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SMALL ENGINE LUBRICANT OIL FRICTION TESTER

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ABSTRACT

Extreme friction often occurs in engine components, causes energy loss and reduces the lifespan of the engine. Changing the engine lubricating oil according to scheduled maintenance may reduce the chances of engine breakdown. In this study, an apparatus to test the effectiveness of the engine lubricating oil was developed. It has a special feature that able to test the lubricating performance when subjected to journal bearing abrasion or camshaft-rocker arm abrasion. The experimental procedure was adopted from the ASTM D2782-02 (Timken Test method). Commercially available small engine lubricant oil with an SAE viscosity grade of 20w-40 (mineral-type) from three different manufacturers were tested. In the first experiment, dead weight of 1-10 kilograms were loaded to investigate the effectiveness of the test lubricant oil against extreme pressure. The second and third experiments were on the erosion measured due to abrasion of journal bearings and camshaft intake lobe respectively. Different lubrication performances were found even though the tested oils had the same viscosity grade.

Keywords: friction test, engine lubricating oil, erosion, wear.

INTRODUCTION

Frictional force is a one process in which both surfaces touch each other. These forces are having advantage and disadvantage, but extreme friction can give adverse effect on a surface in engine components and cause wear and erosion which may lead substantial losses to consumers (Abdullah *et al.* 2013). Great losses may happened because the choice of lubricant oil not suitable for the engine characteristics. The immediate effects on the engine are loss performance, increased fuel consumption and increased environmental pollution (Duchesne *et al*. 2000).

There are many lubricant manufacturer in the market. Commonly, the price of the lubricant reflex the quality of the lubrication oil. However, an expensive price lubrication oil may not be effective for all type of engine. In contrast, the oil grade plays important role in providing optimum performance, as the lubricant viscosity depends on the engine temperature and ambient temperature (Barton *et al.* 1981). Quality of lubricant oils give effect for the role in the efficiency of internal combustion engines and can reduce wear and environmental pollution (Spiegelberg & Andersson 2006).

Previous studies found that 60% of the total loss of mechanical efficiency in the piston-liner contact. Meanwhile, the crankshaft bearing journal was 25% of mechanical efficiency followed by the valve train and camshafts was recorded 15% loss of mechanical efficiency. These results were obtained using a single cylinder engine (Allmaier *et al*. 2013).

One of the research on these matters is a High Frequency Reciprocating Rig (HFRR), which is used to test lubricant oil in low temperature. This equipment has a soft disc (190 - 210 Hv) and a hardball at the top. The two components were drowned on the oil tank and the hardball has rubbed on both surfaces. The force of friction was measured using piezoelectric while function to heat the block. The experiment was able to analyze the formation lubrication film and coefficient friction on lubrication engine oil (Mcqueen *et al.* 2005).

The most common method of testing lubrication oil is Timken Test OK Load. The apparatus evaluates the contact pressure at the surface when extreme pressures were given in the test cup and test block. The scoring was produced in test block when the shaft rotates and the load lever was attached to a specific weight. Then the scoring is normally analyzed by a low-power (50× to 60×) microscope and the image scoring was analyzed by image software as suggested by (ASTM 2014).

To date, many other apparatus are available for performing friction test on lubrication oils. Most of them were designed to measure the contact pressure of the oil viscosity and the test on bearings. However, these tools cannot detect the profile radius wear occurring on the camshaft (Neville *et al*. 2007). It is important to study the impacts and effects of wear in order to prolong the engine life cycle life (Wang 1993).

FRICTION TESTER MACHINE

This paper describes the testing done to evaluate a newly developed equipment to perform friction test on journal bearings, camshaft and rocker arm of a four-stroke single cylinder 150cc engine. The equipment is shown in Figure-1. The equipment has a dimension of 530 mm x 510 mm x 750 mm. The equipment consist of 2 shafts, four journal bearings, one 3-phase motor, an inverter and a timer.

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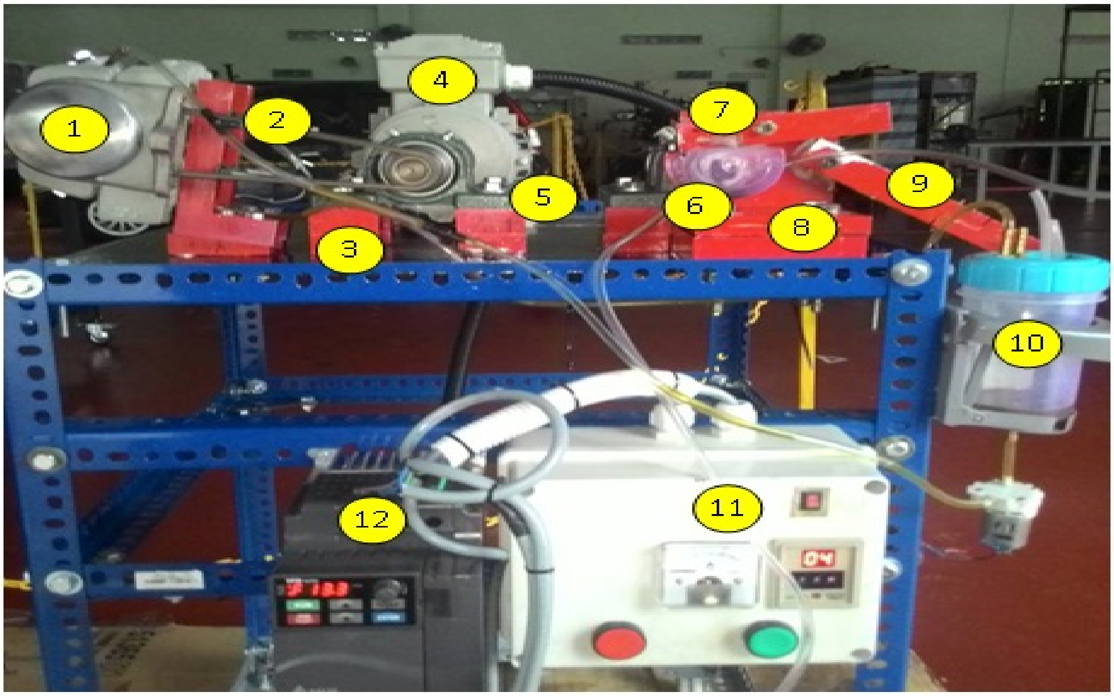

Figure-1. Friction tester machine components.

The function of each component of the friction tester machine is described as follows:

- Cylinder head: Functions to cover and placing the camshaft and rocker arm.
- Timing chain: Functions to transfer the power from rotating gear to another gear.
- Bearing mounting: Functions to position the bearing housing and the mounting has absorbed the vibration form shaft rotating. Size is 45 mm x 38 mm x 25 mm, made from aluminum.
- 3-phase motor: Functions to rotate the shaft in the machine.
- Bearing and housing: Function to ensure the friction reducing when shaft rotating and the vibration also reduce. Specification of the journal bearing is shown in Table-1.
- Bearing sample: The test block as the sample for the experiment. Its specification is shown in Table-2.
- Test cup: Acting as a container to be flooded by the lubricant under test.
- Mounting lever arm: Functions to place the lever arm and test cup; the dimension is 100mm x 100mm.
- Lever arm: Functions to hold the sample (test block) and designed as a beam. The sample was given the extreme pressure; meanwhile the tip of lever arm was attached to dead weights acting as a test load.
- Oil sump: Sump for lubricant under test.
- Control box & timer: Controls the timing of each experiment.
- Inverter: Controls the speed of the 3-phase motor.

Table-1. Journal bearing specifications.

Parameters	Values
Brand	ABR
Inner diameter	25 mm
Outer diameter	47 mm
Width	16 mm
Maximum speed	9500 RPM

Table-2. Test block sample.

Parameters	Values
Type	Journal bearing
Material	Cast iron
Shape	Cylindrical
Diameter	12 mm
Length	24 mm
Weight	30.70 grams

This newly developed friction tester equipment has several useful features such as:

- Ability to perform a friction test on the bearing, camshaft and rocker arm, in addition to the commonly used Timken Test.
- A timer device which can be set to run the tests at any specified duration.
- A cut off the wiring box system, as a safety feature; when the tool is experiencing high load motor, the shaft rotation will stop immediately.

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- A cover for rotating part, to protect the user from high temperature oil and hot chips spark when running the experiment.

TEST METHOD

In order to evaluate the working of this machine a test run was made. The test run method was adopted from ASTM D2782-02, Standard Test Method for Measurement of Extreme-Pressure Properties of Lubricating Fluids (Timken Method). Three SAE 20w-40 engine lubrication oil samples from different manufacturer were tested. In this study, they are labeled as Lube P, Lube S and Lube C. The test method is used widely for the determination of extreme pressure properties for specification purposes. Users are cautioned to carefully consider the precision and bias statements herein when establishing specification limits.

There are three types of test can be performed using this friction tester machine: Lubricant Effectiveness Test, Bearing Abrasion Test, and Camshaft Abrasion Test. Before the start of each test, several measures were taken such as:

- The materials and the tools shall be inspected to ensure that they are in good working condition.
- Protective gear such as goggle and glove shall be worn at all time during the experiment.
- The test cup must be placed on the spindle and making certain that it well seated.
- The test block must be placed in the test block holder and adjust the levers to ensure the part is properly aligned.
- The lubricant to be tested must be filled in the reservoir.
- The test block must be coated with the lubricant to be tested.
- Rotate the machine slowly for few revolution either by hand or by suitable control mechanism before switching on the machine.

Lubricant effectiveness test

The Timken OK Load is a standardized measurement that indicates the possible performance of extreme pressure (EP) additives in a lubricating grease or oil. The unit of measurement is in kilograms-force. The Timken OK Load is the highest standard load at which the spinning bearing race produces no scoring mark on the test block. However, this study attempted a different approach. In this study, tests were to measure the effectiveness of any lubricant when subjected to surface abrasion by extreme pressure load. The test parameters are shown in Table-3. For each lubricant oil sample, a new cylindrical journal bearing was used. The tests set a spindle to rotate at a constant speed of 800 RPM while bringing into contact with the test block under load by an arbitrary dead weight attached at the end of the lever arm. The contact area was flooded with the lubricant being tested. During the test the load was increased gradually until the spindle seized i.e. stopped rotating. The maximum load was recorded.

Table-3. Effectiveness test parameters.

Parameters	Values
The rotating speed	800 ± 5 RPM = 13.3Hz
Sample of lubricant	Lube P, Lube S, Lube C
Lubricant viscosity	20w - 40 (Mineral)
Test block	1 bearing for each sample
Effective load	1 to 10 kilograms
Duration	Until it seized

Bearing abrasion test

The objective of this test is to measure the rate of abrasion of any sample block. From this test, the performance of the lubricant can be compared. The experiment was conducted by attaching a specified weight at the end of the lever arm. 80% of the maximum weight the lubricant can withstand were arbitrarily chosen. In this particular case, a 4kg weight was chosen because the previous experiment found that the rotating shaft stopped when the attached weight on the lever arm is slightly over than 5kg. The pressure was exerted in the test cup and test block in a specified duration as shown in Table-4.

At the beginning, weight of each test block was measured at 30.70g. The experiment had a set time of 1-30 minutes by a timer on the machine. For every 5 minutes, the test was stopped and each test block was cleaned using an ultrasonic cleaner to ensure the accuracy of the test. Next the block was weighted using a gold scale. Then the test block was reattached to the friction tester machine, and the experiment continued until the total duration reached 30 minutes for each sample.

Table-4. Bearing abrasion test parameters.

Parameters	Values
The rotating speed	800 ± 5 RPM =13.3 Hz
Sample of lubricant	Lube P, Lube S, Lube C
Lubricant viscosity	20w - 40 (Mineral)
Test block	1 bearing for each sample
Effective load	4 kg (fixed)
Duration	5, 10, 15, 20, 25 and 30 mins

Camshaft abrasion test

The purpose of this test is to measure the erosion of the surface of a camshaft profile caused by friction when rubbing against the rocker arm. The camshaft and the rocker arm for this experiment were taken from a four-stroke single cylinder 150cc engine. The method for running the equipment is similar to the bearing abrasion test, but the shaft of spindle need to be changed to another spindle to enable the camshaft rotation. The settings of this experiment are shown in Table-5.

The experiment has a fixed time of 30 minutes for each lubricant sample. The erosion on the camshaft intake lobe was measured using a dial gauge on the camshaft profile at eight selected cam angles between 0° and 360° as shown in Figure-2. Prior to the test, the intake camshaft lobe was measured to have a base circle radius of

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10.50 mm and a flank radius of 10.70 mm measured at 45° and 315° cam angle. At the nose peak i.e. at 0° cam angle, the lobe profile radius was measured as 16.0mm.

Table-5. Camshaft abrasion test parameters.

Parameters	Values
The rotating speed	800± 5 RPM =13.3 Hz
Sample of lubricant	Lube P, Lube S, Lube C
Lubricant viscosity	20w - 40 (Mineral)
Test block	Camshaft
Test point	Intake lobe
Duration	30 minutes

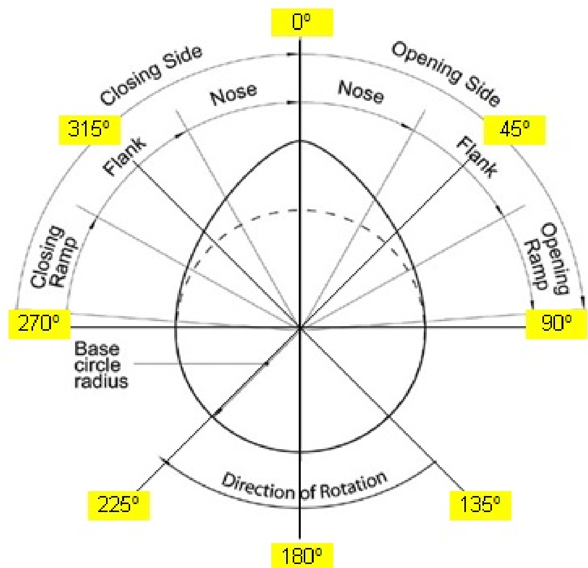

Figure-2. Measurement points on the camshaft lobe.

RESULTS AND DISCUSSION

The result of the lubricant effectiveness test is shown in Table-6. From the test, it was found that lubricant sample P can withstand the highest load at 8.0kg before the spindle seized. Although all three samples have the same viscosity grade, Lube S and C can only withstand 5.5kg and 7.0kg respectively. Such results signified that Lube P might be able to provide superior lubrication and moving parts abrasion protection that resist seizure even under extreme load condition compared with Lube C and Lube S.

Table-6. Result for the effectiveness test.

Lubricant Sample	Maximum Load (kg)
Lube P	8.0
Lube S	5.5
Lube C	7.0

Figure-3 shows test block weight reduction when using lubricant oil sample Lube P, S and C, measured on an interval of 5 minutes. The test for each sample last for 30 minutes. Initially, each test block has the same weight of 30.70g. The load given was 4.0kg. From the time start to the first 5 minutes, a large difference of erosion rate was observed between lubricant samples. Lubricant sample S has the highest erosion rate calculated at 8mg/min while lubricant sample P has the lowest rate at 4mg/min. Between test time 5 minutes to 30 minutes, all test blocks shows similar rates of erosion at 2mg/min. At the end of the tests, test block with Lube P has the lowest total weight loss followed by Lube C and Lube S, measured as 60mg, 70mg and 80mg respectively.

The results showed that lubricant sample Lube P has the best erosion protection during cold-start. When the tests had reached a steady state, all three lubricant samples showed similar performance in erosion protection. It is expected that if the test were to be performed much longer than 30 minutes, all lubrication samples would still provide similar erosion protection. Thus the key for better lubrication can be characterized by their performance during the cold start period.

The result of the camshaft abrasion test is presented in a form of a radar chart shown in Figure-4. Measurements were made after 30 minutes of running at 800 RPM. The radius of eight points distributed across the camshaft intake lobe were measured, where the nose is regarded as 0° in this case. The rotation of the camshaft is in a clockwise direction. The figure shows the decrement of camshaft intake lobe radius due the erosion during the lubricant tests. From the figure, Lube P shows the best lubricating performance among the three oil samples; the camshaft showed the lowest wear. Although Lube C shows better performance compared with Lube S at the valve opening side, both samples show almost similar performance at the closing side.

From the same figure, it is clearly seen that the erosion had heavily occurred only on one side of the camshaft lobe, that is on the valve opening side. Such occurrence was caused by the force exerted by the valve spring against the rocker arm, thus against the intake lobe on the opening side. The stiffer the valve spring, the stronger abrasion force will be exerted by the rocker arm on the camshaft lobe. Although the nose has the largest radius compared to the other section, only minimal erosion occurred. It is believed that at this test rotational speed of 800 RPM, the perpendicular velocity gained by the rocker arm at the opening ramp and the opening flank has enough momentum to sustain the rocker arm motion all the way through the nose region. Thus the minimal force exerted by the rocker arm on the nose of the intake lobe. Similar phenomena occurred throughout the valve closing side.

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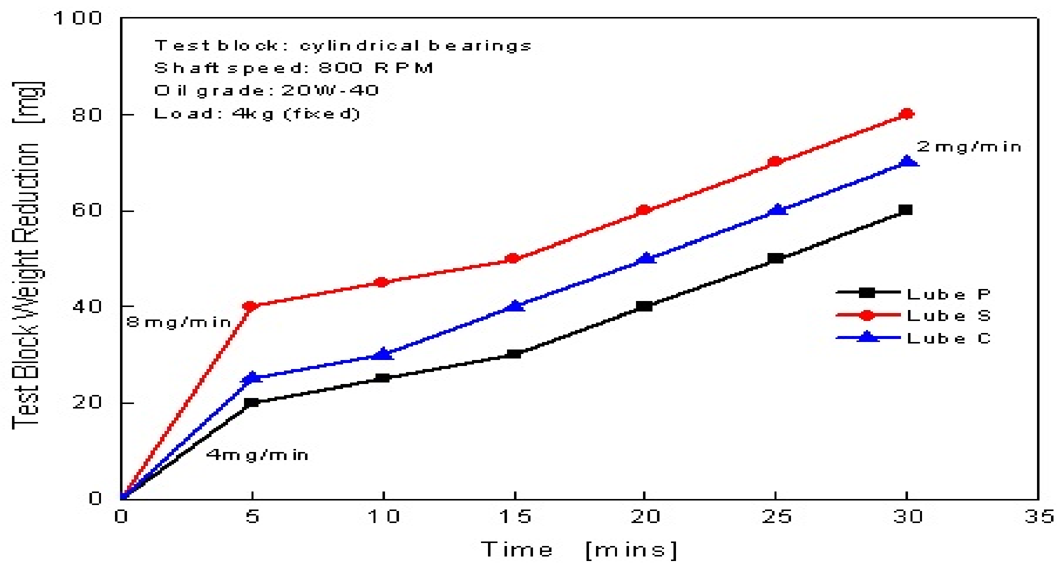

Figure-3. Erosion of the test bearings due to abrasion.

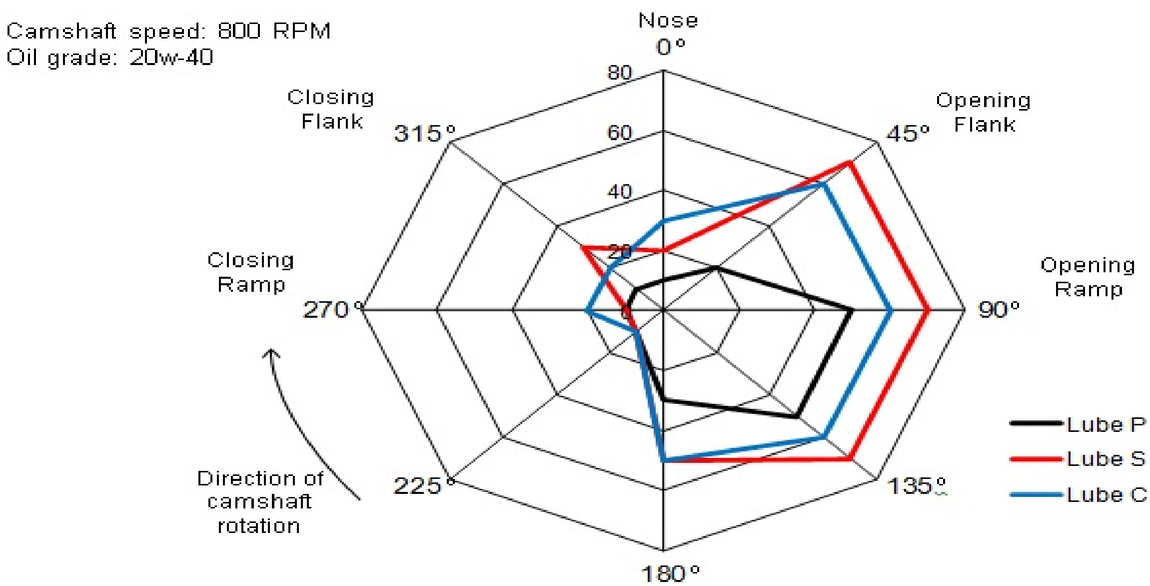

Figure-4. Camshaft intake lobe radius reduction due to erosion (in micron).

CONCLUSIONS

A lubricant friction tester with the ability to perform friction tests on journal bearings, camshaft and rocker arm of a four-stroke single cylinder 150cc engine was developed. Three types of tests were performed during commissioning of this friction tester machine: Lubricant Effectiveness Test, Bearing Abrasion Test, and Camshaft Abrasion Test. From the tests, several conclusions can be made:

- Different lubrication oil from different manufacturer gave different performances, even though the tested oils had the same viscosity grade, and are within similar price range.
- The Lubricant Effectiveness Test may distinguish which tested lubricant has superior lubrication and moving parts abrasion protection that resist seizure even under extreme load conditions.
- The Bearing Abrasion Test confirmed that most erosion occurs during cold-start. When the tests had reached a steady state, all three lubricant samples showed similar performance in erosion protection. Thus the key for better lubrication can be characterized by their performance during the cold start period.
- Camshaft Abrasion Test showed that the erosion had heavily occurred only on the valve opening side of the camshaft lobe. In contrast, minimal erosion occurred

on the valve closing side, including throughout the nose region.

- As this project is still considered a work in progress, the next upgrade would be to install a temperature controller and monitoring system for the lubricant under test.

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