The tribological behavior of TiO_2, CeO_2 and ZrO_2 nano particles as a lubricant additive in rice bran oil

Rani S, College of Engineerring Trivandrum
ranigiri2011@gmail.com

Abstract

The present work is to understand a comparative effect of tribological and thermal properties of three different nanoparticles in bio lubricant formulation based on rice bran oil. The nanoparticles included in our study are Cerium dioxide, Titanium dioxide and Zirconium dioxide nanoparticles. Each particle were separately dispersed at 0.1 to 2% by weight of the rice bran oil using an ultra sonicator for 5 hours. The tribological properties were obtained by a four ball tester. The surfaces were analyzed by scanning electron microscopy and energy dispersive spectrometry after the wear test. The thermal properties were analyzed by thermo gravimetric analysis and differential scanning calorimeter. All nanoparticle suspensions show a reduction in tribological properties among which titanium dioxide at 0.3% by weight shows very good wear and friction reduction. The SEM and energy dispersive spectrometry shows that a tribolayer of nanoparticles are formed. The layering capability is good for titanium dioxide nanoparticles. The mechanism can be explained in terms of rolling and sintering of nanoparticles. These nanoparticles can be used as anti-wear and anti friction additive for biolubricant formulation.

Index Terms— Minimum 7 keywords are mandatory, Keywords should closely reflect the topic and should optimally characterize the paper. Use about four key words or phrases in alphabetical order, separated by commas

1 Introduction

Finding out a renewable energy source is one of the main aims of modern industrialization. Frictional losses are the main source of energy loss in mechanical systems and are very much important to reduce the frictional forces using energy efficient lubricant with suitable additives. The selection of the base oil and additives are based on the performance, environmental friendliness and renewability. In this context, vegetable oil is one of the suitable base oil to develop different types of lubricants by adding proper additives. The biodegradability, non toxicity and good lubrication properties of vegetable oils are well established in many literatures[1-3]. The disadvantages of vegetable oils are high pour point , low oxidative stability and high wear rate [4, 5].

In this paper, three inorganic rare earth nanoparticles Titanium dioxide, Cerium dioxide and Zirconium dioxide have been selected for improving the tribological properties of rice bran oil. Copper oxide and titanium dioxide have been added to engine oil and the performance was evaluated and seen that it shows a better performance [6]. The performance of titanium dioxide in liquid petroleum also have been evaluated and seen that it reduces wear and improves extreme load carrying capacity [7]. The Zirconium oxide has been added to poly alpha olefin and seen that it attains good wear reduction[8]. Hence it is necessary to know the comparative effect of wear reduction of these nanoparticles in rice bran oil as part of the biolubricant formulation. Rice bran oil is found to be potential base oil for biolubricant formulation in our previous studies [9, 10]. The titanium dioxide is found to be the best nanoparticles in case of wear reduction and Zirconium dioxide has got the least wear reduction property.

2 Experimental Details

2.1 Preparation of nanolubricant

The main properties of nanoparticles used in the experiments are listed in Table1. The nanoparticles CeO_2, TiO_2 and ZrO_2 are supplied by M/s Sigma Aldrich, India. The nanoparticles are added into the rice bran oil on the weight percentage basis ranging from 0.1 to 2% by weight. The oil was then agitated using ultra sonicator for five hours to ensure uniform dispersion

2.2 Tribological properties

The four ball tester consists of three fixed balls and one rotating ball on top of these fixed balls. The three fixed balls are tightly packed in a ball pot. The coefficient of friction of lubricants can be evaluated as per ASTM D5183-05. The rotating ball is rotated at a speed of 600rpm for one hour. The balls are made up of chrome alloy steel with 12.7mm diameter. This is made from AISI standard steel no E – 52100. The hardness is around 64 HRC. The load applied is 400N and temperature inside the pot is 75°C. The wear test also is conducted by using four ball testers as per ASTMD4172-94. The rotating ball is rotated at 1200rpm with a load of 400N for one hour .The temperature is kept at 75°C. After one hour the wear scar diameter of the fixed balls are noted. The balls should be cleaned by acetone and heptanes before each run.

3 Results and discussions

3.1 Tribological properties

The coefficient of friction, wear scar diameter and extreme pressure load of mixture of the rice bran oil and nanoparticle has been evaluated using four ball testing machine. Among the three nanoparticles, titanium Oxide nanoparticle shows a lesserr wear scar as shown in Fig1.

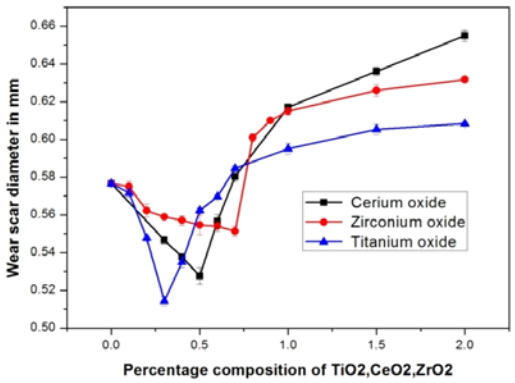

Fig.1 The variation of wear scar diameter of rice bran oil with various percentage compositions of nanoparticles

The coefficient of friction and wear rate was evaluated for various percentage composition of titanium dioxide in rice bran oil and seen that the coefficient of friction and wear scar diameter are lower at 0.3% by weight of titanium dioxide. The tribological properties are increasing with increase in percentage of titanium dioxide in rice bran oil. The tribological properties of mixture of CeO2 and rice bran oil are minimum at 0.5% by weight of CeO2. Similarly ZrO2 show a minimum wear and friction at 0.7% by weight. The suspension of 0.5% of cerium dioxide shows low friction and wear. Cerium oxide also shows good wear reduction of the 8% decrease in wear scar diameter and 90% decrease in specific wear rate. The highest wear rate is observed for zirconium dioxide. The reduction in wear scar diameter for 0.7% zirconium oxide in rice bran oil is 4.3% .The variation of coefficient of friction at various proportions of each nanoparticles are shown in Fig. 2. The low coefficient of friction is observed for cerium dioxide at 0.5% by weight of rice bran oil

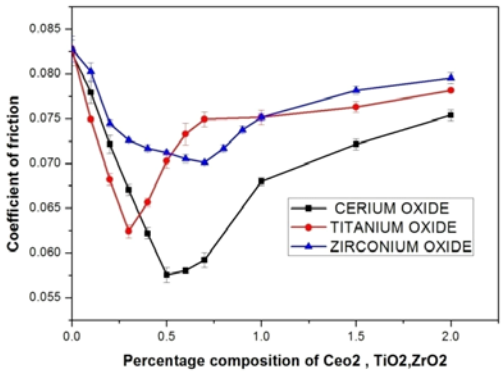

Fig.2 The variation of coefficient of friction of rice bran oil with various percentage compositions of nanoparticles

3.2 Wear scar surface analysis.

The SEM images of wear scar of pure rice bran oil and mixture of rice bran oil with various nanoparticle are shown in Fig 3. The SEM image shows a reduction in scar diameter and with the surface look smoother in case of rice bran oil with cerium dioxide and rice bran oil with zirconium dioxide .The SEM image of titanium dioxide in rice bran oil shows rough texture than that of the other two. As the percentage composition of nanoparticles increases, the wear also reduces till it reaches an optimum value. At this optimum concentration the maximum tribofilm formation happens which protects the surface from wear. When the percentage content increases from the optimum value, layer thickness will not increase further and the extra nanoparticles present in the interface will cause third body abrasion and the wear increases slightly. Among all the nanoparticles , ZrO2 has the highest hardness and it has got more wear compared to other two nanoparticles

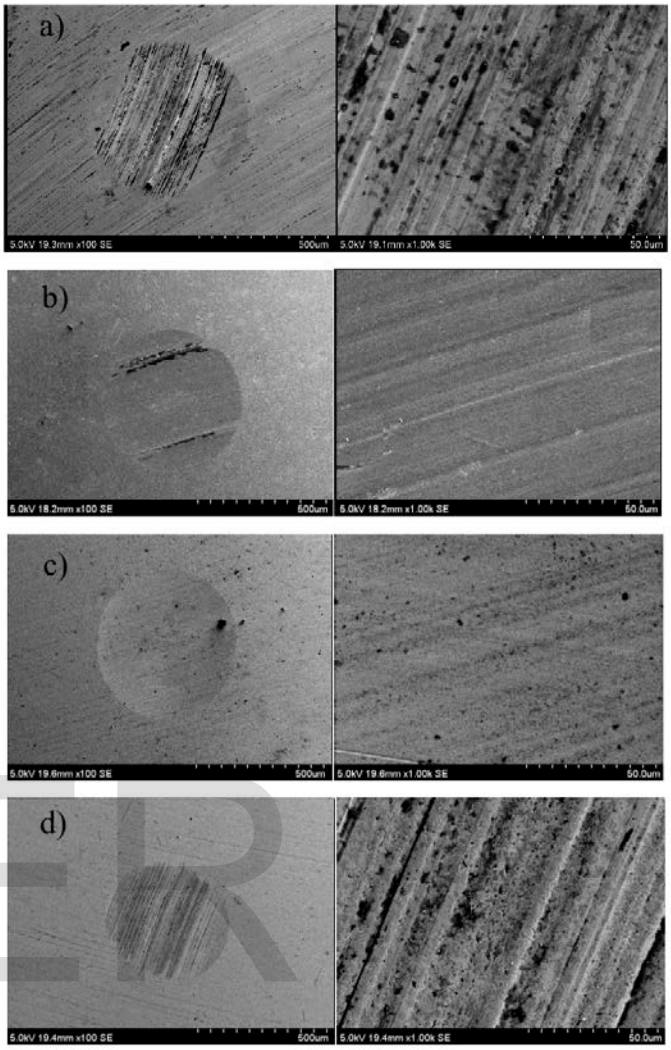

Fig. 3 SEM image of wear scar diameter of a) RBO+ 0.7%Zirconium dioxide b) RBO+ 0.5% Cerium dioxide c)RBO+ 0.3% Titanium dioxide

The reduction in the coefficient of friction is due to the combined effect of sintering of nanoparticles and rolling effect of nanoparticles between the mating surfaces. The percentage content of nanoparticles increases the number of nanopartilces present in the interface also increases and reaches a proportion at which friction and wear has a minimum value. At this minimum value, the sintered tribofilm reaches maximum thickness and some nanoparticles causes rolling effect too. Thus the nano lubricant achieves minimum wear and friction at this percentage. As the concentration increases further , rolling

effects of nanoparticles reduces and due to more concentration of nanoparticles third body abrasion happens which leads to high wear and friction.

4 Conclusions

1. The coefficient of friction of the nano lubricants with optimum percentage of each nanoparticle is very less compared to the coefficient of friction of the base oil.

2. Cerium dioxide shows the maximum reduction in the coefficient of friction at a percentage of 0.5% by weight. This composition of rice bran oil has the lowest coefficient of friction among all the three nanoparticles.

3. Titanium dioxide shows the highest wear reduction at an optimum percentage of 0.3% by weight. This is the lowest percentage among the other nanoparticles. The EDS shows that the capability of forming tribo layer is more for titanium dioxide.

4. Zirconium nanoparticles are the hardest nanoparticle among the three nanoparticles selected for study. The optimum percentage content of Zirconium oxide nanoparticle is 0.7% , which is higher among all the other nanoparticles. The wear reduction is very less for Zirconium dioxide and the reduction in the coefficient of friction also is less for zirconium dioxide. Acknowledgement

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