Triboengineered Industrial Lubricant Using Perlite Loaded Fe_2O_3 Nano-Additives: A Greener Approach

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Abstract

Nanoscale additives has received significant importance as anti-wear additives by minimizing the wear and material surface destruction of machines induced by friction between the moving parts. The friction and wear are the two essential factors that are inevitable during the manufacturing process. In this work, an attempt is made to enhance the tribological properties of industrial oil by blending the nanoparticles of Fe_2O_3 *with pearlite. The study is carried out with two different compositions of nanoparticles in aluminum and steel using pin-on-disc wear tester. The experimental outcomes demonstrate the existence of nanoparticles enhances the wear resistance in the base lubricant.*

Keywords: *Fe_2O_3, perlite, aluminum graphite, pin on disk*

1. Introduction

The lubrication process is considered as the most essential parameter involved in the moving parts in machine tools and manufacturing process. The different types of lubricant in solid, liquid and gas forms are inset between two moving parts so as to minimize the friction and maximize the smoothness which avoids the surface distortion. The parameters such as load, sliding speed, geometry of the component, surface roughness of the material, material type, temperature, and lubrication determines the friction and wear rate [1–3]. The attempt of modifications in friction and wear rate is governed by load and sliding speed. Also, friction force is an activity of both contact time and velocity by which friction coefficient may be minimum at smooth surfaces [4]. Many investigations have been carried out in minimizing the frictional force by introducing several types of lubricants and suggested it as capable interpose in minimizing the interfacial friction and wear [5–8]. Howsoever, the base lubricant alone doesn't provide enough durability of the sliding

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materials in the complex machineries and in manufacturing process. Enhancing the lubricant tribological property and durability of the mating components, definite additive compounds are added to the base lubricant in certain percent [9]. The triboactive additives of classes like organic or with metallic compounds like zinc (Zn), carbon (C), and tungsten (W) provides tribo-positive layers on material surfaces especially iron alloys [10–16].

Summarizing the literature, the iron alloys additive in nano-scale maximizes the antiwear property on sliding material surfaces and prevent surface distortion. The objectives of this study are narrowed as: (i) Synthesis of iron oxide nano particles loaded over perlite and (ii) study of tribological properties of nano-additives blended lubricant using pin-on-disk method.

2. Materials and methods

2.1 Synthesis of perlite loaded iron oxide

A mixture of 0.5 g of $FeCl_2$.4H2O and 1.2 g FeCl3.6H2O in 2M HCl was added to 25% NH4OH and stirred (pH - 11). The pH of the solution was adjusted to 2 by drop wise addition of 2M hydrochloric acid and continued stirring for 2 hours, centrifuged and washed with excess water. The resulting nanoparticles were dried at 80°C for 8 hours. Prepared perlite and ferric-oxide in 2:1 ratio were suspended in 25 mL of water: alcohol (1:1) respectively and stirred for 8 hours. Then the solvent was evaporated and dried at 80°C for 8 hours.

2.2 Preparation of Nano Lubricant

A typically available low-cost heavy engine oil (15w-40 CI4) is considered as the base oil in this present tribological evaluation. The lubricant is prepared by blending additives into the lubricating engine oil at 0.3 wt % of Fe_2O_3+Pearlite and 0.5wt % of Fe_2O_3+Pearlite. The given additives are then uniformly mixed with base oil by ultrasonication (Fig. 1) for 90 minutes. The obtained lubricants containing same additives with different compositions shown in Fig. 2.

Fig. 1 Ultra sonicator

Fig. 2 Nanoparticles blended lubricant

2.2 Materials

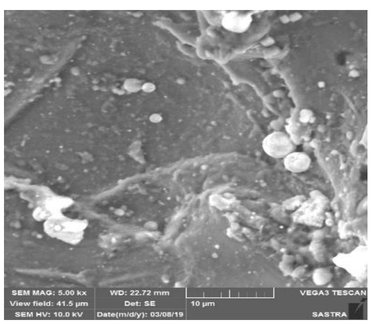
The specimen selection is performed based on the application of materials and lubricants in manufacturing process. The commercially pure aluminum and aluminum-graphite composite is opted for this study. The aluminum graphite is stir casted in three different compositions as shown in Table 1.

Table 1. Material selection

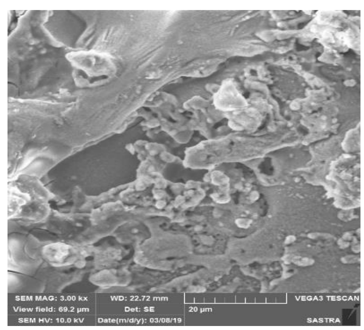
Pin material	Variants	
Pure aluminum		
Aluminum graphite	 Al+0.3% graphite	 Al+0.5% graphite

2.2.1 Stir casting of Aluminum graphite

Aluminum is weighed for melting and graphite is melted at 900 °C. Nitrogen gas is employed for inertness and to prevent oxidation. Pure magnesium of 1% by weight is used for wetting agent during the process with reinforcement powder for complete blending process. The stirrer is up to 300 RPM. Cautiously, the temperature of the heater is set to 630 °C that is below the melting point of matrix. Pouring of preheated reinforcements at the semisolid stage of the matrix enhance the wettability of the reinforcement, reduces the particle settling at the bottom of the crucible [17]. The mould is preheated to 500 °C to have the composite slurry and then heated up to 900 °C. The following micro images (Fig. 3) shows the different aluminum graphite compositions.



Al + 0.3% graphite



Al + 0.5% graphite

Fig. 3 SEM Micrographs of aluminum graphite

2.4 Experimentation

The experiments are conducted at room temperature 26 °C. The base oil (SAE-15W40) is purchased from Shell Helix 15W40 engine oil. The nano-additives blended with base oil in the glass wares whereas the glass wares are rinsed thoroughly with ethanol and dried for around 2 hours at 100 ^{o}C in an oven. The pin materials are of aluminum and its alloys, and EN32 steel as disc material. The pin materials are polished with alumina (10 μm). The uniform hardness is maintained throughout the pin material by annealing process. It supports in repeatability throughout the experiments. Similarly EN32 disk steel material is polished with SiC (60 μm) [18].

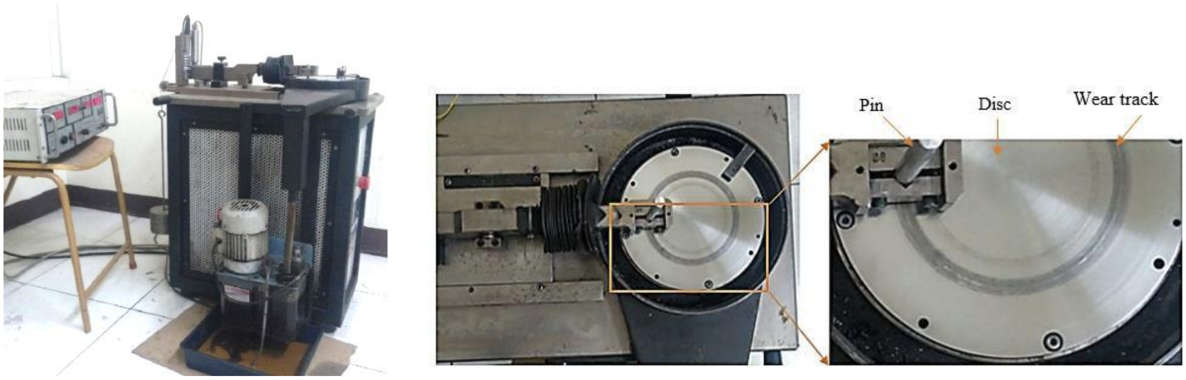
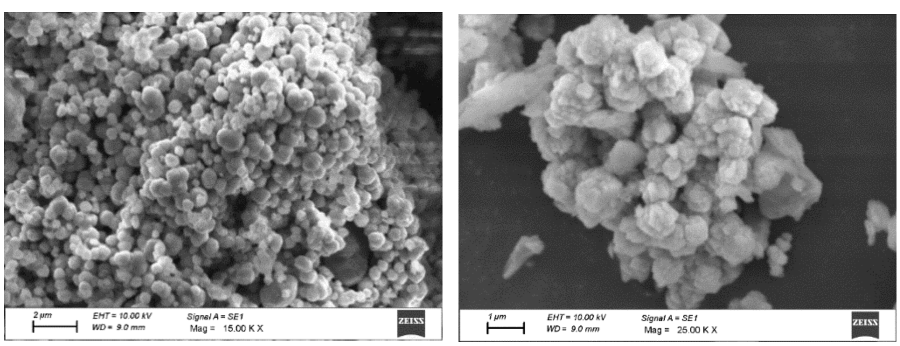


Fig. 4 Pin-on-disk tribometer

The individual experiments are conducted using 0.3% perlite and 0.5% perlite loaded with Fe_2O_3. The wear test is conducted using Ducom TR20M36 pin-on-disk tribometer as shown in Fig. 4 [19]. The instrument is sufficiently equipped with a data acquisition system which collects and produces the information to WINDUCOM 2010 tool for interpretation of results.The initial surface roughness measured using Taylor Hobson - Surtronic surface roughness tester. The surface roughness measured in rotating disc and stationary pin is 1.62 and 3.87 μm respectively. The coefficient of friction is calculated using the piezoelectric sensor and wear rate.

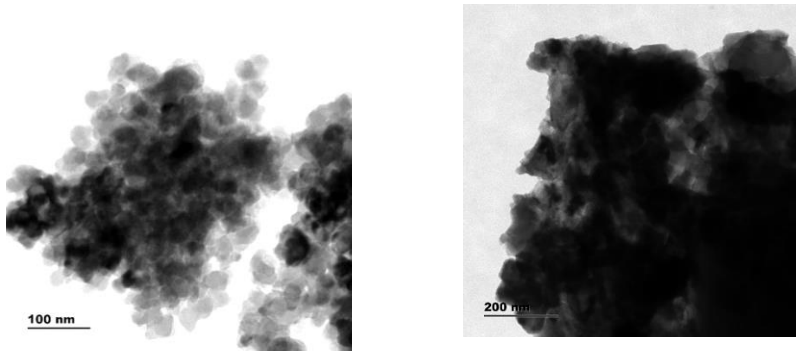


(a) α-Fe_2O_3 (b) α-Fe_2O_3 loaded Perlite

Fig. 5 SEM images

3. Results and discussion

The surface morphology of the prepared α-Fe_2O_3 nano particle and α-Fe_2O_3 loaded perlite is examined by SEM technique. Surface morphological study indicated spherical nature of α-Fe_2O_3 (Fig 5a). The SEM image of α-Fe_2O_3 loaded perlite depicted in Fig.5b exposes uniform loading of α-Fe_2O_3 on layer like structure of perlite. The prepared α-Fe_2O_3 and α-Fe_2O_3 loaded perlite was characterized by IR, SEM and TEM analytical techniques. The IR spectrum (Fig 7) shows characteristic peaks at 1041.56 cm^{-1}, 810.10 cm^{-1}, 594.08 cm^{-1}, 439.77 cm^{-1} for Fe-O stretching and bending vibrations.



(a) α-Fe_2O_3 (b) α-Fe_2O_3 loaded Perlite

Fig. 6 TEM Images

TEM results depicted in Fig. 6a also reveals that the prepared α-Fe_2O_3 nanoparticles were spherical in nature with mean particle size of 22 nm. Also, constant and uniform loading of nanoparticle over perlite was established from Fig 6b.

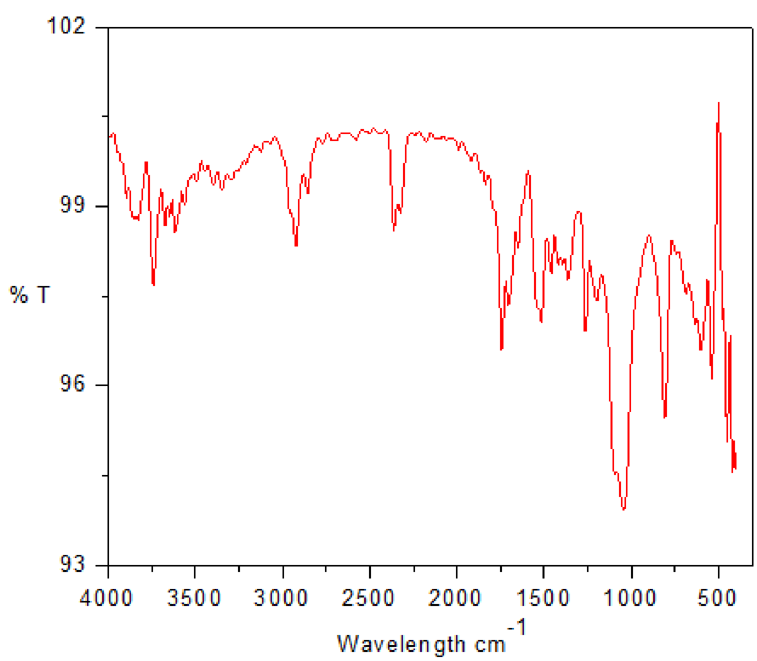


Fig. 7 Fe_2O_3 + perlite IR graph

The MgO-ZnO blended with engine oil to evaluate the friction and wear characteristics is performed and the results are tabulated below. Wear test are conducted with a load of 4.6 N and track diameter of 100 mm with duration of 300 sec. The weight loss of the pin material after experiment is measured to calculate the wear rate. The volume of the pin and its mass are measured before and after the experiments to calculate the loss during the experiments is shown in Table 1. The same procedure of experiments are repeated in different lubricating conditions and weight loss.

Table 2 Mass and Volume loss of Aluminium and Graphite

Sample name	Lubricating condition	Pin material	Wt. loss g	Volume loss m^3
B1	Base oil	Al	0.008	50.24
B2		Al-0.3%Gr	0.009	38.4
B3		Al-0.5%Gr	0.008	89.6
A1	Fe_2O_3 + 0.3% pearlite	Al	0.005	25.12
A2		Al-0.3%Gr	0.004	32
A3		Al-0.5%Gr	0.005	51.2
A4	Fe_2O_3 + 0.5% pearlite	Al	0.002	10.048
A5		Al-0.3Gr	0.003	25.6
A6		Al-0.5Gr	0.003	38.4

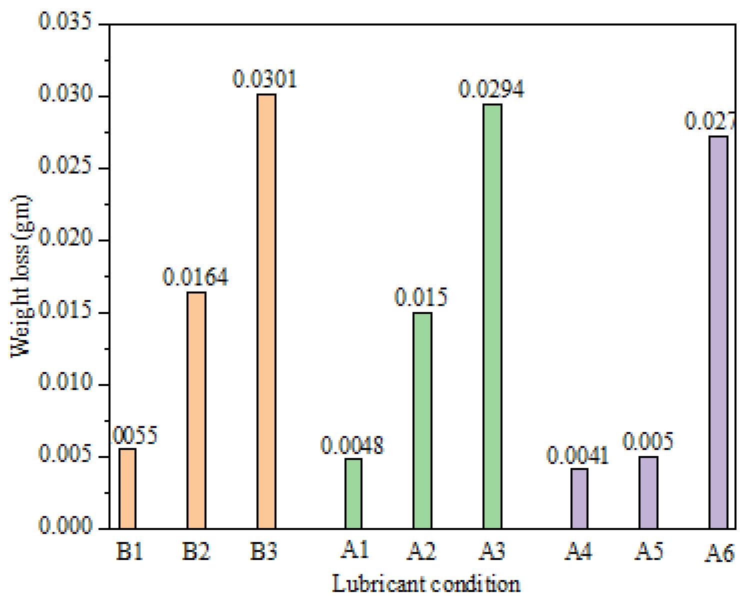


Fig. 8 Weight loss vs. lubricant condition

The test performed with a pin-on-disk apparatus in room temperature. The load is applied to the pin through dead weights. The load cell contacted with the supporting arm measured the value of the friction force constrain on the static Aluminium pin specimen. The test is performed at a variable load of 19.61, 49.03, 78.45 N, sliding speed of 1200, 1400 and 1600 rpm and for sliding velocity 0.25 m/s. The samples are cleaned thoroughly to avoid the entrapment of wear debris and to achieve homogeneity. Weight loss of specimen is calculated from the difference in the weight measured before and after every test shown in Fig. 8 and microscopic images of worn surfaces are shown in Fig 9. It is evident that every material has their own impact with other material and it can only be reduced using lubricants and additives.

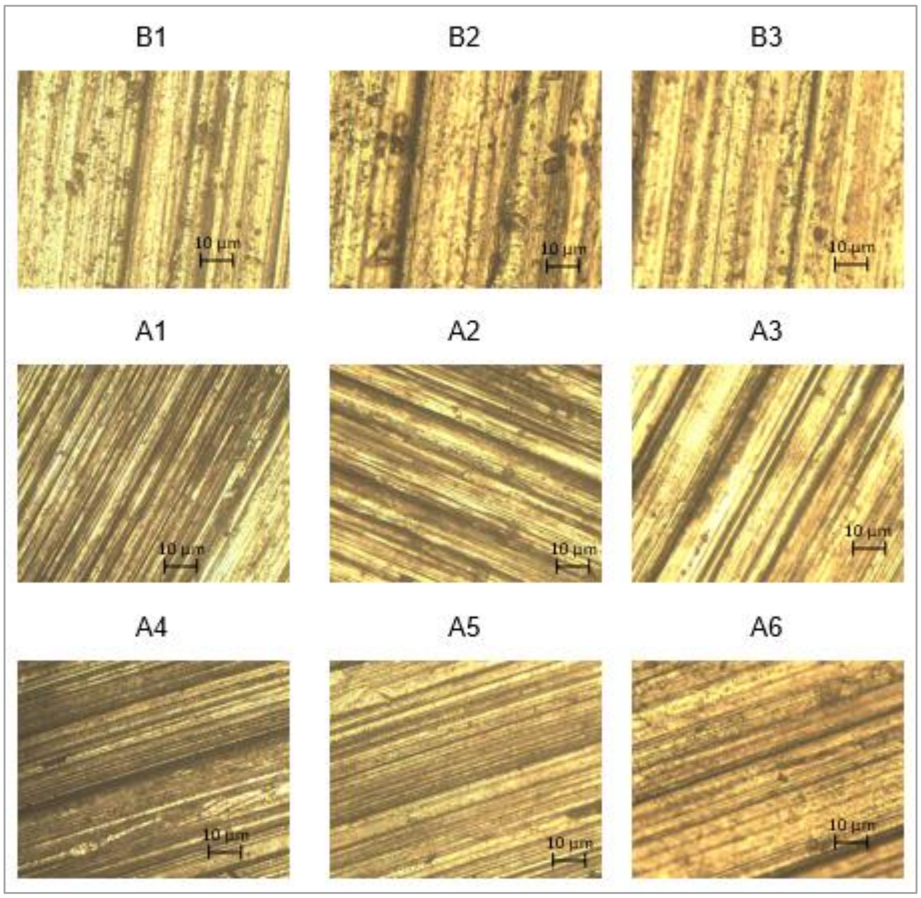


Fig. 9 Optical microscopic images of worn surfaces

4 Conclusions

The effect of Fe_2O_3 nano particle loaded perlite addition with two different concentration on tribological characteristics are investigated. With reference to the results obtained the following conclusions are made.

- Spherical nano Fe_2O_3 particles are successfully synthesized via coprecipitation method and loaded over perlite for lubrication purpose.
- Nanoparticles synthesized exhibits wear reduction in all concentration. Comparatively good results are obtained for nanoadditives with 0.5% of concentration. Also, it is noted that nanoparticles effects more on wear rather than friction reduction.
- The weight loss has been reasonably reduced upon using 0.5% concentration lubricant compared with other concentrations. It is achieved by sintering of nanoparticles on the metal surface and making it smoother by reducing metal-to-metal interaction.

Acknowledgements

Author B. Sathishkumar wish to thank the management of Sri Krishna College of Technology, Coimbatore for facilities. Author P. Amutha wish to thank GRG Trust, Coimbatore for financial support in carrying out this work.

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