Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 91, 2015: 65-69
(Ann. WULS - SGGW, For. and Wood Technol. 91, 2015)

Effect of wood flour type on tensile properties of wood-polymer composites

CEZARY GOZDECKI, ARNOLD WILCZYŃSKI

Institute of Technology, Kazimierz Wielki University in Bydgoszcz

Abstract: *Effect of wood flour type on tensile properties of wood-polymer composites.* The aim of the study was to evaluate the effect of wood flour type on the mechanical properties in tension for two wood-polymer composites: one with polypropylene and the other with polyvinylchloride. Two types of wood flour with different wood particle size were used. The mechanical properties in tension (tensile modulus and tensile strength) were determined. It was found out that these properties for both composites substantially depend on the type of wood flour.

Keywords: wood-polymer composite (WPC), wood flour, tensile modulus, tensile strength

INTRODUCTION

Wood-polymer composites (WPCs) are good substitutes for wood, particularly in outdoor applications. They do not require painting, toxic additives and preservative treatments and they can be worked with typical tools used for woodworking. Therefore, they are becoming increasingly popular in the world. One of the advantages of WPCs is a possibility to control its properties. Some important properties considered in evaluating composite materials are their mechanical properties. These properties of WPC depend on many factors, whose effects have been the subject of many studies. The effects of wood species, kind of polymer, wood content, and coupling agent content have been mainly investigated, whereas there are relatively few studies on the effects of wood particle size. Typical WPC are made of small wood particles or short wood fibers. The effect of the size of small wood particles on WPC mechanical properties has been mainly evaluated for wood-polypropylene composites (Stark and Berger 1997, Stark and Rowlands 2003, Zaini et al 1996, Salemane and Luyt 2006, Khalil et al 2006, Kumari et al. 2007, Pan et al. 2009). Mechanical properties of WPCs with PVC as the matrix and small wood particles have rarely been studied (Bledzki et al. 1998, Takatani et al. 2000, Xu et al. 2008). Chen et al (2006), Gozdecki et al. 2008, 2011, 2012; Kociszewski et al. 2012 studied the effect of particle size on mechanical properties of WPC made of large-sized wood particles. They suggested using of large wood particles larger than 1 mm as a good alternative to a standard wood flour (WF). Generally, it was found out that increasing wood particle size enhanced mechanical properties of WPC.

The most common wood fillers used for the production of WPC is currently WF of different particle sizes and shapes, and from different wood species. This causes that manufacturers of WPCs often apply the economic criterion and do not take into account the effect of WF type on the properties of products made from WPC. Usually this is due to insufficient knowledge of the effect of WF size on the properties of WPC. The objective of the study was to evaluate the effect of particle size of typical WF on the tensile properties of WPC made of different thermoplastic polymers.

MATERIALS AND METHODS

Two types of typical soft WFs: C120 and L9, obtained from J. Rettenmaier & Söhne GmbH+Co. (Germany) (Fig.1), was used as a filler. Characteristics of these WFs are

presented in Table 1. Wood particles of WF L9 were much greater than those of WF C120. A size of WF L9 particles was 0.07-0.15 mm (170-100 mesh) whereas WF C120 particles had a size of 0.8-1.1 mm (35-16 mesh).

The polypropylene (PP) used in the study was homopolymer Moplen HP648T with a density of 0.90 g/cm^3. The polyvinylchloride (PVC) used was POLANVIL S-58 with a density of 0.97 g/cm^3. Both polymers were obtained from Anwil S.A. (Poland).

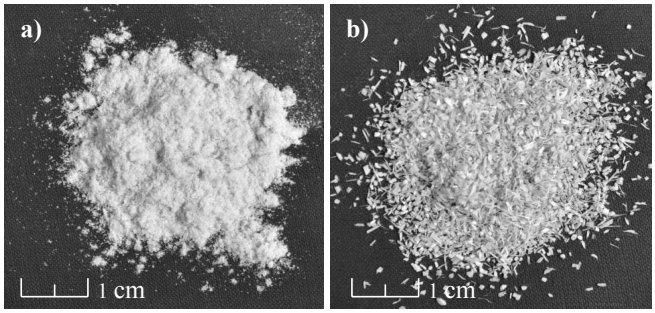

Fig. 1. Wood flour: a) C120, b) L9

Table 1. Characteristics of WFs used to prepare WPCs.

Factor	C120	L9
Strukture	fibrous	cubic/fibrous
Fraction	0.07-0.15 mm	0.8-1.1 mm
Mesh	170-100	35-16
Bulk density	100 -135 g/l	140 -210 g/l

First wood components were dried at 100 ºC in an air-circulation oven for 24 hours in order to achieve a moisture content of less than 3%. Next, the WFs were mixed with PP or PVC at 40% by weight. Test specimens were made by injection moulding using a screw injection moulding machine Wh-80 Ap. The temperature profile was 160, 175 and 180 ºC. The injection pressure time, hold pressure time and cooling time were 3, 6 and 40 s, respectively. The specimens were made according to EN ISO 527. After processing, specimens were stored under controlled conditions (50 % relative humidity and 20 ºC) for 2 weeks prior to testing. In this way four kinds of WPC were obtained: PP with WF C120 (PP/C120), PP with WF L9 (PP/L9), PVC with WF C120 (PVC/C120) and PVC with WF L9 (PVC/L9). Ten specimens were produced for each kind of WPC.

Tensile properties were determined according to EN ISO 527, using an Instron 3367 machine. Cross-head speed was 2 mm per min. All tests were performed at a room temperature of 20 ºC and a constant relative humidity of 50 %. The obtained data were statistically analyzed using the Statistica version 10.

RESULTS

Table 2 presents the results of the one-way ANOVA test on the effect of WF type on the tensile properties of WPCs. They show that both tensile properties of WPC vary significantly depending on the type of WF.

The mean values of the tensile modulus and strength of the tested WPCs are given in Figs. 2 and 3. Tukey's test was used to evaluate statistical significance (at $\alpha = 0.05$) between the mean values of tensile properties of WPCs containing different WF types. The values

marked with different letters for a given property are significantly different at the 5% significance level. Small letters represent the significance of the differences between the mean values of tensile properties of WPC containing PP. Capital letters indicate Tukey's test result of WPC containing PVC.

Table 2. One-way ANOVA test on the effects of WF kind on WPC tensile properties (p-values).

Variable	WPC with PP		WPC with PVC	
	tensile modulus	tensile strength	tensile modulus	tensile strength
WF type	<0.0001*	0.0103**	0.0016*	0.0001*

*Denotes significance at 0.01; **denotes significance at 0.05.

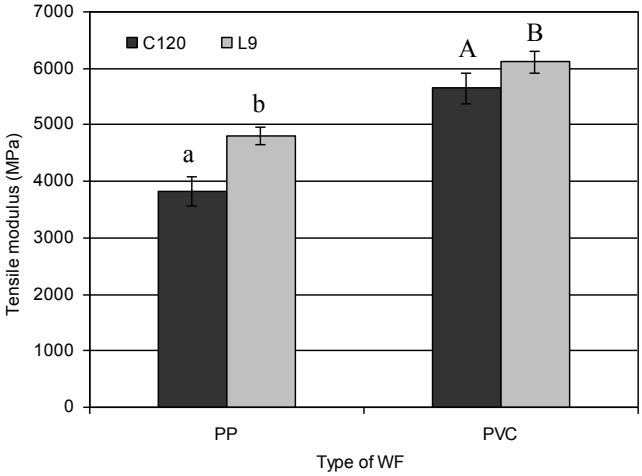

Fig. 2. Tensile modulus of tested composites. The mean values with different letters for a given property were significantly different at the 5% significance level.

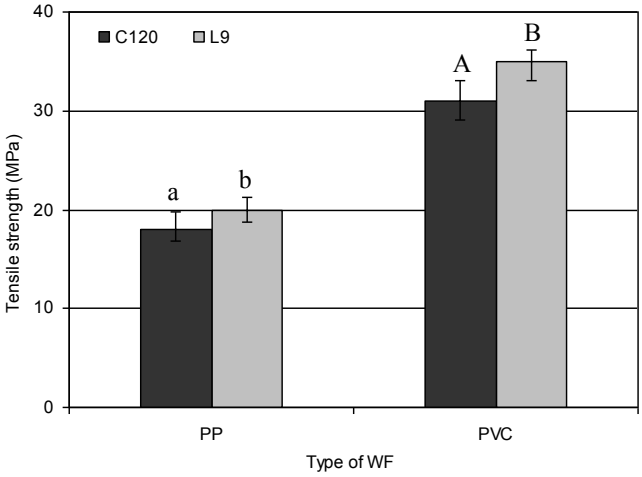

Fig. 3. Tensile strength of tested composites. The mean values with different letters for a given property were significantly different at the 5% significance level.

The use of WF L9 as a filler of WPCs increases both tensile properties in comparison to the WPCs containing WF C120. The tensile modulus of WPC with WF L9 is 26% and 8% greater than that of WPC with WF C120, for WPC with PP and PVC, respectively. The tensile strength of WPC with WF L9 is 11% and 13% greater than that of WPC with WF C120, for WPC with PP and PVC, respectively. The greater tensile properties of WPCs with WF L9 than those of WPC with WF C120 is due to the fact that particles of WF L9 are larger than particles of WF C120.

CONCLUSIONS

The tensile properties of WPCs with WF as a filler substantially depend on type of WF. WF L9 with larger wood particles provides better tensile modulus and strength of WPCs than WF C120 with smaller wood particles.

REFERENCES

1) BLEDZKI A., GASSAN J., THEIS S., 1998: Wood-filled thermoplastic composites. Mech. Compos Mater 34: 563-568
2) CHEN C., CHEN T., HSU C., 2006: Effects of wood particle size and mixing ratios of HDPE on the properties of the composites. Holz Roh- Werkst. 64:172−177
3) GOZDECKI C., KOCISZEWSKI M., WILCZYŃSKI A., ZAJCHOWSKI S., 2008: Use of coarse wood chips for fabrication of wood-polypropylene composites by means of injection molding. Annals of Warsaw Agricultural University of Life Sciences, Forestry and Wood Technology 65: 80-83.
4) GOZDECKI C., WILCZYNSKI A., KOCISZEWSKI M., TOMASZEWSKA J., ZAJCHOWSKI S., 2012: Mechanical properties of wood–polypropylene composites with industrial wood particles of different sizes. Wood Fiber Sci 44(1):14-21.
5) GOZDECKI C., ZAJCHOWSKI S., KOCISZEWSKI M., WILCZYŃSKI A., MIROWSKI J., 2011: Effect of particle size on mechanical properties of industrial wood particle-polyethylene composites. Polimery 56(5):375-380.
6) KHALIL H., SHAHNAZ S., RATNAM M., AHMAD F., FUAAD N., 2006: Recycle polypropylene (RPP) wood saw dust (WSD) composites – Part 1: The effect of different filler size and filler loading on mechanical and water absorption properties. J Reinforced Plast Comp 25:1291−1303
7) KOCISZEWSKI M., GOZDECKI C., WILCZYNSKI A., ZAJCHOWSKI S., MIROWSKI J., 2012: Effect of industrial wood particie size on mechanical properties of wood-polyvinyl chloride composites. Eur J Wood Prod 70:113-118.
8) KUMARI R., ITO H., TAKATANI M., UCHIYAMA M., OKAMOTO T., 2007: Fundamental studies on wood/cellulose-plastic composites: effects of composition and cellulose dimension on the properties of cellulose/ PP composite. J Wood Sci 53:470–480.
9) PAN M., ZHOU D., BOUSMINA M., ZHANG S., 2009: Effects of wheat straw fiber content and characteristics, and coupling agent concentration on the mechanical properties of wheat straw fiberpolypropylene composites. J Appl Polym Sci 113:1000–1007.
10) SALEMANE M., LUYT A., 2006: Thermal and mechanical properties of polypropylene-wood powder composites. J Appl Polym Sci 100:4173–4180.
11) STARK N., BERGER M., 1997: Effect of particle size on properties of wood-flour reinforced polypropylene composites. Pages 134-143 *in* Proc Fourth International

Conference of Wood Fiber-Plastic Composites. May 12-14, 1997. Portland, Madison WI.
12) STARK N., ROWLANDS R., 2003: Effects of wood fiber characteristics on mechanical properties of wood/polypropylene composites. Wood Fiber Sci 35(2):167–174.
13) TAKATANI M., ITO H., OHSUGI S., KITAYAMA T., SAEGUSA M., KAWAI S., OKAMOTO T., 2000: Effect of lignocellulosic materials on the properties of thermoplastic polymer/wood composites. Holzforschung 54:197−200
14) XU Y., WU Q., LEI Y., YAO F., ZHANG Q., 2008: Natural fiber reinforced poly(vinyl chloride) composites: Effect of fiber type and impact modifier. J Polym Environ 16:250-257
15) ZAINI M., FUAD M, ISMAIL Z., MANSOR M., MUSTAFA J., 1996: The effect of filler content and size on the mechanical properties of polypropylene/oil palm wood flour composites. Polym Int 49:51−55

Streszczenie: *Wpływ rodzaju mączki drzewnej na właściwości mechaniczne przy rozciąganiu kompozytów drzewno-polimerowych.* Celem badań była ocena wpływu rodzaju mączki drzewnej na właściwości mechaniczne przy rozciąganiu dwóch kompozytów drzewno-polimerowych – kompozytu drewno-polipropylen i kompozytu drewno-polichlorek winylu. Uwzględniono dwa rodzaje mączki drzewnej o różnej wielkości cząstek drzewnych. Wyznaczano moduł sprężystości przy rozciąganiu i wytrzymałość na rozciąganie kompozytów. Stwierdzono, że właściwości te dla obu kompozytów istotnie zależą od rodzaju zastosowanej mączki drzewnej.

Corresponding author:

Cezary Gozdecki
Institute of Technology,
Kazimierz Wielki University
Chodkiewicza 30 str.
85-064 Bydgoszcz, Poland
e-mail: gozdecki@ukw.edu.pl