International Journal of Research in Chemistry and Environment
Vol. 2 Issue 3 April 2012(44-47)
ISSN 2248-9649

Research Paper

Effect of Polytetrafluoroethylene on Wear Properties and Extreme Load Carrying Properties of Lubricating Oil

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Available online at: www.ijrce.org

(Received 09th March 2011, Accepted 19th April 2012)

Abstract: *In this paper, optimization of ultrasonication process to improve the mixing of polytetrafluoroethylene (PTFE) in lubricating oil has been done. The effect of PTFE on wear preventing and extreme pressure (EP) properties of lubricating oil with AISI 52100 steel balls were studied using four ball testers. The composition of oil lubricants changed by adding 0.5 wt% to 4.0 wt % of PTFE powder. Initially ultrasonic treatment was given to PTFE powder for proper mixing of PTFE powder in lubricating oil. Values of wear scar diameter with respect to applied load, extreme pressure values i.e. weld point value were tested for various PTFE compositions in oil. Wear scar diameter (WSD) was measured with optical microscope results show a reduction of average scar in the three lower balls and the increase in the welding point. The oil sample with higher PTFE percentage had higher welding loads and the smaller scar diameter for the same load. Coefficient of friction for both with and without PTFE additive mixed lubricating oil is estimated experimentally. The topography of ball specimens was examined using 60 mm macro lens canon 1000D camera. The observed wear response of the sample has been substantiated through the characteristics of wear surface.*

Keywords: Extreme pressure, Four ball tester, Polytetrafluoroethylene (PTFE), Wear scar.

Introduction

Polytetrafluoroethylene is widely used for numerous engineering applications owing to its unique properties, such as excellent chemical resistance, excellent frictional properties and high-temperature stability [1]. It exhibits a low coefficient of friction and a low wear rate. Wear is extremely important to industry from both a mechanical maintenance and economic point of view. One of the reasons for the failure of mechanical system is wear of moving components therefore wear becomes a much more important factor in determining the life of mechanical system. In the case of sliding elements, extreme pressure (EP) additives are extensively used in hypoid gears, metal cutting and metal forming operations.

Much research has been done over years on the friction and wear mechanisms of PTFE and PTFE composites to optimize material selection in mechanical engineering design and to develop new types of lubricating materials [1, 2, 3, 4, 5].

This paper reports the results of evaluating PTFE as an additive to mineral oil. A four ball tester was used to evaluate the wear and extreme pressure properties of PTFE added lubricating oil with standard test method for wear preventive characteristics of lubricants.

The results obtained with the additive in different percentages were compared with those obtained without additive.

Material and Methods

PTFE powder with average particle diameter of 0.2 μm procured from Dupont chemical. Base oil manufactured from Hindustan Petroleum Limited.

Ultrasonic Mixing: The present study deals with treatment of PTFE by ultrasonic waves at frequency of 20 kHz using fully automated lab-scale 750 Watt ultrasonic processor (Sonics Vibra-cell materials, Inc.USA). Ultrasonic wave is a pressure wave that propagates through a medium, resulting in vast amount of energy dissipation, and violent collapse of gas and vapour bubbles (termed “acoustic cavitation”), which possibly induces many physico-chemical effects. The ultrasonic probe was dipped in such a way that it was immersed 2-3 cm into the lubricating oil.

PTFE powder with different percentage (0.5%, 1%, 2%, 3%, and 4%) was added to engine oil and uniformly mixed with ultrasonic processor for different time duration i.e.30, 45, 60 and 90minutes. It was observed that the ultrasonication intensity and treatment exposure time significantly affects the efficiency of the ultrasonication process followed by the solids concentration. The optimum condition of ultrasonic treatment was 75 W/cm^2 ultrasonication intensity, 60 min time duration, and 0.5 - 2 % total solids concentration.

Four ball Testing: Four ball tester KTR-30L-M manufactured by Ducom India was used to find out wear scar and extreme pressure load. The tester unit consists of main body in which spindle assembly, AC motor with AC drive and loading arrangement are mounted, main body is fixed firmly to base plate.

The machine has a vertical spindle that rotates a 12.7 mm diameter male ball chuck with an alloy steel ball at 1200 rpm. Underneath it, three other identical balls that form an equilateral tetrahedron with the first ball are clamped together in a pot with a lock ring that is filled with the lubricant to be tested. The pot is mounted on a disc over a thrust bearing which automatically centers the top ball held in the chuck. The load is thus evenly distributed over three points of contact between the top rotating ball and the three stationary balls underneath. Loads in the range of 15 to 400 kg were applied to the thrust bearing. Rotation of the driving spindle causes frictional torque, which produces a scar on the three lower balls.

Tests were carried out according to the standard test methods for measurement of wear preventive properties and extreme pressure properties of Lubricating Fluids, using an ASTM D4172 and ASTM D2783. For extreme pressure test Pre-selected successively higher loads were applied in 10sec. run series until the balls were welded at their weld point. Wear preventive test were carried out at 15, 20, 40, 60, 80 and 100 Kg load. New balls were used for each test, all pieces and balls were first cleaned with an acetone and then carefully dried. On each of the three lower balls, two measurements of the wear spot were made with microscope. One of which was on X-axis direction and other on Y-axis direction, the average scar diameters obtained were plotted versus the load in kg also the resulting welding load was plotted for each lubricant

Coefficient of friction test: The high frequency reciprocating rig was used to calculate coefficient of friction of lubricating oil. A 2ml test specimen placed in the test reservoir and it is pushed against a non rotating steel ball on reciprocating arm with a load of 200gm. The ball is made to rub against the disc with a 1mm stroke at a frequency of 50Hz for 30 min.

Test Disc: 10mm disc of AISI E-52100 steel machined from annealed rod with Vickers hardness HV 30.

Test Ball: AISI E-52100 steel balls with a diameter of 6mm having Rockwell hardness ‘C’ scale 58-66.

Results and Discussion

Sliding wear preventive and extreme pressure tests were run on a four-ball tester using mineral base oil without additive and with additive in different percentages (0.5%, 1.0%, 2.0%, 3.0% and 4.0%) in order to estimate the influence of the additive and its concentration on lubricant. Average scar diameters of the three lower balls in each run are shown in table 2.

Table1
Physical charecteristics of base oil

S. No.	Property	Value
1	Density	887kg/m^3
2	Kinematic Viscosity at 40^0C	120cSt
3	Viscosity Index	120
4	Flash Point	210^0C
5	Pour Point	-22

Table 2
Average wear scar in mm at different load

Load in Kg	Average Scar Diameter in mm					
	Oil without PTFE	Oil + 0.5%PTFE	Oil + 1.0%PTFE	Oil + 2.0%PTFE	Oil+ 3.0%PTFE	Oil + 4.0%PTFE
15	0.25	0.22	0.20	0.18	0.15	0.15
20	0.28	0.24	0.20	0.20	0.16	0.16
40	0.40	0.34	0.34	0.32	0.30	0.25
60	0.54	0.44	0.42	0.42	0.40	0.34
80	0.74	0.60	0.54	0.50	0.52	0.50
100	0.87	0.76	0.72	0.68	0.66	0.63

Four ball wear test: The relationship between the load and wear scar diameter for lubricating oil with and without additive is shown in Table 2 and Figure.2. it has been observed that the wear scar value reduced with increase in PTFE percentage in lubricating oil.

Figure 1: Ball pot assembly and Four ball testing assembly

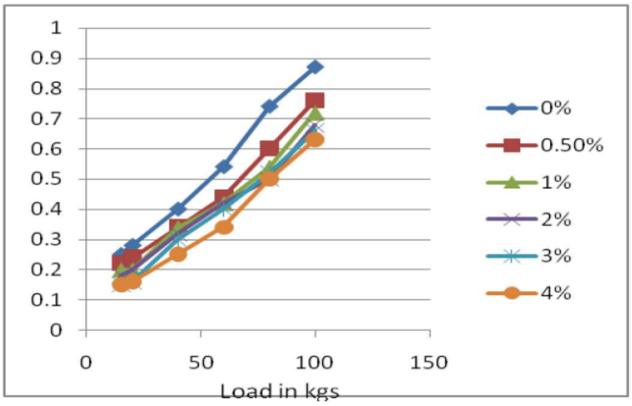

Figure 2: Wear Scar diameter (mm) for oil with different PTFE percentage at different Load (kg)

Four ball extreme pressure test: Figure 3 shows final weld load for base oil and the different percentage of PTFE added oil. It highlights the spectacular increase from 270kg for the pure base oil to 350 kg for the lubricant with 4% PTFF. This result represents 30% increase in efficiency.

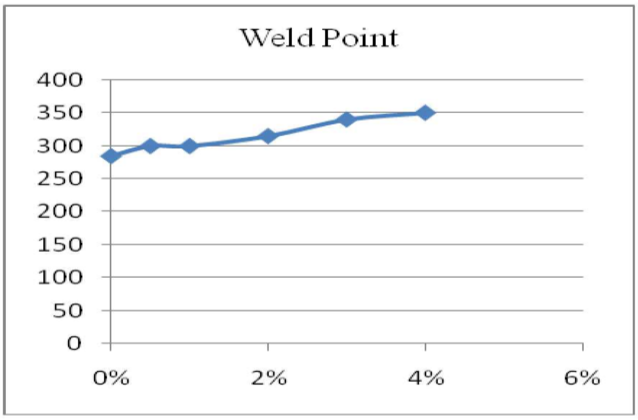

Figure 3: Weld points for oil with different PTFE percentage

Coefficient of Friction: The coefficient of friction property studied with varying the concentration of PTFE in lubricant. PTFE based lubricants shows the significant decrease in the coefficient of friction from 0.05 to 0.026 with increasing the PTFE concentration in lubricant. This is due to low surface tension and low friction nature of PTFE material, which decrease the frictional force between the two sliding surface, which leads to decrease in coefficient of friction of lubricant with increasing the concentration of PTFE.

Conclusion

The following conclusions can be drawn from the results presented above:

It has been demonstrated that the wear behavior of the lubricant tested turns out to be sensitive to the percentage additive, the more additive in the lubricant, the smaller and the wear scar for the same load.

Weld point increases with increase in PTFE percentage in the lubricanting oil i.e. the load carrying capacity of the oil increases with Percent increase of PTFE in lubricant.

The optimum condition of ultrasonic treatment was 75 W/cm^2 ultrasonication intensity, 60 min time duration, and 0.5 - 2 % total solids concentration.

Coefficient of friction decreases with increase in PTFE percentage in lubricating oil. The protective mechanism of the PTFE is caused by formation of thin layer of PTFE on metal surface which absorbs the mechanical energy

Acknowledgement

UGC grant Commission of India for providing fellowship and contingency grant to carry out the research.

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