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Faculty of Health, Engineering and Sciences

TRIBOLOGICAL BEHAVIOUR OF GRAPHITE/DATE PALM FIBRES REINFORCED EPOXY COMPOSITES

A dissertation submitted by

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Abstract

Natural fibres are becoming alternative candidates to synthetic fibres because of their environmental and economic advantages. In this study, the mechanical and the tribological performance of epoxy composites (ECs) based on date palm fibres (DPFs) was evaluated and compared with neat epoxy (NE). The work is divided into three stages: fibre optimisation, graphite optimisation and final composite selection.

Different fibre diameters (0.3–0.7 mm) and concentration of sodium hydroxide (NaOH) (zero to nine per cent) were used in preparing the fibre. For optimisation purposes, the interfacial adhesion between the DPFs and the epoxy matrix was studied using a new fragmentation technique that considers the influence of the NaOH treatment and the fibre diameter. At this stage, the results revealed that NaOH treatment significantly influences both the fibre strength and the fibre interfacial adhesion. Six per cent NaOH exhibited the optimum concentration to gain good mechanical properties for the EC, since it can maintain good interfacial adhesion, while maintaining good fibre strength.

In the second stage, the influence of the graphite weight presentation on ECs was evaluated from a mechanical and tribological perspective. Different weight percentages were used in the sample preparation (zero to seven per cent) for tensile, hardness and adhesive wear experiments. In the first part of this study, ultimate tensile strength and modulus of elasticity values and fracture morphology are determined. In the second part, specific wear rate, friction coefficient, interface temperature and surface morphology of the composites are determined. The results are discussed to gain the optimum mixing ratio of graphite with epoxy. The results revealed that there is a significant influence of the weight fraction of the graphite on both mechanical and tribological performance of the composites. Intermediate weight percentage of three weight per cent graphite in the EC was considered the optimum from both mechanical and tribological performance, since there is a slight reduction in the tensile properties and significant improvement to the hardness, wear and frictional characteristics. The modification on the wear track roughness significantly controlled the wear and frictional behaviour of the composites. Micrographs of the worn surface showed different wear mechanisms, depending on the content of the graphite in the composites. Softening and fragmentation appeared with low content of graphite presence in the composite, since there was no sign of aggregation or detachments of fillers.

From the second stage on the graphite percentage in the composite, it was concluded that three weight per cent of graphite in the ECs represents the optimum content from mechanical and tribological perspectives. In the third stage, the mechanical and tribological performance of the ECs based on three weight per cent graphite, DPF and three weight per cent graphite plus DPF are discussed and compared with NE. Further, the tribological performance of the composites is discussed, considering two different adhesive wear techniques: block on ring (BOR) and block on disk (BOD). This stage revealed that DPF is able to improve the mechanical properties of the ECs with no signs of pull out or debonding of the fibres. The main fracture mechanism was breakage in the fibre, fracture in the resinous regions and micro-cracks with graphite presence in the composites. Further, the addition of the three weight per cent of the graphite into the date fibre/ECs contributed to the improvement of the ECs; the fibres assisted in strengthening the surface, while the graphite generated the lubricant film transfer. Tribological experimental configuration significantly controlled the wear behaviour of the composite; the wear performance worsened under BOD compared to BOR because of the high thermo-mechanical loading in the case of BOD compared to BOR.

List of publications

Shalwan, A** & Yousif, BF 2013, 'In state of art: mechanical and tribological behaviour of polymeric composites based on natural fibres', *Materials & Design*, vol. 48, June, pp 14–24.

Shalwan, A** & Yousif, BF 2014, 'Investigation on interfacial adhesion of date palm/epoxy using fragmentation technique', *Materials & Design. Volume 53*, Pages 928–937.

Shalwan, A** & Yousif, BF 2013 in press, 'Correlation between mechanical and tribological performance of polymer composite materials', *International Journal of Precision Technology*, August.

Shalwan, A** & Yousif, BF 2013, 'Influence of graphite content on mechanical and wear characteristics of epoxy composites', under review August 2013, *Wear*.

Shalwan, A** & Yousif, BF 2013, 'Mechanical, wear and frictional performance of epoxy composites based on date palm fibres and graphite filler', under consideration since July 2013 *Tribology Letter*.

Arhaim, YH, Shalwan, A** & Yousif, BF 2013, 'Correlation between frictional force, interface temperature and specific wear rate of fibre polymer composites', *Advanced Materials Research*, vol. 685, pp. 45–49.

**Note: the candidate used his Arabic surname (Shalwan, A) instead of the English (Al-Ajmi, A.)

Certification of thesis

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this thesis are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Endorsement

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Date Date

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List of abbreviations

ABS	Acrylonitrile butadiene styrene
ASTM	American Society for Testing and Materials
BFRP	Betelnut fibres reinforced in polyester
BOD	Block on disk
BOR	Block on ring
CFRP	Coir fibre-reinforced polyester
CPC	Cotton-polyester composite
Df	Fibre diameter
DPF	Date palm fibre
DPFE	Date palm fibre-reinforced epoxy
EC	Epoxy composite
GJ	Gigajoule
GR	Graphite powder
HDPE	High-density polyethylene
ICMF	Incomplete maturation fibres
KFRE	Kenaf fibre-reinforced epoxy
MoS2	Molybdenum disulfide
NaOH	Sodium hydroxide
NE	Neat epoxy
PA	Polyamides
PEEK	Polyarylethe-retherketone
PLA	Polylactic acid
PMMA	polymethyl methacrylate
PP	Polypropylene
PPESK	Polyphatalazinone ether sulfone ketone

PPE	Polyphatalazinone ether
PPS	Polyphenylene sulfide
PTFE	Poly-tetrafluoroethylene

Ra	Roughness average
RNFPC	Reinforced natural fibre polymer composite
SCRP	Sugarcane fibre/polyester composite
SEM	Scanning electron microscopy
SiC	Silicon carbide
SFFT	Single fibre fragmentation test
SFTT	Single fibre tensile test
SP	Sisal fibres/polyester composites
T-OPRP	Treated oil palm fibre-reinforced polyester
TS	Tensile strength
T-SP	Treated sisal fibres/polyester composites
UHMWPE	Ultra-High Molecular Weight Polyethylene
US	United States
UT-OPRP	Untreated oil palm fibre-reinforced polyester
UT-SP	Untreated sisal fibres/polyester composites
Vf	Volume fraction
Ws	Specific wear rates
Wt	Weight