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EFFECT OF SOLID ADDITIVES ON THE TRIBOLOGICAL BEHAVIOR OF LUBRICATING OILS

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ABSTRACT

In lubricating oils, oil additives are among very important parameters because they significantly improve the performance of motor oils and other types of lubricants. In this paper, spherical calcium carbonate and graphite particles were added to two types of lubricating oils (Paraffin and PAO oils). A tribometer was used to examine the oil's frictional properties using a stainless-steel pin on disc. Based on the experimental results calcium carbonate showed good dispersity and uniform particle distribution. When the $CaCO_3$ addition is dispersed to PAO and paraffin oil, it performs well as a solid lubricant in reducing wear and friction on the steel specimens. The wear values were greatly enhanced when graphite particles were added to lubricating oils as a solid addition. Research results showed that the best concentration of the additives is 20 wt. %. As a result, the suggested coating approach lowers the steel specimens wear values and friction coefficient because the precipitated anti-wear serves as a barrier to lessen metallic contact.

KEYWORDS

Solid additives; lubricating oils; graphite; calcium carbonate; wear.

INTRODUCTION

Mechanical systems lose energy mostly due to friction and wear. Friction and wear of materials consume around 25 % of energy in industrial countries and contribute to 1.3 - 1.6 % of global GDP, [1]. Lubrication is a highly effective way to reduce friction and heat in mechanical systems, [2]. Liquid lubricants, [3], including mineral oil, synthetic oil, vegetable oil, and water-based compounds, have been tested for use in various mechanical systems. The ability to create a thin lubricating coating during friction or wear protects friction pairs and ensures mechanical stability, [4]. Thus, improving lubrication performance has primarily involved changing the lubricant oil, [5]. Engine oil tribological behavior and vibration (RMS) at various running temperatures and Al_2O_3 nanoparticle contents were investigated. It was discovered that adding nanoparticles improved the tribological characteristics of the currently available commercial engine oils (20W - 50), [6]. The performance of motor oils and other lubricants is significantly enhanced by oil additives, making them some of the

most significant items, [7]. Multiple materials can be used as anti-wear additives. Talc is a common material that can be used as a solid lubricant and anti-wear additive, [8]. The effect of solid lubricant additives such as graphite was discussed, [9]. The tested solid lubricants are dispersed throughout lubricating grease. Performance tests were carried out using tribometer testing apparatus. The anti-wear performance of hydraulic lubricants with zinc dialkyl dithiophosphates is discussed. The addition of the additive to hydraulic oil decreased the friction coefficient. Furthermore, the wear rate decreased as the additive amount increased, [10]. New environmentally friendly lubricating oil additives with superior anti-friction and anti-wear qualities are in development, [11]. Lubricant additives act as sacrificial materials to improve friction and wear resistance, [12].

Mechanical system performance depends on the combination of materials, tools, and lubricants, as well as surface coatings, contact pressure, speed, temperature, and other factors, [13]. Adding small but efficient additions to lubricating oil improves lubricant properties significantly, [14]. Many hydrocarbon fluids, [15], can be used as lubricants. However, industrial economics severely limits their useful range. Oil refineries are currently producing low-cost synthetic oils. Graphite is commonly utilized as a micro-scale powder lubricant in the industry, [16]. Lee et al., [17], investigated graphite as a lubricant addition for industrial gear oils.

EXPERIMENTAL

As seen in Fig. 1, experiments were conducted with a pin-on-disc wear tester. It is made up of a variable speed motor-driven rotating horizontal steel disc. The specimen holder attached to the loading lever holds the test specimen. Friction force is measured through two thin spring steel sheets, on which strain gauges are affixed. By using strain gauges to detect the friction force caused by the spring steel sheets deflection, the friction coefficient was found. Weights are used to apply the load. The test specimens were cylindrical pins with a diameter of 6 mm and a length of 30 mm. Using ultrasonic dispersion technology, the commercially supplied graphite and calcium carbonate "$CaCO_3$" particles (99.98 % purity with an average particle size of less than 50 µm) were suspended in acetone and sonicated for almost 6 hours to acquire the desired particle size. Following sonication, the additive particles were distributed at concentrations of 0, 5, 10, 15 and 20 weight percent using an ultrasonic homogenizer in two distinct lubricating oil types (PAO and paraffin oils). A load cell is installed on the test rig to measure the frictional force produced in the area where the stationary pins and rotating disc come into contact. Weights fastened to a loading lever applied a 10 N normal load while the rotational speed was 170 r.p.m. Prior to and throughout the test, lubrication was applied to the spinning specimens every 30 seconds. Each test lasted five, ten, or fifteen minutes. The carbon steel (St. 60) test specimens have the following compositions: 0.65 weight percent Mn, 0.65 weight percent C, 0.045 weight percent P, and 0.045 weight percent. Using an electronic scale with an accuracy of ± 1 mg, the specimens were weighed before and after the test to determine the amount of material lost during sliding. Test specimens were loaded onto a grey cast iron disc with an outer diameter of 150 mm and a composition of 3.60 % C, 2.30 % Si, 0.50 % Mn, 0.12% S, and 0.75 % P. The disc was fastened to a rotating mechanism. Prior to the test, 320 grid sandpaper was used to grind the friction surfaces of the cast iron discs and the test specimens. The experimentation was done at 25 °C. The prepared sample underwent a tribological test in ambient conditions, with a temperature of (20 ± 5) °C and a relative humidity of 60 % ± 5 %.

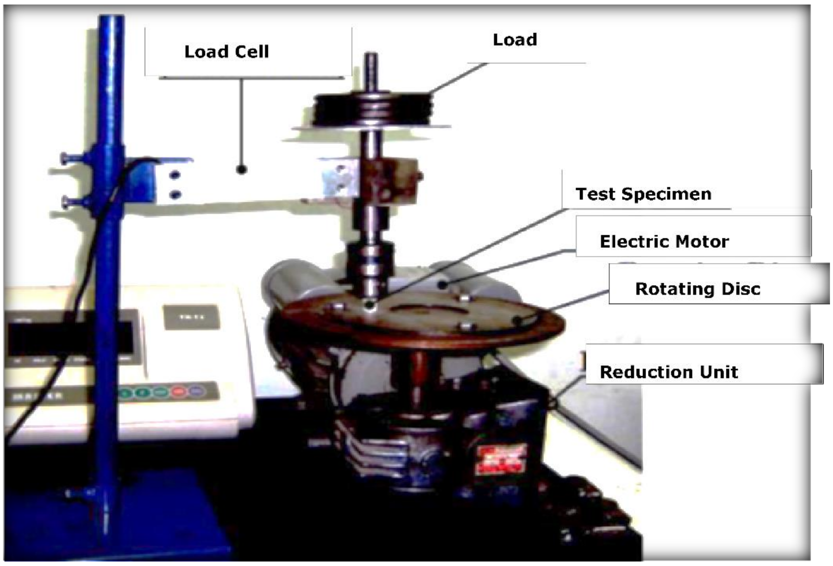

Fig. 1 Pin on disc tribometer.

Figures 2, 3 show the commercially provided graphite and calcium carbonate "$CaCO_3$" particles (99.98 % purity with an average particle size of less than 50 µm) were sonicated for nearly 6 hours in acetone to achieve the necessary particle size using ultrasonic dispersion technology. After sonication, the $CaCO_3$ particles were dispersed using an ultrasonic homogenizer in two different types of lubricating oil (PAO and paraffin oils) at concentrations of 0, 5, 10, 15, and 20 weight percent.

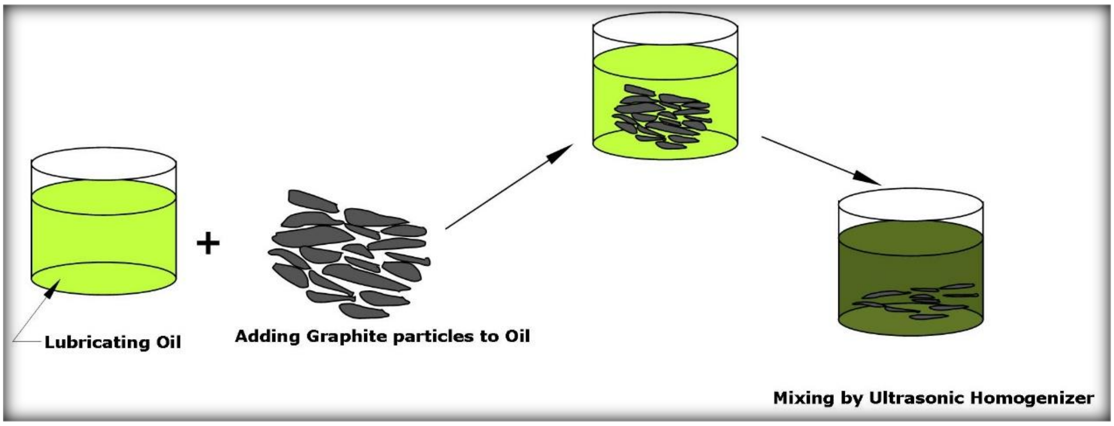

Fig. 2 Scheme of Graphite particles dispersed in base lubricating oils.

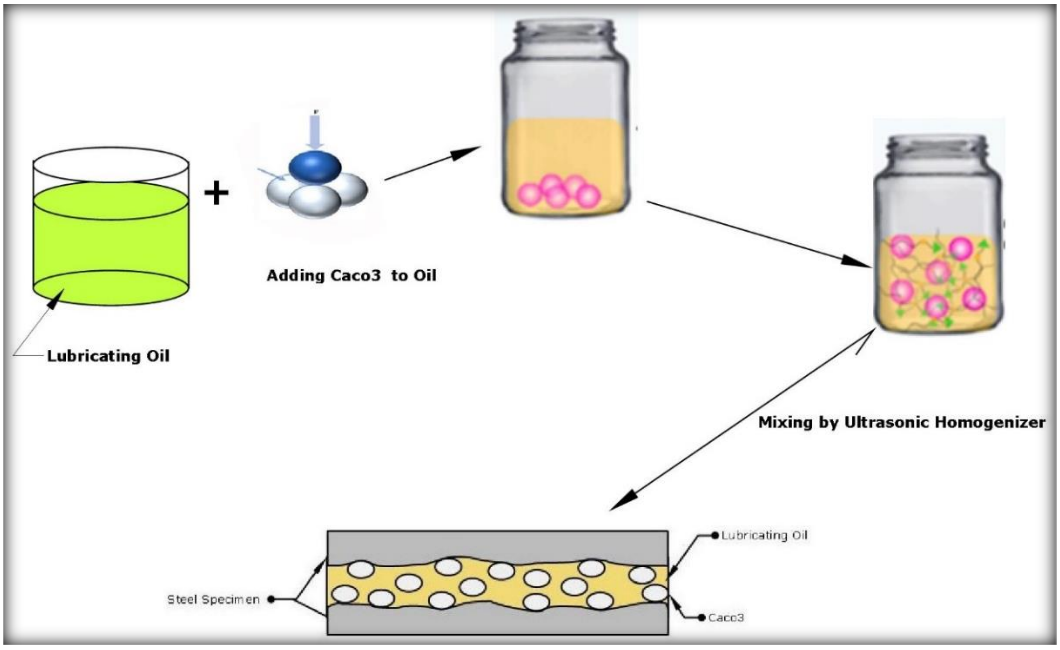

Fig. 3 The scheme of $Caco_3$ particles dispersed in base lubricating oils.

Fig. 4 prepared samples.

RESULTS AND DISCUSSION

Figure 5 shows the effect of varying graphite powder amounts on paraffin oil friction coefficient values after 5, 10, and 15 minutes. Whereas the friction coefficient was 0.28, 0.355, 0.435 for pure addition of paraffin oil after 5, 10, and 15 minutes of testing, the friction coefficient decreased when different amounts of graphite were added, reaching 0.09, 0.155, and 0.26 after 5, 10, and 15 minutes of testing. Meanwhile weight loss (g) after 5, 10, and 15 minutes was 0.0008, 0.0012, and 0.0016, as shown in Fig. 6.

Wear loss decreased to about 0.00011 (g) after adding 20 weight percentage of graphite powder to PAO oil. This indicates that on the sliding contact contacts, graphite powder created a conformal protective covering and decreased friction. This makes it easier for shear to occur and slows down surface scratches in steel, as shown in Fig. 7.

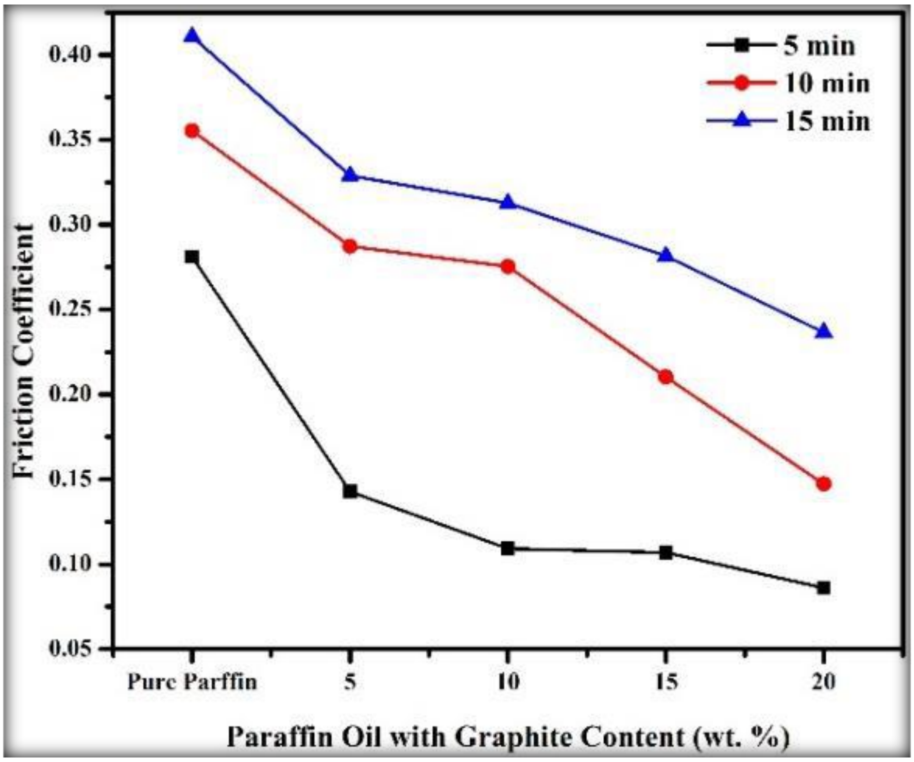

Fig. 4 Effect of addition of various graphite particle contents to paraffin oil on the values of the friction coefficient.

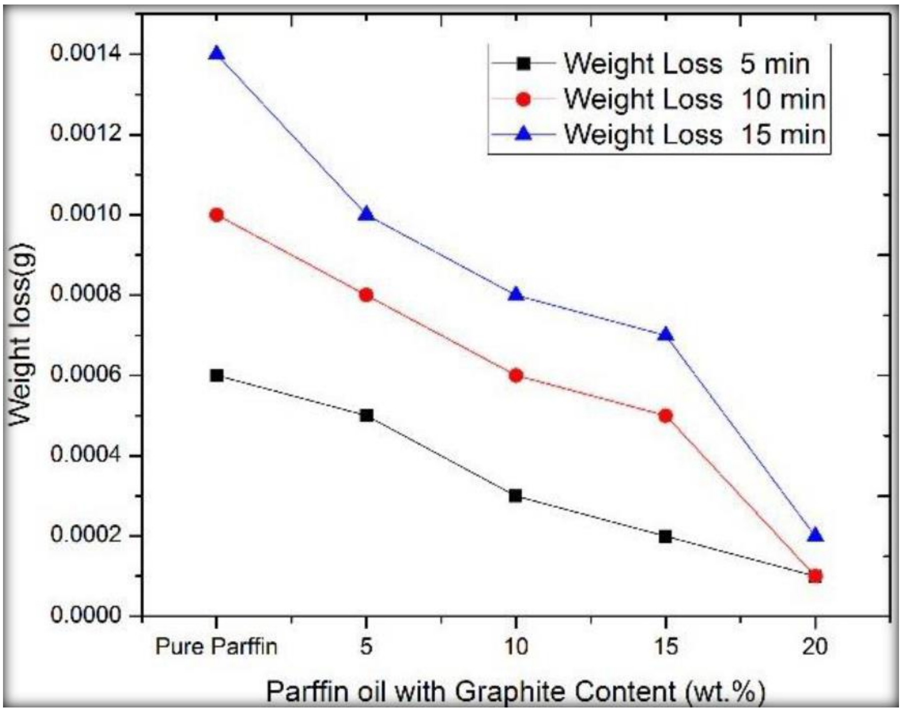

Fig. 5: Paraffin oil with varying graphite particle contents.

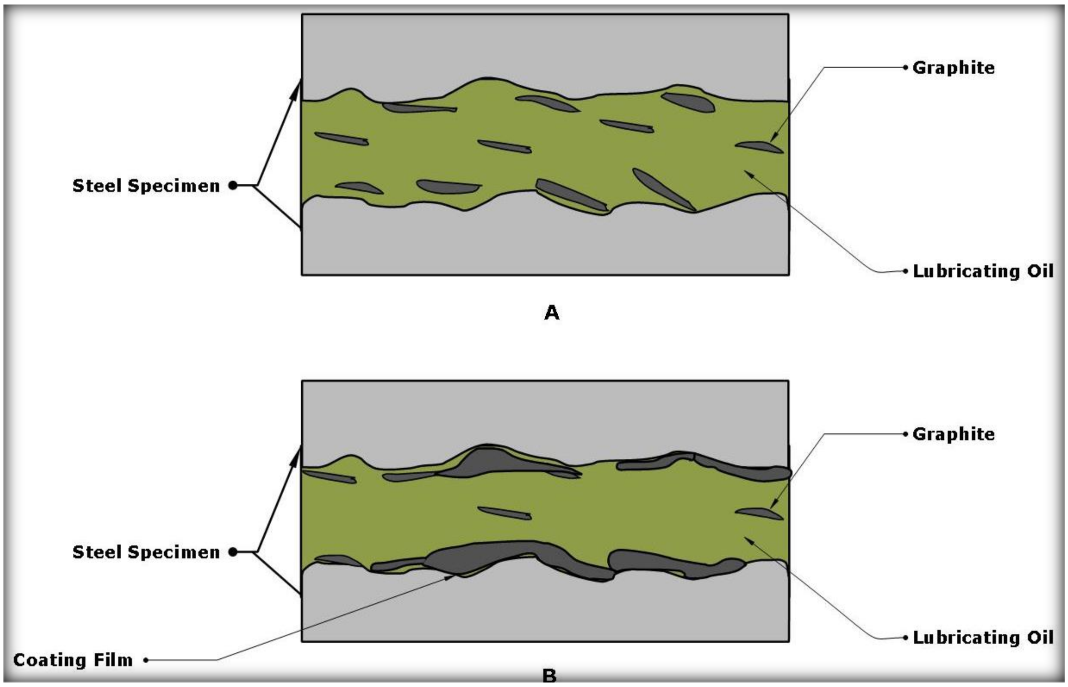

Fig. 6: Film of graphite flakes coated steel surfaces.

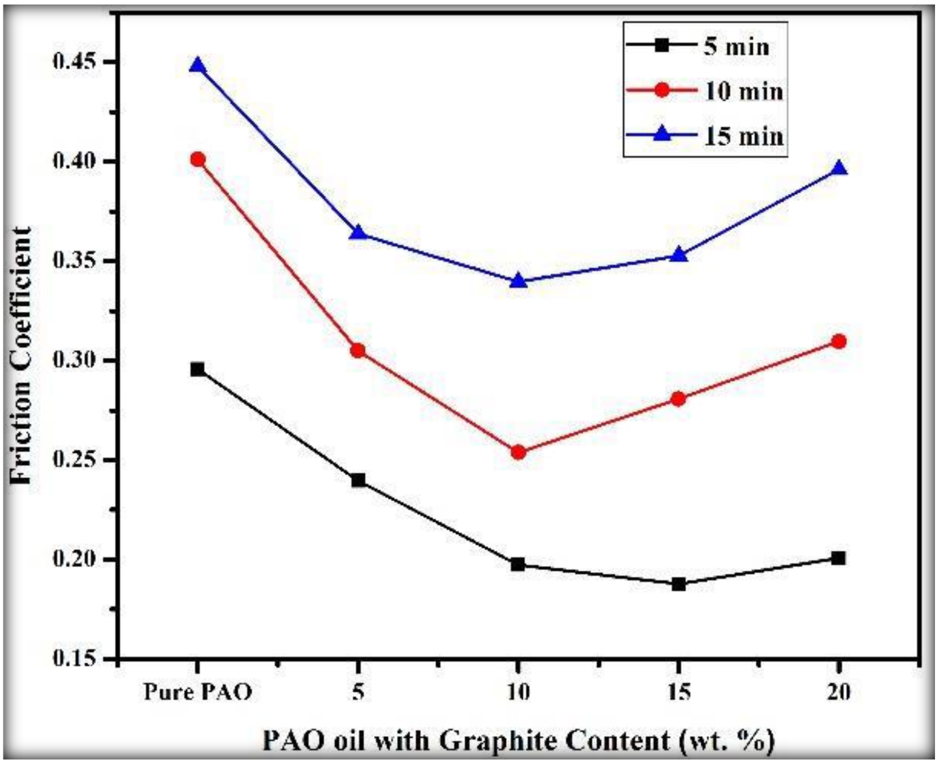

Fig. 7 Friction coefficient changes when different graphite contents are added to PAO.

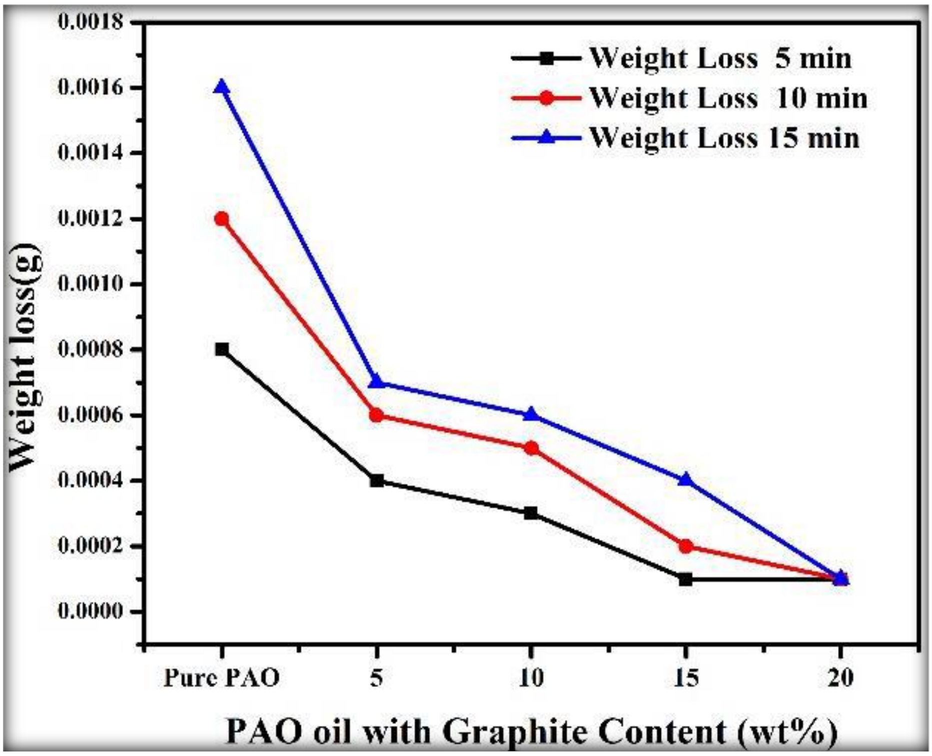

Fig. 8 Weight loss of a steel specimen with varying amounts of graphite particles and PAO oil.

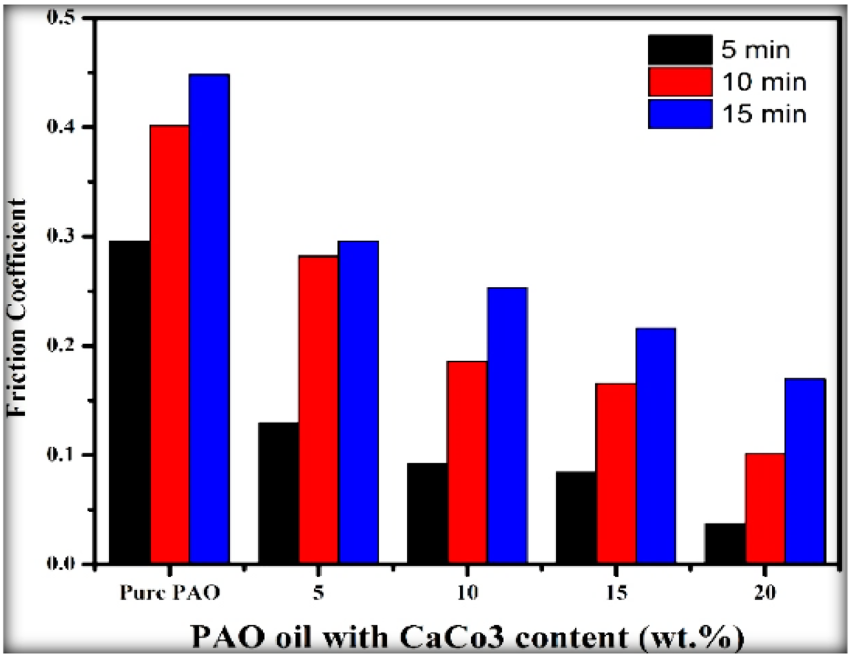

Fig. 9 Comparison of the effects on friction values of varying $CaCO_3$ amounts applied as a solid addition to PAO.

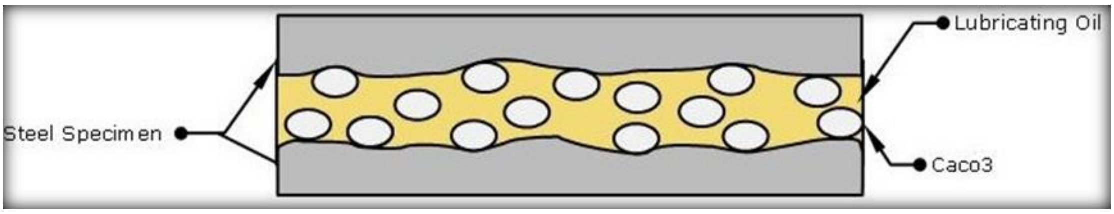

Fig.10 Scheme to $CaCO_3$, added to PAO as solid additive.

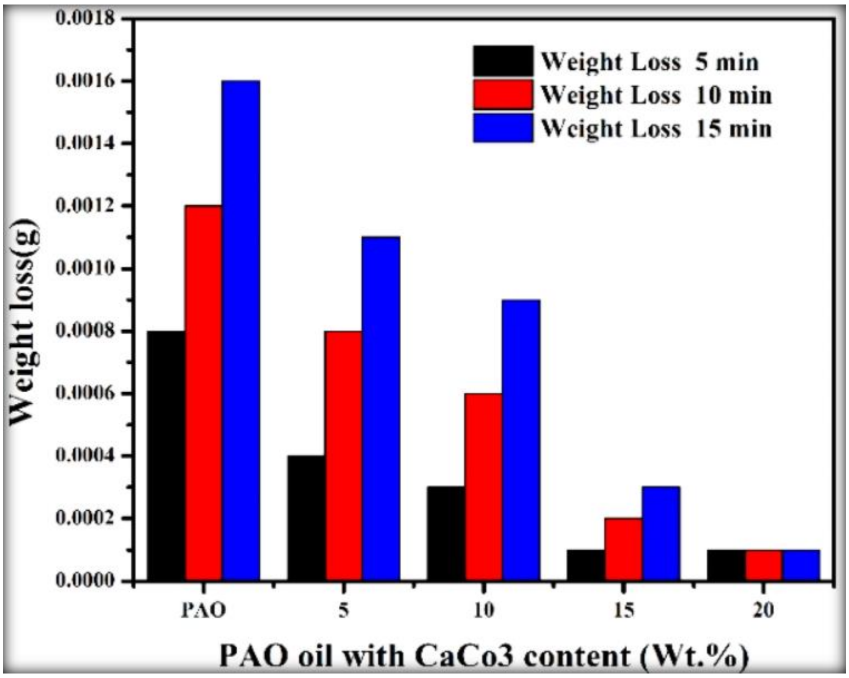

Fig. 11 shows the behavior of PAO filled with varying $CaCO_3$ contents on wear values.

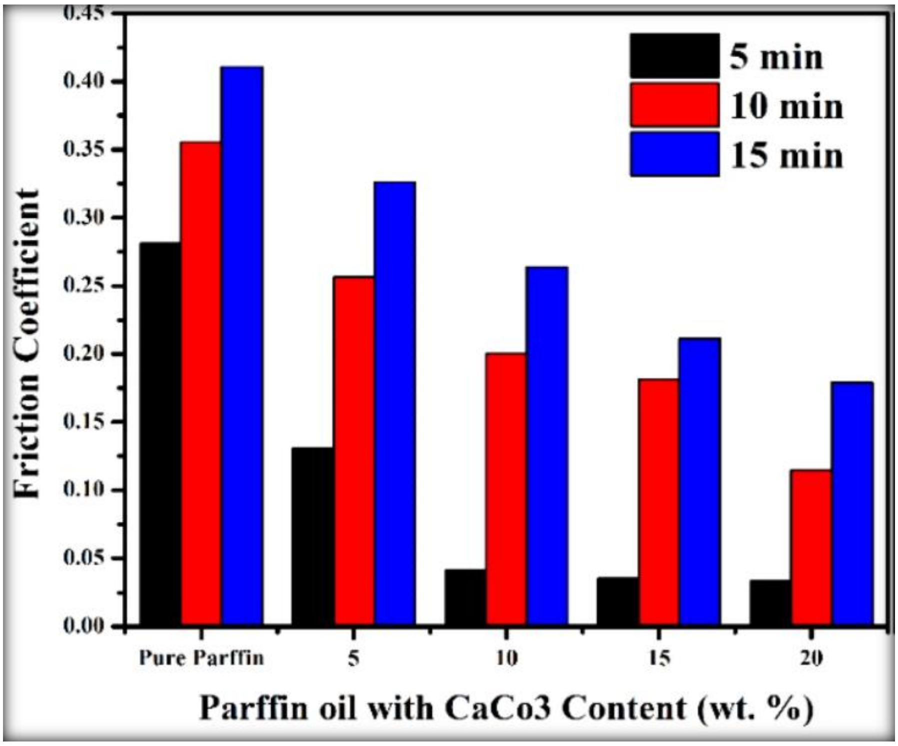

Fig. 12 Friction coefficient changes by varying the amount of calcium carbonate added to paraffin oil.

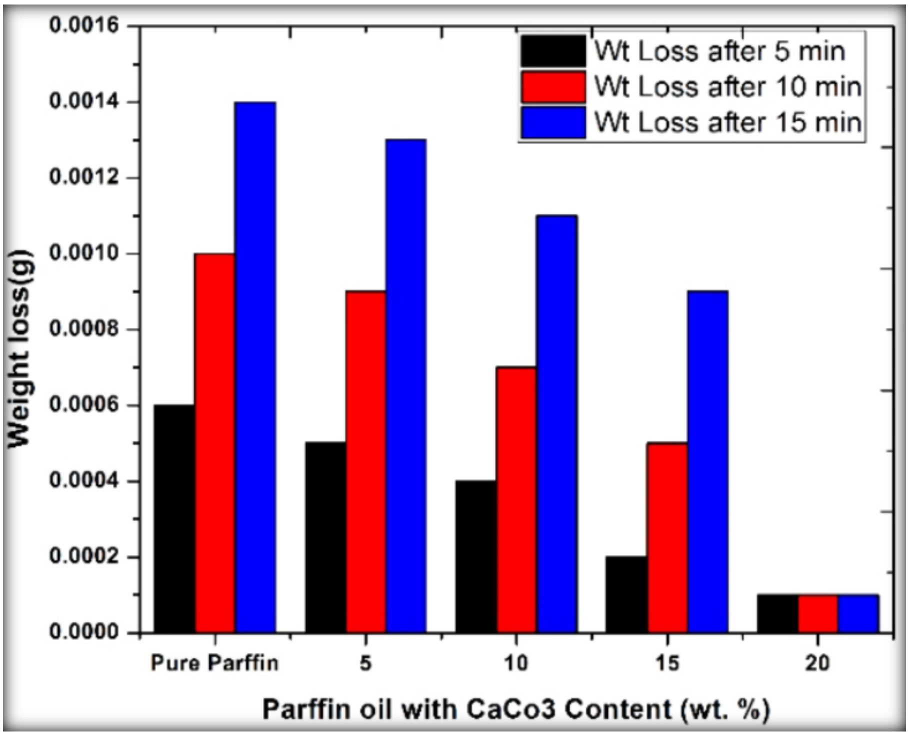

Fig. 13 shows the weight loss of a steel specimen lubricated with paraffin oil and various calcium carbonate particle concentrations.

The effect of varying the amount of calcium carbonate microparticles added to paraffin oil on the friction coefficient values after five, ten, and fifteen minutes is shown in Figure 9. In the cases where adding varying amounts of calcium carbonate particles lowers friction values, the friction coefficient was, after 5, 10, and 15 minutes

of testing, 0.29, 0.39, and 0.45 for pure paraffin oil addition, respectively. The friction coefficient decreased after adding 20 weight percent of calcium carbonate microparticles, reaching 0.005, 0.1, and 0.15 after 5, 10, and 15 minutes of testing. Meanwhile, after 5, 10, and 15 minutes, weight loss (g) was 0.0008, 0.0012, and 0.0016, as shown in Fig. 11. Wear loss decreased to about 0.0001 (g) after 20 % weight percentage of $CaCO_3$ powder was added to PAO oil. This indicates that on the sliding contact contacts, calcium carbonate microparticles acted as rollers and decreased friction. For this reason, scratching between steel surfaces is slowed down and sheared more easily. Based on the research results on the friction and wear performance of Graphite and calcium carbonate in lubricating oil additives, it can be concluded that when the weight percent of graphite does not exceed 20 %, the particles can be uniformly dispersed in the lubricating oils, as shown in Fig. 13.

CONCLUSIONS

Based on the results of the experiments, spherical calcium carbonate had good dispersity and uniform particle distribution in the lubricated oils. The results indicated that the CaCO3 additive, as a solid lubricant, exhibits good performance in wear and friction reduction of the steel specimens when added to PAO. 20 wt. % additive concentration is the optimal concentration.

Wear and friction are decreased because of the additives, which function as solid lubricants. However, by increasing its viscosity, the oil was able to form a relatively thicker oil layer between the moving surfaces.

The change in friction coefficient under different contents of the fillers also shows that the addition of graphite and calcium carbonate can greatly promote the lubrication performance of lubricating oil, especially the amount of 20 wt. % graphite shows excellent lubricating properties, which can reduce the wear loss by eight times compared with the original lubricating oil.

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