POLYETHYLENE BONDED COMPOSITE CHIPBOARD
Part 1 Mechanical properties

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Abstract
Work deals with special chipboard, bonded with polyethylene (30, 50 and 70 % PE addition). Produced boards were tested against physical and mechanical properties. Results were compared with regular urea-formaldehyde bonded boards. Polyethylene bonded boards, with comparable average density and density distribution show in general loss of strength in comparison with traditional boards. On the other side, especially with higher amount of thermoplastic material, water resistance is better.

Key words: *particleboard, polyethylene, waste thermoplastics*

INTRODUCTION

WPC are significant on the market of wood-based materials [Youngquist 1995, Gordon 1988, Research Report 2003]. They are usually worse in terms of mechanical properties in comparison to typical wood-based board materials [Clemons 2002 after Stark, Falk *et al.* 1999], main advantage is increased resistance to environmental conditions, especially water [Clemons 2002]. Certain restriction of WPC composites is mainly the extrusion technology and connected with this necessity of fine wood fraction application. Contemporary research shows, that wood-polymer composites may be fabricated with coarser wood grain sizes (chips or veneer) with technological process similar to traditional hot pressing [Borysiuk *et al.* 2006, 2008, Hu *et al.* 2005, Noskowiak 1997, Youngquist *et al.* 1993, 1994]. As a result of this work properties of polyethylene bonded chipboard are presented.

MATERIAL AND METHODS

Boards were manufactured as a single-layered, with 750 kg/m^3 density and 16 mm thickness. Three thermoplastic percentages were used: 30 %, 50 % and 70 %. Typical industry standard pine chips were used. Polyethylene was recycled from waste wrappings, boxes and single-use goods. Thermoplastic did not contain any organic contamination. Selected properties of used polyethylene are shown in table 1.

Reference boards were made with urea-formaldehyde SILEKOL W-1C resin. Processing parameters are shown in table 2.

Table 1 Selected parameters of utilized polyethylene.

Property			Value
Density [1]		[kg/m^3]	915 ÷ 996
Glass transition temperature	reference data [1]	[^{o}C]	- 105 ÷ - 30
	measured [2]	[^{o}C]	40
Plastification temperature		[^{o}C]	about 130
Total surface energy	Reference data [3]	[mJ/m^2]	27 ÷ 36
	measured [4]	[mJ/m^2]	38.28

[1] [Saechtling 2000], [2] with Hoeppler consistometer, [3] [www.kruss.info], [4] with contact angle Phoenix 300 analyzer (SEO, Korea)

Table 2 Pressing parameters.

Pressing parameter:	Polyethylene	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

Boards were conditioned by 48 h in normal conditions an then cut into test samples. For each variant and each tested property 10 samples were used. Following properties were tested: density and density distribution (DAX of GreCon), MOR and MOE (EN 310: 1994), shear strength parallel to surface (PN-D-04212:1979), screw pull resistance (PN-D-04204:1979), swell and absorbability after 2 and 24 h soaking (EN 317:1999), surface absorption (EN 382-1:2001).

DISCUSSION

Results of polyethylene bonded chipboard tests are shown on fig.1 and tables 3 and 4.

Average densities of tested boards ranged from 731 up to 797 kg/m^3 (table 3). Similarly as traditional chipboard, changes in polyethylene bonded board's density influence changes in mechanical properties, especially strength. It is assumed that analysis of differences in various board's properties is reasonable if densities of the compared material differ by no more than 10%. For tested boards maximal density differences reached 9%. There is no visible dependence of thermoplastic material percentage and density. Figure 1 shows density distribution of tested boards.

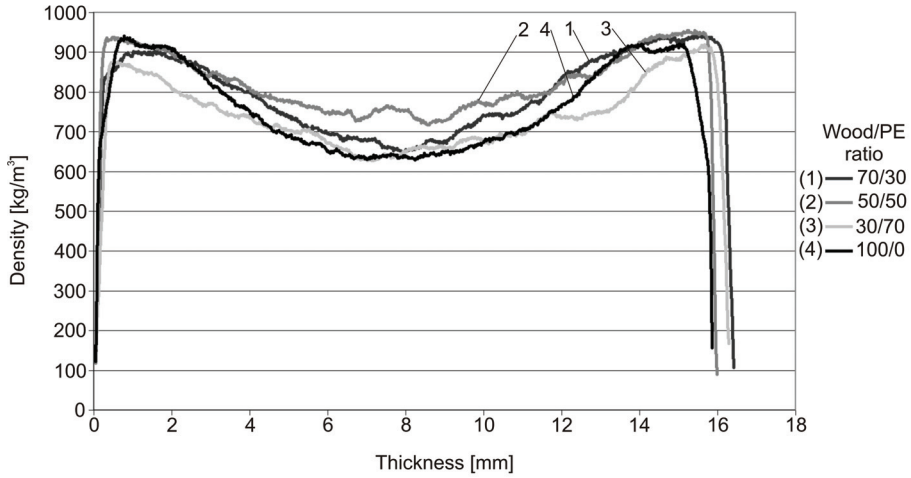

Fig. 1 Sample density distributions of tested polyethylene bonded chipboard.

Basically, clear differences between density distributions of modified and control boards are not visible, it may be assumed that polyethylene bonded boards were slightly more uniform in density characteristics. It is necessary to mention about thermoplastics bonded boards density irregularities, caused by not uniform polyethylene distribution.

Table 3 Strength properties of PE bonded boards.

Wood/PE ratio	Density		MOR		MOE		Shear strength	
	kg/m^3	% [1]	N/mm^2	% [1]	N/mm^2	% [1]	N/mm^2	% [1]
70 / 30	797	3	11,2	9	1339	2	0,83	8
50 / 50	796	4	12,9	7	1259	6	1,68	7
30 / 70	731	6	12,8	6	1065	8	1,72	9
100 / 0 [2]	750	5	19,4	10	2194	10	2,49	6

[1] variation coefficient, [2] control board

Considering MOR results (table 3) it may be concluded that polyethylene introduction into boards causes strength loss by 33 up to 42 % in comparison to urea-formaldehyde bonded reference boards. MOE tests show similar results. Polyethylene bonded boards showed MOE loss ranging from 51 to 39% in dependence on wood/thermoplastic ratio. One of the standard strength tests in case of chipboard is IB test, describing internal cohesion of the boards. In case of thermoplastics bonded boards this test is difficult, because of their presence on the board's surface. This causes low glue adhesion and problems with shear pads, slipping off the surface. This property may actually turn into advantage, preventing faces from unwanted dirt. In aim to determine internal cohesion shear strength in direction parallel to board's face was performed, test samples destruction occurs similarly in the internal layer. Like in previous strength tests for polyethylene bonded boards significant loss was noticed, ranging from 31 up to 66 % in dependence with the wood/thermoplastic ratio.

Lower strength properties are caused by specific character of wood-polyethylene bonding. Thermoplastics in comparison to traditional glue show worse connection with the wood, caused by large difference in surface energies: PE – 38.28 mJ/m^2 and for wood - 50 ÷ 80 mJ/m^2 [Meijer *et al.* 2000]. Plastic surrounds chips, which is testified by distinct boundary between two materials, often containing defects of empty space type (Fig. 2).

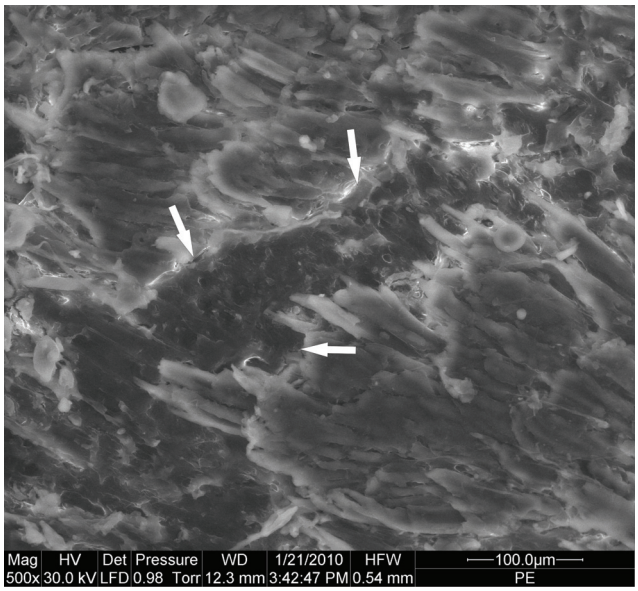

Fig. 2 Defects occurring on wood-polyethylene boundaries.

After analysis of water resistance of chipboard basic conclusion may be withdrawn, that swell and absorbability of the boards diminish significantly in relation to PE ratio increase. Boards of polyethylene ratio of 30% show swell and absorbability values similar to regular chipboard. This is caused by chips, bonded on the basic of mechanical clamps when moistened, show tendency to loosening. Swelling wood forces cementing thermoplastic out, causing loosening of the board's structure. This process is intensified by relatively small samples (50 mm x 50 mm x thickness) used in this experiment. Boards with 70% polyethylene after 24h soaking show swell of 5,9 % and absorbability of 29,1 %, witch means 70 % and 65 % less than control boards. This phenomena is caused by tighter locking of chips by thermoplastics, which means limited contact with water.

Table 4 Physical properties of polyethylene bonded boards

Wood/PE ratio	Swell				Absorbability				Surface absorption	
	2 h		24 h		2 h		24 h			
	%	%[1]	%	%[1]	%	%[1]	%	%[1]	g/m^2	%[1]
70 / 30	40,1	12	43,0	14	71,6	7	77,4	9	2920	9
50 / 50	11,6	18	14,7	17	37,0	14	44,6	12	1048	10
30 / 70	4,4	18	5,9	14	24,4	20	29,1	16	436	5
100 / 0[2]	15	9	20	10	80	9	85	10	5158	5

[1] variation coefficient, [2] control board

Significant improvement in water resistance in thermoplastics bonded chipboard shows up with surface absorption tests. Unlike in other cases, water affects only boards‘ surface. At 30% polyethylene surface absorption drops by 40%, from 5158 g/m^2 of control board to 2920 g/m^2 of polyethylene-bonded ones.

CONCLUSION

Waste polyethylene can be utilized for chip bonding in technology similar to classic chipboard production. Boards bonded with polyethylene with similar average density and density distribution usually show loss of strength properties in comparison to regular chipboard. However, especially with higher thermoplastics percentage water resistance is better.

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