Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No 74, 2011: 82-85
(Ann. WULS-SGGW, Forestry and Wood Technology 74, 2011

Mechanical properties of wood-polymer composites with different polymers

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Abstract: *Mechanical properties of wood-plastic composites with different polymers.* The paper presents the investigations into possibilities of using industrial wood particles to produce wood-plastic composites based on HP-LD, HP-HD, PP and PVC polymers. The specimens were made by injection moulding. Mechanical properties in tension and bending and impact strength were determined. Tested mechanical properties of WPC significantly depend on the kind of a polymer used.

Keywords: wood-plastic composite, WPC, mechanical properties, industrial wood particles

INTRODUCTION

Rising demand for composite materials, including wood-plastic composite (WPC), entails their continuing development and improvement. From among them are those particularly in demand that, having sufficient mechanical properties, are at least partially biodegradable. WPC is a composition of a polymer and lignocellulose particles, the latter being most often wood flour or fibres of annual plants. In comparison with wood WPC is characterised by higher resistance to changing atmospheric conditions. This property makes WPC a better substitute for wood, e.g. in producing pieces of garden architecture. Mechanical properties of WPC depend on many factors such as a kind of a used polymers, wood species, filler content or a size of a used wood particle. The effect of a size of a wood particle on WPC's mechanical properties was investigated by, among others, STARK 1999, STARK and ROWLANDS 2003, MIGNEAULT et al. 2008, BOUAFIF et al. 2009, PAN et al. 2009, GOZDECKI et al. 2011. They have shown that using larger wood particles generally results in greater mechanical properties. An important ecological aspect is also a possibility of re-using of used wood. GOZDECKI et al. 2007, CHEN et al. 2006 have shown a possibility of using waste wood for filling WPC. Apart from smaller wood particles with dimensions similar to those of wood flour the wood industry also generates considerably larger particles. The effect of using coarse wood particles as a filler in WPC on mechanical properties of a composite was also studied by GOZDECKI et al. 2008. They proved that coarse wood particles used in producing a core layer of particleboard can be employed for filling a polypropylene matrix, and that WPCs with coarse particles show good mechanical properties.

A very important factor that affects mechanical properties of a composite is a polymer used. Polymers most frequently used worldwide for producing WPC are PP, PVC and PE. Using a given type of a polymer very often results from economic reasons or local traditions, with mechanical properties being considered as less important. Therefore, investigations were carried out 1) to determine a possibility of using industrial wood particles a filler in various types of polymers and 2) to compare mechanical properties of the composites made of industrial wood particles and various types of polymers, produced by injection moulding.

MATERIALS AND METHODS

Industrial soft wood particles (WPs) used for manufacturing three-layer particleboards, fine particles for face layers and coarse particles for a core layer, were employed as a raw wood material. They were supplied by Kronospan Szczecinek (Poland). The particles were screened by an analytical sieve shaker LAB-11-200/UP using the sieves of 60 and 5 meshes to obtain particle sizes: 0.25-4 mm. WPs smaller than 0.25 and larger than 4mm were removed. As a matrix were employed four kinds of polymers: (1) - the polyethylene PE-LD Malen E FABS, 23-DO22 obtained from Basell Orlen Poliolefins (density 920 kg/m^3), (2) – the polyethylene PE-HD Tipelin 550-13 produced by Basell Orlen Poliolefins (density 956 kg/m^3), (3) - the polypropylene hompopolymer Moplen HP 648T obtained from Basell Orlen Poliolefins, (density 900 kg/m^3), and (4) - the PVC based on POLANVIL S-58 obtained from Anwil S.A. (bulk density 595 kg/m^3). Wood particles were mixed in a ratio of 40/60% - wood/polymer, with each of the polymers separately. Test specimens were made by injection moulding using a screw injection moulding machine Wh-80 Ap, using the standard temperature program for wood flour-polymer composites.

The mechanical properties of the obtained WPCs were evaluated according to standard procedures. Tensile and flexural properties were determined according to EN ISO 527 and EN ISO 178, respectively. Cross-head speed was 2 mm/min. Unnotched Charpy impact strength tests were conducted according to EN ISO 179. Ten replicates were run for each test. All tests were performed at room temperature (21^{o}C) and constant relative humidity (50%).

RESULTS

Mean values of the tensile modulus and strength, the flexural modulus and strength, and the impact strength of the tested WPCs are given in Figure 1. The significance of the difference between mean values of a given property was evaluated by Tukey's HSD test. The same letters, indicates that there is no significant difference (at $\alpha = 0.05$) for a given property between compared composites with different kinds of polymers.

In general the mechanical properties of tested WPCs substantially depended on a kind of polymer used. When analyzing the results one can observe that both during tension and flexural tests the highest values were obtained for PVC based composites. The moduli of elasticity in tension and bending of PVC based composites are on average higher by about 5.7 times than those of the PE-LD based composite, by about 1.9 times than that of the PE-HD based composite, and by about 1.5 times than that of the PP based composite. Similar features were observed for the composites' tensile and bending strengths. The strengths of the WPC with PVC are on average greater by about 3.8 times than those of the WPC with PE-LD, by about 1.6 times than those of the WPC with PE-HD, and by about 1.5 times than those of the WPC with PP, with the differences between the strengths of the composites based on PE-HD and PP being statistically insignificant.

Different features can be observed during impact strength tests. The greatest force necessary to destroy WPC in a dynamic test was noticed in the PE-HD based composite. Slightly lower values of impact strength, on average by 1.3 times, were observed for the composites based on PP and PVC, and about 1.8 times for the WPC with PE-LD. There were noted no statistically significant differences between the composites based on PP and PVC.

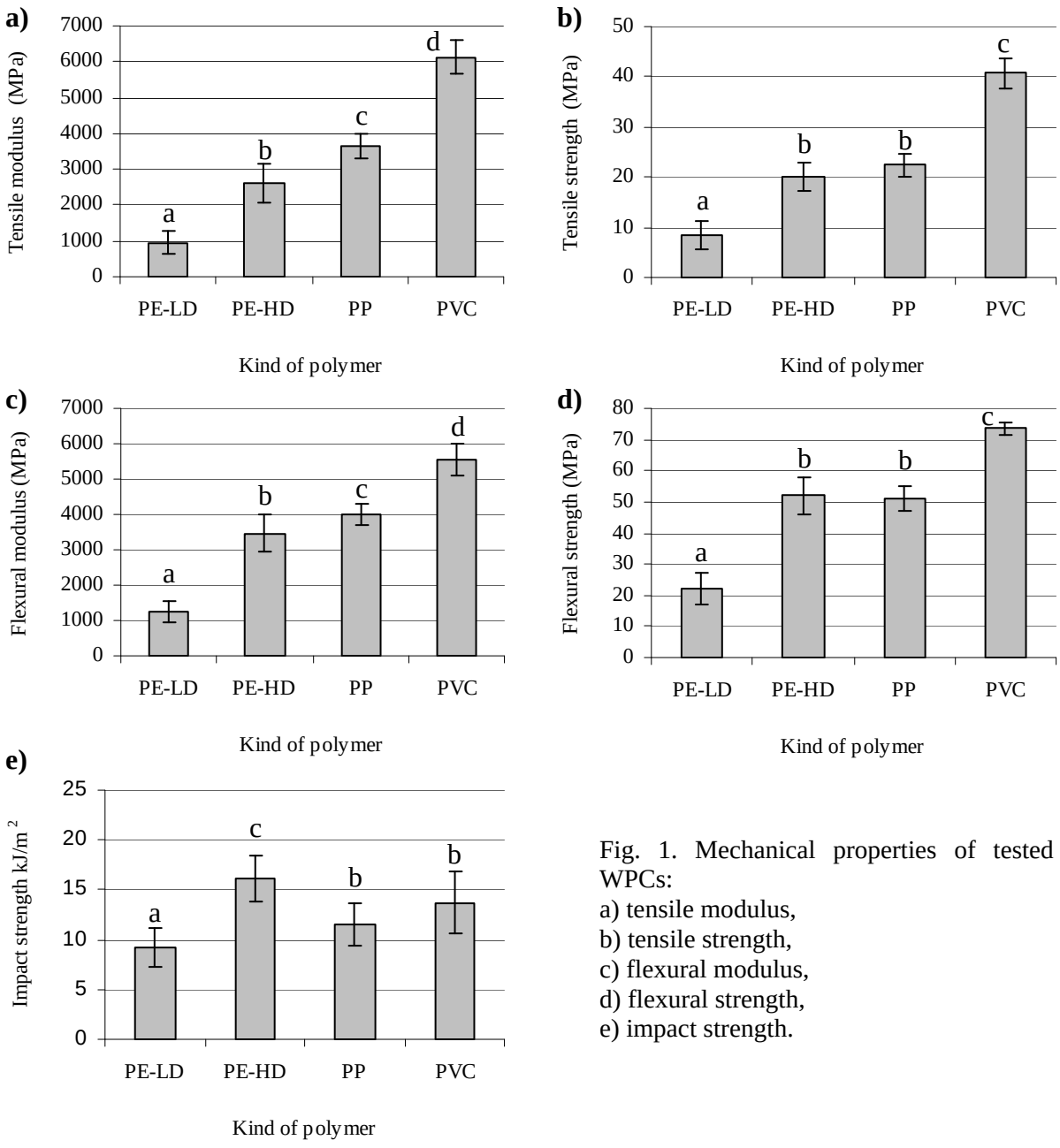

Fig. 1. Mechanical properties of tested WPCs:
a) tensile modulus,
b) tensile strength,
c) flexural modulus,
d) flexural strength,
e) impact strength.

CONCLUSIONS

1. The industrial WPs used for producing particleboard can be efficiently used for fabrication of WPC based on PE-LD, PE-HD, PP and PVC by means of injection moulding.
2. In general, the mechanical properties of the tested WPCs substantially depended on a kind of polymer used. The greatest mechanical properties in tension and flexural tests were possessed by the PVC based composite and the lowest by the PE-LD based composite.
3. The PP based composites have slightly greater moduli of elasticity in tension and bending compared with the PE-HD based WPC, whereas the tensile and flexural strengths of both composites do not differ statistically.

4. The greatest force necessary to destroy WPC in a dynamic test noticed in the PE-HD based composite. Slightly lower impact strength values were recorded for the composites based on PP and PVC and the lowest ones for the LD-PE based WPC.

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Streszczenie: *Właściwości mechaniczne kompozytów drzewno-polimerowych z różnymi polimerami.* W pracy opisano badania nad możliwością zastosowania przemysłowych wiórów drzewnych stosowanych do produkcji płyt wiórowych do wytwarzania kompozytów drzewno polimerowych na bazie czterech rodzajów polimerów. Próbki wykonano metodą wtryskiwania. Wyznaczono właściwości mechaniczne przy rozciąganiu, zginaniu oraz udarność metodą Charpy. Stwierdzono, że właściwości mechaniczne badanych kompozytów istotnie zależą od rodzaju użytego polimeru..

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