Some Exploitation Properties of Wood Plastic Composites (WPC) Based on High Density Polyethylene (HDPE) and Plywood Production Waste

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Abstract. A lot of researchers are connected with partially green, biocomposites producing and investigations. Various of polymer matrices, mainly polyolefines, reinforcement-natural fibres and their combinations are used. Our studies are focused on high density polyethylene based biocomposites, containing investigation results of plywood production by-product sanding dust (PSD) exploitation properties (flexural strength and modulus, impact strength, microhardness, and water uptake). Also, the fluidity of composite melts was noted, but the fracture mechanism of the composites tried to clear up with SEM studies. For wood plastic composites (WPC) modification coupling agents maleated polypropylene (MAPP) and polyvinylbutyral (PVB) were used.

Introduction

During the last 20-30 years many researchers have paid attention to the studies of exploitation properties of wood polyolefine composites (WPC) [1-7]. The most useful from the wide selection of polyolefines are high density polyethylene (HDPE) or polypropylene, but as reinforcement of WPC different waste materials comprising lignocellulose fibres often are used. Such materials also are a lot of waste which arises, for example, in plywood production industry [8]. In this work for reinforcing of HDPE we approbated one of the by-product-plywood sanding dust (PSD), which contain fractions of wood fibres with different length (l). The main fraction (68%) are fibres with length of l=0.25-0.5 mm. Our previous studies [8] showed that plywood sanding dust (PSD) is promising filler for PP reinforcing. Additions of the PSD up to 40 wt.% increase tensile and flexural modulus, but decrease deformation ability of PP matrix, impact strength, water resistance and fluidity of composite melts. Modification of composites with interfacial modifier maleated polypropylene (MAPP up to 5-7 wt.%) considerably improve all the above-mentioned properties. Also, very popular matrix for preparing WPC also is different types of recycled HDPE [4,9]. In the work [9] was shown that for composites based on virgin HDPE, recycled rHDPE and grinded coniferous tree (pine) shavings (length of wood fibres up to 0.5 mm) properties considerably increase: flexural strength up to 2, but modulus up to 3 times to compare with pure polymer matrices. Maximum bending deformation and impact strength values decrease till 1.2-1.8% and 6.28, 4.61 kJ/m² for rHDPE and virgin HDPE respectively. All WPC practically do not swell in water and total amount of absorbed water after 250 h water uptake is not more than 4-8%. Noteworthy, microhardness of the samples increase (2-3 times) from 70 MPa for rHDPE up to 150-200 MPa for composites with 50-60 wt.% of the wood fibres. It means, that it is possible to use these systems for production of WPC materials and different products from WPC. The goal of this study was to determine plywood production by-product plywood sanding dust (PSD) influence on some virgin HDPE composites physical-mechanical and other exploitation properties.
Materials and methods

As a polymer matrix virgin HDPE type Liten PND 33-300, (MFI=15.58g/10min.) was used. Filler was plywood production by-product birch wood plywood sanding dust (PSD) and content in the composites were (30, 40, 50, 60 wt.%). As an interfacial modifier maleated polypropylene type Licocene PP MA-7452 (1,3,5 wt.%) and polyvinylbutyralgrade B 60HDE (content 5,10 wt.%) were used.

Composites were prepared by mixing on a two-roll mill, then cooled, granulated and pressed in 1 mm thick sheets for microhardness measurements by Vikers M-41. Flexural and impact strength tests were done for standard specimens (EN ISO 178 and ASTM D 256M respectively), bars produced by injection moulding. Melt fluidity (melt flow index-MFI) was estimated by standard ASTM D 1238. Water resistance measurements were done according to standard ASTM D 570-88. Microstructure of the fracture surface of specimens were examined with scanning electronic microscope Vega Tescan 5136 MM. Au-sputtering was used.

Results and discussion

First of all, for clearing up of the optimal content of plywood sanding dust (PSD) in HDPE some physical-mechanical test measurements for the composites with different amount of PSD fibres were done. Results of these experiments are given in Table 1.

| Parameters                      | Concentration of PSD, wt.% |
|---------------------------------|----------------------------|
|                                 | 0  | 30 | 40 | 50 | 60 |
| Flexural strength, MPa          | 17.20 | 25.46 | 26.74 | 27.06 | 26.72 |
| Flexural modulus, MPa           | 449.3 | 1222.5 | 1558.8 | 1863.0 | 2218.9 |
| Maximum of bending deformation, mm | 12.13 | 8.26 | 5.31 | 3.33 | 2.50 |
| Impact strength, kJ/m²          | 26.03 | 13.31 | 7.50 | 5.78 | 4.90 |
| Microhardness, MPa              | 58.57 | 75.05 | 92.56 | 112.96 | 115.74 |

From presented results (see Table 1) we can conclude, that all investigated properties improve with increase of PSD content in composites up to 50 wt.%. Extension of the filler content till 60 wt.% give only small increases of microhardness and flexural modulus, but decreases flexural and impact strength. If it is necessary to process gained composites in different products, then very important parameter is fluidity of the composite melts which is able to evaluate by melt flow index (MFI) measurements. PSD loading in HDPE considerably (more than 20 times) diminish polymer matrix fluidity from 15.6 g/10min. for virgin HDPE till 0.62 g/10 min. for system with 60 wt.%. Such a dramatic decrease of MFI values can make worse possibilities to process these materials in different products, especially by injection molding method. Bearing in mind previous physical-mechanical experimental results and fluidity of the composite melts, as the optimal content of PSD in a composite was chosen 50 wt.%.

For improving WPC exploitation properties, frequently coupling agents like maleated polypropylene (MAPP) are used [1,6,8]. Additions of the MAPP and PVB to HDPE+50 wt.% PSD in the aggregate improve exploitation properties of these composites (see Table 2).
Flexural strength increase up to 28.98 MPa (3 wt.% MAPP) and modulus up to 2067.5 MPa (5 wt.% PVB). Impact strength properties of composites was optimal at 3 wt.% MAPP concentration. At the same time, melts of these composites maintain rather good fluidity (MFI values are 2.65 and 2.4 g/10 min. for composites with 50 wt.% PSD+3 wt.% MAPP and 50 wt.% PSD+5 wt.% PVB respectively). The greatest microhardness shows composites containing 50 wt.% PSD (112.96 MPa) and 50 wt.% PSD + 3 wt. % MAPP (155.26 MPa). It is well known fact [1,2], that coupling agents like MAPP promote better distribution of lignocellulose fibres in polymer matrix, intensify interfacial interaction between polar fibres and nonpolar polyolefine matrix. Obviously, these phenomenons take place also in investigated systems, for example microhardness increase up to 155.3 MPa. From this point of view and bearing in mind high cost of MAPP, as optimal concentration of the MAPP in composite we chose 3 wt. %. Besides, at the higher concentrations of the MAPP can be observed its plasticizing influence on WPC properties [1,8]. Our presented investigations also showed positive influence of the MAPP on WPC melts fluidity. MFI values increase at the presence of MAPP from 2.15 g/10min. for nonmodified system up to 2.65 and 3.4 g/10min. for composites with 3 and 5 wt.% MAPP correspondingly. Additions of interfacial modifier (3-5 wt.% MAPP) also promote the increase of water resistance (see Fig.1). Water absorption after 28 days water uptake decreases from 10% for unmodified composite (curve 1) till 5.7-6% for modified with 3 and 5 wt.% MAPP systems (curves 2,3) that indicates positive action of the MAPP, strengthens interfacial adhesion between components. Samples thickness swelling also is small at the presence of the MAPP and fluctuate in the range of 1-2%.

![Figure 1. Water absorption kinetics of high density polyethylene (HDPE) composites. 1- HDPE+50 wt.% PSD, 2- HDPE+50 wt.% PSD + 3 wt.% MAPP, 3- HDPE+50 wt.% PSD+5 wt.% MAPP, 4- HDPE+50 wt.% PSD +5 wt.% PVB, 5- HDPE+50 wt.% PSD+10 wt.% PVB.](image-url)
Fig. 2 a,b. Scanning electron microscopy pictures (SEM) of the fracture surface of specimens made from different composites: a-HDPE+50 wt.% PSD, b-HDPE+50 wt.% PSD + 3 wt.% MAPP.

In order to clear up coupling agent influence on the strengthening effect of composites and fillers distribution degree in polymer matrix, scanning electron microscopy (SEM) investigations were used (see Fig. 2 a,b). Looking over SEM pictures, replicas of a fracture surface of unmodified material (Fig. 2 a) partially or completely uncovered particles are observed. This indicates poor interfacial interaction between wood fillers and high density polyethylene. Besides, distribution of the fibres in polymer is irregular. Coupling agent MAPP additives strengthen border between wood fibres and HDPE that provides evidence, that interface surface only partially is broken (see Fig. 2 b) and the fine particles in polymer matrix hold well. SEM studies once more confirmed the fact of strengthening the interfacial
adhesion between wood fillers and HDPE matrix as a result of the action of the MAPP, that evidently gives increase in exploitation properties of the wood (PSD) high density polyethylene composites.

**Conclusion**

1. Wood (PSD) high density polyethylene composites physical mechanical properties studies showed that loading of PSD considerably increase flexural strength, modulus and microhardness of WPC and optimal concentration of plywood sanding dust content in HDPE could be 50 wt.%.

2. Modification of WPC with MAPP and PVB showed that coupling agents improve actually all exploitation properties of HDPE+50 wt.% PSD composites compared to unmodified systems and optimal content of the MAPP is 3-5 wt.% Particulary, remarkable decrease of water absorption and the best water resistance was demonstrated by composites with 5 wt.% MAPP.

3. SEM studies confirmed the MAPP strengthening effects of the interfacial adhesion between wood fillers and high density polyethylene matrix and plywood production by-product sanding dust (PSD) is useful for preparing wood plastic composites based on a high density polyethylene.

**References**

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