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Performance study on waste cooking oil methyl ester biodiesel with diesel engine

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Abstract
This study has been conducted to showcase the utilization of waste cooking oil in four stroke direct injection diesel engine which ultimately helps to reduce the fuel bill of any country. It was observed in the study that the fuel properties of WCO biodiesel is comparable with petroleum diesel. It was also found that performance and emission characteristics are near to conventional diesel fuel. The CO, HC and smoke opacity are considerable reduced while NOx marginally increases with WCO biodiesel. The BTE was also found comparable to diesel fuel. It has been suggested to use WCO in blended form with petroleum diesel to improve the growth of the country.
Keywords – waste cooking oil, fuel bill, emission

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I. Introduction

The continuous depletion of fossil fuel has posed a daunting challenge in front of the mankind society. This is high time to explore the viability of alternative fuels so that demand of automobile sector, transportation sector and industrial sector meet out. Several alternative fuels including edible oils have been researched in the past but have diminished due to high prices of these oils. This research study investigates the performance of biodiesel produced from waste cooking oil on four stroke direct injection diesel engine.

It was reported that India produces only 30% of the crude oil required and remaining 70% is imported, which costs about Rs. 80,0000 million per year. It is evident that mixing of 5% of biodiesel fuel to the crude oil can save Rs. 40,000 million per year. It is also reported that India can supplement around 42% of the total diesel fuel consumption, if waste cooking oil and other bio wastes were used as raw material for biodiesel production [1,8,9,11]. Due to a sustainable solution, low cost and greenhouse gas reduction potential biodiesel is nowadays popular all over the world especially in developed countries like USA, France, Brazil in different proportions with diesel.

The diesel engines are having operational and durability problems with vegetable oils. These problems lead to higher viscosity and lower volatility of vegetable oils [2]. To improve the fuel characteristics, transesterification is a proven effective method of reducing viscosity and eliminating operational and durability problems. Also, biodiesel can be defined as a methyl or ethyl esters extracted from vegetable oils or animal fats by transesterification process. Waste cooking oil biodiesel was used in diesel engines at a rated speed of 1500 rpm and different engine loads. It was found that the exhaust gas temperatures elevated as concentration of biodiesel increases. It was also found that WCO biodiesel blends were performing in a better way to substitute diesel fuel. The calorific value of WCO biodiesel is relatively inferior to diesel fuel by about 15% [3,9,10,12,13,14].

The experimentations have been performed with biodiesel and its blends with diesel to solve the problem of depletion of fossil fuels and environmental impact. A four stroke DI diesel engine was run to investigate engine performance with WCO biodiesel. The study finds out that on adding 20% of waste cooking oil biodiesel by volume, specific fuel consumption was increased and on the other side brake thermal efficiency decreased for biodiesel blends compared to diesel fuel [4], [5] [6] [7] [8].

II. Materials and Methods

The raw material for biodiesel preparation used is waste cooking oil, which was collected from different sources such as hostels, restaurants, canteen, and cafeterias. Unnecessary impurities in the oil such as solid matter and food residues were removed using vacuum filtration. Waste cooking-oil was used to produce biodiesel by using transesterification method. Transesterification method was conducted using a conical equipped with a reflux condenser and thermometer with magnetic stirrer. The flask was charged with waste cooking-oil and preheated to 65 °C. Sodium hydroxide (NaOH) 1% by weight of waste cooking oil; as a catalyst was dissolved in methanol solution of 6:1 molar ratio methanol to waste cooking oil. Meth-oxide solution was set in a flask for 1.5 hour to react. Then mixture was poured into a separating funnel to separate glycerol from biodiesel. Biodiesel is then washed three times, using warm water with 5% acid then with water. The residual methanol, catalyst and water were separated from biodiesel using a rotary evaporator at 80 °C. Waste cooking-oil biodiesel methyl was dried at 100°C. Biodiesel is mixed with diesel oil at different proportions by volume [15,16,17,18,19,20]. Density, flash point, kinematic viscosity and calorific value of biodiesel blends were measured as shown in Table 1.

Table 1 – Fuel characterization of biodiesel blends using ASTM standards.

Property	**Testing Procedure**	**Diesel**	**WCME 100**	**WC ME8 0**	**WC ME 60**	**WCM E40**	**WCM E20**
Kinematic viscosity at 40°C (mm^2/sec)	ASTMD445	4.3	6.2	5.7	5.6	5.5	5.3
Density (Kg/m^3)	ASTMD1298	841	900	880	875	870	860
Calorific value (KJ/kg)	ASTMD240	44500	39600	4020 0	4110 0	41700	42900
Flash point (°C)	ASTMD93	50	94	80	78	76	65

III. Experimental setup

This work used a constant speed, single cylinder, 4-stroke, DI diesel engine to test the fuels. The schematic arrangement of the experimental setup is shown in figure 1. An eddy current dynamometer is coupled to load the engine. Fuel flow rate was measured using standard burette apparatus.

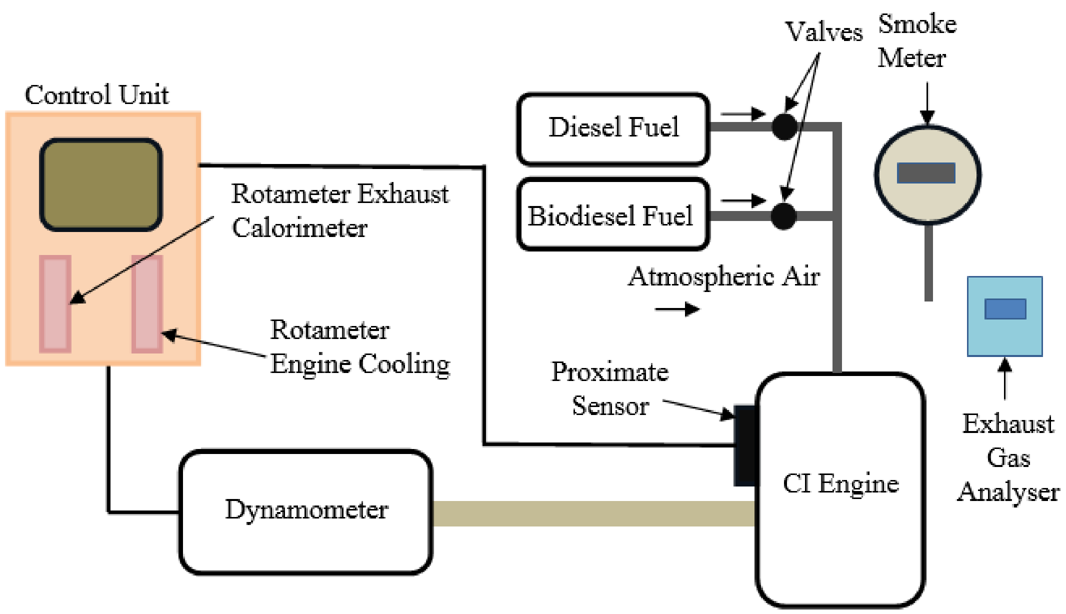

Figure 1: Schematic diagram of engine setup

The K-type thermocouple is used to measure exhaust gas temperature. The exhaust gas emissions such as CO, HC, NO_x and fuel–air equivalence ratio were measured using a AVL exhaust gas analyser. The smoke opacity was measured by AVL smoke meter. The specifications of the engine are given in Table-2. The experiments are carried out with fixed injection timing of 23° bTDC at an injection pressure of 200 bar. The engine performance parameters such as brake thermal efficiency, engine emissions, smoke opacity are recorded during the test. Engine was run at 1500 rpm and load was varied from no load to full load in step increments.

Table 2: Technical Specification of Test Engine

Particulars	**Details**
Engine	Single cylinder 4 stroke diesel engine
Fuel	Diesel / Biodiesel
Rated output / Rated speed	3.5 KW / 1500 rpm
Cylinder diameter or Bore diameter	87.5 mm
Stroke length	110 mm
Compression Ratio	16.5:1
Orifice diameter	20 mm
Inlet Valve Opens	4.5° Before TDC
Inlet Valve Closes	35.5°After BDC
Fuel Injection	23° Before TDC
Exhaust Valve opens	35.5° Before BDC
Exhaust Valve Closes	4.5° After TDC
Dynamometer used for loading	Eddy current dynamometer

IV. Results and discussions

The engine performance characteristics such as BTE, SFC and emission characteristics such as CO, UBHC, NO_x and smoke were analysed for all blends of biodiesel along with fuels with conventional diesel at different engine loads.

4.1.1. Specific fuel consumption (SFC)

The specific fuel consumption of various biodiesel blends and petroleum diesel is shown in figure 2. SFC was found higher for all WCME and its blends than diesel under various loading conditions. This is due to high viscosity, density and lower heating value of biodiesel.

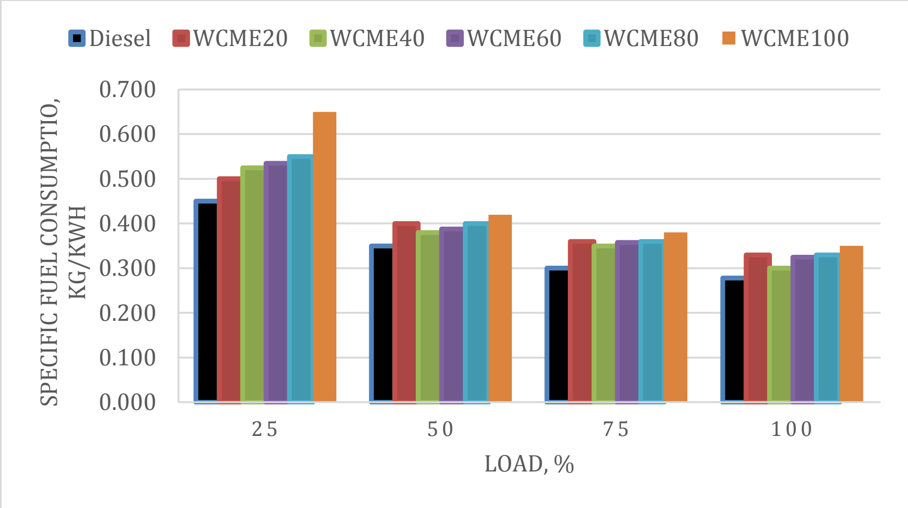

Figure 2: Variation of brake specific fuel consumption with load

4.1.2. Brake Thermal Efficiency (BTE)

Figure 3 shows the variations of brake thermal efficiency of biodiesel and its blends with respect to diesel fuel. BTE of biodiesel blends was found marginally lower than that of diesel fuel. This is due to lower heating value of biodiesel, higher density and increased viscosity which leads to poor atomization and fuel vapourization.

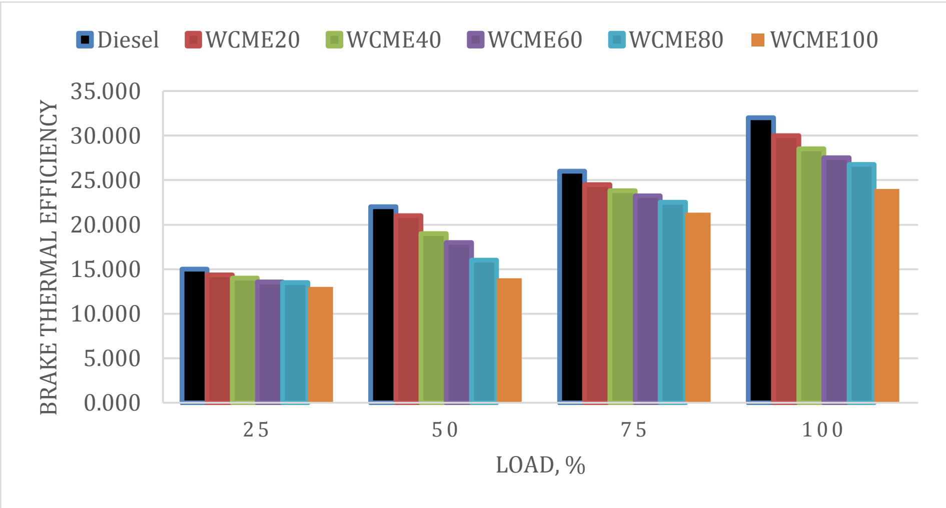

Figure 3: Variation of brake thermal efficiency

4.1.3 Unburned hydrocarbon (UBHC) emission

The figure 4 shows that UBHC emissions decreases with increasing WCME percentage in the blend. It is also observed that UBHC emission increases as the load of the engine was increasing with diesel and blends of WCME as the result of increase in fuel consumption at high engine loads. WCO biodiesel involves high oxygen content, which leads to more complete combustion.

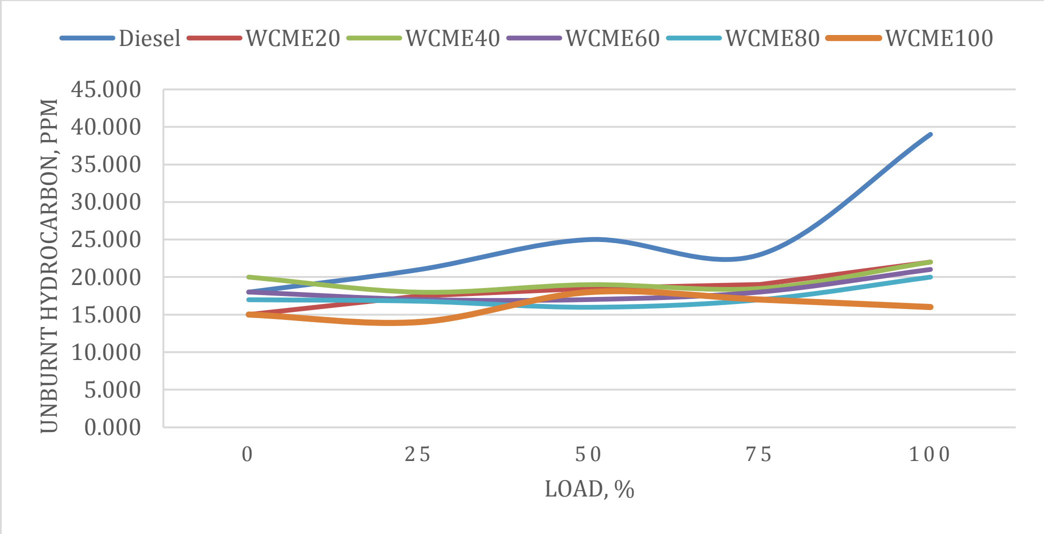

Figure 4: Variation of UBHC emission for various blends and diesel

4.1.4. Carbon monoxide (CO) emission

The figure 5 is showing the comparison of the carbon monoxide (CO) emission of biodiesel and its blends with conventional diesel. CO produced at intermediate stage during the intermediate combustion of hydrocarbon fuels. CO formation depends on air fuel equivalence ratio, fuel type, combustion chamber design, starting of injection timing, injection pressure and speed. Experimental results reveal that CO concentration of biodiesel, and its blends is 60%, 39%, 36%, 32% and 30% lesser for WCME20, WCME40, WCME60, WCME80 and WCME100, respectively, when compared to diesel fuels operation. This is due to the oxygen content in biodiesel which allows more carbon molecules to oxidize when compared with diesel fuel.

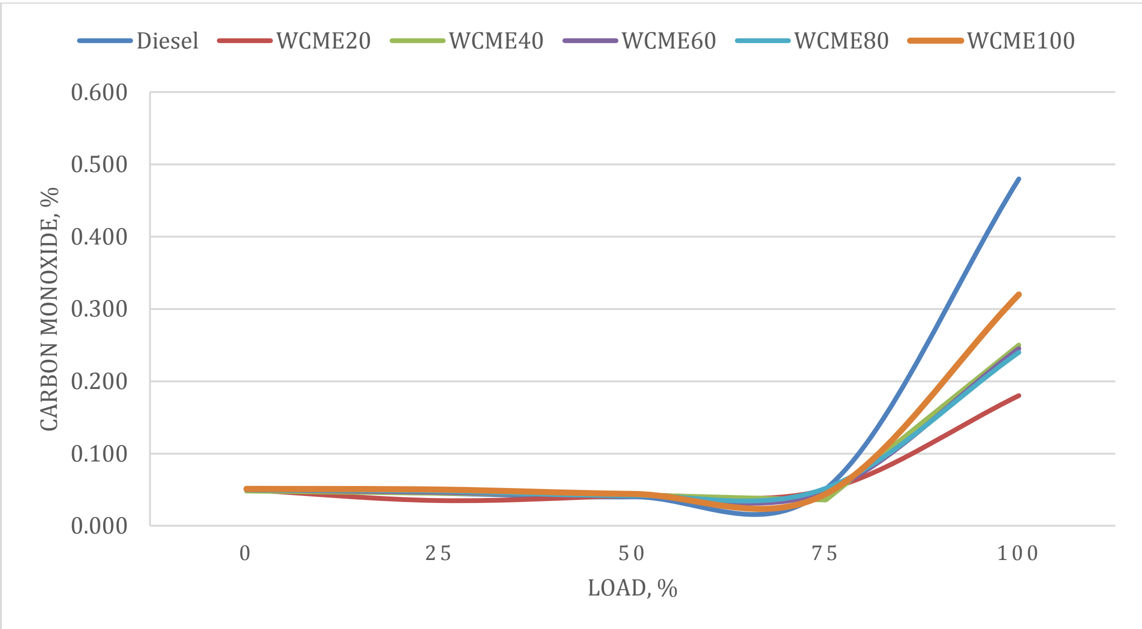

Figure 5: Variation of CO emission for various biodiesel blends and diesel

4.1.5. Nitrogen Oxides (NO_x) emission

The variation of Nitrogen oxides (NO_x) concentration with load for biodiesel blends and diesel is shown in Figure 6. The NO_x formation in the cylinder is affected by oxygen content, combustion flame temperature and reaction time. NO_x formation of all biodiesel and blends is slightly higher than that of diesel fuel. It is also observed that as load increases, the NO_x formation increases and maximize at peak load. This is due to higher temperature of combustion and the presence of oxygen with biodiesel cause higher NO_x emission.

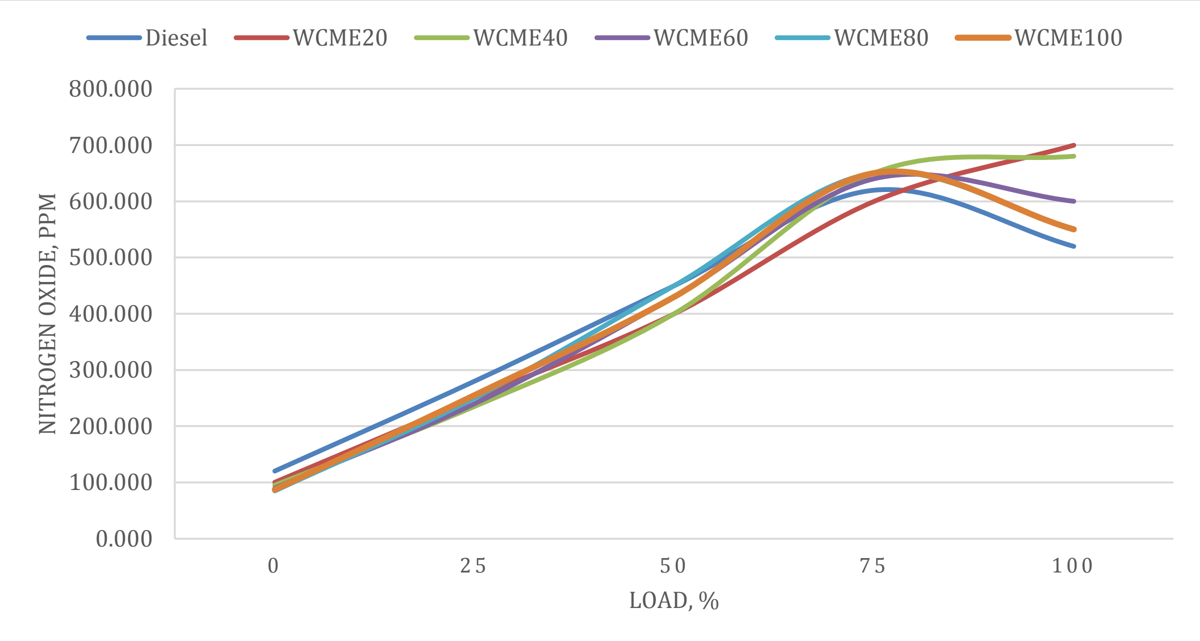

Figure 6: Variation of NO_x emission with load

4.1.6. Smoke opacity

Figure 7 shows that the smoke content of biodiesel and its blends are 25% higher than that of diesel fuel at low and middle engine loads. This is due to high viscosity of biodiesel, which results in poor atomization and locally rich mixtures at part load operations. But, at high engine load, smoke opacity of all biodiesel blends is lower than diesel fuel. It is because of oxygen content of biodiesel compared to conventional diesel fuel.

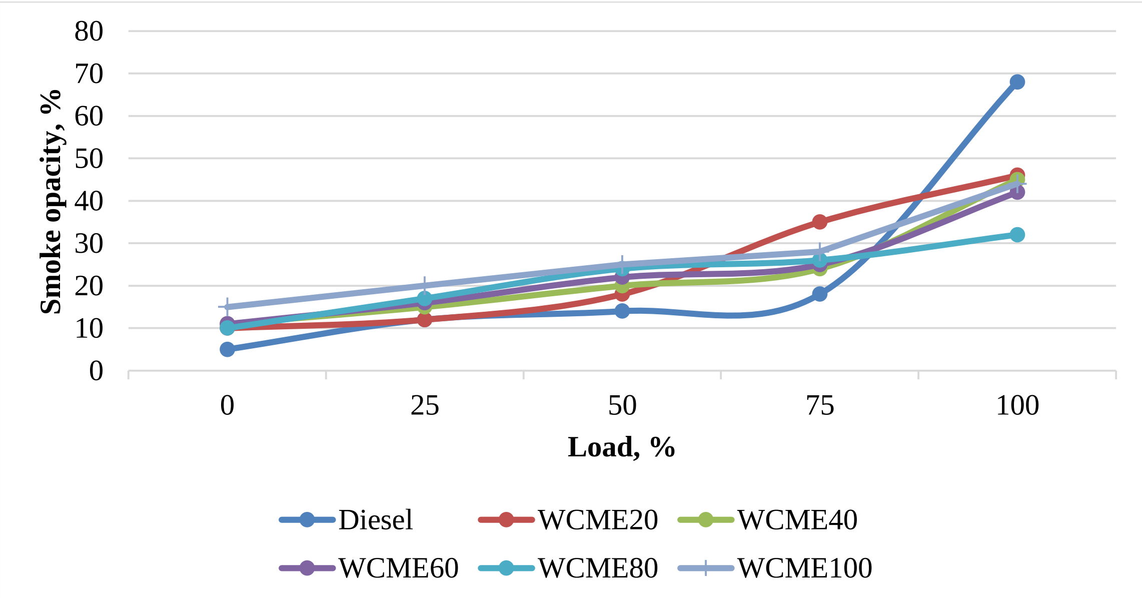

Figure 7: Variation of smoke opacity with load

V. Conclusion

In the present investigation, the performance and emission characteristics of a direct injection compression ignition engine fuelled with waste cooking oil methyl esters and their blends have been discussed and compared with diesel fuel. Results of the present work are summarized as follows:

1. The diesel engine operates adequately on biodiesel and its blends with the diesel fuel without any major modifications.
2. Thermal efficiencies of biodiesel are found slightly lower than diesel but comparable to operate with biodiesel up to a certain extent.
3. The SFC increases with change in percentage of biodiesel in the blends due to the lower heating value of biodiesel.
4. It is also observed that there is significant reduction in CO, UBHC and smoke emissions for biodiesel and its blends compared to diesel fuel. However, NO_x emission of WCME biodiesel is marginally higher than petroleum diesel.

This study concludes that WCO biodiesel can replace the diesel to help in controlling air pollution, encouraging the collection, and recycling of waste cooking oil to produce biodiesel and simultaneously reduces the dependency on fossil fuel resources to some extent without sacrificing engine performance. It also helps any nation to boost up the economy and accelerates the growth.

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