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TRIBOLOGICAL PERFORMANCE OF POLYMER COMPOSITES REINFORCED BY AGRICULTURAL WASTES

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ABSTRACT
Palm fronds and mango's dry leaves are examples of the agricultural wastes (AW), which are added as reinforcement materials for the polyester, as one of the polymer composites. This work is to investigate the effectiveness of these reinforcements in improving the tribological properties of the polyester composite. Two factors have been taken into consideration when designing the experiment. First is the size of the added particles; soft and hard particles with 0.5 mm and 3 mm particle size respectively were used. Second factor is the percent of the weight of the added waste (WOAW %) to the weight of the whole test specimen, ranging from 0% to 50%. A Pin-on-disc tribometer has been used to perform the tribological measurements. Polynomial regression analyses have been made. Trends and Coefficients of correlation have been obtained and used as the assessment measures. The results show that agricultural wastes improve the tribological properties of polyester composite.

KEYWORDS
Tribology, agricultural wastes, polymer composites.

INTRODUCTION
Polyester composites are commonly used nowadays in industrial applications such as bearing materials, brake pads materials, flooring materials and so on, [1]. Further approaches in designing polymeric composite in order to operate under low friction and low wear against steel counterparts are described, [2]. Due to the great changes in technology that occurred in the last century, a larger number of components fabricated in engineering polymers and composites have been used; substituting the most traditional metals in diverse applications, attaining in many cases better advantages as reduction of maintenance costs, save in weight and higher freedom for designing. Some examples of applications can be cited as: self-lubricant bearings, linear guides, mechanical seals, bushings, bearings cages, transporting belts, gears, and pulleys. These components are in turn more required in the aspects of mechanical resistance, fatigue

strength and resistance to wear, [3]. Analysis of the wear resistance of polymeric fibres requires a better understanding of their abrasive scratch behaviour and their frictional response, [4]. Fiber Reinforced Plastics (FRP) are widely used as structural materials in the manufacture of, for example, marine boats, automobiles and bathtubs due to their light weight, high degree of rigidity and superior moldability, [5]. Polymers have been favorably introduced as sliding materials in offshore structures for over ten years because of good wear resistance. Mainly under high loads, surface plasticity contributes to low friction, which is favorable for a reduction in dissipated sliding energy, [6]. in industrial applications, the increase in the use of composite materials means that it is necessary to know their behaviour under working conditions. Wear is an important parameter and its experimental behaviour must be known, [7]. Polymers are frequently used in tribological applications because of their self-lubricating ability and loadability. However, most research on their friction and wear mechanisms is performed on small-scale test samples under relatively low normal loads, [8]. As polymers generally posses good self-lubricating abilities through the formation of a polymer transfer film or 'third body', they are also used in industry as sliding materials in gears, slides and bearings, [9]. Fibre-Reinforced-Polymer composites are used particularly in the automotive and aircraft industries and the manufacture of spaceships and sea vehicles. [10]. There are the two main characteristics which make these materials attractive compared to conventional metallic designs. They are of relatively low density and they can be tailored to have stacking sequences to provide high strength and stiffness in directions of high loading, [11]. Composite materials consist of a resin and reinforcement chosen according to desired mechanical properties and the application, [12].

Polyester is an economic material that has high chemical resistance and is resistant to environmental effects. It has high dimensional stability and low moisture absorption. The production technologies for thermosetting glass/polyester composites are easier and cheaper than those for other glass/resin materials. Its application at low temperatures and under service terms is easy when this material is compared to advanced polymer composites with a complex molecule structure, high strength and working under terms of difficult service, [13].

In the present work, palm fronds and mango's dry leaves are added as reinforcement materials into polyester, as one of the polymer composites. The effectiveness of these reinforcements in improving the tribological properties of the polyester composite is investigated.

EXPERIMENTAL

The coefficient of friction and wear rate are the two tribological properties that would be tested in the present study. The change in the coefficient of friction and wear rate are traced with the change in the percent of the weight of the added waste (WOAW %) from the two types under applied normal loads 2, 4, and 6 N.

For the purpose of conducting the experiments, a "Pin-on-Disc" test rig has been designed and manufactured, Fig. 1. It consists of a steel disc of 150 mm diameter and 5

mm thickness driven by variable speed motor, specimen holder, load cell, load holder at which the normal loads were applied and digital screen attached to the load cell.

Test specimens were formed in shape of cylindrical pins of 10 mm diameter and 30 mm height, Fig. 2. Polyester was mixed with the agricultural waste by weight ratio from 0 to 50 wt. %.

Fig. 1 Pin-on-Disk test rig.

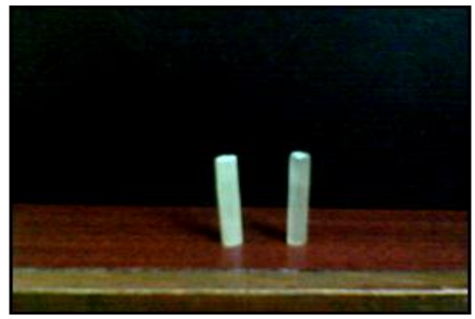

Fig. 2 Pins of polyester.

Tests were carried out at room temperature and normal level of humidity by means of "pin-on-disc" tribometer at 1700 rpm under different applied loads (2, 4, and 6N). Polyester composites were held in specimen holder and loaded normal to the rotating steel counter face. Due to friction between test specimens and steel counter face a tangential force is generated at the contact area resisting the rotating disc. This force depends on the friction coefficient of composites and it is monitored on the digital screen. Friction coefficient is the quotient of dividing the friction force by the applied load. Wear is the loss in weight of the composite test specimen after contact with the steel counter face for 3 minutes under 2 N normal loads. The following equations are applied in calculating the values of wear rate and friction coefficient.

Wear rate = $(W_1-W_2)/ t$ g/min (1)
Friction coefficient = $\mu = F_f / F_n$ (2),
Where
W_1 = specimen's weight before test (g),
W_2 = specimen's weight after test, (g)
T = test time (min),
F_f = Friction force N, and
F_n = Normal force N.

RESULTS AND DISCUSSION

Results of experiments are illustrated in graphs of which the horizontal axis represents the percentage of agricultural waste contents (AW contents %). The vertical axis represents either the friction coefficient or wear rate.

Effect of palm fronds

Figure 3 show that the increase of hard particles contents of palm fronds in polyester composite increases the friction coefficient. The regression curves of the three normal loads indicate positive correlation between the friction coefficient and the waste contents ranging from +0.45 to +0.76. For instant, the friction coefficient has increased from 1.06 for polyester free of agricultural wastes to 1.433 for composite containing 50 % palm fronds under the load of 2 N. This may be explained by the cause that the particles of palm fronds form an abrasive layer that increases the friction coefficient. Also from this figure there is a significant effect of the applied loads on the friction coefficient which decreases under high loads. Figure 4 shows that, for this type of agricultural wastes, there is no significant effect of the particle size, for example the friction coefficient of polyester composite contains 50 % palm fronds soft particles is 1.433 under low loads is the same value for composite contains 50 % palm fronds hard particles. The rate of wear increased from 0.02 g/min to 0.003 g/min. There is a strong negative correlation between the wear rate and WOAW %. It seems that the increase of palm fronds increases the cohesion between composite contents which may be responsible for the reduction of wear rates. This recommends these composites as frictional material for industrial applications such as brake pad. Figure 5 shows that there is no significant effect for the size of particles on the friction coefficient of polyester composite reinforced by palm fronds. The trend of wear rate for polyester composite reinforced by soft particles of palm fronds represented in Fig. 6 is the same for composite reinforced with hard particles of palm fronds.

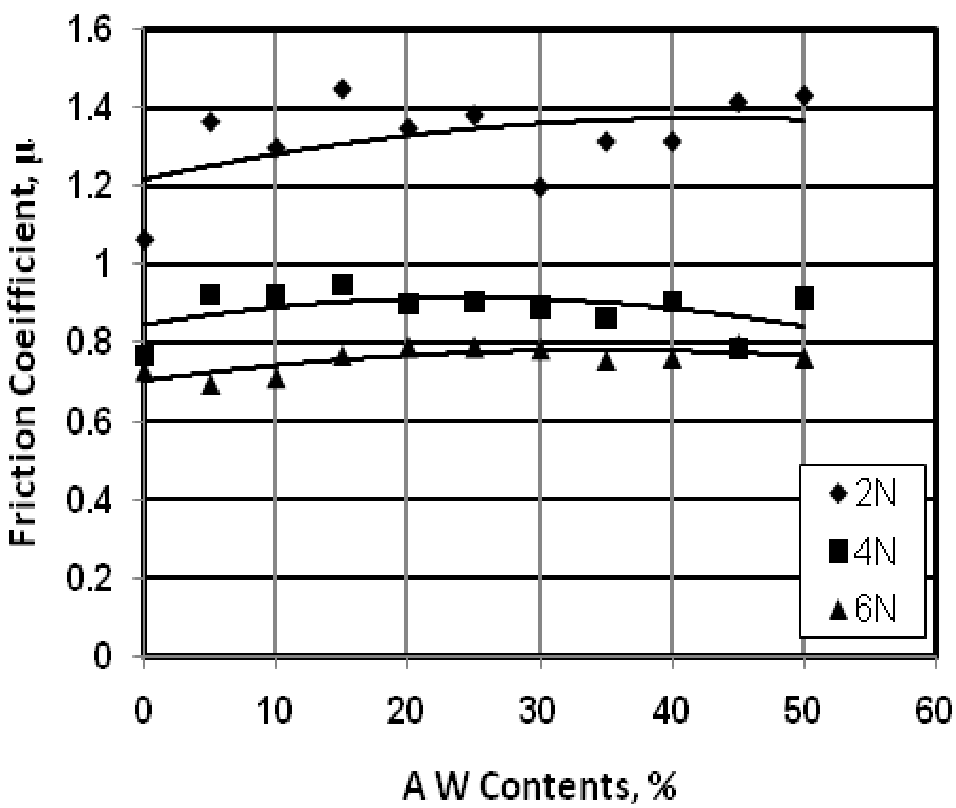

Fig. 3 Effects of hard particles of palm fronds on the friction coefficient of polyester composite.

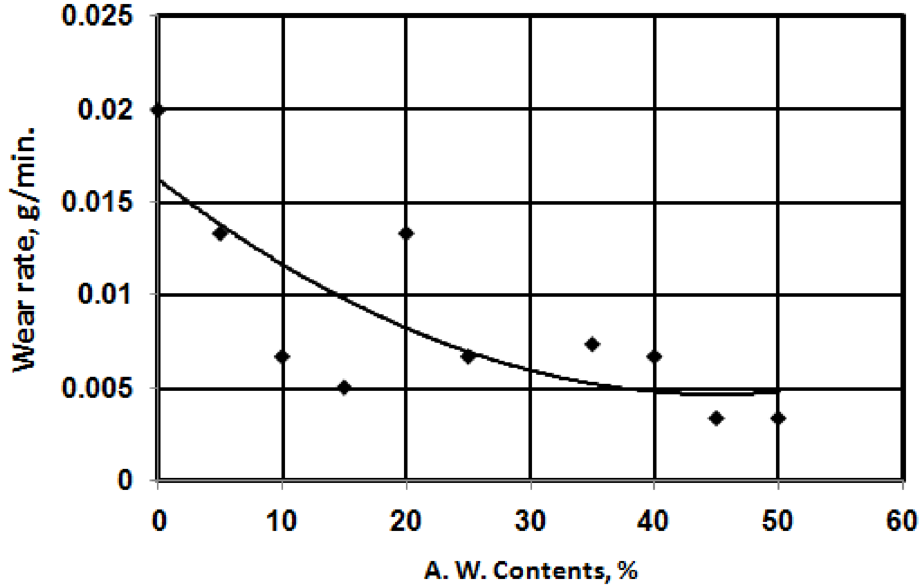

Fig. 4 effects of hard particles of palm fronds on wear rate of polyester composite.

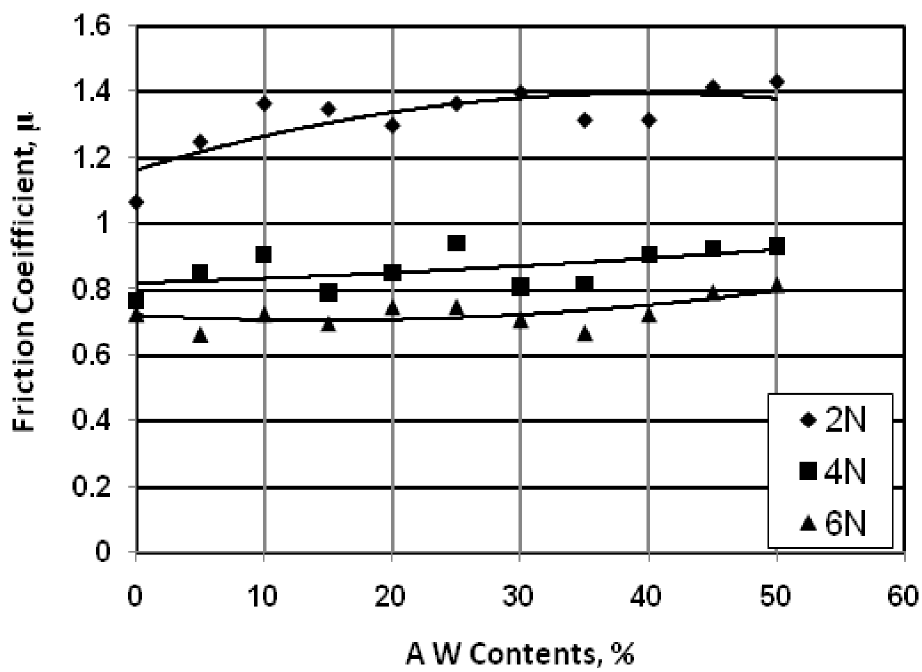

Fig. 5 effects of soft particles of palm fronds on the friction coefficient of polyester composite.

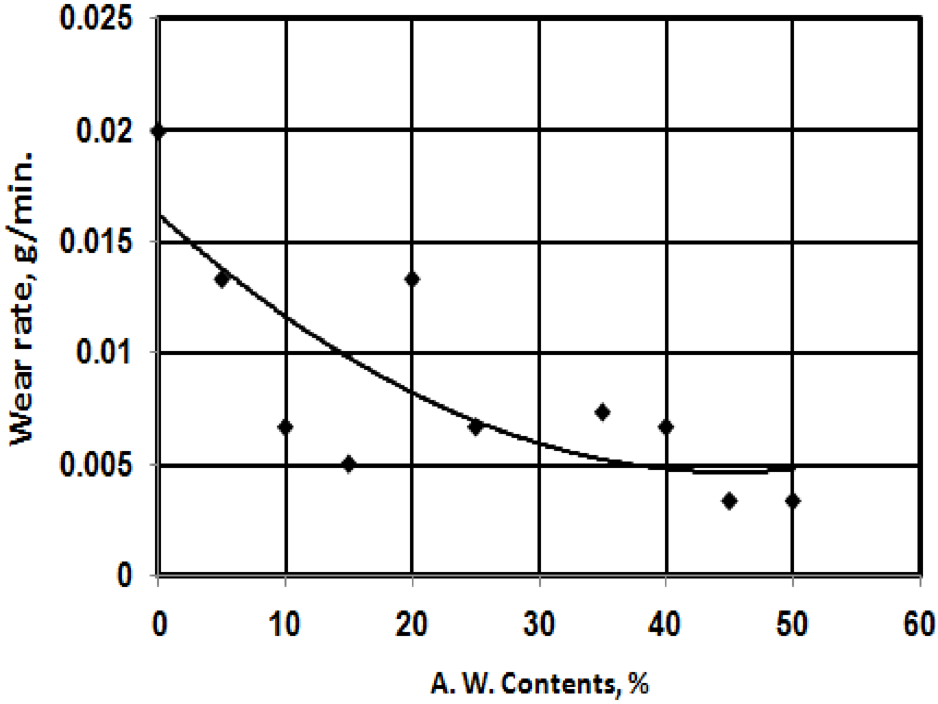

Fig. 6 Effects of soft particles of palm fronds on wear rate of polyester composite.

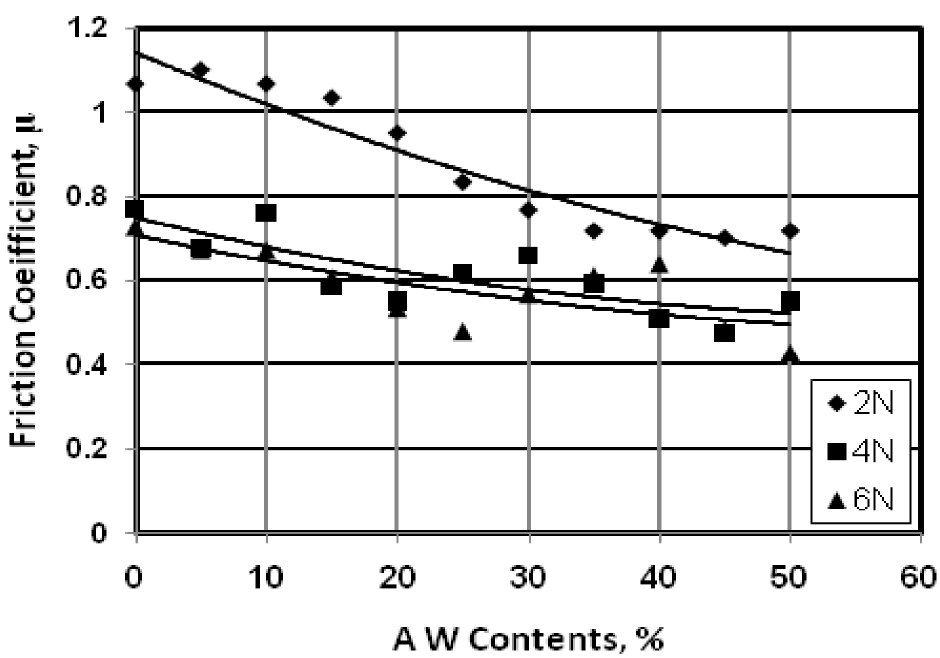

Fig. 7 Effects of hard particles of mango dry leaves on the friction coefficient of polyester composite.

Figure 7 shows that the increase of hard particles of mango dry leaves in polyester composite decreases the friction coefficient remarkably to 0.23 for composite reinforced by 30 % hard particles of mango dry leaves under 6 N. There is a strong negative correlation between the friction coefficient and AW contents % ranging from 0.55 to 0.90 until the 30 %, then further increase of particles in composite increases the friction coefficient to 0.9 for composite with 50 % hard particles of mango dry leaves. This may be explained as a result of transfer abrasive particles from the composite surface to the counter face which forms a third body on the frictional area and raise the friction coefficients. As represented in Fig. 8 increase of hard particles of mango dry leaves in polyester composite slightly decreases the rates of wear from 0.033 g/min to 0.015 g/min for composite containing 50 % hard particles of mango dry leaves.

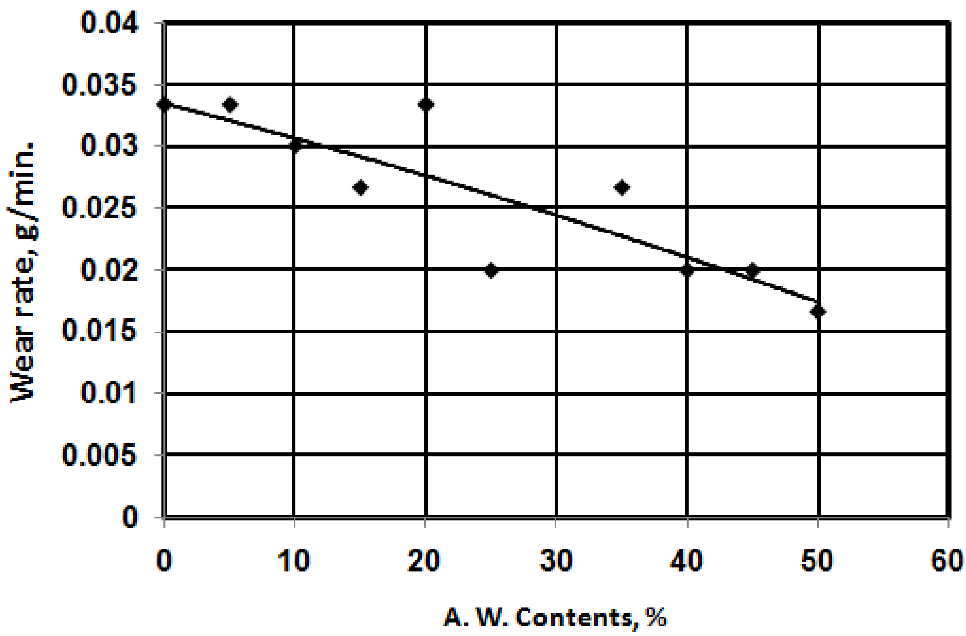

Fig. 8 effects of hard particles of mango dry leaves on wear rate of polyester composite.

The friction coefficient of polyester composite reinforced by soft particles of mango dry leaves decreases significantly to 0.42 as shown in Fig. 9 with increase of wastes to 50 % under 6 N. It is clear that there is a strong negative correlation between the friction coefficient and AW contents % ranging from +0.74 to +0.95. It seems that there is an elastic deformation has been occurred on the surface of the test pins under high loads which responsible for the friction reduction. The results of wear measurements for polyester composite reinforced by soft particles of mango's dry leaves represented in Fig. 10. The rate of wear decreases remarkable to 0.013 g/min with increase of AW contents in composite to 50 %. These results recommended this composite as

low friction coefficient and high wear resistance materials for industrial applications such as solid lubricants, bearing materials and sliders.

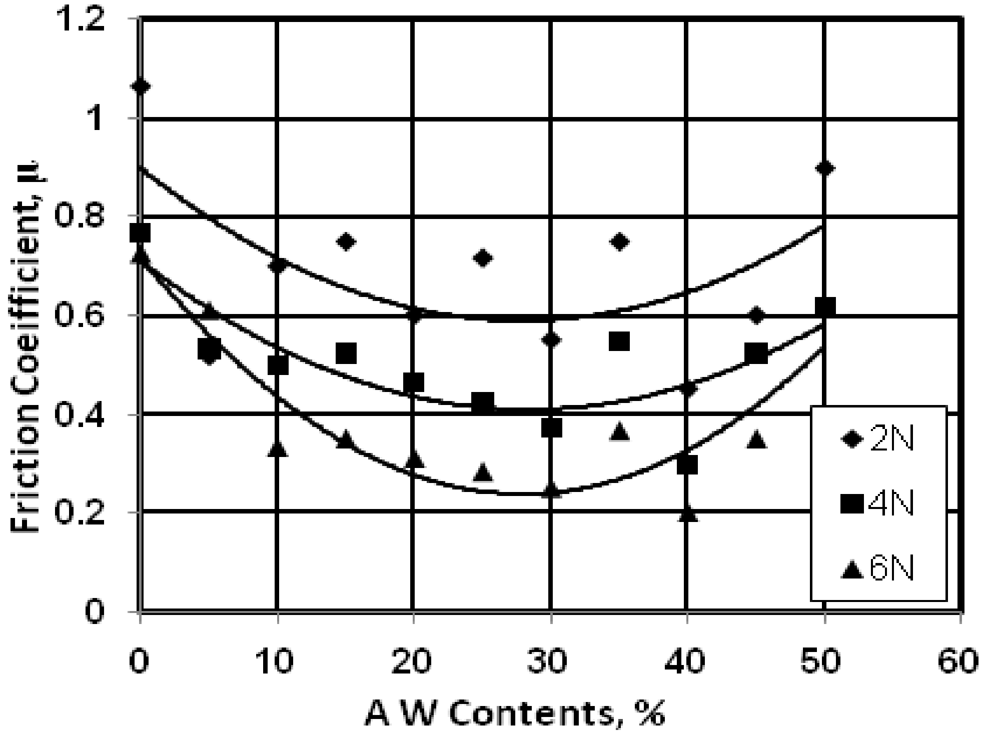

Fig. 9 effects of soft particles of mango dry leaves on the friction coefficient of polyester composite.

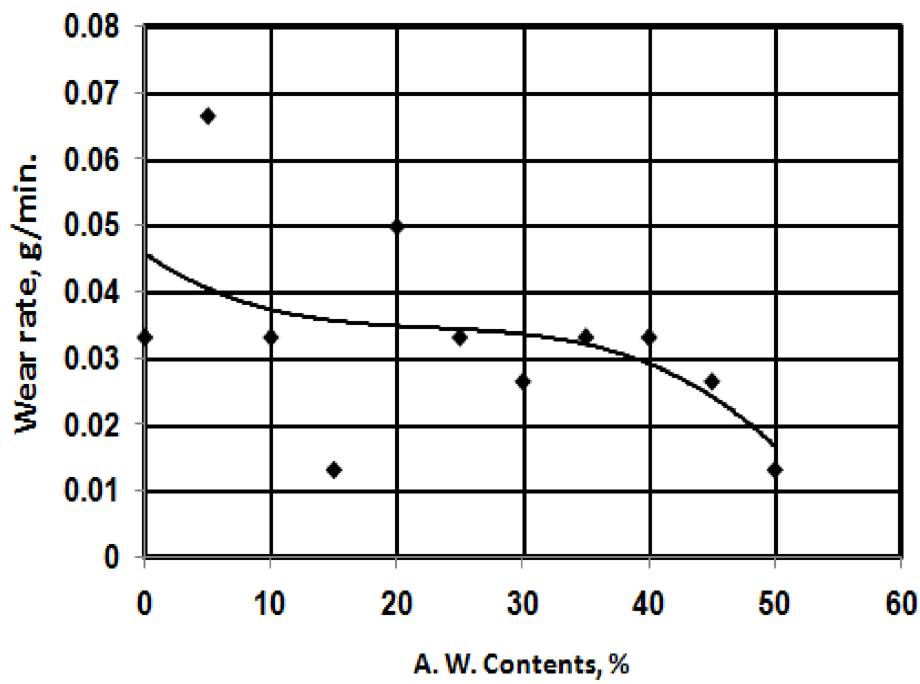

Fig. 10 effects of soft particles of mango dry leaves on wear rate of polyester composite.

CONCLUSIONS

From the previous results it can be concluded that:

1. The friction coefficients of polyester composite increases with increase of palm fronds particles in composite.

2. Increase of palm fronds in polyester composite remarkably decreases the rates of wear.

3. Polyester composites reinforced with palm fronds were recommended as high friction and low wear rate material for industrial applications such as brake pads.

4. Increases of soft particles of mango's dry leaves in polyester composite decrease the friction coefficient of composite.

5. Increase of hard particles of mango's dry leaves in polyester composite to more than 30 % increases the friction coefficients of composite.

6. Wear rate of polyester composite decreases with increase of soft particles of mango's dry leaves in composite.

7. Polyester composites reinforced with mango's dry leaves were recommended as low friction coefficient and high wear resistance material for industrial applications such as solid lubricants.

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