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Mechanical, sorption and adhesive properties of composites based on low density polyethylene filled with date palm wood powder

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ABSTRACT

Low density polyethylene (LDPE) was blended with date palm wood powder (DPW) to prepare composites with concentrations of filler ranging from 10 to 70 wt.%. The Youngś modulus of the composites significantly increased with an increase in the filler content in the entire concentration range. The maximum value of 1933 MPa for the composite filled with 70 wt.% of the filler is approximately 13 times higher than that for the neat LDPE.

The presence of the filler improved the flexural strength, which was represented by the flexural stress at peak. The flexural strength of 17.8 MPa for the composite filled with 70 wt.% of the filler was two-times greater than that for the neat LDPE. The water absorption test revealed that the composites had a strong tendency to absorb water, which was dependent on the filler content. The experimental data were compared with several theoretical models.

1. Introduction

During the last few decades, both ecological and economic interests have resulted in a more intensive utilisation of natural materials for the creation of new composites, and issues such as recyclability and environmental safety have become increasingly important for the introduction of new materials and products [1]. An important group of these materials is represented by natural fibres from secondary wastes. These materials, after appropriate treatment, are an interesting alternative to synthetic fibres. The main group of these materials is represented by wood fibres, whereas natural fibres such as flax, hem, cotton, jute, banana, ramie, sisal, coir, and date palm fibres represent a minor part [2,3]. However, both groups can be utilised as an effective filler material for the reinforcement of inorganic (such as concrete) and polymeric matrices.

The polymeric matrix is usually selected on its inherent properties, product need, availability, cost, and the manufacturer's familiarity with the material. Polymeric matrices include both thermoplastic and thermosetting resins [1–3].

Most composites based on thermoplastics for use in interior and exterior building components are currently produced from polyethylene [4] and polypropylene [5], both recycled and virgin. Composites formed from polypropylene filled with wood flour are typically used in automotive applications and consumer products, and these composites have recently been investigated for use in building applications [4]. The wood employed in such composites is most often in particulate form (or very short fibres) rather than longer individual wood fibres. Products typically contain approximately 50 wt.% wood, although some composites contain very little wood and others as much as 70 wt.% [6].

Obviously, the research and development activities in each country are primarily focused on the utilisation of locally available sources of natural fibres. In the country of our interest, Qatar, date palm is a dominant source of secondary waste that can be utilised for the production of natural fibres. In general, the date palm plant consists of six different potential sources of natural fibres, namely bunches, mesh, petiole, fruit (pits), leaves and palm trunk [7]. Both date palm fibres and wood themselves and their composites have been recently investigated. For example, Agoudjil et al. studied the use of date palm wood powder as a potential renewable material for reducing building heat losses with the goal of using this natural material in the manufacturing of thermal insulation for buildings. Alsewailem and Binkhder [8] studied HDPE and PS matrices reinforced with powder from date palm pits and their mechanical and thermal properties. Alsaeed et al. [9] investigated epoxy resins reinforced with long date palm fibres. The authors searched for the optimum length of embedded fibres that have controlled interfacial adhesion properties and determined that 10 mm was the optimum length. Similar research focused on the effect of diameters and alkali treatments on the tensile properties of date palm fibre reinforced epoxy composites was performed by

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Abdal-Hay et al. [10]. The authors determined that the ultimate tensile strength and percentage elongation of a single fibre after alkali treatment increased by 57% and 24.7%, respectively. Because the alkali treatment of date palm fibres was able to provide good adhesion within the matrix, the tensile strength, elastic modulus and the fibre–matrix interaction of the composite were improved. Date palm wood powder/glass fibres reinforced hybrid composites of recycled polypropylene were investigated by AlMaadeed et al. [11]. The influence of date palm fibres from different parts of the date palm plant (the trunk, rachis, and the petiole) on the mechanical properties of HDPE-based composites was studied by Mahdavi et al. [12]. The highest strengths were achieved in composites with 30 and 40% fibre content, and these gains were dependent on what parts of the original tree were used.

In this paper, we present the results from a study on the mechanical properties (static and dynamic) of composites based on low density polyethylene and date palm wood powder. The water absorption of the composites was carefully investigated and modelled. The polarity and adhesive properties of the prepared composites were also studied.

The surface characterisation of the date palm wood powder was performed using the XPS method.

2. Experimental details

2.1. Materials

Low density polyethylene from QAPCO (Qatar) was used as the matrix (melting point = 110.6 ± 0.1 °C and specific enthalpy of melting = 118 ± 5 J/g) and ground date palm wood powder (DPW) was used as the filler.

2.2. Filler preparation and characterisation

Large pieces of date palm wood were ground using a high energy mill. The obtained filler had a fibrous shape, as shown in Fig. 1, with a broad distribution of diameters and lengths. Meshes of various pore sizes were used to separate the filler according to its size. Obviously, it is difficult to perform a correct separation solely based on diameter and length. Therefore, the sieving of the filler material using the mesh can provide only an approximate size characterisation. Each fraction was also analysed using an optical microscope [Kapa 2000 with a CCD camera (CC-63KW1P, Mintron Malaysia) equipped with Prover Image Forge 1.1] to determine the average length of the fibres. The average length and the standard deviation were calculated from at least 20 measurements. The average length distribution of the filler is summarised in Table 1. The majority of the filler particles had sizes ranging from 0.25 to 1 mm. The diameter distribution is approximately characterised by the mesh size.

2.3. XPS characterisation

The chemical compositions of both LDPE and DPW were characterised using the XPS method. XPS data were recorded using a Thermo Scientific K-Alpha XPS system (Thermo Fisher Scientific, UK) equipped with a micro-focused, monochromatic Al Kα X-ray source (1486.6 eV). An X-ray beam that was 400 μm in size was used at 6 mA × 12 kV. The spectra were acquired in the constant analyser energy mode with a pass energy of 200 eV for the survey. Narrow regions were collected with the pass energy of 50 eV. Charge compensation was achieved with the system flood gun that provides low energy electrons (~0 eV) and low energy argon ions (20 eV) from a singe source. The argon partial pressure was 2×10^{-7} mbar in the analysis chamber. The Thermo Scientific *Advantage* software, version 4.84 (Thermo Fisher Scientific), was used for digital acquisition and data processing. Spectral calibration was performed using the automated calibration routine and the internal standards of Au, Ag and Cu that were supplied with the K-Alpha system.

The surface compositions (in atomic %) were determined from the integrated peak areas of detected atoms and the respective sensitivity factors. The fractional concentration of a particular element, *A*, was computed using the equation:

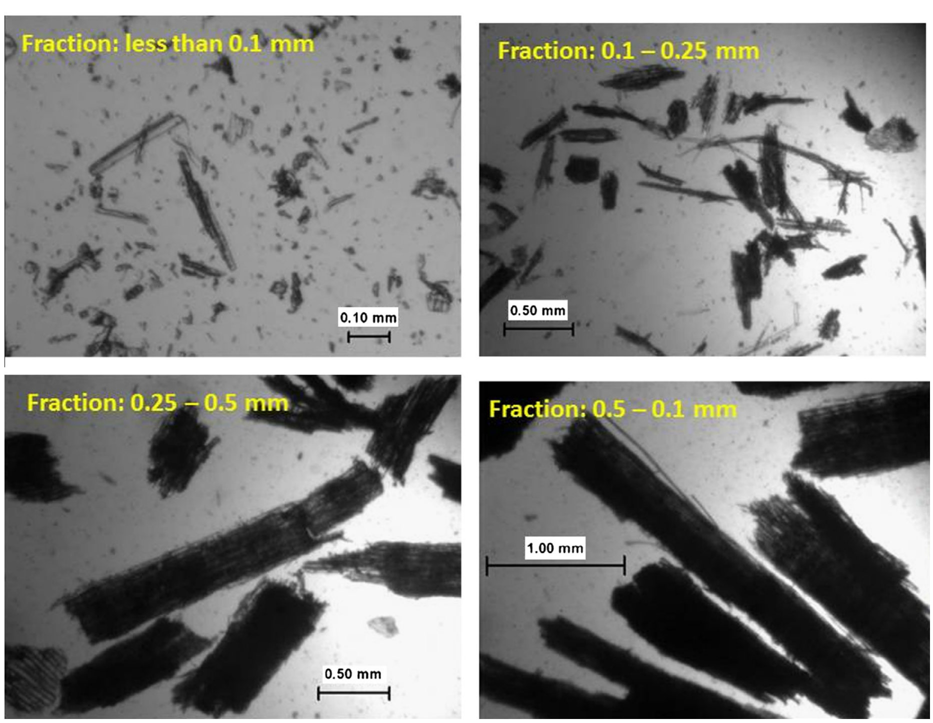

Fig. 1. Optical micrographs of the filler.