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INVESTIGATION OF PLASTIC/WOOD COMPOSITES

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ABSTRACT

Polyolefin (linear low-density polyethylene, LLDPE) was blended with date palm wood (DPW) powder to prepare composites with concentrations of filler ranging from 10 to 70 wt.%. The Young´s modulus of the composites significantly increased with an increase in the filler content in the entire concentration range. The presence of the filler improved the flexural strength, which was represented by the flexural stress at peak. 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.

Key words: LLDPE, date palm wood, composites, mechanical properties, water absorption, adhesion.

INTRODUCTION

The important group of polymeric composites 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 (Bledzki and Gassan 1999, Peijs 2002). 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 (Marcovich and Villar 2003).

Most composites based on thermoplastics for use in interior and exterior building components are currently produced from polyethylene (Li *et al.* 2012) and polypropylene (Keledi *et al.* 2012), 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 (Li *et al.* 2012). The wood employed in such composites (Wolcott and Adcock 2000, Agoudjil *et al.* 2011, Alsewailem and Binkhder 2010, Alsaeed *et al.* 2013, Abdal-Hay *et al.* 2012, Almaadeed *et al.* 2012, Smith *et al.* 2002, Moghadamzadeh *et al.* 2011, Kúdela *et al.* 2018) is most often in particulate form (or very short fibres) rather than longer individual wood fibres. Products typically contain approximately 50 weight per cent wood, although some composites contain very little wood and others as much as 70 weight per cent (Wolcott and Adcock 2000). In this paper, we present the results from a study on the mechanical properties of composites based on LLDPE and date palm wood filler. The polarity and adhesive properties of the prepared composites were also studied.

EXPERIMENTAL

Materials

Linear low-density polyethylene (LLDPE) (QAPCO, Qatar) was used as the matrix (melting point = 110.6 and specific enthalpy of melting = 118 ± 5 J/g) and ground date palm wood fibres/powder (DPW) was used as the filler. The prepared wood fibres have a broad size distribution; the majority of the fibres have a length between 1 and 3 mm.

Filler preparation and characterisation

Large pieces of date palm wood were ground using a high energy mill. The obtained filler had a fibrous shape 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.

RESULTS AND DISCUSSION

The mechanical properties of the composites are summarised in Table 1. The stiffness and hardness of the composites, which are characterised by the Young´ s modulus, significantly increase with an increase in the filler content in the entire concentration region. The maximum value of 1933 MPa for the specimen filled with 70 wt. % of the filler is approximately 13 times greater than the one of the LLDPE. This result indicates that the filler has a very strong reinforcing effect.

Table 1: Mechanical properties of the composites at 25 °C. The x/y notation represents the LLDPE/DPW w/w ratio

Sample	φ	$\varepsilon_y \pm S\varepsilon_y$ %	$\sigma_y \pm S\sigma_y$ MPa	$\varepsilon_b \pm S\varepsilon_b$ %	$\sigma_b \pm S\sigma_b$ MPa	$E \pm S_E$ MPa
LLDPE	0	15.5[a] (0.3)	8.0 (0.2)	633 (20)	18.5 (0.7)	150 (7)
90/10	0.069	15.2 (0.3)	9.2 (0.2)	22 (19)	9.0 (0.3)	285(22)
80/20	0.142	br	br	8.8 (0.6)	9.2 (0.4)	376 (22)
70/30	0.221	br	br	4.8 (0.6)	9.4 (0.2)	562 (71)
60/40	0.306	br	br	3.2 (0.3)	9.3 (0.5)	800 (42)
50/50	0.398	br	br	2.1 (0.1)	9.7 (0.5)	1064 (83)
40/60	0.498	br	br	1.4 (0.1)	10.2 (0.4)	1457 (122)
30/70	0.608	br	br	1.1 (0.1)	11.1 (0.6)	1933 (124)

ε_y, σ_y, ε_b, σ_b, E – elongation at yield, yield stress, elongation at break, stress at break, and Young's modulus of elasticity; $S\varepsilon_y$, $S\sigma_y$, $S\varepsilon_b$, $S\sigma_b$, S_E are the standard deviations, φ is the volume portion of the filler, br refers to the brittle rupture.

The dependence of the water contact angle on composites' surface vs. the filler content in LLPE is shown in Figure 1.

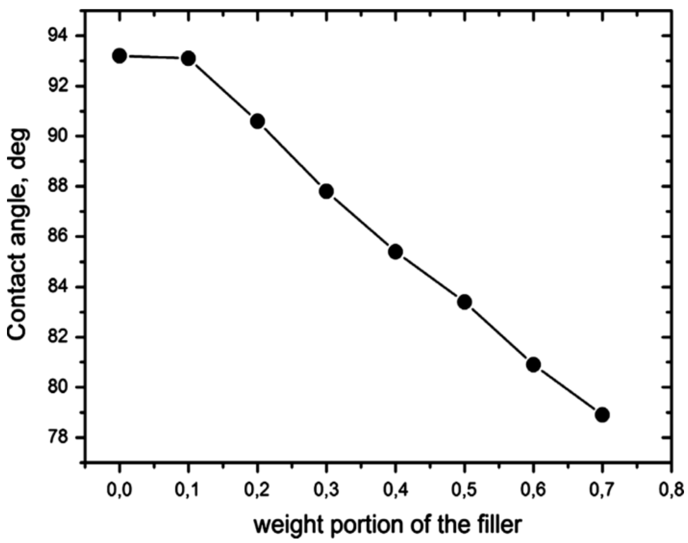

Figure 1: Water contact angle on the LLDPE/DPW surface versus filler content

The increase in the filler content results in a more polar nature of the composite material. The dependence of the water contact angle vs. the wood content decreases nonlinearly. The water contact angle on the LLDPE/DPW composite surface significantly decreases with the DPW concentration from 93.2 deg (unfilled polyethylene) to 87.8 deg (30 wt.% of wood in composite), and to 78.9 deg (70 wt.% of the filler). For the surface properties, it can be concluded that the water contact angles on the surface of the LLDPE/DPW composites decreased from 93.2 deg (unfilled polyethylene) to 78.9 deg (LLDPE/DPW composite filled with 70 wt.% of the filler).

The results of the shear strengths in the adhesive joint LLDPE/DPW composite – epoxy vs. filler content are shown in Figure 2. Figure 2 reveals an increase in the shear strengths of the adhesive joint between the LLDPE/DPW composite and the epoxy substrate with an increase of the filler content. As shown in Figure 2, the shear strength of the adhesive joint significantly increased from 0.62 MPa (unfilled LLDPE) to 1.37 MPa if filled with 70 wt.% of DPW. The shear strength of the adhesive joint between the LLDPE/DPW composite and the epoxy resin significantly increased from 0.62 MPa (unfilled LLPE) to 1.37 MPa (LLDPE/DPW composite with 70 wt.% of the filler).

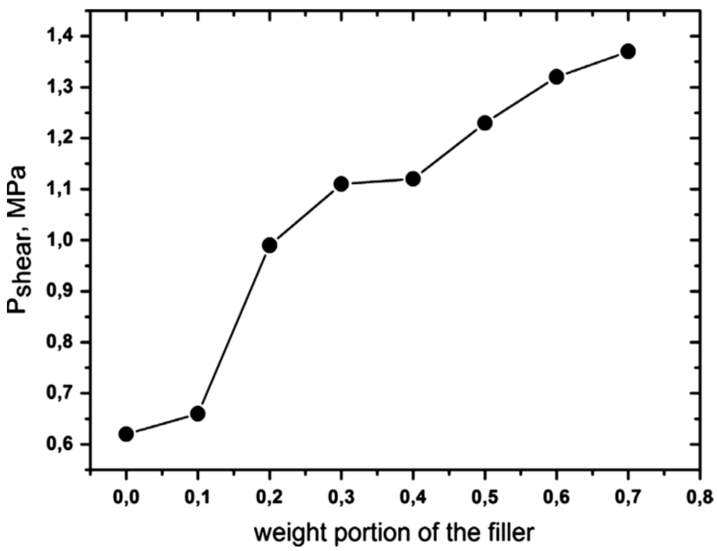

Figure 2: Shear strength of adhesive joint LDPE/DPW composite – epoxy adhesive versus filler content

CONCLUSION

A fine powder with a fibrous shape was prepared from date palm wood (DPW) by grinding in a high energy mill. The prepared fibres have a broad size distribution; the majority of the fibres have a length between 1 and 3 mm. Linear low-density polyethylene (LLDPE) was used as the matrix for preparing LLDPE/DPW composites. The filler concentration ranged from 10 to 70 wt.%. The stress at the break of the composites and its dependence on the filler fraction varies nonlinearly. The material becomes brittle if filled with more than 10 wt.% of the filler. The incorporation of DPW into the LLDPE matrix led to a significant increase in the polarity of composites and to an increase in their adhesion to polar substrates.

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