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Influence of compatibilizing system on morphology, thermal and mechanical properties of high flow polypropylene reinforced with short hemp fibers

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ABSTRACT

Simultaneous influence of polypropylene-graft-maleic anhydride (MAPP) and silane-treated hemp fibers (HF) on morphology, thermal and mechanical properties of high-flow polypropylene (PP) modified with poly[styrene-b-(ethylene-co-butylene)-b-styrene] (SEBS) was studied in this paper. The addition of SEBS reduced the efficiency of MAPP in PP composites with HF, thus silane-treated fibers (HFs) were used to improve polymer–fiber interface. Thermal stability of HF was improved after silane treatment and less than 2% weight loss was observed at 240 °C in composites with 30 wt% HF. Better dispersion of fibers and better efficiency in enhancing static and dynamic mechanical properties of PP, doubling its strength and stiffness were observed in composites with treated fibers compared to untreated ones. High ability to absorb and dissipate energy and well-balanced strength and stiffness were showed by PP modified with SEBS and MAPP containing 30 wt% HFs. These composites were studied as an alternative to conventional PP/glass fibers composites for injection molding of small to medium auto parts.

1. Introduction

Composites with natural fibers are increasingly considered as a viable alternative to glass fiber (GF) reinforced polymer composites in industrial applications [1,2]. This arises mainly from the advantages of natural fibers such as biodegradability, low density, specific mechanical properties comparable to those of glass fibers, reduced tool wear, and cheapness. Moreover, they are obtained from renewable resources in practical unlimited quantity as compared with glass or carbon fibers. Another reason is related to the recent progress in understanding the factors which may contribute to the improvement of mechanical properties of natural fibers reinforced polymer composites [1,3,4]. Between these factors, pre-treatment of fibers and the manufacturing process of the composites are very important [1]. Most of the work was concentrated on press molding process to obtain different interior parts in automotive industry from natural fibers–polymer composites and less on injection molding although this can provide high quality complex small to medium sized components [1,2].

Hemp fiber (HF) reinforced polypropylene (PP) composites have attracted increased attention especially in automotive industry [5–9]. The low stiffness of PP matrix can be significantly improved by reinforcement with natural fibers. Different type of hemp fibers such as noil HF, scotched HF, hemp strands, Moroccan HF and others and different surface treatment or coupling agents were tested to improve both stiffness and strength of PP [5–10]. Mechanical properties of PP composites could significantly vary depending on the type of natural fibers or PP matrix and the compatibilizer used in the composite [5,9,11]. For example, an increase of 2.5 times of tensile modulus was reported for high flow PP (melt flow index of 30 g/10 min according to ISO 1133) reinforced with 30 wt% hemp strands compared to non-reinforced PP and no increase in modulus when maleated polypropylene (MAPP, 0–8%) was used as compatibilizer in composites [8]. Unlike the above mentioned results, Yan et al. observed a slight decrease of tensile strength in a low flow PP (melt flow index of 8.0 g/10 min) reinforced with 30 wt% noil HF compared to neat PP and a significant influence of MAPP on tensile or flexural strength [5]. Young's modulus increased with almost 50% when PP was reinforced with 20 wt% Moroccan HF and with ~70% when poly[styrene-b-(ethylene-co-butylene)-b-styrene] grafted with maleic anhydride (SEBS-MA) was used as compatibilizer in this composite [10]. SEBS and SEBS-MA are preferred as modifier in PP composites since they act both as impact modifier and compatibilizer [11–14].

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PP/GF composites are currently used to obtain car parts because of their high stiffness. In the case of complex parts, obtained by high speed injection molding, issues related to both processing and mechanical properties could occur with traditional GF containing composites because of the high brittleness of GF [15]. Moreover, the failure of GF composites is dangerous during crash accidents, which is not the case with natural fiber composites. Using PP/HF composites for injection molded car parts one can benefit from the high flexibility of hemp fibers, their eco-friendliness and low-cost besides weight saving. However, the quality of PP/HF injection molded parts will be strongly influenced by the compatibilizing system [5,7,9]. It is expected that using short HF as reinforcement together with a strong compatibilizing system in a high flow PP will result in high quality injection molded parts for auto and other applications.

Treatment of natural fibers with silane coupling agents was recently reviewed and their benefits in terms of enhanced wettability of the natural fiber surface by non-polar polymers, enhanced interfacial adhesion and improved water resistance of fibers were reported [16]. Likewise, the efficiency of MAPP as compatibilizing agent in PP composites is widely recognized [4,6]. However, addition of MAPP may not be enough to achieve good mechanical properties in PP composites containing SEBS as impact modifier for high quality injection molded parts. The benefits of using together MAPP and silane treated fibers have been reported in only a few papers most of them related to PP/GF composites [17,18]. Elsabbagh et al. pointed out significant improvement in strength (by 210%) in PP/flax composites when MA-PP and trimethoxyvinylsilan were used to modify the polymer matrix and flax fibers, respectively [18]. However, the efficiency of this compatibilizing system in the presence of an impact modifier in PP/HF composites was not studied. This paper aims to study the simultaneous influence of MAPP and silane treated hemp fibers on morphology, thermal and mechanical properties of high flow PP containing 15 wt% impact modifier (SEBS). PP composites with 10, 20 and 30 wt% silane treated and untreated HF were prepared using a twin screw extruder. These composites were studied as an alternative to conventional PP/GF composites for injection molding of small to medium auto parts.

2. Experimental part

2.1. Raw materials

High flow polypropylene copolymer BJ380MO (PP) produced by Borealis AG (Austria) with a MFI of 80.0 g/10 min (230 °C/2.16 kg) and a density of 0.906 g/cm^3 was used as matrix. Kraton 1652G (SEBS) from Kraton Polymers (USA), a linear poly[styrene-b-(ethylene-co-butylene)-b-styrene] with 29% styrene content, Mn = 79,100, density of 0.91 g/cm^3, and MFI = 5.0 g/10 min (230 °C/5 kg) was used as impact modifier. Maleic anhydride grafted polypropylene (MAPP), Polybond 3200 from Crompton (USA), with a density of 0.91 g/cm^3, a melting point of 157 °C served as compatibilizer. Short cut hemp fibers (HF) with the length of about 2 mm were kindly donated by Euro Master Srl (Italy). 3-Aminopropyl triethoxy silane (s) was purchased from Dow Corning (USA) as XIAMETER OFS-6011 and used as received.

2.2. Fiber surface treatment

A solution was prepared from 3-aminopropyl triethoxy silane (3%) in a 80/20 ethanol/water mixture and gently stirred at room temperature for 2 h. HF were added to silane solution (pH $\sim$ 5 with acetic acid) and kept at room temperature for 2 h. Then, the hemp fibers were filtered and dried at room temperature for 24 h, resulting silane-treated hemp fibers (HFs). To induce chemical coupling, HFs were thermally treated at 120 °C for 1 h.

2.3. Preparation of composites and specimens

Before using, treated (HFs) and untreated hemp fibers (HF) were heated at 90 °C for 4 h to remove the absorbed moisture. PP, MAPP and SEBS, in the proportion of (80−x)/5/15 by weight, where x is the concentration of added fibers, were mixed in a rotating mixer at room temperature for 30 min. Composites with 10, 20 and 30 wt% HF or HFs were prepared using a DSE 20 Brabender Twin Screw Extruder at a screw rate of 120 rpm, fibers being added through a second feeder [19]. Extruder temperature profile from hopper to die was 160–165–165–170–170–160 °C. The extruded

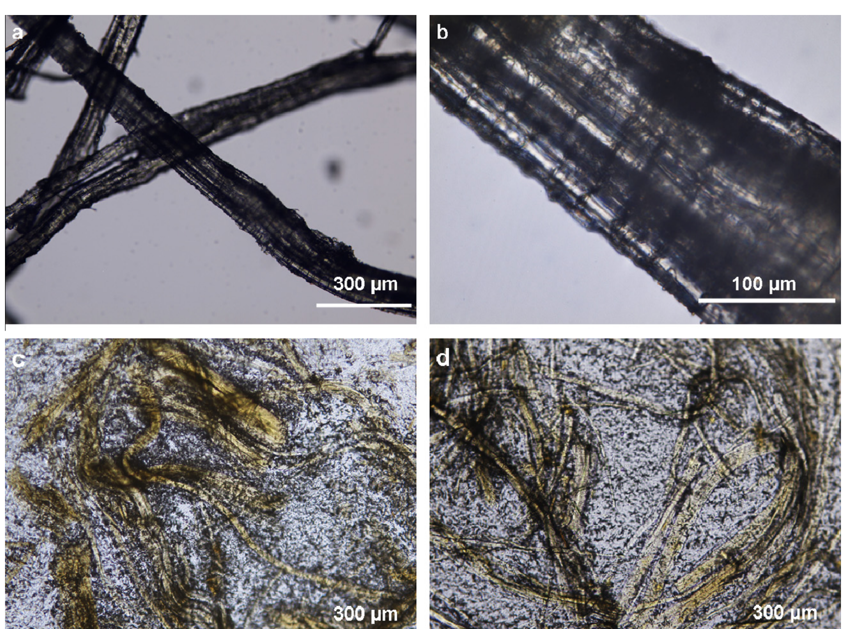

Fig. 1. Optical microscope images of original hemp fibers, different magnifications: ×100 (a) ×500 (b) and PP composites with 20 wt% untreated (c) and treated HF (d).