EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 8, NO. 3, JULY 2011, 54 - 64

EFFECT OF POLYMERS DISPERSING LUBRICATING GREASES ON WEAR IN DUSTY ENVIRONMENT

Al-Osaimy A. S.[1] and Ali W. Y.[2,3]

[1]Faculty of Engineering, Taif University, Al –Taif, SAUDI ARABIA.
[2]Faculty of Engineering, Minia University, P. N. 61111, El-Minia, EGYPT,
[3]Current Address: Faculty of Engineering, Taif University, Al –Taif, SAUDI ARABIA.

ABSTRACT
The operating environment in cement industry is particularly severe in terms of the high ambient dust concentrations. During the severe working conditions dust concentrations of the order of 100 to 500 times higher than the normal may be encountered. The present work aims to develop the abrasion resistance of moving surfaces of machine elements lubricated by contaminated greases. The intended development is to disperse lubricating greases by polymeric thickeners in powder form, such as polytetrafluoroethylene (PTFE), polymethylmethacrylate (PMMA), high density polyethylene (HDPE) and low density polyethylene (LDPE).

Wear resistance of cylindrical steel specimens was examined using a cross pin wear tester. Experiments were carried out using clean and contaminated lubricating greases. The contaminants in the cement industry such as sand clay, air cooled slag (high ferric particles), air cooled slag (low ferric particles), iron ore, limestone, fatty clay and water cooled slag (with medium ferric particles) were added to the grease at a concentration of 10 wt. %.

The results showed that wear caused by the tested contaminants can be reduced by dispersing the lubricating greases by HDPE and PTFE. LDPE and PMMA showed the relatively lower wear resistance than that observed for HDPE and PTFE.

KEYWORDS
Wear, grease, polymers, dusty environment.

INTRODUCTION
Solid contaminants are challenge for the cement industry due to the highly dusty environment. The contaminants cause excessive wear of the moving surfaces and this in turn leads to rapid mechanical failure of the machine elements. The solid particle contaminants get into the lubricant among the metal surfaces due to the environmental

conditions. The conditions get more severe in cement factories due to the excessively dusty atmosphere leading to high rates of mechanical component failure. It was found that the effect of abrasive action of sand particles on the wear of the friction surfaces can be reduced by adding different polymeric thickeners in powder form, [1], such as high density polyethylene (HDPE), low density polyethylene (LDPE), polyvinylchloride (PVC), polystyrene (PS), polyamide (PA6) and polymethyl methacrylate (PMMA) into lithium based grease.

The effect of solid contaminants on the wear process of the equipments of a cement factory was experimentally quantified, [2]. Several contaminants were collected from different areas in the cement factory. HDPE, LDPE, MoS_2, Al Powder, PTFE, and PMMA were used as lubricant additives in paraffin oil to reduce the effect of the solid contaminants.

A mechanism of action of the polymeric particles dispersed in grease was proposed, [3, 4]. The mechanism depends on the ability of polymeric particles to adhere into the sliding surfaces by the help of the electric static charge generated on their surfaces as a result of the friction with each other and the steel surfaces. Adhesion force depends on the deformed surface area of the polymeric particles which increases with soft polymers. As for hard polymers, their particles roll on the sliding surfaces protecting them from excessive wear. Intensive care should be considered in selecting the solid lubricants suitable for dispersing greases. Electrical conductivity is one of the critical properties which influences the action of the solid lubricants.

Rolling contact wear is a particular type of wear that results from the repeated mechanical stressing of the surface of a loaded body rolling against another, [5 - 8]. Greases with different compositions will lead to lubricating films exhibiting different thicknesses, which will determine rolling contact wear performance. When studying the relation between grease composition and the lubricating film thickness, several authors concluded that when the contact is being lubricated under fully flooded conditions, an increase both on the base-oil viscosity and percentage of soap concentration results in a greater film thickness [9, 10].

The failure mechanisms of the machine elements in a contaminated environment can be divided into two cases. The first mechanism involves surface denting in terms of scratches or pits resulting from the abrasion action of particles in bearing gap. The second mechanism comprises fluid starvation due to the accumulation of debris particles in the inlet zone of the bearing gap, which may lead to scuffing, [11]. It was concluded that with a thin oil film small and medium size particles can cause surface denting, while large particles can lead to agglomeration, fluid starvation and scuffing, [12]. The influence of debris particles on the mechanism of surface dent formation in bearings was investigated, [13, 14]. If the particle size is larger than the film thickness of the lubricant, the particle causes a high local Hertzian pressure when it travels through the contact zone. A grease lubricated rolling bearing typically operates in a starved lubrication regime with a film thickness of 35 – 70 % of the corresponding film thickness obtained

with an oil of the same type as the base oil of the grease. When analyzing the influence of solid contaminants in a thin lubricating film on the operation of a grease lubricated bearing, the differences in the rheological properties of lubricating greases and oils, respectively, must be seriously taken into consideration.

The greases can be contaminated from some contaminants which may be built into the system because of inadequate cleaning of the component parts or because of faulty assembly. Contaminants may be picked up when adding fresh grease to the sliding surfaces, and during the installation of spare parts, where traces of casting sand and machining swarf are usually present in new machine elements in spite of the care devoted by manufacturers to excluding them, [15]. Contaminants may be generated at sliding surfaces of bearings, where metallic wear debris is constantly being added to the abrasive content of the grease. Greases in storage containers may have become contaminated during processing and filling. The major part of abrasive material in the grease is the sand.

Little attention was considered for the effect of sand particles on lubricating greases, [16]. The usual method of increasing the load carrying capacity of a journal bearing operating under boundary or mixed lubricating condition is to use a lubricant containing extreme pressure (EP) additives. Tests have been carried out to study the wear of journal bearing lubricated by polytetrafluoroethylene (PTFE) additive dispersing grease. The results show that the wear of the bearing lubricated by such a grease is initially greater than that of the bearing lubricated by grease with PTFE.

In the present work, wear resistance of cylindrical steel specimens was examined using a cross pin wear tester. Experiments were carried out using clean and contaminated lubricating greases. The contaminants in the cement industry such were added to the grease at a concentration of 10 wt. %.

EXPERIMENTAL

Experiments were carried out using a cross pin wear tester, Fig. 1. It consists, mainly, of a rotating pin and stationary one of 14 mm diameter and 120 mm long. The materials of the pins are alloy steel of 746 MPa ultimate tensile strength and 1540 MPa Vickers hardness. The stationary pin was fixed to the loading block where the load was 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 frictional 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. Wear tests were carried out at 0.36 m/s sliding velocity and 10 N normal loads for 5 minutes. Prior to and after each test, the tested pins were cleaned with solvent and dried in air. At the beginning of the test the contact area was greased then regreasing was applied every 30 seconds. Wear scar diameter of the

stationary pin, as a measure of wear, was determined using optical microscope at the end of the experiments.

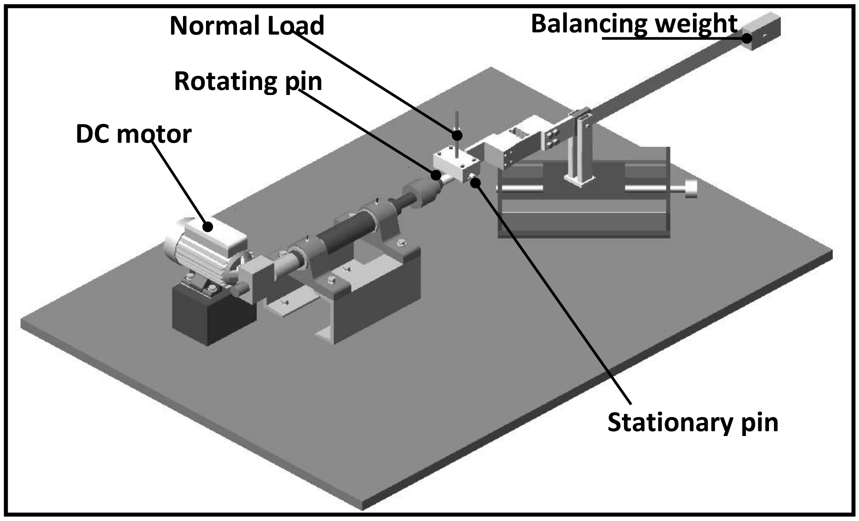

Fig. 1 Arrangement of the test rig.

RESULTS AND DISCUSSION

Wear of the test specimens measured by the value of wear scar width is shown in Figs. 2 – 9. Wear scar width caused by clean grease is shown in Fig. 2. Grease free of polymers displayed the highest wear, while grease dispersed by PTFE showed the lowest wear followed by HDPE, LDPE and PMMA. Grease contaminated by sand clay showed relatively higher wear than clean grease, Fig. 3. This behaviour may be attributed to the abrasive action of the sand particles which abraded the sliding surfaces and caused an excessive wear rate. The best performance was displayed by PTFE and HDPE. The friction of the polymeric particles against the steel surfaces produces electric static charge on both the surfaces of polymers and steel. The sign and amount of the charge depends on the location of the polymeric materials and steel in the triboelectric series. 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 one. 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 adherence of polymeric particles in the surface of sand particles decreased the ability of sand to abrade the sliding surfaces and consequently decreased friction and wear.

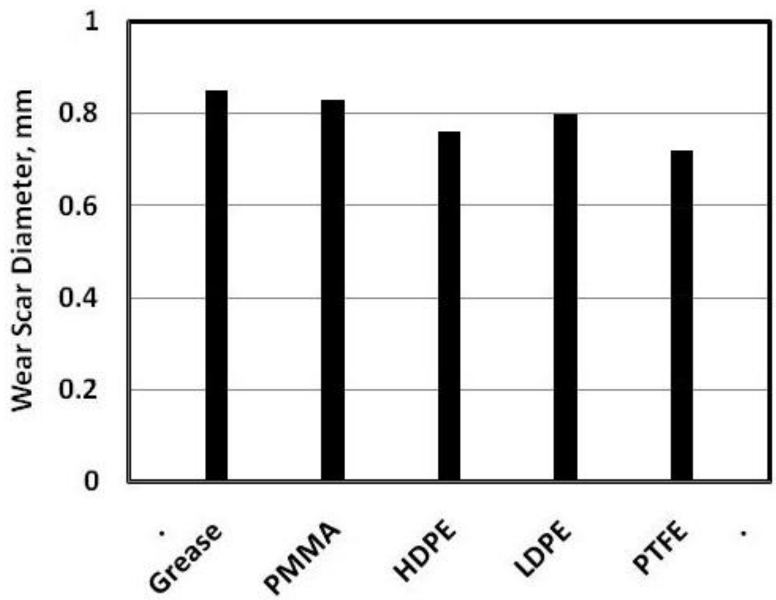

Fig. 2 Wear scar width caused by clean grease.

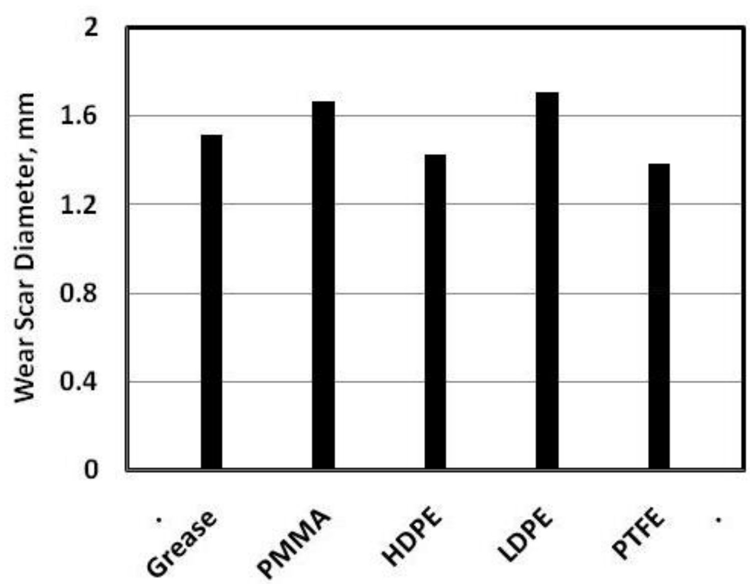

Fig. 3 Wear scar width caused by grease contaminated by sand clay.

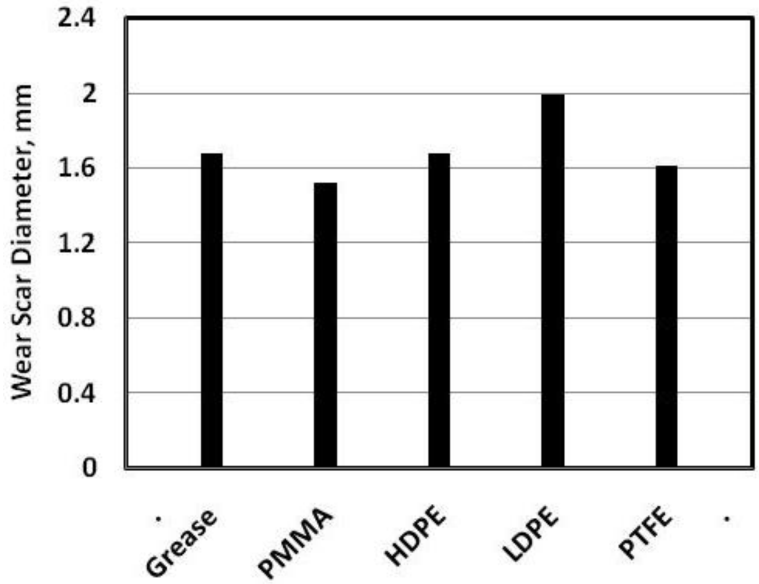

Fig. 4 Wear scar width of caused by grease contaminated by air cooled slag (high ferric particles).

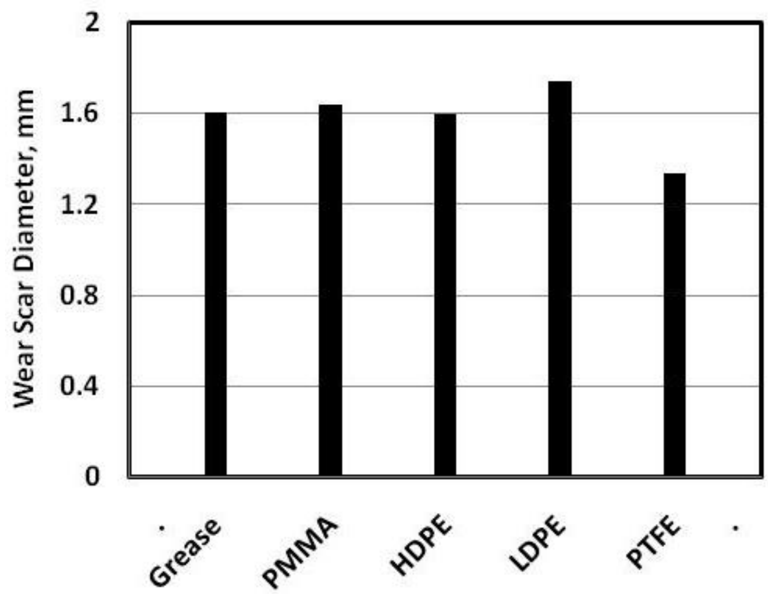

Fig. 5 Wear scar width caused by grease contaminated by air cooled slag (low ferric particles).

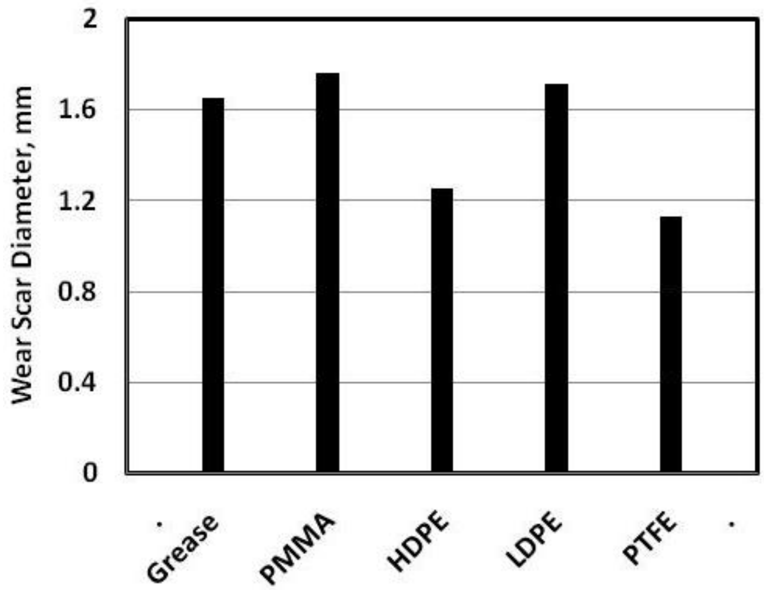

Fig. 6 Wear scar width caused by grease contaminated by iron ore.

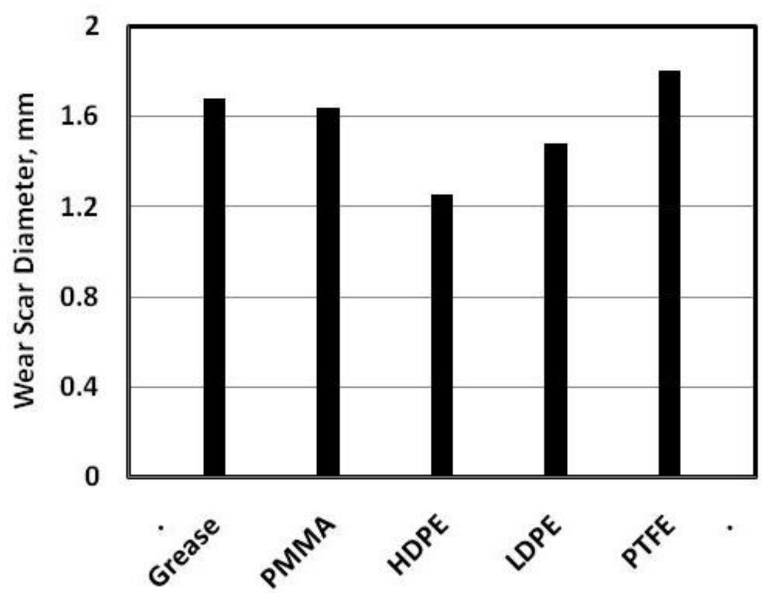

Fig. 7 Wear scar width caused by grease contaminated by limestone.

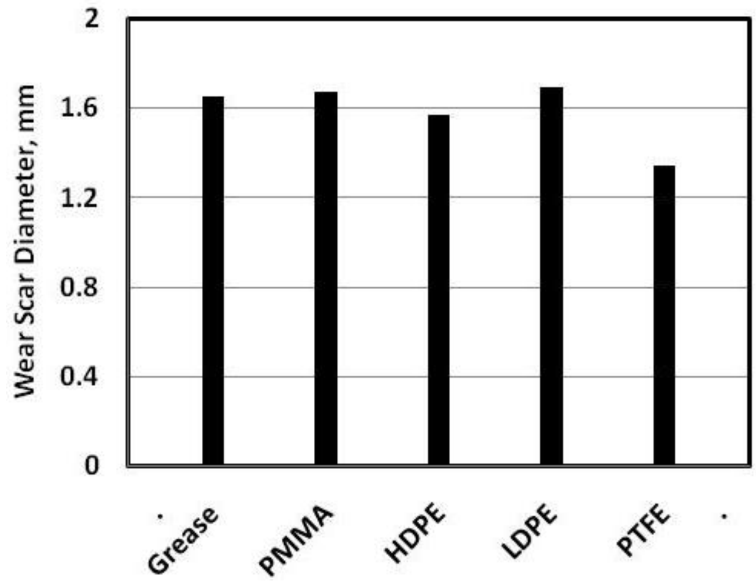

Fig. 8 Wear scar width of test specimens caused by grease contaminated by fatty clay.

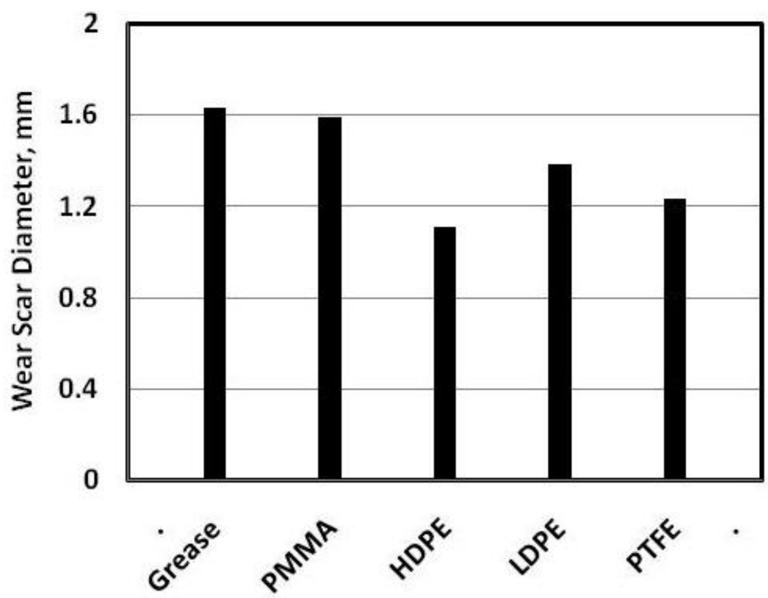

Fig. 9 Wear scar width caused by grease contaminated by water cooled slag (medium ferric particles).

High ferric particles contaminating grease displayed higher wear than sand clay, Fig. 4. The best wear resistance was observed for PMMA. It seems that the positive charge gained by PMMA particles as well as the rolling motion were responsible for that performance. LDPE displayed the highest wear value. Low ferric particles showed higher wear than high ferric particles, Fig. 5, where PTFE experienced the lowest wear.

PTFE and HDPE decreased wear displayed by the grease that was contaminated by iron ore, Fig. 6. Wear reduction might be attributed to the relatively strong adhesion of PTFE and HDPE particles into the surfaces of steel and iron ore. As for limestone, HDPE gave the best wear resistance, Fig. 7. Wear scar width of test specimens caused by grease contaminated by fatty clay is shown in Fig. 8. PTFE showed the best wear resistance. HDPE displayed the minimum wear caused by grease contaminated by water cooled slag (medium ferric particles), Fig. 9, followed by PTFE and LDPE.

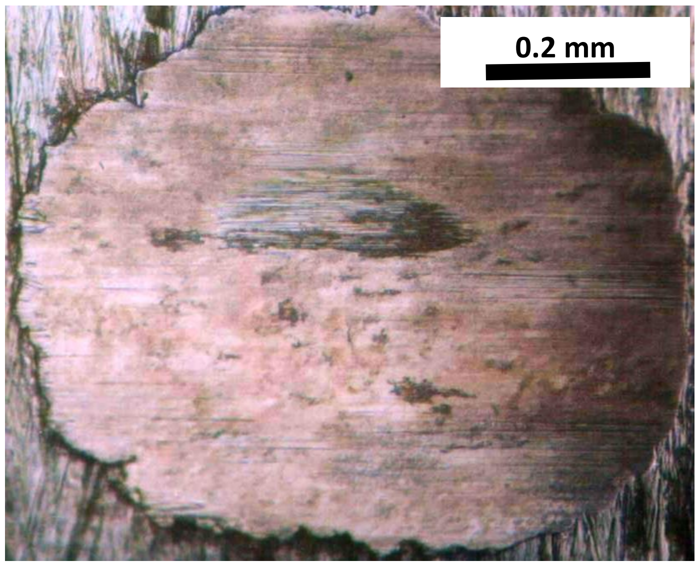

Fig. 10 Photomicrograph of the wear scar diameter caused by grease free of contaminants.

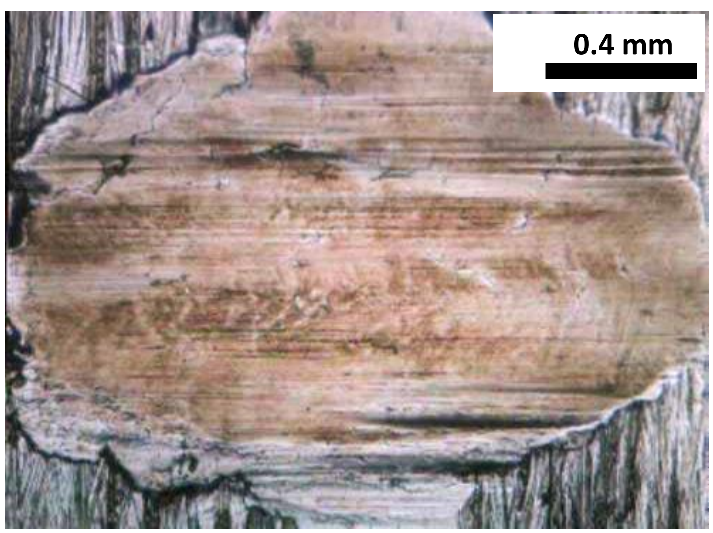

Fig. 11 Photomicrograph of the wear scar diameter caused by grease contaminated by sand clay.

The evidence of the wear on the surface of the stationary pin is shown in Fig. 10 and 11 for grease free of contaminants and grease contaminated by sand clay respectively. The abrasive wear tracks are clearly illustrated as the action of the particles of sand clay when abrading the steel surface.

CONCLUSIONS

The improvement in the wear resistance displayed by grease contaminated by the contaminants of the cement industry and dispersed by the tested polymeric powders can be explained on the basis that polymeric particles adhered into the sliding surfaces by the help of the electric static charge generated on their surfaces as a result of the friction with the steel surface. Adhesion of polymeric powders protected the sliding steel surfaces from excessive wear. Soft polymers such as PTFE, LDPE and HDPE were easily deformed on the contact area and consequently area covered by polymeric layer increased.

REFERENCES

1. 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. 3, July 2010, pp. 39 – 49, (2010).

2. El-Sheikh A., Khashaba M. I., Ali W. Y., "Reducing the Mechanical Wear in a Dusty Environment (Cement Factory)", MS11Cairo Conference to be held at the AMSE and the University of Sadat Academy, March 22-25, 2011, Cairo, Egypt, (2011).

3. Hasouna A. T., Samy A. M., Ali W. Y., "Influence of Solid Lubricants on Reducing Friction and Wear Caused by Sand Contaminating Greases", MEATIP5 Conference, Assiut University, Assiut, Egypt, 29 – 31 March 2011, (2011).

4. Khashaba M. I., Youssef M. M., Ali W. Y., "Mechanism of Action of Lubricating Greases Dispersed by Polymeric Powders, Graphite and Molybdenum Disulphide", MEATIP5 Conference, Assiut University, Assiut, Egypt, 29 – 31 March 2011, (2011).

5. Mota V., and 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", Lubr Sci 19, pp. 183 – 196, (2007).

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

8. Cann P. M., Webster M. N., Doner J. P., Wikstrom V., and 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., and Roberti R., "The competitive role of wear and RCF in a rail steel", Eng Fract Mech,72, pp. 287 – 308, (2005).

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

12. Nikas G. K., Sayles R. S., and Ioannides E., "Effects of debris particles in sliding/rolling elastohydrodynamic contacts", in: Proceedings of the Institution of Mechanical Engineers, 212 (J5), pp. 333 – 343, (1998).
13. Sayles R. S., Ioannides E., "Debris damage in rolling bearings and its effects on fatigue life", Transactions of the ASME, Journal of Tribology, 110 (1), pp. 26 – 31, (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., 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 to September 2, (1993), Lubrication Science 8-4, July 1996, pp. 359 – 368, (1996).