Penerbit Akademia Baru

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 5, No.1. Pages 10-16, 2015

The Effect of Fuel Contamination on the Wear Characteristics of Used Motor Oils

K. F. Abdullah[*,a] *and M. Z. Bahak*[b]

Faculty of Mechanical Engineering, Universiti Teknologi Malaysia (UTM), 81310 Skudai, Johor, Malaysia.
[a,*]*kamelfaizeen@yahoo.com,* [b] *mzubil@utm.my*

Abstract – *There are many contaminants that could lead to the alteration of oil viscosity. Diesel fuel is one of the deteriorating contaminants for diesel engine oils. It is among the main factors that give high impact towards the deterioration of engine oils as one study has found that, in average, 0.36% of total fuel consumption ends up in the crankcase. Many studies have demonstrated the effect of fuel dilution on the wear characteristic. However, there are limited studies that focused on the percentage amount affecting the wear characteristics together with other influencing factors such as load, speed and temperature. In this research, used motor oil - Gibson 20W50 had been mixed well with fuel percentages of 0, 1, 3, 5 and 7, hence creating 5 samples that were run under different speeds. The experiment is conducted by following the ASTM 4172 standard. Based on the results, the fuel contamination in used motor oil was considered limiting at 5% contamination and became totally deteriorated at 7%. Through a Stribeck Curve, it could be understood that wear is inversely proportional to sliding velocity, where it is one of the lubrication parameters together with speed and load. Rough surface on the balls indicated that abrasive wear has occurred due to the use of used motor oil.*

Keywords: Viscosity, Diesel Fuel, Engine Oil, Stribeck Curve, Wear Characteristic

1.0 INTRODUCTION

The durability and lifespan of an engine is highly dependent on its engine oil. Without proper oil, the engine could suffer from wear that could often lead to engine failure [1]. The most important parameter of engine oils is its viscosity. Viscosity plays a significant role in the performance of an engine, as such, it is important that the value must be within a specified range, based on the specifications of the engine [2].

After a certain period of time, the viscosity would undergo changes because of several factors. One of the factors is contamination. Viscosity will gradually increase as the engine oil becomes contaminated with soot, dirt and sludge; or it can be oxidized and thereby decrease in value if it is contaminated with fuel. If the viscosity of the engine oil is too high, the engine must do additional work to overcome the increased viscous drag. However if it is too low, it will lead to the increase in rate of wear as boundary lubrication is created between the surfaces. For this reason, the contaminant levels must be kept low [2, 3].

Fuel dilution is one of the most frequent contaminations in diesel engines, due to its structure. Fuel dilution is defined as the amount of unburnt fuel present or accumulated in the lubricant. It can be caused by problems in the fuel line, injector, carburettor and pump leaks. Fuel

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 5, No.1. Pages 10-16, 2015

dilution will affect the viscosity, increase volatilities of the motor oil and reduce motor oil efficiency [2, 3].

2.0 METHODOLOGY

This research has been done to determine the effect of fuel contamination on the wear characteristic of motor oils from its coefficient of friction and wear scar diameter on the ball bearing by using a Four Ball Tribotester.

Experimental Apparatus. The test is conducted according to ASTM 4172. As shown in Fig. 1 and 2, a Four Ball Test is a test rig designed to test the anti-wear properties of lubricating oils. This machine uses four balls, where three balls are at the bottom and one ball at the top. The upper ball is held in a collet at the lower end of the vertical spindle, which is driven by the motor. The bottom three balls are held firmly in a ball pot containing the lubricant being tested and are pressed against the upper rotating ball at a certain speed for a set of duration.

Figure 1: Four Ball Tribotester

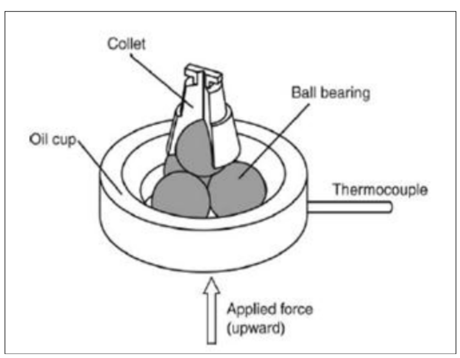


Figure 2: Schematic diagram of the Four Ball Tribotester assembly [5].

Material of Ball Bearing. The ball test material is of AISI E-52100 steel, 12.7mm in diameter, with a surface finish of 0.1mm CLA and Rockwell C hardness of 64 to 66. Before starting a series of tests, four new balls for each test run were cleaned using acetone and tissues before dried in ambient temperature.

Lubricant. The lubricant used in this project was taken from a forklift heavy duty diesel engine. The forklift used Gibson Oil 20W50 SJ/CF mineral oil as the engine oil. Shell FuelSave Diesel was used as a contamination element.

Experimental Parameters. In this experiment, it has been decided that the temperature and the load are kept constant whereas speed is varied. From the literature review, it was found that the speed gives major effect to the wear rate as well as the load. Although the temperature also influences the result, it was decided as to keep the temperature constant.

Table 1: Experiment Parameters

Parameters	**Value**
Speed [*RPM*]	1000, 1200, 1400, 1600
Load [*N*]	392±2 [*N*] or 40±0.2 [*kgf*]
Temperature [^oC]	75±2 [^oC] or 167+4 [^oC]
Time [*min*]	60 [*min*]
Samples [%]	0, 1, 3, 5, 7 fuel contamination

Initially, after the sample preparation was done, the viscosity was inspected to identify the changes it went through after being introduced to the contamination. As the end result, four data were measured, calculated and recorded, which are the friction torque, coefficient of friction, wear scar diameter and flash temperature parameter. Finally, the wear worn surface characteristics were observed and analysed by using a microscope as in Fig. 3.

Figure 3: High resolution computerized microscope Motic BA310MET

Penerbit Akademia Baru
Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 5, No.1. Pages 10-16, 2015

3.0 RESULTS AND DISCUSSION

Viscosity. There have been changes in the viscosity for every contaminated sample. Based on Fig. 4, a higher percentage of fuel contamination in the oil would lower the viscosity obtained. Besides, the viscosity of the samples decreases as the temperature increases. Initially, the samples were being measured of their density by using a hydrometer. The entire sample recorded approximately the same density, which is 0.87 g/cm^3 even though the samples were already contaminated with the fuel.

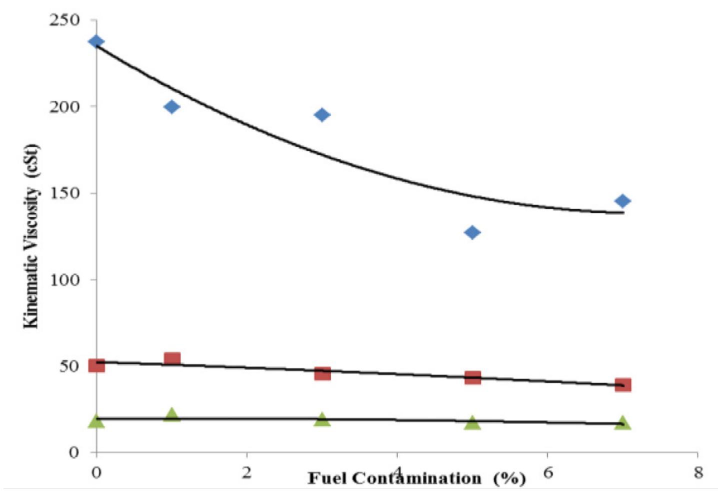


Figure 4: Graph of viscosity [cSt] against fuel contamination [%]

Coefficient of Friction. Fig. 5 shows that an increase in fuel contamination leads to viscosity degradation, hence increasing the value of the friction coefficient. Gur'yanov [4] said that motor oil will lose their minimum carrying capacity when contaminated by fuel. This deterioration, according to him, was due to the significant decrease in film thickness caused by dilution of the oil by the fuel. As a result, the wear of friction increases by two to three orders of magnitude. From the same figure, it shows that when the speed was increased from 1000 to 1400 RPM, the friction coefficients become lower. However, the graph still presents the same pattern.

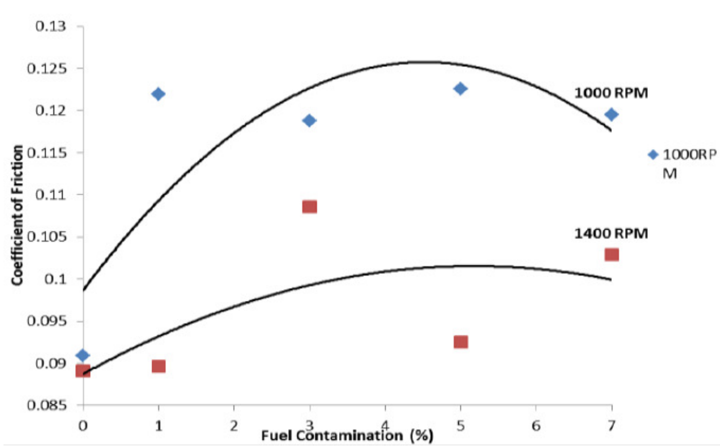


Figure 5: Graph of coefficient of friction against fuel contamination [%]

Journal of Advanced Research Design
ISSN (online): 2289-7984 I Vol. 5, No.1. Pages 10-16, 2015

Wear Scar Diameter. Based on Fig. 6, it shows that the wear scar diameter increases with the increase of fuel contamination. This is due to the degradation of viscosity. As the viscosity is decreasing, the lubrication regime will change as well. Before the contamination, the lubrication layer was thick. However, after being contaminated, it cannot sustain that condition anymore thus degraded to lower viscosity. Because of this, the thickness of the separation layer between the metal becomes smaller, which leads to wear [6]. With the temperature set to 75°C, it significantly affects the wear scar. This is aggravated with the sample condition in which the used oil has lost all additives and performance characteristics

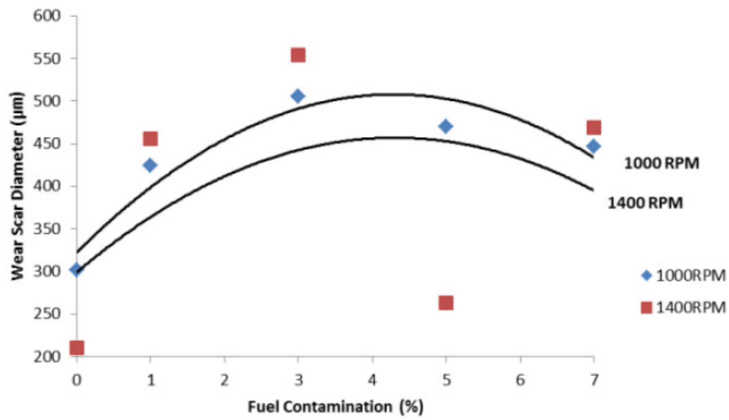


Figure 6: Graph of wear scar diameter [μm] against fuel contamination [%]

Flash Temperature Parameter. Based on Fig. 7, the value of FTP will decrease as the contamination is increased. This is a resulting reaction due to the decrease in the viscosity of the oil. A greater FTP number shows good characteristics of the oil, which also means that it is less likely for the lubricating film to breakdown [7].

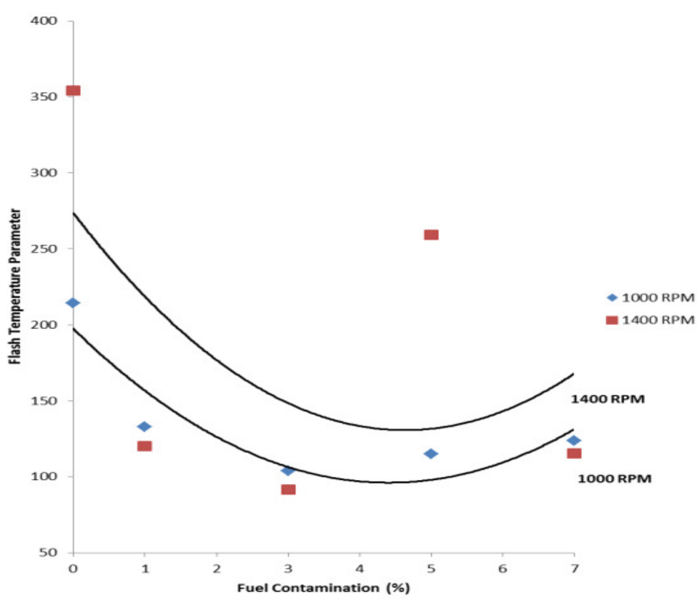
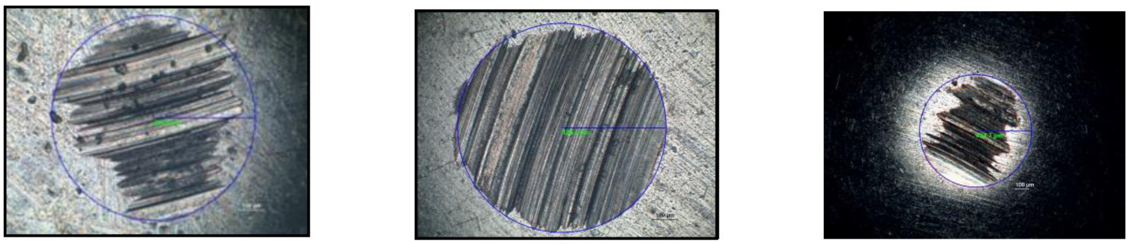


Figure 7: Graph of flash temperature parameter versus fuel contamination [%]

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 5, No.1. Pages 10-16, 2015

Wear Worn Surface Characteristic. Fig. 8 depicts the wear worn surface on the ball bearings under 100x magnification of an optical photomicrograph. All worn surfaces obtained have indicated the infliction of abrasive wear. The surfaces exhibit grooves that are parallel to the steel ball rotational direction. Some of the grooves were deep (dark region) and some were shallow (light-color region). Another observation is that the edge is slightly ragged and obscured by the metal particles. In this case, it can be said that it is possible for rough regions and adhesive wear to occur as the films rupture due to the increase in the percentage of fuel contamination.



(a) (b) (c)

Figure 8: (a) Worn surface at 1000 RPM, 1% contamination; (b) Worn surface at 1400 RPM, 1% contamination; (c) Worn surface at 1000 RPM, 7% contamination

4.0 CONCLUSION

From the experiment, it can be concluded that a higher percentage of fuel contamination in the oil would lower the viscosity obtained. Furthermore, an increase in the operating temperature would also reduce the viscosity as well. Better lubricity could be obtained with a lower coefficient of friction. The friction coefficient increases as the viscosity decreases due to a lesser film thickness, which is caused by fuel dilution. Wear is inversely proportional to sliding velocity. This can be understood through the Stribeck Curve where lubrication parameter is contingent on viscosity, speed and load. However, after a certain speed, it increases linearly.

Contamination of fuel in used motor oil is considered limiting at 5% contamination and totally deteriorating at 7%. Wear scar diameter is found increasing with the increase of fuel contamination. In addition, the wear scar diameter depends on many factors such as load, temperature, speed and properties of the lubricant. Some oils have lower coefficient of friction but produce higher wear scars such as RBD palm olein oil. Contaminations reduce the value of FTP. A greater FTP number signifies greater lubricant performance. All resulting worn surfaces indicated that abrasive wear has occurred. This extreme effect is due to the used motor oil that was applied in this experiment.

REFERENCES

[1] P. Lakshminarayanan, N.S. Nayak, (2011). Critical Component Wear in Heavy Duty Engines. Singapore: John Wiley & Sons (Asia) Pte Ltd

[2] J.A. Addison, W.M. Needelman, (2008). Diesel Engine Lubricant Contamination and Wear. New York: Pall Corporation.

[3] J. Fitch, (2007). Four Lethal Diesel Engine Oil Contaminants. Machinery Lubrication Magazine, May 2007, page 5-7.

[4] Y.A. Gur'yanov, Criteria for Limiting Contamination of Motor Oil by Fuel, Chemistry and Technology of Fuels and Oils 43 (2007) 30-36.

[5] T.C. Ing, M. Rafiq, Y. Azli, S. Samion, Tribological behaviour of refined bleached and deodorized palm olein in different loads using a four-ball tribotester, Scientia Iranica 19 (2012), 1487-1492.

[6] E.R Booser, (2000). CRC Handbook of Lubrication: Theory and Practice of Tribology. Florida: CRC Press.

[7] H. Masjuki, M. Maleque, Investigation of the anti-wear characteristics of palm oil methyl ester using a four ball tribometer test, Wear 206 (1997) 179-186.