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COMPATIBILITY EFFECT OF TRIBOLOGICAL BEHAVIOR OF OIL USING HIGHER ALCOHOL BLENDS IN SINGLE CYLINDER DIESEL ENGINE

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Article Info

Abstract

Through a single-cylinder compression ignition (CI) engine, this study examines a 200-hour endurance test using DF100 (diesel fuel) as the base fuel and blended fuels, DF95WCO5 (5% waste cooking oil and 95% DF) and DF65WCO20Pe15 (20% waste cooking oil, 65% DF, and 15% n-pentanol). Additionally, DF100, DF95WCO5%, and DF65WCO20Pe15's impacts on exhaust valve surface deposits were examined. In comparison to DF100 and DF65WCO20Pe15, the SEM and EDS research revealed that DF95WCO5 had a greater concentration of carbon deposits surrounding the exhaust valve surface. In addition, ternary blend fuel exhibited less carbon buildup on the exhaust valve than the other two types. This demonstrated that the carbon deposition on the exhaust valve surface was considerably decreased by the addition of pentanol. In comparison to DF100 and DF95WCO5, the ternary blend fuel also showed lower concentrations of iron, copper, nickel, and wear debris. Ultimately, the viscosity and density readings decreased when the engine was run on both blend fuels.

Keywords: *CI engine; Density; Viscosity; Debris analysis*

Introduction

Growing fuel demands and more stringent environmental rules have prompted researchers to look into the term "alternative fuels" [1]. Diesel engines are essential in the locomotive, agricultural, construction, and industrial sectors because of their unparalleled efficiency in turning fuel into power, dependability, durability, and torque capacity [2]. Their widespread usage increases dependency on fossil fuels, leaving developing countries like India mostly reliant on imports to meet their fuel requirements, which has a negative impact on their economy [3–4]. The excessive NOx and smoke emissions from diesel engines are well known to be detrimental to the environment and all living beings [5]. Even a modest substitution of renewable biofuel for fossil fuels will have positive effects on the economy and the environment [6].

Recycling is a crucial step in achieving environmental sustainability. Every year, billions of gallons of used cooking oil are discarded worldwide [7]. Many studies have been conducted on the utilization of spent cooking oil in CI engines in different ways [8–9]. Additionally, the most widely used method for turning residual cooking oil into biodiesel and producing oil with qualities comparable to diesel oil is transesterification [10–11]. However, a practical solution is required to use waste cooking oil as the fuel oil because the process of turning waste cooking oil with a high acid content into biodiesel is difficult [12].

Since reformulating WCO with alcohols is a simple, useful, and reasonably priced method of lowering the viscosity of vegetable oils, researchers have recently grown interested in this approach [13–19]. Ravi Kumar and Saravanan [20] investigated the effects of mixing n-pentanol with spent cooking oil and diesel mixture under different load conditions. The wear particles stay in suspension within the fluid lubricating system. To offer sufficient information about the element source, wear rate, and engine health, variations in the concentrations of metallic particles included in the lubricating fluid may be examined and studied after a specific operating period [21].

The cam shaft, valve system, crankshaft, cylinder liner, pistons, bearings, piston pins, tappet, and so forth are often worn parts in diesel engines [22]. Thus, lubricating oil analysis can reveal direct indicators of engine wear and condition [23].
The impacts of "diesel," "used cooking oil," and "pentanol" fuel were experimentally assessed in one-cylinder engines. This work's main objective is to compare lubricating oil analysis and engine wear using DF, DF5WCO5, andDF65WCO20Pe15 blends respectively.

MATERIALS AND METHODOLOGY

Formulation of Fuels

Reputable restaurants got used cooking oil that was mainly used for frying at temperatures ranging from 130 to 180 degrees Celsius. To get rid of particulates and water particles, the oil was heated and filtered before being blended. Since diesel repels water and water can eventually cause phase separation, this was done to modify the combinations' strengths.

FIGURE 1. Appearance of selected fuels for experiments.

For WCO filtration, a 4µm filter was used. Each test fuel mixture (% vol) was prepared prior to the engine being fueled. The test fuels were blended using a mechanical homogenizer set to 4000 rpm and splash blending for 30 minutes. Surfactants were added, and there were no cetane refiners. Fuel's physical location before combining is shown in Figure 1. Table 1 lists the characteristics of the two blended fuels that were created using diesel fuel (DF100) as the base fuel. The binary fuel, DF95WCO5 ratio, is defined as diesel fuel with 95% vol + WCO-5% vol, and the ternary blended fuel, D65-WCO20-Pe15 ratio, is defined as diesel fuel with 65% vol + WCO-20% vol + nPe-15%vol. were formulated, and their characteristics are shown in Table 1.

TABLE 1. Characteristics of DF100, DF95WCO05 and DF65WCO20Pe15.

Properties		**DF100**	**D95WCO5**	**D65WCO15Pe15**	**Test Method**
Density g/ml		0.85	0.89	0.84	ASTM D-7042
Calorific valve MJ/Kg		42.5	39	40	ASTM D-5468
Viscosity 40 °C Cst		2.28	2.34	1.95	ASTM D-7042
Cetane number		50	53	55.5	ASTM D-6890
Flash point °C		78	85	94	ASTM D-93

Testing Bed of Engine

The experiments were conducted using a water-cooled, four-stroke, single-cylinder, compression ignition engine coupled to an eddy current dynamometer. The engine's schematic diagram is shown in Figure 2. Additionally, Table 2 lists the primary specifications for compression ignition engines.

FIGURE 2. Experimental setup.

TABLE 2. Engine specifications

Model	**Single-Cylinder, Horizontal, water cooled four stroke pre-combustion chamber**
Stroke	80mm
Bore	75mm
Displacement	0.353L
Output (12 hours rating)	4.4kW/2600r/min
Injection pressure	14.2 + 0.5 MPa
Compression ratio	21-23
Specific fuel consumption	278.8 g/kW h
Cooling water consumption	1360 g/kW h
Specific oil consumption	4.08 g/kW h
Maximum engine power	7.7 kW
Valves clearance	Inlet valve 0.15-0.25mm
Maximum engine torque	80 Nm

Lubricant oil samples were taken every 20 hours for each fuel sample during the engine endurance test in order to examine the effects of DF100, DF95WCO5, and DF65WCO20Pe15 mixtures on engine oil. A Say bolt viscometer (two-tube type) was used to measure the viscosities of lubricant oil samples, and a Glass pycnometer was used to measure the density. Engine attrition was measured at the end of the endurance test using an atomic absorption spectrophotometer.

FIGURE3. Fuel samples of lubricating oil.

RESULTS AND DISCUSSION

Lubricating oil analysis

Lubricating oil is a crucial component of IC (internal combustion) engines. It combines basic oils with additives and is made up of a complicated blend of hydrocarbons. Lubricants serve as detergents, dispersion agents, antioxidants, viscosity modifiers, and other cleaning agents in addition to reducing friction and wear on various sliding and rotating engine components [24-25]. After every 20 hours of operation, lubricating oil samples were taken in order to examine the impact on the engine oil during the endurance tests conducted on the DF100, DF95WCO5, and DF65WCO20Pe15 mix. The following parts provide the investigation's findings.

Viscosity

Kinematic viscosity is a critical feature of engine lubricating lubricants. While a drop often denotes lubrication fluid dilution, a rise in viscosity typically suggests that the lubricant is degrading due to contamination or oxidation [26]. Kinematic viscosity measurements were made at 40°C and 100°C, and the results are depicted in Figures 4 and 5, respectively. The experimental results depicted that throughout the endurance test, the kinematic viscosity of all blended fuels and base fuel dropped for 40°C and 100°C. The most likely cause of this drop in lubricating oil viscosity is gasoline dilution of the crankcase oil. Viscosity was significantly reduced during the first 20-hour operation, as can be observed. Lubricants contain variety of chemicals, including antioxidants and anticorrosion agents, and it is expected that various additives could be activated (form protective coatings) due to combine effect of pressure and temperature with the passage of time of operation [27]. The lubricant first passes through various tribochemical processes rather of forming the protective coating, which causes viscosity degradation to occur more quickly than it would for the remainder of the working time [28]. However, DF65WCO20Pe15 demonstrated a more significant decline in engine lubricating oil viscosity in comparison to DF100 and DF95WCO5 during the engine endurance test.

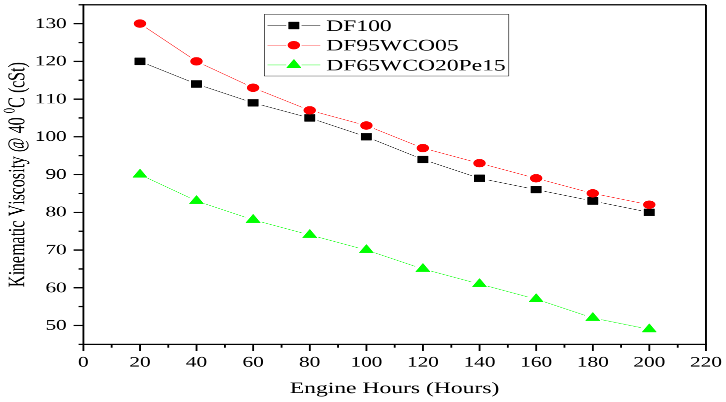

FIGURE 4. Kinematic viscosity at 40°C of diesel and blend fuels.

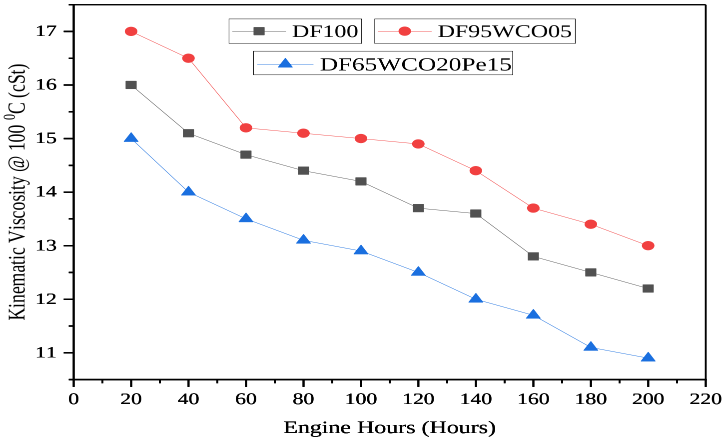

FIGURE 5. Kinematic viscosity at 100°C of diesel and blend fuels.

The engine oil samples' decreased viscosity during the endurance test may result in increased wear on the moving parts, which could shorten the engine's life [29]. Some report state that unburned biodiesel mix that gradually enters the crankcase may cause the lubricating oil's viscosity to weaken, reducing the lubricant coating's thickness and ultimately hastening oil component wear [30]. The DF95WCO5 fuel's incomplete combustion was caused by inadequate atomization and larger droplet sizes from the injectors due to its higher viscosity, surface tension, and specific gravity combined with lower volatility led to the fuel's incomplete combustion, and the leftover unburned fuel on the cylinder walls is scraped into the crankcase by the piston rings. Furthermore, this unburned gasoline deteriorates the engine oil by dissolving in it. Consequently, biodiesel fuel accumulates in the crankcase, further diluting the engine oil. Furthermore, a number of problems, such as catalyst poisoning and a reduction in oil performance and durability, can result from excessive engine oil dilution [31]. Taking into account the previously mentioned data, Figs. 5 and 6 demonstrate that lubricating oil viscosity decreased more when DF65WCO20Pe15 was used as engine fuel than when DF100, DF95WCO5 was used.

Density

It is possible to measure the density of engine lubricating oil, which is essential for figuring out whether the oil has been diluted with gasoline or contaminated by wear metals. Consequently, the density of used engine oil increases due to the presence of wear particles, diluted gasoline, and increased moisture content [32].

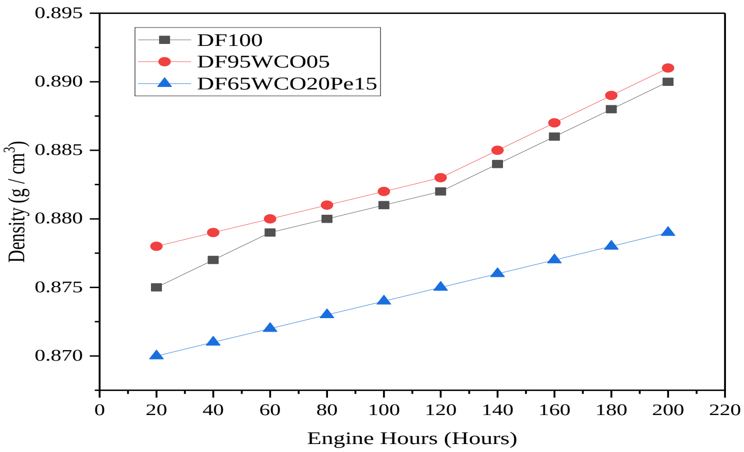

FIGURE 6. Density of Diesel and Blended Fuels.

As the engine oil samples are used, their density shows an increasing trend (Figure 6). First, the engine's components start to wear down faster, and gasoline starts to dilute. Therefore, when the engine is running with the DF65WCO20Pe15 mix, the combined effect of these factors has a greater impact on the rate of rise in the engine oil's density than when it is running with the DF100, DF95WCO5 mix. As can be seen, the density increased most during the first 20 hours of operation. Kinematic viscosity decrease explanations are consistent with density increases.

Engine wear

The amount of metallic particles in engine oil during endurance testing gives important details about the rate of wear and the element's origin. The amount of wear that has occurred on the engine's essential components can therefore be reasonably estimated by performing a metal analysis on the lubricating oil. Consequently, it is feasible to predict the engine's state at that moment , Additionally, the crankshaft and cylinder liner may produce chromium (Cr) , the bearings and bushings may produce copper (Cu) , the piston or ingested dust may produce aluminum (Al), the bearings, paints, and grease may produce lead

(Pb), and the bearings, bushings, and lubricants may produce magnesium (Mg) [33]. By analyzing the amount of metallic particles in the lubricating fluid, one can accurately predict the wear rate, element source, and engine condition of a diesel engine. Iron (Fe), copper (Cu), and nickel (Ni) are frequently found in lubricating oil following engine use [34]. To measure engine analysis wear and debris, hollow cathode lamps of each element were positioned independently in an Atomic Absorption Spectrophotometer (AAS). Standard solutions containing elements such as iron (Fe), copper (Cu), and nickel (Ni) were produced. DF100, DF95WCO5, or DF65WCO20Pe15 were used to fuel the engine during the endurance test. The various wear particles found in the engine lubricant are depicted in Figure 8. Compared to DF100 and DF65WCO20Pe15, it is evident that DF95WCO5 has a higher metal concentration. Research indicates that while fuels with additives might result in lower exhaust emissions, they might also wear down more quickly than fuels with a high sulfur content. Oxidation and wear may result from a chemical reaction that happens when N-pentanol'soxygenand unsaturated fatty acids come into contact with metal surfaces [35].Furthermore, there's a possibility that there are traces of metal contaminants. As a result, there is more wear debris or metal fragments breaking off surfaces in the lubricant for DF95WCO5. This is particularly evident in areas with elevated levels of Fe, Cu, and Ni. The wear rate is subsequently greatly decreased. The composition of the lubricant contains a variety of additives, including anti-corrosion compounds and antioxidant additives. Depending on the kind and function of foreign matter, the lubricant first undergoes a number of tribochemical reactions with metals before producing a protective film. The participating additives must have time to participate in or neutralize the metal debris that was blown into the lubricant.

Iron (Fe)

The iron metal particles that have accumulated in the old lubricating oil of the engine sump are the result of corrosion, wear of the crankshaft, bearing, piston rings, gears, cylinder liner, valves, and their guides [40].

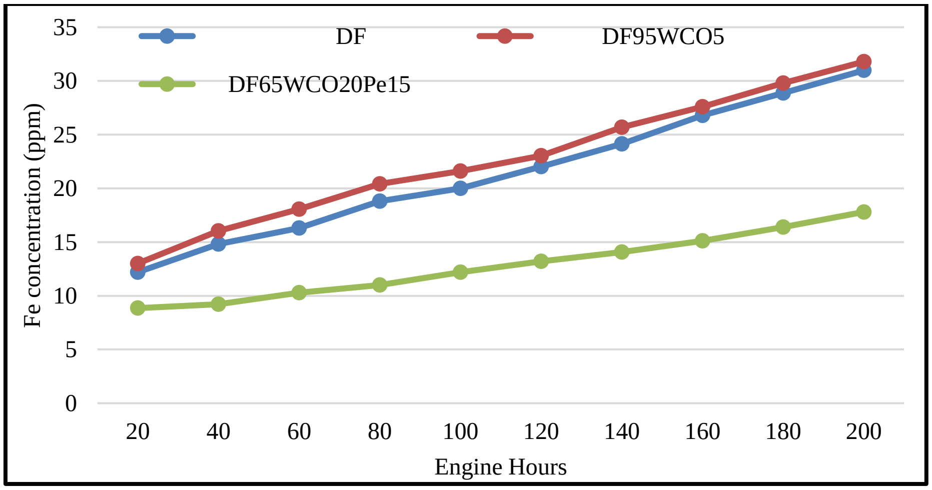

FIGURE 7. Iron Concentration V/s Engine Hours

It is clear from Figure 8 that the iron growth rate is higher for DF95WC05 and DF100 fuel. Iron concentration was lower in the lubricating oil drained from the diesel-powered engine than in the engine powered by the mix fuel DF65WC020Pe15. Compared to the blend-fuel engines, the diesel-fueled engine in Figure 7 showed less iron wear. The highest concentrations of iron were found in the binary blend DF95WCO5 and the ternary blend DF65WCO20Pe20 converted to DF100, respectively.

Copper (Cu)

Bearing and bushing are the most typical sources of copper concentration [36]. Based on the examination of wear debris. Figure 8 showed the copper concentration in binary and ternary blends of pure diesel, such as DF95WC05 and DF65WC020Pe20-fueled engines, in relation to the number of hours that lubricating oil was consumed after every 20 hours. The figure clearly showed that a binary blend yields a higher copper proportion. However, compared to diesel fuel, the engine was barely affected by the addition of n-Pentanol as a ternary blend.

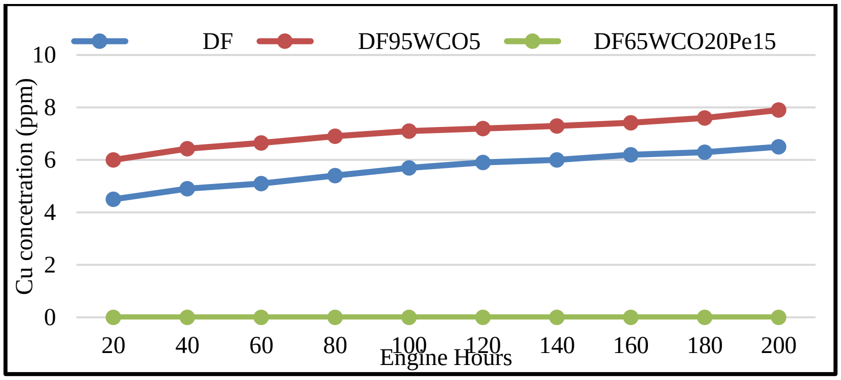

FIGURE 8. Iron Concentration v/s Engine Hours

The ternary fuel blend exhibits reduced copper wear, as seen in Figure 8. The highest copper concentration is found in the binary DF95WC05 and DF100 combination. However, due to their extremely low or insignificant concentrations, the computer considered the ternary mixes DF65WC020Pe20 to be non-detective.

Nickel (Ni)

Nickel is concentrated in parts such as shafts, cams, rods, springs, valves, and valve guides [37]. Figure 10 displays the findings in relation to the lubricating oil's dominant nickel metal concentration.

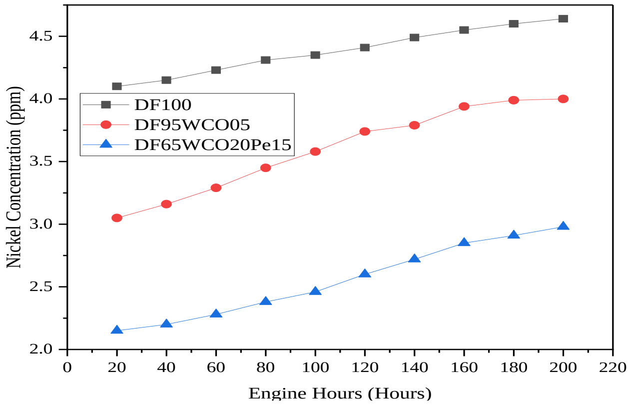

FIGURE 9. Nickel Concentration v/s Engine Hours

The figure illustrates that the amount of nickel element is only marginally at its lowest level when an engine is powered by a ternary blend of DF60WCO20Pe15 and diesel fuel. In this case, however, binary blend (DF95WCO5) was determined to be better than diesel fuel.

CONCLUSIONS

In this investigation, a 200-hour endurance test was used to examine how DF100, DF95WCO5, and DF65WCO20Pe15 mix fuels affected lubricating oil and engine wear. In this regard, the following conclusions might be made in light of the experimental findings:

1. When the engine was powered by DF and DF95WCO5 rather than DF65WCO20Pe15, the viscosity of the lubricating oil decreased in relation to engine running time at 40 °C and 100 °C. When used, DF65WCO20Pe15 demonstrated a higher reduction in engine lubricating oil viscosity than DF100 and DF95WCO5.
2. Throughout the endurance testing with both fuels, the engine oil's density increased. When the engine was powered by the DF65WCO20Pe15 mix, the engine oil density increased more.
3. When the engine was running on DF95WCO5 instead of DF100 and DF65WCO20Pe15 during the engine endurance testing, there were more metallic particles in the engine oil.

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