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Determination of The Performance of a Diesel Engine When the Engine Oil Is Contaminated with Water

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ABSTRACT

A laboratory study was conducted to test a four-stroke diesel engine's performance when its SAE 50 engine oil was contaminated with water in three volumetric ratios, 0%, 0.2%, and 0.5%, and to determine which of the three ratios of water contamination most affects engine performance. The research performed a one-way ANOVA test with a probability level of 5% to compare the differences in average engine performance produced by the three contamination levels. Engine performance was gauged according to the following characteristics: friction power, fuel consumption, indicated power, and mechanical efficiency. The results showed significant differences at the 5% probability level resulting from increasing water contamination levels. The 0.5% contamination level produced the highest friction power (10.54625 kW), the highest fuel consumption (2.1659 kg/hr), the highest indicated power (16.17 kW), and the lowest mechanical efficiency (34.78595%). The results obtained show that the diesel engine's performance was affected when its engine oil was contaminated with water. According to the engine performance indicators that were studied, the engine performed well with low levels of water contamination (0%) and performed poorly with high levels of water contamination (0.5%). Thus, further research should be conducted to examine other contaminants that engine oil may be exposed to and determine their effects on diesel engines' performance.

KEYWORDS

Diesel engine, engine oil, oil contaminants, engine performance, water contamination

INTRODUCTION

Lubricants are necessary elements of internal combustion engines. No engine can work for even a few minutes without oil. The oil protects machine elements from corrosion and damage by reducing friction between moving parts [1], thus maintaining the engine and extending its service life. Oil reduces friction by functioning as a thin layer that separates the surfaces to which it is applied [2] and will reduce friction between two different metals at a high-stress location if the friction coefficient is around 0.3 [3]. Engine oil contamination is a common occurrence that deserves attention because it harms the engine and leads to engine breakdown. Common contaminants include water [4, 5, 6], fuel [7], and glycol [8]. Water forms in the oil pan due to water condensation caused by the temperature difference during fuel combustion and therefore occurs more frequently in cold weather. Contaminating oil with water causes the chemical additives in the oil to deteriorate. Consequently, the oil loses its properties and degrades. Contaminants change engine oil into an emulsion that closes the oil corridors and filter. This increases friction between moving parts and leads to engine damage. Water also increases the prevalence in oil of harmful acids that corrode an engine's internal parts [9].

Several studies have examined water contamination's effect on engine oil's physical and chemical properties. However, few studies have investigated water contamination's effects on engine performance and associated characteristics such as friction power, fuel consumption, indicated power, and mechanical efficiency. Friction power is a measure of the power lost in the engine due to friction between moving parts—the difference between indicated power and braking power [10]. Friction occurs in engines between the piston and the cylinder wall and at the piston rings, small and large end bearings, fuel pump, oil pump, and water pump as well as due to gas movement in the suction, compression, and exhaust strokes [11]. Engine oil contamination changes its properties, thus increasing friction power [12]. Fuel consumption is the amount of fuel an engine consumes during a specific period; fuel consumption is considered one of the engine's essential performance indicators [13]. Increases in friction power due to water contamination lead to increased fuel discharges [14]. Indicated power depends on the pressure of the combustion gases on the piston inside the cylinder.

This power can be calculated from the internal combustion engine cycle diagram, whose area is proportional to the gases' work during the combustion cycle [15]. The increase in the friction power due to water contamination leads to an increase in the amount of fuel entering the combustion chambers, which in turn leads to an increase in the indicated power needed to overcome the increased friction power to reach the required load [16]. Mechanical efficiency is the relationship between the flywheel's power and the power resulting from burning fuel inside the combustion chambers [10]. Mechanical efficiency is inversely related to friction power. When the friction power increases, the mechanical efficiency decreases [17]. Few empirical studies have investigated water contamination's effects on engine performance while the engine is running. Therefore, three levels (0%, 0.2%, and 0.5%) of volumetric water contamination in SAE 50 engine oil were studied. This research aims to determine which of the three volumetric ratios have a significant effect on engine performance.

MATERIALS AND WAYS OF WORKING

The experiment was conducted in the workshop of the Department of Agricultural Machines and Equipment in the College of Agricultural Engineering Sciences at the University of Baghdad. The experiment was conducted to test the performance of a four-stroke diesel engine manufactured for the Kia Bongo. The engine had a six-liter oil tank connected to a three-line electrical generating unit. The engine's technical specifications are shown in Table 1.

Table 1. The Diesel engine specification.

Manufacturer	Kia company 2J 4 stroke
The way the air is suctioned	Natural aspirated
Number of cylinders	4 cylinders
Bore*Stroke	95*95 mm
Capacity	2.7 L
Valve number	1 Suction * 1 Exhaust
Cooling type	Water type
Generator type & power	Stc 24-kw

Engine oil

SAE 50 engine oil was bought at a local market in Baghdad, Iraq. The engine oil was produced by the Dora refinery. The engine oil was contaminated with water at three levels (0%, 0.2%, and 0.5%) a week before the test began. The fresh engine oil was contaminated with water in three 10-liter plastic containers. We contaminated the first container at 0%, the second container at 0.2%, and the third container at 0.5%. The engine oil was contaminated with distilled water, and the contamination process was as follows:

1. Fill a plastic container with new engine oil SAE 50 in the amount of 6 liters.
2- Calculate the amount of distilled water to be added to contaminate 6 liters of oil with water at level 0.2% of the total volume of oil, as each liter is equal to 1000 ml.

$6 \times 1000 = 6000$ mL

$6000 \times (0.2/100) = 12$ mL

3 - 12 mL of oil was drawn utilizing a syringe and placed in a graduated tube to ensure the volume drawn accuracy.
4 - 12 mL of distilled water is placed in the oil and mixed well with an electric finned mixer for a minute and a half.

The same procedure was used when contaminating the other container of 0.5% oil with distilled water.

Fuel consumption

Fuel consumption was calculated by measuring a particular volume (50 cm^3) of fuel over a calculated period- by utilizing a graduated glass tube in cubic centimeters with a stopwatch [17].

$M{\cdot}f = Qf \times \rho f$

$Qf = Vf / t$

Where M·f = mass flow rate of fuel (kg /s), ρf = fuel density, Qf = fuel discharge (m^3/s), Vf = fuel volume (m^3), t= time (sec)

Brake power

The brake power was calculated by dividing the total electrical loads connected to the generator by the generator efficiency by means of the equation provided by [18].

$BP = T.E.P / Eff_{gen}$

we calculated the total power of a three-line generator on the way of the equation provided by [19].

$T.E.P = P_{L1} + P_{L2} + P_{L3}$

The power of each line was calculated on the path of the equation provided by [19].

$P_L = V \times A \times PF$

Where BP = Brake power (Kw), T.E.P = Total electrical power (kw $_{Elect}$), Eff $_{gen}$= Generator efficiency (80%), P_L= Power for one phase (kw), V = Volte, A= Ampere, PF= Power factor.

Indicated power

The indicated power was calculated with (Morse test) by the equation provided by [20], Considering that the number of engine cylinder was four.

T IP = IP 1 + IP 2 + IP 3 + IP 4

IP 1 = T BP - BP 1

P 2= T BP – BP 2

IP 3 = T BP – BP 3

IP 4 = T BP - BP 4

Where T IP = Total indicated power (KW), IP1, IP2, IP3, IP4 = Indicated power for piston 1, piston 2, piston 3 & piston 4 (KW), T BP = Brake power for four cylinders (KW), BP 1 = Brake power when piston 1 is off (KW), BP 2 = Brake power when piston 2 is off (KW), BP 3 = Brake power when piston 3 is off (KW), BP 4 = Brake power when piston 4 is off (KW).

Friction power

Friction power was calculated by the equation provided by [21].

FP = IP - BP

Mechanical efficiency

Mechanical efficiency calculated by the equation provided by [22].

$Eff_{mech} = BP/ IP$

Procedure

Engine oil SAE 50 was used (locally made from Dora refinery, Baghdad, Iraq) holds the following specifications as showed in table 2:

Table 2. Engine oil SAE 50 specifications.

Lab. Insp. Data	**Dora refinery oil**
SAE	50
Sul. Ash % Wt.	Nil
T.B.N. mg KOH/g Oil	2.04
Kinematic Viscosity at 100C, Cst.	15.4 Cst.
Kinematic Viscosity at 40C, Cst.	144.5 Cst.
Viscosity Index	111
Flash Point	210 C°
Density at 15 C°	0.867 g/ml
Water (%wt.)	Nil

The experiment used a one-way ANOVA model at a 5% significance level. The experiment examined three treatments. The first treatment was not to contaminate the oil with distilled water. The second and third treatments were contaminating the oil with distilled water such that 0.2% and 0.5%, respectively, of the container's volume was water. Each treatment was repeated three times, and the number of experimental trials was therefore nine. The 0% contamination level was tested first, followed by the 0.2% contamination level and then the 0.5% contamination level. After each treatment had been tested three times, the engine oil was changed and the oil filter was replaced. Before starting the experiment, we checked the engine's oil level and ran the engine at 1000 rpm without load for 15 minutes. We then raised the engine's speed to 1500 rpm. We ran the engine until its temperature stabilized. Then, we recorded the data on fuel consumption, indicated power, friction power, and mechanical efficiency.

RESULTS AND DISCUSSION

Figure 1 shows the water contamination levels' effects on fuel consumption. There are significant differences in fuel consumption between the three water contamination levels. The 0.5% contamination level resulted in the highest fuel consumption rate (2.1659 kg/hr). The 0% contamination level resulted in the lowest rate of fuel consumption (2.1659 kg/hr). This is because the contamination of oil with water leads to an increase in friction power, resulting in decreased engine power. Therefore, fuel consumption increases to overcome the increase in friction power [23].

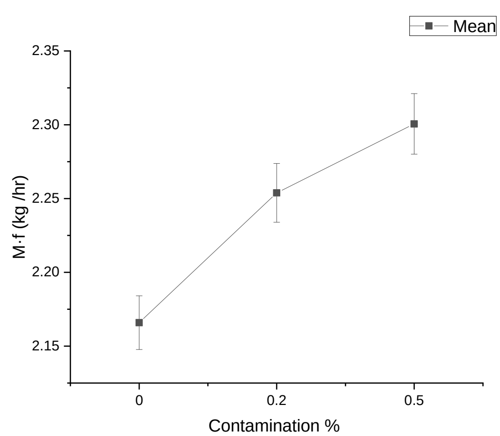

Figure 1. The effect of three water contamination levels of SAE 50 diesel engine on fuel consumption.

Figure 2 shows the effects of the three contamination levels on friction power. Significant differences were found between the treatments at the 5% probability level. The results showed that the 0.2% and 0.5% contamination levels had higher mean friction power (10.255 and 10.54625 kW, respectively) than the 0% contamination level. Water contamination causes engine oil to lose its properties and causes the degradation of additives, leading to oil deterioration and decreasing its capacity to reduce friction, as [24] has demonstrated.

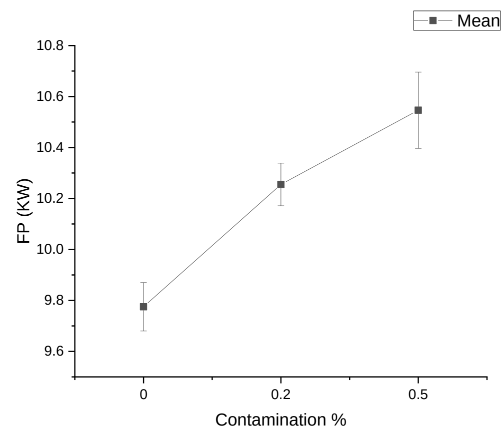

Figure 2. The effect of three water contamination levels of SAE 50 diesel engine on friction power.

Figure 3 shows the water contamination levels' effects on indicated power. There were significant differences in the indicated power between the three contamination levels. The 0.2% and 0.5% contamination levels yielded higher levels of indicated power (15.88 and 16.17 kW, respectively) than the 0% contamination level. This is because the increase in friction power leads to a decrease in engine power; therefore, the indicated power increased to overcome the increase in friction power to reach the desired load, as [25] has demonstrated.

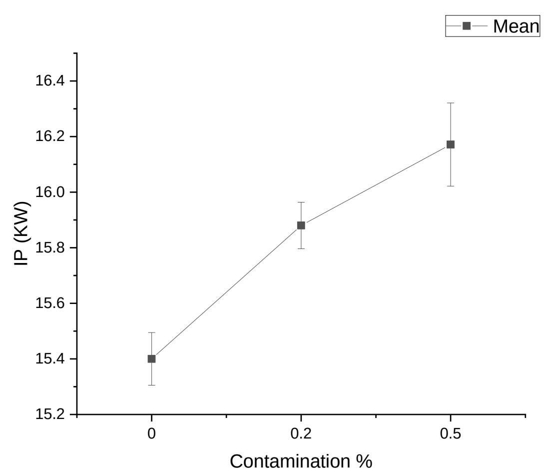

Figure 3. The effect of three water contamination levels of SAE 50 diesel engine on indicated power.

Figure 4 shows the effects of the three water contamination levels on mechanical efficiency. Significant differences were found between the treatments at the 5% probability level. The 0.2% and 0.5% contamination levels resulted in less mechanical efficiency (35.42257% and 34.78595%, respectively) than the 0% contamination level. This is because the increase in friction power leads to a decrease in mechanical efficiency, as [26] has demonstrated.

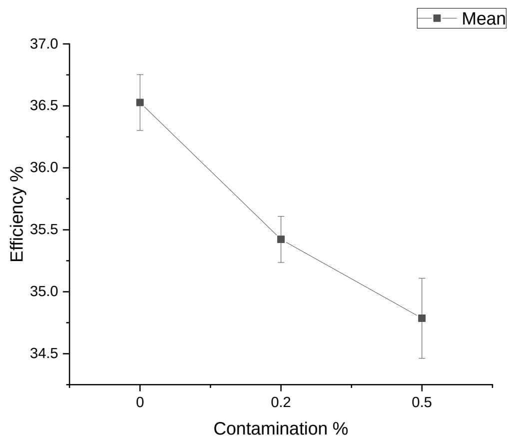

Figure 4. The effect of three water contamination levels of SAE 50 diesel engine on mechanical efficiency.

CONCLUSION

SAE 50 diesel engine oil produced by the Dora refinery in Iraq was contaminated with three different levels (volumetric ratios of 0%, 0.2%, and 0.5%) of distilled water. The three contamination levels were tested in a four-cylinder diesel engine to determine their effects on engine performance. We found that:

1. the 0.2% and 0.5% contamination levels’ fuel consumption were significantly different from that of the 0% contamination level at the 5% level of significance,

2. the 0.2% and 0.5% contamination levels have significantly higher mean friction power and mean indicated power when compared to the 0% contamination level, as confirmed statistically by the one-way ANOVA test,

3. and the 0.2% and 0.5% contamination levels were on average less mechanically efficient than the 0% contamination level.

The results obtained show that the diesel engine's performance is affected when it is exposed to different levels of water contamination. This applied study demonstrated statistically significant differences in engine performance resulting from SAE 50 engine oil being exposed to different levels of water contamination. The highest level of water contamination (0.5%) had the most detrimental effect on engine performance indicators (friction power: 10.54625 kW, fuel consumption: 2.1659 kg/hr, indicated power: 16.17 kW, and mechanical efficiency: 34.78595%). Therefore, it is recommended that more research be conducted to study the effects on engine performance of other types of contaminants that engine oil may be exposed to.

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CONFLICTS OF INTEREST

The researchers declare that there is no conflict of interest.

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