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Bending Properties of Wood Flour Filled Polyethylene in Wet Environment

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Abstract

Wood polymer composites (WPCs) are made of a mixture of a thermoplastic or thermoset polymer, wood fiber or sawdust and small amount of additives. These materials represent an increasingly growing area in polymer industry, in particular they are frequently used as substitutes of wood especially for outdoor products in wet environment. This particular application is due to the hydrophobicity of the matrix that protects the natural fiber reinforcement and increases the durability of the final product. The present work investigates the bending properties and the water uptake of wood flour filled polyethylene in a range of temperatures, spanning from 10°C up to 40°C. The tests show a remarkable decrease of the mechanical properties, in particular strength and stiffness, and an increase in ductility with increasing water temperature. The water uptake tests have shown the influence of temperature on the characteristics of diffusion.

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Keywords: WPC; mechanical properties; wet environment, water uptake, wood fibers

1. Introduction

Wood fibers are more and more used as fillers for thermoplastic polymers due to their low cost, high filling level and possibility of increasing the matrix mechanical properties [1,2]. Indeed, the strength and stiffness increase

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conferred by wood fibers is less significant with respect to more traditional reinforcement such as glass fibers, nevertheless their reduced hardness makes them less abrasive against the surface of processing machineries and this allows longer lifespan and reduced amortizing costs. Wood fiber filled polymers or wood plastic composites (WPCs) have also some important advantages over natural wood. Besides their reduced environmental impact [3], the presence of the hydrophobic polymeric matrix enables them to withstand wet environment better than natural wood, thus WPC profiles can be successfully employed in structures such as docks, piers and boardwalk decking that must perform in close contact with water and moisture. Nevertheless, natural fibers show a relatively high moisture absorption, which leads to dimensional changes, accelerated ageing which affect mechanical properties of WPCs [4].

In literature there are several studies that link the effect of moisture or water exposition with the loss of impact and creep properties [5], the loss of modulus of elasticity [6] and with bending properties [7]. Some authors [8,9] explained that the decrease can be due to internal stress developed inside the composite because of the water-swollen filler. This swelling effect breaks the interfacial adhesion formed between the filler and the matrix, reducing the mechanical properties of the material. However, only few papers [8, 10] have connected the effect of moisture with temperature, even though this aspect can be particularly interesting because these materials are mainly used in outdoor applications where temperature can vary in a quite large range.

The aim of this study is to investigate the influence of water exposition at various operating temperatures (from 10°C up to 40°C) on the mechanical performance, in particular in bending after 4 hours preconditioning in water, on a high density polyethylene based WPC filled with 50 wt.% wood flour. In order to evaluate the water content of the specimens during preconditioning, water absorption tests have also been performed.

2. Experimental

2.1. Materials

The materials used in this study are a polyethylene matrix (PE) (Eraclene BC-82 by Versalis) and wood flour obtained from wood planning residues. A commercially available maleic anhydride grafted polyethylene (Licocene PE MA 4351 by Clariant) has been used as a coupling agent in the amount of 4 wt.% to improve compatibility and adhesion between matrix and fibers.

2.2. Sample preparation

Wood fibers have been initially dried at 80°C in an air–circulation oven for 24h before mixing process to reduce the moisture content. The PE, the wood fibers at 50% by weight and the coupling agent have been mixed together using a compounding-extrusion unit composed of a twin screw co-rotating extruder (50 mm screw) directly feeding into a single screw extruder (80 mm screw) for profile extrusion. The specimens have been obtained by cutting the profiles in bars of 10 mm x 15 mm rectangular cross section.

2.3. Mechanical testing

All specimens have been preconditioned for 4 hours in water at the selected temperature. Bending tests have been performed with the three point bending method using a length span of 100 mm at a cross head speed of 1 mm/min in water kept at 10°C, 20°C, 30°C and 40°C. An Instron 4467 with a 500 N load cell was used to measure the stiffness and the strength of the samples. A minimum of five specimens have been tested for each condition.

2.4. Water absorption

Before testing, all samples have been dried in an air –circulation oven for 24h and subsequently weighed with a precision scale. Three samples (10 x 15 x 60 mm) for each temperature (10°C, 20°C, 30°C and 40°C) have been immersed in different thermal baths of distilled water. Periodically the specimens were removed from water and