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EFFECTIVE REMOVAL OF EXHAUST VALVE DEPOSITS USING HIGHER ALCOHOL WITH GUTTER OIL IN SINGLE CYLINDER DIESEL ENGINE

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Article Info

Abstract

This study examined a CIDI engine's exhaust valve. while excessive silt builds up on the exhaust system walls, especially while driving in an urban area, or when there are leaks in the vacuum or exhaust pipes, the valve has a tendency to become stuck. To determine the amount of deposition buildup on the exhaust valve, the engine was operated at a constant speed and load. Regarding this, to find out how three tested fuels—DF, DF90GO10, and DF70GO15Pn15—affect long-term endurance tests, a single-cylinder diesel engine was chosen and tested for 200 hours on each fuel sample. The results of the analysis showed that the exhaust valve's running surface was severely damaged. The results demonstrated that DF90WCO10 generated comparatively more deposits, especially on the exhaust valve. Additionally, the deposits formed on important engine parts, including intake/exhaust valves, when DF90WCO10 was employed had a completely different elements composition and structure than when DF and DF70GO15Pn15 were used. In contrast to both fuels, it was found that adding n-pentanol as a ternary mix produced less deposits. Overall, the inclusion rate of waste cooking oil showed that deposits were more common, especially on the valves, and that they were also more likely to be brittle and moist.

Keywords: *Diesel Engine, Gutter oil, N-pentanol, Deposit formation, Exhaust Valve.*

Introduction

To solve environmental problems, several countries are now attempting to create a cleaner, more sustainable energy source [1]. Recently, researchers have placed a higher priority on alternative fuels, especially ones that can partially or completely replace diesel fuel. The most promising alternative to diesel fuel is biodiesel [2-4]. One of the most crucial elements in achieving environmental sustainability is recycling [5]. The globe throws away billions of gallons of wasted cooking oil year [6]. However, GO poses a serious environmental risk if it is not disposed of appropriately. GO has the potential to pollute and obstruct waterways. The regular operation of waste water treatment facilities may be hindered by the WCO's entry into the waste water system [7]. Treating and recycling waste combustion products (GO) for use in diesel engines is a reasonable approach for energy security and environmental well-being [8]. With all expenses related to collection and treatment, GO also has the added advantage of being affordable [9]. Recycling GO as a renewable fuel for diesel locomotives is another promising strategy to reduce dependency on finite fossil oil supplies. Even though the inventor of the diesel engine, Rudolf Diesel, originally intended for it to run on vegetable oils [10], using vegetable oil directly in contemporary diesel engines can result in problems like excessive engine wear, lubrication oil gelling, heavy carbon buildup in engine parts, injector coking, piston ring sticking, and fuel filter clogging [11]. Due to inadequate fuel-air mixing, atomization, and vaporization, diesel engines generate a lot of particles because of GO's high viscosity and low volatility. Researchers have taken notice of GO reformulation using alcohols because it offers a simple, useful, and affordable method of lowering the viscosity of vegetable oils [12–18]. There aren't many research on the examination of diesel and n-pentanol combinations [19]. One of the most promising alcohols is n-pentanol, which belongs to the class of high carbon alcohols. N-pentanol, a five-carbon straight-chain compound, has been investigated in diesel engines [20–27]. This study's primary objective is to compare the exhaust valve deposits generated by 200-hour endurance tests using waste cooking oil driven by diesel fuel and n-pentanol, respectively.

Nomenclature

ASTM	American society for testing and materials
C	Carbon
^{0}C	Degree centigrade
Cu	Copper
CI	Compression ignition
DF	Diesel fuel
DI	Direct injection
DF95GO5	Diesel fuel 95% + Waste cooking oil 5%
DF70GO15Pn15	(70% volume diesel, 15% volume gutter oil, and 15% volume 1-pentanol).
EDX	Energy dispersive X-ray spectroscopy
Fe	Iron
IC	Internal combustion
Ni	Nickel
O	Oxygen
SEM	Scanning electron microscopy
Ni	Nickel
WCO	Waste cooking oil

1. **Material and methods**

2.1. Fuel Preparation and Characterization

The spent cooking oil was donated for collecting by a restaurant. The purpose of adding n-pentanol was to make the used cooking oil less viscous. In temperatures ranging from 130 to 180 degrees Celsius, the GO was mostly utilized for frying tasks. To remove food particles and water dribbles, the oil was heated and squeezed before combining. It was essential to modify the mixes' strength since water might lead to phase separation and diesel detests it. A 4m filter was used to refine the GO. Fuels for the test mix (percent vol.) were made. Every test gasoline was miscible and operated engines steadily. Figure 1 shows how diesel, gutter oil, and 1-pentanol look in comparison to test fuel characteristics.

Figure 1: Appearance of diesel,1-pentanol and gutter oil.

This was accomplished by employing a mechanical homogenizer machine to mix all of the fuel ingredients together for 30 minutes at 4000 rpm using the splash blending technique. (1) 100% amount of DF; (2) 90% volume of diesel and 10% volume of gutter oil (DF90GO10) (3) DF70GO15Pn15 (70% diesel, 15% gutter oil, and 15% 1-pentanol on volumes). The ASTM-standard essential fuel characterizations are provided in the table.1

Table 1: Blend fuel properties.

Properties	**D100**	**D90GO5**	**DF70GO15Pn15**	**Test method**
Flash point ^oC	78	85	98	ASTM D-93
Viscosity 40 ^oC Cst	2.28	2.34	1.14	ASTM D-7042
Cetane number	50	53	56	ASTM D-6890
Density g/ml	0.85	0.89	0.83	ASTM D-7042
Heating valve MJ/Kg	42.5	39	41.5	ASTM D-5468

2. Experimental set up

A one-cylinder, four-stroke diesel engine with direct injection was employed in the experimental study. The engine was connected to the eddy current dynamometer. Before beginning any trials, the engine was stabilized by running for ten minutes. It was then ran for eight hours each day. Every gasoline sample was put through a different testing process to guarantee accurate and consistent readings. Below is a schematic representation of the engine test setup.

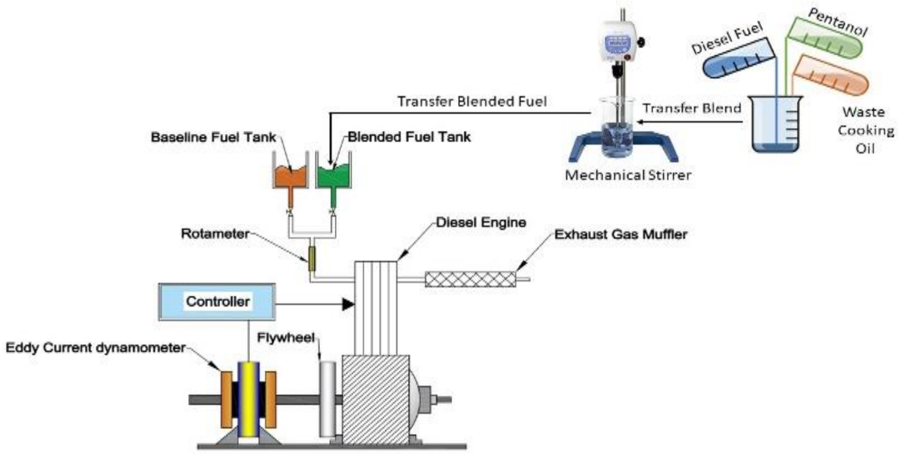

Figure 2: The engine test rig schematic diagram.

In three test fuels: 1-pentanol DF70GO15Pn15 (70% diesel fuel, 15% gutter oil, and 15% 1-pentanol), DF90WCO10 (10% gutter oil, 90% diesel fuel), and DF (diesel fuel) as the baseline. The endurance test was run for 200 hours with a steady load and 1300 rpm. Table 2 lists the engine configurations.

Table 2:Configurations.

Model	Compression ignition indirect diesel engine
Maximum engine torque	80 Nm
Maximum engine power	7.7 kW
Injection pressure	14.2 + 0.5 MPa
Valves clearance	Inlet valve 0.15-0.25mm
Piston mean speed	6.93 m/s
Cooling water consumption	1360 g/kW h
Specific fuel consumption	278.8 g/kW h
Compression ratio	21-23
Specific oil consumption	4.08 g/kW h
Means effective pressure	576 kPa
Stroke	80mm
Bore	75mm
Output (12 hours rating)	4.4kW/2600r/min

Displacement	0.353L

Following the 200-hour endurance test, the locomotive was dismantled and the exhaust valve was taken out. The cycle was performed in the same way for every test fuel. Later. All exhaust valve samples were taken to the laboratory for energy dispersive x-ray spectroscopy (EDS) and scanning electron microscopy (SEM) studies in order to identify the deposits that had formed on each sample and their elemental makeup.

3. Results and Discussion

4.1. Exhaust visual inspection

In diesel engines, the deposits, often referred to as carbon accumulations, are heterogeneous mixtures of carbon ash, soot, and the residues of oxygenated compounds [28]. It has been suggested that the thickness of deposits might be estimated by measuring the area of fuel impingement and the temperature of the combustion chamber wall [29–30]. More deposits may form in the engine chamber as a result of low wall temperature and unburned fuel [31]. A 200-hour endurance test was conducted on mixes of DF, DF70GO15Pn15, and DF90GO10. After that, pictures of the exhaust valve were taken, as shown in Figure 3. A DSLR camera was used to capture the photos of each valve. Upon visual inspection after the operation was finished, all gasoline samples showed a particular deposit accumulation on the surfaces around the exhaust, as shown in Figure 3. But when DF90WCO10 gasoline was used instead of DF100 fuel, the exhaust valve was dirtier. It is evident that the exhaust valve operating on DF70GO15Pn15 showed less deposit development than the other fuel.

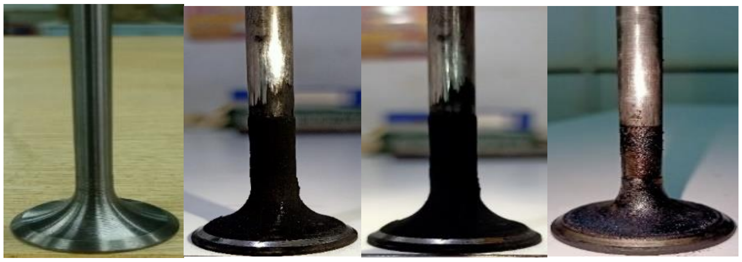

Figure 3: Deposits on the valves via (a) Fresh valve (b) DF(c) DF90WCO10 (d) DF70GO15Pn15.

4.2 SEM and EDS analysis

A combination of low wall temperature and unburned gasoline can increase the quantity of deposits that can build in the engine chamber [32]. The cylinder head houses the intake and exhaust valves, two components of the engine's operation. The amount of gas and liquid that enters and leaves the combustion chamber is controlled by these valves [33]. A diesel engine running on waste cooking oil (WCO), which is just waste cooking oil plus diesel fuel, underwent a protracted endurance test. It has been claimed that the thickness of deposits may be ascertained by measuring the temperature of the combustion chamber wall and the region of fuel impingement [34–36]. Unburned gasoline and low wall temperature may cause further deposits to accumulate in the engine chamber. The engine was partially dismantled and the deposit formation on each exhaust valve was inspected following the long-term 200-hour endurance test with the test fuels DF, DF90WCO10, and DF70GO15Pn15. Understanding the formation of the deposit and its related composition was made feasible by the use of SEM and EDS methods. The deposits' SEM micrographs at a 25x magnification and any associated EDS are shown in Figure 4 to determine the chemical composition of each test fuel.

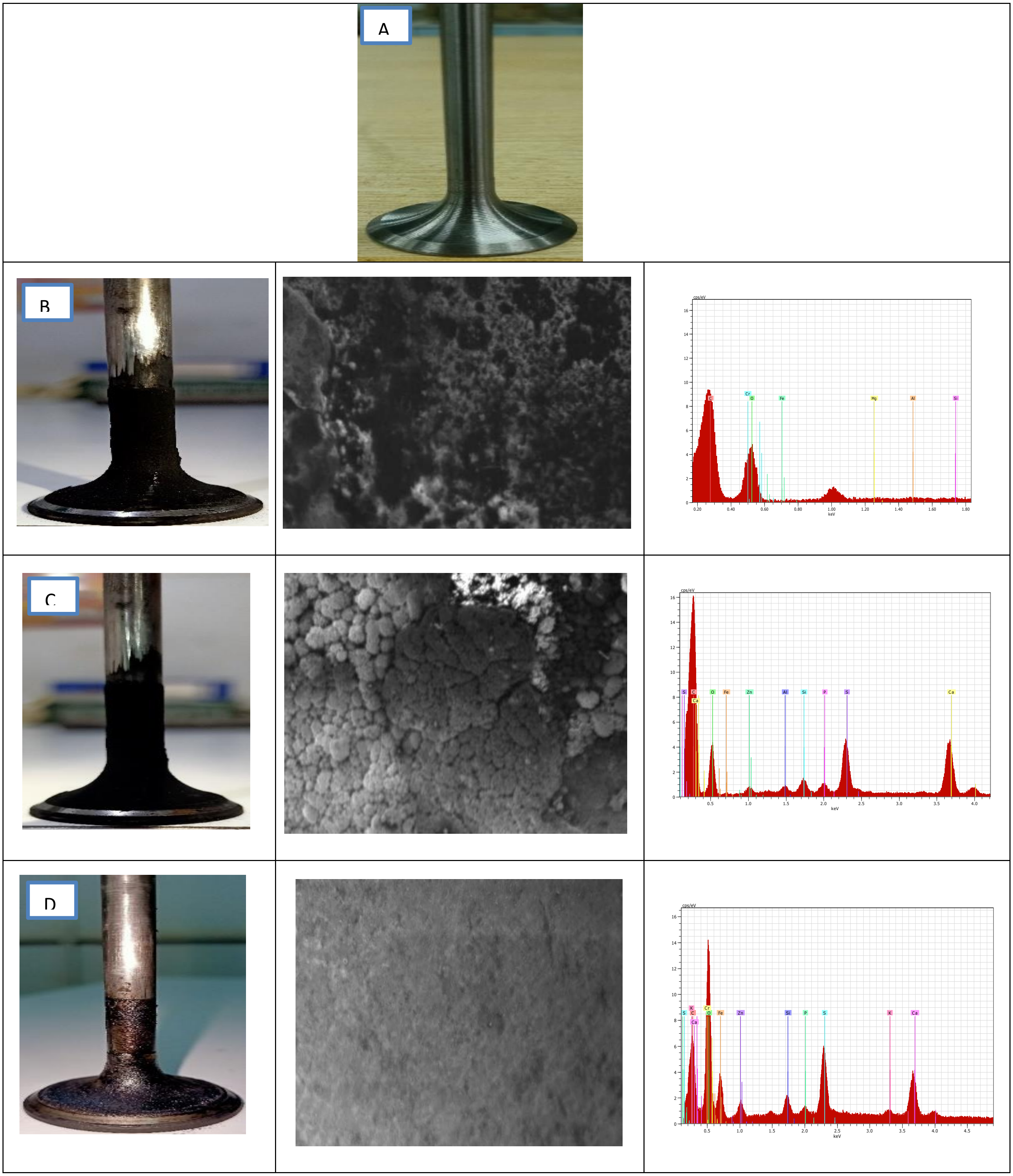

Figure 4: The SEM magnified micrographs of the deposited exhaust valves operated on DF, DF90WCO10 and DF70GO15Pn15 related elemental analysis.

The EDS of deposits on exhaust valves fuelled with three mix fuels and compared to baseline fuel, respectively, is displayed with SEM micrographs at 25_ magnifications in Fig. 4. Figure 4 shows that deposits with DF70GO15Pn15 are significantly lower than those with the other two mixes and baseline fuel. DF (diesel fuel)-fueled exhaust valve deposits are shown in Fig. 4(a) by SEM at 25_ magnification and associated elemental analysis by EDS on deposited surfaces, which are shown to be on the top layer and indicate the quantity of oxygen (O) (52.66%). When DF95WCO5 is present, the top layer displays an oxygen concentration of 39.54. On the other hand, these have relative carbon (C) concentrations of 44.63% and 45.42%. The carbon (9.96%) and oxygen (24.81%) concentrations are lower on the surfaces of the deposited valves that are fueled with DF70GO15Pn15. This implies a low concentration of carbon in the accumulation layer. In comparison to DF, the research findings revealed that DF95WCO5 had a greater amount of deposit buildup.

4. **Conclusions**

The research findings are:

- Deposit accumulations on diesel engine components, especially the exhaust valve, were accelerated by the increased inclusion rate of used cooking oil.
- There was a propensity for the engine component to accumulate more deposits when the direct waste cooking oil inclusion rate was raised.
- A significant number of deposits were caused by DF gasoline. More precisely, the exhaust valve was very moist when DF90WCO10 was used. As a result, the deposits produced by DF90WCO10 are often brittle and moist. DF70GO15Pn15, on the other hand, causes less deposit development on the exhaust valve.
- The observed structures were dominated by spherical patterns in the deposits induced by DF95WCO5. This may primarily be explained by the unburned fuel that did not ignite correctly and would thereafter dominate the structure of the deposit. There are similarities between this deposit structure and the one seen in the piston groove.

Additionally, it may be said that a combination of leftover cooking oil and n-pentanol is readily accepted as a fuel alternative for CIDI engines without requiring any changes.

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