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Friction and Wear Behaviour of Fibre / Particles Reinforced Polyester Composites

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Abstract

In the present work, frictional and wear behaviour of polymer (polyester) matrix composites reinforced with different types of fibre / fillers have been investigated under dry wear sliding conditions. There are two types of fibre; carbon and coir fibre used as continuous reinforcements phase and two types of powders; graphite and coconut shell powder used as particulate reinforcements. Friction coefficient and wear rate measured for the proposed materials under dry sliding contact with steel counter-face. Pin on disc tribometer used to performing the proposed tribological measurements under 2.3 ms^{-1} sliding speed and 4, 6, and 8N applied normal loads. Effect of applied loads, reinforcement type and reinforcement content observed. The results shows that the friction coefficient of carbon or coir powder filled polyester less than friction coefficient of carbon or coir fibre reinforced polyester. Nevertheless, wear resistance of carbon or coir fibre reinforced polyester is higher than wear resistance of carbon or coir powder reinforced polyester.

Keywords

Polyester Composites, Carbon Fibre, Graphite Powder, Coir Fibre, Coconut Shell Powder, Tribological Performance

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1. Introduction

Previously it was concluded that natural fibre reinforced polyester composites have good tribological properties as nontraditional materials for industrial applications such as bearing, brake pads and flooring materials that require proper friction coefficient and wear resistance [1]. An increasing demand on the polymeric composites reinforced or filled with natural fibres or powders respectively for use in a wide range of industrial applications because it maintain good environmental properties and affordable and ease of manufacturing in compare with traditional materials [2]. For its good properties polymer composites used in automobiles industries, furniture industries and constructions [3–6]. Polymer matrix composites distinguished in several advantages compared to conventional materials, such as their lower cost, low density, chemical resistance, good mechanical properties, high strength, low weight and flexible for processing equipment [7–9]. An example of recommended polymer matrix composites; that use natural reinforcements as an alternative option to synthetic fibres, fibres extracted from date palm trees, mangos trees, corn plants and coir fruit are the most desirable reinforcements for polymeric composites in recent decades. [10–11]. However, there is an increasing research effort for use natural fibres as reinforcement for polymer composites in mechanical and tribological applications [12–14]. Tensile, flexural, impact, friction, wear and other mechanical and tribological properties can improved by means of fillers or fibres to reinforce and enhance performance of polymers, [15–18]. There are expanded studies have been carried out to discuss the effect of additives, like fibres or filler, the content percentage or modifications of the additives, and the conditions of application on the mechanical performance of polymeric composites [18-22]. Few studies explained the relationship between tribological and mechanical

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properties of polymer matrix composites. Moreover, the literature, as reported by many scholars, has not resolved the great dispute on the relation between the mechanical and the tribological performances of engineering materials [23-27]. Carbon or graphite as filling materials to polymeric composite has had a selective effect on the mechanical performance, whereas it has led to a favorable effect on the frictional properties. [28] Aireddy et al [29] Investigated coir dust reinforced epoxy matrix composites of different compositions, they conclude that; "abrasive wear resistance of the composite depends on the coir dust concentration, sliding distance and applied normal load". Mechanism of wear dominated by reinforcement because of higher coir dust loading. The abrasive wear resistance decreased with increase in normal load and increased with increasing coir dust concentration. Researchers have begun to pay attention on natural fibre reinforced composites, which are composed of natural or synthetic resins, reinforced with natural fibres. Natural fibres exhibit many desirable properties; they are a low-density material yielding relatively lightweight composites with high specific properties. These fibres also have significant cost advantages and ease of processing along with being a renewable resource, in turn reducing the dependency on foreign and domestic petroleum oil, Verma et.al [30]. The incorporation of rice husk in to epoxy can significantly reduce the abrasive wear loss. Suitable treating of rice husk increases wear resistance of the rice husk reinforced epoxy composite [31]. Palm fronds and mango's dry leaves are other examples of the natural reinforcements that added to improve the tribological properties of polyester composites. [32-33]. in the present work, carbon and coir fibre and powder proposed as natural reinforcements for polyester composites to improve wear and friction behaviour for the proposed composites. Effect of reinforcement type, shape and percentage content as well as the applied normal loads on the tribological properties will discussed.

2. Experimental Work

2.1. Raw Materials

2.1.1. Polymer Matrix

The proposed composite consist of polyester resin (SIR RESIN, SABIC KSA) as a polymeric matrix.

2.1.2. Fibre Reinforcements

Coconut outer shell (coir) fibre and carbon fibres with 0.5 mm diameter are different types of continuous fibre reinforcements used for the proposed composites.

2.1.3. Particulates

To compare the effect of the reinforcement type there are two types of randomly distributed filling particles for the proposed composites graphite powder and coconut shell (coir) powder in particle size less than 0.1mm.

2.2. Preparing of Test Specimen

Polyester resin mixed with its corresponding hardener by ratio of 8:1 then poured into cylindrical mold (25 mm height and 8 mm diameter) that previously filled by long vertical fibres in volumetric ratio from 5 to 25%. For test specimens which filled by soft particles, polyester composites mixed with filling powder in volumetric ratio up to 25% before poured into empty cylindrical mold under ambient conditions of temperature, humidity and pressure, after 24 hours test specimens become completely solid and ready to performing required measurements. All test specimens subjected to soft sandpaper to clean the surfaces for performing the tribological measurements.

2.3. Tribological Measurements

In the present work; friction coefficient and wear rate measured by means of pin-on-disc tribometer –ASTM G99 – for the proposed composites to obtain the effect of reinforcing type, shape and content under different applied loads. All measurements performed on five test specimens under each condition of content, shape and type, the mean readings used to construct result curves.

2.3.1. Test Procedure

Polyester composite test specimen mounted as a pin in the test holder, composite pins subjected to rotating counter face -steel disk- under different contact pressure. Friction force displayed by means of load cell then used to calculate the friction coefficient for each sample under each test condition. Rate of wear measured on the principle of weight loss for sliding distance for each sample under each test condition.

2.3.2. Test Conditions

Tribological measurements carried out for test specimens under different conditions as following: Contact area: A=12.56 mm^2, applied loads 4, 6 and 8N and sliding velocity 2.35 ms^{-1} for five minutes each sample.

3. Results and Discussion

3.1. Effect of Carbon Fibre/Filler on the Friction and Wear of Polyester Composite

Friction coefficient of polyester composite reinforced with carbon fibre or particulates displayed in figures 1-3, coefficient of friction decreases from 0.75 for empty polyester specimen to 0.52 and 0.33 with increase of carbon fibre and carbon particles to 25% respectively under 4N applied normal load.

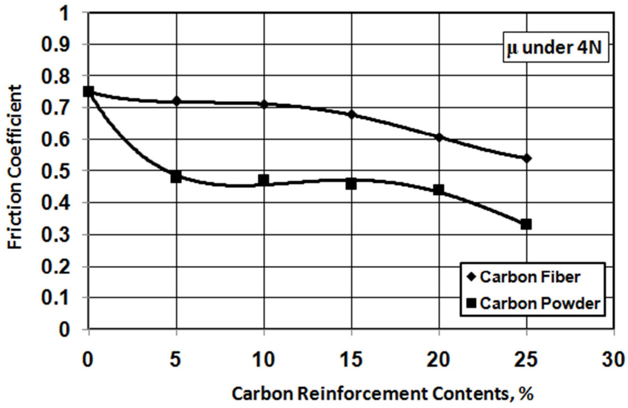

Fig. 1. Effect of carbon reinforcements on friction coefficient of polyester composites under 4N applied load.

With increase of applied loads to 6N, the friction coefficient decreases from 0.62 for free polyester sample to 0.48 and 0.32 with increase of carbon fibre and carbon particles to 25% respectively. It seems that carbon fibre behaves as an abrasive or scratching points on the contact area; which increases the friction coefficient of carbon fibre reinforced polyester than it for carbon powder reinforced polyester. Continuously increase of applied loads to 8N increases the coefficient of friction in compare with composites sliding under low loads 4N and 6N. It may be a result of surface crumbling under high loads that produce a third body and change the adhesive friction mode to abrasive friction.

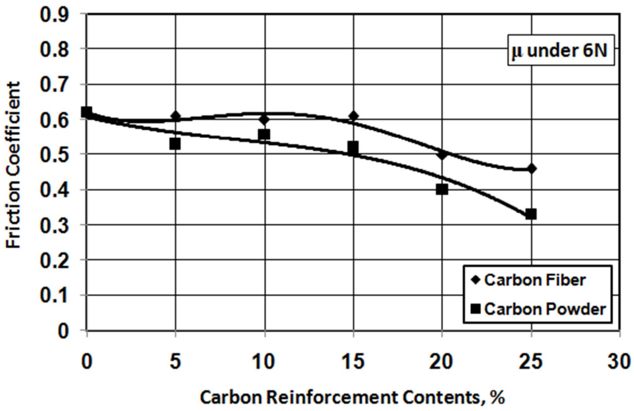

Fig. 2. Effect of carbon reinforcements on friction coefficient of polyester composites under 6N applied load.

Wear rate of carbon fibre reinforced polyester and carbon powder filled polyester explained in figure 4. The rate of wear decreases significantly from 0.0035 g/m for polyester sample to less than 0.0005 g/m with increase of carbon fibre/ powder in polyester to 25%. It seems that – from figure- the wear resistance of carbon fibre reinforced polyester is high in compare with it for carbon particles filled polyester. This may be come from the ease of particles disengaging from composite profusely than fibre breakdown.

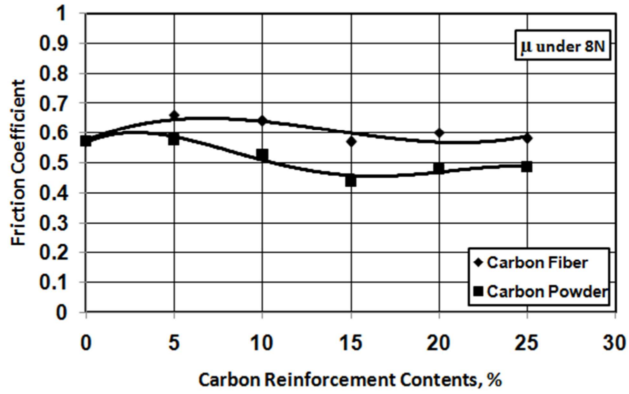

Fig. 3. Effect of carbon reinforcements on friction coefficient of polyester composites under 8N applied load.

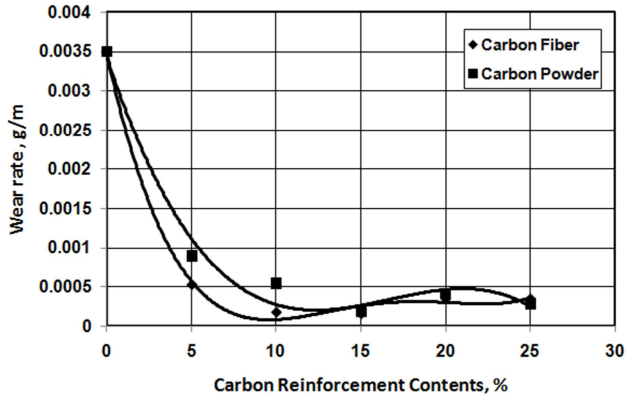

Fig. 4. Effect of carbon reinforcements on wear rate of polyester composites.

3.2. Effect of Coir Fibre/Filler on the Friction and Wear of Polyester Composite

Friction coefficient of polyester composite reinforced with carbon fibre or particulates displayed in figures 5-8, coefficient of friction decreases from 0.75 for empty polyester specimen to 0.55 and 0.38 with increase of coir fibre and coir powder to 25% respectively under 4N applied normal load. With increase of applied loads to 6N, the friction coefficient decreases from 0.62 for polyester to 0.43 and 0.35 with increase of coir fibre and coir powder to 25% respectively. It seems that coir fibre behave as scratching tools on the contact area; which increases the friction coefficient of coir fibre reinforced polyester than it for coir powder reinforced polyester. But friction coefficient more than it in compare with polyester reinforced with carbon fibre or carbon powder. Increase of applied loads to 8N increases the coefficient of friction. It may be a result of surface crumbling under high loads that produce a third body and change the adhesive friction mode to abrasive friction.

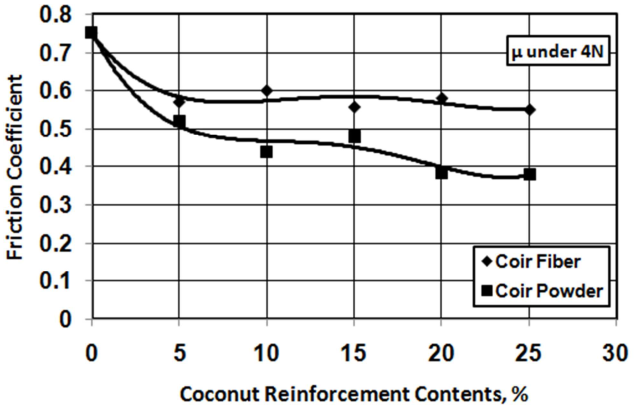

Fig. 5. Effect of coconut reinforcements on friction coefficient of polyester composites under 4N applied load.

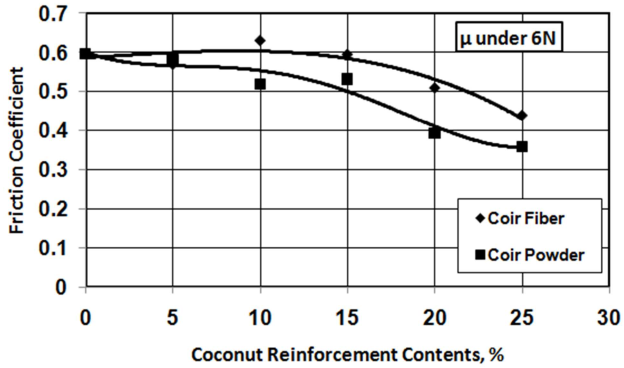

Fig. 6. Effect of coconut reinforcements on friction coefficient of polyester composites under 6N applied load.

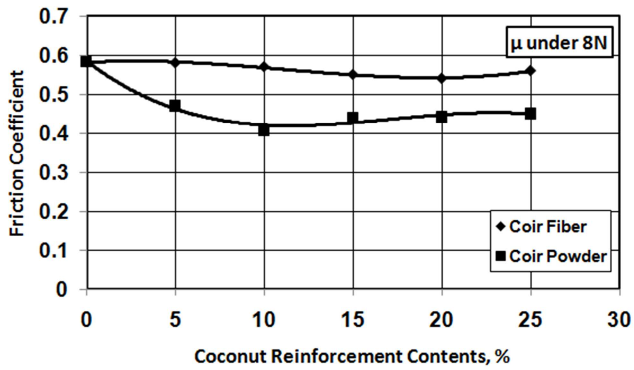

Fig. 7. Effect of coconut reinforcements on friction coefficient of polyester composites under 8N applied load.

Wear rate of coir fibre reinforced polyester and coir powder filled polyester explained in figure 8. The rate of wear decreases significantly from 0.0035 g/m for polyester sample to 0.00089 g/m with increase of coir powder in polyester to 25%, also it reduced to 0.00018 g/m for polyester reinforced by 25% coir fibre. It seems that the – as resulted for polyester reinforced by carbon fibre/ carbon particles- wear resistance of coir fibre reinforced polyester is high in compare with it for coir particles filled polyester. This may be come from the ease of particles disengaging from composite more than fibre breakdown.

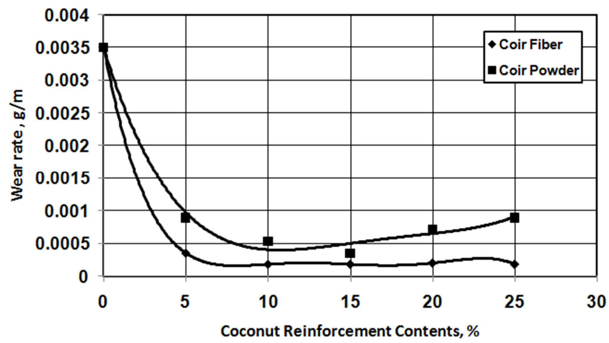

Fig. 8. Effects of coconut reinforcements on wear rate of polyester composites.

4. Conclusion

From this work, it can be conclude that:

1. Friction coefficient of carbon fibre reinforced polyester decreases to 0.48 with of fibre content to 25%.
2. Increase of carbon powder to 25% decreases the coefficient of friction for carbon filled polyester composites to 0.32.
3. The rate of wear decrease with increases of carbon fibre or powder
4. Increase of coir powder decreases the friction coefficient of polyester composites.
5. Wear rate of coir powder filled polyester significantly decreases from 0.0035g/m to 0.00018 g/m with increase of coir powder to 25%.
6. Slightly increase of applied normal loads from 4N to 6N decreases the friction coefficient of polyester composites
7. Extra increase of applied loads increases the coefficient of friction of polyester composites.

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