ISSN 2229-5518

DEVELOPING THE TRIBOLOGICAL PROPERTIES OF LITHIUM GREASES TO WITHSTAND ABRASION OF MACHINE ELEMENTS IN DUSTY ENVIRONMENT

Elhabib O. A.[1,2] and Ali W. Y.[1,3].

[1]Faculty of Engineering, Taif University, P. N. 888, Al-Taif, SAUDI ARABIA,
[2]Faculty of Engineering, Al-Neelain University, SUDAN,
[3]Faculty of Engineering, Minia University, El-Minia, EGYPT.

Abstract-The relatively high concentration of abrasive contaminants in cement industrial plants causes severe wear of moving surfaces leading to rapid failure of the machine elements. In the present work, polymeric particles such as polymethyl methacrylate (PMMA), high density polyethylene (HDPE), low density polyethylene (LDPE), and polytetrafluoroethylene (PTFE) were used as solid lubricants dispersed in lithium grease. The effect of main components of white cement such as kaolin, sand and limestone contaminating lithium grease on friction and wear of test specimens was discussed. The tests were carried out using cross pin wear tester to determine friction coefficient and wear .Based on the experimental results it was found that friction coefficient slightly decreased with increasing the content of polymeric particles. Kaolin particles represented the highest friction coefficient, while limestone caused the lowest one. Sand displayed moderate friction values between kaolin and limestone. Sand particles displayed the higher wear values than kaolin and limestone. Addition of the polymeric particles into the grease decreased wear. HDPE displayed the lowest wear values followed by PTFE, PMMA and LDPE.The mechanism of action of polymer dispersion in lithium grease can be explained on the basis that the polymeric particles fill the pits and valleys in the roughness of the sliding surfaces, thereby increasing the contact area and providing an area of low shear strength. This performance will be enhanced if the particles are strongly adhered to the contact area and the shear strength of the polymer is less than its adherence to the substrate. In addition, a film of polymers is built up of sufficient thickness to cover the contact area completely, and sliding takes place between two smooth oriented layers of polymers. In the presence of abrasive contaminants polymeric film can protect the sliding surfaces from the abrading action of the abrasive

Keywords-Friction coefficient, wear, lithium grease, sand kaolin, limestone.

1 INTRODUCTION

The effect of main components of white cement such as sand, kaolin and limestone contaminating lithium grease on friction coefficient and wear of steel test specimens was discussed, [1]. Based on the experimental results it was found that tin proved to be effective as solid lubricant dispersed in lithium grease to decrease abrasion wear of the sliding surfaces. This behaviour might be attributed to the action of tin to cover the sliding surfaces as well as the contaminant particles and consequently decreased their ability to abrade the sliding surfaces. Friction coefficient showed relatively higher values when the grease was contaminated by sand particles compared to that observed for kaolin and limestone. Presence of sand particles showed the highest wear values. The effect of tin was more pronounced in the presence of sand particles at 5 wt. % content. It seems that adherence of tin into the surfaces of sand particles was quite effective to lessen their ability to abrade the sliding surfaces. Besides, the presence of tin on the steel surfaces decreased friction coefficient and facilitated the sand to slide more than to abrade .

The effect of solid contaminants on the wear process for a cement factory was experimentally quantified, [2]. Several contaminants were collected from different areas in the cement factory including the air cooled slag with low ferric particles, fatty clay, sandy clay, water cooled slag with medium ferric particles, lime stone, iron ore and air cooled slag with high ferric particles. HDPE, LDPE, MoS2, Al powder, PTFE, and PMMA were used as lubricant additives in paraffin oil to reduce the effect of the solid contaminants. The experiments were carried to reproduce the working conditions in the factory and the results were obtained using cross pin wear tester. The performances of the pure and mixed lubricant were tested and the results showed significant reduction in wear with the addition of the proposed lubricant additives into the oil.

Graphite (C) and PMMA were used as solid lubricants dispersed in lithium grease. Their effect on friction and wear of moving surfaces contaminated by solid contaminants in the cement plant was discussed, [3]. The tests were carried out at sliding velocity of 0.5 m/s and load of 10 N. The rotating specimens were greased before the test and further greasing was carried out every 30 second during the test. The test time was 5 minutes. The wear scar diameter was measured for the upper stationary pin by using an optical microscope with an accuracy of ± 1.0 μm. Experiments were carried out at 25 °C. Based on the experimental results, it was found that, graphite caused slight increase in friction and significant reduction of wear, while PMMA in most case causes decrease in friction and wear. Besides, wear and friction decreased with increasing oil content in grease. Besides, wear and friction decreased with increasing PMMA. Graphite displayed low wear, while friction coefficient increased gradually when graphite content increased.

The surface roughness of engineering surfaces appears as a series of peaks and valleys. The function of lubrication is to separate these peaks and valleys so that contact is avoided in metal to metal to reduce or eliminate wear. Solid lubricants include graphite, glass, boron nitride, polytetrafluoroethylene, molybdenum disulfide, tungsten disulfide, lime, talc. Talc is a naturally occurring hydrous magnesium silicate. Structurally, talc is comprised of a sheet of brucite or Mg (OH)2 sandwiched between SiO2 sheets, [4 – 6]. The elementary sheets are weakly bonded to each other. As a result the layers slide apart with minimal force giving talc its inherent softness and lubricity. Talc is naturally hydrophobic which contributes to its functional lubricity as well .

In dusty environment, abrasive particles entering the machines cause serious wear of the sliding components, [7, 8]. Abrasive wear of composite materials is a complicated surface damage process, affected by a number of factors, such as microstructure, mechanical properties of the target material and the abrasive, loading condition, environmental influence, etc. Microstructure is one of the major factors; however, its effect on the wear mechanism is difficult to investigate experimentally, [9, 10], due to the possible synergism with other influences. Lubrication is critical for minimizing wear in mechanical systems, [11], that operate for extended time periods. Developing lubricants that can be used in engineering systems without replenishment – particularly those that are environmentally friendly – is very important for increasing the functional lifetime of mechanical components. 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, [12]. The raw materials involved in white cement are Sand (80 %), limestone (12 %) and kaolin (8.(%

Interest has risen in solid powder lubrication due to its proven ability to provide low friction and wear in interfaces unsuitable for traditional oils. This may be in the form of augmenting oil performance as an additive, or in the form of thin, solid transfer films since it was found that sliding materials sometimes inherently generate a film that can protect the contact interface during relative motion, [13]. Graphite is used as lubricant in machines which have to be operated at high temperatures. All such machines cannot be lubricated with oils, grease, etc. As they vaporize immediately at the high temperature. As a lubricant it is used as dry powder or mixed with water or oil, [14]. PMMA is the most commonly used polymer among the methacrylate family and has found tremendous application in automotive and home appliances. PMMA is one of the most polymers commonly used in the plasticized polymer electrolytes, [15 - 18], with another polymer that can provide a good mechanical property .

In the present work, polymeric particles are used as solid lubricants dispersed in lithium grease. The effect on friction and wear of moving surfaces contaminated by solid contaminants in the cement plant is discussed.

2 EXPERIMENTAL

Experiments were carried out using a cross pin wear tester, Fig. 1. It consists, mainly, of rotating and stationary pins of 18 mm diameter and 100 mm long. The material of the pins is carbon steel (St. 60), (0.6 % C, 0.25 % Si, 0.65 % Mn, 0.045 % P and 0.045 % S) of 1800 MPa hardness. 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. The main shaft of the test machine is driven by DC motor (300 watt, 250 volt) through a V-belt drive unit. Moreover, the motor speed is adjustable and can be controlled by varying the input voltage using an autotransformer. The test rig is fitted by a load cell to measure the friction torque generated in the contact zone between the rotating and stationary pins. Normal load was applied by means of weights attached to a loading lever. A counter weight is used to balance the weights of the loading lever, the loading block and the stationary specimen.

Different polymeric powders were used as additional thickeners which were PMMA, HDPE, LDPE and PTFE of 0 – 50 μm particle sizes. They were added to the grease at concentration of 0, 5, 10, 15, 20 and 25 wt. %. Tests were carried out at sliding velocity of 0.5 m/s and 10 N load. Test specimens were greased before the test and further greasing was carried out every 30 sec during the test. The test time was 300 seconds. Wear scar diameter of the upper

ISSN 2229-5518

stationary pin was measured by an optical microscope with in an accuracy of ±1 µm. Experiments were carried out at 25 °C using lithium based grease dispersed by polymeric particles. The contaminant materials tested in the present work were kaolin (Kaolinite), sand and limestone. Kaolinite is a clay mineral, part of the group of industrial minerals composition {Al2Si2O5(OH)4}. Rocks that are rich in kaolinite are known as kaolin or china clay. Limestone is a form of calcium carbonate (CaCO3). Sand is silica (silicon dioxide, or SiO2). Those contaminants are the main components of white cement. 12-Hydroxy stearic acid, lithium hydroxide and a naphthenic mineral lubricating oil (density at 20 °C: 916 kg/m3; kinematic viscosity at 40 °C:115 mm2/s-1) were used to prepare lithium 12-hydroxystearate lubricating greases (14 wt. % soap) and 319 (1/10 mm at 25 °C) penetration. The oil added to the grease to balance the solid contaminants was made of synthetic esters, API Group V base oils including diesters and polyolesters.

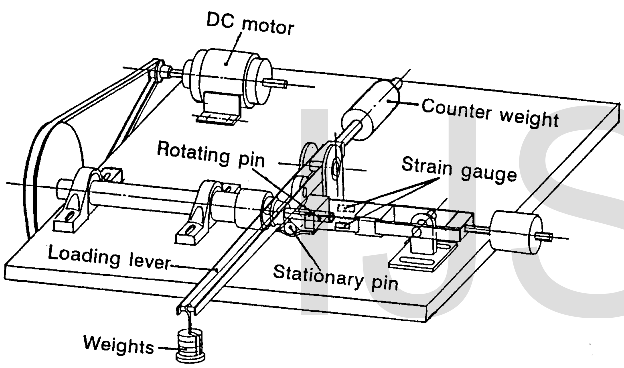

Fig. 1 Arrangement of wear tester.

3 RESULTS AND DISCUSSION

Effect of PMMA content in grease on friction coefficient of the test specimens is shown in Fig. 2. Friction coefficient slightly decreased with increasing PMMA content. Kaolin particles represented the highest friction, while limestone caused the lowest one. Sand displayed moderate friction behaviour between kaolin and limestone. Addition of HDPE into lithium grease showed the same trend observed for grease dispersed by PMMA. Values of friction coefficient were relatively higher than that observed for PMMA dispersed grease,Fig. 3. The relationship between friction coefficient and LDPE content in lithium grease is shown in Fig. 4. When LDPE content increased friction coefficient slightly increased. Friction values were 0.15 and 0.135 at 5 and 25 wt. % % LDPE content. The effect of PTFE content on the friction coefficient is shown in Fig. 5. PTFE showed relatively higher friction than PMMA, HDPE and LDPE.

The effect of sand content, in lithium grease diluted by different oil content, on wear is shown in Fig. 6. Sand particles displayed the highest wear values among the tested contaminants like kaolin and limestone. This behaviour could 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. It can be seen that adding PMMA into the lithium grease was enough to reduce the wear scar diameter. The same trend was observed for the other tree tested polymers. HDPE displayed the lowest wear followed by PTFE, PMMA and LDPE.

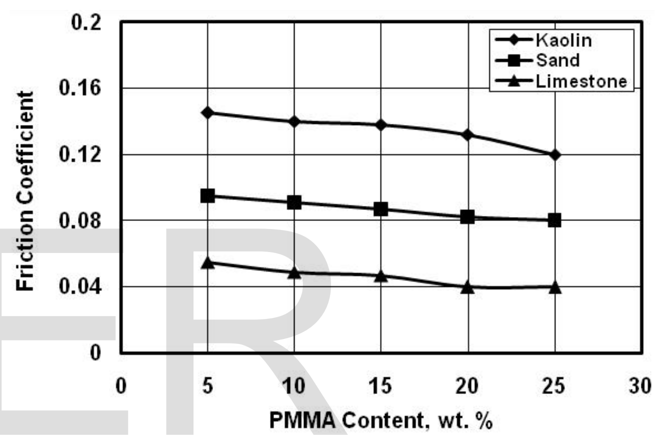

Fig. 2 Effect of PMMA content on the friction coefficient.

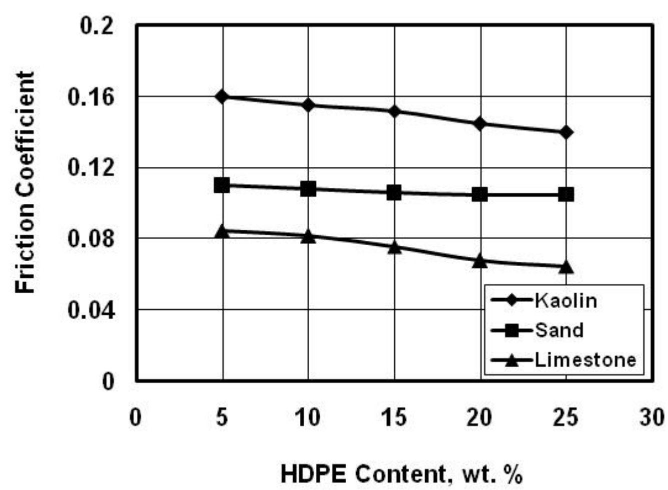

Fig. 3 Effect of HDPE content on the friction coefficient.

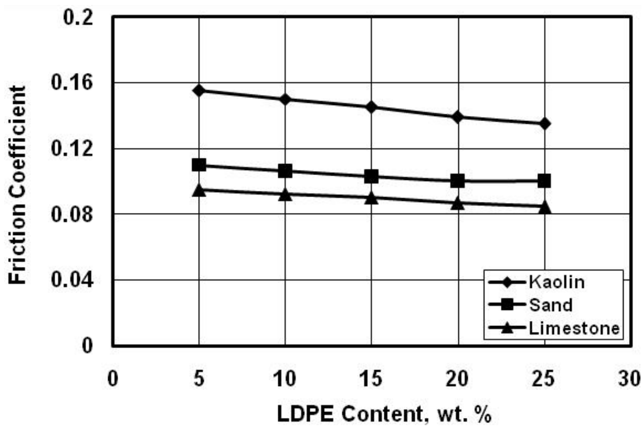

Fig. 4 Effect of LDPE content on the friction coefficient.

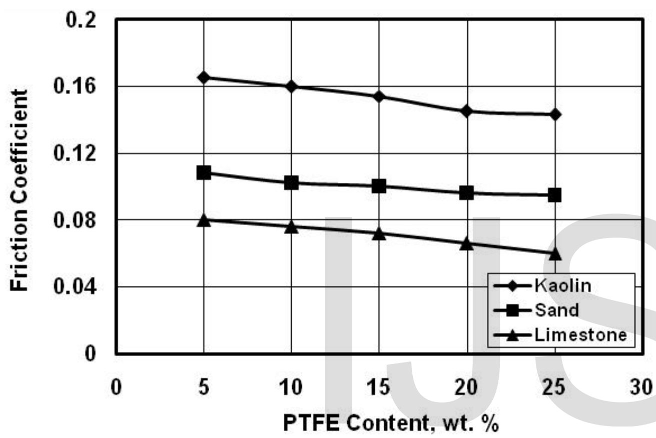

Fig. 5 Effect of PTFE content on the friction coefficient.

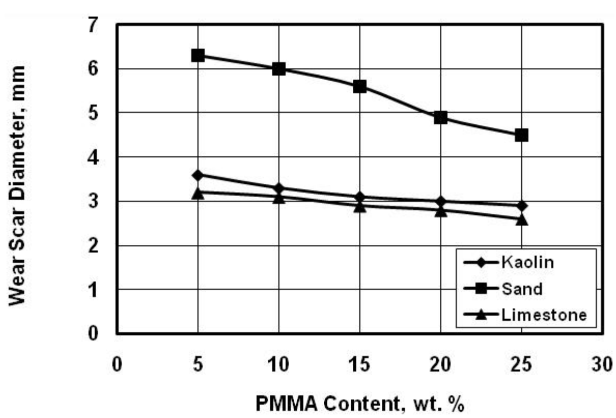

Fig. 6 Effect of PMMA content on the wear of the tested specimens.

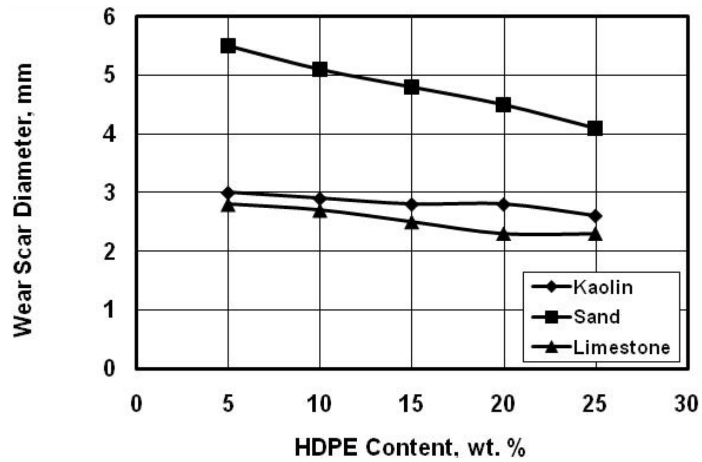

Fig. 8 Effect of LDPE content on the wear of the tested specimens.

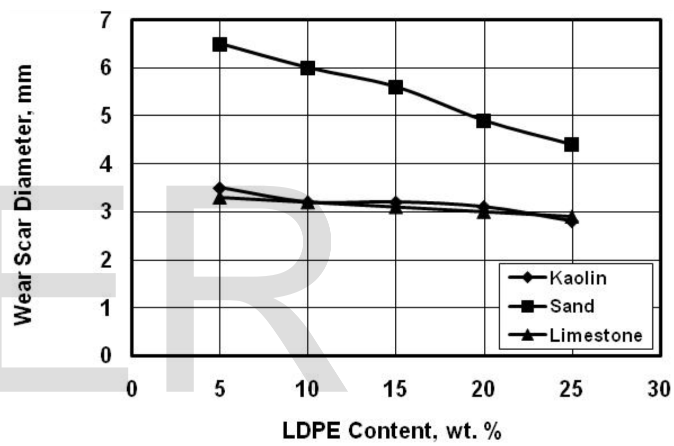

Fig. 7 Effect of LDPE content on the wear of the tested specimens.

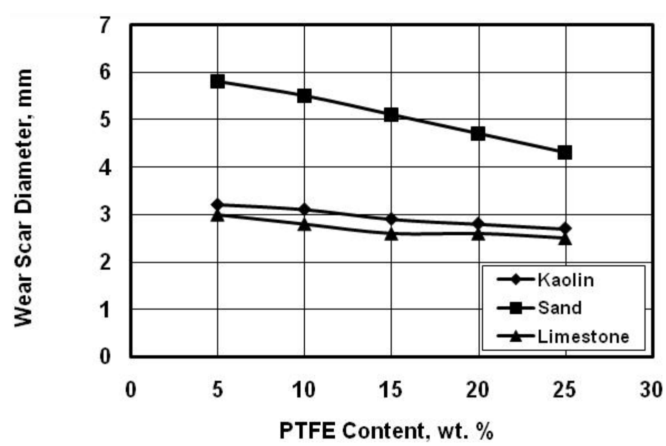

Fig. 9 Effect of PTFE content on the wear of the tested specimens.

When two different materials are pressed or rubbed together, the surface of one material will generally gain some electrons from the surface of the other material. The material that gains electrons has the stronger affinity for negative charge of the two materials, and that surface will be negatively charged after the materials are separated. The other material will have an equal amount of positive charge. The amount and polarity of the charge on each surface can be measured for insulating materials. The triboelectric series predict which will become positive or negative and how strong the electric charge will be.

Based on the triboelectric series it is well known that, PTFE, HDPE and LDPE have negative charges as a result of their friction with steel, while PMMA has positive charge. Sand particles gain positive charge when they rub steel surface. Some of those particles would strongly adhere to the steel surface protecting it from excessive wear. The tendency of the adherence of PTFE, HDPE and LDPE particles into the surface of sand depends on their location in the triboelectric series. It is expected that those polymeric particles are more effective in reducing the abrasion action of the sand than PMMA. The electric static charge generated from the friction of PTFE with steel is much higher than that generated from the HDPE, LDPE and PMMA.

The enhacement observed in friction and wear of the tested specimens when polymeric particles were added to the grease could be explained on the basis that adherence of polymeric particles in the surface of sand, kaolin and limestone particles decreased their ability to abrade the sliding surfaces and consequently decreased friction and wear. The highest values of friction coefficient were displayed by PTFE followed by HDPE, LDPE then PMMA. Friction increase observed for PTFE may be attributed to its adhesion into the sliding surfaces. Generally, the relatively low yield strength of PTFE, HDPE and LDPE enabled their particles trapped between the two sliding surfaces to be completely deformed and consequently covered the contact area more efficiently than the other tested polymers, [19, 20]. The lowest friction was observed for PMMA due to the rolling of its particles between the two sliding surfaces.

The relative improvement of wear resistance of the rubbing surfaces was displayed by the dispersion of HDPE, PTFE, LDPE and PMMA. This can be attributed to the relatively strong adhesion of polymeric particles into the contact surfaces. However, relatively lower wear scar width was obtained from the test specimens lubricated by grease containing HDPE, PTFE and LDPE while PMMA displayed relatively higher wear scar width. The ranking of polymeric materials in reducing wear caused by sand particles depends on their adherence to the surfaces of sand particles and contact area.

The mechanism of action of polymer dispersion can be explained on the basis that the particles fill the pits and valleys in the roughness of the sliding surface, thereby increasing the contact area and providing a reservoir of lubricant. This performance will be enhanced if the particles are strongly adhered to the contact area and the shear strength of the solid lubricant is less than the adhesion to the substrate. In addition, a film of polymers is built up of sufficient thickness to cover the contact area completely, and sliding takes place between two smooth oriented layers of polymers.

4 CONCLUSIONS

1. Friction coefficient slightly decreased with increasing the polymeric particles content. Kaolin particles represented the highest friction, while limestone caused the lowest one. Sand displayed a moderate friction behaviour between kaolin and limestone .
2. Sand particles displayed the highest wear values among the tested contaminants like kaolin and limestone. Addition of the polymeric particles into the grease decreased wear. The lowest wear was displayed by HDPE followed by PTFE, PMMA and LDPE.
3. The decrease in friction and wear may be attributed to the ability of polymeric particles to adhere into the sliding surfaces and contaminants particles and protect the contact area from further abrasion.

REFERENCES

[1]. Samy, A. M. and Ali, W. Y., “The effect of Tin as solid lubricant dispersing Lithium grease in reducing friction coefficient and wear in dusty environments”, 1 – 2 / 2013, 65, Jahrgang, METALL, pp. 568 – 573, (2013).
[2]. Ezzat, F. M., Youssef, M. M., Abd-El Aal, G. M., and Hakim, k. A., “Effect of Operating Conditions on Wear of Diesel Engine Liner and Rings”, Proceedings of The 5th International Conference of the Egyptian Society of Tribology, Cairo University, EGYPT, 10-12 April, pp. 355 - 363, (1999).
[3]. Ali, W. and Mousa, M., “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).

[4]. Youssef M. M., "Influence of Oil Contaminants on Friction and Wear of Moving Surfaces of Internal Combustion Engines", Proceedings of the 6th International Conference of Tribology, EGTRIB6, December 28 - 29, 2002, Faculty of Engineering, Cairo University, pp. 345 – 356, (2002).

[5]. Mota V., Ferreira L. A., "Influence of grease composition on rolling contact wear: Experimental study", Tribology International 42, pp. 569 - 574, (2009).

[6]. Cann P. M. "Grease lubrication of rolling element bearings - role of grease thickener", LubrSci 19, pp. 183 - 196, (2007).

[7]. Cann P. M. "Grease degradation in a bearing simulation device", TribolInt; 39, pp. 1698 – 1706, (2006).

[8]. Cann P.M, Webster M.N., Doner J. P., Wikstrom V., Lugt P., "Grease degradation in ROF bearing tests", Tribol Trans, 50 (2): pp. 187 - 197, (2007).

[9]. Couronne I., Vergne P., Mazuyer D., Truong-Dinh N., Girodin D., "Effects of grease composition and structure on film thickness in rolling contact", Tribol Trans; 46 (1), pp. 31 - 26, (2003).

[10]. Donzella G., Faccoli M., Ghidini A., Mazzu A., Roberti R., "The competitive role of wear and RCF in a rail steel", EngFract Mech,72, pp. 287 - 308, (2005).

[11]. Miettinen J., Andersson P., "Acoustic emission of rolling bearings lubricated with contaminated grease", Tribology International 33, pp. 777 – 787, (2000).

[12]. Nikas GK, Sayles RS, Ioannides E., "Effects of debris particles in sliding/rolling elastohydrodynamic contacts", In: Proceedings of the Institution of Mechanical Engineers;212, (J5), pp. 333–43, (1998).

[13]. Sayles RS, Ioannides E. Debris damage in rolling bearings and its effects on fatigue life. Transactions of the ASME, Journal of Tribology (1998).

[14]. Ioannides E. Contamination and the SKF New Life Theory for rolling bearings. NLGI Spokesman; 54 (9), pp. 14 – 19, (1990).

[15]. Ali, W. Y., and Balogh, I. "The CMOC Additive Dispersion In Lubricating Greases", IV International Seminar Of Wear, AUTOKUT, Budapest, June 10 - 11, (1986).

[16]. Ali, W. Y., "Solid Lubricant Dispersion In Lubricating Greases", Proceedings of the VIII Int. Seminar On New Development In Engine And Industrial Oils, Fuels And Additives, Cairo, Egypt, Feb. 24 - 27, (1992).

[17]. Ali, W. Y., Mousa M. O. and Khashaba, M. I., "Reducing The Effect of Three Body Abrasive Wear By Adding Polymeric Powder To Lubricating Grease", Proceedings Of The EUROTRIB'93 Congress, Technical University Of Budapest, Budapest. August 29 - September 2, (1993), Lubrication Science 8-4, July 1996, pp. 359 - 368, (1996).

[18]. Ali W. Y., Mousa M. O. and Khashaba M. I., "Effect of Polymeric Powder on the Friction and Wear of Sand Contaminated Greased Surfaces", Journal of the Egyptian Society of Tribology, Vol. 7, No. 1, January 2010, pp. 50 – 61, (2010).

[19]. Khashaba M. I., Youssef M. M., Ali W. Y., "Mechanism of Action of Lubricating Greases Dispersed by Polymeric Powders, Graphite and Molybdenum Disulphide", Tribologie + Schmierungstechnik, Jahrgang 50, 1/2012, pp. 42 – 47, (2012).

[20]. Hasouna A. T., Samy A. M., Ali W. Y., "Influence of Solid Lubricants on Reducing Friction and Wear Caused by Sand Contaminating Greases", Tribologie + Schmierungstechnik, Jahrgang 50, 2/2012, pp. 46 – 50, (2012).