Reducing the Mechanical Wear in a Dusty Environment (Cement Factory)

A. M. Sheikh*, M. I. Khashaba and W. Y. Ali**[1]**

* Engineering Material and Mechanical. Design Dept. Faculty of Engineering- Qena, South Valley University, Qena, Egypt 83511 (fax: +20 965 211 279)
**Production Engineering and Design Dept. Faculty of Engineering, Minia University, Minia, Egypt
[1]Current Address: Faculty of Engineering, Taif University, Taif, Saudi Arabia
ahmad.elsheikh@hotmail.com

Abstract

The solid particle contamination is a challenge for the cement industries due to the highly dusty environment. The contaminants cause severe wear between 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. In this study, the effect of solid contaminants on the wear process for a cement factory was experimentally quantified. 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.

Key words: (Lubrication, solid particle contaminants, three body friction)

1. Introduction

Condition monitoring and maintenance are two essential components of modern industry. The purpose of condition monitoring is to detect faults occurring in machinery; maintenance is to maintain and extend, if possible, the lifetime of the machinery. In addition to detecting and distinguishing faults, the key purpose of machine condition monitoring using wear debris analysis techniques is to fully understand wear mechanisms, to effectively assess the real wear stage of machinery, and to develop strategies to eliminate or decrease wear. When a machine is in operation, wear particles generated by the interaction of two moving surfaces or carried in from outside may cause abrasive wear if these particles have a relatively high hardness. Abrasive wear of engineering machine components caused by the abrasive particles is a major industrial problem, especially for mining and port machines. The significance of abrasive wear has received considerable attention over the last decades [4 - 7]. Wear caused by the presence of abrasive particles is influenced by their size, concentration, shape, hardness, and sliding velocity, [1, 5 - 7]. Many researchers have studied the effect of particle size in abrasive wear. It was revealed that, in a two-body abrasive system, the wear rate increases with increase of particle size up to a critical size (around 100 lm), and above this value, the particle size effect in wear rates become almost negligible, [8].

It was reported that friction rises alongwith and also conducted, [12 – 14]. Two types of contaminants corresponding to relatively soft particles (Titania) and hard quartz particles in two series of tests, were studied, [15]. The results have shown that the small Titania particles have been found to reduce wear in hybrid rolling bearings and increase the polishing wear effect of particle concentration as well as particle quantity was or particle size, [9 - 11]Studies on the in all-steel bearings. The large quartz particles in the grease reduce wear of the silicon nitride balls in hybrid bearings, but cause severe wear of all components in all steel bearings. Graphite, ZnO powder and MoS_2 powder have been proved to be good solid lubricants by many researchers, [4]. The common contaminants in the mining, mineral processing, and shipping industries are environmental dust (mainly silica) and metal compounds such as iron, copper, and nickel. 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. It was found that the vast majority of airborne in the Eastern Province are concentrated in the smaller sizes. 95% of all particles are below 20 μm and 50% of all particles are below 1.5 μm in size, [16]. Contaminants in the lubricating oils and greases are considered as one of the major reasons for machine elements failure, [17]. Solid contaminants can be classified into three groups. The first is the external contaminants that enter the lubricating oils and greases through air, fuel and fresh oil as well as fresh grease. The second is the contaminants generated due to friction and wear of the rubbing surfaces while the third item covers the contaminants introduced during manufacturing and assembly of different elements of the machine. The majority of previous studies the increase in particle concentration focused on the influence of the sand particles contaminated in the lubricating oils on the friction and wear of engineering surfaces. The effect of the liquid and solid contaminants on the friction and wear of the moving surfaces of internal combustion engines, were discussed, [18]. The test results showed that friction coefficient caused by oil contaminated by sand showed maximum values for sand particles of 5 – 10 and 15 – 20 μm, while wear increased significantly with increasing particle size. Iron oxide, as lubricant contaminant, showed the highest values of friction and wear followed by carbon black and copper. Wear is one of the surface damage that involves a progressive loss of material and affects the life time of machine elements such as gears and rolling element bearings. 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, [19 - 22]. 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 [23, 24]. Experimental tests for the tested greases and correspondent base oils were carried out on a twin disc machine under pure rolling conditions, where base oil viscosity; percentage of soap concentration and the presence of additives were varied. In the present work, the effect of the addition of HDPE, LDPE, MoS2, Al, PTFE, and PMMA used as lubricant additives into the paraffin oil on wear caused by solid contaminants such as 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 was studied.

2. Scope and Limitations

This work aims to quantify the effect of solid contaminants getting into the lubricant from the polluted and dusty ambient. The cement factory is a case study in this work as the environment in such factories is extremely polluted and dusty because of the cement manufacturing plant. The raw materials for cement (sand clay, iron ore and lime stone), are the main reason for dust. Additionally, this work aims to determine the most suitable lubricant additives that can reduce the contamination effects on wear rates of mechanical parts. This work was limited according to the time loose to carry out the experiment.

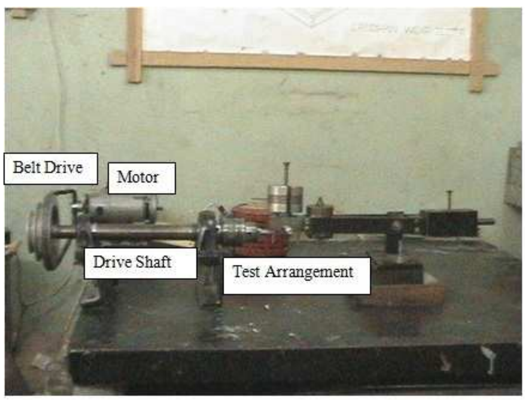

Fig. 1 Cross pin wear tester

As every oil specimen should be experimented 3 times and the apparatus setup was quite simple, so one experiment can take at least 15 minutes.

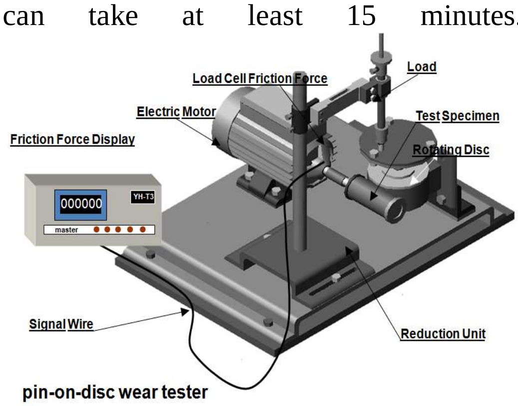

Fig. 2 Pin on disc tribometer

The used test rig is called cross pin wear tester shown in fig.1. It was not available to use the pin on disc tribometer shown in fig. 2 as it was not available a good setup to run lubricated friction test

3. Experimental Work

This section discusses the methodology of carrying out the experiments and measuring the Wear Scar Diameter (WSD). Laboratory investigation of wear rate is carried out to examine which type of the contaminants caused the highest wear rate. Also to identify the additive type that highly reduced wear.

Experiments were carried out using a cross pin wear tester, Fig. 1. It consists, mainly, of rotating and stationary pins of 100 mm long and 15 mm diameter.

Fig. 3 Stainless Steel Specimen.

The material of the pins is stainless steel (St. 304 of 1000 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.

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. The oil used in the experiments was paraffin oil (SAE 30). The concentration of contaminants was 1.0 %, while the concentration of the additives used is (10wt. %).

The grain sizes for all contaminants were less than 90 µm. The used load for all experiments was constant (10 N). The test arrangement is shown in Fig. 4, where oil was introduced into the contact area between the two surfaces periodically at the beginning of the experiment and after each minute to ensure that the two surfaces are separated by a fluid film. The measurement of wear scar diameter (WSD) was carried out using Large Tool Maker's Microscope. The accuracy of this device is 0.001µm.

Contaminant	***Name***
A	***Air cooled slag with low ferric particles***
B	***Fatty clay***
C	***Sandy clay***
D	***Water cooled slag with medium ferric particles***
E	***Lime stone***
F	***Iron ore***
G	***Air cooled slag with high ferric particles***
H	***Pure oil with no contaminants***

Table (1) Types of Contaminants

- *The oil +High Density Polyethylene for each type of contaminants and clean oil.*
- *The oil + low density Polyethylene (LDPE) for each type of contaminant and clean oil.*
- *The oil + Poly Methyl Mehta Acrylate (PMMA) for each type of contaminants and clean oil.*
- *The oil + Aluminum Powder for each type of contaminants and clean oil.*
- *The oil + Poly Tetra Floroehtylene (PTFE) for each type of contaminants and clean oil.*
- *The oil + Molybdenum Disulphide (Mo S_2).*

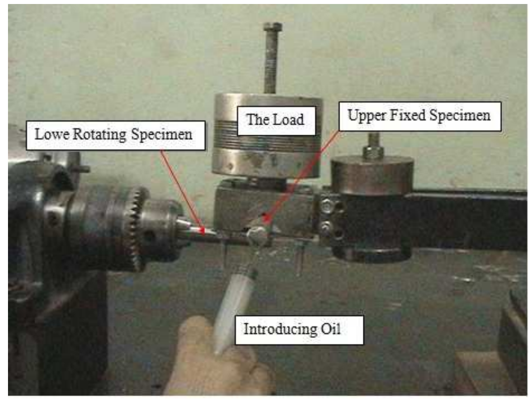

Fig. 4 The test arrangement

Experiments were conducted as following: Clean oil without additives for each type of contaminants was tested, while clean oil without both additives and contaminants was tested as a base of comparison.

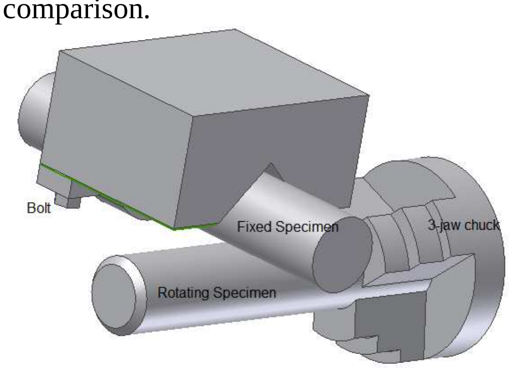

Fig.5 Test setup (3-D)

1. Results and Discussion

This section discusses the results of the Wear Scar Diameter (WSD). The contaminants used in the experiments are shown in table (1). Fig. 6 shows the wear scar geometry, ellipse resulting after the experiments.

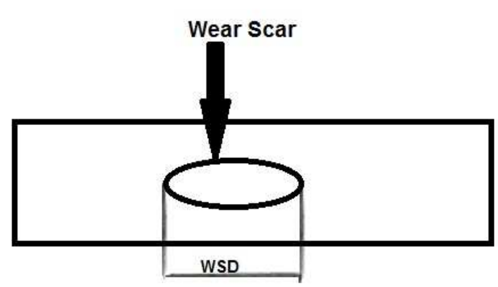

Fig.6 Wear Scar Diameter

3.1 Clean Oil without additives

It is clear from Fig. 7 that the contaminant A (air cooled slag with low ferric particles) shows the highest wear, while C (sandy clay) shows the lowest one.

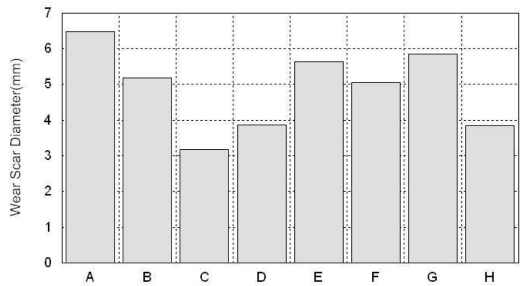

Fig. 7 Wear displayed by oil without additives

3.2 Oil + HDPE

Figure 6 shows the results obtained from experiments carried out using high density polyethylene (HDPE). It is clear that the most dangerous contaminant is C (sandy clay). The effect of this contaminant increased. The least dangerous contaminant is E (lime stone). Wear caused by contaminant B (fatty clay) decreases by adding HDPE. For contaminant D (water cooled slag with medium ferric particles), the situation that addition of HDPE is not recommended. For contaminant F (iron ore), adding HDPE is recommended. Nearly the WSD is reduced from 5 to 3.8 mm. For contaminant G (air cooled slag with high ferric particles), the addition of HDPE is also recommended in case of clean oil.

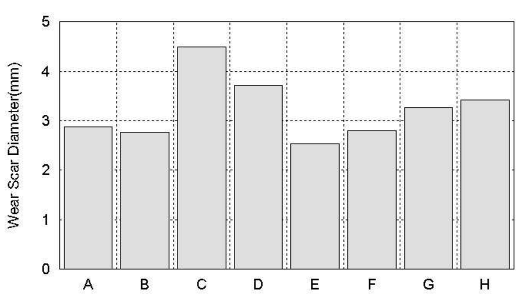

Fig.8 Wear displayed by oil dispesed by HDPE

3.3 Oil + PMMA

Fig.9 shows the results obtained from experiments using oil dispersed by Polymethylmethacrylate PMMA, where WSD is reduced by adding PMMA. Also for contaminants A and B the WSD is reduced. It is not recommended to add PMMA in case of contaminants C and D because WSD increases by adding PMMA. The situation for contaminants E, F and G is like contaminants A and B. It can be said that adding PMMA is recommended for all cases of oil contamination in cement factories.

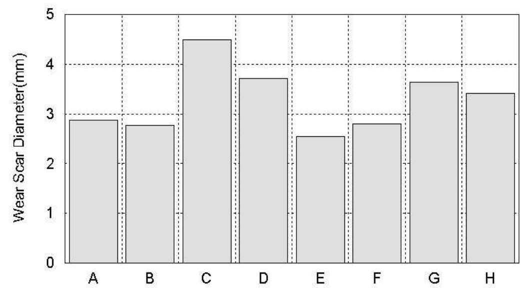

Fig.9 Wear displayed by oil dispersed with PMMA

3.4 Oil + LDPE

Fig.10 shows the results obtained from experiments in condition of adding Low density polyethylene LDPE into the oil. LDPE is recommended for contaminated oil. For contaminant A (air cooled slag with low ferric particles), B (fatty clay), C (sandy clay) and D (water cooled slag with medium ferric particles) it is recommended to add LDPE.

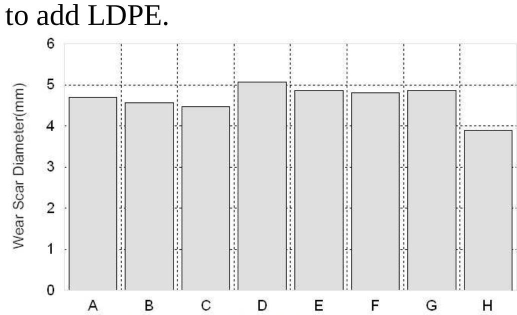

Fig.10 Wear displayed by oil dispersed with LDPE

Generally, adding LDPE does not affect wear caused by contaminants E (lime stone), F (iron ore) and G (air cooled slag with high ferric particles).

3.5 Oil + PTFE

PTFE Coatings are specialized Dry Film Lubricant Coatings. PTFE coatings provide engineering solutions where non-stick (release), low friction, chemical resistance and wear resistance are important concerns.

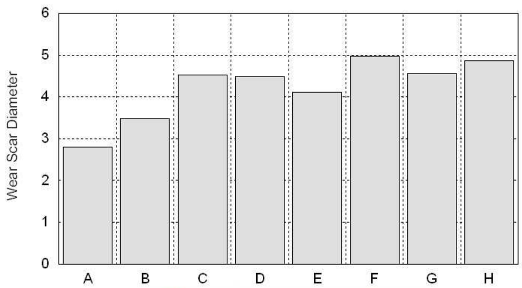

Fig. 11Wear displayed by oil disperesed with PTFE

Comparing the results shown in Fig 11 and 7, it is found in condition of clean oil that adding PTFE increases the wear rate although PTFE and MoS_2 may be considered as solid lubricants.

3.6 Oil + Aluminum Powder

Addition of Al powder increases Wear Scar Diameter (WSD) according to Fig.12

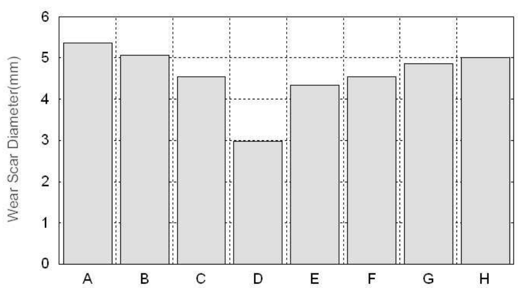

Fig. 12Wear diplayed with oil dispersed with AL powder

This occurred for clean oil, while effect of Al on oil contaminated by A (air cooled slag with low ferric particles), B (fatty clay), C (sandy clay), E (lime stone), F (iron ore) and G (air cooled slag with high ferric particles) is insignificant.

3.7 Oil + MoS_2

Fig. 13, it is obvious that clean oil dispersed with Molybdenum Disulphide MoS_2 shows an increase of WSD.

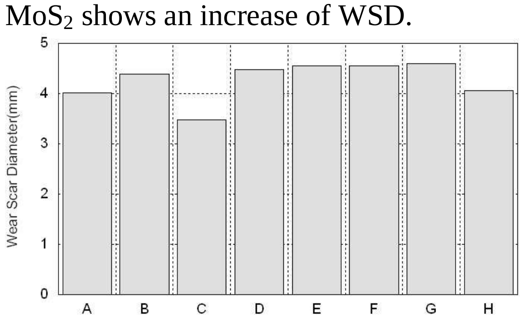

Fig. 13 Wear displayed by oil dispersed with MoS2

Also it is seen that for contaminants A (air cooled slag with low ferric particles), B (fatty clay) and C (sandy clay) WSD shows insignificant change for oil dispersed by MoS_2. For contaminants D (water cooled slag with medium ferric particles), E (lime stone), F (iron ore), G (air cooled slag with high ferric particles) wear significantly increases.

CONCLUSION

Based on the results obtained from this work, Wear Scar Diameter decreases in presence of Paraffin oil for all contaminants except contaminant C (sandy clay). It is recommended to add HDPE as additive for reducing the wear rate for all contaminants A (air cooled slag with low ferric particles, B (fatty clay), E (lime stone), F (iron ore) and G (air cooled slag with high ferric particles). PMMA has the same performance like HDPE. It is recommended to add PMMA to the lubricant in presence of contaminants A, B, E, F and G. Adding PTFE and Al is not very effective in reducing the wear rate. Addition of MoS_2 should be avoided.

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