Vol. 36, No. 2 (2014) 127-133

Tribology in Industry

www.tribology.fink.rs

RESEARCH

Tribological Behavior of Journal Bearing Material under Different Lubricants

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Keywords:

Journal bearing
Bio-lubricant
Pin on disc
Nano CuO
Formulated rapeseed oil

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A B S T R A C T

The friction and wear behavior of journal bearing material has been investigated using pin on disc wear tester with three different lubricating oils i.e. synthetic lubricating oil (SAE20W40), chemically modified rapeseed oil (CMRO), chemically modified rapeseed oil with Nano CuO. Wear tests were carried out at maximum load of 200 N and sliding speeds of 2 – 10 m/s. The results showed that the friction and wear behavior of the journal bearing material have changed according to the sliding conditions and lubricating oils. The journal bearing material has a lower friction coefficient for CMRO with Nano CuO than other two oils. Higher wear of journal bearing material was observed in SAE 20W40 and CMRO. Worn surfaces of the journal bearing material with three lubricating oils were examined using scanning electron microscope (SEM) and wear mechanisms were discussed.

1. INTRODUCTION

Study of mechanics of friction and the relationship between friction and wear back to the sixteenth century, almost immediately after the invention of Newton's law of motion. It was observed by several researchers that the variation of friction depends on interfacial conditions such as normal load, geometry, relative surface motion, sliding velocity, surface roughness of the rubbing surfaces, type of material, system rigidity, temperature, stick-slip, relative humidity, lubrication and vibration.

Among these factors normal load and sliding velocity are the two major factors that play a significant role for the variation of friction. In the case of materials with surface films which are either deliberately applied or produced by reaction with the environment, the coefficient of friction may not.

2. RESEARCH BACKGROUND

Erol Feyzullahoglu and Nehir Sakiroglu the were investigated aluminium-based alloys produced by metal mould casting and analysed tribological properties of these alloys under lubrication. The experiments were carried out at pressures of 0.231–1.036 N/mm^2 and sliding speeds at 0.6–2.4 m/s. The results showed that the friction and wear behaviour of the alloys have changed according to the sliding conditions. Al8.5Si3.5Cu alloy has a lower friction coefficient value than other alloys [1].

Massimo Del Din and Elisabet Kassfeldt were examined the friction and wear of a two grooved journal bearing at different shaft speeds, oil temperatures and contamination levels. They investigated environmentally adapted rape seed-synthetic ester oil in a full scale application. The result of this investigation shows that the rape seed-synthetic ester oil gives lower values of wear and there is also a tendency of lower values of frictional torque compared with the mineral oil [2].

Bekir Sadik Unlu and Enver Atik were investigated friction coefficient of bronze radial bearings by a new approach. The result shows that high friction coefficient and high wear have been observed in dry test conditions and the lubricated conditions have low friction coefficient and low wear have been observed [3].

Boncheol Ku et al., were examined the comparative tribological behaviour of journal bearings made from polytetrafluoroethylene composites and aluminium alloys. The tribological properties of journal bearings were evaluated as a function of the applied normal load by measuring the temperature of lubricating oil and coefficient of friction. The results showed that the Al alloy journal bearings reduce the friction coefficient by 28 % compared to the PTFE composite bearings and the PTFE composite journal bearings exhibited strong adhesion at the loads ranging from 6300 to 8000 N. Based on this experiment the Al alloy is a more promising material in journal bearings than PTFE composites [4].

Ramesh Kumar et al., studied the mechanical and tribological properties of plain bearing alloys used in internal combustion engines. The wear and sliding friction of aluminium-tin alloy against high carbon high chromium steel were experimented at different loads in lubricated conditions with a sliding speed of 1 m/s. They found that the friction and wear value of aluminium alloy bearings is less than that of pure aluminium bearing [5].

Voong et al., were examined the wear properties of Al–Si alloys used in the crankshaft bearings of internal combustion engines under two fully formulated lubricants, which have the same viscosity grade It was found that in a completely ferrous-based system fully formulated lubricants are effective in reducing wear and friction [6].

Das and Biswas were examined the tribology properties of Al–Si alloys under the lubricants with additives. They analyzed the data in terms of the formation of a mechanically mixed layer at the interface and the corrosive action of additive addition [7].

Jiang and Xie were investigated the tribological behaviour of plasma-spray TiO_2 coating pairing with conventional metallic bearing materials and triphenyl thiophosphate and tricresyl phosphate. The results shown that the copper–lead alloy paired with TiO_2 coating lubricated with the base oil exhibited the optimum tribological performance [8].

Wu et al., were examined the tribological properties of two lubricating oils with CuO, TiO_2, and Diamond nanoparticles used as additives. The results shown that the nanoparticles especially CuO, added to standard oils exhibit good friction-reduction and anti-wear properties. The addition of CuO nanoparticles in the engine oil and the base oil decreased the friction coefficient and reduced the worn scar depth compared to the one without CuO nanoparticles [9].

Ertugrul DurakIn was studying the effects of addition of rapeseed oil to the base oil on the friction coefficient in the journal bearing under static loading at different temperatures. The rapeseed oil is added to a mineral-based lubricant acts as an additive that decreases the friction coefficient at high journal speeds, and even at medium loads [10].

Alves et al., were studied the development of vegetable based lubricants and the tribological behaviour of nanoparticle additives in an oil base. The results showed that the addition of nanoparticles to conventional lubricant, the tribological properties can be improved, the friction and wear can be reduced due to formation of tribo film on the worn surface. The lubricants developed from modified vegetable oil can replace mineral oil, improving the tribological and environmental characteristics [11].

Feyzullahogflu et al., discussed the tribological behaviour of tin based alloys and brass in oil lubricated conditions. It is shown that the performance of brass under oil lubrication is better than tin based alloys due to its hardness.

The wear in brass is lower than the tin-based alloys under similar tribological loading conditions [12].

Y. Choi et al., were investigated the friction coefficient for raw oil and nano-oil mixed with copper nano particles by using a disc-on-disc tribotester. The result shown that the average friction coefficient of raw oil and nano oil under a load of 3000 N is decreased by 44 % and 39 % respectively [13].

Yu et al., were studied friction and wear properties of copper nano particles. The morphologies, typical element distribution and chemical states of the worn surfaces were characterized by SEM, EDS and XPS, respectively. The results indicate that the higher the oil temperature applied, the better the tribological properties of Cu nano particles [14]. Yu et al., were investigated copper nano particles dispersed in SN 650 oil to improve the lubricating properties of the oil. The result shown that the friction-reducing and anti-wear properties of SN 650 oil have been improved by adding Cu nano particles [15].

M.A. Chowdhury et al., found that the frictional coefficient increases with a duration of rubbing and decreases with increase in normal load [16]. M.A. Chowdhury et al., were examined the coefficient of friction for different material pairs and found that the frictional coefficient differs with rubbing duration, normal load and sliding velocity [17].

Hernandez Battez et al., were discussed the extreme-pressure behaviour of nano particle suspensions in a polyalphaolefin. The nano particles of CuO, ZnO and ZrO_2 were dispersed at 0.5, 1.0 and 2.0 wt.% in PAO 6 using an ultrasonic probe during 2 min in four ball wear tester. The wear scar diameter (WSD) was measured using an optical microscope and scanning electron microscopy and energy dispersive spectrometry. From the analysis of the worn surface all concentrations of nano particles improved the extreme properties of PAO 6 and CuO nano particles exhibited the best extreme property behaviour [18].

Arumugam et al., were examined the formulating environmental-friendly lubricant with good oxidative stability and improved cold flow behaviour. Rapeseed oil was chemically modified via, epoxidation, hydroxylation followed by esterification process. The results shown that the friction and wear characteristics of diesel engine liner–piston ring combination using diesel-contaminated chemically modified rapeseed oil bio-lubricant and diesel-contaminated commercial synthetic lubricant (SAE20W40) in a high frequency reciprocating tribometer test rig. The chemically modified rapeseed oil exhibits good oxidative stability, improved cold flow property and reduced the frictional force and co-efficient of friction [19].

Arumugam et al., studied comparative of the tribological properties of chemically modified rapeseed oil with and without nano- and micro scale titanium dioxide (TiO_2) particles and investigated the influence of TiO_2 particles to reduce the friction and wear in chemically modified rapeseed oil. The results showed that the TiO_2 nanoparticles exhibited good friction reduction and anti-wear properties compared with the micro scale TiO_2 and without TiO_2 additives to chemically modified rapeseed oil. Nano scale TiO_2 is suitable as an anti-wear additive in chemically modified rapeseed oil. [20]. The different operating conditions for coefficient of friction and wear rate of metals and alloys showed different behavior [21-23].

Manu Varghese et al., found that the coconut oil enhanced by addition of copper oxide nanoparticles reduced the friction very effectively [24]. All the review of the literature done left the scope for the authors to study the impact of chemically modified rapeseed oil as lubricant for the journal bearing. The present study is intended to bridge this gap in the investigation on the behaviour of chemically modified rapeseed oil with nano copper oxide as anti-wear additives in engine lubricant compound with synthetic lubricant on the tribological characteristics of journal bearing material.

3. EXPERIMENTAL WORK

Raw rapeseed oil was chemically modified via epoxidation, hydroxylation or ring opening process and followed by esterification of the ring opened product in order to improve its thermo-oxidative and stability and lower the pour point. Further nano copper oxide (size of 40 nm) of 0.5

%w/w [24] was dispersed in chemically modified rapeseed oil as anti-wear additives using ultrasonic sonicator and rotary shaker. Table 1 shows the properties of raw rapeseed oil and chemically modified rapeseed oil dispersed with CuO nano particles.

Table1. Properties of raw and formulated oil.

Properties	Standard	Raw rapeseed oil	CMRO
Viscosity @100°C (cSt)	ASTM D445	8	15.4
Viscosity @40°C (cSt)	ASTM D445	35	90
Pour point (°C)	ASTM D97	-11	-15
Flash point(°C)	ASTM D92	320	242
Viscosity index	ASTM D2270	220	179
Specific gravity @ 15°C	ASTM D287	0.85	0.89
Oxirane content (%)	AOCS cd 9-57	--	5.81
Biodegradability (%)	CEC-L-33-A93	>95	>95

The material of this study was a commercially supplied brass plate (64%Cu-34%Zn-2%Pb). From this plate, cylindrical specimens of 8 mm diameter and 30 mm length were machined as per ASTM G99. A Pin on disc test machine was used to establish the wear and friction characteristics of a journal bearing material under different lubricated conditions. The pin on disc wear tester as per ASTM standard (ASTM G99) is shown in Fig. 1 [5]. The elements of the test machine included a pin sliding on the flat face of a disc rotating in a vertical plane, with provisions to control the load, speed, and oil flow. The test oil was contained in a cup and it was swept up into the contact area of the rotating disk. The load was applied along the axis of the pin. The tribological investigations were conducted by using pins of 8 mm diameter and 30 mm length of brass [12] with hardness of 70 HRB and surface roughness of 1.1 R_a and rotating disc diameter of 165 mm and 8 mm thick of EN-31 hardened steel of hardness 60 HRC, ground to surface roughness 1.6 R_a was used to test with the different lubricants like SAE 20W40, chemically modified rapeseed oil (CMRO) and Nano additive chemically modified rapeseed oil (NACMRO). These investigations were performed by the maximum load of 200 N and different sliding speed of 2 m/s – 10 m/s as per ASTM G99 [5]. The successively recorded data were used for the frictional force and coefficient of friction at the different sliding speeds. Accordingly the frictional force and coefficient of friction results plotted as a function of testing time in minutes.

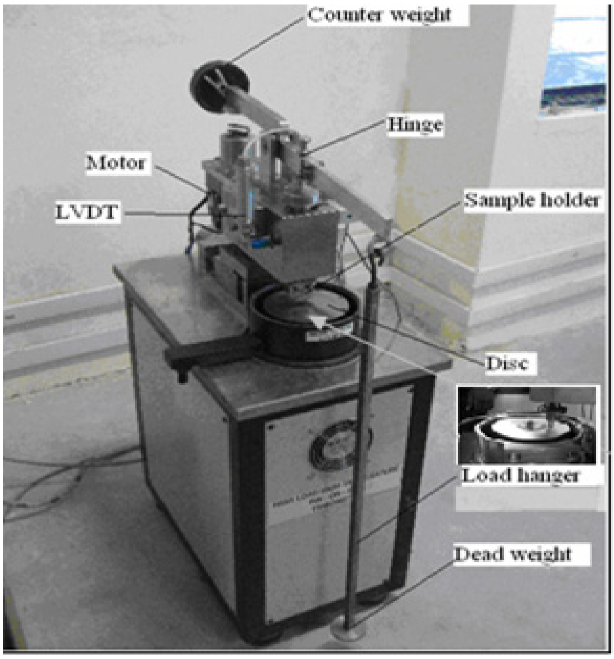

Fig. 1. Pin on Disc wear tester.

The maximum load is 200 N and applied at maximum load and different sliding distance, speeds and the track diameters i.e. 2 m/s is sliding speed at 478 rpm and track diameter of 80 mm, 4 m/s is sliding speed at 956 rpm and track diameter of 80 mm, similarly 6 m/s at 1478 rpm and same track diameter of 80 mm, speed of 8 m/s at 1528 rpm and track diameter of 100 mm and similarly 10 m/s at a speed of 1592 rpm and same track diameter of 100 mm. The readings on the graph were plotted at a regular interval of 15 minutes. The detail experimental conditions are shown in Table 2.

Table2. Experimental Conditions.

Sl. No.	Parameters	Operating Conditions
1	Load	200 N
2	Sliding Velocity	2 m/s – 10 m/s
3	Disc material	EN31 steel
4	Pin material	Brass
5	Surface Condition	Lubricated
6	Duration of Rubbing	15 min

4. RESULTS AND DISCUSSION

The coefficient of friction, wear and frictional force of the three different lubricants SAE20W40, chemically modified rapeseed oil

(CMRO) and chemically modified rapeseed oil with Nano CuO (CMRO with Nano CuO) are shown in Figs. 2, 3 and 4.

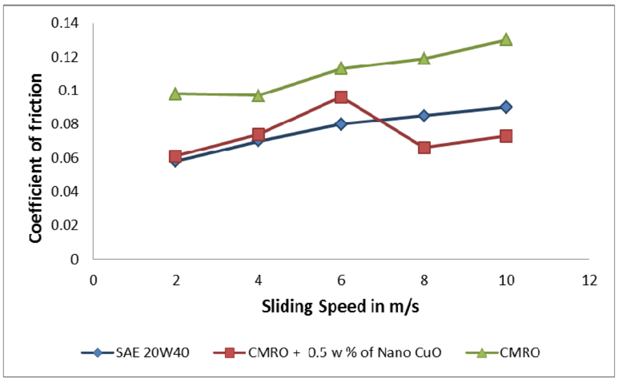

Fig. 2. Coefficient of friction Vs Sliding speed.

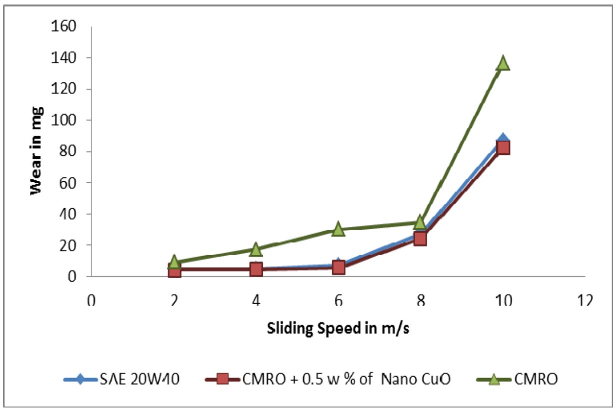

Fig. 3. Wear Vs Sliding speed.

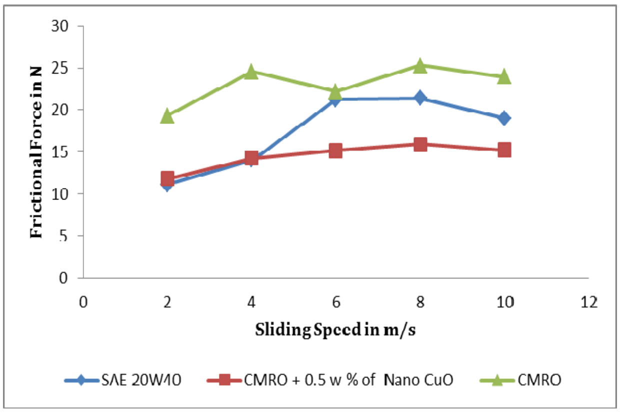

Fig. 4. Frictional force Vs Sliding speed.

The variation of friction coefficient with the duration of rubbing at normal load for SAE20W40, CMRO and CMRO with nano CuO is shown in Fig. 2. The friction coefficient values of brass lubricated with CMRO have higher value than brass lubricated with SAE20W40 and CMRO with nano CuO. The nano CuO dispersed in CMRO has lesser friction coefficient value. The results obtained are in-line with Feyzullahogflu et al., found that reduction in coefficient of friction was obtained for brass in oil lubricated conditions [12]. From Fig. 2, it can be observed the coefficient of friction decreases by enhancing the nano CuO in CMRO and it shows the lowest value of frictional coefficient of 0.5 % by wt. of nano CuO with CMRO, about 49 % lower than that of CMRO.

This might be accredited to the spherical nano CuO producing the rolling medium between pin and disc, when boundary lubrication occurred. However, it is 18 % lower than the coefficient of friction of bearing tribo pair under the influence of synthetic lubricant (SAE20W40) of same viscosity range of CMRO. The addition of nano CuO in CMRO increases the value of wear resistance. The wear values of brass were evaluated and the results are shown in Fig. 3. The brass was lubricated with CMRO had a higher wear value than the other two lubricating oils. The nano CuO in CMRO decreases the value of frictional force.

The results obtained are similar to Yu et al., found that the friction and wear reduction in SN 650 oil enhanced with copper nano particles [15]. The frictional forces of brass were evaluated and the results are shown in Fig. 4. The increase in wear resistance and decrease in frictional force of bearing material is due to the nano copper oxide spread over a pin material as foreign material to control wear and frictional force. The worn surfaces were examined using scanning electron microscope and shown in Figs. 5, 6 and 7.

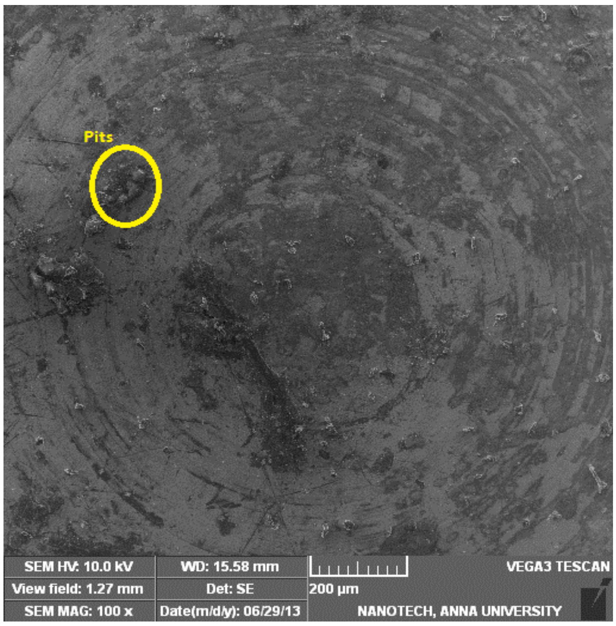

Fig. 5. SEM micrograph of the bearing material lubricated in SAE20W40.

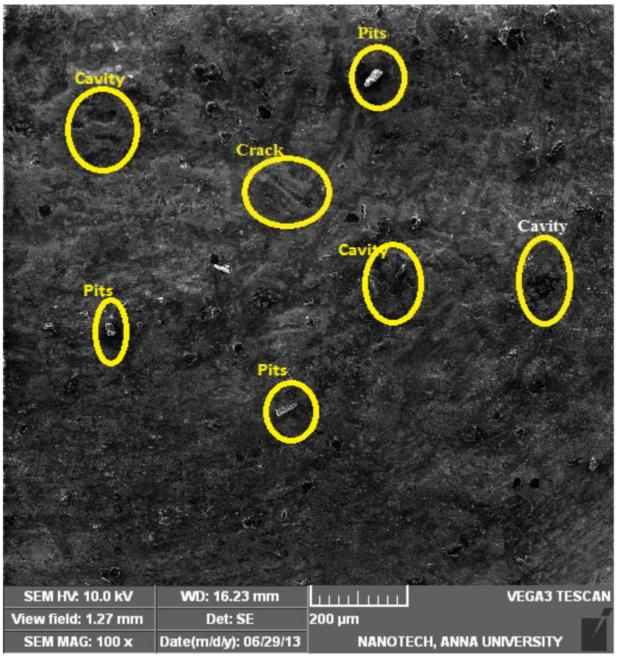

Fig. 6. SEM micrograph of the bearing material lubricated in CMRO.

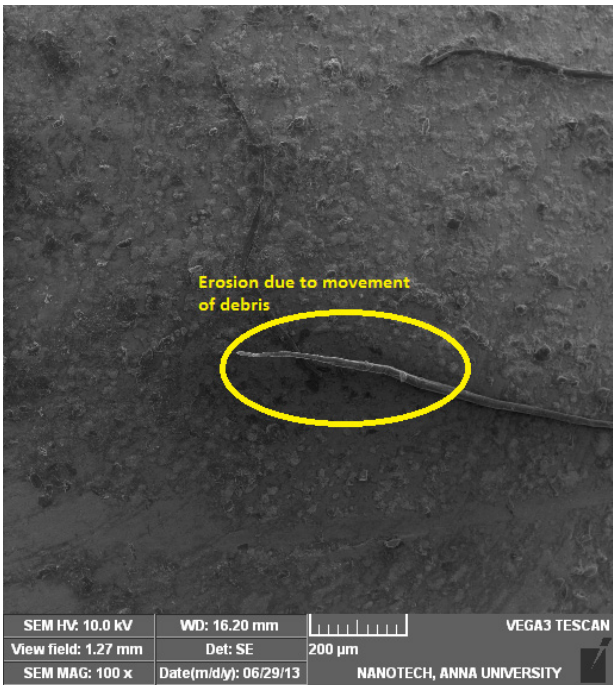

Fig. 7. SEM micrograph of the bearing material lubricated in CMRO with 0.5 % Nano CuO.

Figure 5 show the bearing material lubricated in SAE20W40 has fewer amounts of pits and cavity. The deeper wear traces, more amounts of pits and cavities are presented in the bearing material lubricated in CMRO as shown in Fig. 6. From Fig. 7 shows the bearing material lubricated in nano CuO dispersed in CMRO has very fewer amounts of pits and cavity compared to bearing material lubricated in CMRO.

5. CONCLUSION

In this study, the friction and wear behaviour of journal bearing material (brass) was evaluated and focusing on the effect of nano CuO in the chemically modified rapeseed oil. The bearing material (brass) lubricated with CMRO + 0.5 w.% nano CuO has the lowest friction coefficient of 0.073. The frictional coefficient of bearing material lubricated with CMRO is 0.13 and SAE20W40 is 0.09. The frictional coefficient of CMRO + 0.5 w.% nano CuO is 49 % lesser than CMRO and 18 % lower than SAE20W40. The wear of bearing material lubricated with SAE20W40, CMRO and CMRO + 0.5 w.% nano CuO of 86.77, 136.34 & 82.07 mg. The wear value of bearing material lubricated with CMRO + 0.5 w.% nano CuO has lowest wear and 39 % lesser than CMRO. The wear value of bearing lubricated with CMRO + 0.5 w.% nano CuO has 5 % lesser than SAE20W40. It is also possesses superior tribological behaviour in chemically modified rapeseed oil with nano CuO than the other two lubricating oils. The above mentioned discussions are evaluated, it can be stated that among the three lubricating oils, one can contain nano CuO can be preferred for the lubrication purpose in Journal bearing application.

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