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EFFECT OF TALC AS SOLID LUBRICANT DISPERSING LITHIUM GREASE IN REDUCING FRICTION COEFFICIENT AND WEAR IN DUSTY ENVIRONMENT

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ABSTRACT
In cement factories abrasive contaminants cause severe wear of moving surfaces leading to rapid failure of the machine elements. In the present study, talc used as solid lubricants dispersed in lithium grease. The effect of main components of white cement such as sand, kaolin 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 both of friction coefficient and wear.

Based on the experimental results it was found that lithium grease should be dispersed by 30 wt. % oil to balance the contaminants and get the lowest friction and wear values. As the oil content, added to the grease, increased friction coefficient and wear slightly decreased. Besides, sand displayed the highest friction and wear values followed by kaolin, while limestone showed the lowest friction and wear. Friction coefficient generated from the action of the mixture showed relatively higher values than limestone and lower values than sand and kaolin. Friction coefficient and wear slightly decreased with increasing talc content.

INTRODUCTION
The solid particle contamination is the main cause of rapid failure of the mechanical equipments in cement industries due to the highly dusty environment, [1]. 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, MoS_2, 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 polymethyl methacrylate (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, [2]. 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, polytetrafluoroethene, 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 SiO_2 sheets, [3 – 5]. 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, [6, 7]. 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, [8, 9], due to the possible synergism with other influences. Lubrication is critical for minimizing wear in mechanical systems, [10], 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, [11]. 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, [12]. 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, [13]. Poly (methyl methacrylate) or 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. PMMA, [14 - 16], with another polymer that can provide a good mechanical property.

In the present work, talc is 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.

EXPERIMENTAL

Experiments were carried out using a cross pin wear tester, Fig. 1. It consists of rotating and stationary pins of 18 mm diameter and 180 mm long. 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).

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 is driven by DC motor (300 watt, 250 volt) through reduction unit. Moreover, motor speed is adjustable and can be controlled by varying the input voltage using an auto transformer. 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 is applied by weights. A digital screen is 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, while wear is determined by measuring the wear scar diameter by optical microscope.

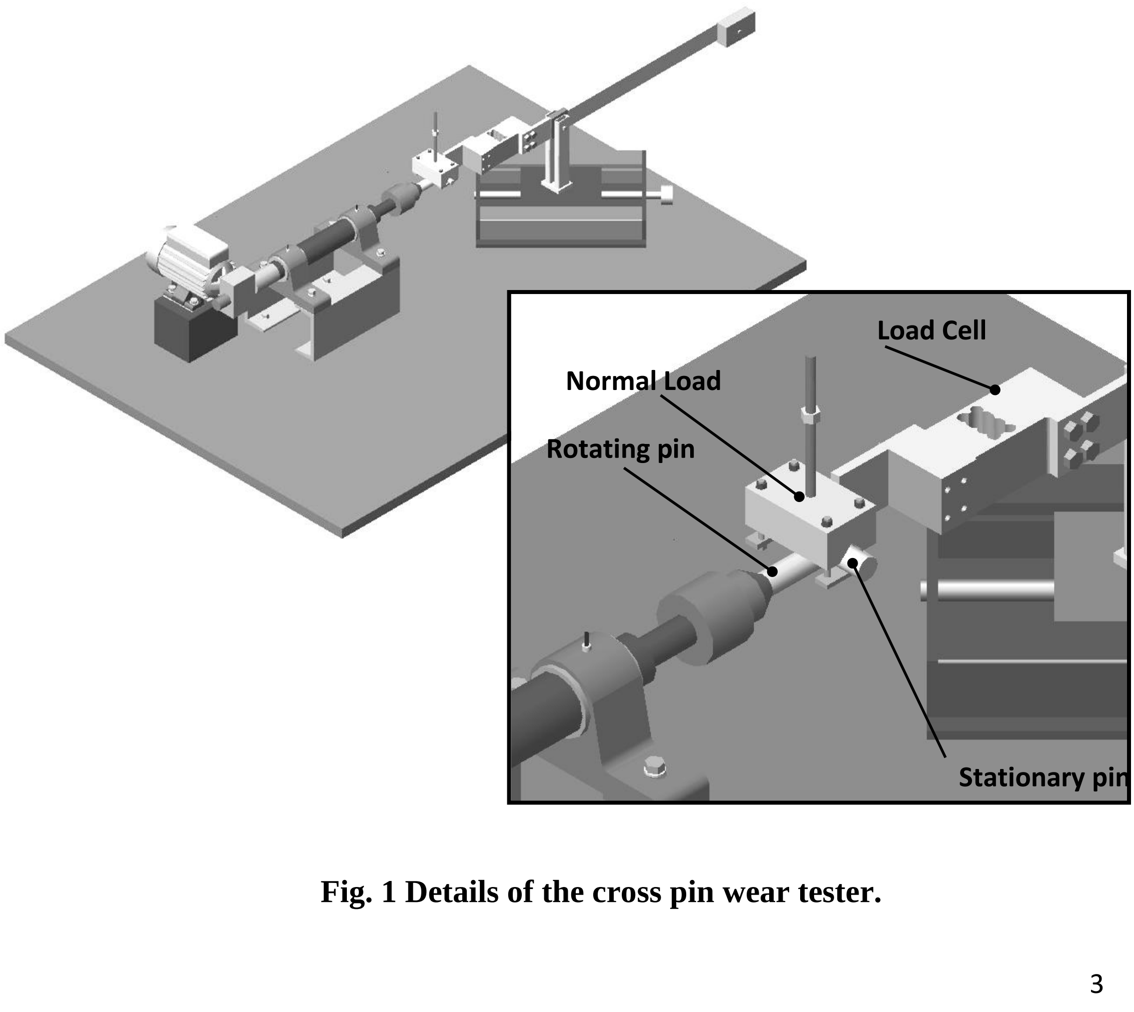
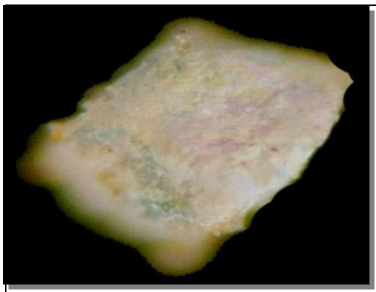
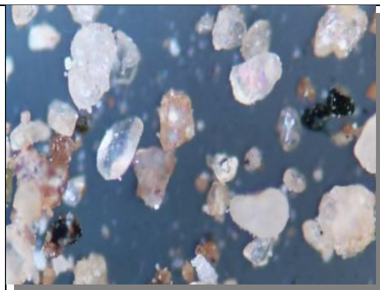
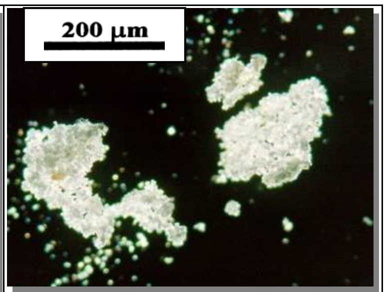


Fig. 1 Details of the cross pin wear tester.

Table 1 Solid contaminants used in the experiments.

		
Kaolin	**Sand**	**Limestone**

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 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 talc powder. The contaminant materials tested in the present work were kaolin, sand and limestone. Kaolinite is a clay mineral, part of the group of industrial minerals, with the chemical composition $Al_2Si_2O_5(OH)_4$. Rocks that are rich in kaolinite are known as kaolin or china clay. Limestone is a form of calcium carbonate ($CaCO_3$). Sand is silica (silicon dioxide, or SiO_2). Those contaminants are the main components of white cement, Table 1. A blend of the contaminants materials (80 wt. % sand, 12 wt. % limestone and 8 wt. % kaolin to represent the white cement was tested; it is referred in the text as mixture. 12-Hydroxy stearic acid, lithium hydroxide and a naphthenic mineral lubricating oil (density at 20 °C: 916 kg/m^3; kinematic viscosity at 40 °C:115 mm^2/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, polyolesters, alklylated napthlenes and alkyklated benzenes.

RESULTS AND DISCUSSION

Addition of the tested contaminants into the grease was balanced by adding oil into the grease in three percentage contents, 10, 20 and 30 wt. %. The effect of oil added into the grease on friction coefficient is shown in Fig. 2. As the oil content increased friction coefficient decreased. Sand displayed the highest friction values followed by kaolin, while limestone showed the friction. Based on the results shown in Fig. 2, it can concluded that the grease should be diluted by 30 wt. % oil to get the lowest friction valued.

Effect of oil content in grease on wear of the test specimens is shown in Fig. 3. Wear values slightly decreased with increasing oil content. The same trend observed for friction was shown for wear. Sand particles represented the highest wear, while limestone caused the lowest wear. The oil content of 30 wt. % showed the lowest wear. Referring to the hardness of the tested contaminants it can be seen that as the hardness of the contaminants increased wear increased. It seems that as the oil content added to the grease increased a semi fluid film was formed in the contact area leading to friction decrease. The film could also decrease the friction of abrasive particles against the sliding surfaces.

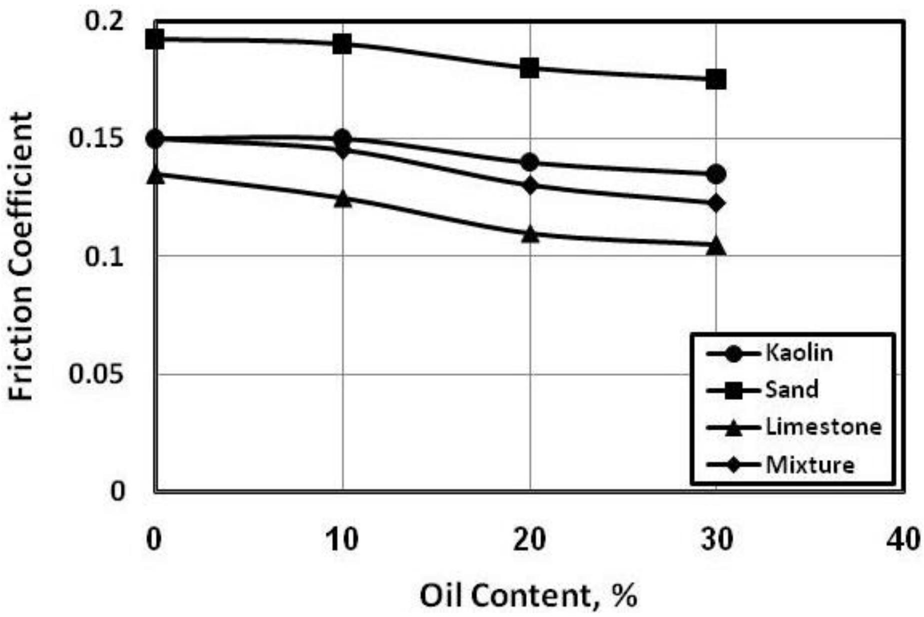


Fig. 2 Effect of oil content in grease on friction coefficient.

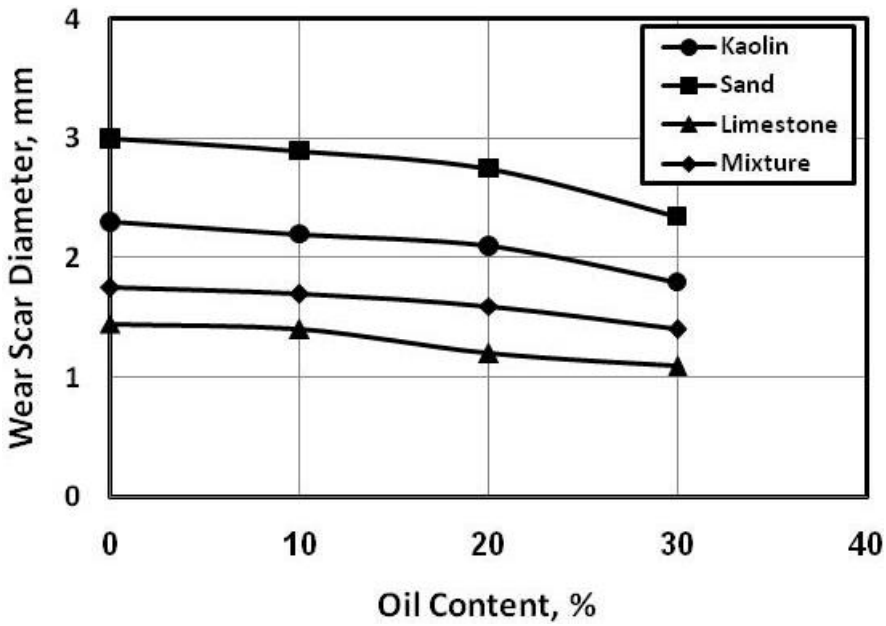


Fig. 3 Effect of oil content in grease on wear of the test specimens.

The followings are the friction coefficient and wear of the test specimens greased by lithium grease diluted by 30 wt. % oil. Figure 4 shows the effect of talc content in grease contaminated by kaolin on friction coefficient. Slight friction decrease was observed as talc content increased. This behaviour might be attributed to action of talc which were able to cover the sliding surfaces as well as the contaminants particles and consequently decreased the ability of contaminant particles to abrade the sliding surfaces.

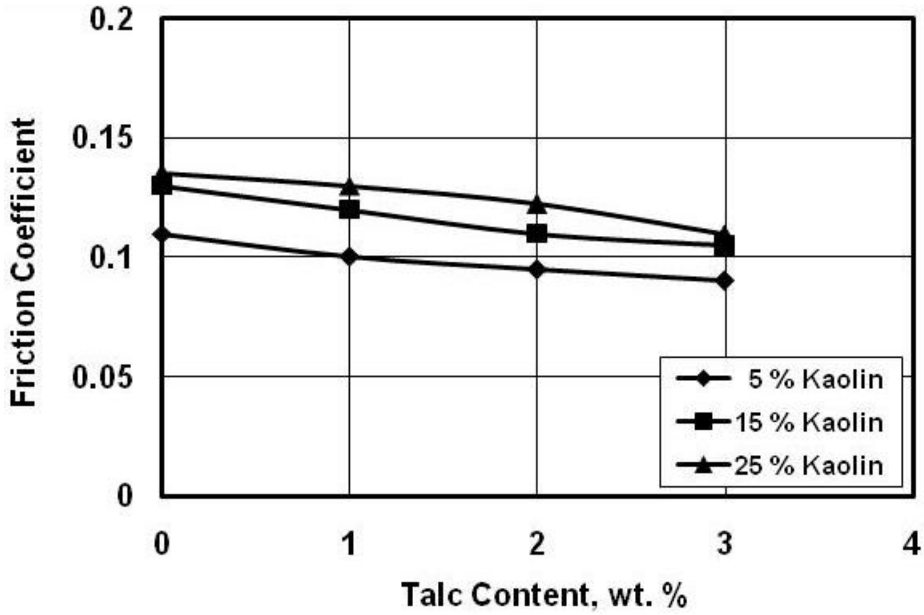


Fig. 4 Effect of talc content in grease contaminated by kaolin on friction coefficient.

Friction coefficient showed relatively higher values when the grease was contaminated by sand particles, Fig. 5, compared to that observed for grease contaminated by kaolin. As the sand content increased friction coefficient increased. Addition of talc displayed slight friction decrease. It seems that dispersing grease by talc did not give enough friction reduction required to withstand the abrasion action of sand particles.

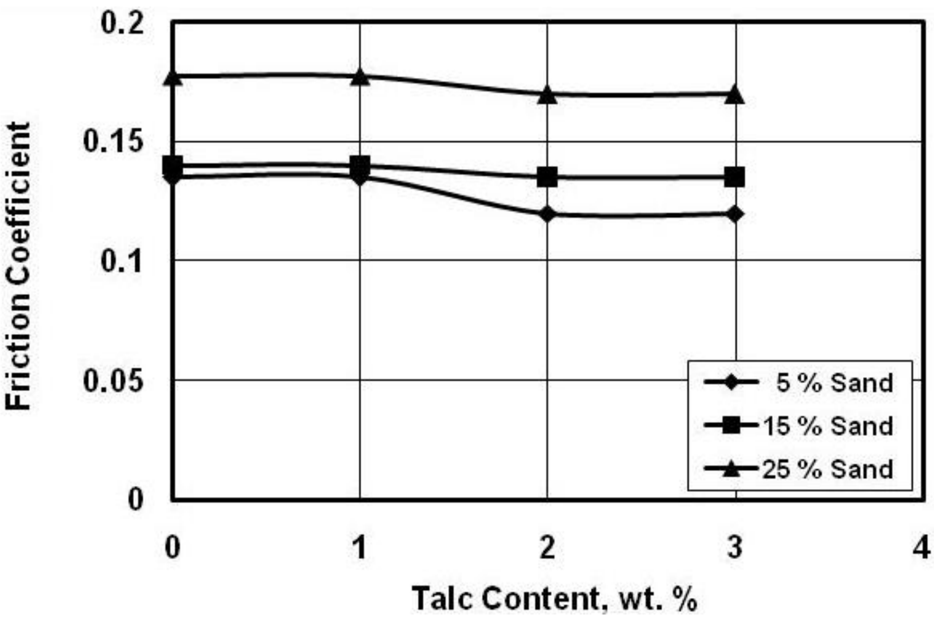


Fig. 5 Effect of talc content in grease contaminated by sand on friction coefficient.

Effect of talc content in grease contaminated by limestone on friction coefficient is shown on Fig. 6. Generally, values of friction coefficient were lower than that presented by sand and kaolin contaminants. Addition of tin showed insignificant friction change.

This behaviour could be attributed to relatively low value of the hardness of limestone, where the increase of limestone content did affect friction coefficient.

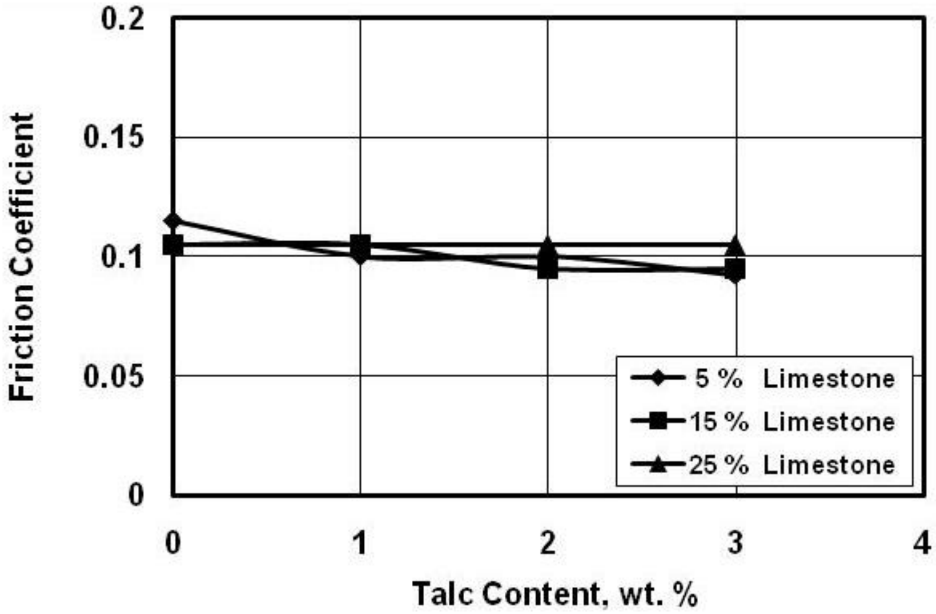


Fig. 6 Effect of talc content in grease contaminated by limestone on friction coefficient.

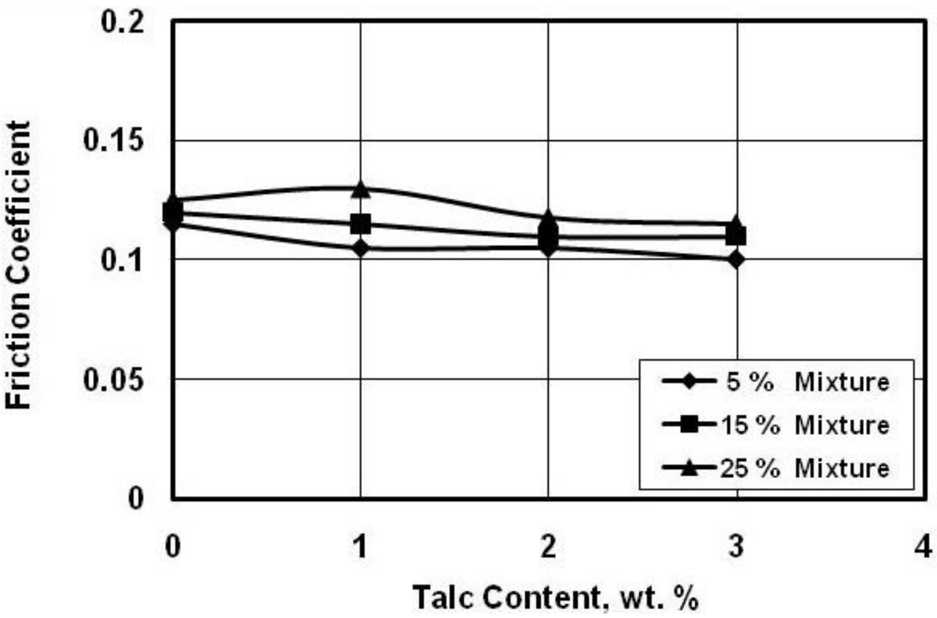


Fig. 7 Effect of talc content in grease contaminated by the mixture on friction coefficient.

Friction coefficient generated from the action of the mixture showed relatively higher values than limestone and lower values than sand and kaolin, Fig. 7. Friction coefficient slightly decreased with increasing talc content. The friction decrease may be explained on the basis that talc is consisted of a sheet of brucite or Mg $(OH)_2$ sandwiched between SiO_2 sheets. The easy separation of brucite sheets which are weakly bonded to each other is responsible for the lubricating effect of talc particles. The layers of the talc slide

apart with minimal force giving talc its inherent softness and lubricity. Presence of talc on the sliding surfaces as well abrasive particles like sand, kaolin and limestone could control the friction in the contact area.

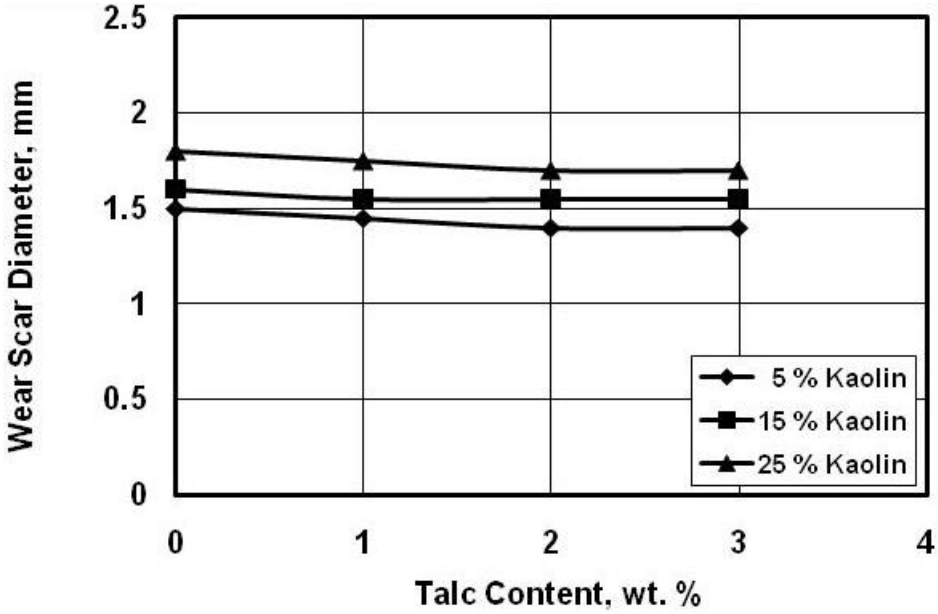


Fig. 8 Effect of talc content in grease contaminated by kaolin on wear.

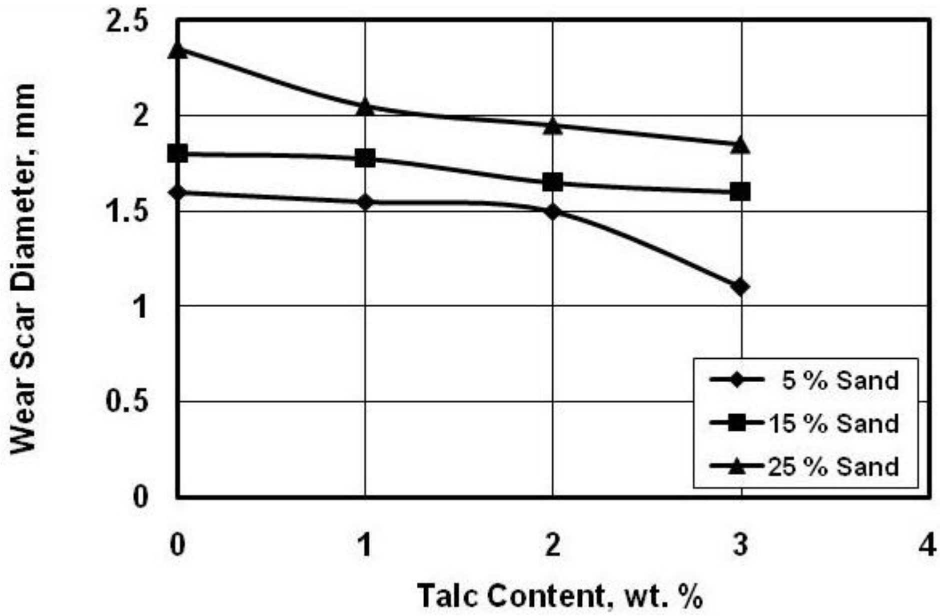


Fig. 9 Effect of talc content in grease contaminated by sand on wear.

Wear of the test specimens, in the presence of kaolin particles dispersing the lithium grease, measured in wear scar diameter is shown in Fig. 8. Wear slightly decreased with increasing kaolin content. As kaolin content increased wear increased. It is clearly shown that addition of talc did not affect wear, where the values of wear scar diameter

decreased from 1.8 mm for grease free of talc to 1.7 mm for grease dispersed by 3 wt. % talc at 25 wt. % kaolin content.

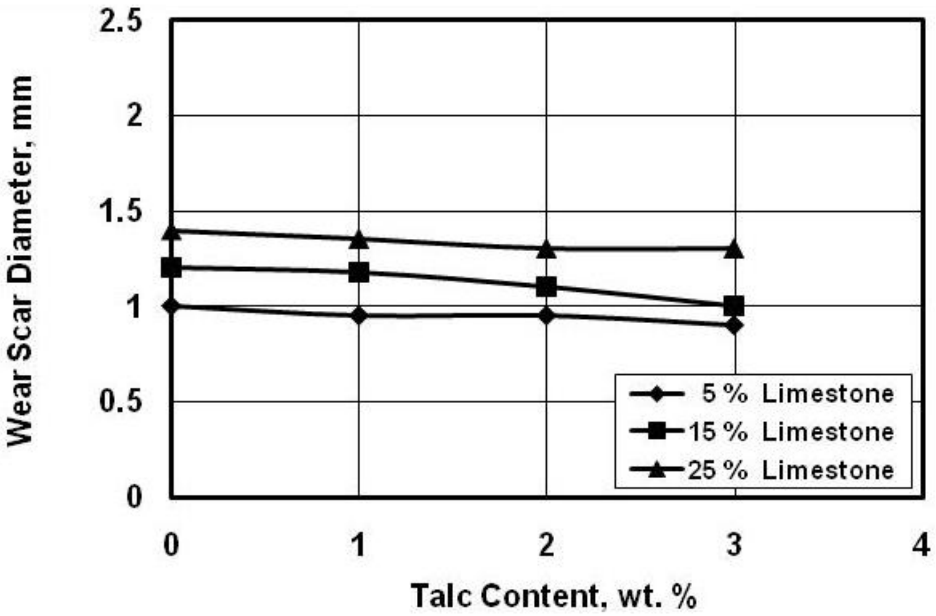


Fig. 10 Effect of talc content in grease contaminated by limestone on wear.

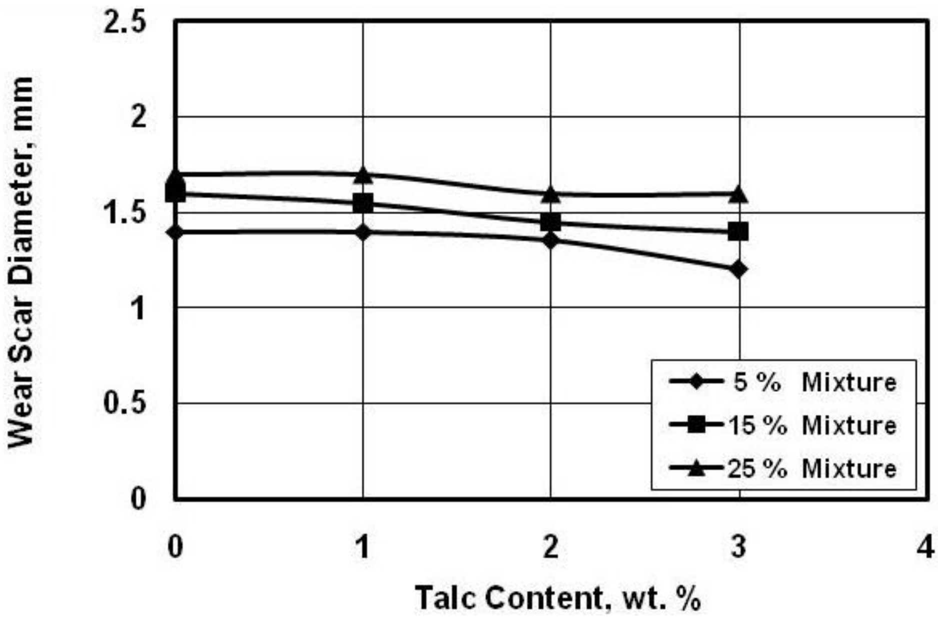


Fig. 11 Effect of talc content in grease contaminated by the mixture on wear.

Contaminating the grease by sand particles showed significant wear increase, Fig. 9. Wear scar diameter displayed by grease contaminated by sand particles of 5, 15 and 15 wt. % content was 1.65, 1.7 and 2.3 mm, while it was 1.5, 1.6 and 1.8 mm for grease contaminated by kaolin respectively. The effect of talc was more pronounced in the presence of sand particles. It seems that adherence of talc into the surfaces of sand particles was quite enough to lessen their ability to abrade the sliding surfaces. Besides, the presence of talc on the steel surfaces decreased friction coefficient and facilitated the

sand to slide more than to abrade. The action of talc to defeat abrasive wear increased with increasing talc content.

Effect of talc content in grease contaminated by limestone on wear is shown in Fig. 10. Limestone as contaminant showed the lowest wear values. Addition of talc displayed slight wear decrease. This behaviour could be attributed to the relatively low hardness of limestone. Based on the results of friction and wear displayed by grease dispersed by limestone it can be concluded that limestone showed insignificant abrasion action against sliding surfaces.

The same trend was observed for grease contaminated by the mixture, Fig. 11, where wear values were lower than that displayed in the presence of sand as well as kaolin particles and higher than that observed for limestone. Lubricants are supposed to help in the reduction of friction between abrasive particles and between the sliding surfaces. Talc is believed to form a coat around each particle of solid contaminants and this effect also gets extended to the sliding surface. Talc is alkaline in nature. The other main activities attributed to talc are prevention of sticking of abrasive particles to the sliding surfaces and anti-adherent.

CONCLUSIONS

1. The grease should be dispersed by 30 wt. % oil to get the lowest friction and wear values. As the oil content, added to the grease to balance the contaminants, increased friction coefficient and wear slightly decreased. Sand displayed the highest friction and wear values followed by kaolin, while limestone showed the lowest friction and wear.

2. Friction coefficient significantly increased with increasing contaminant content. Slight friction decrease was observed as talc content increased.

3. Friction coefficient generated from the action of the mixture showed relatively higher values than limestone and lower values than sand and kaolin.

4. Wear slightly decreased with increasing talc content. As the contaminants content increased wear increased. Contaminating the grease by sand particles showed significant wear increase. The effect of talc was more pronounced in the presence of sand particles.

5. Wear values were lower than that displayed in the presence of sand as well as kaolin particles and higher than that observed for limestone.

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