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Tribological analysis of extreme pressure and anti-wear properties of engine lubricating oil using four ball tester

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Abstract

Lubricants play a key role in lubrication of components of internal combustion engine and enhancing the working life of engine. Load carrying capacity of lubricating oil is important parameter for their various different applications. The anti-wear and extreme pressure additive properties studied have been found to show anti wear anti friction properties of lubricants under the experimental condition. In this paper, extreme pressure and anti-wear of fresh and used SAE 15W40 and SAE 20W50 grade lubricating engine oil of different working time cycle were investigated. Tests were carried out according to the standard test methods for measurement of wear preventive properties and extreme pressure properties of lubricating oils, using an ASTM D4172 and ASTM D2783. The tests were carried out on Ducom four ball tester TR-30L under atmospheric pressure of lubricating oil at 392N loads and at 75°C temperature with constant speed of 1250 rpm.

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Keywords: Anti wear properties; Extreme pressure properties; lubricating oil; Wear scar.

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1. Introduction

The lubricant oil reflects the performance of engine through its properties, while condition of lubricant oil can affect the performance of engine as well. Lubrication is widely used in machines, automotives and industries to eliminate surface to surface contact of components of machines and engines. Lubrication increases the efficiency as well as working life of engines and it protects against the corrosion and wear. Wear affects the life of engine; if wear of engine components increases life of engine decreases. [1] This interrelationship between engine performance and

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engine lubricant is an important diagnostic tool to evaluate the engine health and performance. [2] The components affect by adhesive and abrasive wear of engine components. and due to these contamination abrasion of surface of engine bearings, cams valve train, piston rings and cylinder liners. Contaminations were abrasive based on observed scars and debris generated between metallic tests surfaces. [3]

The main function of lubricant is to reduce friction, wear, corrosion, temperature, contamination and shocks. Extreme pressure and anti-wear additives eliminate the metal to metal contact by addition of lubricant film forming agents that protect by direct contact of surfaces and abrasive wear phenomena. The addition of anti-wear and extreme pressure additives are used for enhancing the anti-friction and anti-wear properties of lubricants. [4]

The four ball tester is used to investigate the anti-wear and extreme pressure properties of lubricating oil at various conditions such as higher load, controlled temperature and constant rotating speed of ball., Investigate the comparison of depletion of the extreme pressure and anti-wear additive and properties of fresh and different working life cycle lubricant oils using four ball tester and make a interrelation ship between the working life of lubricating oil and performance of engine. [5]

2. Experimental Procedure

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. New balls were used for each tests, all pieces and balls were first cleaned with an acetone and then carefully dried. The steel ball bearings were placed into the oil cup assembly and the oil cup was tightened using a torque wrench to prevent the bottom steel balls from moving during the experiments as shown in fig. 1(a) The upper spinning ball was locked inside the collected and tightened into the spindle. The test lubricant was introduced into the oil cup assembly. The researcher confirmed that the oil filled all of the voids in the test cup assembly.

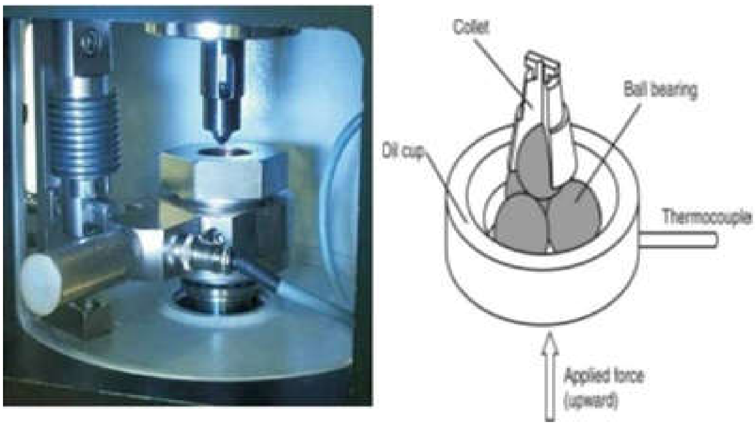


Fig. 1(a) Four ball testing assembly

Fig. 1(b) Four ball tester

The oil cup assembly components were installed into the frictionless disc in the four-ball machine and, to avoid shock, the test load was applied slowly. The lubricant was then heated to the desired temperature of 75º C. When the set temperature was reached, the drive motor, which was set to drive the top ball at the desired speed, was started as shown in fig. 1(a) After the 1-hour test period, the heater was turned off and the oil cup assembly was removed from the machine. The test oil was then drained from the oil cup and the scar area was wiped using a tissue. The bottom balls were placed on a microscope base that was designed to hold the balls during microscopic evaluation. 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. [8]

3. Coefficient of friction

The friction coefficient was calculated according to IP-239, and is expressed as follows:

$$\mu = 0.22248T/W$$

Where T is the frictional torque in kg.mm and W is the applied load in kg [9]. The frictional torque data were recorded by a computer and the friction coefficient was calculated. For experimental conditions with a 40 kg normal load, the worn surface on the ball-bearing lubricated with both unused (D and P) and Used (D1,D2,P1andP2) engine lubricating oil sample showed almost similar wear patterns with parallel grooves. Some of the grooves were deep while others were shallow. This finding shows that the dominant wear mechanism was abrasive wear. The grooves resulted from stiff particles, such as wear debris of the oxide layer, or ragged adhesion. The particles contaminated the lubricant and damaged the ball-bearing surface.

4. Result

4.1. Wear scar diameter

Table 1, shows the effect of load on the measured wear scar diameter for both fresh lubricant and used lubricant sample. From this table, it is very obvious that the wear scar diameter increases gradually with incremental increases in the duration of lubricant used in the engine. The temperature increase contributed to a decrease in the test lubricant viscosity. Low viscosity lubricants tend to create only a thin film. Increasing temperature causes the lubrication film to become less stable and eventually to break down. As a result, the metal-to-metal contact area will increase and produce an increase in the wear scar diameter under high pressure conditions [35]. Weld Region Formula is used for finding out the Minimum Scar Diameter (MSD) as follow:

$$\text{Minimum Scar Dia.} = \frac{\text{Horizontal (Parallel) reading(H.R.)+ Vertical(Normal) reading(V.R.)}}{2}$$

$$\text{M.S.D.} = \frac{\text{Average readings}}{2} \text{ in mm}$$

Table 1.Measurement of wear scar

Engine oil sample	Unused sample (wear scar in mm)			Average wear scar(in mm)
	Ball 1	Ball 2	Ball 3	Unused
Diesel engine unused oil sample (D)	67	71	62	66.67
Diesel engine used oil sample (D1)	128	113	122	121
Diesel engine used oil sample (D2)	119	129	134	127.33
Petrol engine unused oil sample (P)	53	61.5	54	56.17
Petrol engine used oil sample (P1)	91.5	78.5	87	85.666
Petrol engine used oil sample (P2)	157.2	160	160	159.06

Fig. 2. Wear scar (a) Sample D; (b) Sample D1; (c) Sample D3

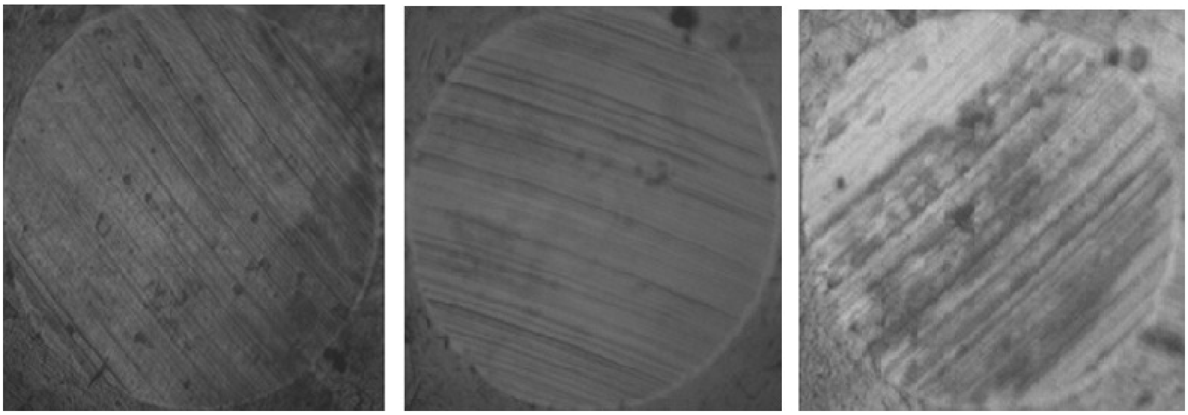
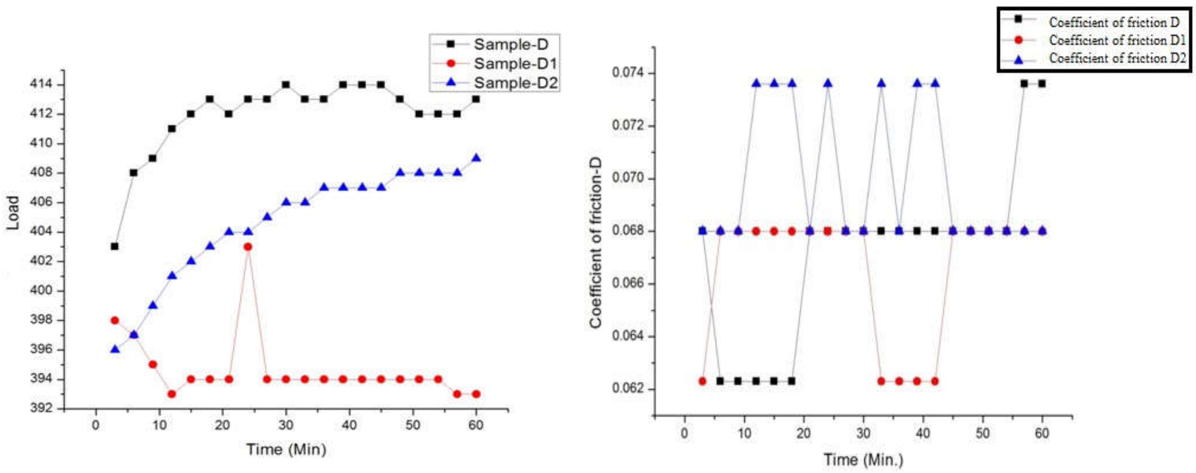
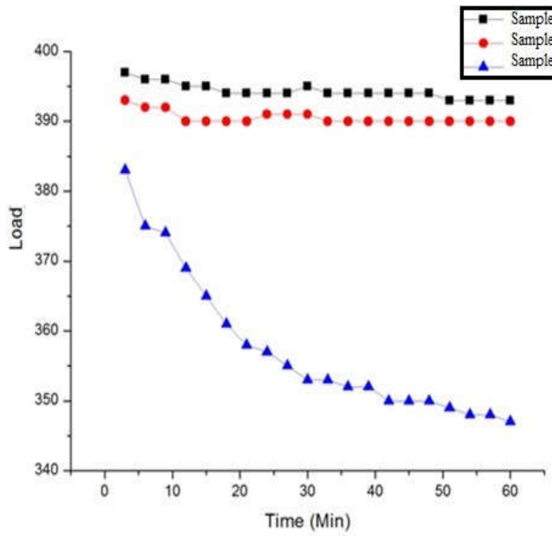
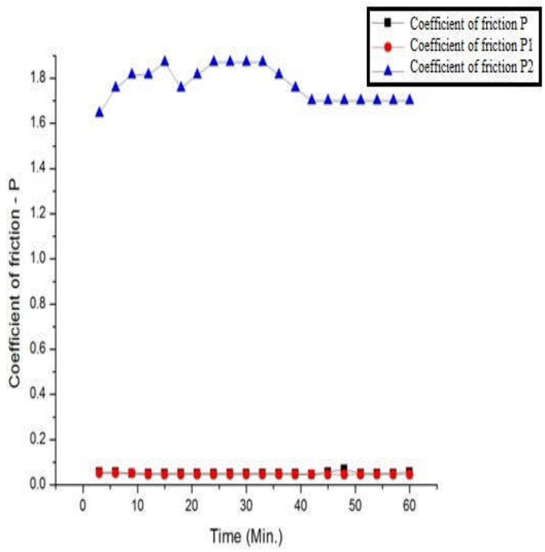


Fig. 3. Wear scar (a) Sample P; (b) Sample P1; (c) Sample P3



Graph 1. Diesel engine oil sample (a) Load vs time (b) Coefficient of friction vs Time





Graph 2. Petrol engine oil sample (a) Load vs time; (b) Coefficient of friction vs Time

5. Discussion

Discussion of following result of Diesel and Petrol Engine Car oil samples are given below:

- Diesel Engine Car**:** Results and wear scar figure shows that Diesel engine D1 oil sample lubricated steel-chromium alloy ball has less wear scar diameter and shallow groves as compare to Diesel engine car D2 engine oil samples. These observations were giving information about state of antifriction and anti-wear properties of Diesel engine D2 engine oil that properties have been depleted firstly as compare to Diesel engine D1 oil. Finally concluded that components of diesel engine D2 have max wear out.
- Petrol Engine Car: In this test, result and wear scar figure shows that Petrol engine P1 oil sample lubricated steel-chromium alloy ball has less wear scar diameter and shallow groves as compare to Petrol engine P2 engine oil samples. This observation gives information about state of antifriction and anti-wear properties of Petrol engine P1 engine oil samples that these properties has been depleted firstly as compare to Petrol engine P1 oil sample. Finally concluded that components of petrol engine P2 have max wear.

6. Conclusion

The balls lubricated with both unused (D and P) and used (D1, D2, P1and P2) engine lubricating oil samples showed almost similar wear patterns with parallel grooves. Some of the grooves were deep while others were shallow. These findings show that the dominant wear mechanism was abrasive wear. The grooves resulted from stiff particles, such as wear debris of the oxide layer, or ragged adhesion. The particles contaminated the lubricant and damaged the balls surface.

- In diesel engine, anti-wear and anti-friction properties of lubricating oil sample D2 has been depleted maximum and before the lubricating oil sample D1.
- In petrol engine, anti-wear and anti-friction properties of lubricating oil sample P2 has been depleted maximum and before the lubricating oil sample P1.

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