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Effect of Date Palm Seeds on the Tribological Behaviour of Polyester Composites under Different Testing Conditions

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Abstract

Natural Fiber Reinforcement Polymeric Composites (NFRPC) used in the recent days in wide range of industrial applications. For its good environmental properties and availability, natural fibers and natural additives used as reinforcing material for most of polymeric composites. In the present work, polyester composites filled by date seeds powder as a natural filling material were proposed as (NFRPC). Effect of different parameters on the tribological behavior of the proposed composite is studied. The proposed variables are; applied normal load, sliding speed, sliding distance and the percentage of filler contents. Pin on Disk tribometer was designed and constructed for the tribological measurements. Friction coefficient and rate of wear for the proposed composites have been obtained. The results show that; the coefficient of friction for polyester composites filled with date seed powder decreases by 15% with increase of filler under high contact pressure, beside the increase of velocity increases friction coefficient up to 10%. Rate of wear decreases to 10E-5 gm^{-1} with increase of date seed filler up to 10% under low contact pressure and low sliding speed, but; unfortunately, continuous increases of date seed filler from 15% to 25% decrease the resistance of wear for proposed composites under high contact pressure and high sliding speed. There is a significant effect of the applied load (contact pressure) and sliding velocity on the wear rate of polyester composite filled with date seed.

Keywords: Polymer composites; Natural fillers; Green composites; Friction; Wear

Introduction

In the recent decades more efforts spent to looking for an alternatives (non conventional) materials for the industrial applications. Many scientific researches employed to find new materials with desirable and Distinctive properties. Polymer composites filled/reinforced with natural fillers/fibers are the proposed materials; these are low weight, easy for manufacturing and fabrication, high resistance for chemicals and friendly environmental materials. Polyester composites are commonly used nowadays in industrial applications such as bearing materials, brake pads materials and flooring materials. It was concluded that using of agricultural wastes as a filling material improve the mechanical and tribological properties of polyester composites [1-4]. Environmental awareness among all over the world also provided reasons for the focus of the attention towards the use of green fiber polymer composites. The availability of the natural fibres of plant origin in abundance has also been a reason for the study in this area. Specific properties of natural fiber composite such as light weight, low cost, renewable in nature, high specific strength and modulus have widened the usage over other materials. Kumar concluded that; the mechanical behaviour of sundi wood dust reinforced epoxy composite is studied under the variation of filler content and speed. The experimental results support that successful fabrication of sundi wood dust reinforced epoxy composites is possible and that sundi wood dust possesses good filler characteristics as it improves the tensile and flexural properties of the polymeric resin. Composites based on natural fiber reinforcement have generated wide research and engineering interest in the last few decades due to their small density, high specific strength, low cost, light weight, recyclability and biodegradability and has earned a special category of green composite [5]. Polymer matrix materials such as unsaturated polyester, epoxy resin, polyethylene and polypropylene reinforced by the commonly available natural plant fibres that are cheap and abundant in nature [6]. Mirmehdi found that the flexural strength and tensile strength of date wood palm flour based polyethylene composite was decreased by increasing the filler content while the flexural modulus was increased [7]. Sudheer reported that Dry sliding performance of epoxy/glass composites were poor and it improved after addition of ceramic whiskers and graphite, ceramic whiskers alone has increased the friction coefficient whereas graphite has considerably reduced the friction coefficient of end composites. However both fillers have improved the wear resistance property of epoxy/glass composites [8]. During last few years, the interest in using natural fibers as reinforcement in polymers has increased dramatically. Natural fibers are not only strong and lightweight but also relatively very cheap. Vivek Mishra were proposed a jute fiber as a new set of natural fiber based polymer composites consisting of bidirectional jute fiber mat as reinforcement and epoxy resin as matrix material [9]. Jyoti R. Mohanty were investigate experimentally the effect of fiber contents on wear behavior of date palm leaf reinforced polyvinyl pyrrolidone (PVP/DPL) composites, and they found that incorporation of date palm leaf fibers leads to significant improvement in the wear resistance of composites up to optimum fiber content and then decreases as fiber content increases. Further, it is found that surface modification has significant effect on wear performance. Worn surfaces of some selected samples were studied by scanning electron microscopy to analyze the wear mechanism [10]. The increasing demand for greener and biodegradable materials leading to the satisfaction of society requires a compelling towards the advancement of nano-materials science. The polymeric matrix materials with suitable and proper filler, better filler/matrix interaction together with advanced and new methods or approaches are able to develop polymeric composites which show great

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prospective applications in constructions and buildings, automotive, aerospace and packaging industries [11]. Analysis of properties of polymer composites shows that they depend on the properties of the individual components; the relative amount of different phases; the orientation of various components; the degree of bonding between the matrix and the reinforcements; and the size, shape and distribution of the discontinuous phase [12]. Sudeepan concluded that the most influential factor which affects the tribological properties is normal load followed by filler content and spee [13]. Salar report that the usages of fiber reinforced polyesters are in airplanes, electronics components, automotives, rail ways and wagon systems and sporting equipments. Beside their desired mechanical properties, their resistance to corrosion is also a tempting factor to use these composite in different areas. Although they are sensitive to UV light, heat and moisture environments, good maintenance could increase their life time [14,15]. Polyesters are also commonly used as matrix materials, particularly with glass-fibre-reinforcement. Polyester is an economic material that has high chemical resistance and is resistive to environmental effects. It has high dimensional stability and low moisture absorption. Low volume- fraction glass-fiber/ polyester composites with a wide range of colors have been in use for a long time. The production technologies for thermoset glass/polyester composites are easier and cheaper than those for other glass/resin materials. Glass-fiber-reinforced polymer with thermoset polyester resin is an attractive material that is economically desirable [16,17]. In the present work effect of sliding speed, contact pressure and percentage of filling materials on the friction and wear performance of polyester composite will be experimentally studied.

Experimental Work

Raw materials

The proposed composite consist of polyester resin (commercial name SIR RESIN from SABIC KSA) as a polymeric matrix and natural filler in form of powder of palm date seeds which has been cleaned, dried by heating in furnace to 120 C° and finally crushed into very fine powder (less than 0.1 mm).

Preparing of test specimen

Polyester resin as a matrix material hand mixed – by means of a long wooden stirrer - with date seed powder in volumetric ratio up to 25% and mixed with its corresponding hardener by ratio of 3:1. After well mixing of the composite contents for 3 to 5 minutes it poured into cylindrical mold (25 mm height and 4 mm diameter) under ambient conditions of temperature, humidity and pressure, after 24 hours test specimens become completely solid and ready for measurements. All test specimens subjected to soft sandpaper for cleaning the surfaces and remove irregular layers for performing the tribological measurements. It was observed that there is a symmetrical distribution of the filling powder on the projected area of polyester composites, which mean that there is a different amount of fillers on the surface of composite vary from 0% to 25% of the contact surface.

Tribological measurements

In the present work; friction coefficient and wear rate measured by means of pin-on-disk tribometer – according to ASTM G99 - for the proposed composites under different conditions of filler contents, applied loads and sliding velocity. All measurements performed on five test specimens under each condition of content, velocity and pressure, the mean of five readings used to construct result curves.

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 and different sliding speed. Friction force recorded 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.

Test conditions

Tribological measurements were carried out for test specimens under different conditions as following:

Contact area: $A=12.56\ mm^2$

Contacts pressure:

$P_1 = 0.318$ MPa

$P_2 = 0.477$ MPa

$P_3 = 0.636$ MPa

Sliding velocity:

$V_1 = 3.0\ ms^{-1}$

$V_2 = 3.5\ ms^{-1}$

$V_3 = 4.0\ ms^{-1}$

Results and Discussion

Friction coefficient of polyester composites under different sliding speed and contact pressure

Figure 1 show that the friction coefficients of polyester composite slightly decreases with increase of date seeds powder, this figure show a little decreases of friction coefficient with increase of contact pressure. Friction coefficient decreases from 1.4 for polyester without filler to 1.27 for composite filled by 10% date seed under low contact pressure, with increase of date seed filler to 15% the friction coefficient increases slightly to 1.38 then it – friction coefficient- decreases again to 1.2 with increase of filler to 25%. Increase of contact pressure decreases friction coefficient of polyester composite to 0.97 with increases of date seed contents to 20% under 0.63 MPa contact pressure. It seems that there is a transfer layer - may be from date seed powder- formed on the contact area which may be responsible for the friction reduction.

Figure 2 shows that there is a slightly decreases of friction coefficient of polyester composites under low contact pressure to 1.2 as date seed content increased to 25%. Beside; there is little variation in the values of friction coefficients of the other two contact pressure values (0.47 MPa, 0.6 MPa) at different contents of date seed which mean that there is a low effect of filler contents on the friction coefficient for polyester composite under these pressures value and sliding speed ($3.5\ ms^{-1}$).

Figure 3 explain the effect of filling content on the coefficient of friction under high sliding speed (4 m/s). It was observed that friction coefficient decreases to the lowest value – 0.80- with increase of filler contents to 10% under high applied loads (contact pressure); but it increased under low contact pressure for the same contents. Beside; increases of filler to 25% increase the friction coefficient to 1.42 under low contact pressure. It seems that increase of contact pressure lead to decreases the surface asperities by surface deformation or cutting (Figure 4a) which may be responsible for the reduction in friction coefficient under high normal loads. Also the presence of surface

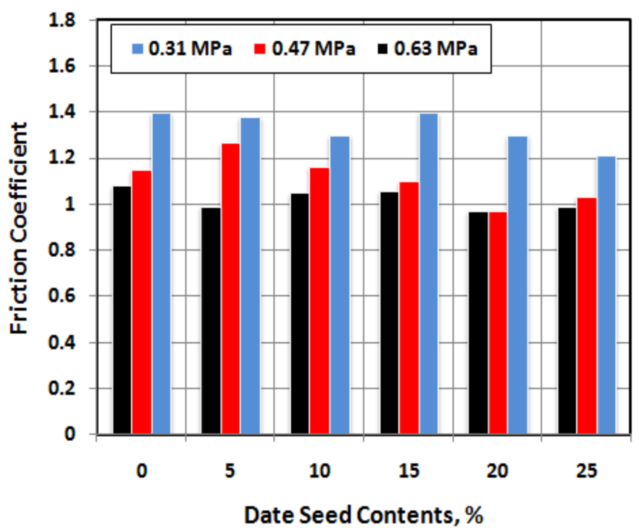

Figure 1: Friction coefficient of polyester composites sliding by 3.0ms^{-1}

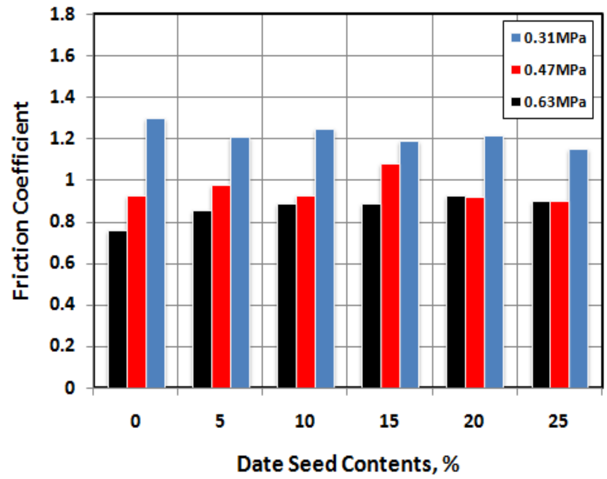

Figure 2: Friction coefficient of polyester composites sliding by 3.5ms^{-1}

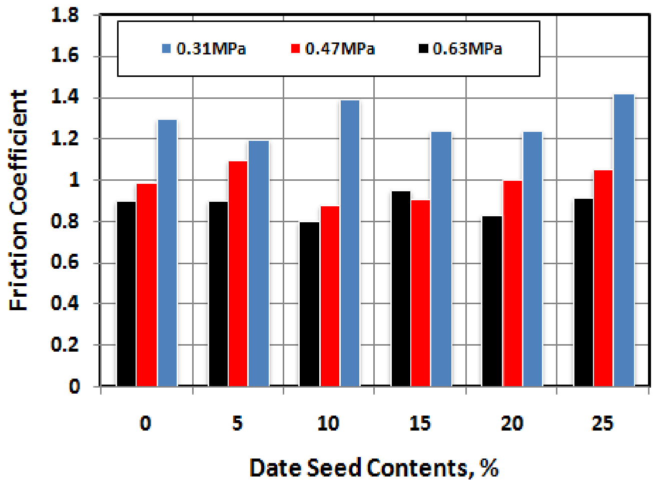

Figure 3: Friction coefficient of polyester composites sliding by 4ms^{-1}.

asperities may be increases the friction coefficient under low contact pressure (Figure 4b).

Wear rate of polyester composites under different sliding speed and contact pressure

Wear rate of polyester composites sharply decreases with increase of date seed contents to 10% from 3.2E-05 g/m to 1E-05 g/m under low contact pressure, then it increases slightly to 3.1E-05 g/m as the filling powder increases to 25%. Beside the rates of wear increase under high contact pressure which may be a result of weak coherent between the contents of composites under high loads (Figure 5). Increases of date seed contents to 25% under medium sliding speed (3.5 m/s) and low contact pressure (Figure 6) shows the minimum rate of wear (6.67E0-6 g/m). Figure 7 show that there is a high significant effect of contact pressure and sliding speed on the rates of wear for the proposed composites. This figure also shows that wear rate increases dramatically under high contact pressure with increases of filling powder contents. It seems that there is a surface deformation or surface cutting (Figure 4b) occurred under high speed and high loads which decreases wear resistance of polyester composite.

Figures 8-11 discuss two examples of polyester composites filled with date seed, these figures shows the effect of sliding speed and contact pressure on the friction coefficient and wear rate for composites filled with 10% or 25% date seed. Friction coefficient decreases with increase of both sliding speed and contact pressure; but this behaviour reversed under low contact pressure. Beside; the rate of wear increases under high speed and high contact pressure.

Conclusion

From the current work it can be conclude that Friction coefficient decreases to 0.80 with increase of filler contents to 10% under high

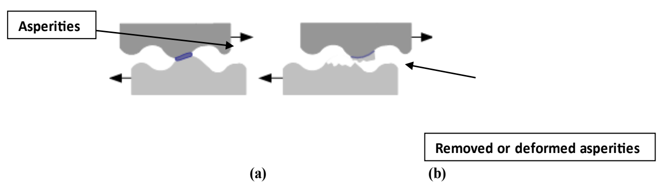

Figure 4: Adhesive mechanism for wear and friction.

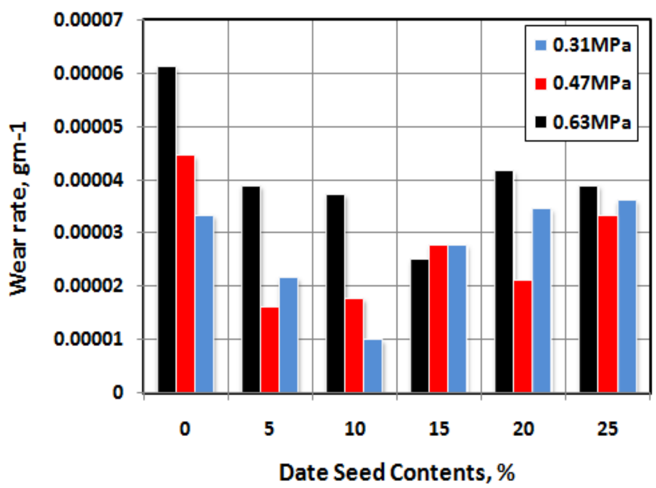

Figure 5: Wear rate of polyester composites sliding by 3.0ms^{-1}.

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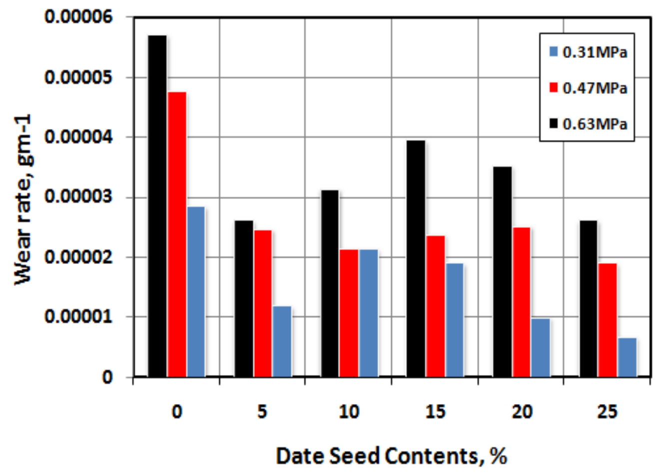

Figure 6: Wear rate of polyester composites sliding by 3.5ms^{-1}.

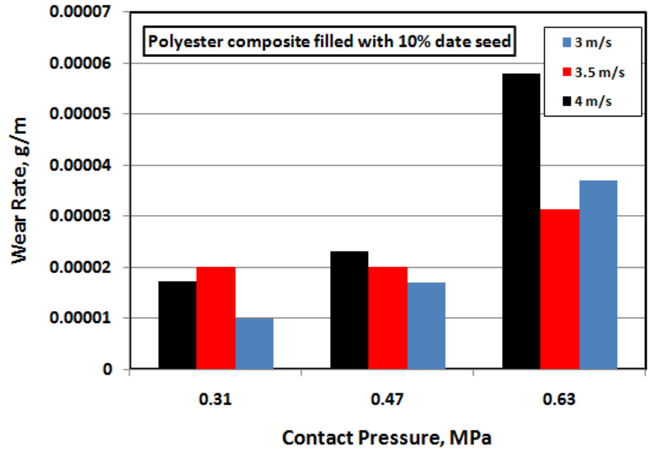

Figure 9: Wear rate of polyester composites filled with 10% date seed under different sliding speed and contact pressure.

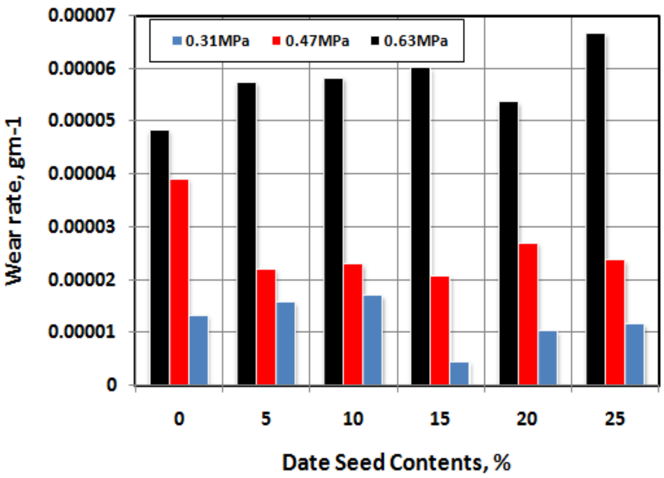

Figure 7: Wear rate of polyester composites sliding by 4ms^{-1}.

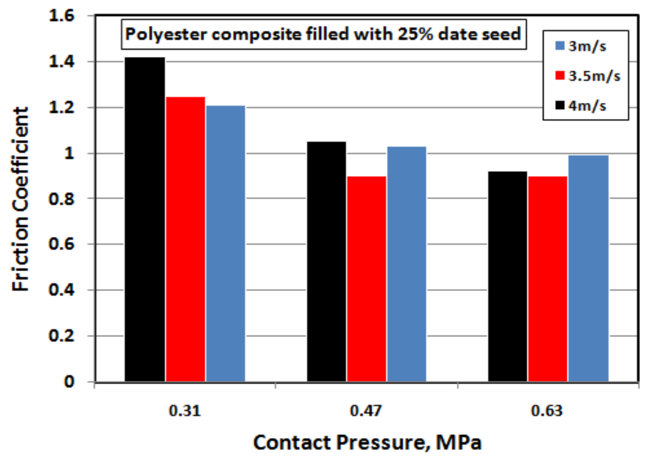

Figure 10: Friction coefficient of polyester composites filled with 25% date seed under different sliding speed and contact pressure.

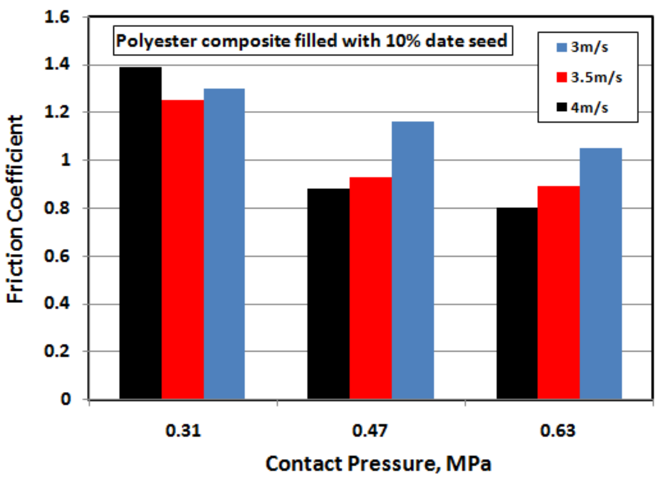

Figure 8: Friction coefficient of polyester composites filled with 10% date seed under different sliding speed and contact pressure.

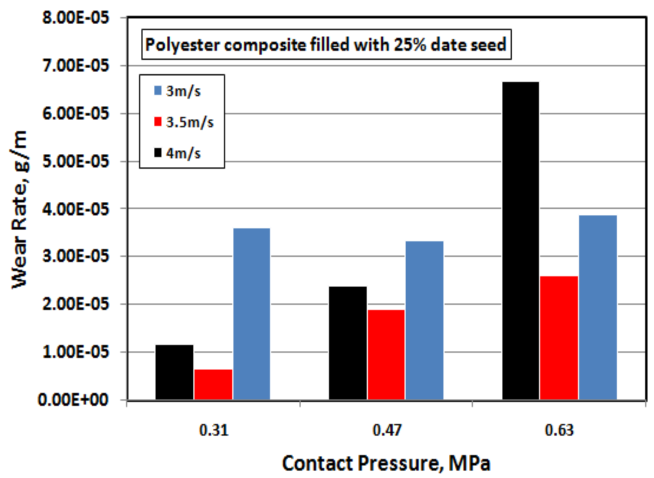

Figure 11: Wear rate of polyester composites filled with 25% date seed under different sliding speed and contact pressure.

applied loads (contact pressure) and high sliding speed (4 m/s). Increases of date seed contents to 25% increase the friction coefficient to 1.42 under low contact pressure and high speed. The Rate of wear of polyester composite decreases to 6.67E0-6 g/m with increase of date seed to 25% under medium sliding speed (3.5 m/s) and low contact pressure. The Coefficient of friction of polyester composite materials decreases with increase of sliding speed. Increase of contact pressure decreases the friction coefficient but sharply increase the rates of wear for polyester composites filled with date seed powder.

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