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Effect of wood flour type on flexural properties of wood-plastic composites

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Abstract: *Effect of wood flour type on flexural properties of wood-polymer composites.* The aim of the study was to determine an effect of the size of wood flour and filling ratio on the mechanical properties of wood-plastic composite. The composites were made from two types of wood flour and PVC. Mechanical properties (flexural modulus and flexural strength) were determined. It was found out that mechanical properties of composite substantially depend on the type of wood flour and filling ratio.

Key words: wood-plastic composite (WPC), mechanical properties, wood flour

INTRODUCTION

An increasing popularity of wood-plastic composites (WPCs) entails their new applications. Nowadays WPCs are being used both indoors and outdoors. These applications nececessitate producing such WPC that would meet specified technical requirements One of the most important properties considered in evaluating composite materials is their mechanical properties. The mechanical properties of WPCs depend on many factors. One of the major factors affecting properties of a wood component are e. g. wood species, wood content, coupling agent and wood particle size. Most of these factors have been vastly studied, whereas there are relatively few studies on the effects of a wood particle size. The effect of this factor on WPC mechanical properties was mainly evaluated for typical WPCs containing small wood particles (Stark and Rowlands 2003; Salemane and Luyt 2006; Kumari et al. 2007; Pan et al. 2009, Cui et al. 2008; Migneault et al. 2009; Bouafif et al. 2009) or coarse wood particles (Gozdecki et al. 2008. Gozdecki et al. 2011; Gozdecki et al. 2012; Kociszewski et al. 2012;). Generally it was found out that increasing a wood particle size increased mechanical properties of WPC, however, the divergence of the results of these studies is difficult to interpret. It is due to many factors, mainly such as a type of thermoplastic, wood content, wood particle geometry, coupling agent content or processing method.

A basic kind of wood filler used in manufacturing WPCs is wood flour (WF) which is produced in many countries around the world in a variety of sizes. Very often manufacturers of WPC at random choose the type and size of WF. This is often due to insufficient knowledge of the effects of WF sizes on the properties of WPC. Therefore, the aim of the study was to determine an effect of a WF size and filling ratio on the mechanical properties of WPC.

MATERIALS AND METHODS

Investigations were made into the composites whose matrix was the PVC POLANVIL S-58 obtained from Anwil S.A. (Poland). Its bulk density was 0.595 g/cm^3. Two kinds of typical soft wood flour L9 (mesh 35-16) and C120 (mesh 170-100) obtained from J. Rettenmaier & Söhne GmbH+Co. (Germany) (Fig.1) was used as a filler.

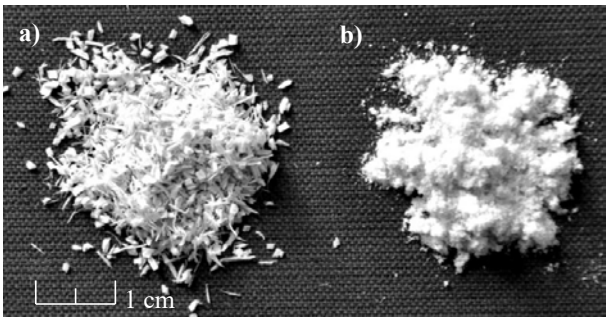

Fig. 1. Wood flour: a) L9, b) C120

All the wood components were dried at 100oC in an air-circulation oven for 24 hours in order to achieve a moisture content of less than 3%. Afterwards the WFs were mixed with PVC at 40% by weight, separately.

Test specimens were made by injection moulding using an AH-80 screw injection moulding machine, according to EN ISO 527. Next they were kept under laboratory conditions (at a temperature of 20°C and humidity of 50 %) for 7 days. In this way two kinds of WPC were obtained: PVC with WF L9 (PVC/L9) and PVC with WF C120 (PVC/C120).

Their mechanical properties were evaluated according to standard procedures. Flexural properties were determined according to EN ISO 178. Cross-head speed was 2 mm/min. Ten replicates were run for each test. All tests were performed at a room temperature of 20oC and a constant relative humidity of 50%.

RESULTS

The results of the ANOVA test on the effect of the WF kind and filling ratio on the mechanical properties of wood-polymer composite are presented in Table 1. The results of this analysis show that all mechanical properties vary significantly depending on the kind of WF and filling ratio. The interaction between these two variables is significant only for the flexural modulus.

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Table 1. Two-way ANOVA test on the effects of WF kind and filling ratio on WPC mechanical properties (p-values).

Variable	Flexural modulus	Flexural strength
WF kind	<0.0001*	0.0042*
Filling ratio	<0.0001*	<0.0001*
WF kind x filling ratio	0.0005*	0.4878 ^{ns}

*Denotes significance at 0.01; ns-non significant at 0.05.

In order to determine the effect of the filling ratio on the flexural properties, the specimens with different WFs and the same filling ratio were included in one group. The mean values of mechanical properties for these groups are presented in Table 2. Tukey's test was used to evaluate statistical significance between mean values of mechanical properties of WPCs with different filling ratios. The values marked with the same letter for a given property are not significantly different at the 5% significance level.

Table 2. Effects of filling ratio on WPC mechanical properties.

Filling ratio	Flexural modulus	Flexural strength
10	3.50[a]	50.5[a]
20	3.88[b]	38.0[b]
30	4.33[c]	31.5[c]

Mean values marked with the same letter for a given property are not significantly different at the 5% significance level

Mean values of the flexural modulus and strength of tested WPCs are given in Figs. 2 and 3.

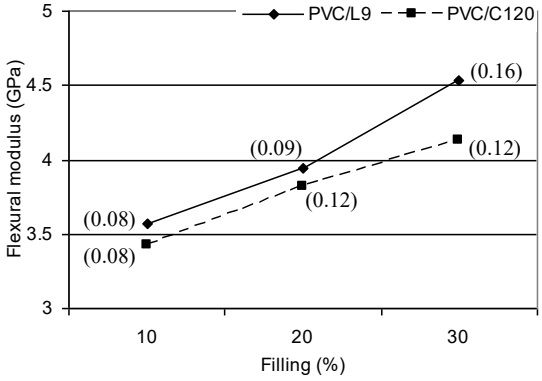

Fig. 2. Flexural modulus of tested composites. Standard deviations in parentheses

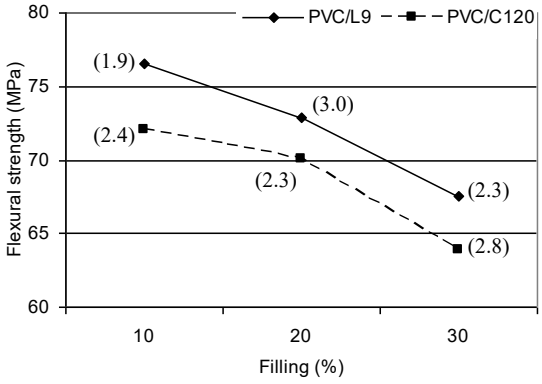

Fig. 3. Flexural strength of tested composites. Standard deviations in parentheses

It should be noted that filling WPC with WF L9 increases mechanical properties in comparison to the WPC containing WF C120. When analyzing the results (Table2, Fig.2 and 3) one can observe that these characteristics are presented for each filling ratio and for both flexural properties. The WPC containing WF L9 and filled to 10% has flexural modulus greater on average by 4%, filled to 20% on average by 3%, and filled to 30% on average by 10% than the WPC with WF C120, respectively. The flexural strength of the WPC containing WF L9 is greater than the WPC containing WF C120 for 10 % filling on average by 6%, for

20 % filling on average by 4%, and for 30 % filling on average by 6%, respectively. The greater mechanical properties of WPC/L9 than those of WPC/C120 is due to the fact that L9 is composed of larger particles than C120. Neverthelss the effect of a kind of WF on both mechanical properties is slight.
An analysis of the research results (Table2, Fig.2 and 3) shows that mechanical properties in bending of WPCs substantially depend on the quantity of filler, generally for both kinds of WPCs (PVC/L9 and PVC/C120). Increasing the filling ratio in WPC from 10 to 20 % caused an increase in flexural modulus on average by 11 %. A further increase by next 10 % caused a growth of this mechanical property on average by 12 %. A different characteristics was observed for flexural strength. Increasing filling ratio in WPC from 10 to 20 % resulted in reducing this mechanical property on average by 25 %. A further increase by next 10 % caused decreasing flexural strength on average by 17 %.

CONCLUSIONS

The investigations carried out show that the mechanical properties of WPC substantially depend on the filling ratio and kind of WF. The filling of WPC with WF L9 increases both mechanical properties in bending in comparison to the WPC containing WF C120, although the effect of the kind of WF on the mechanical properties is slight. Increasing the degree of filling of WPC with WF in a statistically significant way affects the growth of flexural modulus and decreases flexural strength.

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Streszczenie: *Wpływ rodzaju mączki drzewnej na właściwości przy zginaniu kompozytów drzewno-polimerowych.* Celem badania było określenie wpływu rodzaju mączki drzewnej, rozmiaru cząstki drzewnej i stopnia napełnienia na właściwości mechaniczne kompozytu drzewno-polimerowego. Kompozyty były wykonane z dwóch rodzajów mączki drzewnej oraz PVC metodą wtryskiwania do formy. Określono właściwości mechaniczne (moduł sprężystości przy zginaniu i wytrzymałość na zginanie). Stwierdzono, że właściwości mechaniczne kompozytu istotnie zależą od rodzaju zastosowanej mączki drzewnej i stopienia napełnienia mączką.

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