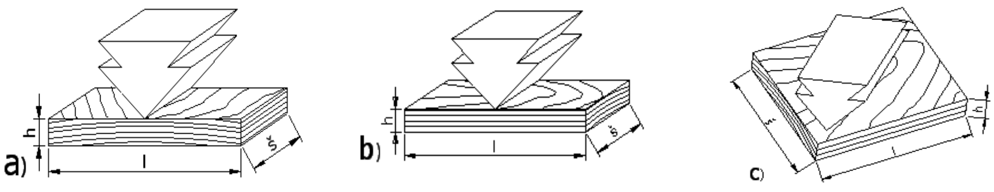

Fig.6 Pressing directions of experimental samples during experimental tests. Pressing to tangential surface: a. in parallel with grain, b. perpendicular to grain, c. angle-wise 45°

We choose qualitative groups for quality description of obtained surface: a – suitable quality (shape of embossed surface is identical with wedge shape, surfaces were without mechanical defects and could contain cracks with length max. 1 mm); b – partially suitable quality (shape of embossed surface was partially different than wedge shape, allowed small presence of defects which can't to invade a optical integrity of embossed surface, allowed longitudinal cracks with length max. 10 mm); c – inconvenient quality.

Quality of obtained surface – embossment was evaluated by subjectively with magnifying glass and according to size of cracks we classified embossed surfaces to individual qualitative groups [6, 7].

Results and discussion. The main objective of work was experimental verification of plasticizing method by IR and resistance heating for achievement residual depth of embossment and quality of surface at 2 moistures of experimental samples and in 3 pressing depth. Other investigated factors, which influenced basic factors, were pressing direction according to anatomical grain direction and cutting-wedge angle. Dimensional stability was evaluated from measured and calculated values of residual depth of embossment where results were obtained after 48 hours from releasing. Measured and calculated values were evaluated statistically and graphically.

Values of residual depth of embossment are shown in Tab.1. Comparison individual group we can to assert that most suitable is plasticizing by IR heating. In comparison with samples plasticized by resistance heating and unplasticized was obtained the highest values residual depth of embossment (h_z) during IR heating.

Tab.č.1 – The measured values of residual depth of embossment. **Where: K – Plasticizing by Resistance heating; I – Plasticizing by IR heating; B – Without plasticizing; Z – The highest measured values**

METHOD OF PLASTICIZING	PRESSING DEPTH [mm]			GRAIN DIRECTIONS	USED WEDGE	MOISTURE
	2 [mm]	4 [mm]	6 [mm]			
K	0,75	2,34	4,26	II	45°	8
I	0,64	2,15	4,51	II	45°	8
B	0,64	1,44	3,09	II	45°	8
K	0,36	1,59	3,43	⊥	45°	8
I	0,47	1,84	3,40	⊥	45°	8
B	0,36	0,97	2,80	⊥	45°	8
K	0,37	1,21	3,19	45°	45°	8
I	0,43	1,66	3,29	45°	45°	8
B	0,33	0,72	2,36	45°	45°	8
K	0,86	1,61	3,38	II	45°	16
I	0,79	1,86	3,15	II	45°	16
B	0,70	1,70	3,46	II	45°	16
K	0,32	1,55	2,00	⊥	45°	16
I	0,71	1,30	1,98	⊥	45°	16
B	0,52	1,10	2,92	⊥	45°	16
K	0,54	1,49	2,32	45°	45°	16
I	0,59	1,32	2,36	45°	45°	16
B	0,44	0,89	2,36	45°	45°	16
K	0,79	2,22	3,44	II	90°	8
I	1,17	2,50	3,81	II	90°	8
B	0,67	2,31	4,02	II	90°	8
K	0,51	1,63	2,77	⊥	90°	8
I	0,64	1,95	2,99	⊥	90°	8
B	0,31	1,61	2,61	⊥	90°	8
K	0,37	1,21	3,19	45°	90°	8
I	0,49	1,66	3,29	45°	90°	8
B	0,33	0,72	2,36	45°	90°	8
K	0,75	1,52	2,96	II	90°	16
I	1,09	1,91	2,60	II	90°	16
B	1,01	1,91	3,39	II	90°	16
K	0,37	0,90	2,36	⊥	90°	16
I	0,69	1,13	1,82	⊥	90°	16
B	0,57	1,27	2,39	⊥	90°	16
K	0,40	1,39	2,47	45°	90°	16
I	0,54	1,35	1,82	45°	90°	16
B	0,58	1,22	2,21	45°	90°	16

The results have shown that with increasing residual depth of embossment the values h_z rises but at pressing depths (6 mm) quality of surface layers gets worse. Less positive results were obtained without plasticizing utilization. We can to confirm that increasing of moisture (16%) decreases values of residual depth of embossment. Comparison residual depth of embossment values in relation to anatomical grain direction we can to assert that the highest values h_z were achieved at parallel direction with grain. Other factors – perpendicular direction to grain and angle-wise 45˚ weren't statistically different.

By basic statistical characteristics we evaluated statistical signification of individual factors to residual depth of embossment and surface quality. We used multifactor analysis of variance for evaluation results. This multifactor analysis confirms or disallows statistical signification of investigated factors influenced on residual depth of embossment and surface quality.

Tab. 2 and Fig.7 shows that moisture is statistically very significant factor which influences values of residual depth of embossment. Better results h_z we obtained at 8% moisture what confirmed theory that with decreasing moisture rises the values of residual depth of embossment [2]. Tab. 2 and Fig.8 shows pressing direction parallel with grain is statistically significant factor (in comparison with pressing direction perpendicular to grain and angle-wise 45°). Pressing directions perpendicular to grain and angle-wise 45° are not statistically different. Tab.2 and Fig.9 shows the influence of cutting wedge angles 45° a 90° on values of residual depth of embossment is statistically non-significant. We thought about 15° wedge but wasn't technically possible to measure values of residual depth of embossment with our timing gauge. Tab.2 and Fig.10 shows the pressing depth is statistically very significant factor. The highest values of residual depth of embossment we obtained at pressing depth 6 mm. Plasticizing methods were statistically moderately significant what is shown in Tab.2 and Fig.11. The most suitable plasticizing method was IR heating. At evaluation of influencing factors wasn't evaluated quality of embossed surface. Experiments show that residual depth of embossment had higher values (especially at pressing depths 4 and 6 mm) at the expense of worse embossed surface quality [8]. We used five-factor analysis for evaluation of surface quality and evaluative influences were moisture, pressing direction, shape of wedge, pressing depth and plasticizing method.

Tab.2. The five-factor analysis of variance, evaluated the influence of moisture, pressing direction, shape of wedge, pressing depth and used plasticizing method to residual depth of embossment

(Legend: 1- moisture, 2 – pressing direction, 3 - wedge, 4 – pressing depth, 5- plasticizing method)

Summary of all Effects						
	df Effect	MS Effect	df Error	MS Error	F	p-level
1	1	0,11019	324	0,00115	95,8393021	0,00000
2	2	0,15741	324	0,00115	136,902527	0,00000
3	1	0,00006	324	0,00115	0,04994241	0,82330
4	2	1,81481	324	0,00115	1578,42175	0,00000
5	2	0,00682	324	0,00115	5,93514395	0,00294

Tab.3. Five- factor analysis of variance, evaluative influence of moisture, pressing direction, shape of wedge, pressing depth and plasticizing method on surface quality

Summary of all Effects						
	df Effect	MS Effect	Df Error	MS Error	F	p-level
1	1	0,006173	486	0,152263	0,04054054	0,84051
2	2	9,705247	486	0,152263	63,7398643	0,00000
3	2	14,27932	486	0,152263	93,7804031	0,00000
4	2	32,43673	486	0,152263	213,030411	0,00000
5	2	0,075617	486	0,152263	0,49662161	0,60889

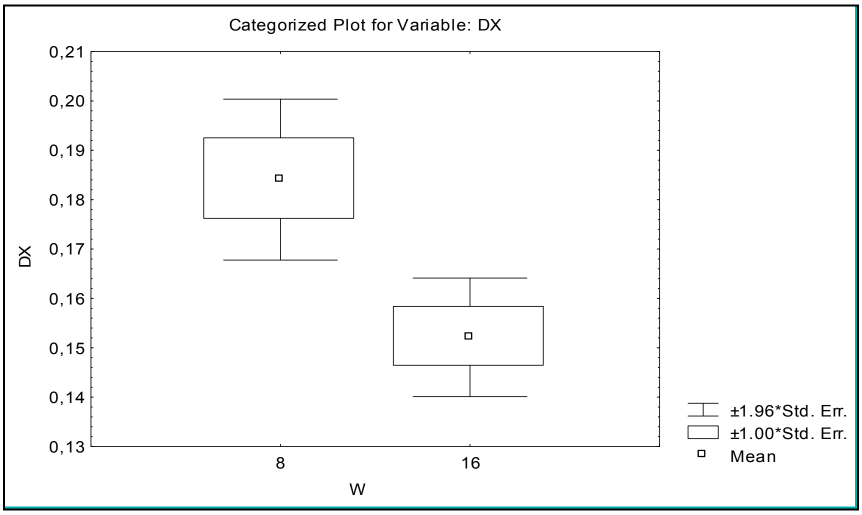

Fig. 7. 95% intervals reliability of variance analysis for values of residual depth of embossment (h is marked as Dx) at moisture 8% and 16%

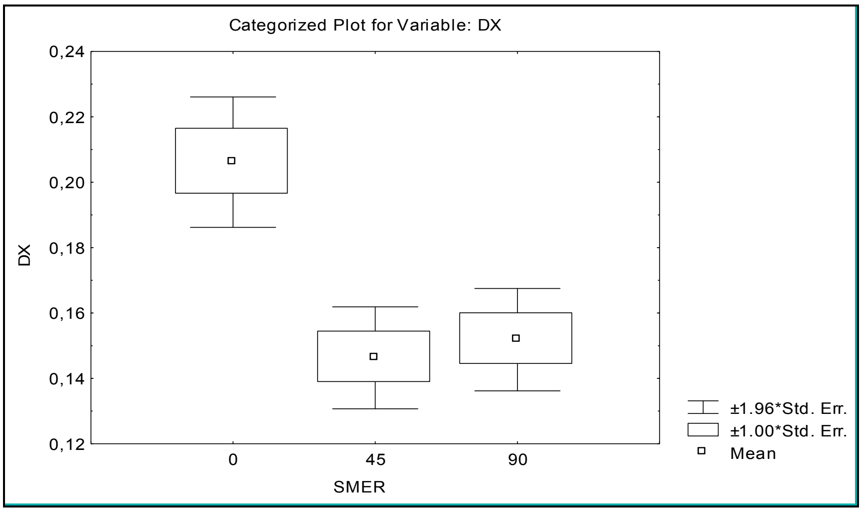

Fig. 8. % intervals reliability of variance analysis for values of residual depth of embossment (h is marked as Dx) at investigated pressing directions (o parallel with grain, 45 – angle –wise 45, 90 – perpendicular to the grain)

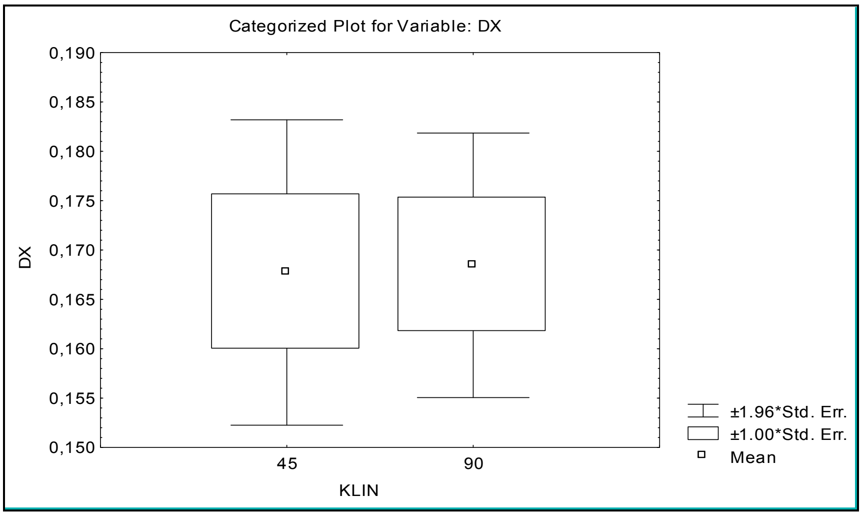

Fig. 9. 95 % intervals reliability of variance analysis for values of residual depth of embossment (h is marked as Dx) at used wedges with cutting-wedge angles 45° and 90°

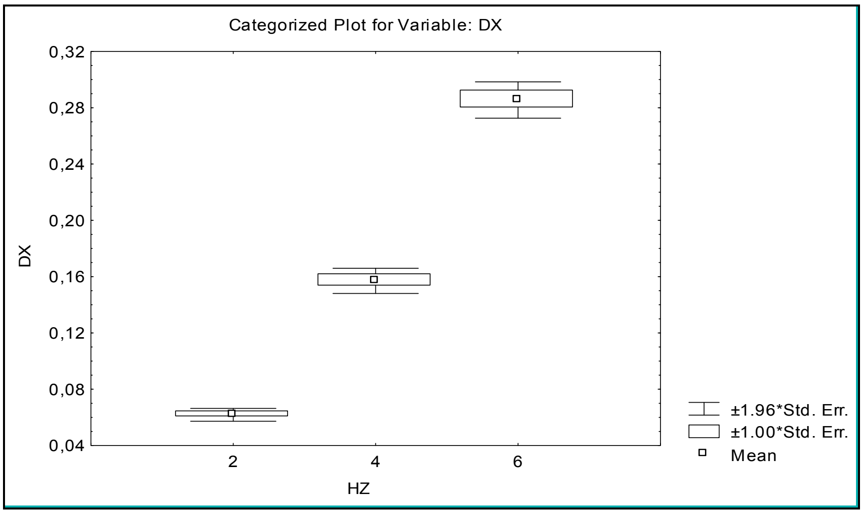

Fig. 10. 95 % intervals reliability of variance analysis for values of residual depth of embossment (h is marked as Dx) at pressing depth (2, 4, 6 mm)

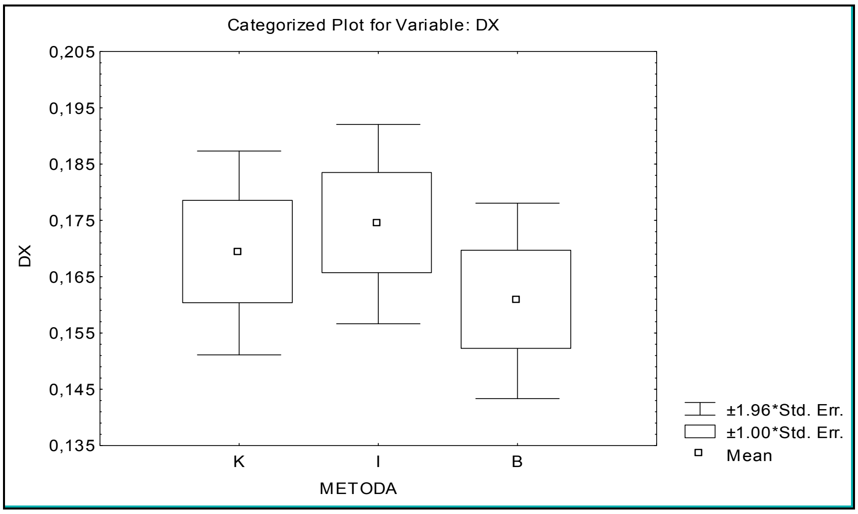

Fig. 11. 95 % intervals reliability of variance analysis for values of residual depth of embossment (h is marked as Dx) at plasticizing method (K, I, B)

We needed evaluative key substituted by number values for statistical evaluation of influencing factors.

Surface quality A – substituted by 1
B – substituted by 2
C – substituted by 3

Tab.3 and Fig. 12 shows statistically non-significance of moisture. Fig.13 shows that pressing direction is statistically very significant factor at evaluation of analysis variance. The most suitable pressing direction is direction parallel with grain for wedge pressing to aspen wood surface. Fig.14 inscribes cutting-wedge angle than statistically very significant factor which can to influence a surface quality. The most suitable pressing direction for surface quality is direction parallel with grain which achieved the best surface quality. The least suitable wedge was wedge with cutting-wedge angle 90°. Fig.15 shows that the most suitable is pressing depth to 2 mm which was statistically significant different from others pressing depths. Figure shows that surface quality get worse with increasing pressing depth. Plasticizing methods were statistically non-significant factors in relation to surface quality (Fig.16).

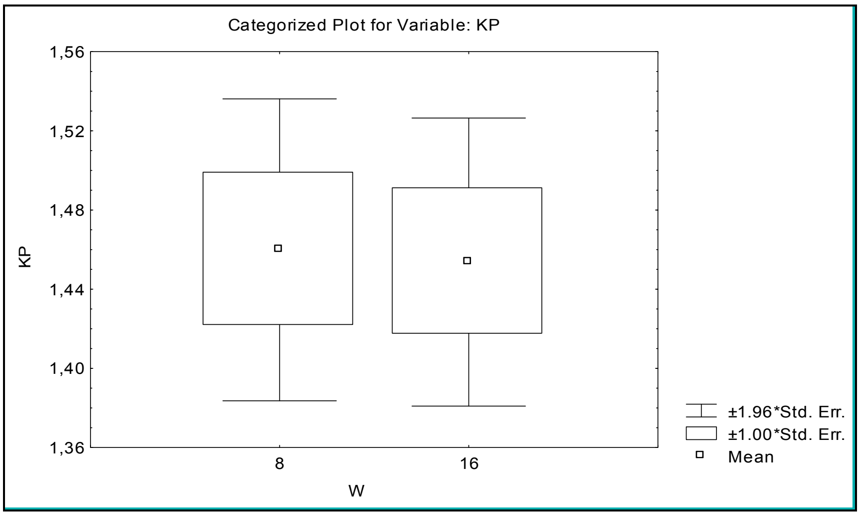

Fig. 12. 95 intervals reliability of surface quality (Kp) at moisture 8% and 16%

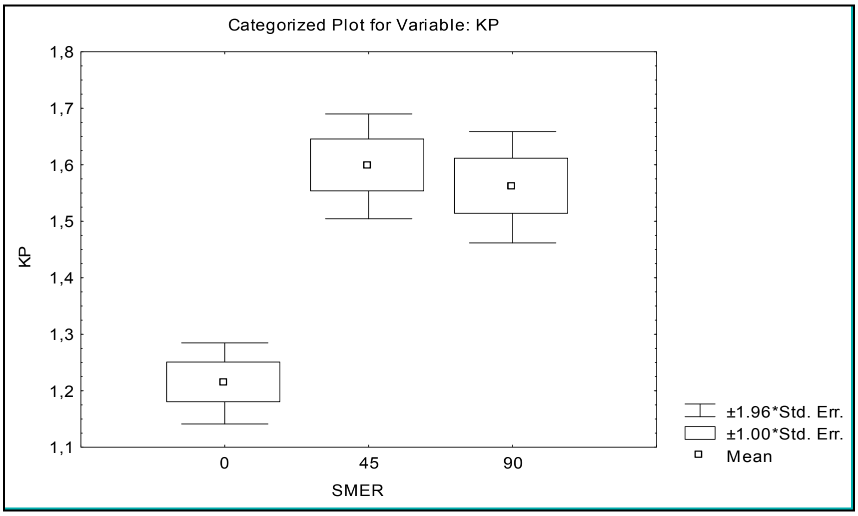

Fig. 13. 95 intervals reliability of surface quality (Kp) at pressing directions 0°, 45°, 90° (parallel with the grain, angle-wise 45°, perpendicular to the grain)

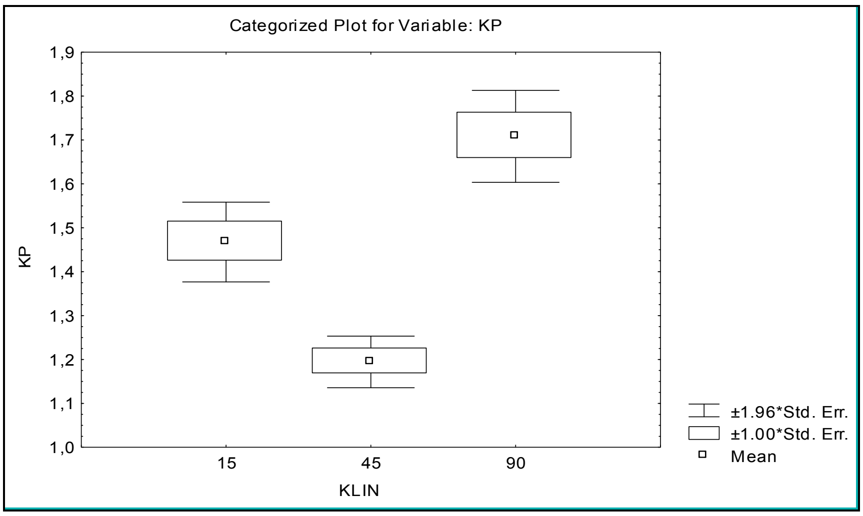

Fig. 14. 95 intervals reliability of surface quality (Kp) at pressing to wood surface with cutting-wedge angle 15°, 45°, 90°

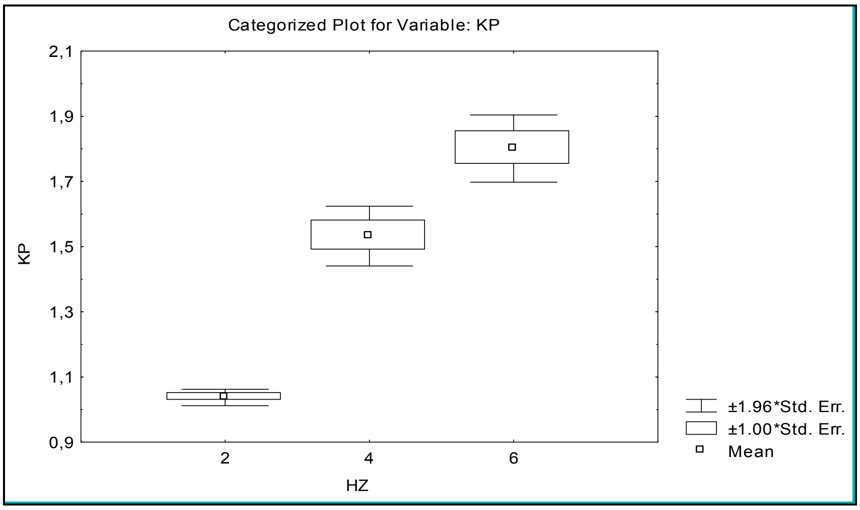

Fig. 15. 95 intervals reliability of surface quality (Kp) at pressing depths 2, 4, 6 mm

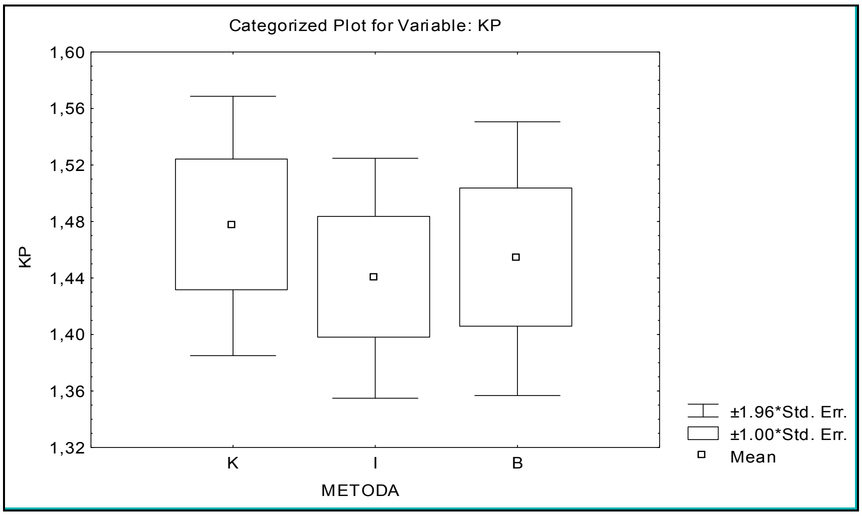

Fig. 16. 95 intervals reliability of surface quality (Kp) at plasticizing methods by resistance heating. , IR heating and without heating

In our work we dealt with embossing of wood surface by pressing in relation to wood treatment with IR and resistance heating. The basic evaluative criteria of the influence plasticizing methods were residual depth of embossment and surface quality.

Results confirmed assume that values of residual depth of embossment rise with decreasing of moisture [9]. Dimensional stability rises with moisture decreasing, too. This fact is significantly influenced by plasticizing method and pressing direction. The most suitable plasticizing method is IR heating; the most suitable pressing direction is direction parallel with grain.

The second evaluated criterion of embossing process was surface quality. Surface quality was influenced by these factors: pressing direction, pressing depth and pressing wedge angle. The best surface quality was achieved at pressing direction parallel with grain and cutting-wedge angle 45°.

This work was supported by the Slovak Research and Development Agency under the contract No.APVV-0282-06".

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