

## **Analysis of the influence of particle and poplar fibres share on selected properties of particle-fibre boards**

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**Abstract:** *Analysis of the influence of particle and poplar fibres share on selected properties of particle-fibre boards. As a part of the study, one-layer particle-fibre boards with 12 mm thick and of average density 650 kg/m<sup>3</sup> were manufactured from plantation poplar ‘Hybrid 275’ wood.. For the control variant a typical industrial raw material (pine wood) was used. The following properties were determined for the boards: modulus of rupture (MOR), density profile, modulus of elasticity at static bending (MOE), internal bond (IB), thickness swelling (TS) after 2h and 24h soaking in water. On the basis of conducted study, it was found that the addition of poplar fibers to particle-fibre boards in most cases has a positive effect on the values of determined properties – an increase in strength was noted, except for internal bond (IB). In the case of thickness swelling of the boards after 24 h soaking in water, it was noted that with the increase in the share of poplar fibers in the boards, the value of the tested property decreased (which was not clear in the case of thickness swelling of boards after 2 h soaking in water).*

*Keywords: fiber boards, particle boards, particle-fibre boards, plantation, poplar ‘Hybrid 275’*

### INTRODUCTION

The use of wood in the world, as well as in Poland, is increasing year after year. The demand for wood as a raw material is constantly growing - which in 2006 equated to approximately 0.56 m<sup>3</sup> of wood per one person. The main reason for this phenomenon is the continuous population growth (Zajączkowski and Wojda 2012). It is expected that in about 40 years this ratio will amount to 1 m<sup>3</sup> per capita (Zwoliński 2008). Especially in Europe the factor causing the decrease of wood supply, is the constantly increasing area of protected forests - in 1990, it amounted to 4 million ha, in the assumptions it may even reach 12.3 million ha in 2050 (Nabuurs et al. 2000). In the near future, it can be expected that the shortage of wood will increase with the increasing use of wood as a renewable energy source (Pach et al. 2010). In order to meet the market needs for wood raw material, alternative solutions are used, consisting mainly in diversification of the currently used raw material structure in the wood industry. In recent years, more attention has been paid to the possibility of obtaining wood from plantation crops. Currently there is a dynamic increase in the adaptation of areas for fast-growing tree plantations. From 1990 to 2005, plantation areas worldwide increased by 27 million ha (Del Lungo et al. 2006). The most effective fast-growing tree plantations are in China, United States and India (West 2006). In Poland the interest in fast-growing species (especially poplar) occurred in the 1950s. The target area of the plantation in 2000 was to be about 300 thousand ha (Szczuka 1973). Long-term plans were not fulfilled. It was caused by, among others, planting poplars on unsuitable habitats, poor knowledge about biological properties of cultivars owned at that time, but also a lack of necessary instructions about establishing and running a plantation (Zajączkowski 2013). Currently, on the plantations managed by State Forests, mainly the poplar cultivars ‘Hybrid

275' is grown, the estimated average age of trees is 13-28 years (Padzil et al. 2018). Taking into account the length of their manufacturing cycle, three plantation cycles can be distinguished (according to modified Muchs et al. 1986 classification):

- I. Plantations with long full cycle: 25-60 years,
- II. Plantations with mid-cycle: 15-20 years,
- III. Short cycle plantations: 2-6 years.

Wood raw material grown on mid-cycle and short cycle plantations can be used in wood-based materials industry. Due to the large genetic diversity of poplars, the age needed to grow trees has an important role for energy resources and wood-based materials production (Stanton et al. 2014). There are many clones and poplar hybrids. Most often they are assigned to one of three sections: black poplar (s. Aigeiros), balsam poplar (s. Tacamahaca), white poplar and aspen (s. Populus). In Poland, black and balsam poplars are best adapted (Zajączkowski and Wojda 2012), mainly:

- *P. maximowiczii x trichocarpa* 'Androscoggin',
- *P. maximowiczii x berolinensis* 'Geneva',
- *P. maximowiczii x berolinensis* 'Oxford',
- *P. trichocarpa* 'Fritzi Pauley',
- *P. maximowiczii x trichocarpa* 'Hybrid 275'.

Mechanical properties and resistance to biological corrosion of fast-growing trees species are potentially low (Strauss et al. 2004). Taking into account the known hybrids, 'Hybrid 275' is characterized by the highest health among them (Kozłowska 1974). The increase height of poplar from plantation is estimated from 1.5 m to 3.1 m per year. The trees are cut in the range from 2 to 7 years (Stobrawa 2014). Many scientists recommend growing poplars in cycles not shorter than 5-6 years (Fang et al. 1999). The highest resistance was shown by trees planted in the Carpathian and Baltic regions (Kozłowska and Oszako 1999). Poplar species are characterized by significant dynamic growth (Deswal et al. 2014). In Poland the yields are much higher compared to other fast growing species under the conditions of short-rotation plantations (Zajączkowski 2013). Fibers from fast-growing species mainly from poplar and willow trees are used for production of wood-based materials and composite materials, but also have their application in the paper industry (Szostak et al. 2013, Baletinecz and Kretschmann 2001).

The paper presents research results of the possibility of using poplar wood 'Hybrid 275' from fast growing trees plantations as a raw material for the production of particle boards, fiber boards and particle-fiber boards.

## MATERIALS AND METHODS

For the purpose of this study, one-layer particle-fibre boards with a nominal thickness of 12 mm and an assumed density of 600 kg/m<sup>3</sup> were manufactured. The boards were made of fibers and particles obtained from plantation poplar wood 'Hybrid 275'. The properties were compared with boards of the same structure, based on a typical industrial raw material (pine wood). Parameters adopted in the process of board manufacturing were presented in Table 1.

**Table 1.** Parameters adopted in the process of board manufacturing

Hydrophobic agent (paraffin)	1% in relation to dry matter of wood particles
Glue composition	100 g UF resin, 4 g hardener (10% NH <sub>4</sub> Cl water solution), 15 g water
Pressing temperature	180 °C
Maximum pressure	2.5 MPa
Pressing time per unit	18 s/mm

On the laboratory conditions, particle-fibre boards were made in 5 variants for each species of wood raw material (10 variants in total). Assumptions of particular variants of boards were presented in Table 2.

**Table 2.** Assumptions of individual board variants

VARIANT	Wood raw material	Percentage share of wood particles	Percentage share of wood fibres
1T	Poplar	100%	0%
2T		75%	25%
3T		50%	50%
4T		25%	75%
5T		0%	100%
1S	Pine	100%	0%
2S		75%	25%
3S		50%	50%
4S		25%	75%
5S		0%	100%

After the boards were manufactured, they were seasoned for 14 days at 21°C (±2°) and 60% (±5%) relative humidity. Next, the boards were cut into samples of appropriate dimensions in order to carry out tests in relation to the selected properties:

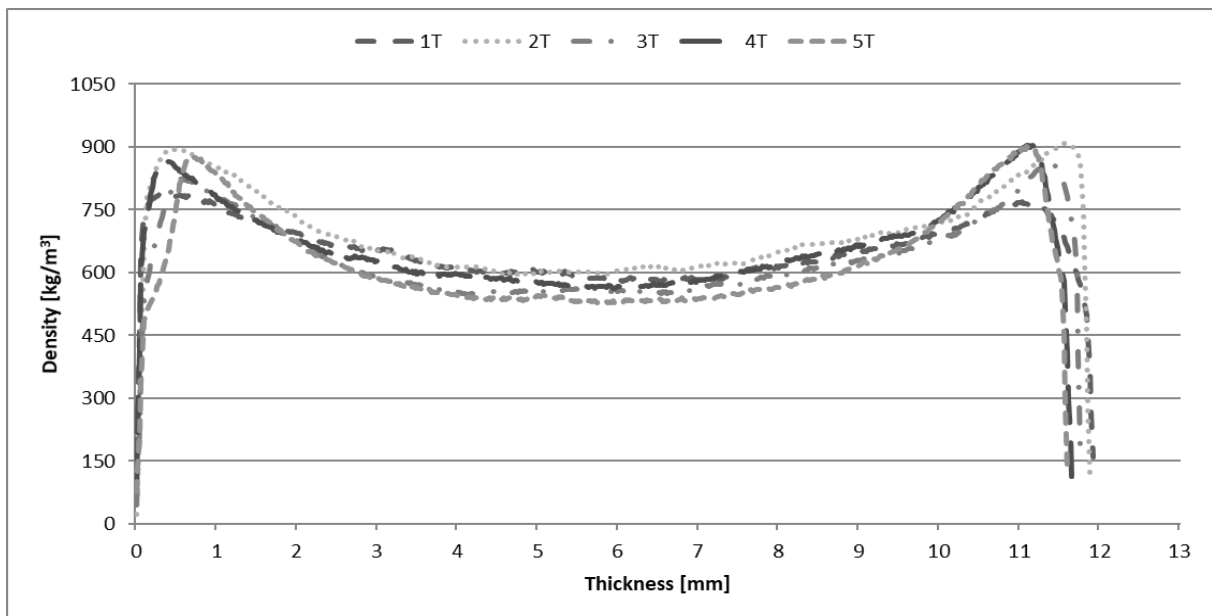
- ✓ density profile on the cross-section – the X-ray density analyzer GreCon Da-X (Fagus-Grecon Greten GmbH & Co. KG, Alfeld-Hannover, Germany) was used for testing, the device was measuring at the speed of 0.05 mm/s and with the accuracy of 0.02 mm;
- ✓ modulus of rupture (MOR) – based on EN 310:1994 standard, 10 samples from each variant were used for testing;
- ✓ modulus of elasticity at static bending (MOE) – based on EN 310:1994, 10 samples from each variant were used for testing;
- ✓ internal bond (IB) – based on EN 319:1999, 10 samples from each variant were used for testing;

- ✓ thickness swelling after 2h and 24h soaking in water – based on EN 317:1999, 10 samples from each variant were used for testing.

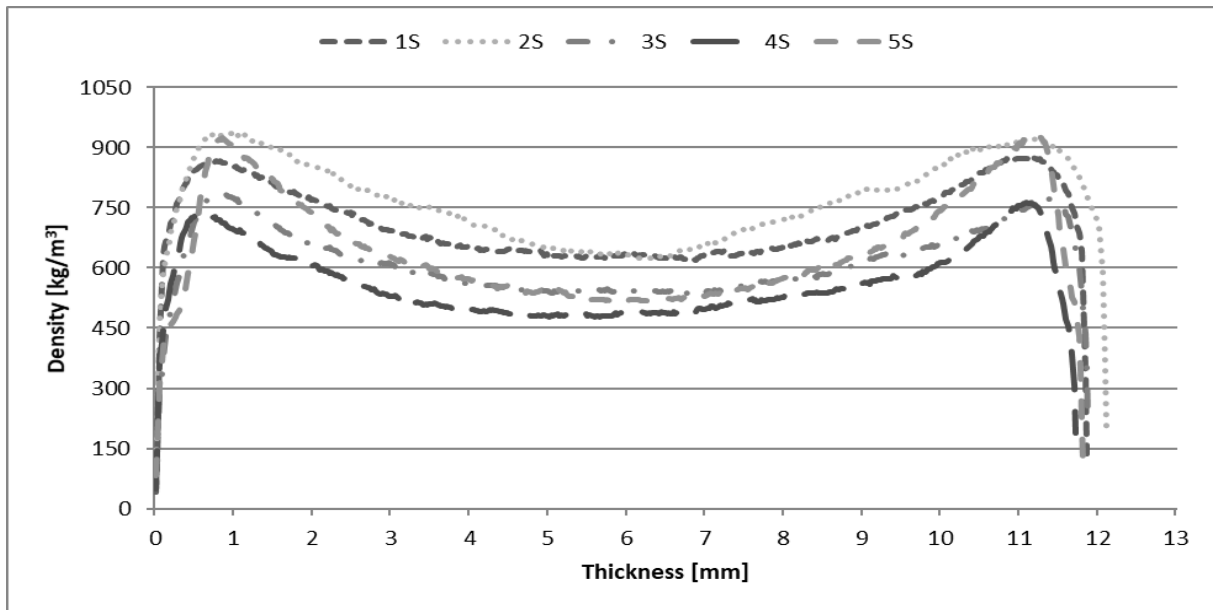
Statistical differences between variants of different species were analyzed in the Statistica 13.1. program, which was used to carry out the Student T-test.

## RESULTS

Figure 1 and 2 show the cross-sectional density profile for poplar and pine boards respectively. All boards were characterized by a smoother course of density profiles, with a typical “U” shape course. In case of boards made of plantation raw material, the spread of density on the cross-section was relatively even. In case of boards from variants 1T, 2T, 3T, 4T, 5T, the average density was  $654 \text{ kg/m}^3$ . For boards from variants 1S, 2S, 3S, 4S, 5S, the average density was  $650 \text{ kg/m}^3$ .

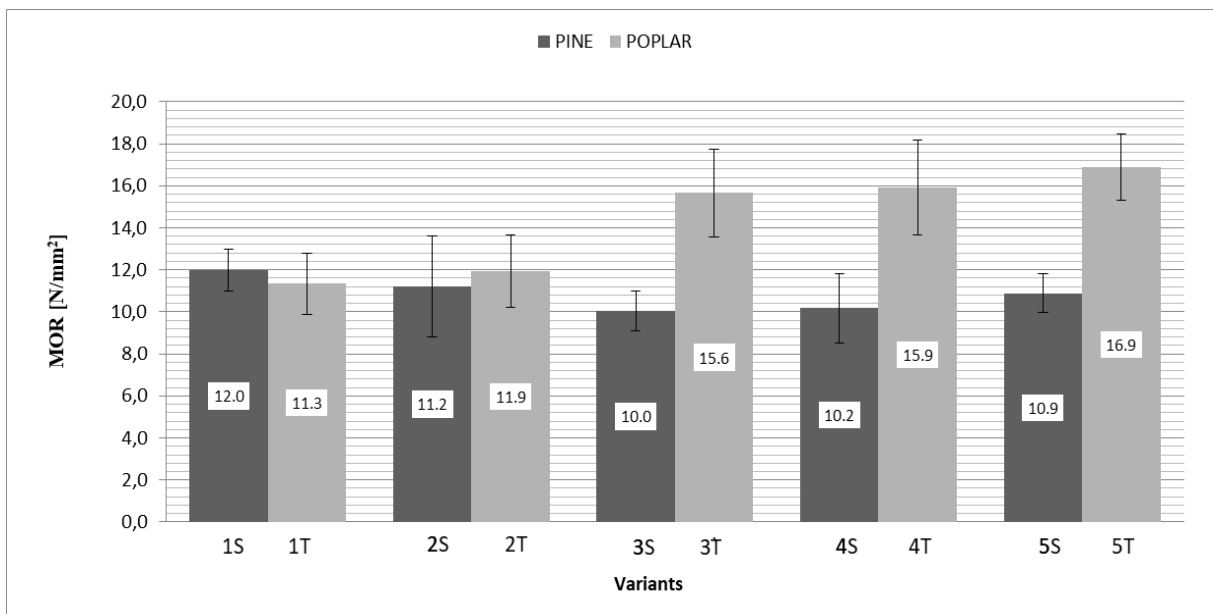


**Figure 1.** Density profiles on the cross-section of analyzed boards variants (raw material: poplar wood)



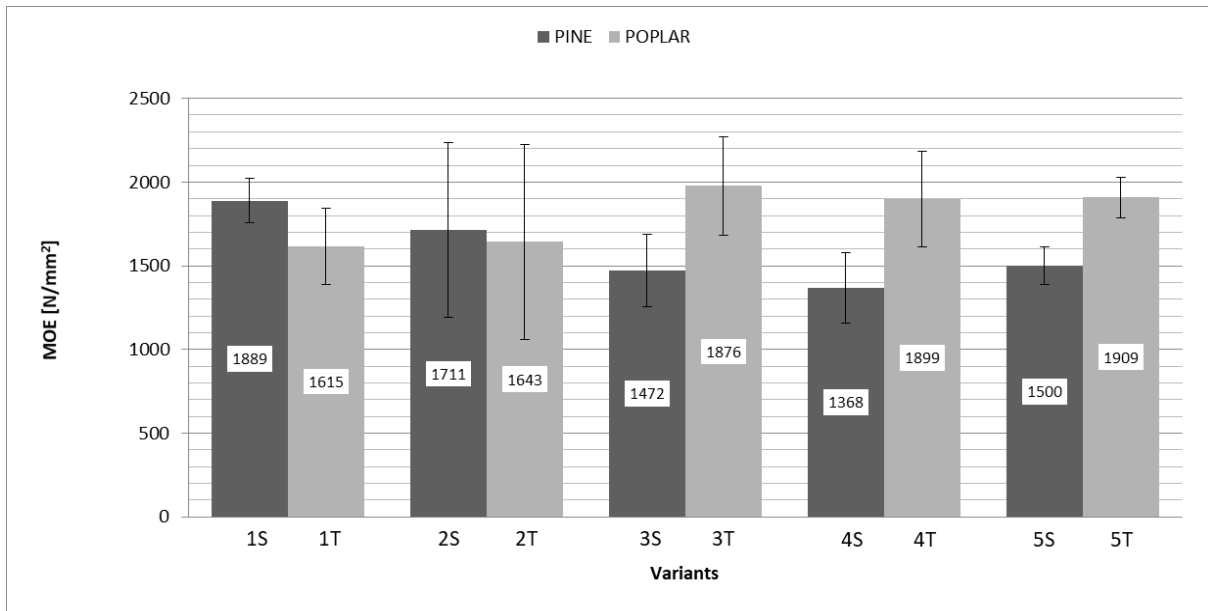
**Figure 2.** Density profiles on the cross-section of analyzed boards variants (raw material: pine wood)

The results of modulus of rupture tests of boards were shown in Figure 3. Based on the analysis, statistically insignificant differences were found for variants 1T-1S and 2T-2S. With variants 3T-3S, 4T-4S and 5T-5S the differences in the obtained values of determined property were statistically significant. Therefore, it should be concluded that with the increase in proportion of poplar fibers in boards (from 50% and more), the value of MOR increases. Taking into account the standard deviation from the average strength, it did not exceed 2.5% in all cases considered. It should be noted that the significance of variability was noticeable. For pine boards in the 2S variant it reached even 25%, while for boards made of poplar material it was not higher than 14%. Analyzing the obtained data, it can be stated that the addition of poplar fibers (from 50% and more) significantly increases the value of modulus of rupture of boards in comparison with boards made of a typical industrial raw material (pine wood).



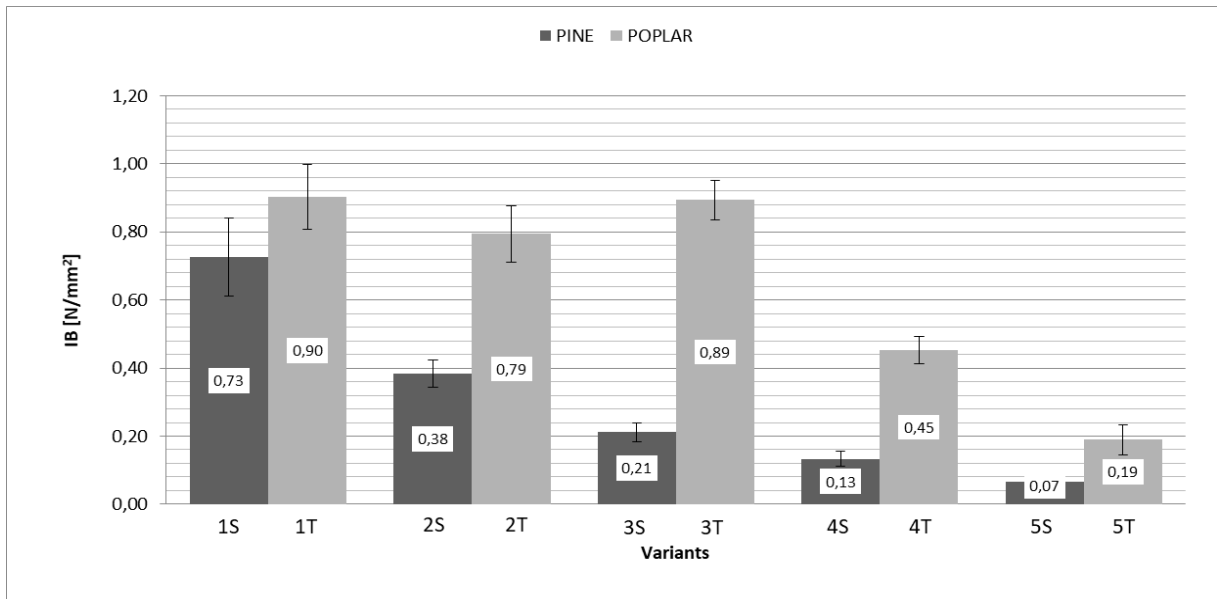
**Figure 3.** Modulus of rupture of manufactured boards

The obtained values of modulus of elasticity at static bending for boards manufactured according to the assumptions of particular variants were shown in Figure 4. On their basis, statistically significant changes can be recorded for each of the board variants. In variants 2T and 2S the highest coefficient of variation was obtained, 35% and 30% respectively. The lowest coefficient of variation was recorded in variant 5T (6%) and variant 1S (7%). It should be noted that the highest values of the modulus of elasticity at static bending were observed in boards with addition of 50% and more poplar fibers.



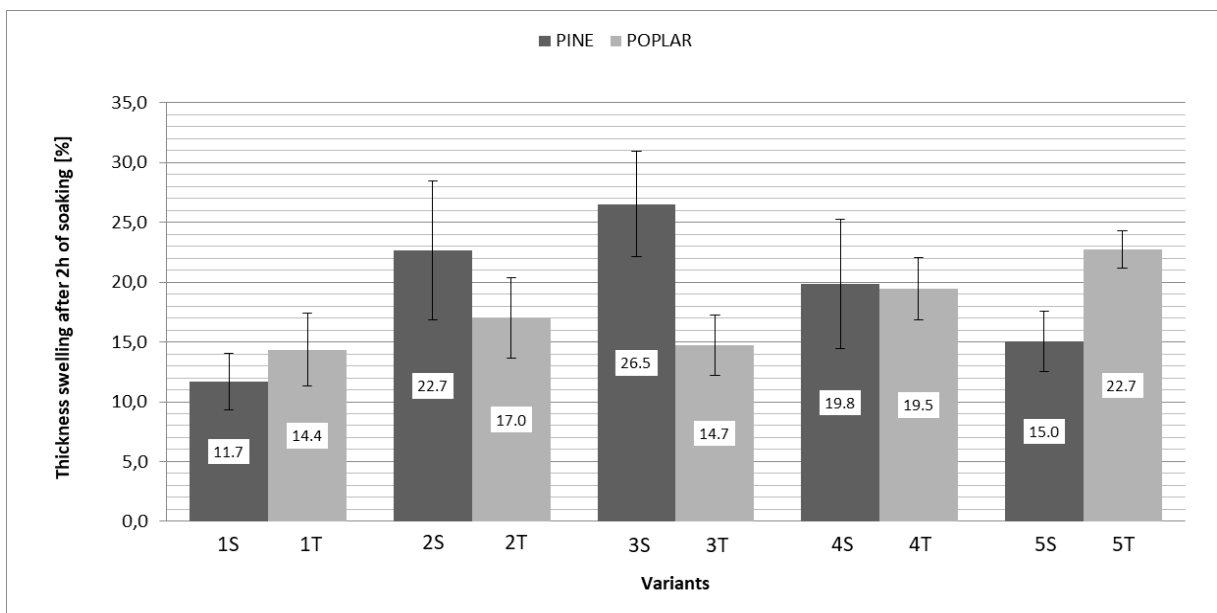
**Figure 4.** Modulus of elasticity at static bending of manufactured boards

Figure 5 shows the results of boards' internal bond. Generally, it was observed that the share of plantation poplar wood particles in the board improves the internal bond. The changes in values of determined strength between particular variants of boards were statistically significant. Moreover, a decrease in the determined strength was observed in the case of boards with fibers made of pine wood. In this case, obtaining low values of internal bond could have been caused by more effective overheating of fibrous mats in comparison to the particle mats during the pressing process. It should be also noted that according to Niemz (1993), the heat transfer coefficient for pine wood is higher than that for poplar (pine, 0.14 W/mK; poplar, 0.10 W/mK, which explains the much more intensive heat transfer rates and more efficient generation of water vapor in the mat. This phenomenon resulted in the difficulty in removing moisture from the mats during pressing (mainly for fiber mats with share of pine wood). During the pressure reduction and opening the press, a sudden expansion of water vapour in the mat could occur. This caused a significant weakening of the adhesive joints between the individual fibers in boards.



**Figure 5.** Tensile strength in the perpendicular direction to the planes of manufactured boards

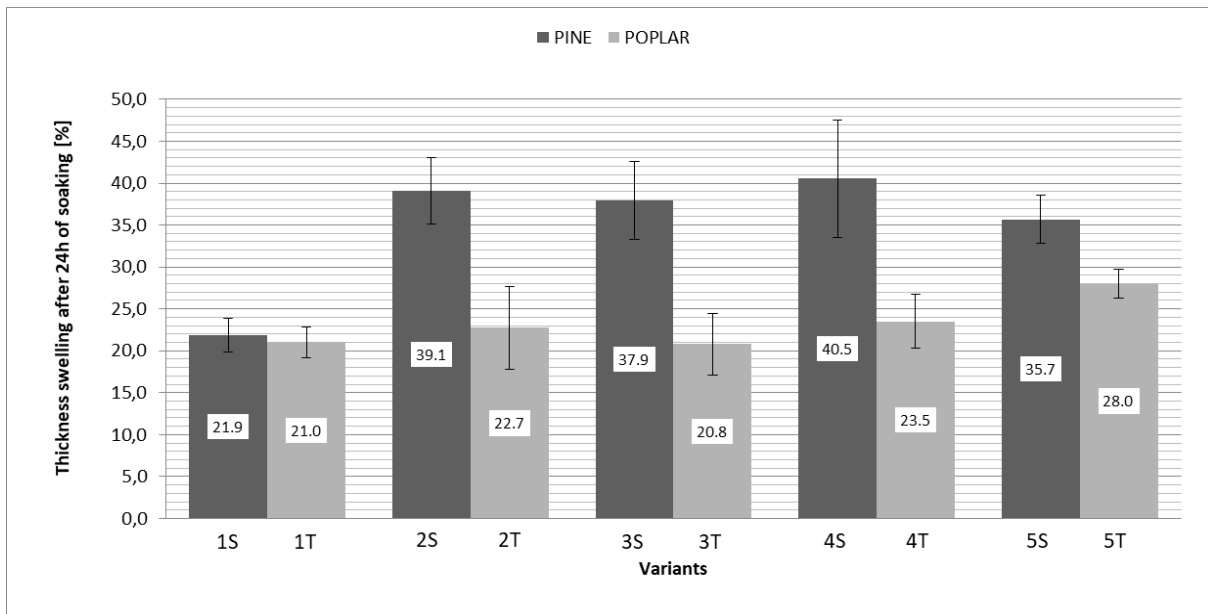
In order to assess the susceptibility to swelling of boards manufactured according to the assumptions of individual variants, tests were carried out on swelling for thickness after 2 and 24 hours soaking boards in water. Figure 6 shows the results of tests for boards after 2 hours soaking in water. Statistically significant changes have been found for all presented variants except for variant T4 and S4. The coefficient of variation did not exceed 30%. After 2h of soaking samples in water, the highest increase of thickness swelling was recorded for a board from variant S3 and the lowest for a board from variant S1.



**Figure 6.** Thickness swelling after 2h of soaking in water

Figure 7 shows the thickness swelling values for individual variants of boards after 24h soaking in water. When comparing variants 1S and 1T the changes were statistically insignificant. In the remaining 4 variants the obtained differences in the thickness swelling values of boards after 24h soaking in water were statistically significant. In general, higher

thickness swelling after 24h soaking the samples in water was recorded for boards made of a typical industrial material (pine) than for boards made with plantation poplar wood.



**Figure 7.** Thickness swelling after 24h of soaking in water

## CONCLUSIONS

On the basis of conducted study, the following conclusions were formulated:

1. Along with an increase in the proportion of poplar fibers in boards (from 50% and more), the modulus of rupture and modulus of elasticity of boards increases.
2. In general, it has been observed that the addition of plantation poplar wood particles to the boards improves the internal bond.
3. There was no clear influence of the addition of poplar fibers and particles to boards with respect to thickness swelling after 2 h soaking boards in water.
4. In general, boards made with share of poplar fibers or particle characterized lower thickness swelling compared to boards made of share of pine fibers or particles.

## ACKNOWLEDGMENTS

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**Streszczenie:** *Analiza wpływu udziału wiórów i włókien topolowych na wybrane właściwości płyt wiórowo-włóknistych. W ramach pracy wytworzono jednowarstwowe płyty wiórowo – włókniste z topoli plantacyjnej 'Hybrida 275', o grubości 12 mm i średniej gęstości 650 kg/m<sup>3</sup>. Do wariantu kontrolnego użyto typowego surowca przemysłowego (drewna sosnowego). Dla powstałych płyt wyznaczono: wytrzymałość na zginanie statyczne (MOR), profil gęstości, moduł sprężystości przy zginaniu statycznym (MOE), wytrzymałość na rozciąganie w kierunku prostopadłym do płaszczyzn płyt (IB), spęcznienie na grubość po 2h oraz 24h moczeniu w wodzie. Na podstawie przeprowadzonych badań stwierdzono, że dodatek włókien topolowych do płyt wiórowo – włóknistych w większości przypadków wpływa pozytywnie na wartości określanych właściwości - odnotowano wzrost wytrzymałości z wyjątkiem rozciągania w kierunku prostopadłym do płaszczyzn (IB). W przypadku pęcznienia płyt na grubość po 24 h moczenia w wodzie odnotowano, że wraz ze wzrostem udziału włókien topolowych w płytach, wartość badanej cechy maleje (co nie było jednoznaczne w przypadku pęcznienia płyt na grubość po 2 h moczenia w wodzie).*

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