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FRICTION COEFFICIENT DISPLAYED BY POLYAMIDE FILLED BY VEGETABLES OILS

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ABSTRACT

The aim of the present work is to introduce new self-lubricating polymeric materials for bearing applications, where external lubricant such as oil or grease can be excluded and the design can be simplified and maintenance cost can be reduced. The proposed polymeric composites are consisting of polyamide (PA6) filled by different types of vegetables oils such as (almond oil, camphor oil, castor oil, cress oil, flaxseed oil, habetelbaraka oil, lettuce oil, olive oil, sesame oil, and sunflower oil) in concentration up to 10 wet. %. The friction coefficient of the proposed composites is investigated at different value of applied load.

Based on the experimental results, it was found that, as the oil content increases friction coefficient decreases. It seems that friction decrease was displayed due to oil transfer from the specimen to the counterface forming a thin layer which was responsible for the friction decrease. The adhesion of oil molecules into the sliding surfaces depends on the polarity of oil molecules. Polar molecules will form multilayer which strengthened the adhesion of oil into the solid surface. Polarity of oil influences the thickness of oil film. As the normal load increases friction coefficient decreases. This behavior may be related to increase of exiting oil from test specimens covering the contact area. The minimum value of friction coefficient (0.15) was observed at PA6 and flaxseed oil specimens, at oil content 10 wt. % and 30 N normal load. It seems that friction decrease was displayed due to oil transfer from the specimen to the counterface forming a thin layer, which was responsible for the friction decrease. The decrease of friction coefficient is attributed to the adhesion of oil molecules into the sliding surfaces.

KEYWORDS

Friction coefficient, polyamide, vegetable oils.

INTRODUCTION

Polymer composites are extensively used in many of tribological applications such as automotive and agricultural machinery as well as chemical industries. It was found that polyphenylene sulfide (PPS) composites filled with short carbon fibres and submicro-scale titanium oxide particles were prepared by extrusion and subsequently injection-molding, [1]. Polyamide 4, 6 and its aramid fibre composites were tested as candidate materials for tribological applications, [2]. Over the range of tests, the average coefficient of friction results showed that the Polyamide + 15% aramid fibres generally had the lowest values compared to the other types of samples. Friction and dry sliding

wear behavior of glass and carbon fabric reinforced vinyl ester composites have been presented, [3]. The results show that the coefficient of friction and wear rate increased with increase in load/sliding velocity and depends on type of fabric reinforcement and temperature at the interphase.

To improve the friction and wear behavior of basalt fabric reinforced phenolic composites, single graphite or nano-silicon oxide and both of them were incorporated, [4]. Experimental results showed that graphite was more beneficial than nano-silicon oxide in improving the tribological properties of basalt fabric composites when they were singly incorporated. Polyimide composites filled with short carbon fibres, micro SiO_2, and graphite particles, showed that single incorporation of graphite and short carbon fibres significantly improve the tribological properties of the PI composites, but micro silicon oxide was harmful to the improvement of the friction and wear behavior of the PI composite, [5]. Experimental results showed that surface modification decreased the friction coefficient of carbon nano fibres/polytetrafluoroethylene (PTFE) composites slightly, and reduced the wear volume loss of PTFE composites obviously [6]. Flyash-filled and aramid fibre reinforced phenolic based hybrid polymer matrix composites were fabricated followed by their characterization and tribo-evaluation, [7]. Wear analysis has revealed that material integrity and temperature rise of the disc decide the wear behaviour. The effect of short carbon fibre, and graphite on the friction and wear behavior of polyimide composites were studied, [8]. Experimental results revealed that single incorporation of short carbon fibres and graphite can improve the friction-reducing and anti-wear abilities of the polyimide composites significantly.

The tribological performance of pure vinyl ester, glass fibre reinforced, silicon carbide filled glass fibre reinforced vinyl ester composite under dry and water lubricated sliding conditions was studied and explored, [9]. The results showed that the coefficient of friction decreases with the increase in applied normal load values both under dry and water lubricated conditions. The sliding performance of polymeric composites was investigated in vacuum environment, [10]. Tests were performed with carbon fibre reinforced polymeric composites filled with solid lubricant. Friction coefficient, wear rate and wear micromechanism of wood reinforced polypropylene, pine wood and polypropylene have been compared, [11]. Wood reinforced polypropylene and wood present very similar coefficients of friction, [12]. To improve the friction and wear behavior of carbon fabric reinforced polymer composites nano-silicon oxide was deposited on the fabric surface, [13]. Experimental results revealed that fibre surface treatment contributed to largely improve the tribological properties of the tested composites. The friction and wear behavior of carbon nanotube reinforced polyamide 6 (PA6/CNT) composites under dry sliding and water lubricated condition was comparatively investigated using a pin on disc wear tester at different normal loads [14]. The results showed that CNTs could improve the wear resistance and reduce the friction coefficient of PA6 considerably under both sliding conditions, due to the effective reinforcing and self-lubricating effects of CNTs on the PA6 matrix. The composites exhibited lower friction coefficient and higher wear rate under water lubricated condition than under dry sliding.

The investigation presented on wear and friction characteristics of chopped strand mat glass fibres reinforced polyester composite under wet contact condition against polished stainless steel counterface, [15]. The results revealed that glass fibres orientations and test parameters have a significant influence on the wear and frictional characteristics of

the composite. Novel poly (phthalazinone ether sulfone ketone) resins have become of great interest in applications such as bearing and slider materials. Dry sliding wear of PTFE and graphite-filled polymeric composites against polished steel counterparts were investigated on a block-on-ring apparatus at the same sliding velocities and different loads, [16]. The results indicated that the addition of 5 - 25 wt% PTFE and 5–30 wt% graphite contribute to an obvious improvement of tribological performance of the polymeric composites at room temperature. The effects of fibre orientation on the tribological behavior of a short carbon fibre / PTFE / graphite (10 wt. % for each) filled polymeric composite was studied under different nominal pressures, [17]. The results indicate that the effect of fibre orientation shows strong dependence on the nominal pressure.

Several composites of epoxy reinforced with carbon fabric were fabricated with different processes [18]. The role of the electric charges on the friction behaviour of non-conductive materials was confirmed [19]. This correlation is proven by using tribotests and SEMME (Scanning Electron Microscope Mirror Effect) measurements carried out on the neat epoxy matrix and on two polymeric composites, which only differ by the sizing of the fibres. For the matrix, the influence of friction is only obvious inside the friction track but, for the composites, a modification of the properties of the whole composite (inside and outside the friction track) is observed after friction.

Tribologically loaded polymer parts such as gears, bearings and other machine elements are exposed to a load spectrum, which is composed, amongst others, of a relative movement, causing heat and wear, and a surface pressure in an application dependent environment [20]. This is especially true for systems without external lubrication, where melting, material fatigue and wear are the lifetime-limiting factors. The continuous operating temperature, mechanical strength and dimensional stability are significantly increased by electron beam irradiation and the related cross linking of the polyamide. Thus, machine elements consisting of this radiation cross linked polymer can be used at higher ambient temperature and resist introduction of higher friction energy. The capability of cross linked polyamide 66 has been ascertained by tribological testing in a pin-on-disc wear device. Radiation cross linking leads to a significant improvement in the performance of tribologically loaded systems.

An extensive investigation of polymer gear (acetal and nylon) friction and wear behaviour was presented [21]. First, a unique test method for polymer gear wear will be described in brief and later used in the extensive investigation of acetal and nylon gear wear. POM nanocomposites with various contents of nano-aluminium oxide were prepared by twin-screw extruder in order to study the influence of inorganic nanoparticles on tribological properties of POM nanocomposites under dry sliding and oil lubricated conditions, respectively [22]. Results indicated that nanoparticles were more effective in enhancing the tribological properties of polymeric nanocomposites in oil lubricated condition than in dry sliding condition.

The effect of short carbon fibre and graphite on the friction and wear behavior of polyimide composites were studied using a block on ring arrangement, [23]. Experimental results revealed that single incorporation of short carbon fibre and graphite can improve the friction-reducing and anti-wear abilities of the polyimide composites significantly. The friction and wear properties of polyamide 66, polyphenylene sulfide and PTFE sliding against themselves under dry sliding and oil-

lubricated conditions were studied, [24]. Experimental results showed that friction properties of the three sliding combinations could be greatly improved by oil lubrication, the antiwear properties of PTFE and polyphenylene sulfide were improved by oil lubrication, while that of polyamide 66 were decreased by oil lubrication.

In the present work, the frictional behavior of the proposed composites consisting of polyamide (PA6) filled by different types of vegetables oils such as (almond oil, camphor oil, castor oil, cress oil, flaxseed oil, habetelbaraka oil, lettuce oil, olive oil, sesame oil, and sunflower oil) in concentration up to 10 wt. %. The friction coefficient of the proposed composites is investigated at different value of applied load.

EXPERIMENTAL

Experiments were carried out using pin on disc, Fig. 1. It consists of an electric motor connected to the gear box used to reduce the velocity and convert the direction of motion from horizontal motion to vertical one. The shaft of the gear box is connected to the friction disc that acts as a counterface. The specimen is held by chuck at the end of vertical column connected to horizontal load cell connected to digital screen which displays the friction force.

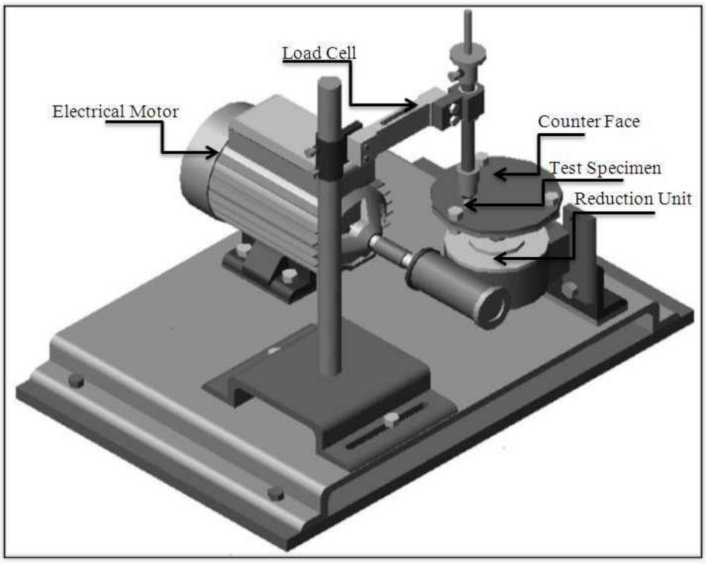

Fig. 1 Arrangement of friction test rig.

The test specimen, in the form of a cylinder, is 10 mm diameter and 30 mm height. The diameter is reduced to 5 mm to contact the friction disc. The polymer used in the present work is polyamide 6 (PA6). The polymer was mixed with different types of vegetable oils in concentrations of 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 wt. %. These oils were almond, camphor, castor, cress, flaxseed, habetelbaraka, lettuce, olive, sesame, sunflower oils. The mixure was compressed in the die under high temperature (150 °C) by using hydraulic jack. Friction test was carried out under constant normal applied loads of 10, 20 and 30 N and for 600 seconds. The measurement of friction force was carried by using load cell.

RESULTS AND DISCUSSION

The followings are the results of the tested polymer filled by vegetables oils. Figure 2 shows the friction coefficient for PA6 filled by almond oil. It can be noticed that, the

friction coefficient decreased with increasing almond oil content. It seems that friction decrease was displayed due to oil transfer from the specimen to the counterface forming a thin layer which was responsible for the friction decrease. The adhesion of oil molecules into the sliding surfaces depends on the polarity of oil molecules. Polar molecules will form multilayer which strengthened the adhesion of oil into the sliding surfaces. Polarity of oil influenced the thickness of oil film. Friction coefficient displayed by PA6 filled by almond oil test specimens decreased with increasing normal load. This behavior may attributed to increase of oil squeezed from surface of the test specimens. The minimum value of friction coefficient (0.22) was observed when oil percentage was 10 wt. % in PA6 specimen at 30 N normal load. Friction coefficient displayed by PA6 filled by camphor oil is shown in Fig. 3. It can be noticed that, the friction coefficient decreased with increasing camphor oil content. The friction of PA6 and camphor oil specimens decreased with increasing normal load. The minimum value of friction coefficient (0.20) was observed when oil percentage was 10 wt. % of PA6 specimen and 30 N normal load.

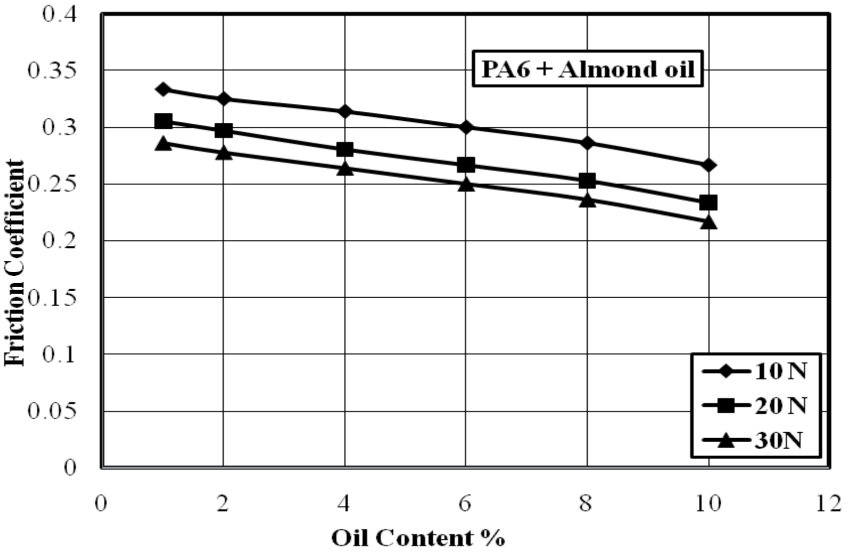

Fig. 2 Friction coefficient displayed by PA6 filled by almond oil and sliding against steel surface.

Friction coefficient displayed by PA6 filled by castor oil specimens, Fig. 4, decreased with increasing castor oil content. The minimum value of friction coefficient (0.18) was observed when oil content was 10 wt. % at 30 N normal load. This value was lower than that observed for almond and camphor, which confirms the good lubricating properties of castor oil.

Figure 5 shows the friction coefficient displayed by PA6 filled by cress oil. It can be noticed that, at 10 N normal load the friction coefficient decreased with increasing cress oil content. At 20, 30 N the effect of increasing the oil content was insignificant on friction coefficient. In this condition, the contact area was divided into two parts. The first was the contact between polymer and steel, while second was covered by the oil film that separated the two sliding surfaces, Fig. 6. As the oil content increased, the friction coefficient due to the presence of oil film covering the contact area decreased. Adhesion of polymer into steel surface depends on the type of polymer. Increase of friction may be attributed to the polymer transfer into steel surface so that the contact would be

polymer/polymer. The friction of PA6 filled by cress oil specimens decreased with increasing normal load. The minimum value of friction coefficient (0.20) was observed when oil content was 2 wt. % at 30 N normal load. Friction coefficient displayed by PA6 filled by flaxseed oil, Fig. 7, decreased with increasing normal load. This behavior may be related to increase of exiting oil from test specimens. The minimum value of friction coefficient (0.15) was observed at 10 wt. % oil content at 30 N normal load.

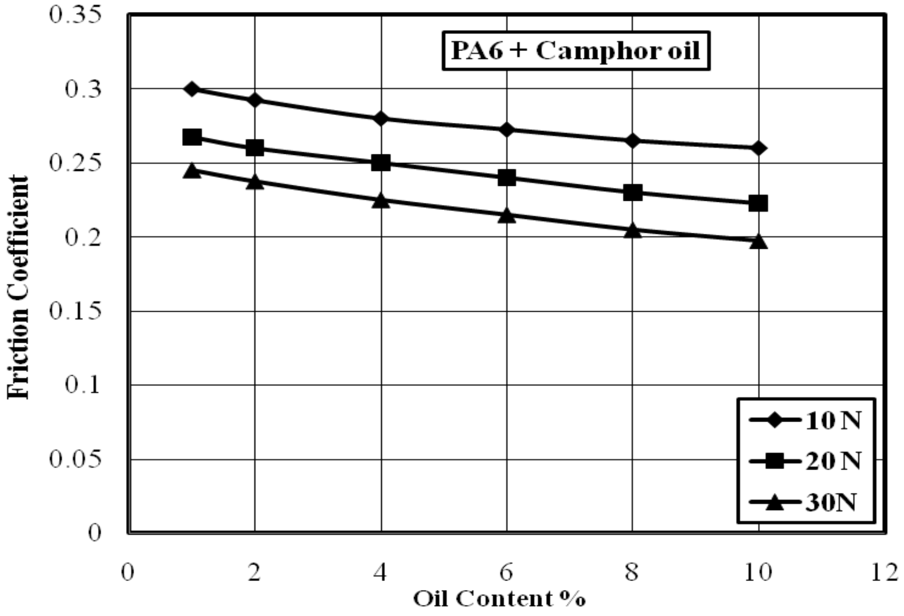

Fig. 3 Friction coefficient displayed by camphor oil and sliding against steel surface.

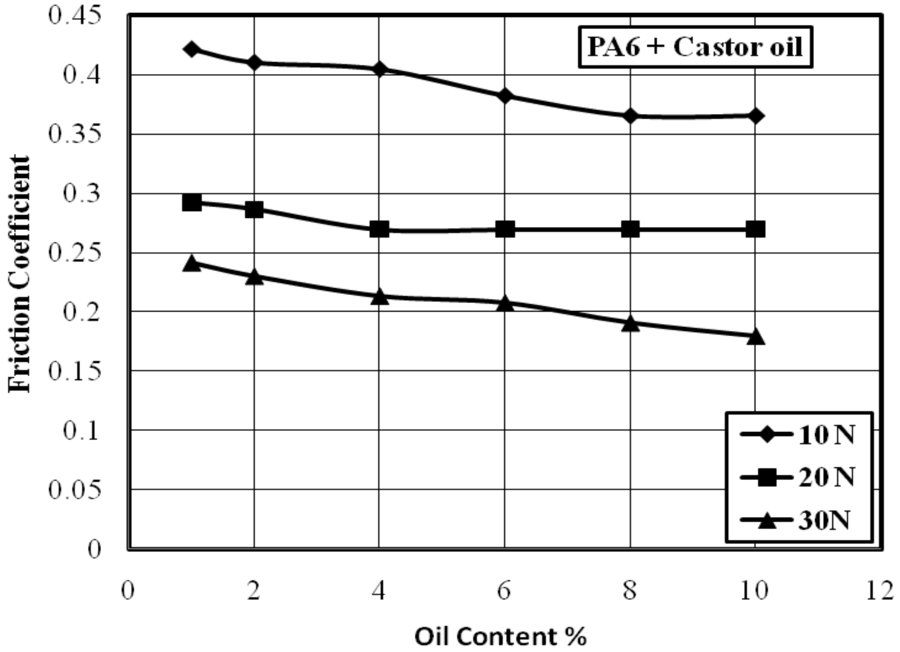

Fig. 4 Friction coefficient displayed by castor oil and sliding against steel surface.

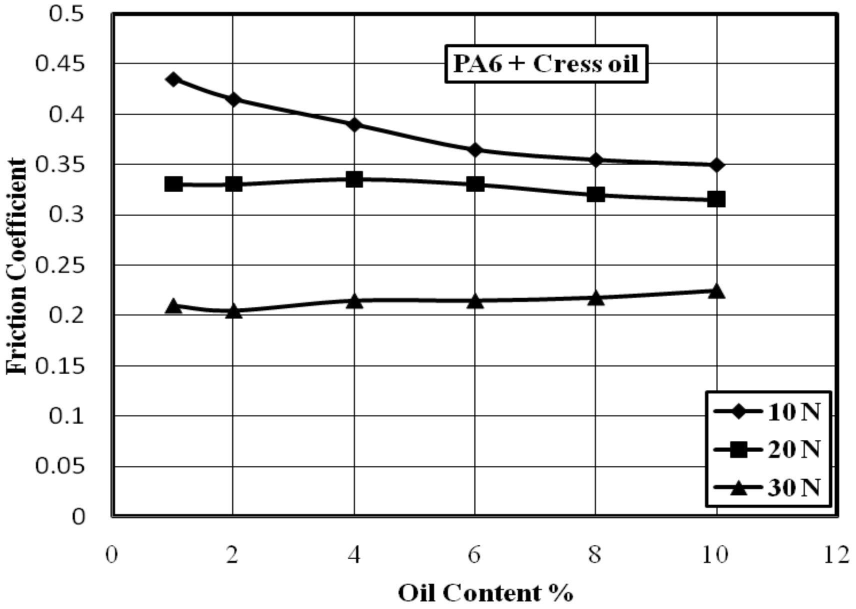

Fig. 5 Friction coefficient displayed by PA6 filled by cress oil and sliding against steel surface.

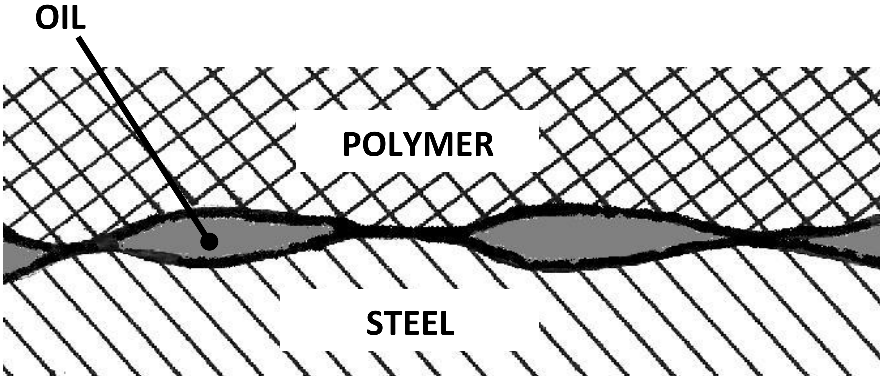

Fig. 6 Mixed lubrication for polymer specimen sliding against steel surface.

Figure 8 shows the friction coefficient for PA6 filled by habtelbaraka oil specimens. It can be noticed that, at 10 N normal load the friction coefficient decreased with increasing Habtelbaraka oil content. It seems that friction decrease was displayed due to oil transfer from the specimen to the counterface forming a thin layer which was responsible for the friction decrease. At 20 and 30 N normal loads the increase of the oil content was insignificant on friction coefficient, in this condition the contact area was divided into two parts. The first was the contact between polymer and steel, while the second was the oil film that separated the two surfaces. The friction of PA6 filled by Habtelbaraka oil specimens decreased with increasing normal load. The minimum value of friction coefficient (0.21) was observed when oil percentage was 10 wt. % of PA6 specimen at 30 N normal load.

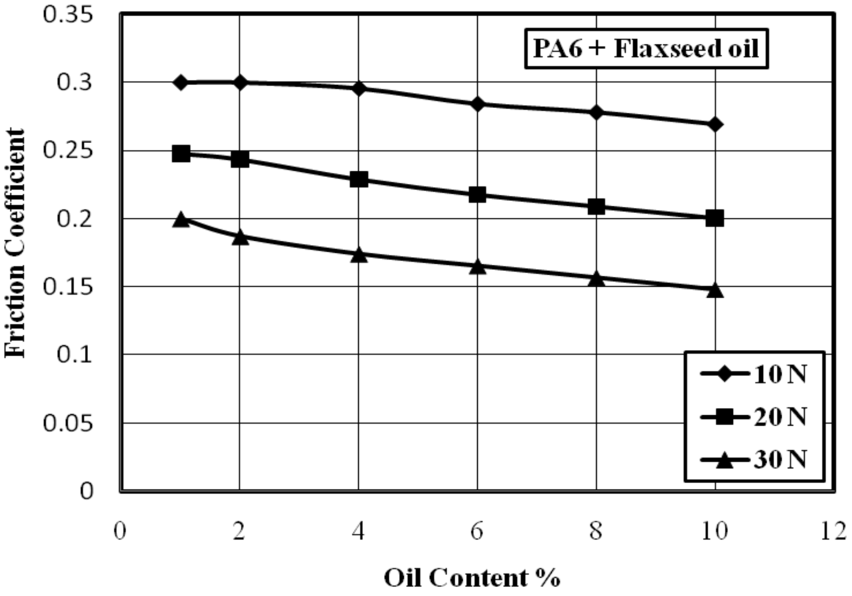

Fig. 7 Friction coefficient displayed by PA6 filled by flaxseed oil and sliding against steel surface.

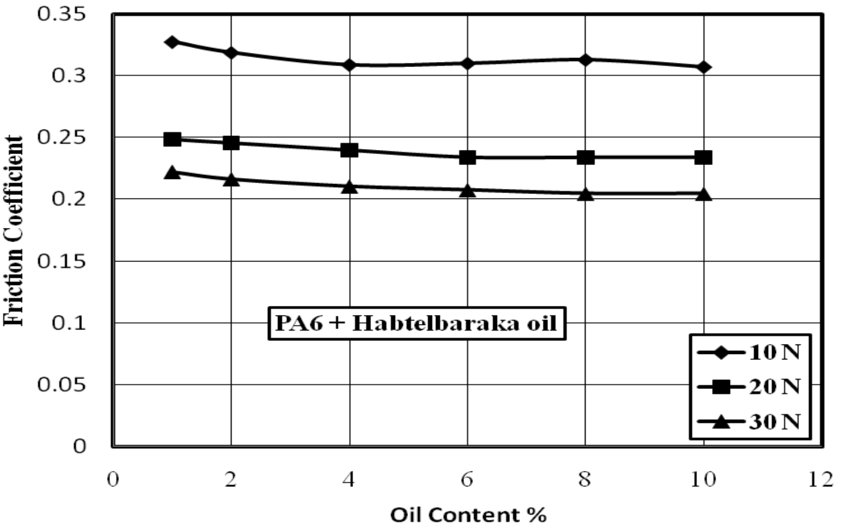

Fig. 8 Friction coefficient displayed by PA6 filled by habtelbarka oil and sliding against steel surface.

At 10 N Normal load the friction coefficient increased with increasing lettuce oil content, Fig. 9. It seems that friction increase may be attributed to the polymer transfer into steel surface so that the contact would be polymer/ polymer. At 20 and 30 N normal loads the increase of the oil content was insignificant on friction coefficient. In this condition, the contact area was divided into two parts. The first is contact between polymer and steel, while second the oil film covering the two surfaces. The friction of PA6 filled by lettuce oil specimens decreased with increasing normal load. The minimum value of friction coefficient (0.21) was observed when oil percentage is 2 wt. % of PA6 specimen and 30 N normal load.

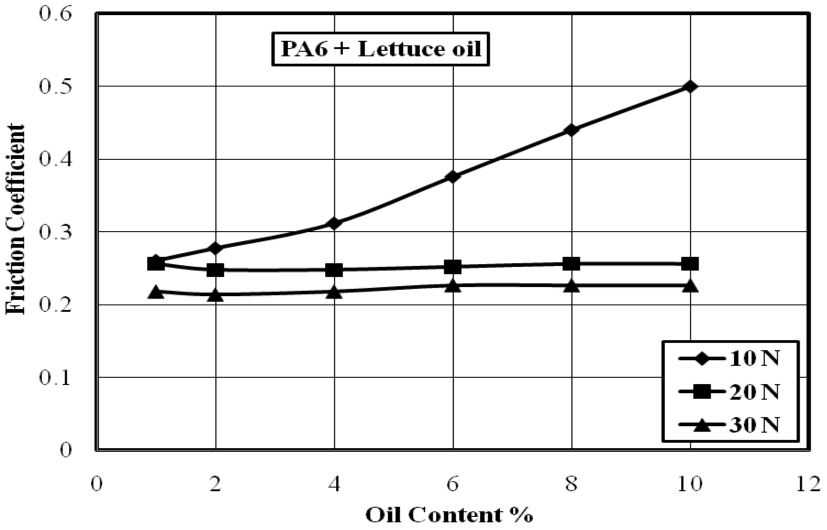

Fig. 9 Friction coefficient displayed by PA6 filled by lettuce oil and sliding against steel surface.

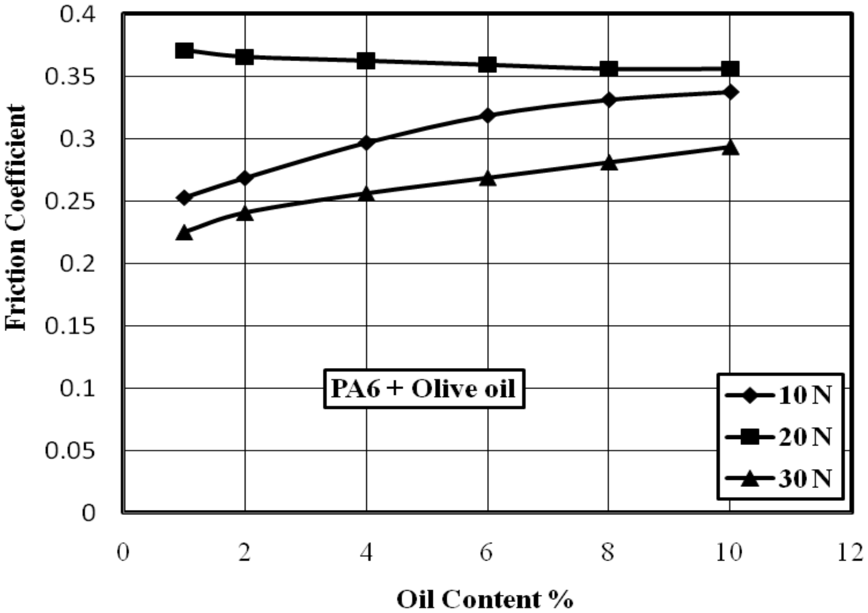

Fig. 10 Friction coefficient displayed by PA6 filled by olive oil and sliding against steel surface.

Friction coefficient of PA6 filled by sesame oil specimens is shown in Fig. 11. It can be noticed that at 10 and 30 N normal loads the friction coefficient decreased with increasing Sesame oil content. It seems that friction decrease was displayed due to oil transfer from the specimen to the counterface forming a thin layer, which was responsible for the friction decrease. The friction of PA6 filled by sesame oil specimens decreased with increasing normal load. The minimum value of friction coefficient (0.17) was observed when oil percentage was 10 wt. % of PA6 specimen at 30 N normal load.

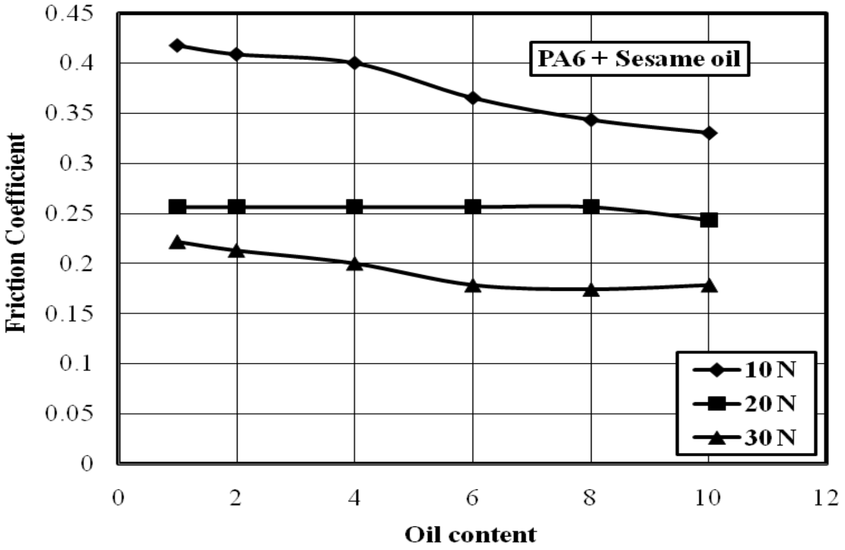

Fig. 11 Friction coefficient displayed by PA6 filled by seasame oil and sliding against steel surface.

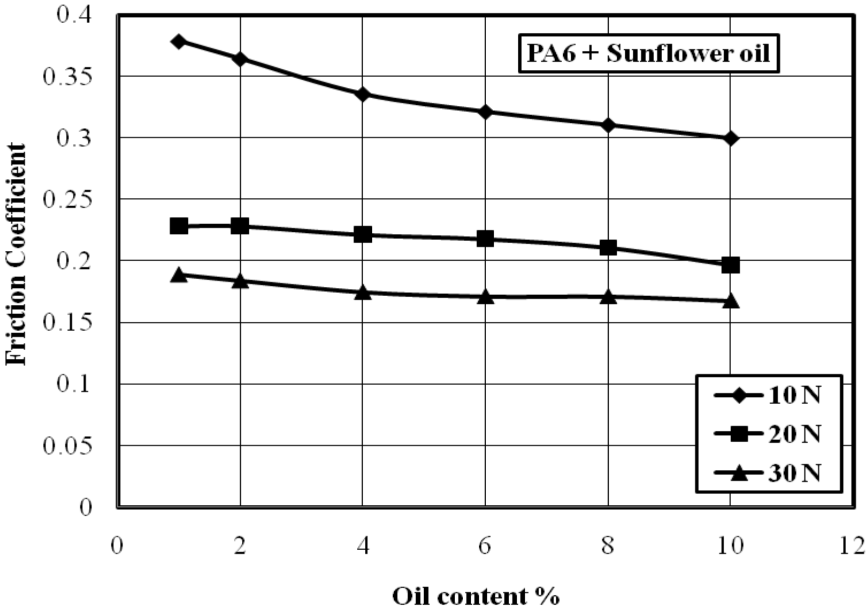

Fig. 12 Friction coefficient displayed by PA6 filled by sunflower oil and sliding against steel surface.

Friction coefficient decreased with increasing sunflower oil content in PA6, Fig. 12. It seems that friction decrease was displayed due to oil transfer from the specimen to the counterface forming a thin layer, which was responsible for the friction decrease. The minimum value of friction coefficient (0.17) was observed when oil percentage was 10 wt. % of PA6 specimen at 30 N normal load.

CONCLUSIONS

Based on the experiments carried out in the present work, the following conclusions can be withdrawn:

1. Friction coefficient for PA6 filled by almond, camphor, castor, cress, flaxseed, habtelbaraka, seasame and sunflower oils decreased with increasing almond oil content. Friction coefficient decreased with increasing normal load. This behavior may attributed to increase of oil squeezed from surface of the test specimens. In contradiction to that, friction coefficient increased with increasing lettuce oil content. It seems that friction increase may be attributed to the polymer transfer into steel surface so that the contact would be polymer/ polymer.

2. The minimum value of friction coefficient (0.18) was observed when castor oil content was 10 wt. % at 30 N normal load, which confirms its good lubricating properties.

3. As the oil content increases friction coefficient decreases. It seems that friction decrease was displayed due to oil transfer from the specimen to the sliding surfaces forming a thin layer, which was responsible for the friction decrease. The adhesive force of oil molecules into the sliding surfaces depends on the polarity of oil molecules. Polar molecules will form multilayers, which strengthen the adhesion of oil into the solid surface. Polarity of oil influences the thickness of oil film.

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