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THERMOPLASTIC BONDED COMPOSITE CHIPBOARD
PART 1 - MECHANICAL PROPERTIES

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Abstract
Within this work, polypropylene and polystyrene bonded chipboards (at the level of 30 % and 50 % share of thermoplastic) were produced. Physical and mechanical properties of obtained chipboards were tested. Results were related to urea-formaldehyde bonded boards. Chipboards bonded with thermoplastics, with similar average density and density distribution in general characterize by decrease of strength properties when compared to traditional chipboards. However, especially boards with higher ratio of thermoplastics, characterize by better water resistance.

Keywords: *chipboard, polypropylene, polystyrene*

INTRODUCTION

WPC are an important material on the market of wooden-based materials [Youngquist 1995, Gordon 1988, Research Report 2003]. It is estimated, that this market is worth about 2 - 2.5 billion. U.S. dollars worldwide [Van Vuure 2008, Research Report 2003]. United States are the leader in the production of WPC for years - in 2009 the production based on WPC reached the level of approximately 1,000 thousand. tones. In Europe in 2010, ca. 190 thousand. tons of these materials were produced [http://woodplasticcomposites.org/] – including about one third of total production in Germany. In comparison to typical wood-based board materials, WPC usually characterize by worse mechanical properties [Clemons 2002, Falk *et al* 1999], while their main advantages include higher resistance to external factors, particularly water [Clemons 2002]. Typical WPC composites are produced in a process derived from the plastics processing - extrusion and injection. This requires the use of wood in the form of small particles (fibres, wood flour). Conducted research shows that wood-polymer composites can also be made of the larger particles of wood such as chips or veneers, while processes of composites manufacturing from such particles may be analogous to the processes of manufacture of traditional wood-based materials [Borysiuk *et al.* 2006, 2008, Hu *et al.* 2005, Noskowiak 1997, Youngquist *et al.* 1993, 1994]. This paper presents the properties of chipboards bonded with polypropylene and polystyrene.

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MATERIAL AND METHODS

Single-layer chipboards were prepared with density of 750 kg/m^3 and a thickness of 16 mm. Two thermoplastics weight ratios were used: 30% and 50%. In the research, standard pine chips (manufactured under industrial conditions) were used for the inner layer of chipboards. Thermoplastics (PP and PS) were obtained in the form of post-consumer packaging and disposable items and do not contained any organic contamination.

Control boards were prepared with the use of urea-formaldehyde SILEKOL W-1C. Parameters of manufactured boards are presented in table 1.

Table 1. Pressing parameters.

Pressing parameter:	Thermoplastics	UF resin
glue amount	—	12%
temperature	200 ^{o}C	195 ^{o}C
hot pressing time	600 s	280 s
under pressure cooling time	900 s	—
maximal specific pressure	2.5 MPa	2.5 MPa

Manufactured boards were first conditioned for 48 h under normal conditions, and then were cut into test samples. To determine the specific properties for each variant of the research, 10 samples were used. In obtained boards, density and density distribution was determined (DAX of GreCon), as well as MOR and MOE (EN 310: 1994), swell and absorbability after 24 h soaking (EN 317:1999) and surface absorption (EN 382-1:2001).

DISCUSSION

Test results of polypropylene and polystyrene bonded chipboards are shown on fig. 1 and tables 2 and 3.

Average densities of examined chipboards bonded with thermoplastics were in the range 772 - 787 kg/m^3 (table 2). Just as traditional chipboard, changes in the density of thermoplastics bonded boards affect their properties, in particular – strength [Kowaluk *et. al.* 2011]. It is assumed, that examining the differences in properties of boards in different variants resulting from the accepted variables is possible, when differences in their density are not greater than 10%. For examined boards, differences in density (minimum to maximum) come to 5%. At the same time there is no clear dependence between density and type and size of thermoplastics ratio in boards. Figure 1 shows the density distribution of examined samples.

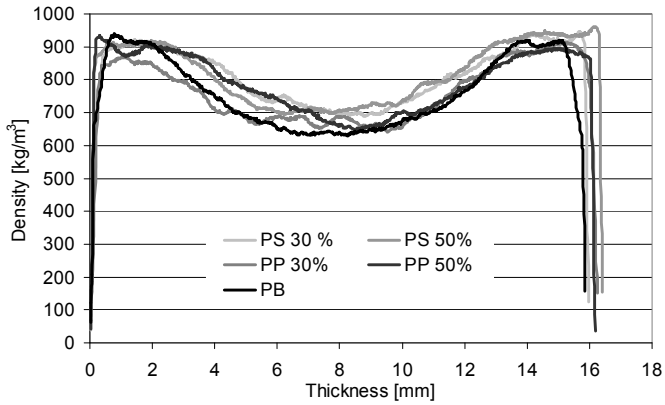

Fig. 1. Sample density distributions of chipboard bonded with polypropylene and polystyrene.

In general, no significant differences in waveforms of curves illustrating the density distribution for each thermoplastics or control board (without thermoplastic) were observed. However, it can be concluded that thermoplastics bonded chipboard characterized by generally lower density spread on the cross section. It is also worth to mention higher irregularity of curves of density distribution in case of thermoplastics bonded boards, which may result from variability in the distribution of thermoplastic in board.

Table 2. Strength properties of PS and PP bonded chipboards.

	Thermoplastic ratio	Density		MOR		MOE	
	%	kg/m^3	% [1]	N/mm^2	% [1]	N/mm^2	% [1]
Polypropylene	30	782	3	12.6	14	1755	2
	50	787	5	18.2	13	2144	9
Polystyrene	30	778	4	8.3	13	1400	10
	50	772	5	12.4	15	1490	6
Control board	0	750	5	19.4	10	2194	10

[1] variation coefficient,

When examining MOR results (table 2) it can be stated, that in case of thermoplastics bonded chipboards strength has decreased, dependently on the type and share of thermoplastic, from 6 to 50% when compared to the control chipboards (bonded with UF resin). Similar situation took place in case of MOE. Thermoplastics bonded chipboards characterized by a decrease of MOE, depending on the type and share of thermoplastic, ranging from 2 to 36% when compared to the control chipboards. In reference to applied thermoplastics, it is necessary to mention that regardless of their ratio, results were better in case of polypropylene.

Decrease of boards strength properties results from type of combined thermoplastics and wood chips. Thermoplastics dampen wood surface much worse than traditional glue, which results, among others, from high difference in surface energies of these materials: PP - 38,28 mJ/m^2, PS - 38,28 mJ/m^2 and for wood - 50 ÷ 80 mJ/m^2 [Meijer *et al.* 2000]. Plastic

only surrounds chips, as shown by the clear and visible in the microscopic images boundary of contact between both materials, often containing defects in the form of free spaces (Fig. 2 and 3).

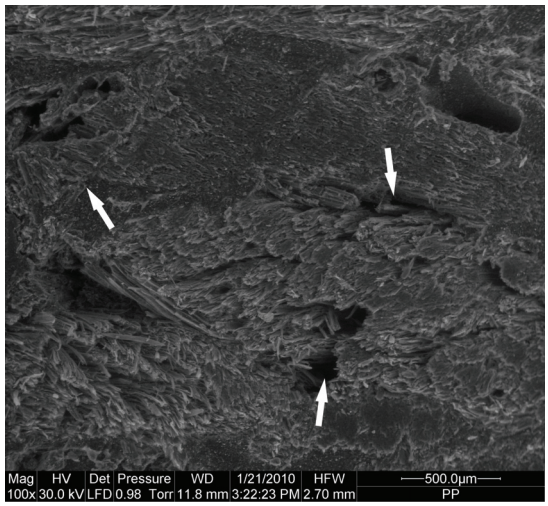

Fig. 2. Defects at the polypropylene-wood border

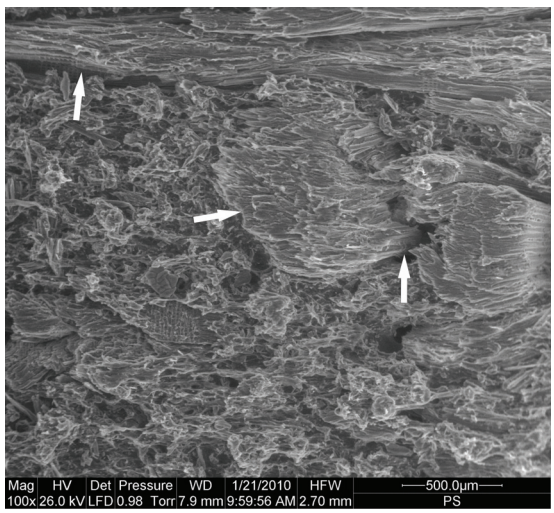

Fig. 3. Defects at the polystyrene-wood border

While analysing properties related to the impact of water on polypropylene and polystyrene bonded chipboards, it is necessary to mention, that both swelling and water absorption are reduced with the increase of thermoplastic ratio. With thermoplastic ratio at 30%, manufactured boards characterized by values of swelling and water absorption comparable or higher than typical chipboards. This results from the fact that chips, which are bonded by mechanical "snaps", tend to release them during moistening. Swelling wood "pushes" thermoplastic binder, so that the structure of board is loosening. This process has been conducive by relatively small samples (50 mm x 50 mm x thickness), which were

used in this test. With the growth of thermoplastic ratio (especially polypropylene), both swelling and water absorption decrease. Boards with 50% ratio of PP, after 24 h of soaking characterize by swelling of 7.9% and water absorption of 44.6%, which is respectively, 60% and 48% less than control boards. This is due to "tighter" chips surrounding by thermoplastic, and thus limited contact of wood particles with water.

Table 3. Physical properties of PS and PP bonded chipboards

	Thermoplastic ratio	Swell after 24 h		Absorbability after 24 h		Surface absorption	
	%	%	%[1]	%	%[1]	g/m^2	%[1]
Polypropylene	30	18.9	17	72.9	15	2784	7
	50	7.9	17	44.6	16	1299	6
Polystyrene	30	30.7	14	89.6	13	2830	10
	50	24.8	11	56.8	11	967	6
Control board	0	20.0	10	85.0	10	5158	5

[1] variation coefficient

Significant effect of improved water resistance of thermoplastic bonded boards is shown during test of surface absorption. Contrary to previous indications, in this case water acts only on the surface of the board. Even at 30% thermoplastic ratio, decrease in the surface absorption is noticeable and amounts about 45% from 5158 g/m^2 for control board (without thermoplastics) to 2784 g/m^2 for PP bonded boards and 2830 g/m^2 for PS bonded boards.

CONCLUSION

Waste thermoplastics such as polypropylene and polystyrene, can be used for chips bonding in the technology similar to the production of chipboards. Chipboards bonded with these thermoplastics, at similar average density and density distribution, characterize by decrease in strength properties in comparison to traditional chipboards. However, they characterize by better water resistance, especially at higher thermoplastics ratio. With regard to the type of thermoplastic, better mechanical and physical properties were obtained for polypropylene bonded boards.

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