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ASSESSMENT OF EXHAUST VALVE DEBRIS FROM GREEN FUEL COMBUSTION

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Abstract
Used cooking oil (UCO) has shown promise as a short-term alternative fuel for compression ignition engines. To evaluate its long-term effects, this study conducted an endurance test using diesel-UCO blends. Results showed minimal wear on the engine head's working surface. Among the tested blends, DF60UCO20Pn20—with the lowest cetane number and highest oxygen content—exhibited the shortest combustion time and longest ignition delay. Engine head and exhaust valve deposits were analyzed and compared to those from emulsion fuels. Visual inspection revealed deposits across all fuels, while SEM and EDS analysis showed that DF95UCO5 produced more carbon buildup than both DF60UCO20Pn20 and pure diesel.

INTRODUCTION

The hunt for renewable fuels with efficiencies on par with those of conventional fuels is a result of growing concern over the depletion of fossil fuels. [1]. Numerous environmental issues are also connected to the use of fossil fuels. It is believed that carcinogens specific to lung cancer are present in the diesel exhaust of vehicles that run on fossil fuels. The use of petroleum-diesel contributes significantly to greenhouse gas (GHG) emissions, which are directly related to climate change and global warming [2]. It is well known that deposits forming around the injector can change the fuel flow rate and injection pattern in the combustion chamber, thereby reducing overall system performance. Deposit development is primarily driven by fuel impurities, soot, volatile lubricating oil, and reactive combustion products [3]. Rapid urbanization and global population growth have increased the demand for energy. This increase in energy demands has an effect on people's welfare, health, and social and economic development. Globally, the unchecked use of fossil fuels has led to environmental degradation and health hazards [4]. Diesel reserves have declined, cost volatility has increased, and environmental impact and public health issues have escalated as a result of the increased demand and use of diesel for engine fuel [5,6]. A study found that frying and cooking generate a large amount of waste cooking oil (WCO) worldwide [7]. This study (Food and Agricultural Organization of the United Nations) estimates that the food processing industry in India generates about 23 million tons of vegetable waste annually. The disposal of waste cooking oil (WCO) has also resulted in environmental issues that call for reprocessing or consumption along with a financial incentive [9,10]. Engine performance was then investigated after the results showed that WCO was transesterified to create biodiesel [11,12]. There isn't much information available about using unmodified WCO as blend fuel with diesel for effluent classification and performance analysis when used in a CI engine. The first search for alternative fuel sources for internal combustion engines began in 1893 when Rudolf Diesel tested peanut oil as an engine fuel [10]. Between 1930 and 1940, when engine power was supplied by vegetable oil derived from different food sources, it became necessary to investigate this issue, and research on alternating fuel oil was initiated at multiple locations [11]. Every year, between 0.4 and 0.6 million tons of WCO are produced, according to research done in Japan. However, only 0.25 to 0.26 million tons are collected for industrial use; the rest is drained through home sinks, damaging the drainage system and placing needless strain on sewage systems. WCO has reached and affected the aquatic ecosystem [12]. Inadequate handling and disposal of this fluid waste can have detrimental impacts on the environment and human health (WCO). Vegetable oil can cause excessive engine scratching, lubricating oil clotting, carbon buildup in machine parts, fuel strainer obstruction, and injector choking, among other problems, when used directly in compression ignition engines [13]. In compression ignition (CI) engines, WCO's high viscosity can lead to issues like excessive fuel consumption at startup, poor atomization during injection, carbon settling in the burning cylinder, and filter blockage [14]. WCO shows a high viscosity and low volatility in terms of deprived atomization. Because leftover cooking oil doesn't contain any particles, it can be used as fuel for internal combustion engines, like diesel engines. Used cooking oil can be used as fuel to generate more power. As a result, handling WCO carefully is necessary when using it as an uncommon fuel for CI engines. Techniques such as trans-esterifying WCO to biodiesel or preheating WCO are common [14].

In order to investigate the carbon deposition of an engine exhaust valve from a compression ignition engine, this study used diesel, cooking oil, and n-pentanol as fuel samples.

1. METHODOLOGY

The engine under study is currently in operation at QUEST University, Nawabshah's thermodynamics lab, which is part of the Mechanical Engineering Department. The required fuel properties are listed in Table 1. The actual fuel sample and the experimental setup are shown in Figures 1 and 2, respectively. A four-stroke, one-cylinder diesel engine is selected and set up on a test bed. Two fuel tanks—one for mix fuels and the other for DF—provided the test engine's fuel. The engine is connected to an eddy current dynamometer. The engine was fueled with DF at first, and then with mix fuels to create baseline values. To obtain mean values, each test was conducted three times.

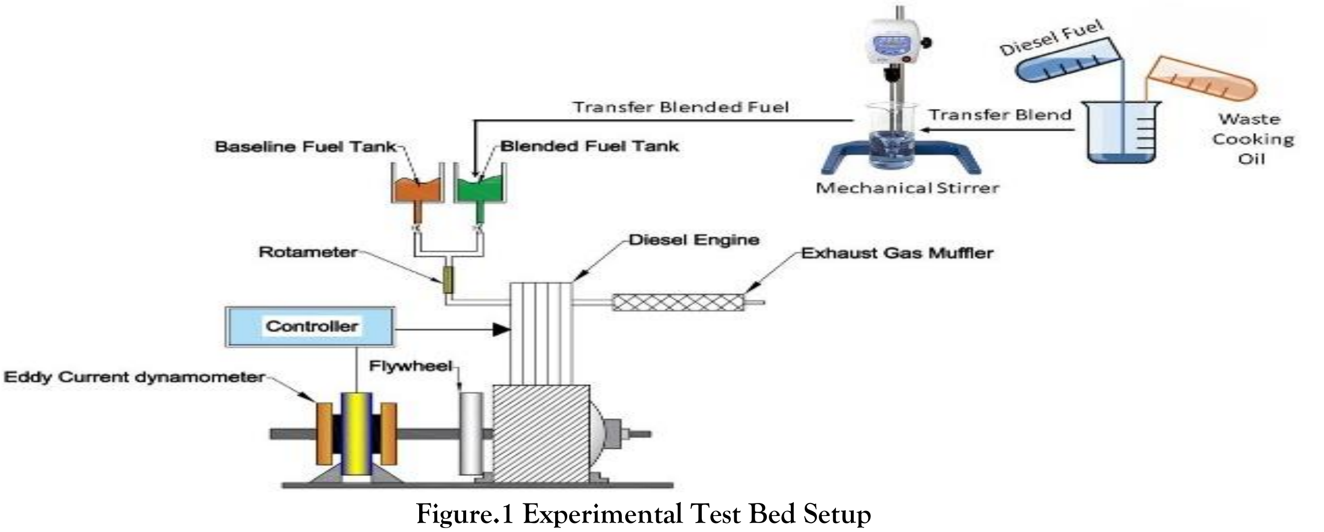

Figure.1 Experimental Test Bed Setup

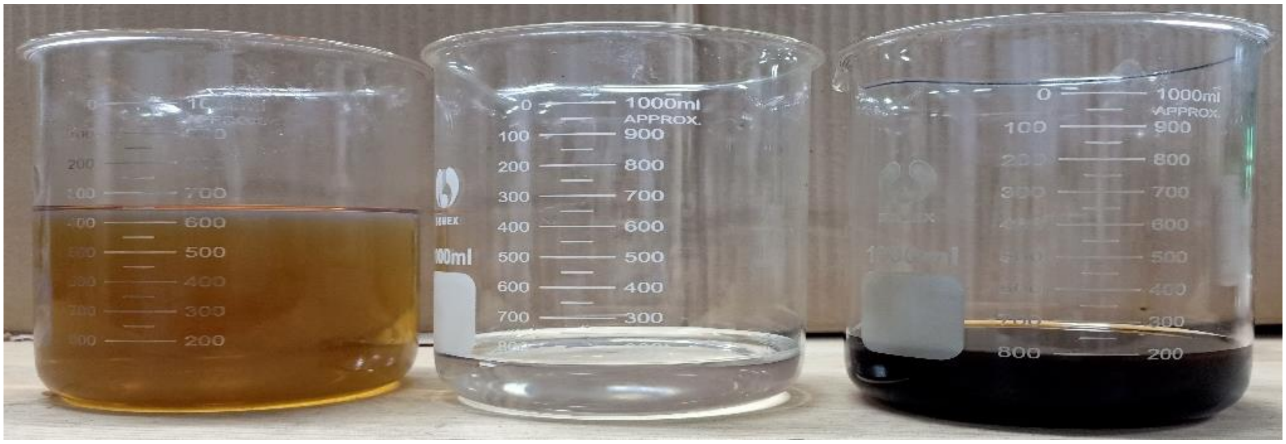

Figure 2. Physical appearance of test fuels (a)DF (b) N-pentanol (c) Used cooking oil

Table 1. Properties of tested fuel samples

Properties	Diesel Fuel	WCO	n-Pentanol
Viscosity 40 °C Cst	2.28	52	2.89
Right Density g/mL	835	900	814.4
Flash point °C	78	271	49
Oxygen (wt %)	0	20	8.47
Calorific valve MJ/Kg	42.5	37.68	34.75
Cetane number	50	54	20

2. RESULTS AND ANALYSIS

Endurance test

To evaluate deposition on engine parts such as exhaust valve, an endurance test was conducted in a compression ignition engine. The studies used n-pentanol (DF60UCO20Pn20), diesel (D100), and waste cooking oil (DF95UCO5). After 200 hours of operation, each sample's engine exhaust valve was swapped out for a deposition analysis. Prior to running on alternative fuels, the engine was warmed up with diesel petroleum for ten minutes. To maintain consistency throughout the test, the engine was run at a constant load and speed after the warm-up phase was finished. Determining the amount of elemental deposition on the engine exhaust valve for each of the three fuels under evaluation was the primary objective of this investigation. Elemental deposition was observed on the surface of three distinct engine exhaust valve after 200 hours of testing. Using microscopic and visual inspection tests at various engine head locations, a deposition study was carried out to determine the elements deposition on the valve surface. The analysis revealed that the endurance test resulted in the accumulation of aromatic chemicals on the surface of the engine head piston for all three fuels. The microscopic test using the energy-dispersed X-ray method showed elemental deposition of aromatic compounds on the engine exhaust valve's surface. Compared to diesel and blended fuel. Additionally, more deposit was discovered on the piston's exhaust side than on its intake. The deposit was also found to be unevenly distributed across the engine exhaust valve surface, with more deposition in some areas than others, when examined under a microscope. The unequal distribution of fuel in the engine cylinder was found to be the cause of the unequal deposition, resulting in localized combustion and increased deposition in certain areas.

3.1 Engine exhaust valve deposit visual inspection

Engine head pictures were taken during a 200-hour endurance test on DF, DF95UCO5, and the DF60UCO20Pn20 mix, as shown in Fig. 3. Visual inspection after different operating hours showed some deposit deposition on the injector liners and head surfaces for both fuel types, as shown in Fig. 3.

Figure. 3 visual inspections of DF, DF95UCO5 and DF60UCO20Pn20.

However, the engine exhaust valve running on DF95WCO5 was dirtier than the engine head running on DF. There are reports of similar results. Additionally, it was observed that deposits on the engine head running with the DF95UCO5 mix were dry, while deposits on the engine head running with DF were greasy and oily. The engine head has less deposit when using mix fuel sample DF60UCO20Pn20.

2.2 SEM (scanning electron microscopy)

Following the completion of the 200-hour endurance test on DF, DF95UCO5, and the DF60UCO20Pn20 mix, the engine was partially disassembled and the deposit formation on each engine exhaust valve was inspected. High temperatures surrounding the injector tip, which can result in extremely persistent deposits in and around the engine head, are a characteristic of improved diesel injection systems [15-16].

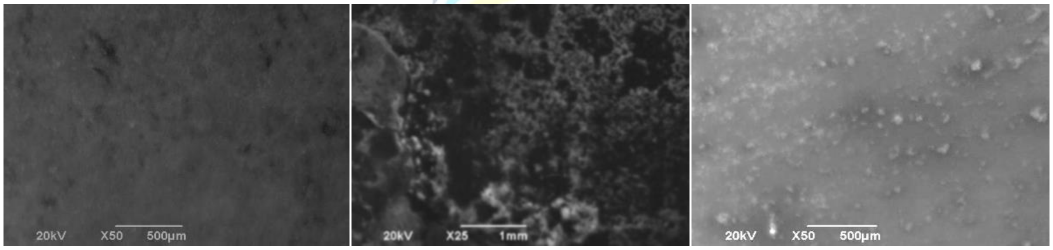

Figure. 3 SEM running 200h on diesel fuel DF100, DF95UCO5 and DF60UCO20Pn20.

Figure 3 shows the SEM micrographs of deposits on engine exhaust valve that were fuelled with DF and DF95WCO5, respectively, at 43 magnifications. Deposits containing DF are clearly much lower than those containing the DF95UCO5 mix. Figures 3 show the SEM of deposits on an engine exhaust valve that was fuelled with DF (diesel fuel), waste cooking oil (DF95UCO5), and n-pentanol (DF60UCO20Pn20) at various magnifications.

3. CONCLUSIONS

The engine exhaust valve deposition endurance test using blend fuels like DF100, DF95UCO5, and DF60UCO20Pn20 was examined in this work and contrasted with diesel fuel:

Visual examination of the exhaust valves of the two fuel-running engines (DF, DF95UCO5, and DF60UCO20Pn20) showed slight deposit deposition. However, the engine exhaust valve that used DF95UCO5 was found to be dirtier than the engine exhaust valve that used DF and DF60UCO20Pn20. After the endurance test, SEM and EDX analysis revealed that deposits on the engine exhaust valve were considerably less when the engine was run with DF and DF60UCO20Pn20 than when it was run with the DF95UCO5 mix. The carbon was not deposited in a uniformly thick layer. Moreover, deposits on or near the engine exhaust valve did not significantly impair it.

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