EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 11, NO. 2, April 2014, pp. 53 - 62 **ISSN 2090 - 5882**

TRIBOLOGICAL AND MECHANICAL PROPERTIES OF POLYMERIC COMPOSITES REINFORCED BY METALLIC FILLERS

Ibrahim R. A.[1] and Samy A. M.[2]

[1]Beni-Suif University,
[2]Minia University, Egypt

ABSTRACT

Polymer matrix composites (PMCs) filled with metals are widely studied to be used in industrial applications, such as gears, self-lubricated materials, sliding materials, flooring materials and brake lining materials. In view of this, the polymer matrix composites based on high-density polyethylene (HDPE) and polypropylene (PP) with different metallic additives were prepared. The mechanical and tribological properties of the prepared composites will be tested to obtain the optimum composition and optimum properties. Oxides of copper and aluminum in form of very fine powder (0.5 microns) were used as reinforcement additive. Wear rates and coefficients of friction of proposed composites as a tribological measurement were performed by means of tribometer devices (Pin-on-Disk). Mechanically; compression test performed by means of universal testing machine and stress-strain curve have been constructed for composites. The results show that the increase of copper powder reinforcement in the PMCs (polymer matrix composites) remarkably decreased the friction coefficient of those composites and increased their wear resistance. Besides, the ultimate strength of polymer matrix composites improved with increasing copper content in the composites.

KEYWORDS

Wear resistance, friction coefficient, polymer composites, metallic reinforcements, mechanical strength

INTRODUCTION

Composite materials are known to have high specific modulus, high specific strength, high resistance to corrosion, low weight and can be tailored to meet specific purpose, which give them advantage over traditional materials such as metals and ceramics [1]. Polymer matrix composites (PMCs) are commonly used nowadays in industrial applications such as bearing materials can used in fishing boats, brake pads materials, flooring materials and so on [2]. They have wide range of applications in aerospace, marine, automotive, biomedical, defense, offshore drilling, leisure goods and low pressure pipes [3]. Further approaches in designing polymeric composites in order to operate under low friction and low wear against steel counterparts are described [4].

Fig. 1 INA Metal-Polymer Composite Plain Bearings

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, plain bearings, Fig. 1, 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 [5]. Analysis of the wear resistance of polymeric fibres requires a better understanding of both their abrasive scratch behaviour and their frictional response. [6]. A solid lubricant material is used as powder or thin film to provide protection from damage during relative movement and to reduce friction and wear. Most polymer films are more plastic than metals, and many of them have sufficient ductility to deform together with the topography of the contact surface. Thus they may be interposed either as a separate film, or they may be deposited on the contact surface. Polyethylene (PE), polytetrafluoroethylene (PTFE), and polymethylmethacrylate (PMMA) are the normally applied as polymeric films. The PTFE thickener to form a chemically inert product was described, [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 [8]. Use of agricultural wastes (jasmine leaves) can improve the mechanical and tribological behavior of polyester composites which can be used in industrial applications [9].

The aim of the present work is to investigate the mechanical and tribological properties of the prepared composites to obtain the optimum composition and optimum properties. Oxides of copper and aluminum in form of very fine powder (0.5 microns) were used as reinforcement additive.

EXPERIMENTAL

Experiments were carried out using pin-on-disc wear tester. It consists of a rotary horizontal steel disc driven by variable speed motor. The arrangement of the test rig is shown in Fig. 2. The test specimen is held in the specimen holder that fastened to the loading lever. Through load cell, friction force can be measured. Friction coefficient was determined through the friction force measured by the load cell. The load is applied by weights. The counterface in form of a steel disc, of 100 mm diameter wear track of 3.2 µm, Ra, surface roughness.

The investigation was carried out to examine the effect of adding metallic fillers on the mechanical and tribological properties of high density polyethylene (HDPE) and polypropylene (PP) composites. Polymers are in form of granules with 2-3 mm diameter. The reinforcing phases for the proposed composite consist of copper oxides powder and Aluminum oxides powder in form of very fine powder with particle size of 0.5 – 2.0 µm. Test specimens were prepared by mixing polymer with selected types of metallic powders by weight ratio from 0 % to 35 % from the total weight of the specimen. Test specimens and its components are shown in Fig. 2. This mixture molded in a steel die

with 15 mm diameter and 50 mm height then compressed under high temperature 200-300 C° and 25 MPa for 20 minutes. Test specimens were prepared in the form of a rod of cylindrical cross section with 15 mm diameter and 50 mm length. The test specimens were loaded against counterface of steel disc.

Friction test were carried out under constant sliding velocity of 105 mm/sec and different applied load values 6, 8, 10 and 12 N. Wear test were carried out under constant sliding velocity of 105 mm/sec and constant time of 200 seconds under 6 N applied load. Mass difference technique was used to obtain wear rates, wear was measured by the difference between the mass of test specimens before and after test using an electronic balance of ± 0.1 mg accuracy. A compression test was carried out on the composite pins to indicate the effect of metallic reinforcements upon the stress-strain behaviour of the proposed composite. Mechanical investigations performed by means of WP 300.20 universal testing machine. A stress-strain curve has been plotted directly by the testing device for each test sample.

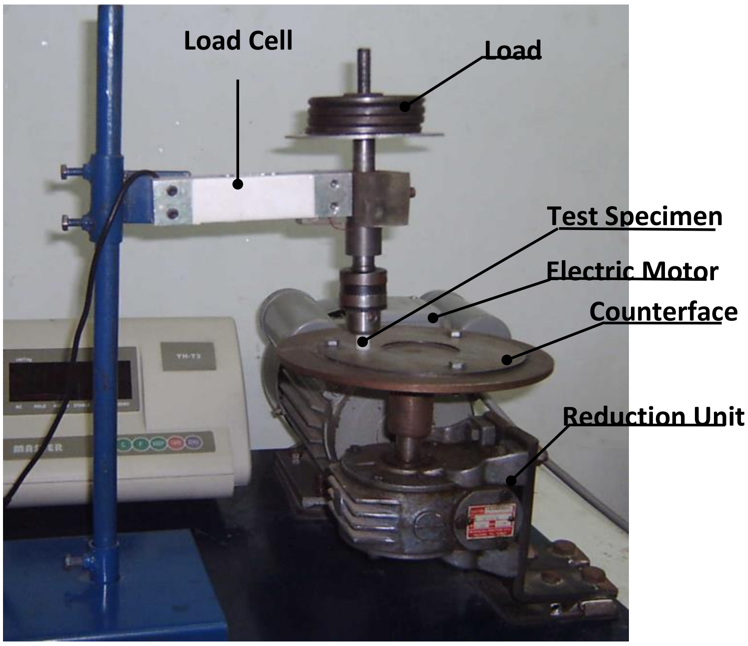

Fig. 2 Arrangement of the test rig.

RESULTS AND DISCUSSION

Effect of Copper Fillers on the Friction Coefficient

Figure 4 shows that the friction coefficient decrease with increasing copper content for High Density Polyethylene (HDPE) composites, for the free specimen it record high friction coefficient ranged from 0.28 under low loads to 0.21 under high load of 12 N. As shown in figure the friction coefficient of HDPE composites decrease remarkably to 0.205 with increasing of copper contents to 35 %, beside; the friction coefficient decrease with increasing of applied normal loads. It seems that a thin layer composed of copper and polymer particles formed at the contact area which may be responsible for the friction reduction.

Figure 5 shows that increase of copper content decreasing the friction coefficient of Polypropylene (PP) composites, for the free specimen it record high coefficient of friction ranged from 0.58 under low loads to 0.33 under high load of 12 N. As shown in figure the friction coefficient of PP composites decreases remarkably to 0.25 with increase of copper contents to 35 %, beside; the friction coefficient decreases with increase of applied normal loads. It seems that a thin layer composed of copper and polymer particles formed on the contact area which may be responsible for the friction reduction.

Effect of Aluminum Fillers on the Friction Coefficient

Figure 6 shows the effect of aluminum powder on the friction coefficient of HDPE composite which represents a reverse behavior for the composite filled by copper. It can be noticed that the friction coefficient increases remarkably to 0.91with increase of aluminum fillers in the HDPE composites to 35% under 6 N and the same behavior under high loads, friction coefficient increases from 0.205 for free specimen to 0.42 for composite containing 35 % aluminum contents under 12 N applied loads. Figure 7 shows the effect of aluminum powder on the friction coefficient of PP composite, the friction coefficient of PP composites decrease remarkably with increasing of aluminum contents, beside; the friction coefficients values decrease with increasing applied normal loads. It seems that there is an elastic deformation on the contact area of composite under high loads which may be responsible for reduction of surface roughness and so friction reduction.

Effects of Metallic Fillers on the Wear Rates

Figure 8 shows that increase of copper contents in HDPE composite decreases the wear rate from 0.001 g/min for free specimen to 3E-5 g/min for HDPE composite reinforced by 35 % copper powder. On the other hand the wear rate for HDPE composites increases remarkably to 0.0024 g/min with increase of aluminum reinforcement in composite to 35%. It seems that there is a transferred layer of aluminum particles formed on the counter face and behaved as an abrasive interface which may be responsible for the increases of friction and decreases the resistance of wear for HDPE composites. Figure 9 shows that increase of copper and aluminum contents in PP composites decrease the rates of wear from 0.0017 g/min for free specimen to 0.0007 and 0.001 g/min for PP composite reinforced by 35 % copper and aluminum content.

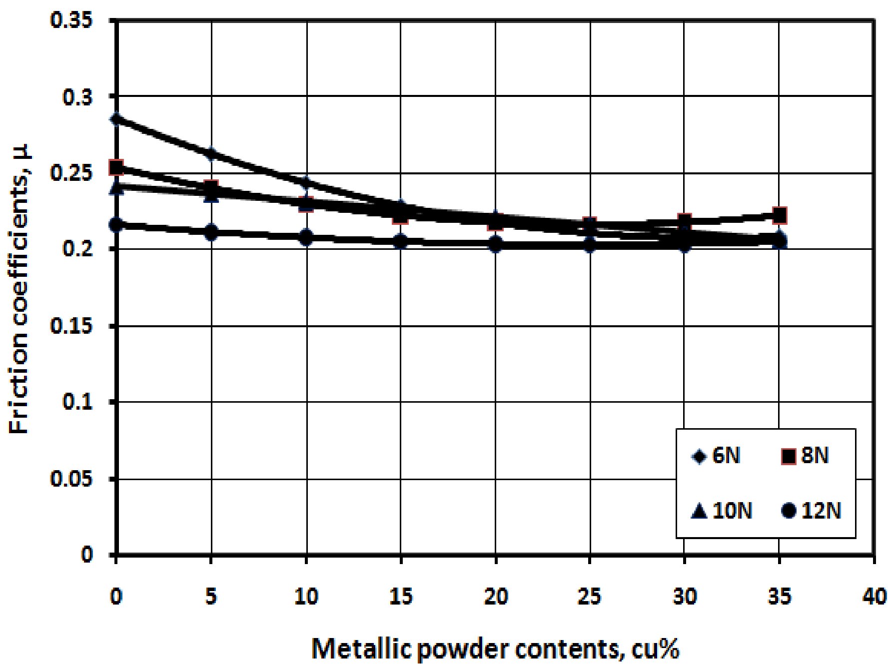

Fig. 4 Effect of copper powder content on the friction coefficient of HDPE composites.

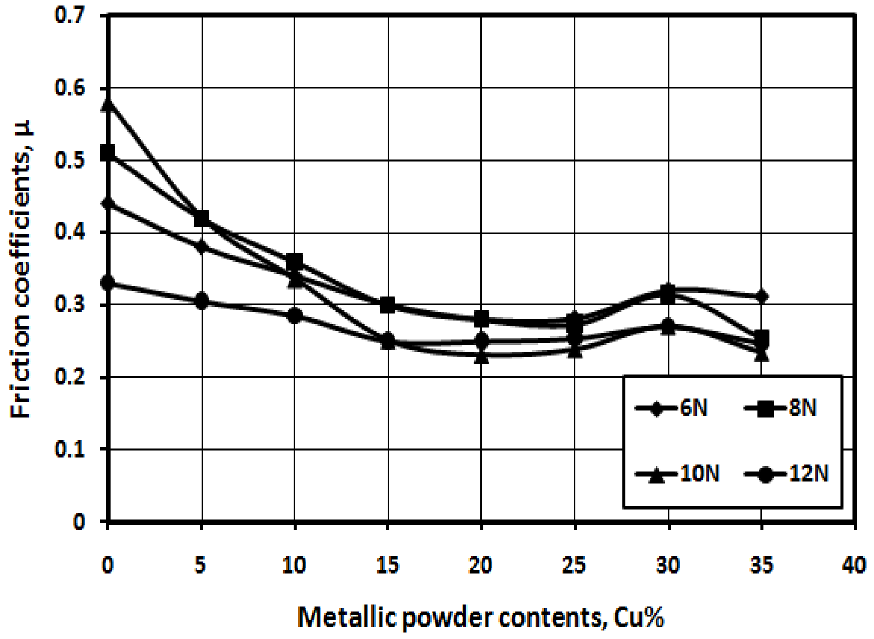

Fig. 5 Effect of copper powder content on the friction coefficient of PP composites.

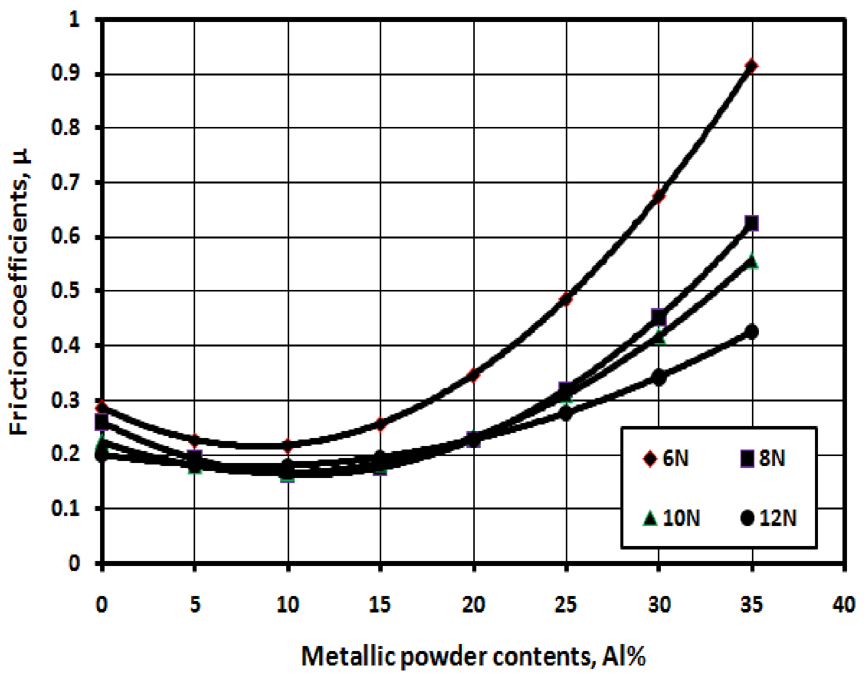

Fig. 6 Effect of aluminum powder content on the friction coefficient of HDPE composites.

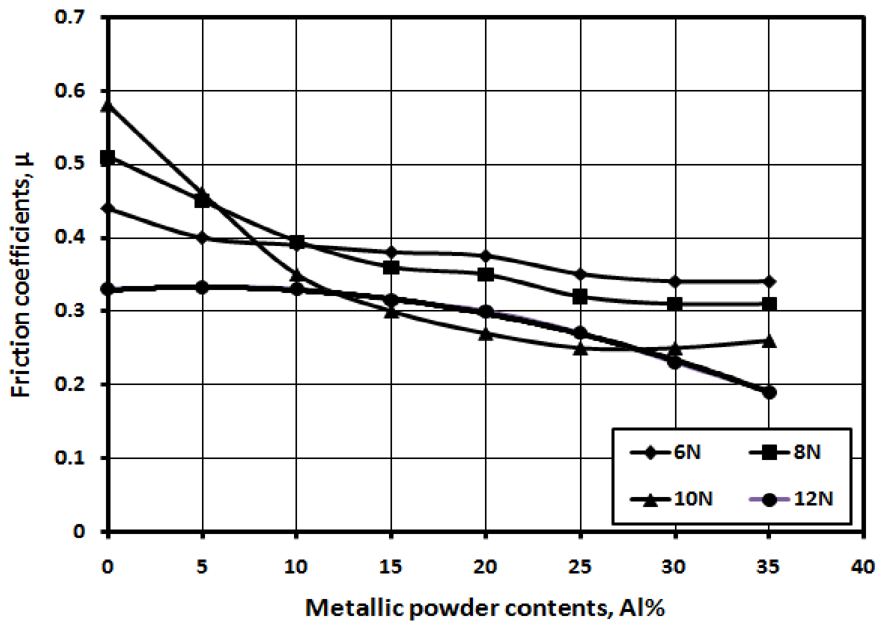

Fig. 7 Effect of aluminum powder content on the friction coefficient of PP composites.

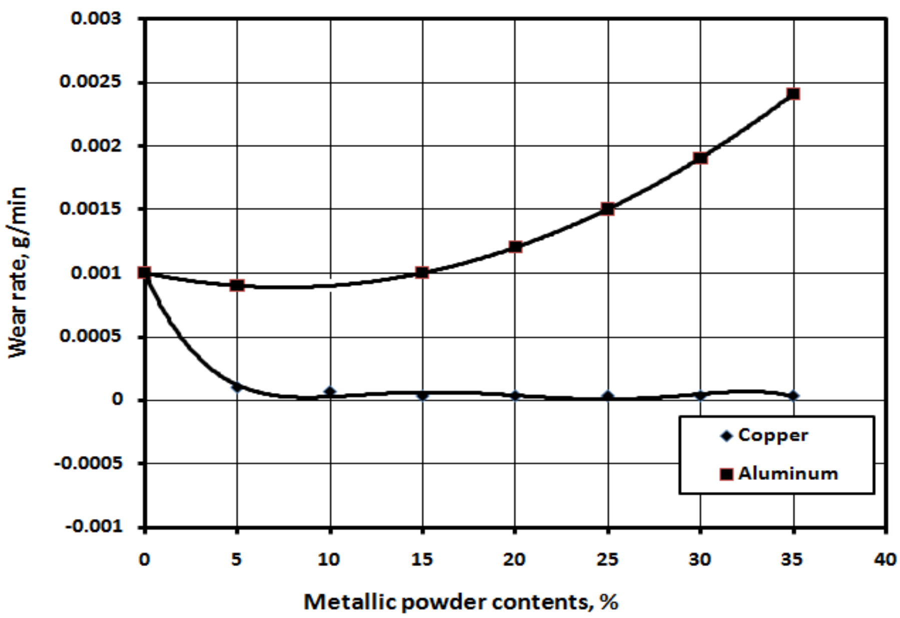

Fig. 8 Effect of metallic powder on the wear rates of HDPE composites.

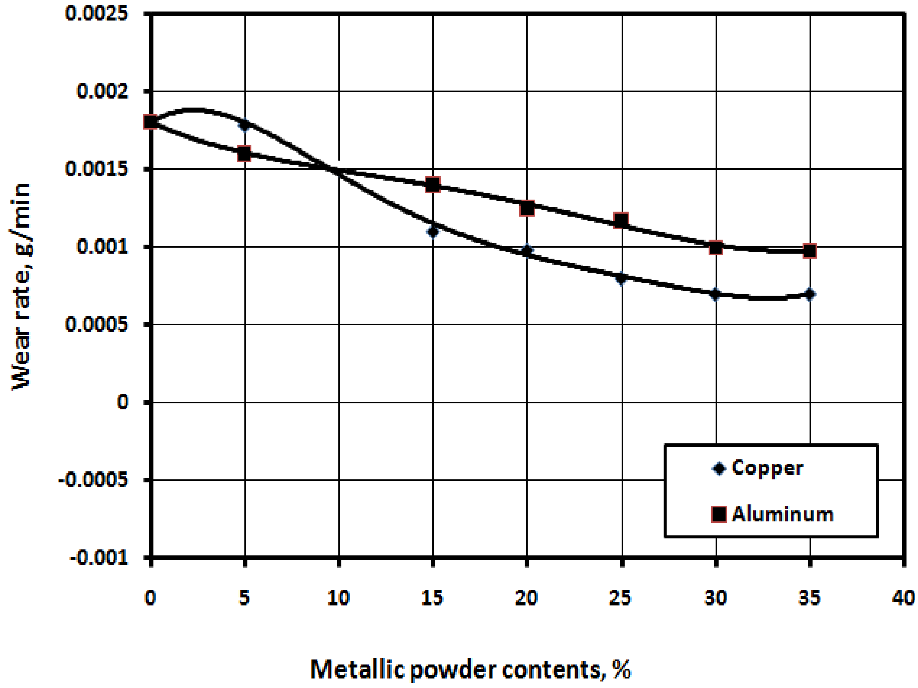

Fig. 9 Effect of metallic powder on the wear rates of PP composites.

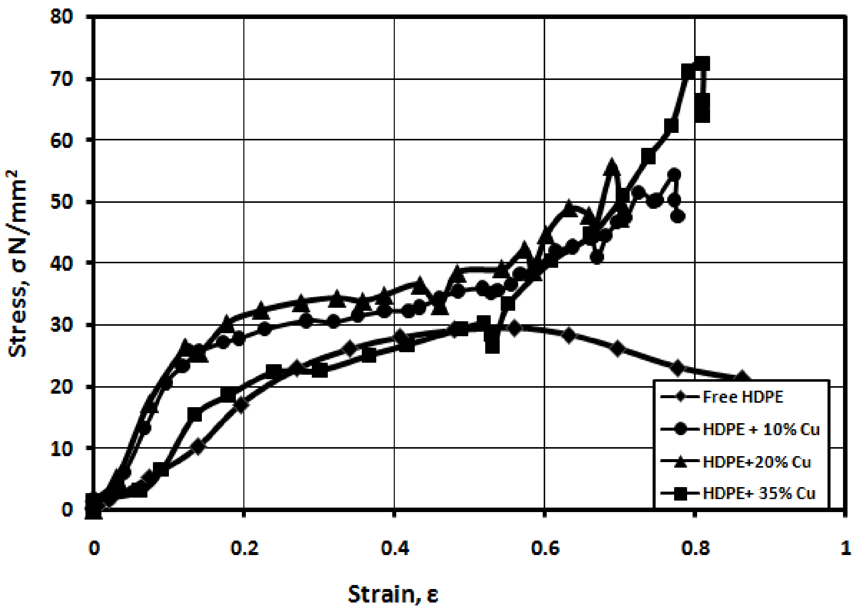

Fig. 11 Stress-strain curves of HDPE composites filled by aluminum powder.

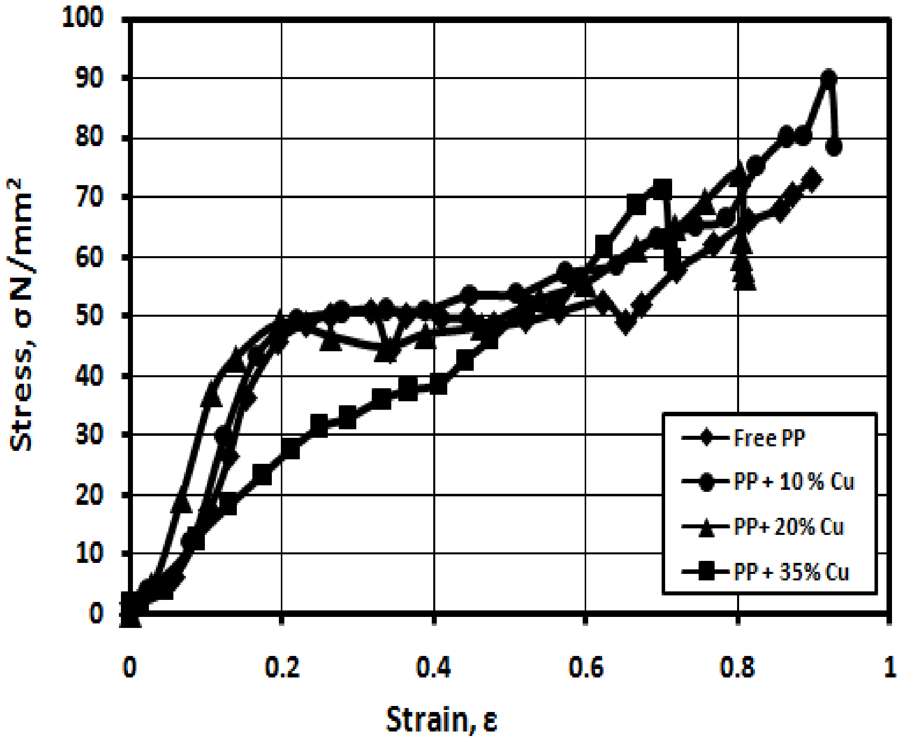

Fig. 12 Stress-strain curves of PP composites filled by copper powder.

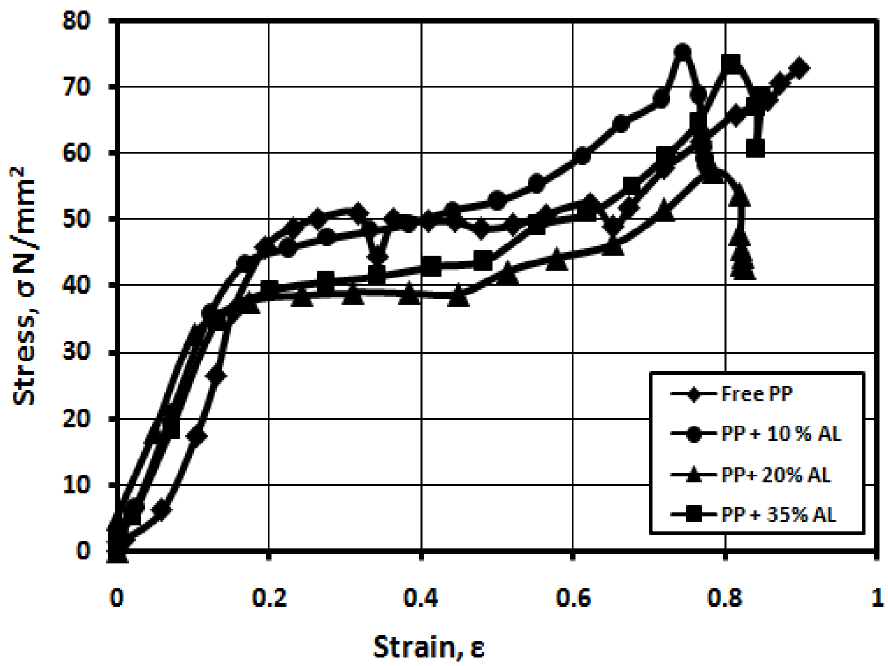

Fig. 13 Stress-strain curves of PP composites filled by aluminum powder.

Results of Mechanical Tests

Figures 10 and 11 shows the relationship between stress and strain for HDPE composites filled by copper and aluminum powder respectively, from fig. 10 the ultimate strength of HDPE composite increases from 24 N/mm^2 for free HDPE to 75 N/mm^2 for the composite filled by 35 % copper powder which recommended this composites for the applications which required high compression strength materials. Fig. 11 shows that increases of aluminum powder in HDPE composite to 20 % increase the ultimate strength to 53N/mm^2 but continuously increases of aluminum in composite to 35% decreases the ultimate strength to 41N/mm^2 and also decreases the fracture strain from 85% for free HDPE to 57% for composite containing 35% aluminum powder. Figure 12 shows that the ultimate strength of PP composite increases from 73 N/mm^2 to 90 N/mm^2 with increases of copper contents from 0 % to 10 % respectively. This recommended these composites for the applications which required high compression strength materials. Fig. 13 shows that increases of aluminum powder in PP composite to 10 % increase the ultimate strength slightly from 73 N/mm^2 to 76 N/mm^2 and also decreases the fracture strain from 90% for free PP to 82% for composite containing 20% aluminum powder.

CONCLUSIONS

1. The friction coefficient and wear rates of HDPE and PP composites decrease with increasing copper content.

2. The friction coefficient of HDPE composites increases with increasing aluminum contents.

3. The mechanical behavior of HDPE composites in form of ultimate strength and fracture strain can be improved by reinforcing these composite by 35 % copper powder or 20 % aluminum powder.

4. The mechanical behavior of PP composites in form of ultimate strength and fracture strain can be improved by increasing the content of aluminum and copper reinforcements in composites.

5. Use of copper powder reinforcements can improve the mechanical and tribological behavior of HDPE and PP composites which can be used in industrial applications.

REFERENCES

1. Thanomsilp C., Hogg P. J., “Penetration Impact Resistance of Hybrid Composites on Coming Led Yarn Fabrics”, Comp. Sci Technol 2003; 63, pp. 467 – 482.

2. Ibrahem R. A., Ali W. Y., "Tribological performance of Polyester Composites Filled by Vegetable Oils", Journal of Material Science and Engineering Technology, 2010, vol. 41, issue 5, pp. 287 - 292.

3. Singh S., Mohanty A. K., Misra M., “Hybrid bio-composite from talc and wood fiber and bio-plastic: fabrication and characterization”, Composites A 2010; 41 pp. 304 – 312.

4. Klaus F., Zhong Z. , Alois K., "Effects of various fillers on the sliding wear of polymer composites", Composites Science and Technology 65 (2005) pp. 2329 – 2343

5. Hutchings I. M., "Wear-resistant materials: into the next century", J. Mat. Sci. Eng., (1994) pp. 185 – 195.

6. Czichos H., Klaffke D., Santner E., Woydt M., “Advances in Tribology: the Materials Point of View”, Wear 190 (1995) 155–161.

7. Johnson R. L., "A Review of the Early Use of Molybdenum Disulphide as a Lubricant", NLGI Spokesman, 32 (Nov. 1968), p. 238, (1968).

8. Ibrahim R. A., Abdel-Barr M. M., Eladawi A. E. "Tribological Performance of Polymer Composites Reinforced by Agricultural Wastes" Journal of the Egyptian Society of Tribology vol. 10 No.2 April 2013 pp. 36-45.

9. Ibrahim R. A., Abdel-Barr M. M. "Tribological and Mechanical Performance of Polyester Composites Filled by Jasmine Dry Leaves" Journal of the Egyptian society of tribology vol. 10 No.4 October 2013 pp. 58-65.