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EFFECT OF MAGNETIC FIELD ON THE PERFORMANCE OF VEGETABLES OILS DISPERSED BY POLYMERIC PARTICLES S

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ABSTRACT
The present work discusses the effect of magnetic field on the performance of vegetables oils dispersed by polymeric particles. Experiments were carried out using castor, olive, corn, almonds, jasmine and camomile. Fine particles of polyethylene (PE) and polyamide (PA) were dispersed into the oils. Magnetic field was applied by a coil assembled above the pin holder of 0.2 flux intensity.

It was observed that, for sliding of steel pin against oil lubricated brass disc, magnetic field decreased friction coefficient for all the tested oils. Castor and almonds oils displayed the lowest friction coefficient followed by corn, jasmine, olive and camomile oils. Dispersing oil by polyethylene (PE) particles significantly increased friction coefficient. Camomile oil showed the highest friction coefficient in the presence of magnetic filed. A drastic reduction of friction coefficient was observed for olive, castor and almonds oils, when dispersing the tested oils by polyamide (PA) particles. Corn, jasmine and camomile oils displayed relatively higher friction coefficient. Sliding of steel pin on oil lubricated aluminium disc caused significant friction increase for all the tested oils. The friction increase could be attributed to the nature of the friction of aluminium against steel surface. Drastic friction reduction was observed for castor, almonds, jasmine and camomile oils when dispersed by PE particles. Dispersing vegetables oils by PA particles showed relatively lower friction coefficient for olive and castor oils, while corn almonds, camomile and jasmine oils showed relatively higher friction values. Sliding of steel pin on oil lubricated steel disc showed the highest values of friction coefficient. Dispersing the tested oils by PE particles did not decrease friction coefficient. Jasmine oil displayed relatively lower friction than the other tested oils. No enhancement was observed for dispersing the tested oil by PA particles. Generally, olive oil displayed the lowest friction coefficient. Besides, magnetic field showed relatively lower friction in spite of the extra normal force exerted by the magnetic field.

KEYWORDS
Magnetic field, friction coefficient, vegetables oils, polyethylene and polyamide particles.

INTRODUCTION
It is necessary to investigate the tribological performance of sliding surfaces that perform under the effect of magnetic field in the mechanical drives of electronic appliances. Several recent works were carried out to test the effect of magnetic field and direct electric current on the friction and wear of moving surfaces. The effect of

magnetic field on the friction coefficient displayed by sliding surfaces lubricated by paraffin oil and dispersed by different lubricants additives such as zinc dialkyldithiophosphates (ZDDP), molybdenum disulphide (MoS_2), heteropolar organic based additive (CMOC), graphite (C), detergent additive (calcium sulphonate) (DA), polytetrafluroethylene (PTFE) and polymethyl methacrylate (PMMA) was investigated, [1]. The experiments showed that, for steel surfaces lubricated by oil, friction coefficient increased as the magnetic field increased due to the increase of the normal load caused by the magnetic force. The charged surfaces can interact with each other due to the direct electrostatic forces. Since magnetic forces are strong and effective, they contribute a major part of the adhesion force. The magnetic field decreased friction coefficient when the oil was dispersed by CMOC by means of increasing the adherence of CMOC particles into the sliding surfaces due their electronic properties. Besides, it was observed that magnetic field much affected the performance of oil dispersed by additives of electrical properties such as CMOC, DA and C. PTFE particles dispersed in the oil were much influenced by the magnetic field, where the lowest value was displayed at the highest intensity. The same trend of friction decrease was observed for PMMA particles dispersed in oil.

The friction and wear of polyethylene sliding against steel in the presence of magnetic field was investigated, [2]. It was found that, application of magnetic field decreases friction coefficient at dry sliding due to its influence to decrease the adherence of polyethylene worn particles into the steel counterface. Besides, the magnetic field favors the formation of oxide film on the contact surface, where it plays a protective role in dry friction, modifies the friction and changes wear from severe wear to mild. Lubricating the steel surface by oils caused significant reduction in friction coefficient, where the maximum reduction was displayed by paraffin followed by glycerine, almond, jasmine, corn, castor, olive and sun flower oils.

The effect of the magnetic field on the friction and wear of steel and brass sheets scratched by a steel insert at dry, lubricated by vegetable oils and dispersed by polymeric particles such as high density polyethylene (HDPE), polyamide (PA6) and polymethyl methacrylate (PMMA) was investigated, [3, 4]. Based on the experimental observations, it was found that Olive oil displayed the lowest values of friction coefficient followed by castor oil, almonds, corn, camomile and jasmine oils, where their polar molecules could significantly improve the wear resistance developed by their strong adsorption on the sliding surfaces. Application of magnetic field on the sliding surface caused significant friction reduction at dry sliding due to the enhanced ability of the oil molecules to orient themselves in relatively long chain adhered to the sliding surface and thus decreased the friction and wear.

The effect of applying external voltage on the sliding of copper, aluminium and polyethylene against steel surface lubricated by paraffin oil dispersed by polymeric particles such as polyethylene, polyamide and PMMA was tested, [5]. It was noticed that the friction coefficient and wear were significantly influenced by the generation of electric static charge on the contact surfaces which caused an attractive force imposed to the normal load. It was found that wear was more influenced by the electric static charge than friction coefficient.

It was shown that the magnetic field had no effect on friction coefficient observed for lithium grease without additives, [6]. Grease dispersed by high density polyethylene

showed friction decrease. The lowest friction reduction was observed for polymethyl methacrylate. The strong adhesion of PTFE particles into the sliding surfaces significantly increased friction coefficient. It seems that PTFE particles were adhered to surfaces of inner and outer races as well as the balls. Changing the terminal of the voltage applied to the rotating shaft cased significant friction decrease for PMMA. Viscosity of the grease decreased with increasing the voltage. Friction coefficient decreased for HDPE and PTFE.

In the presence of magnetic field around the tribocontact and in ambient air, the contact track was covered with very fine ferromagnetic particles, [7]. Friction and wear are influenced by the presence of oxide. The increase of oxide layer on the surface, the retention of passivated particles in the contact and their refinement by grinding modify the contact rheology which transits from metal/metal contact to oxide/oxide contact. It was noticed that magnetic field acts on the ferromagnetic contact surface by modifying their electrical and electronic behaviour. It increases the electronic speed in their orbits, [8], and creates the electrical fields and the electrical currents. Those electrical currents enhance the oxidation. Moreover, dislocations in subsurface of the materials in contact are influenced by contact shear stress field [9]. The stress field presents a decreasing gradient from the Hertzian point. The dislocations displace from the region of strong stress gradient to the region of weak gradient.

Exploring effects of electric field on the frictional behavior of materials has become an attractive subject in recent years to many researchers in the world. It was found that friction and wear were attributed to the migration of electrons across the interfaces of metals with different work functions. The apparent friction coefficient was changed by reversing the polarity of the external electric field due to the change in real normal pressure. The results showed that the change in friction coefficient can reach into 25%. An extraordinary change in friction coefficient of graphite/graphite rubbing couples was discovered, [10], under a large DC current at a critical sliding speed, jumping from a high value (about 0.7) to a low value (about 0.07) as rubbing slows down or from the low value to the high value as rubbing speeds up. It was found that for intentionally insulated metallic contacts lubricated with liquid crystals the relative friction coefficient under boundary lubrication conditions can be reduced by up to 35% by applying an external DC electric field, [11]. DC voltages were found to be able to promote the generation of chemisorbed and chemical reaction films of ZDTP additives in mineral lubricating oils on metal surfaces, leading to a reduction in friction, [12, 13]. It was reported that an AC voltage has effects on lubricating ability of synovia constituents. It was observed that for Al_2O_3/brass couple lubricated with emulsion of zinc stearate the change in friction coefficient due to an external DC voltage is not only remarkable, reaching 200%, but also quick and reversible, [14]. Besides, friction coefficient of Al_2O_3/brass couple increased monotonously with increasing external electric field intensity in the range of 0 - 30 DCV, [16], and that the fastest increase of friction coefficient occurs within the range of 0 - 20 DCV.

From the analyses of experimental data, it is shown that in presence of active gases, the oxide layer growth and the transferred graphite films on the steel track are enhanced by a magnetic field. The graphite layer possesses good adhesion to the steel surface and leads to the best reduction of wear and friction coefficient, [15, 16]. However, when the friction test is operated in inert environment and in presence of a magnetic field, the opposed phenomenon is observed. The transfer of harder steel to a softer graphite

surface is responsible for the increase of friction and wear. This abnormal process is due to a magnetization of a ferromagnetic steel which is known to be accompanied by reduction of plasticity and increasing the brittleness, [17]. It is known that, during friction on metals or dielectric couples, part of the energy consumed turns into electrical energy. In the second part of the study, electrical phenomena induced by friction will be examined in situ. Hence, the appearance of the potential difference generated by lubricated friction will be studied. This electrical effect leads to an embrittlment of friction surfaces and also involves a greater reactivity of surfaces with the lubricant. Indeed, stress corrosion cracking, and hydrogen embrittlement have been described in similar terms. Hence, an externally applied voltage may modify the wear behaviour of the lubricant and also, without friction, its decomposition and its reactivity on the surface; we shall try to analysis these effects in this paper, [18]. Because of triboelectrification, the charged surfaces can interact with each other due to the direct electrostatic forces, [19]. Since these forces are strong and effective, they contribute a major part of the adhesion force.

Friction of polymers is accompanied by electrification. The basic mechanism of solid triboelectrification implies processes, which can be described in terms of surface conditions. During frictional interaction chemical and physichemical transformations in polymers promote increases in the surface and bulk states density, [20]. Ionization and relaxation of those states lead to electric fields of the surface and bulk charges. Electrification in friction is a common feature, it can be observed with any mode of friction, and with any combination of contacting surfaces.

By applying an electric field between the rubbing surfaces, the oxidation of the rubbing surface at anode side is enhanced, and suppressed on the cathode side surface. The oxide film formed on the anode surface being harder than the bulk steel, the rubbing surface at the anode side was little worn, but it at cathode side was abrasively worn considerably. The application of an electric field, however, is considered to promote the breakdown of EHL film formed. Therefore, the effect of the application of an electric condition tested, [21]. The influence of applying electric field on the tribological behaviour of steel in a vertical magnetic field produced by an AC or DC electric current was investigated. The effect of a magnetic field on both oxidation and concentrations of dislocations on the surface is presented, [22]. Experiments show that a magnetic field applied through the sliding contact leads to decrease the wear rate.

In the present work, the effect of magnetic field on the friction coefficient displayed by sliding surfaces lubricated by vegetables oil and dispersed by PE and PA particles is investigated.

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 details of the wear tester are shown in Fig. 1. The bearing steel pin (AISI 52100) is held in the specimen holder that fastened to the loading lever. Friction force can be measured by means of the load cell, fastened to the rotating disc. Its surface roughness was about 3.2 µm, R_a. Test specimens were the rollers of cylindrical rolling bearing in the form of cylindrical pins of 6 mm diameter. Friction tests were carried out under constant sliding velocity of 2.0 m/s and 20 N applied load. Every experiment lasted 30 minutes. All measurements were performed at 25 ± 5 ºC and 30 ± 10 % humidity.

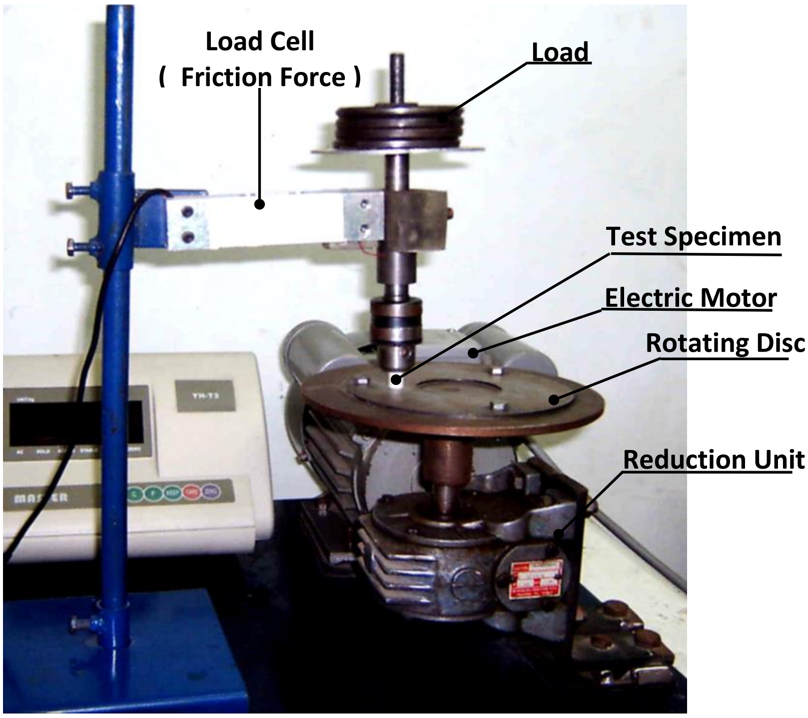

Fig. 1 Arrangement of the test rig.

The lubricants used in the experiments were castor, olive, corn, almonds, jasmine and camomile. Fine particles of PE and PA of 50 – 80 µm particle size were dispersed into the oils at 5.0 wt. % concentration. Magnetic field was applied by a coil assembled above the pin holder of 0.2 flux intensity, Fig. 2.

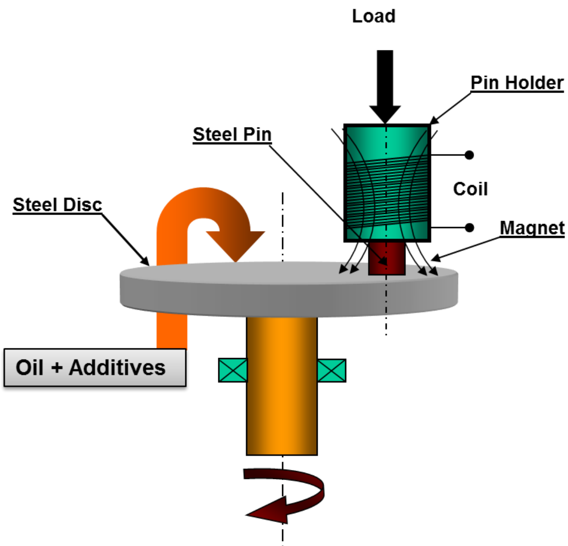

Fig. 2 Application of the magnetic field.

RESULTS AND DISCUSSION

The effect of magnetic field on the friction coefficient displayed by sliding surfaces lubricated by vegetables oil and dispersed by PE and PA particles is shown in Figs. 3 - 11. Friction coefficient displayed by the sliding of steel pin on oil lubricated brass disc is

illustrated in Fig. 3. Castor and almonds oils displayed the lowest friction coefficient followed by corn, jasmine, olive and camomile oils. Generally, magnetic field decreased friction coefficient for all the tested oils. It can be noticed that the friction values ranged between 0.04 and 0.095 and represented hydrodynamic lubrication for the majority of the tested oils except camomile oil which showed mixed lubrication. The friction values indicated the quite good adherence of the oil into the sliding surfaces. Application of the magnetic field increased that adhesion so that friction decreased.

Dispersing oil by PE particles significantly increased friction coefficient, Fig. 4. Friction of the steel pin against brass disc generated negative charge for the brass disc and positive charge for the steel pin. PE particles gained negative charge generated from the friction against both steel and brass. PE particles adhered to the both steel and brass changing the friction to be partially PE/PE. Application of magnetic field to the contact area would produce an induced electric current which would change the sign of the charge of the brass disc to be more negative so that PE particles would adhere to the steel pin. The sliding condition would be partially steel/PE. Camomile oil showed the highest friction coefficient in the presence of magnetic field.

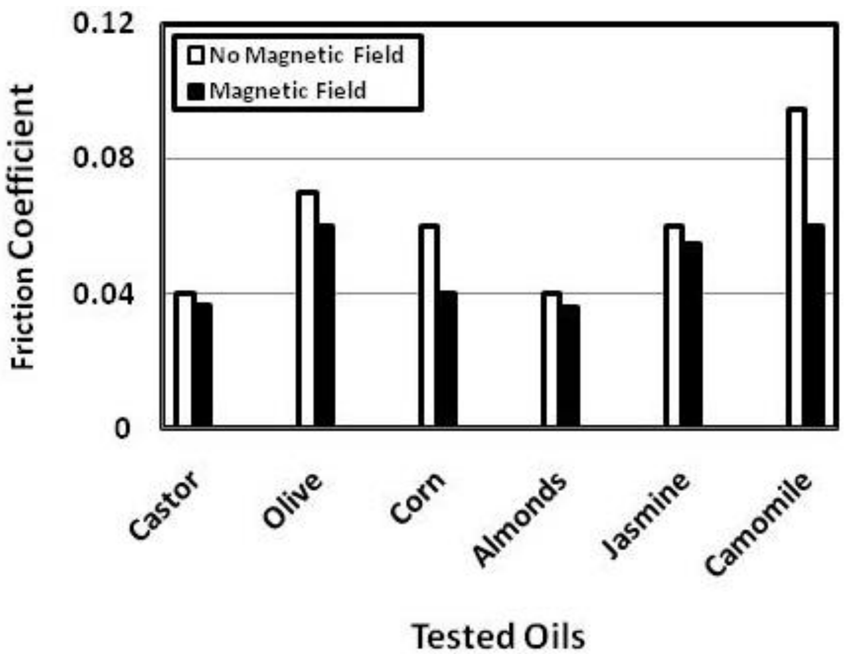

Fig. 3 Friction coefficient displayed by the sliding of steel pin on oil lubricated brass disc.

Friction coefficient displayed by the sliding of steel pin on brass disc lubricated by the tested oils dispersed by PA particles is shown in Fig. 5. A drastic reduction of friction coefficient was observed for olive, castor and almonds oils, where values of friction coefficient were lower than 0.04. Corn, jasmine and camomile oils displayed relatively higher friction coefficient. It seems that PA particles dispersed in the oils were responsible for that behaviour. PA particles gained positive charge during friction so that they adhered into the brass disc. Application of magnetic field generated induced current which increased the negative charge of the brass disc and consequently the adherence of PA particles into the brass disc increased. That behaviour can explain the further friction decrease.

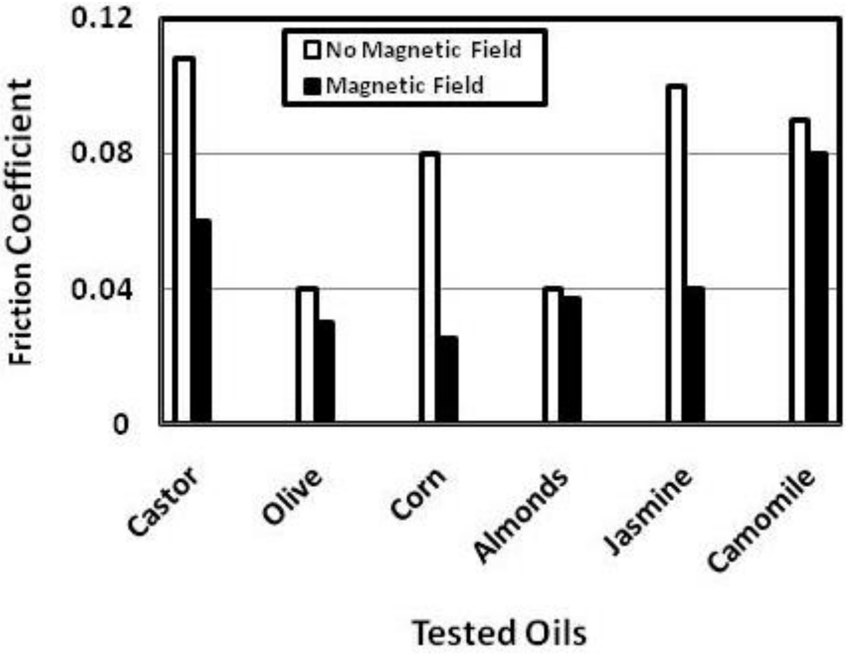

Fig. 4 Friction coefficient displayed by the sliding of steel pin on brass disc lubricated by oil dispersed by PE particles.

Sliding of steel pin on oil lubricated aluminium disc caused significant friction increase for all the tested oils, Fig. 6. The friction increase could be attributed to the nature of the friction of aluminium against steel surface. The tested vegetables oils showed weak adhesion into aluminium disc so the contact area fraction of aluminium/steel increased, while full oil film area decreased. The majority of the oils displayed friction values higher than 0.08 except camomile displayed lower value. Magnetic field decreased friction coefficient.

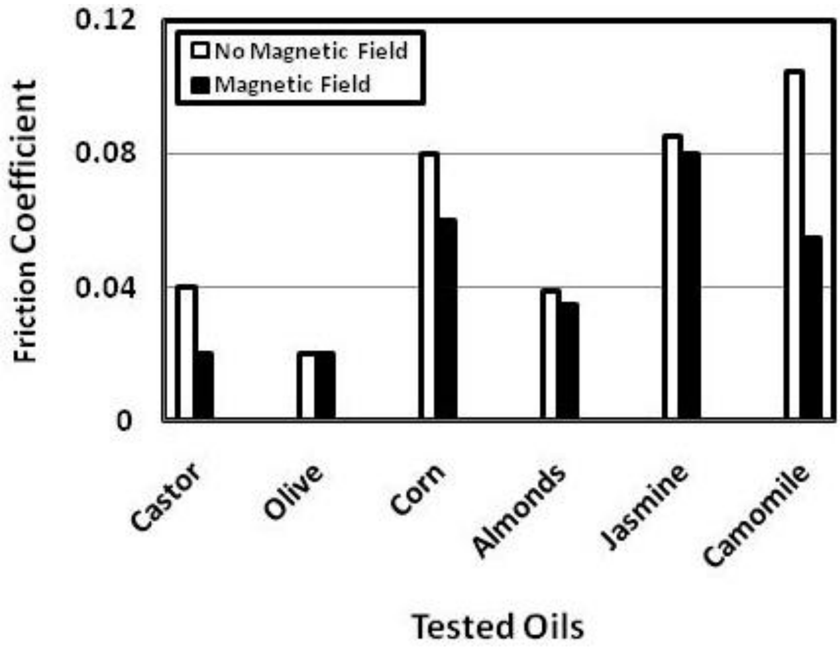

Fig. 5 Friction coefficient displayed by the sliding of steel pin on brass disc lubricated by oil dispersed by PA particles.

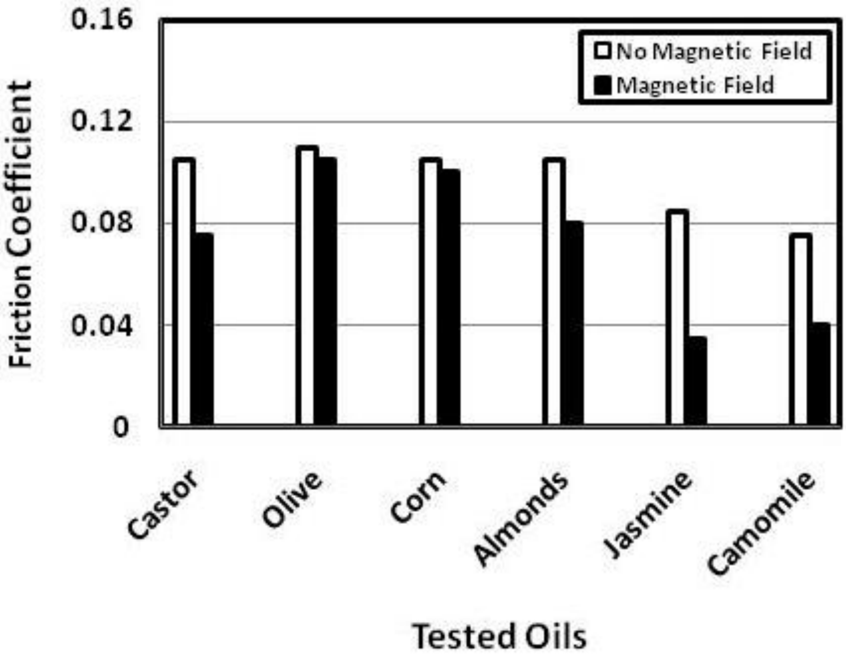

Fig. 6 Friction coefficient displayed by the sliding of steel pin on oil lubricated aluminium disc.

Friction coefficient displayed by the sliding of steel pin on aluminium disc lubricated by oil dispersed by PE particles is shown in Fig. 7. Drastic friction reduction was observed for Castor, almonds, jasmine and camomile oils. The friction reduction could be explained on the basis that PE particles would be adhered into the surface of the steel pin. In that condition the contact area would be partially PE/aluminum which gave friction coefficient lower than steel/aluminum. Magnetic field caused further friction decrease due to the generation of the induced electric current. The values of the friction recommended the use of PE particles as dispersant in the vegetables oils in the presence of magnetic field.

Dispersing vegetables oils by PA particles showed relatively lower friction coefficient for olive and castor oils, Fig. 8, while corn, almonds, camomile and jasmine oils showed relatively higher friction values. It seems that adherence of PA particles into the sliding surfaces was retarded by being aluminium disc of positive charge from friction with steel and gained in the same time negative charge from the induced current generated from the magnetic field.

The results of the friction coefficient displayed by the sliding of steel pin on oil lubricated steel disc are shown in Fig. 9. The highest values of friction coefficient were observed as a result of the increase of the applied load caused by the extra attractive magnetic force that superimposed on the applied load. This performance is well illustrated, Fig. 9, where application of magnetic field showed higher friction values.

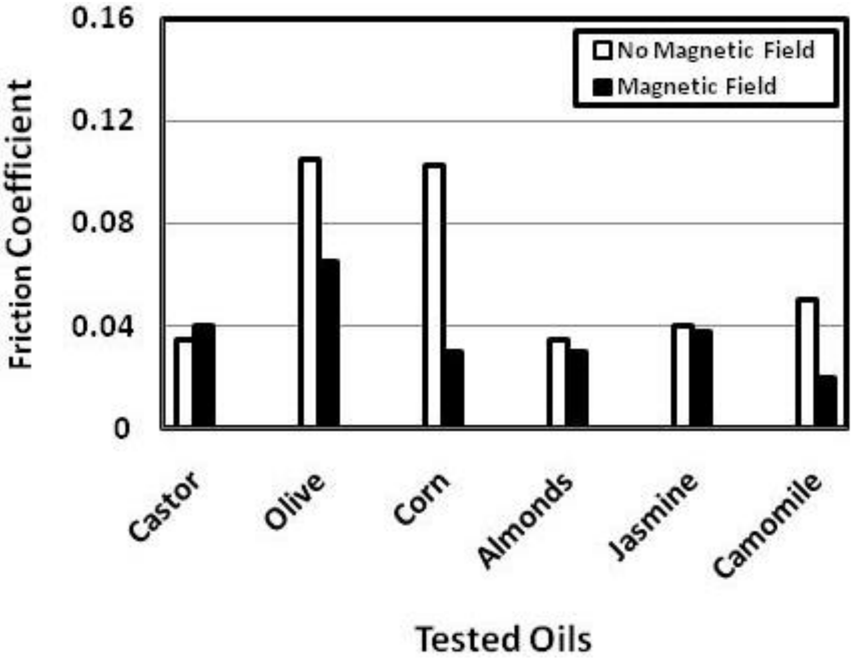

Fig. 7 Friction coefficient displayed by the sliding of steel pin on aluminium disc lubricated by oil dispersed by PE particles.

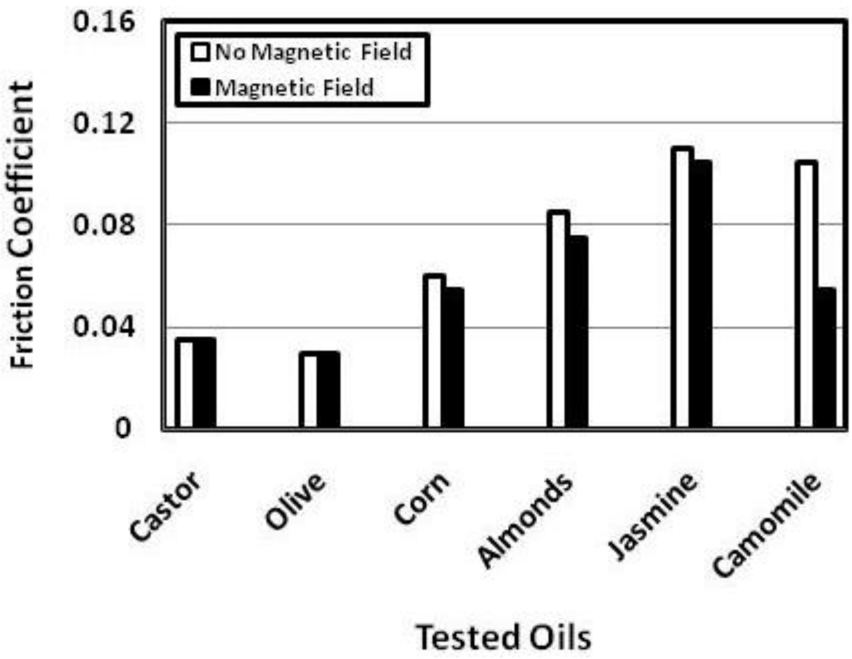

Fig. 8 Friction coefficient displayed by the sliding of steel pin on aluminium disc lubricated by oil dispersed by PA particles.

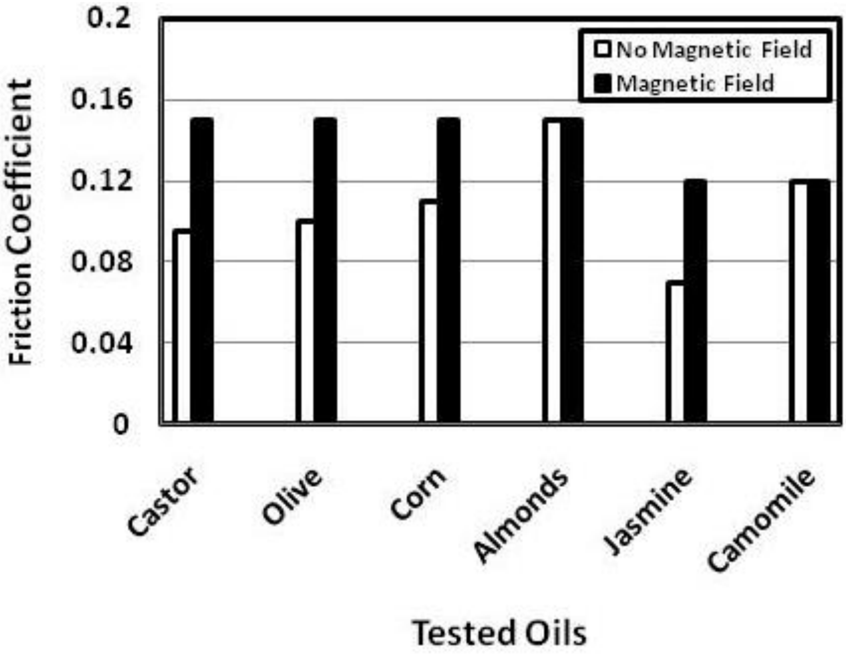

Fig. 9 Friction coefficient displayed by the sliding of steel pin on oil lubricated steel disc.

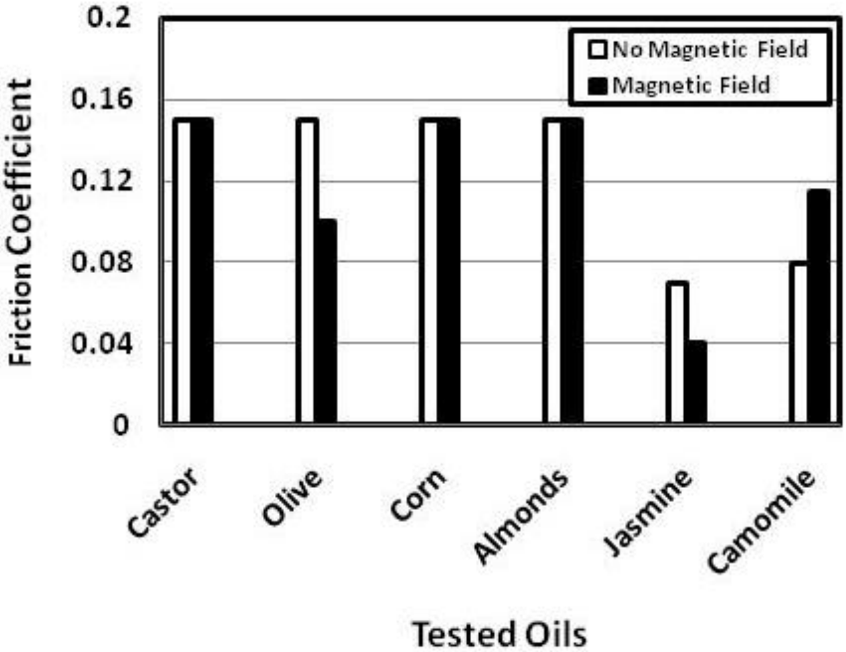

Fig. 10 Friction coefficient displayed by the sliding of steel pin on steel disc lubricated by oil dispersed by PE particles.

Dispersing the tested oils by PE particles did not decrease friction coefficient, Fig. 10. Jasmine oil displayed relatively lower friction than the other tested oils. Friction coefficient was 0.07 at no magnetic field and decreased to 0.04 when magnetic field was applied. Camomile oil showed slight friction decrease in the presence of PE particles.

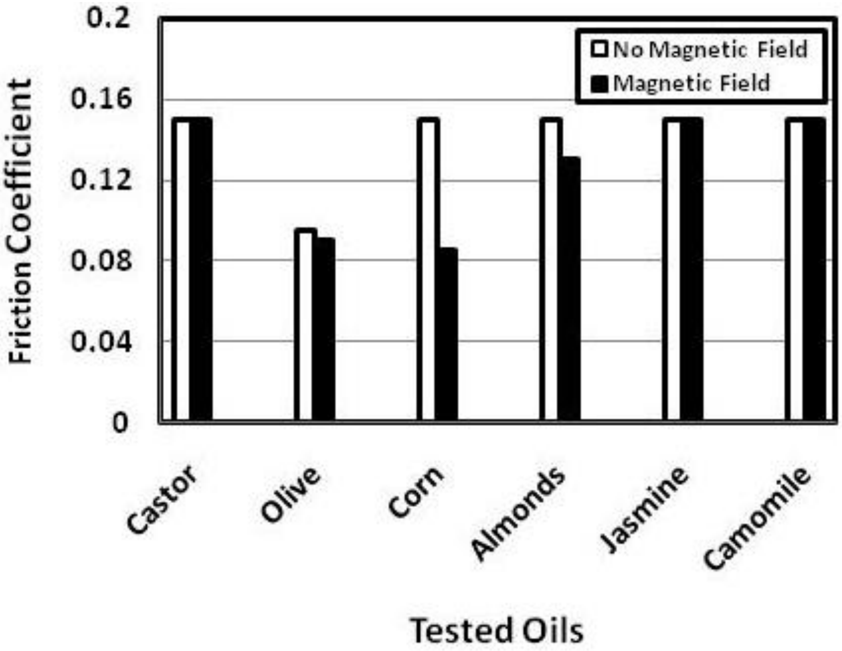

Fig. 11 Friction coefficient displayed by the sliding of steel pin on steel disc lubricated by oil dispersed by PA particles.

Friction coefficient displayed by the sliding of steel pin on steel disc lubricated by oil dispersed by PA particles is shown in Fig. 11. No enhancement was observed for dispersing the tested oil by PA particles. Generally, olive oil displayed the lowest friction coefficient. Besides, magnetic field showed relatively lower friction in spite of the extra normal force exerted by magnetic field.

CONCLUSIONS

1. Sliding of steel pin on oil lubricated brass disc magnetic field decreased friction coefficient for all the tested oils. Castor and almonds oils displayed the lowest friction coefficient followed by corn, jasmine, olive and camomile oils. Dispersing oil by PE particles significantly increased friction coefficient. Camomile oil showed the highest friction coefficient in the presence of magnetic filed. A drastic reduction of friction coefficient was observed for olive, castor and almonds oils, when dispersing the tested oils by PA particles. Corn, jasmine and camomile oils displayed relatively higher friction coefficient.

2. Sliding of steel pin on oil lubricated aluminium disc caused significant friction increase for all the tested oils. The friction increase could be attributed to the nature of the friction of aluminium against steel surface. Drastic friction reduction was observed for castor, almonds, jasmine and camomile oils when dispersed by PE particles. Dispersing vegetables oils by PA particles showed relatively lower friction coefficient for olive and castor oils, while corn, almonds, camomile and jasmine oils showed relatively higher friction values.

3. Sliding of steel pin on oil lubricated steel disc showed the highest values of friction coefficient. Dispersing the tested oils by PE particles did not decrease friction coefficient. Jasmine oil displayed relatively lower friction than the other tested oils. No enhancement was observed for dispersing the tested oil by PA particles. Generally, olive oil displayed the lowest friction coefficient. Besides, magnetic field showed relatively lower friction in spite of the extra normal force exerted by magnetic field.

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