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The influence of particleboard resination on their internal bond strength

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Abstract: *The influence of particleboard resination on their internal bond strength*. The aim of the project was to investigate the main mechanical and physical properties of particleboards, especially focused on internal bond, in terms of their resination. For the tests, the particleboards have been produced in laboratory conditions with the following glue content: 7, 10, 15, 30 and 50%. Particular attention was paid for examining the mechanical property – tensile strength perpendicular to surfaces (Internal Bond – IB). In addition, there were investigated modulus of elasticity (MOE), modulus of rupture (MOR) density and density profile. In the light of above mentioned tests, there is no positive effect of improvement of tested parameters when raise resination over 30% when producing particleboards. With the resination increase from 7 to 50% a significant change (densification) of panels' structure, as well as differences between face and core layers density have been found.

Keywords: particleboard, particle, resination, mechanical properties, IB

INTRODUCTION

Particleboards (PB) are a material obtained from wood particles, which makes them easy to obtain and inexpensive, when compared to other wood-based composites. They are mainly used in the furniture industry as a universal replacement for solid wood. In addition, they are used for example in the production of window sills, door leaves and wall panels.
Particleboards are characterized by the following properties: density, moisture content (MC), thickness swelling (TS) and water absorption (WA), modulus of rupture (MOR), modulus of elasticity when bending (MOE) and internal bond (IB).

Marsavina *et al.* (2019) made studies on the mechanical and fracture properties of particleboard. In the research they used 16 and 25 mm thick medium density PB. They stated that 16 mm thick PB has better mechanical properties –MOR and MOE. The 25 mm thick PB has a higher fracture toughness. Also the Crack Relative Displacement Factor (CRDF) was estimated by using the experimental displacements measured by Digital Image correlation (DIC). Moreover, according to the research, all changes in material properties can be directly connected with the measurement of displacement and indirectly with the CRDF. Summing up, the maximum tensile stresses and the minimum strain energy density ensure correct fracture prediction, which has been confirmed in the tests.

The influence of some manufacturing variables on the properties of PB have been tested by Onuorah *et al*. (2011). Logs of hard maple (*Acer Saccharum* Marsh - oven dry specific gravity 0.67 g/cm^3) and white pine (*Pinus Strobes* L. oven dry specific gravity 0.36 g/cm^3) were used to produce the particles. The tests showed that the specific weight of the board did not affect its elasticity modulus. However, its interaction with other variables was significant. The specific gravity of wood effect will be significant if the production conditions (mat composition, press closing speed) were the same as the following factors: the level of contact between the particles and the density profile, which can increase this modulus. The MOE is more sensitive to manufacturing changes than MOR. Under the same production conditions, the MOR can be predicted based on the known MOE.

Papadopoulou *et al.* (2012) investigated the properties of PB obtained from wood in various forms: three different fractions of sieved particles, same for pellets and boards made of ground granulate. Pellets turned out to be a bad material for the production of traditional PB because their internal bond was small (the surfaces of small pellet particles stick together weakly because they have a small contact surface). The ground pellets had a higher density than the shavings and therefore slightly denser PB have been obtained. These had a noticeable improvement of IB, a slightly less intensive increase in thickness and a slightly higher formaldehyde content (due to higher resination). The MOR values were significantly lower than for other tested PB. Overall, the best panels were these with a particle size of 4 and 6 mm.

Ndububa *et al.* (2013) investigated the influence of arabic gum in sawdust PB. In the tested panels the arabic gum content ranged from 12 to 20% with the 2% step. These samples were characterized by the fact that the ratio of chips to sawdust in each was 1:1 by volume. The results showed that higher the arabic gum content in the samples, the higher MOR. Moreover, the higher the rubber content, the compressive and tensile strength increases (in the case of tension, the force value increases slightly). As the gum content increases, its density also increases. As for the board absorption test, the results showed that with the content of 12, 14 and 16% rubber in the samples and with the simultaneous increase of the soaking time in water, the water absorption increases, but only up to a certain point (approx. within 8 minutes) and then remains at the same level. As the arabic gum content increases, the board's permeability and its ability to absorb water decrease.

Juliana *et al.* (2012) examined the kenaf PB properties in relation to the geometry of its particles. In addition, the 5% MC rubber wood was used in the core of the board. The result of the research was, *inter alia*, the fact that rubber wood particles show better properties because they have longer and wider particles than these derived from the kenaf core. Due to their structure, the larger rubber wood particles have a better contact surface. The research confirmed that kenaf stalk can be used in the production of PB. The best proportion to produce the panels is 30/70 particles proportion, kenaf and rubber wood, respectively.

Rackwitz (1963) examined the effect of particles dimensions on selected properties of PB. He measured the MOR, MOE as well as the compressive and tensile strength parallel to the panel surface. For research purposes, he used spruce particles with a density of 0.38-0.43 g/cm^3, while the particle thickness was 0.2 and 0.4 mm. The particles of individual thicknesses differed in length. For particles with 0.2 mm thickness, the author chose lengths with values in the range of 5-40 mm. For 0.4 mm thick particles, the length was 5-60 mm. The density of the produced wood-based composites was 600 kg/m^3. The results showed that tensile strength is almost directly proportional to the length of the chips. The maximum compressive strength can be obtained with lower slenderness values than for the tensile strength. The relationship between bending strength and slenderness is in the form of a curved line that becomes a straight horizontal line with a slenderness of 12-140 for a particle thickness of 0.2 mm. The author established that below mentioned range of slenderness, when testing the samples by tension parallel to the wide surface, the break occurs in bonding line, whereas above the mentioned slenderness range - in wood (particle) structure. The transverse tensile strength of the PB decreases as the slenderness of the particles increases. The TS increases linearly with increasing slenderness. In addition, no significant effect of particle thickness on the tested strength parameters of PB was observed.

The aim of this work was to evaluate the influence of resination of single layer particleboards on their selected mechanical and physical properties, with the special focus on their internal bond.

MATERIALS AND METHODS

The investigated particleboards have been made from the industrial particles (over 95% softwood – *Pinus sylvestris* L.), typically used for PB core layer production. Glue mass has been made of a combination of industrial melamine-urea-formaldehyde resin (MUF, 9% melamine), industrial latent hardener (water solution of ammonium sulphate, $(NH_4)_2SO_4$) and water with the content of components in the adhesive mass: 100 : 8 : 5 (resin : hardener : water), to reach the curing time in 100°C of about 90 s. No hydrophobic agent was added during particleboards production.

The manufactured single-layer boards were of nominal thickness 10 mm and their resination was 7, 10, 15, 30 and 50%. Nominal density was 700 kg/m^3 and the dimensions of the form was 320 x 320 mm^2. The pressing parameters were as follow: temperature 200°C, pressing factor 18 s/mm of nominal panel thickness, unit pressure 2.5 MPa. Boards were made in a laboratory conditions and after this has occurred air conditioning and manufactured materials at 20°C and 65% of air humidity to stabilize the mass.

Another step was to cut out samples for testing and carrying out tests of strength properties (bending strength and modulus of elasticity, perpendicular tensile strength). The tests of physical properties were density and density profile. The above mentioned tests have been conducted according to standards (PN-EN 310:1994, PN-EN 319:1999, PN-EN 323:1999; at least 10 samples of every testing variant per each test), whereas density profiles have been measured on Grecon DA-X unit, with 0.02 mm sampling step and 0.1 mm/s measuring speed (3 samples of every tested variant, 50 mm x 50 mm x thickness).

On the basis of described above measurements, the statistical significance of the differences of average values between factors as well as levels, has been estimated by analysis of variance (ANOVA) and t-tests calculations ($\alpha = 0.05$).

RESULTS

In the current diagram (fig. 1) showing the dependence of the bending strength of resination, it can be seen that with its increase, the bending strength slightly increases, where reaches its maximum at 30% of resination. A slightly difference test result was obtained when testing particleboards with the addition of gum arabic, where MOR increases with the increase of its content in the tested boards (Ndububa *et al.* 2013). The particular results of the tests of individual panel variants, except of the 30% variant, are characterized by a large dispersion, therefore the differences in mean are not statistically significant.

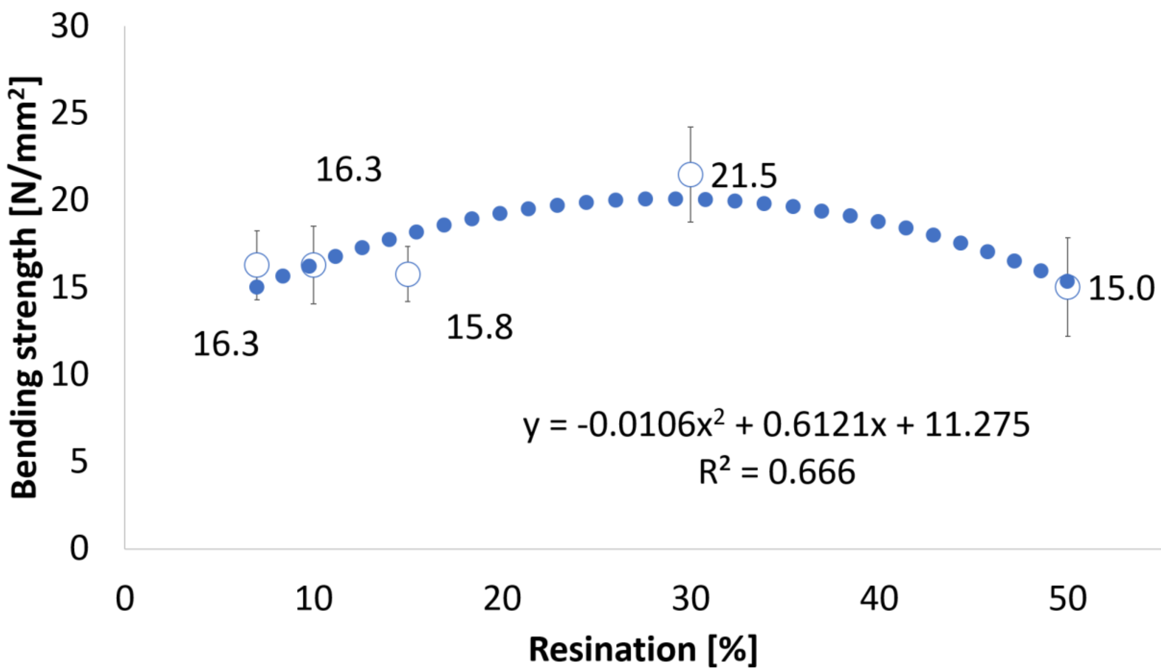

Fig. 1. Bending strength of investigated boards

In the diagram (fig. 2) showing the dependence between modulus of elasticity and resination of the particles, it can be seen that the modulus increases with the resination raise until the resination at the level of 30%. This is confirmed by the quite high values, which are achieved for a board with 30% resination. Above this value the decrease of MOE is observed. The same growth trend of MOE was observed in the study of particleboards with the addition of kenaf fibers and 5% arabic gum. However, the increase in MOE was observed constantly, and not as in the case of increasing the content of adhesive mass only up to a certain point (Juliana *et al.* 2012). Statistically significant differences in the mean values of the modulus of elasticity were noticed between variants 7, 10, 15 and 30%.

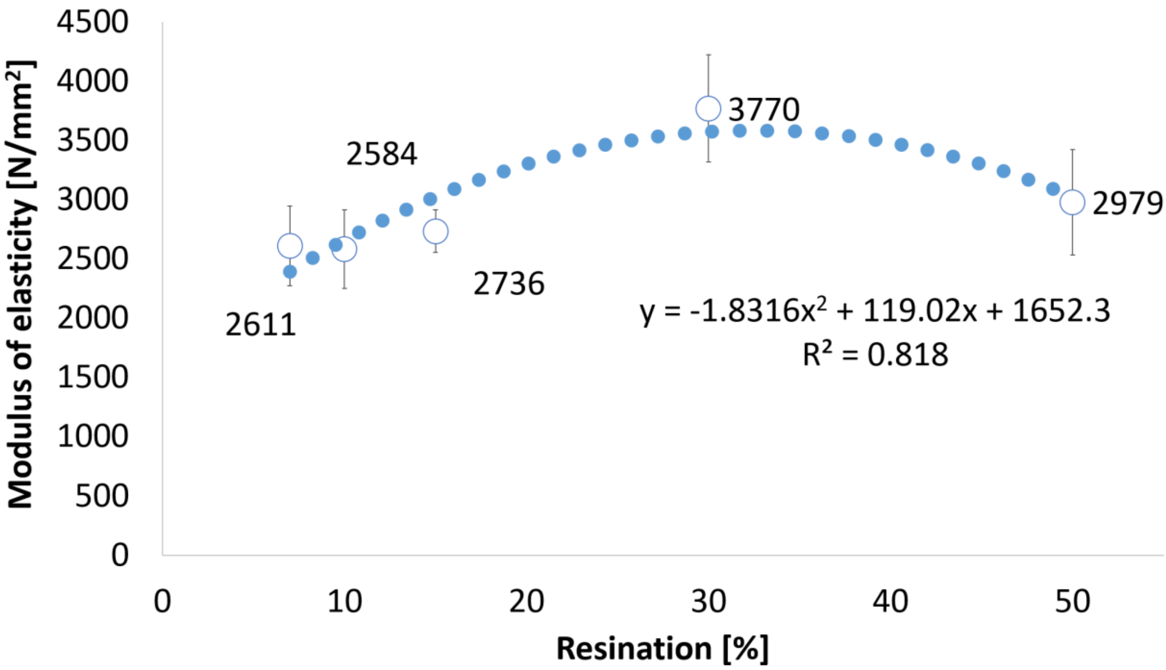

Fig. 2. Modulus of elasticity of investigated boards

The graph (fig. 3) show that when testing the perpendicular tensile strength of the boards, its level clearly increase with the adhesive content raise in the board. The highest value of strength was achieved similarly as in the case of the previously presented tests, at a 30% resination. It can also be seen that with the increase in the resination, the dispersion of the particular results of the perpendicular tensile strength tests increases, which is illustrated by error bars (standard deviation values). Similar results were obtained in examining particleboards in terms of their tensile strength perpendicular to the board surface.
Up to a certain point in the value of particles slenderness, the crack in the boards occurred in the places of the joints, and above – in the structure of particles fibers (Rackwitz *et al.* 1963).
A similar result has been described above. The glue content above 30% reduces the tensile strength of the board. There were no statistically significant differences in mean values between variants 10 and 15 and 30 and 50%.

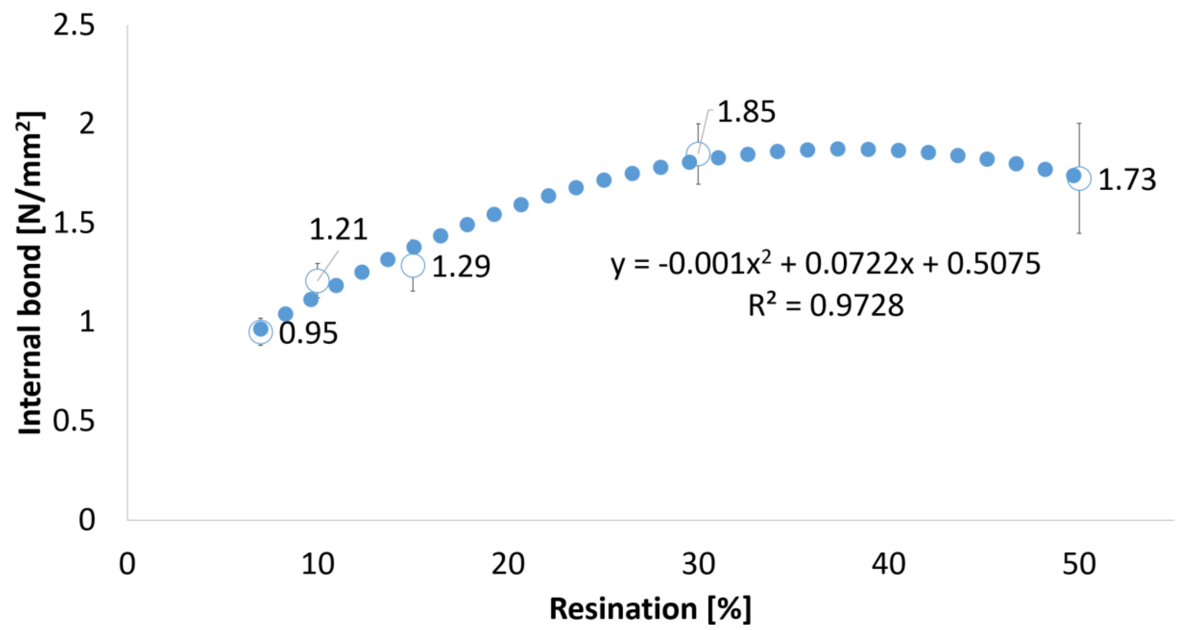

Fig. 3. Internal bond of investigated particleboards

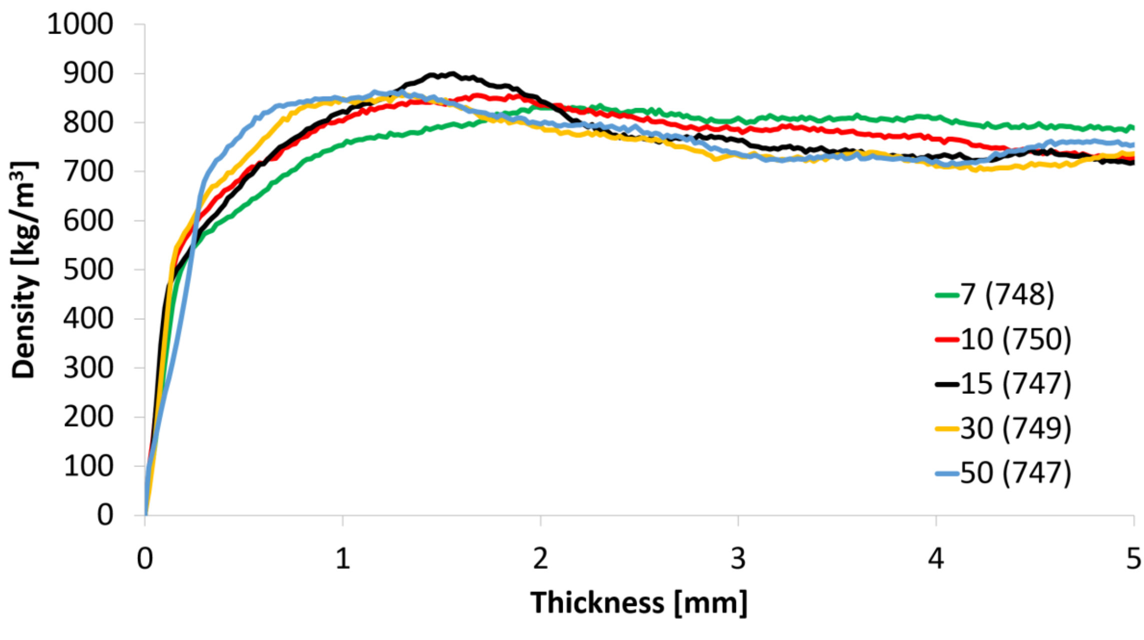

Fig. 4. Density profiles of tested boards (panel average density in parentheses)

Due to the fact that the tested boards had a symmetrical structure with respect to the thickness center, the diagram (fig. 4), to improve its readability, shows only the density distribution to the center of the thickness of the boards. The numbers in parentheses represent the average density of the tested boards. When analyse the results of measuring the density profile, it can be seen that the boards with 7 and 10% size have the flattest line on the chart (excluding thin face layer), which indicates a similar density across the entire board cross-section, while boards with 15, 30 and 50% resination have curves with increased values at the beginning of the cross-section (left zone on plot below), which indicates higher density in the area of the outer layers of the board and is a typical phenomenon when measuring particleboards. The reason for this may be that the adhesive mass conducts heat much more easily and this more efficient than wood (particles), and therefore, in boards with a higher resination, the outer layers are denser earlier during pressing and are of higher density than the core layers. The test result is comparable to the tests carried out after adding arabic gum to particleboards. The density of the board naturally increases by adding a filler to the spaces between the glued particles (Ndububa *et al.* 2013).

The figure (fig. 5) below shows that in the case of particles with a resination of 30 and 0%, the glue can be seen with the naked eye and in the cross-section all free spaces between wood particles are filled by glue. In boards with 7, 10 and 15% resination, free spaces are visible and no glue joints are visible to the naked eye.

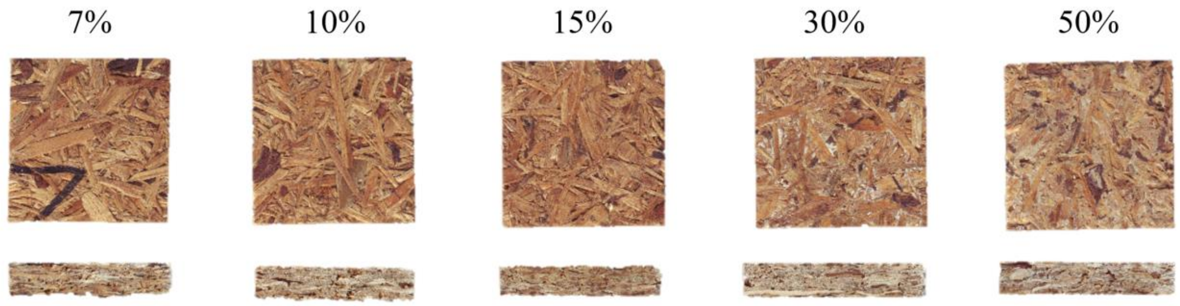

Fig. 5. The appearance of the tested particleboards (face – upper line, crosscut – bottom line)

CONCLUSIONS

According to the conducted research and the analysis of the achieved results, the following conclusions and remarks can be drawn:

1. With the increase of resination of wood particles in the range of 7-30%, the bending strength of the boards, the modulus of elasticity and the perpendicular tensile strength increases.

2. The resination value of 30% is maximum point for modulus of rupture, modulus of elasticity and internal bond values.

3. The structure of the particleboards gets more tight and less porous with the increase of resination between 7 and 50%.

4. With an increase in the resination of the board in the range of 7-50%, the difference between the increasing density of the external layers of the board and the decreasing density of the internal layers deepens.

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REFERENCES

JULIANA, A.H. (2012): "Properties of particleboard made from kenaf (*Hibiscus cannabinus L*.) as function of particle geometry," Elsevier, Materials and Design 34, 404-411

MARSAVINA, L., LINUL, E., POP, O. (2019). "Mechanical and fracture properties of particleboard," Frattura ed Integrita Strutturale, Elsevier, 13(47). DOI: 10.3221/IGF-ESIS.47.20

NDUBUBA, E. (2013): Performance characteristics of gum arabic bonded particleboard made from sawdust and wood shavings. Life Journal of Technology Vol. 22 (1), 5-8

ONUORAH, E.O. (2011) "The effects of some manufacturing variables on the properties of particleboard," Nigerian Journal of Technology: Vol. 20, No. 1

PAPADOPOULOU, E., KOUNTOURAS, S., STATHOPOULOS, C., CHRISSAFIS, K., KALEN, G., LARSSON, S.H. (2016). "Particleboards with Wood in Various Forms," 27th International Conference on Wood Modification and Technology 2016 IMPLEMENTATION OF WOOD SCIENCE IN WOODWORKING SECTOR

PN-EN 310:1994 Wood-based panels. Determination of modulus of elasticity in bending and of bending strength

PN-EN 319:1999 Particleboards and fibreboards. Determination of tensile strength in the direction perpendicular to the plane of the board

PN-EN 323:1999 Wood-based panels. Determination of density

RACKWITZ, G. (1963): Der Einfluss der Spanabmessung en auf einige Eiggeschaften von Holzspanplatten. Holz als Roh-und Werkstoff 21, 200-209

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Streszczenie: *Wpływ stopnia zaklejenia płyt wiórowych na ich wytrzymałość na rozciąganie prostopadłe*. Celem badań było określenie związku pomiędzy wybranymi właściwościami mechanicznymi i fizycznymi płyt wiórowych, ze szczególnym uwzględnieniem wytrzymałości na rozciąganie prostopadłe, a ich stopniem zaklejenia. Do badań zostały wytworzone w warunkach laboratoryjnych płyty wiórowe o następujących stopniach zaklejenia: 7, 10, 15, 30 i 50%. Szczególną uwagę zwrócono na zbadanie właściwości mechanicznych – wytrzymałości na rozciąganie prostopadle do powierzchni (Internal Bond – IB). Ponadto zbadano moduł sprężystości (MOE), wytrzymałość na zginanie (MOR) gęstość oraz profil gęstości. W świetle powyższych badań stwierdzono, że nie ma pozytywnego efektu poprawy badanych parametrów przy podniesieniu stopnia zaklejenia wiórów powyżej 30% przy produkcji płyt wiórowych. Wraz ze wzrostem stopnia zaklejenia z 7 do 50% zauważono istotną zmianę (zagęszczenie) struktury płyt, jak również stwierdzono rosnące różnice pomiędzy gęstością warstw zewnętrznych i wewnętrznych badanych płyt.

Słowa kluczowe: płyta wiórowa, wiór, stopień zaklejenia, właściwości mechaniczne, IB

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