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Influence of date palm fibre and graphite filler on mechanical and wear characteristics of epoxy composites

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ABSTRACT

In this article, mechanical and tribological performance of the epoxy composites based on graphite filler and/or date palm fibre are comprehensively discussed. The influence of the date palm fibre and/or graphite filler on the microstructure of the materials, tensile fracture samples, and worn surface of tribological samples are examined using scanning electron microscopy. The results revealed that interfacial adhesion of the date palm fibre with the epoxy is the key of the mechanical and tribological performance of natural fibre/polymer composites. The addition of the graphite is highly recommended for the natural fibre/polymer composites which can assist to reduce the friction which in turn enhances the wear characteristics of the polymer composites; however, the high content of the graphite deteriorates the mechanical properties.

1. Introduction

In the current decade, natural fibres have been attracted a significant attention in numerous applications such as automobiles, furniture and construction [1–3]. From mechanical point of view, the natural fibres as reinforced material for polymer composites has exhibited positive effects in their mechanical behaviour compared to the pure matrix and encouraging results compared to the synthetic fibres as reinforced material. However, there are several factors related to the natural fibres such as the interfacial adhesion, the strength, Moisture absorption, impurities, orientation, volume fraction and physical properties function constitutive role to determine the mechanical properties of fibre polymer composites.

Form the literature, there are several types of natural fibres have been studied for different applications. With regards to the date palm fibres, there are few recent studies have been conducted to study the interfacial adhesion of the fibres with different matrices. Interfacial adhesion of the single date palm fibre has been studied using single fibre pull out [4,5], and fragmentation techniques [6]. From those works, it is confirmed that 6% NaOH chemical treatment is the optimum solution to gain high interfacial adhesion of the date palm fibres with synthetic matrices such as polyester and epoxy. For the mechanical applications, there are recent works have been reported on the possibility of using data palm fibres for automotive applications [7]. In [7–10], the influence of the date palm fibres on mechanical properties of different matrices such as HDPE [8–10] have been studies and the addition of the fibres significantly improved the tensile properties of the HDPE. However, there is no work have been reported on using the date plam fibre for tribological application and/or with the addition of solid lubricant fillers.

On other hand, in relate to graphite as a filler material for polymer composite, there was significantly reduction in the tensile strength of different polymer composites such as PPE [11], EVA [12], PMMA [13], HDPE [14], and PLA [15], especially at 4 wt.% of graphite and more. Also, those studies have been revealed that the mechanical behaviour of the graphite/polymer composite is depended on the interaction, the distribution, the size, and the orientation of the graphite.

From the tribological point of view, many researchers have reported that the tribological behaviour of composite polymers based on the natural fibre is not intrinsic behaviour and it strongly depends on many processing parameters such as operating parameters, characteristics of polymer martial, physical and interfacial adhesion properties of fibre, additives and contact condition. In other words, understanding the tribological behaviour of natural fibre/polymer composites has an equal role to be considered with the mechanical properties of those materials [16]. In polymer composites, selecting the right compositions assists to reach special requirements for tribological applications. In other words, filling polymer composite with desired fillers and /or reinforcement is frequently employed for specific objective. Many researchers

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studied the tribological behaviour of polymers containing solid lubricants aiming to reduce the friction coefficient of the composites and maintain good wear performance [17–24]. They concluded that frictional characteristics of polymers enhanced dramatically by incorporation solid lubricants. Solid lubricants such as graphite, molybdenum disulfide (MoS_2) and poly-tetrafluoroethylene (PTFE) are good alternative lubricant in many applications where fluid lubricants are undesirable and ineffective.

This present work is aimed to study and understand the mechanical and tribological behaviour of epoxy composites based on graphite content fillers and /or natural fibre reinforcement. Also, it is an attempt to support the environmental efforts such replacement the synthetic fibre, find new applications for natural fibres and saving a database for researchers in future.

2. Materials preparation and experimental procedure

2.1. Material preparation

Raw date palm meshes surrounding the steams of date palm trees were extracted from a farm in Kuwait. The fibres were separated from the meshes manually and washed with tap water (2% detergent solution) to remove the attached dirt and dust. The extracted fibres were air dried for 48 h at room temperature. After that, an optical microscopy (Motic stereomicroscope, SMZ168 series) was used to check the fibre and select the desired ones. The fibres of diameter 0.3 ± 0.05 mm were selected as recommended by many of researcher [25,26]. In determining the fibre diameter, three measurements were taken at different cross sections for each fibre and the average was determined. The fibres were cut to the desired length. The extracted fibres are treated with 6 wt.% Sodium hydroxide (NaOH) for 24 h at room temperature, Fig. 1. Then, the fibre are rinsed with fresh water and then dried at room temperature for 24 h. For the matrix selection, epoxy is selected as thermoset resin since it is considered one of the common, cheap and widely used resins for engineering applications.

Epoxy resin (R246TX) Kinetix (H160 medium) hardener were used for the current work and supplied by Australian calibrating services PTY. Ltd., Australia. The resin mixture was prepared by mixing the epoxy and the hardener with a ratio of 1:3 based on the industrial recommendation. Furthermore, volume fractions of graphite will be used 3 wt.%. The graphite particles will be mixed with the epoxy resin and the hardness and kept for a while to be in jelly form. Also, the volume fraction of fibres (V_f) in matrix will be fixed to about 35 vol.% as shown in Table 1. The mixture was poured carefully inside the cavity of the mould and a small steel tool was used to ensure the distribution of the matrix and the alignment of the fibres. The NE, GE, FE and GFE specimens for the mechanical test are prepared based on ASTM: D638-10 standard with the dimension (specimen geometry) and the used mould.

Table 1
designation of the fillers/epoxy composites.

Material	Matrix (*E*) wt.%	Graphite(*G*) wt.%	Date palm fibre (*F*) vol.%
NE	100	0	0
GE	97	3	0
FE	100	0	35
GFE	97	3	35

With regard to tribological test, tribological composite specimens are prepared based on block on ring (BOR) technique (ASTM: G 77). The prepared specimens are cut into the desired dimension of 25 mm × 58 mm × 20 mm for tribological experiments based on block on ring technique. All prepared mechanical and tribological specimens were cured for 24 h at the atmospheric conditions. Moreover, the specimens were removed from the mould and cured again in an oven with a temperature of 50 °C for 24 h.

2.2. Experimental procedure

2.2.1. Mechanical experiments of the composites

Tensile strength (TS), tensile modulus (*E*) and elongation at break (ε) are determined according to ASTM: D638-10, under ambient conditions, using MTS 810 TestStar Material Testing System. The hardness is measured using a Durometer type D accordance with ASTM: D2240. Three tests are repeated for each set of specimens and the average values are calculated.

2.2.2. Tribological experiments

In this work, the friction and wear characteristics of fillers/epoxy composite is investigated under dry contact condition and ambient conditions (temperature: 25 °C, humidity: 50 ± 5) against stainless steel (AISI 304, hardness = 1250 HB, R_a = 0.1 μm) counterface. The experiments are conducted using block on ring (BOR) techniques. The test is conducted for 7.56 km sliding distance and speed = 2.8 m/s at applied load = 50 N.

3. Results and discussion

3.1. Mechanical results

Mechanical properties of the composites are presented in Figs. 2–6 showing the stress strain diagrams, modulus of elasticity, hardness and the micrographs of the fractured samples for the selected epoxy composites, neat epoxy (NE) 3 wt.% graphite (GE), date palm fibre (FE), and 3 wt.% graphite + date palm fibre (GFE).

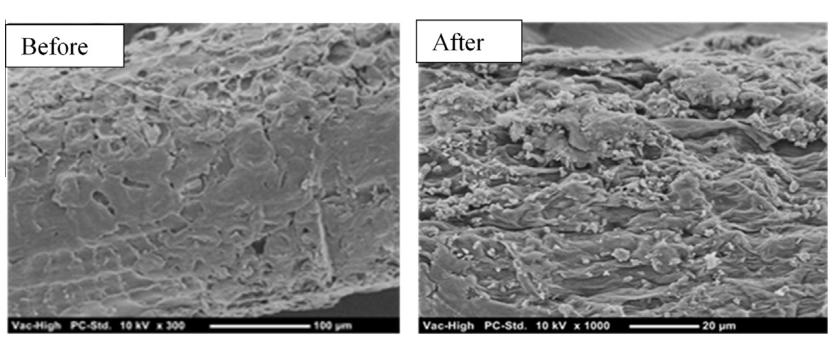

Fig. 1. Micrographs of the fibres before and after treatment.