TRIBOLOGICAL PERFORMANCE OF LITHIUM GREASE DISPERSED BY POLYMERS AND GRAPHENE NANO PARTICLES

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Abstract

The search for promising additives with excellent tribological properties has attracted considerable interest. In this paper, graphene nano particles dispersing lithium grease are used as lubricant filler. Graphene addition is aimed to reduce the effect of sand particles on friction coefficient and wear of steel test specimens, where sand particles considered as the most abrasive component of white cement contaminating lithium grease. Experimental results show that, adding 0.4 wt. % graphene nano filler to lithium grease gives good anti-friction and wear resistance performance. After adding micro particles of polymers to the graphene film, two different results endorsed. Friction and wear decreased after adding 10 wt. % of Polyamide (PA) which earns positive charges when rubbing steel surface according to triboelectric series. This phenomenon helped to scatter the sand particles which have the same positive charges. Besides, the results indicate that 20 wt. % oil should disperse lithium grease to balance the effect of contaminant. As the oil content, added to the grease, increases friction coefficient and wear decreases.

Keywords: Graphene, Nano Particles, Friction, Wear, Solid contaminants, Sand, Lithium Grease, Polyamide, Triboelectrification.

Introduction

Friction, wear, over load and fatigue are the most commonly encountered industrial problems leading to the replacement of components and assemblies in engineering [1]. The abrasive wear, behaviour of many materials is closely related to their hardness [2]. Scores of abrasive wear problems particularly those in the harsh environments involve remarkable breakage of the abrasive [3]. Abrasive wear of composite materials is a complicated surface damage process, that affected by a number of factors, such as microstructure, mechanical properties of the target material and the abrasive particles, loading condition, environmental influence, etc. Microstructure is one of the major factors; however, its effect on the wear mechanism is difficult to investigate experimentally, [4, 5]. The operating environment in Middle East is particularly severe in terms of the high ambient dust concentrations experienced throughout the Eastern and Western Provinces. During severe dust storm conditions dust concentrations of the order of 100 to 500 times higher may be encountered, [6]. Wear by hard particles occurs in many different situations such as with earth-moving equipment, slurry pumps or pipelines, rock drilling, rock or ore crushers, pneumatic transport of powders, dies in power metallurgy, extruders, or chutes. More particularly in the moon probe project, the sand dust environment contains small, angular and irregularly shaped particles that have demonstrated high wear and abrasion on mechanical and sealing systems. In abrasive wear, the material is displaced or detached from the solid surface by hard particles or hard particles between or embedded in one or both two solid surfaces in relative motion, or by the presence of hard protuberances on the counterface sliding with the velocity relatively along the surface. Therefore, one of the best alternatives to resolving the tribological problems of mechanical systems in sand-dust environments is to apply effective protective films with good wear resistance and friction-reducing capacity on the moving parts. The intention of this work was to elucidate the role of sand dust in determining the tribological performance of selected solid lubricant films. The friction and wear behaviour of these films were compared and the influence of amount of contaminant examined. The effect of solid contaminants on the wear process for a cement factory was experimentally quantified. White Portland cement or white ordinary Portland cement (WOPC) is similar to ordinary, gray Portland cement in all respects except for its high degree of whiteness, [7]. Due to the large surface to volume ratios, nano/micro-structured functional materials have been predicted and demonstrated to be excellent functional material, [8]. Compared to their bulk material counterparts, many nano-objects exhibit enhanced mechanical, electrical, magnetic, chemical, friction and wear reducing properties [9]. Approximately10 nm Fe_3O_4 magnetic nano-particles (MNPs), modified by oleic acid, were used as lubricant additives and dispersed into base oil [10]. The tribological properties of 0.45% carbon steel were investigated in sliding contact against 440 C stainless steel lubricated with various concentrations of Fe_3O_4 MNPs. The results show that the coefficient of friction and wear – loss – volume can be reduced efficiently with addition of Fe_3O_4 MNPs. Nowadays, [11], different materials with various nanostructures are used as additives for improving properties of lubricants. The effect of multi-walled carbon nanotubes (MWCNTs) in different concentrations on some of the properties of engine oils was studied. Viscosity, pour point, flash point and thermal conductivity as four quality parameters, which are effective in functionality of engine oil, were also studied. Among the different methods, which have been applied for dispersing nanotubes inside the base oil, the functionalization method for carbon nanotubes and using planetary ball mill have been determined as the best methods for stabilization of nanotubes inside the SAE 20 W50 engine oil. According to the obtained results, thermal conductivity and flash point of nano-lubricants with 0.1 wt. % improved by 13.2% and 6.7%, respectively, with respect to the base oil. Graphene is a kind of very promising filler, [12]. Graphene, is a two dimensional one atom thick allotrope of carbon that displays unusual crystal structure, electronic characteristics, charge transport behavior, optical clarity, physical & mechanical properties, thermal conductivity and much more that is yet to be discovered [13]. Consequently, it has generated unprecedented excitement in the scientific community; and is of great interest to wide ranging industries including semiconductor, optoelectronics and printed electronics. Graphene is considered to be a next-generation conducting material with a remarkable band-gap structure, and has the potential to replace traditional electrode materials in optoelectronic devices. It has also been identified as one of the most promising materials for post-silicon electronics. For many such applications, modulation of the electrical and optical properties, together with tuning the band gap and the resulting work function of zero band gap graphene are critical in achieving the desired properties and outcome. Graphene flakes have been investigated worldwide as an additive for coolants and lubricants due to their excellent thermo-physical and tribological properties [14]. In understanding the importance, a number of strategies including various functionalization, doping and hybridization have recently been identified and explored to successfully alter the work function of graphene. In this review, we primarily highlight the different ways of surface modification, which have been used to specifically modify the band gap of graphene and its work function. This article focuses on the most recent perspectives, current trends and gives some indication of future challenges and possibilities. Triboelectric Phenomena is a list that ranks various materials according to their tendency to gain or lose electrons. It usually lists materials in order of decreasing tendency to charge positively (lose electrons), and increasing tendency to charge negatively (gain electrons). Creating electrostatic charge by contact and separation of materials is known as "triboelectric charging." The word “triboelectric” comes from the Greek words, tribo meaning “to rub” and electros meaning “amber” (fossilized resin from prehistoric trees). It involves the transfer of electrons between materials. The atoms of a material with no static charge have an equal number of positive (+) protons in their nucleus and negative (-) electrons orbiting the nucleus. When the two materials are placed in contact and then separated, negatively charged electrons are transferred from the surface of one material to the surface of the other material. Which material loses electrons and which gains electrons will depend on the nature of the two materials. The material that loses electrons becomes positively charged, while the material that gains electrons is negatively charged, [15, 16]. This process of material contact, electron transfer and separation is a much more complex mechanism than described here. The amount of charge created by triboelectric generation is affected by the area of contact, the speed of separation, relative humidity, and chemistry of the materials, surface work function and other factors. Once the charge is created on a material, it becomes an electrostatic charge (if it remains on the material). This charge may be transferred from the material, creating an electrostatic discharge or ESD event. Additional factors, such as the resistance of the actual discharge circuit and the contact resistance at the interface between contacting surfaces also affect the actual charge that is released, [16]. When two materials contact and separate, the polarity and magnitude of the charge are indicated by the materials' positions in a triboelectric series. The triboelectric series tables show how charges are generated on various materials. When two materials contact and separate, the one nearer the top of the series takes on a positive charge, the other a negative charge. Materials further apart on the table typically generate a higher charge than ones closer together. These tables, however, should only be used as a general guide because there are many variables involved that cannot be controlled well enough to ensure repeatability.

Eperimental

Experiments were carried out using a cross pin tester, Fig. 1. It consists, mainly, of rotating and stationary pins of 18 mm diameter and 180 mm long. The rotating pin was attached to a chuck mounted on the main shaft of the test rig. The stationary pin was fixed to the loading block where the load is applied. AC motor drives the main shaft of test machine, (560 watts, 1280 r.p.m.) with reduction unit (1:7.5). Moreover, the test rig is fitted by a load cell, to measure the frictional force generated in the contact zone between the rotating and stationary pins. Rotational speed was 170 r.p.m. and 10 N normal load was applied by means of weights attached to a loading lever. The rotating specimens were greased before and every 30 secs. during the test. The test time was 5 min. A digital screen was attached to the load cell to detect the friction force. Coefficient of friction is determined by the ratio between the friction force and normal load and wear is determined by measuring the scar diameter on the optical microscope and measuring depth of the dome, then, calculating the wear volume, Fig. 2. The test specimens are prepared from carbon steel (St. 60), (0.6 wt. % C, 0.25 wt. % Si, 0.65 wt. % Mn, 0.045 wt. % P and 0.045 wt. % S). Experiments were carried out at 25 °C using lithium based grease dispersed by the solid additives of graphene nano particles, PA and PE particles have grain size up to 150 μm, and the grain size of sand which contaminated lithium grease is up to 150 μm.

A spherical cap or spherical dome is a portion of a sphere cut off by a plane due to wear, If the plane passes through the center of the sphere, so that the height of the cap is equal to the radius of the sphere, the spherical cap is called a hemisphere [17]. Fig. 2 shows the hemisphere wear debridement.

If the radius of the base of the cap is a, and the height of the cap is h, then the volume of the spherical cap can be expressed as follows:

$$V = \frac{\pi h}{6}(3a^2 + h^2)$$

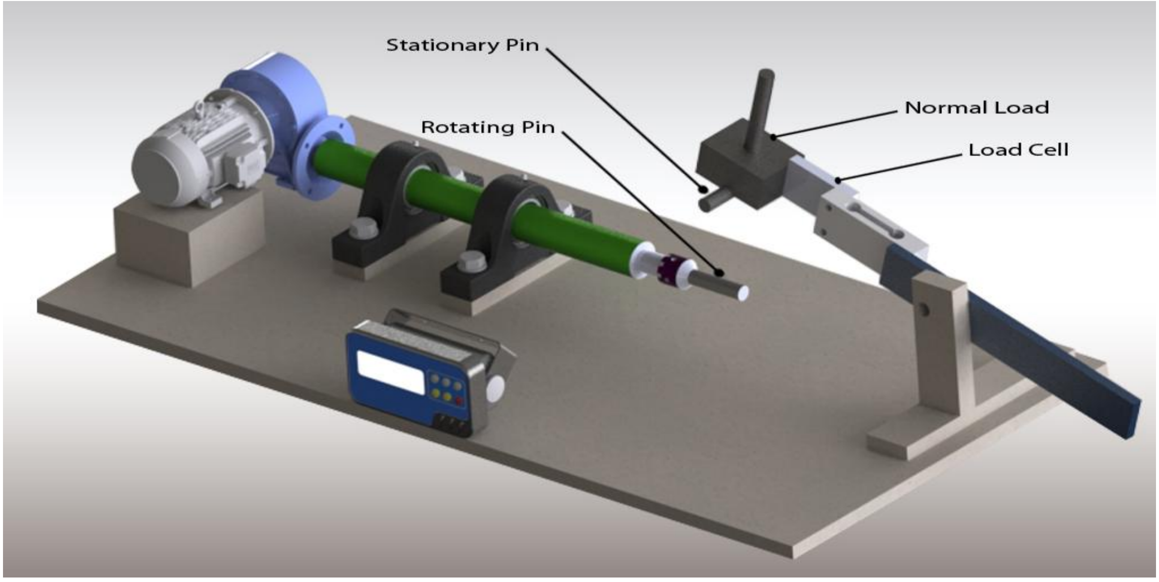

Fig. 1 Layout of cross pin wear tester.

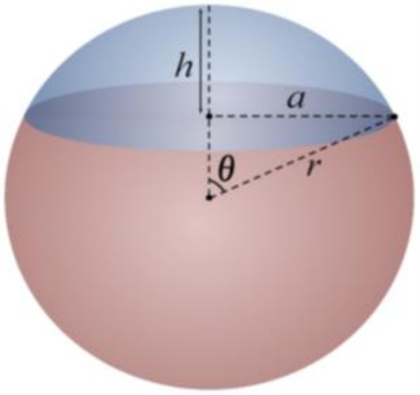

Fig. 2 Wear volume parameters, [17].

Results and Discussion

1. Addition of Synthetic Oil

Increasing sand content as a contaminant filling lithium grease, leads to increase friction between steel sliding surfaces, Fig. [3]. In addition, the presence of sand particles disturbs the correct operation of lubrication mechanisms and consequently leads to noticeable fluctuations of grease film separation. Friction slightly increases with adding oil content, adding oil content makes good distribution to lithium grease at the contact area, and balance the effect of contaminants. This can be attributed to the improvement of the oil dispersion over the running surface as illustrated in Fig. 3.

Wear values increase with increasing sand content, this phenomenon may be related to the higher abrasive action of sand due to its hardness and their irregular particles. Here, penetration of the sharp edges of sand particles can be considered as a reason for the occurrence of three-body abrasion mechanism. Adding 20 wt. % synthetic oil to lithium grease decreases the wear values, Fig. 4, because oil content facilitates the movement of sand particles, and makes good distribution of lithium grease between the rubbing surfaces.

As conferred in Fig. 3 friction increases with increasing sand content in lithium grease. Because they have angular and irregular shapes. Sketch in Fig. 5 describes abrasive sand particles which contaminates lithium grease. The increase of sand content tends to increase the friction between the contact surfaces, this phenomenon may be related to the higher abrasive action of sand, due to its hardness. Here, penetration of the sharp edges of sand particles can be considered as a reason for the occurrence of three-body abrasion mechanism.

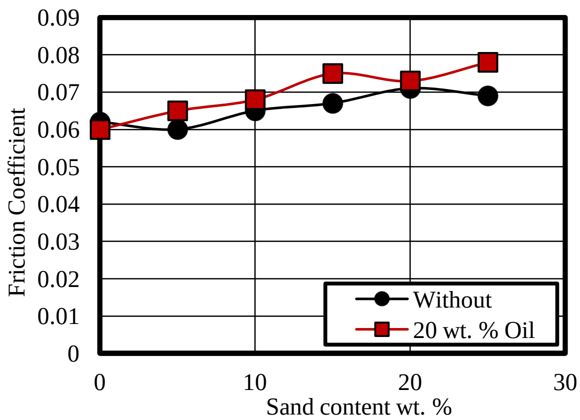

Fig. 3 Friction values caused by rubbing sand against steel surface.

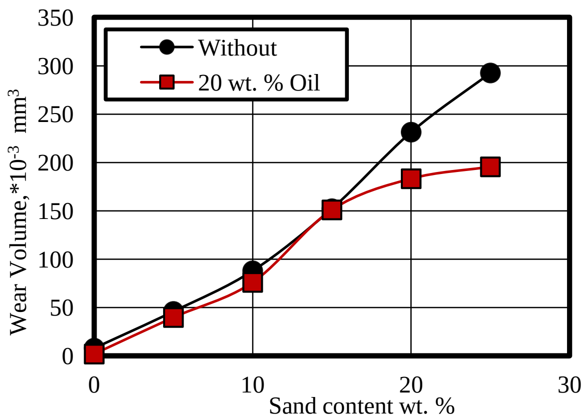

Fig. 4 Wear volume of specimens caused by abrasive sand particles.

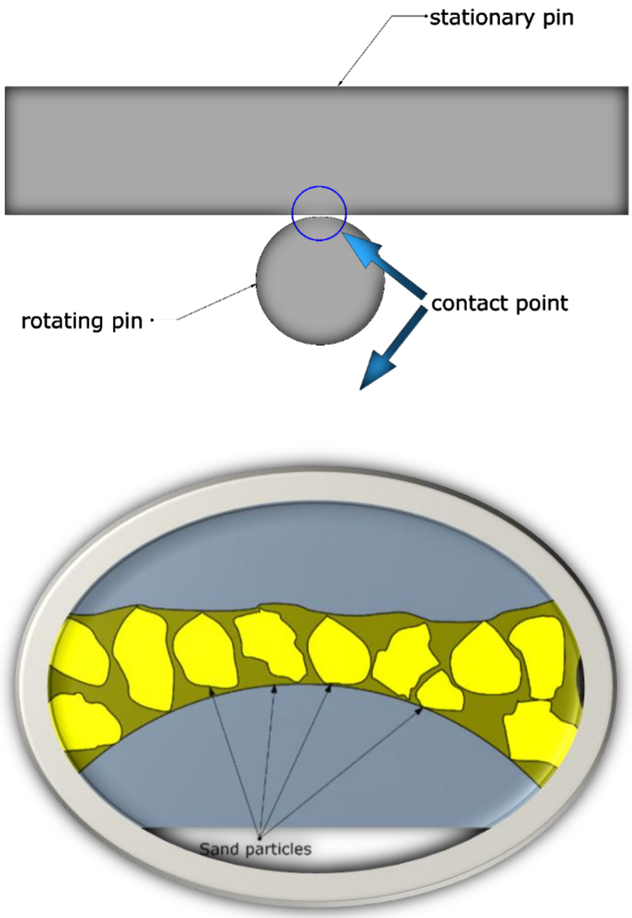

Fig. 5 Effect of abrasive sand particles on friction values.

2. Addition of Synthetic Oil and Graphene Nano Particles

Figure 6 indicates influence of nano graphene on friction coefficient of greased specimens, which contaminated by different contents of sand particles. Adding 20 wt. % of synthetic oil makes good distribution to lithium grease between the rubbing surfaces. Increasing sand content leads to increase friction between contact surfaces, this phenomenon may be related to the higher abrasive action of sand, due to its irregular shapes. Here, penetration of the sharp edges of sand particles can be considered as a reason for the occurrence of three-body abrasion mechanism. Friction values decreases after adding 0.4 wt. % of graphene nano particles to lithium grease, which have high chemical inertness, extreme strength, and easy shear capability on its densely packed, and atomically smooth surface. These properties are the major favorable attributes leads to enhance tribological properties of lithium grease.

Effect of sand, oil content, and 0.4 wt. % of nano graphene added to lithium grease on wear can be illustrated in Fig. 7, where increasing sand content, as a contaminant to lithium grease, leads to increase wear values. The process of abrasive sand particles indentation, and their mechanism of surface removal is based on the irregular shapes and hardness of sand particles, if compared to steel specimen, where sharp tips can easily cut through the steel surface. Meanwhile, adding 0.4 wt. % of nano graphene reduces wear values, this outcome because graphene is an atomically smooth two-dimensional material with low surface energy, and the nano scale of particles which facilities uniform distribution of graphene particles between rubbing surfaces. This reason facilitates shear and slows down abrasive action of sand particles to steel surface, thus drastically reduces wear. Besides, adding 20 wt. % of synthetics oil makes good distribution to lithium grease in contact area.

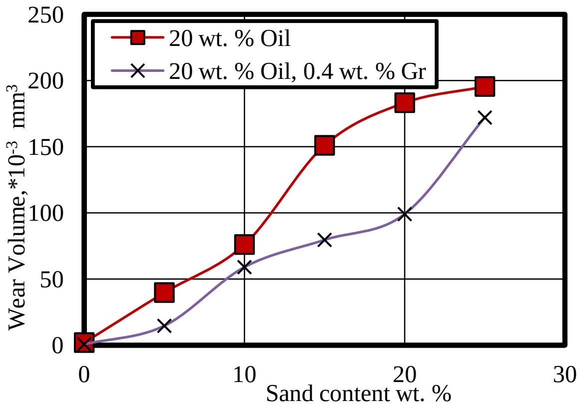

Fig. 6 Influence of nano graphene on friction of greased specimen.

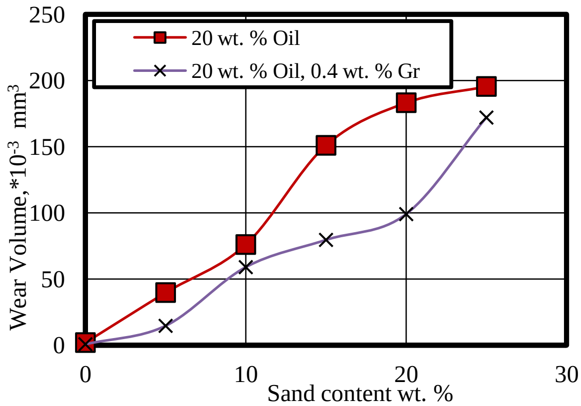

Fig. 7 Effect of sand content contaminating lithium grease.

Tribological Performance of lithium grease may be improved by filling it with graphene nano particles, which have high chemical inertness, extreme strength, and easy shear capability on its densely packed, and atomically smooth surface. These properties are the major favorable attributes for its impressive tribological behavior, where nano particles of graphene easily distributed, because of nano scale, between the rubbing surfaces and produces thin layer, as shown in Fig. 8.

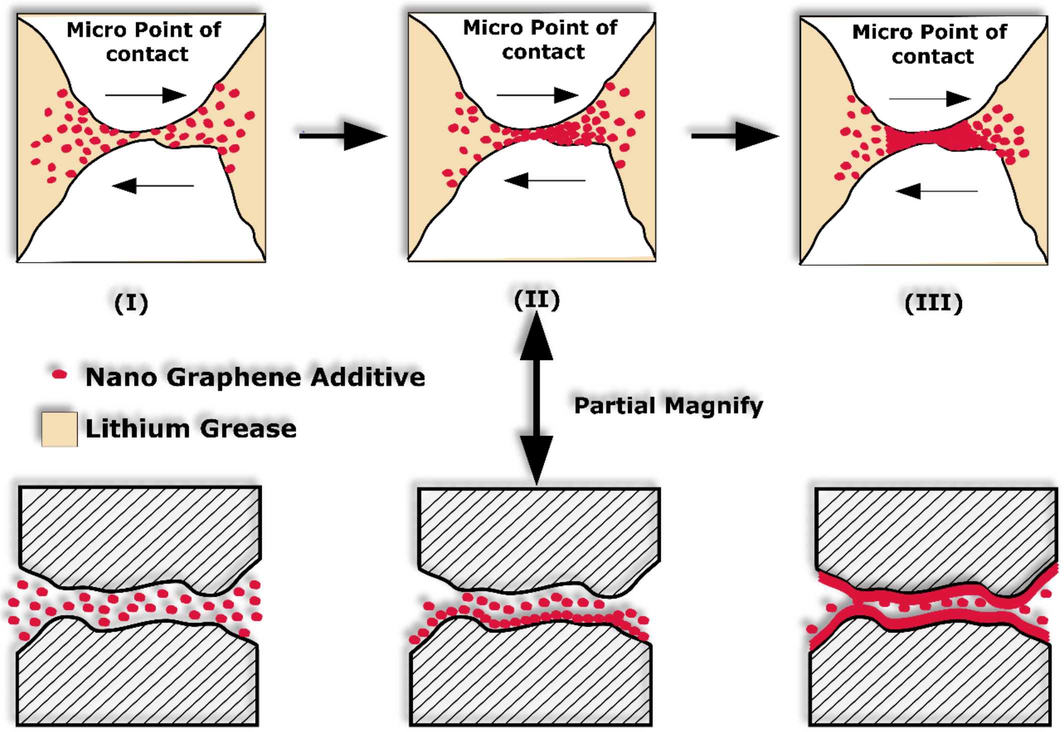

Fig. 8 Schematic sketch of mechanism of 0.4 wt. % of graphene nano particles.

3. Effect of addition of Polyamide (PA)

The results in Fig. 9 indicates that, friction increases with increasing sand content as a contaminant in lubricating grease; this phenomenon may be related to the higher abrasive action of sand due to its irregular shapes. Here, penetration of the sharp edges of sand particles can be considered as a reason for the occurrence of three-body abrasion mechanism. Friction slightly increases after adding 20 wt. % oil, which may be because oil content makes good distribution to lithium grease between the steel specimens. Let's jump to the effect of adding particles of PA to lithium grease, where the friction values significantly decrease, this result perhaps due to the repulsive force between PA and sand particles, which gains same positive charges due to triboelectric charging. Adding PA particles to lithium grease facilitates scattering the sand particles faraway the contact area and reduced friction values. Besides, the good lubricating properties of polyamide.

It could be remarked that; the increase of the sand content increases the wear values, Fig. 10; this phenomenon may be related to the higher abrasive action of sand particles due to its hardness. Here, penetration of the sharp edges of sand particles can be considered as a reason for the occurrence of three-body abrasion mechanism. Furthermore, adding 20 wt. % of synthetic oil makes good distribution to lithium grease between the contact surfaces, due to the antifriction properties of oil which generated a protective thin film over the contact area and prevented the metal damage. Adding polyamide particles enhances the lubricating properties of lithium grease. That means the particles of PA makes thin film and coated the surface of contact; this film increased the wear resistance and extends the lifetime of the contact surfaces. Due to tribo electric charging, PA and sand particles gains positive charges, and then particles of polyamide scatters sand particles from the contact area and reduces wear.

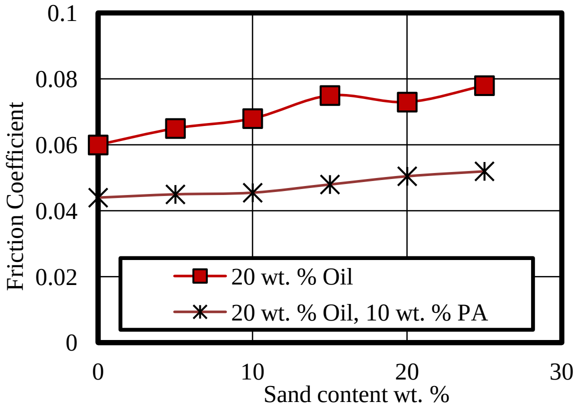

Fig. 9 Effect of adding polyamide to contaminated grease on friction of steel specimen.

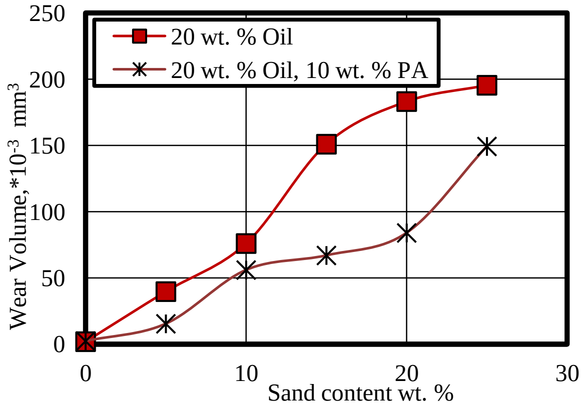

Fig. 10 wear values displayed in steel specimen due to sand particles.

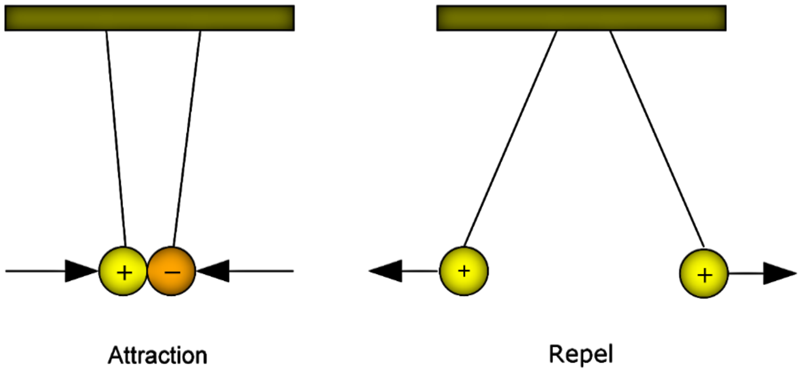

Fig. 11 Similar and dissimilar charges produce due to triboelectrification

When particles of sand and PA rubbed against steel surface, PA and sand particles gain positive charges and steel surface gains negative charge, this phenomenon due to triboelectric charging. But the positive polarity of PA particles is stronger than the positive charges of sand particle, according to triboelectric series, then, the contraction between steel surface and PA particles will be more than contraction between steel surface and sand particles. Then, PA produces protective thin film between sand and steel surface, as shown in Fig. 11.

4. Triboelectrification

Contact electrification, Fig. 12, also known as static electricity or contact charging, is the process that produces surface charges on dissimilar materials when they are contacted and separated. During this contact, each material develops a charge of opposite polarity. In particular, insulators and organic polymers can be arranged in a ‘‘triboelectric series’’ which lists the materials in the order of the relative polarity of the contact charge acquired, from those that charge most positive, like nylon, to those that charge most negative, like the halogenated polymers. In the triboelectric series, the higher positioned materials will acquire a positive charge when contacted with a material at a lower position along the series. Thus, the triboelectric series can be used to estimate the relative charge polarity of the materials.

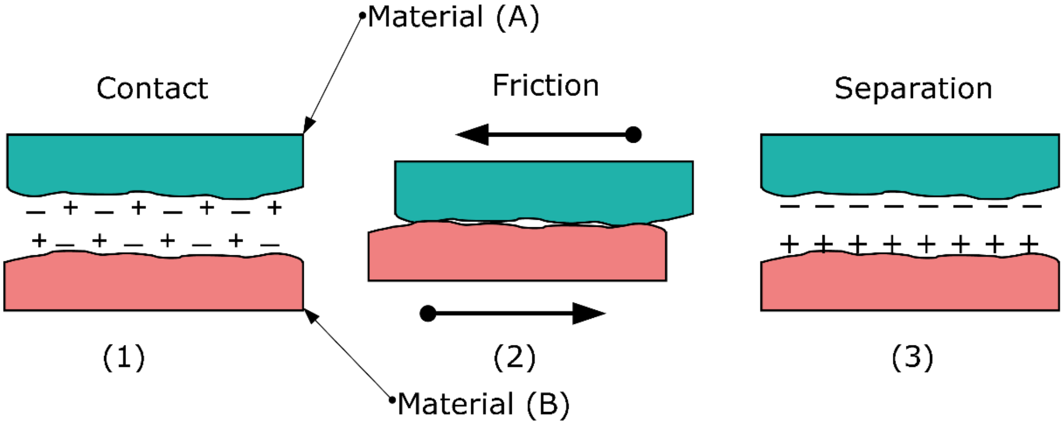

Fig. 12 Tribocharges produced due to rubbing between two different materials.

5. Effect of Dispersing Micro Polymers and Graphene Nano Particles.

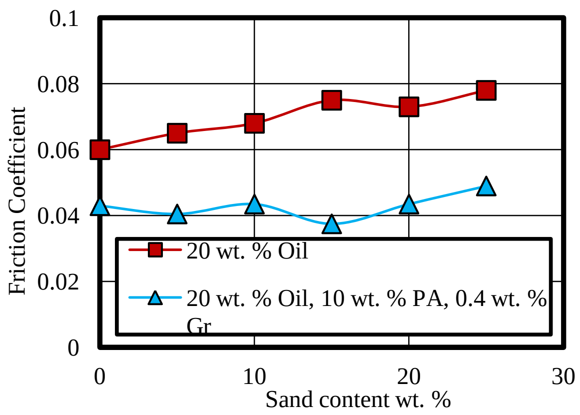

Fig. 13 Effect of PA with nano graphene on friction caused by sand particles.

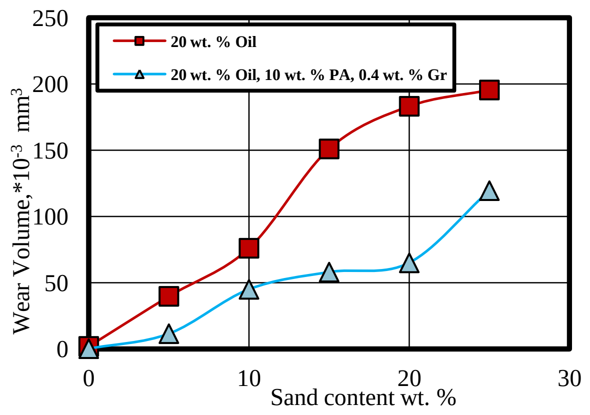

Fig. 14 Wear volume of specimens Caused by abrasive sand particles and method of reducing it.

Relation between sand content, contaminating lithium grease, and friction coefficient is shown in Fig. 13. Increasing sand particles tends to increase friction coefficient, because the abrasive sand particles penetrate surface of steel specimen. This phenomenon may be related to the higher abrasive action of sand due to its sharpness. Here, penetration of the sharp edges of sand particles can be considered as a reason for the occurrence of three-body abrasion mechanism. Filling lubricating grease with 20 wt. % of synthetic oil balances effect of contaminant and makes good distribution to lithium grease between rubbing surfaces. Polyamide addition achieves protective thin layer between contact surface and prevented abrasive sand edges from penetration. Meanwhile, adding graphene nano particles which have good distribution in lithium grease due to its nano scale. Graphene layers act as a two-dimensional nanomaterial and form a conformal protective coating on the sliding contact interfaces. This reason facilitates shear and slow down scratching sand particles to steel surfaces, thus leads to reduce friction between steel surface and sand particles.

It could be remarked that; the increase of the sand content increases the wear values as illustrated in Fig. 14; This behaviour can be explained on the basis that the hardness of sand is higher than steel, so that the sharp edges of sand particles abraded the steel surface. Wear values increase due to hard particles that are forced, due to applied load, against and move along a steel surface. Furthermore, adding 20 wt. % of synthetics oil makes good distribution to lithium grease between the contact surfaces, due to the antifriction properties of oil which generates a protective thin film over the contact area and prevents the steel surface damage. Filling lithium grease by 10 wt. % of PA makes protective thin layer between sliding surfaces and helps in reducing wear values, while nano graphene is an atomically smooth two-dimensional material with low surface energy and, therefore, reduces adhesion and wear of rubbing surfaces.

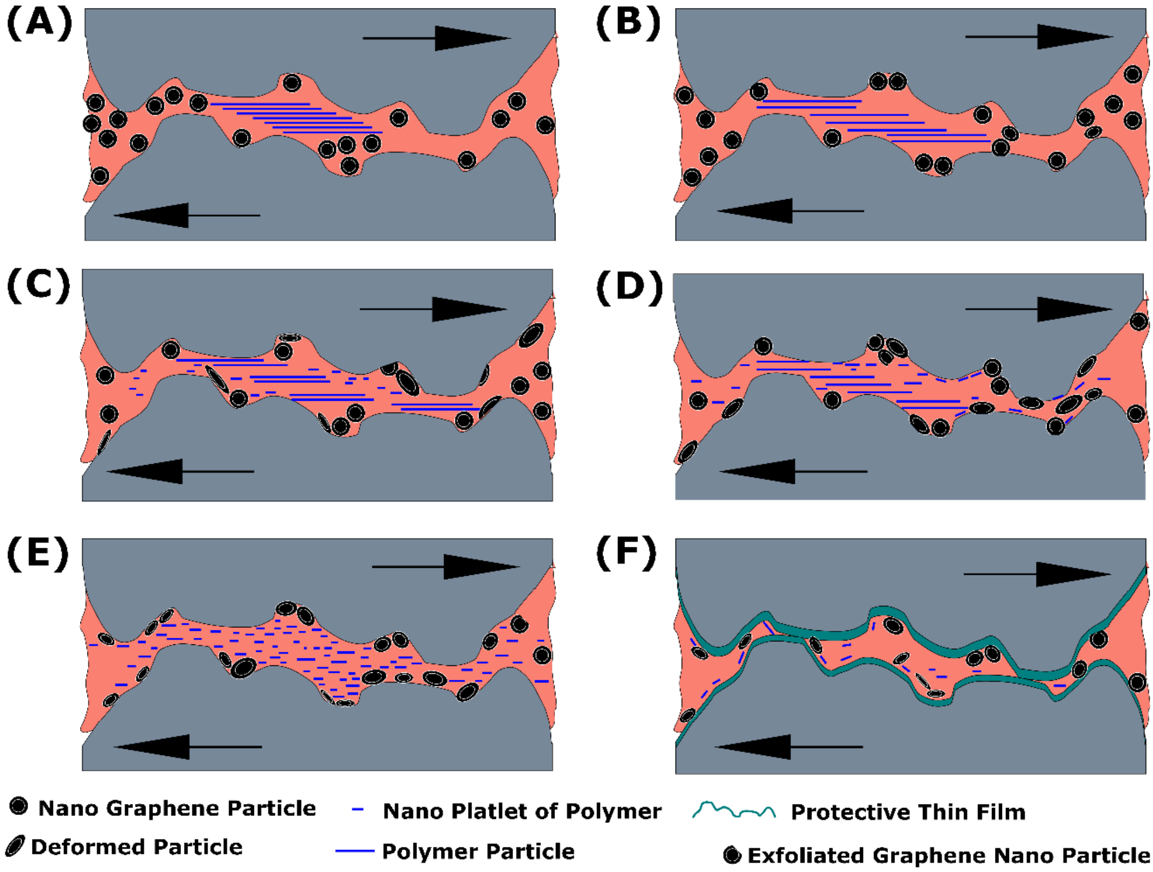

Fig. 15 Effect of polyamide and graphene nano particles on the tribological performance of lithium grease.

When the abrasive PA and sand particles rubbing steel surface, due to triboelectric series, steel surface gains negative charge and particles of sand and PA gain positive charges. This phenomenon creates a repulsive force and dissipates sand particles. Graphene nano particles are excellent nano fillers for enhancing the tribological performance of lithium grease. GNPs can reduce friction and, especially, to increase the wear resistance due to the exfoliation of the nano particles that creates an adhered protective tribofilm, Fig. 15. Adding graphene nanoparticles makes homogeneous distribution of electric static charge, leading to clear disharmonize between polymers and sand particles, then wear decreases, as conferred in Fig. 14.

Conclusion

The present experimental study confirms that, friction and wear values decrease with increasing graphene nano particles up to 0.4 wt. %. Graphene layers' act as a two-dimensional nanomaterial and form a conformal protective coating on the sliding contact interfaces. This reason facilitates shear and slows down abrasion action of sand particles to steel surface, thus drastically reduces wear. In polymers, such as PA, which gains positive charge when sliding against steel surface according to tribo electric phenomena and makes use of the excellent conductivity of graphene which accelerates scattering of sand particles out of the contact area. While PE which gains negative charge, and attracts sand particles into steel surface. Based on the experiments results it is recommended that adding polymers which have positive charge such as PA with 0.4 wt. % graphene nano particles to lithium grease gives excellent tribological performance and reduces the abrasive effect of sand particles. Abrasive sand particles as contaminant in lithium grease are responsible for increasing friction and wear values related to their hardness and their irregular shapes. Wear values decreased after adding 20 wt. % oil content to lithium grease and friction coefficient slightly increased.

References

[1] Unal H., Mimaroglu A., “Friction and wear behaviour of unfilled engineering thermoplastics”, Materials and Design 24, pp. 183–187, (2003).
[2] S. Graça, R. Vilar, R. Colaço, “The role of indentation size effect on the abrasive wear behaviour of ductile metallic materials: A nanotribological study”, Wear 268, pp. 931-938, (2010).
[3] Poorya Hosseini, Peter Radziszewski, “Combined study of wear and abrasive fragmentation using Steel Wheel Abrasion Test”, Wear 271, pp. 689-696, (2011).
[4] Hu J., Li D.Y., Llewellyn R., “Computational investigation of microstructural effects on abrasive wear of composite materials”, Wear 259, pp. 6-17, (2005).
[5] Yousif B. F., El-Tayeb N.S.M., “Wear characteristics of thermoset composite under high stress three-body abrasive”, Tribology International 43, pp. 2356- 2371, (2010).
[6] Ali, W. Y and Mousa, M. O., “Experimental Study of Wear and Friction Caused by Abrasive Contaminants and Fuel Dilution in Lubricating Oil”, 5th International Congress on Tribology EUROTRIB 89, Helsinki, Finland, pp. 437 - 431, June 13, (1988).
[7] Jianwei Qi, Liping Wang, Yunfeng Wang, Jibin Pu, Fengyuan Yan, Qunji Xue, “The tribological performance of selected solid lubricant films in sand-dust environments”, Wear 271, pp. 899-910, (2011).
[8] Ezzat A. A. and Mousa M. O., “Friction and Wear of Moving Surfaces in Abrasive Contaminated Environment”, MJET, Lubrication and Lubricants, Vol. 31, No. 2, pp. 234 – 45, Jan (2012).
[9] Dave Maharaj, Bharat Bhushan, “Friction, wear and mechanical behavior of nano-objects on the nanoscale”, Materials Science and Engineering R 95, pp. 1–43 (2015).
[10] Jing Zheng, Xingfa Ma, Xiaochun He, Mingjun Gao, and Guang Li, “Preparation, characterizations, and its potential applications of PANi/ graphene oxide nanocomposite”, Procedia Engineering 27, pp. 1478-1487, (2012).
[11] Guanghong Zhou, Yufu Zhu, Xiangming Wang, Mujian Xia, Yue Zhang, Hongyan Ding, “Sliding tribological properties of 0.45% carbon steel lubricated with Fe3O4 magnetic nano-particle additives in base oil”, Wear 301, pp. 753–757, (2013).
[12] Ehsan-o-llah Ettefaghi, Hojjat Ahmadi, Alimorad Rashidi, Amideddin Nouralishahi, Seyed Saeid Mohtasebi, “Preparation and thermal properties of oil-based nano fluid from multi-walled carbon nanotubes and engine oil as nano-lubricant”, International Communications in Heat and Mass Transfer 46, pp. 142–147, (2013).
[13] Saihua Jiang, Zhou Gui, Chenlu Bao, Kang Dai, Xin Wang, Keqing Zhou, Yongqian Shi, Siuming Lo, Yuan Hu, “Preparation of functionalized graphene by simultaneous reduction and surface modification and its polymethyl methacrylate composites through latex technology and melt blending”, Chemical Engineering Journal 226, pp. 326–335, (2013).
[14] A.K.Rasheed, M.Khalid, W.Rashmi, T.C.S.M.Gupta, A.Chan, “Graphene based nano fluids and nano lubricants – Review of Recent developments”, Renewable and Sustainable Energy Reviews 63, pp. 346–362, (2016).
[15] ESD Association, Rome, NY., “Fundamentals of Electrostatic Discharge”, an Introduction to ESD, Part One, (2013).
[16] K. Robinson, “Static Beat: Stop Tribocharging Your Products,” Paper, Film & Foil Converter, Vol. 83, NO. 5, P.12, May, (2009).
[17] https://en.wikipedia.org/wiki/Spherical_cap, April 1, (2017).

الآداء التريبولوجي لشحم الليثيوم المضاف اليه البوليمرات والنانو جرافين

م. المعتز بالله عبد الله

م.م. المعهد العالي للهندسة والتكنولوجيا بالمنيا

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كلية الهندسة-جامعة المنيا

ملخص البحث

يهدف البحث إلي محاولة تطوير آداء شحوم الليثيوم المستخدمة في عمليات التزييت، وذلك عن طريق اضافة حبيبات الجرافين ذات حجم النانو وكذلك اضافة البولي أميد. حيث تتعرض الشحوم للتلوث خاصة في بيئة ملوثة بالأتربة والرمال كما هو الحال في مصانع الأسمنت. وتمت دراسة تأثير هذه الاضافات علي الإحتكاك والتآكل بين عينات الاختبار. وكذلك دراسة تأثير تلوث شحم الليثيوم بحبيبات الرمل. وأظهرت التجارب أن قيم الإحتكاك والتآكل تزداد بزيادة نسبة تلوث شحم الليثيوم بحبيبات الرمل، وربما يرجع ذلك لعدم انتظام شكل حبيبات الرمل وكذلك لكبر صلادة حبيبات الرمل إذا ما قورنت بصلادة عينات الصلب. حيث تتسبب حبيبات الرمل في زيادة التآكل بين سطحي عينات الاختبار. كما أوضحت التجارب أن اضافة النانو جرافين إلي شحم الليثيوم يسبب تحسن ملحوظ في قيم الاحتكاك والتآكل، وذلك ربما يكون عن طريق تحسن توزيع شحم الليثيوم بإنتظام بين الأسطح المنزلقة بفضل صغر حجم حبيبات النانو جرافين، وكذلك تحسن الإنزلاق بين الأسطح المتحركة. كما أوضحت التجارب أنه باضافة البولي أميد إلي شحم الليثيوم ،ربما تكونت طبقة رقيقة من البولي اميد علي سطح الصلب، وذلك نتيجة ظاهرة الكهرباء الاستاتيكية. من خلال التجارب المعملية ينصح بإضافة ١٠ % بولي أميد و٢٠ % زيت و ٠,٤ % نانو جرافين إلي شحم الليثيوم.