

SELECTED ASPECTS OF WEAR AND SURFACE PROPERTIES OF POLYPROPYLENE BASED WOOD-POLYMER COMPOSITES

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Abstract: The work demonstrates selected results of the investigations on surface properties and wear resistance of polypropylene based wood-polymer composites (WPC) reinforced with wood flour. WPC are broadly applied in construction and automotive sectors, where mechanical, thermal as well as moisture absorbing characteristics are of great importance. In order to get information about wear resistance of such composites Taber wear test is applied. Surface properties are investigated before and after tribological test. Contact angle values of the investigated compositions are compared after different wear periods (0, 2000, 5000 and 10000 cycles) with abrasives H22 and CS17.

Keywords: biocomposites, WPC, Taber, contact angle.

1. INTRODUCTION

Polypropylene (PP) is the most used polymer material in Europe finding applications in automotive, construction, packaging, design and many other industries [1]. PP is broadly used in composite materials, containing functional additives to enhance raw polymer properties. Inorganic fillers as talc or chalk, traditionally used as low price components, nowadays are mostly applied as reinforcement additive for pipe and profile. In size of 6–10 μm they increase not only stiffness of composite but also impact strength and deformation [2]. High barrier properties and low flammability are also desired in many applications; however designated master batches usually have higher price than raw PP. By developing new formulations of composite materials environmental and human health aspects of ingredients should be considered. One of the main development directions of European Union is Green technology: biopolymers, environment friendly materials, biodegradable materials etc. Customers prefer “green” materials with no effect on health and price as low as possible. In many cases it’s possible to use recycled PP (in some cases price can go down 5 or more times as PP price generally depends from it synthesis process and less from oil price) [3], but at the same time many applications, especially food contact applications, cannot contain recycled materials. Therefore, the preferred way to produce new materials – use of green organic fillers and additives as reinforcements for polymer composites. Nowadays most popular are wood-polymer composites (WPC). Grain husks, cellulose microfibrils and some other natural materials have a great future for use as reinforcements from both theoretical and practical aspects. Although at the moment these materials, available as industrial by-products, are either landfilled or used to obtain energy, they have a potential to be used as reinforcements in WPC composites for both indoor and outdoor applications. Addition of such natural reinforcements usually allows to increase stiffness as well as other mechanical properties of matrix polymer. Increased water absorption and swelling of such composites still remains a problem and consequently are of great practical and also scientific interest. There is only limited information about wear resistance, as well as scratched or worn surface analysis of such WPC. Main goal of this investigation to make conclusions about the effects of the roughness of the abrasive as well as the amount of abrasion cycles on the wear resistance and surface properties of WPC made from PP and 40 wt.% wood flour. Surface wear dynamics and change in hydrophilic/hydrophobic behaviour are important for floor and some other heavy duty applications [4–7].

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2. EXPERIMENTAL

2.1. MATERIALS

As matrix we used injection moulding grade polypropylene homopolymer HP400R from Bassel-Orlen, Poland, with high flowability, MFR = 25 g / 10 min. (230 °C / 2.16 kg). As filler we used commercial micro-fibres made of the industrial grade softwood flour Jeluxyl Weho500 from Jeluwerk, Germany. Jeluxyl Weho500 consists of a mix of European spruce (*Picea abies*) and silver fir (*Abies alba*). A polypropylene to wood flour weight ratio of 60/40 was used for composite in this investigation. As a compatibilizer between the non-polar matrix and the polar lignocellulosic fibres maleic acid anhydride grafted PP wax (MAH-g-PP) TP Licocene PP MA 6452 from Clariant, Germany, was applied in the amount of 3.3 wt.% in relation to the matrix.

2.2. PROCESSING

Wood flour was dried for 16 hours at 103 °C in thermal chamber with ventilation. All components were weighted with precision 0.01 g in proportion as indicted above and dried once more for 4 hours. After drying process finished materials were immediately placed in desiccator with CaCl₂ and stored till extrusion. Extrusion was made using two-screw co-rotating extruder/compounder L/D 16 PRISM TSE 16 TC, from Thermo Electron Corporation. Thermal profile was 170, 175, 180, 185, 190 °C. After extrusion material cooled down and cut in pellets, then mixed for second time for better homogenisation. After than extruded material was dried once more for 4 hours and then rectangular plates were moulded using compression moulding machine Scientific LP-S-50/ASTM, from Labtech Engineering, Thailand. Compression moulding was done at 200 °C with preheating time 5 min, pressing time 5 min, pressure 5 MPa and ramp cooling till 40° temperature at cooling rate of 15 °C / min. 2 mm thick square plates with side dimension 10 cm were obtained. In a centre of the sample 6.3 mm hole was drilled for the wear test.

2.3. TESTING METHOD

Wear test was made using Taber rotary abraser 5135, from Taber Industries, USA. Two series of experiments were made under load of 1000 g using either CS17 and H22 abrasives for medium rough and heavy abrasion respectively. In both cases rotating speed was 72 rpm and rotating distance – 2000, 5000 and 10000 cycles.

Contact angle was measured using optical tensiometer Attension Theta, from Biolin Scientific, Finland. Sample with appropriate dimensions was cut from the compression moulded plate and placed on the sample holding desk of the equipment. Then drop of the test liquid was placed on the surface of the sample and contact angle was automatically measured. Two types of polar liquids were used: distilled water ($\leq 1 \mu\text{S}$) and glycerol.

3. RESULTS AND DISCUSSION

Taber wear test was made in dry condition at room temperature. Weight loss calculated according to equation (1). Taber index was calculated according to equation (2). Samples were weighted before and after the test, as given in table 1.

$$W_l = m_0 - m_1 \quad (1)$$

W_l – weight loss;

m_0 – weight before test;

m_1 – weight after test.

$$I = \frac{w_l * 1000}{\text{test cycle}} \quad (2)$$

W_l – weight loss, mg;

test cycle – 0, 2000, 5000, 10000.

Table 1. Sample weight before and after test.

Abrasive	Cycles	Weight before test, m_0 , g	Weight after test, m_1 , g	Weight loss, WL, g
0	0	–	–	–
H22	2000	14.58588	14.46387	0.12201
H22	5000	15.51812	15.24124	0.27688
H22	10000	15.46485	15.05473	0.41012
CS17	2000	15.49232	15.45712	0.03520
CS17	5000	15.44651	15.35075	0.09576
CS17	10000	15.41425	15.13064	0.28361

Figure 1 shows that wear loss increases by increasing test duration. In the case of H22 abrasive wear loss is higher than in the case of CS17 abrasive. Heavy duty abrasion discs cause wear loss speed decrement at higher wear cycles, it can be explained by worn material filled abrasive and test couple changed from abrasive/material to almost material/material couple. In the case of CS17 abrasive wear is greatly influenced by the presence of harder polymeric surface layer. Only after removal of this layer (which occurred later than in the case of H22 abrasive induced wear) wear of the material gained as testified by increased weight losses. Comparing Taber indexes of investigated composites subjected to wear by H22 and CS17 abrasives, tests show that in the case of heavy abrasive disc induced wear Taber index value of the composite decreases with experiment time. In the case of medium abrasion Taber index of the composite increases with increasing of wear cycles similarly as wear loss.

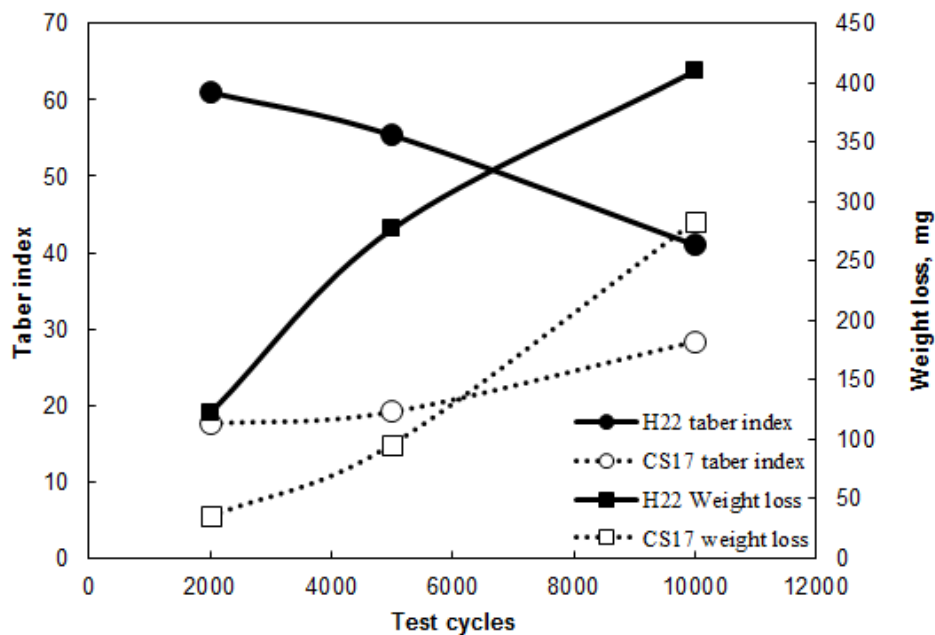


Figure 1. Taber index and wear loss as function of wear cycle.

Before and after wear surfaces of the composite samples were tested for a contact angle with different viscosity fluids. As shown in figure 2, contact angle decreases by increasing the amount of wear cycles of both abrasives. Distilled water tests results show that heavier abrasion faster wears the outer polymer layer and the uncovered composite surface becomes more hydrophilic. More interesting that in the case of H22 worn surfaces the contact angles for water and glycerol are almost similar, that could be affected by higher roughness of the sample overwhelming the effects of the wetting fluids due to their different viscosities. For medium wear CS17 abrasive worn surfaces contact angles for water and glycerol show higher deviation (smaller contact angle for more viscose glycerol and higher – for lower viscosity water).

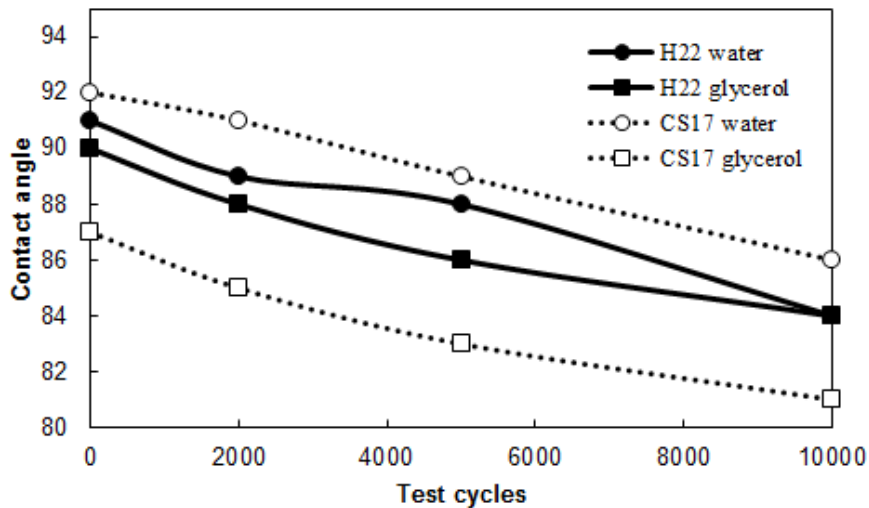


Figure 2. Contact angle as function of wear cycle.

4. CONCLUSIONS

Wear tests of wood polymer samples showed that they have relatively high surface wear resistance. Inner layers of the tested composite samples appeared to be more loose and showed greater wear especially if heavy abrasion abrasive H22 was used. Contact angle measurements demonstrated that after removal of outer polymer layer, the uncovered surface of the material became more hydrophilic (contact angle values decreased). Roughness of the composite sample has a great effect on contact angle of WPC composites.

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