Polymer Testing 27 (2008) 801–806

Contents lists available at ScienceDirect

Polymer Testing

journal homepage: www.elsevier.com/locate/polytest

Material Properties

Mechanical properties of polypropylene/natural fiber composites: Comparison of wood fiber and cotton fiber

Sam-Jung Kim [a], Jin-Bok Moon [b], Gue-Hyun Kim [c,**], Chang-Sik Ha [a,*]

[a] Department of Polymer Science and Engineering, Pusan National University, San 30 Jangjun Dong, Busan 609-735, South Korea
[b] Department of Footwear Fashion Industry, Kyungnam College of Information and Technology, Busan 610-701, South Korea
[c] Division of Applied Bioengineering, Dongseo University, Busan 617-716, South Korea

ARTICLE INFO

Article history:
Received 19 April 2008
Accepted 3 June 2008

Keywords:
Polypropylene
Wood fiber
Cotton fiber
Composite
Compatibilizer

ABSTRACT

In this study, the mechanical properties of polypropylene (PP)/natural fiber composites were studied. For the natural fiber component of the composites, cotton fiber was compared with wood fiber. The effect of the melt index of PP on the mechanical properties of the composites was also investigated. In order to improve the poor interfacial interaction between the hydrophilic natural fibers and the hydrophobic matrix PP, maleic anhydride (MAH) grafted PP (PP-*g*-MAH) was used as a compatibilizer. The tensile strength of the PP/wood fiber composites decreases with increasing wt% of the wood fibers, whereas that of the PP/cotton fiber composites displays different behavior. With the addition of 10 wt% cotton fiber, the tensile strength decreases, but with the addition of 20 and 30 wt% cotton fiber it increases because of the entanglement of the cotton fibers. For the PP/wood fiber composites, the melt flow index (MI) of PP was also found to be a key factor governing the mechanical properties (tensile and flexural strengths). The use of PP-*g*-MAH was helpful to increase the tensile and flexural strengths of the PP/cotton fiber and PP/wood fiber composites, due to the increased interaction between the fiber and PP matrix.

1. Introduction

Plastic/fiber composites are widely used in many industries such as the aircraft, automobile, leisure, electronic, and medical industries. The use of natural fibers in plastic/fiber composites has recently attracted increased attention, due to the increasingly stringent government regulations and growing environmental awareness. The potential advantages of natural fibers, apart from their environmental benefits, are the abundant availability of the raw materials from renewable resources, rather than fossil sources, and their low cost. Also, they have high specific strength due to their low density. Furthermore, it is possible to obtain a higher loading of natural fibers in plastic/fiber composites than conventional inorganic fillers because of the softer nonabrasive nature of the former.

A variety of natural fibers have been tested for use in plastic/fiber composites [1–13]. Natural fibers can be divided into materials with cellulose as a major component, such as seed fibers (cotton, kapok, etc.) and more complex materials where cellulose is associated with hemicelluloses, lignin, peptic cements, etc., such as leaf fibers, bast fibers or wood [14]. Among the various natural fibers, wood fibers have attracted considerable attention in the fields of both fundamental research and applications because PP/wood fiber composites have properties similar to those of PP/glass fiber composites [15,16]. Plastic/wood fiber composites constitute a rapidly growing industry in the United States. Although cotton fibers have very promising physical

* Corresponding author. Tel.: +82 51 510 2407; fax: +82 51 514 4331.
** Corresponding author.
E-mail addresses: guehyun@gdsu.dongseo.ac.kr (G.-H. Kim), csha@pusan.ac.kr (C.-S. Ha).

0142-9418/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.polymertesting.2008.06.002

properties as a filler in plastic/fiber composites, most of the studies on these materials have focused on plastic/cotton fabric composites [17,18], whereas there have been few studies about plastic/cotton fiber composites.

In this study, the mechanical properties of PP/cotton fiber composites were compared with those of PP/wood fiber composites. Since the matrix polymer plays an important role in composite systems, the effect of the melt index of PP on the mechanical properties of the composites was also investigated. The main problem with PP/natural fiber composites has been the poor interfacial interaction between the hydrophilic natural fibers and the hydrophobic matrix PP. Therefore, maleic anhydride grafted PP, which is compatible with PP and can react with the hydroxyl groups of the fiber, was used as a compatibilizer in this study.

2. Experimental

2.1. Materials and composite preparation

The names and important characteristics of the materials used in this study are summarized in Table 1. The wood fiber and cotton fiber were dried in an oven before use. The PP, natural fiber, and compatibilizer were mixed in a plasticorder (Haake Rheocord 9000) using a rotor speed of 50 rpm at 170 °C for 10 min. Then, the obtained mixture was compression molded at 170 °C for 20 min.

2.2. Measurements

A Universal Testing Machine (Model 4466, Instron Co.) was used to obtain the tensile strength and flexural strength of the composites at room temperature. Crosshead speeds of 200 and 50 mm/min were used for the measurement of the tensile strength and flexural strength, respectively. All measurements were performed for five replicates of dumbbell shaped specimens and averaged to obtain the final result. To investigate the morphology of the composites, their cross-sections were cryogenically microtomed and examined with a Scanning Electron Microscope (SEM, JEOL JSM-6100).

3. Results and discussion

Figs. 1–3 show the tensile strengths of the PP/cotton fiber and PP/wood fiber composites incorporating PP with different MIs as the matrix. With increasing wt% of wood fibers, the tensile strength of the PP/wood fiber composites decreases, as would be expected. Generally the tensile strength depends on the weakest part of the composites and the interfacial interaction between PP and wood fiber is weak. Therefore, the tensile strength of the PP/wood fiber composites decreases with increasing wt% of wood fibers. However, the tensile strength of the PP/cotton fiber composites displays different behavior. With the addition of 10 wt% cotton fiber, the tensile strength decreases, but with the addition of 20 and 30 wt% cotton fiber, it increases. This behavior can be explained by the entanglement of the cotton fiber when its content is above 10 wt%. This entanglement was confirmed by the SEM micrographs (Fig. 4). Mwaikambo and Bisanda reported that for polyester/cotton fabric composites, the tensile strength of the composites decreased with increasing content of the cotton fabric, possibly because the void content increases with increasing fabric volume fraction [18]. The difference in the tensile strength depending on the kind of fiber can also be caused by other factors, such as the fiber length, hydrophilicity, etc., as well as the difference in the chemical nature of the fiber. This is why the cotton fiber shows a better reinforcement effect for PP than the wood fiber, even though the length of wood fiber is shorter than that of cotton fiber (since the reinforcement effect usually becomes larger as the length of the fibers is decreased) [18].

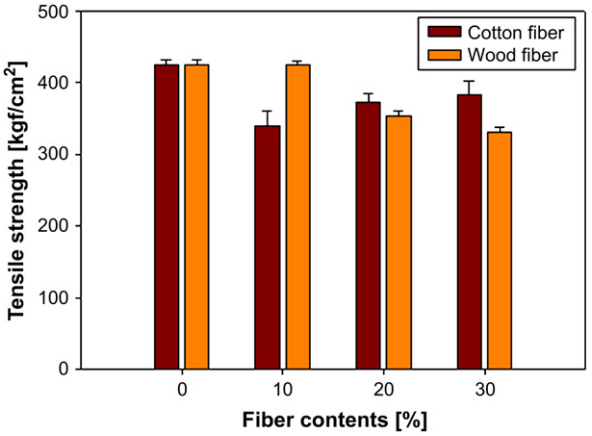

Fig. 1. Tensile strength of PP/natural fiber composites as a function of natural fiber content (PP: H720P).

It is interesting to note that for the PP/cotton fiber composites with high MI PP (H360F and H380F) as the matrix, the tensile strength of the PP composites with 30 wt%

Table 1
Important characteristics of the materials used in this study

Materials	Supplier	Characteristics
Polypropylene (H720P)	SK Chemical Co., Korea	MI (g/10 min): 2
Polypropylene (H360F)	SK Chemical Co., Korea	MI (g/10 min): 12
Polypropylene (H380F)	SK Chemical Co., Korea	MI (g/10 min): 25
Wood fiber	JRS GmbH, Germany	Length: 40 μm; cellulose content: >98.5%
Cotton fiber	Obtained from Korea Apparel Research Institute	Length: 1 cm; cellulose content: 87%
Maleic anhydride grafted polypropylene (Polybond 3150)	Uniroyal Chemical CO., USA	MI (g/10 min): 50; MAH content: 0.5 wt%