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Test Method

Study of the interfacial properties of natural fibre reinforced polyethylene

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Abstract

In the present paper, the interfacial properties of extruded and compression moulded natural fibre reinforced thermoplastics (NFRTP) are studied. The interfacial shear strength of PE-sisal composites was measured using the single fibre fragmentation test (SFFT). The difficulties in obtaining significant measurements are discussed and assessed. The main problems found were the non-transparent nature of the matrix, the irregular shape of the fibres, and the variability in fibre–matrix adhesion encountered even in single fibre specimens. Scanning Electron Microscope (SEM) pictures obtained from fractured surfaces were used for a qualitative evaluation of the interfacial properties of NFRTPs. Fibre treatment with stearic acid increased the interfacial shear strength by 23% with respect to untreated fibres. The improvements in interfacial shear strength found for the treated specimens were consistent with observations from SEM fractographs.

Keywords: Interfacial properties; Single fibre fragmentation test; Natural fibre composites

1. Introduction

Natural fibre composites have found an increasing number of applications in recent years [1–9]. Car manufacturers have shown special interest in these materials for the replacement of glass fibre reinforced panels. The advantages of natural fibres over their traditional counterparts include: relatively low cost, low weight, less damage to processing equipment, improved surface finish of moulded parts (compared to glass fibre composites), good relative mechanical properties. Another important advantage of natural fibres is that they are relatively abundant in nature and, therefore, can be obtained from renewable resources. They can also be recycled. The main disadvantages of natural fibres are: their low permissible processing temperatures, their tendency to form clumps, and their hydrophilic nature [4–6].

Experimental data of their mechanical properties, particularly when tested under different processing conditions, have shown inconsistent values in many cases [1–3]. The irregular characteristics of natural fibres are one of the main reasons for this. On the other hand, natural fibres are hydrophilic and many thermoplastics are hydrophobic. This leads, in many cases, to problems associated with the interfacial properties of this type of composite [1–3].

Various treatments are used to improve the matrix-fibre adhesion in natural fibre reinforced composites. Currently, this step is considered critical in the development of these materials. The methods for surface modification can be physical or chemical according to the way they modify the fibre surface. Other frequently used treatments are bleaching, acetylation and alkali treatment. The main chemical method used in the surface modification of natural fibres is chemical coupling [7]. The coupling agent is chosen to form

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chemical bonds between the cellulose in the fibre and the polymer matrix [8]. Other chemical methods involve changing the surface tension and impregnating the fibres [9]. The change in surface tension is related to the hydrophobicity of the fibre. The use of stearic acid that hydrophobizes the fibres and improves their dispersion [6,9] is an example.

In this paper, the interfacial properties of sisal reinforced polyethylene composites are assessed by means of the single fibre fragmentation test. The results are compared with qualitative data from morphological characterization tests.

2. Single fibre fragmentation test

The single fibre fragmentation test has been used in the past for the measurement of the interfacial shear strength of polymer fibre composites [10–14]. It can be carried out by applying a sustained tensile load to a specimen with an embedded single fibre. The number and length of the fragments produced were monitored and quantified.

For the data analysis, when using the SFFT, the average interfacial shear strength can be calculated with the following equation [15].:

$$\tau_c = k\frac{1}{2}\sigma_c\left(\frac{d_f}{l_c}\right) \quad (1)$$

where:

- τ interfacial shear strength between fibre and matrix
- σ_c fibre tensile strength (MPa)
- d_f fibre mean diameter
- l average fragment length
- k statistical correction factor ($k=0.889$) [15].

3. Experimental

3.1. Materials

The specimens for the SFFT were prepared from polyethylene powder with a melt index of 2.5 (190C/2. 16 kg) and sisal fibres as reinforcement. Untreated, as well as pre-treated fibres (with stearic acid), were used. Stearic acid was used, since it has been found to reduce the presence of processing defects in final products [2].

3.2. Measurement of fibre diameter

Fibre diameter was measured using a profile magnifier at 50×. Five measurements were taken at different cross sections in each fibre and an average diameter was estimated.

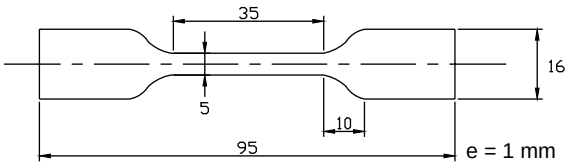

Fig. 1. Specimen geometry for the single fibre fragmentation tests.

3.3. Fibre treatment

All fibres were pre-washed in a solution consisting of water and 3% non-ionic detergent for 1 h at 70 °C followed by washing with distilled water and air drying in an oven for 24 h at 65 °C. The fibres were then treated with 3% of stearic acid. Previous work from this laboratory indicates that this concentration seems to be enough in order to achieve a considerable reduction in the size and number of fibre clumps and agglomerates during standard processing operations [1–3,16].

3.4. Samples preparation

Dumb-bell specimens (Fig. 1) were prepared by compression moulding. Processing conditions were 130 °C/15 min. The fibres had to be placed accurately within the dumb-bell by means of special centring devices attached to the mould.

3.5. Characterisation of matrix and fibres

The tensile strength of the matrix was assessed according to ISO 527. Fibre tensile properties were determined according to ASTM D2256 [17,18]

3.6. Single fibre fragmentation tests

A Columbine tensile testing machine for plastics with a 2.5 KN load cell was used for the experiments. An additional lighting device was used to increase visibility of the fibres in the opaque polyethylene matrices. A crosshead speed of 4 mm/min was used in the experiments. The scheme of the rig used for SFFT experiments is shown in Fig. 2.

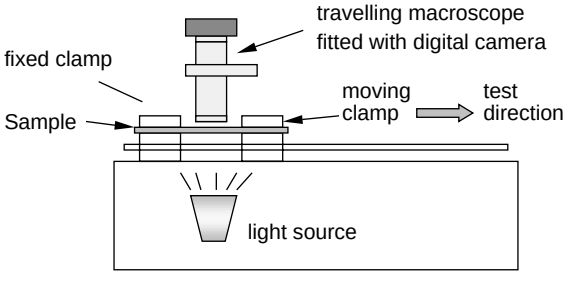

Fig. 2. Disposition used for the SFFT.