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The Influence of Injection Pressure on Performance and Emission Characteristics of Waste Oil Methyl Ester Fueled Diesel Engine

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Abstract : - The world is facing serious problem with crisis of hydrocarbon fuel and uncontrolled extraction of fossil fuels have led to the serious threat to carbon based fuels. The need to exploit bio origin based fuel to meet the world's energy demand has been observed a long. The methyl ester has been proven liquid fuels, known as biodiesel. Such a biodiesel developed from waste cooking oil (WCO) is taken in this research along with varied injection pressure. The 220 bar injection pressure fueled by B100 shows a lowest CO2 emission than the pure diesel. The results indicated lowest NOx emission at full load. The efficiency tested with B20 and B100 WCO biodiesel recorded lower compared to diesel at 220 bar showing poor combustion of methyl ester due to higher values of viscosity and poor volatility.

Keywords*:* Engine, Injection Pressure, Waste Oil Biodiesel, Performance, Emission.

1. Introduction

The biofuels plays a vital role in transportation and agricultural sector. The blends of vegetable oil and their derivatives show some long-term problems in engines. The edible vegetable oil, due to the repeated frying makes them unsuitable for reuse as having high free fatty acid (Figure 1 a) and b)).

a) Vegitable oil cooking **b) Oil frying** **c) Collected WCO**

Figure 1: WCO produced from food cooking and collected WCO

WCO has lot of disposal issues like water pollution, influence on our health and to the aquatic life, so instead of disposing, WCO may be utilized as input for biodiesel preparation minimizing environmental damages. Figure 1c) shows the collected WCO is a waste by-product from motels, restaurants and shops. Infect, utilizing WCO will definitely minimize the use of food crops employed in biodiesel-production. The fuel ignited in diesel engine, is purely due to high temperature happened by mixture compression. In present engines, the injection devices made to get higher pressure to decrease the emissions. During low fuel injection pressure (FIP) diameter of fuel particles will enlarge and larger ignition delay. This cause to inefficient burning and results increased

NOx and CO release. When the FIP is increased diameters of fuel particle are small. There is better fuel and air mix, which results lower CO emission.

The researchers have tried to use WCO for the study in engines. The effect of FIP using biodiesel is summarized here. **Azmi Yahya *et al.* [1]** reported advancement of injection time and found increased in FIP improves performance. The engine performed better at higher FIP. **Narayana Reddy *et al.* [2]** tested engine fueled with Jatropha oil at different FIP (205 to 260 bar). They found larger BTE values and lowest HC emission at 220 bar bar. The lowest smoke recorded at 240 bar. **Agarawal *et al.* [3]** tested diesel engine using preheated jatropha oil (100°C) at various IOP (180-240bar). They found that, variation in rated IOP of 200 bar results reduction in BTE.. **Ghazikhani *et al.* [4]** conducted investigations on Jatropha oil fuelled engine at various IOPs from 200 to 300 bar. At higher injection pressure, BSFC and emission were lower due to better combustion. **Sharma *et al.* [5]** studied Neem oil biodiesel and found the BTE was lower than diesel. At higher FIP, the BSFC recorded some high values than diesel. **Rosli Abu Bakar et al. [6]** studied on diesel engine at various FIP (180 to 220 bar). The better performance was observed at 220 bar. **Rehman *et al.* [7]** investigated suitability of methyl ester of karanja oil (MEKO) and MEKO-diesel blends. They observed that at increase in IOP causes reduction in BSFC. **Purushothaman *et al.* [8]** Studied effect of FIP on effect of orange skin powder oil-diesel blends on engine performance. The engine behavior at designed IOP (215 bar) was inferior to diesel. They found highest BTE, NOx and lowest Hydrocarbon and CO and smoke emissions at 235 bar. **Satish Kumar Sharma *et al.* [9]** tested engine with Karanja oil-diesel blend and the Increase in FIP from 200 - 240 bar resulted in better engine characteristics. Further, they recorded improvement with B40 karanja oil at 240 bar as compared to 200 bar. **Sukumar Puhan *et al.* [10]** conducted experiments with Linseed methyl ester (LOME) at various FIP ranging from 200 to 240 bar. At IOP of 200 bar, engine characteristics with LOME were inferior. They observed increase in FIP results in higher BTE, lower BSFC and BSEC at all loads. **Mustafa *et al.* [11]** studied methanol-diesel blends at different FIP and observed increase in FIP cause the lower emissions. They recorded negative impact on BTE with change in FIP from designed value. **Suryawanshi *et al.* [12]** investigated the effect of EGR and retardation injection timing on engine operated using KME. They reported reduced nitrogen oxide emits with injection time and EGR compared to standard conditions. **Chennakesava *et al.* [13]** studied using pongamia oil and reported that, preheating of vegetable oils decreased smoke and NOx levels with the advancing of the injection time and increase of FIP.

2. Problem Definition and Experimentation

Effects of FIP on engine behavior are investigated. The various parameters measured with gradually increased loads by changing the FIP. The injector opening pressure is adjusted to; 180 bar, 200 bar and 220 bar by varying spring tension of the injector. The engine tested with blends of WOME B20 & B80 at different FIP and increased load (0-100%). Finally the impact of load and FIP on performance of diesel engine and emission were compared in reference to diesel.

2.1 The properties of WOME biodiesel blends.

The WOME properties are actually depends on the frying situations, like temperature and cooking time. The frying can change the chemical and physical nature of oil. This change is due to oxidation and polymerization reactions. Figure 2 shows the WOME produced from WCO, the lighter oil shows is the biodiesel after etherification process.

Figure 2: Sample of WOME

The WCO (sunflower) thermo-chemical properties have been recorded in the Table 1

Table 1: WCO thermo-chemical properties

Properties	***Units***	***Values***
Density	gm/cc	0.937
Kinematic Viscosity @ 40º C	mm^2/s	37.2
Acid value	MgKOH/gm	5.35
Cloud point	Centigrade	3.55
Flash point	Centigrade	215
Pour point	Centigrade	5
Specific gravity	-	0.935

2.2 Comparison of WOME with Diesel

Following Table 2 gives the property comparison of WOME and Diesel. The viscosity of blends measured using Redwood viscometer and the flash and fire point temperature using Clavlend open cup apparatus and the heating value of WOME carried using bomb calorimeter as detailed below.

Table 2: Thermo-physical properties of WOME blends of

Sl No	Property	Unit	Diesel	20B WOME	100B WOME
1	Kinematic viscosity	centi-stoke	2.6	3.4	5.46
2	Density	Kg/m^3	865	887	952
3	Calorific value	Kj/kg	42600	40600	37874
4	Flash point	ºC	63	92	151
5	Fire point	ºC	68	98	164

2.3 Experimentation set up of test-rig

The test set up instrumented for necessary engine study using WOME. The Kirloskar AV1, single cylinder, 4-Stroke, water cooled of 5 HP capacity has been used. The Figure 3 shows the computerized diesel engine including the instrumentation accessories. A load cell sensor is connected near the flywheel to gauge the speed. Air intake has been gauged by air flow sensor that is fitted in an air box. A measuring flask with load cell employed to record fuel flow to the engine. The thermocouple with a temperature indicator shows the EGT. Further, the engine exhaust elements were recorded by exhaust gas analyzer.

Figure 3: The computerized diesel engine test setup with data acquisition system

2.4 Data acquisition system and customized software

The Figure 4 shows the data acquisition system employed to receive data from the different sensors through a data logger helps to gauge and display the necessary data directly on computer display. The engine view software is used to assess the engine parameters.

Figure 4: Data acquisition system and customized software

2.5 Flue gas analyzer (Five gases)

Flue gas analyser is a device employed to gauge the amount of pollutants in the exhaust gas (in parts per million, grams per kilometre, or grams per mile). The Figure 5 indicates the flue gas analyser utilized for measuring contents of engine exhaust.

Figure 5: Exhaust flue gas analyzer

3. Results and Discussion

The performance and emission parameters like; BTE, BSFC, EGT, CO, Co_2, HC, O_2 and NO_x were evaluated. The experiments conducted using blends of WCME; 20B and 100B with at different FIP and load conditions. The extensive experimentation carried and the data recorded, the data are then tabulated and the graphs plotted and the same are discussed.

3.1 Effect on engine performance

3.1.1 Effect on BTE

The BTE of is a function of engine torque/ load shown in Figure 6. The BTE using B20, B100 and diesel increases by the increase of load but tend to decrease with further increased load. Further, the efficiency of biodiesel blends found lesser due to poor combustion quality of WOME because of their nature of viscosity and poor volatility.

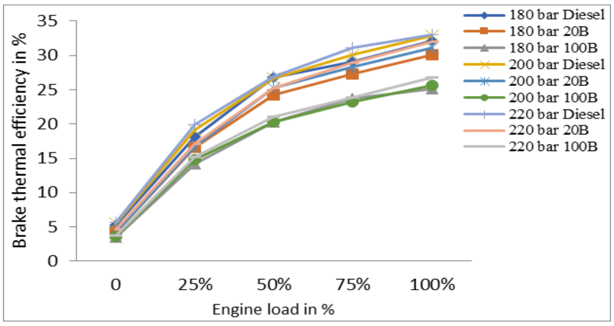

Figure 6: Effect of load and FIP on BTE

3.1.2 Effect on BSFC

The Figure 7 shows the influence of engine load on BSFC. It's visible that, the BSFC at the beginning is higher and decreases gradually with the increased load for tested fuels. The same nature observed for all fuel testing but the BSFC recorded higher for 220 bar FIP and lowest for 180 bar. The main cause for this may be the increase in brake power with increases engine load as compared with consumed fuel. The BSFC of B100 is higher than B20 and diesel fuel during entire load ranges, because of low value of heating value, larger density and bulk modulus, this higher bulk modulus results in more discharge of fuel for same displacements of the plunger in injection pump, there by resulting in increase in BSFC.

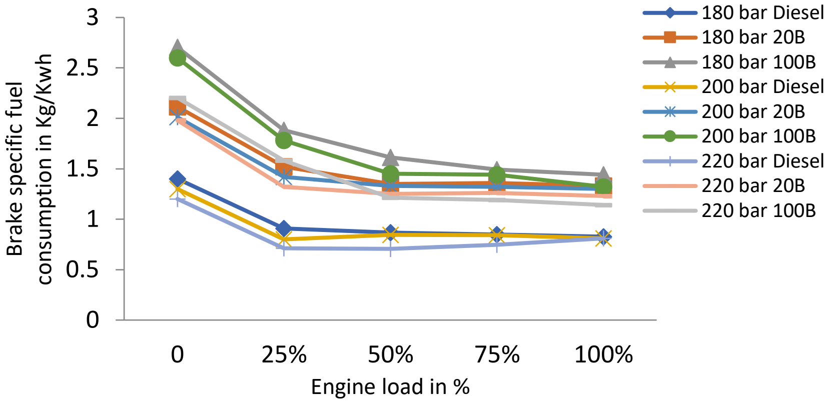

Figure 7: Effect of load and FIP on BSFC

3.2 Effect on engine emissions

The engine emission elements studied and analyzed are; EGT, CO, Co_2, HC, O_2 and NO_x.

3.2.1 Effect on hydro carbon emission

Figure 8 illustrate the effect of variation of engine load on unburnt hydrocarbon (HC) emissions in ppm. The emission of HC is because of unfinished combustion. It is also been observed that, the HC in exhaust is higher for B100 than B20 and diesel and it's found that, the 220 bar FIP fueled by B100 exhibit lower HC emissions.

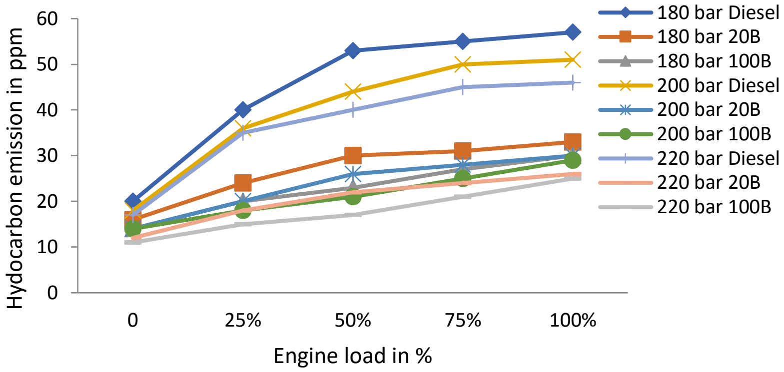

Figure 8: Effect of engine load and FIP on HC emissions

3.2.2 Effect on CO emissions

The influence of FIP and engine load on carbon monoxide (CO) emissions with WOME blends has been shown in Figure 9. It is seen that, the increased load causes the raise in CO in exhaust gas for diesel, 20B and 100B. This is due to decreased air-fuel ratio with increased engine load. Further the B100 results lower CO emissions as the amount of oxygen in that helps to complete oxidation. Among all the results the CO emissions for the 220 bar is lower at full load condition.

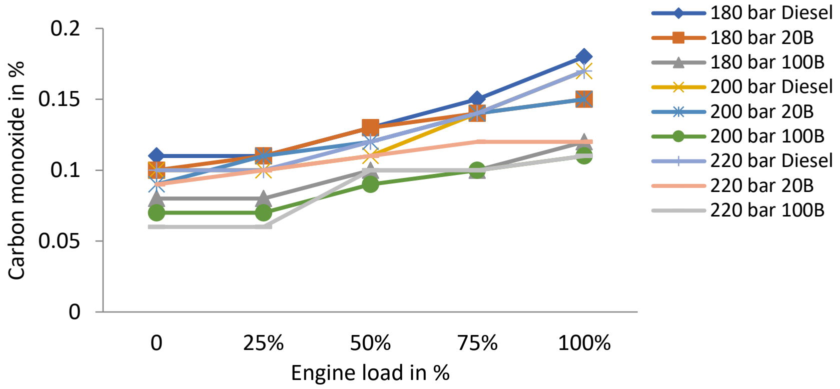

Figure 9: Effect of load and FIP on CO emissions

3.2.3 Effect on carbon dioxide (CO_2) emissions

The comparison of variation in Carbon dioxide (CO_2) with varied load and FIP has been indicated in the Figure 10. It can be said that, an incredible decrease in carbon dioxide emission with more proportion of diesel (20B) but the blend with B100 results in lower outputs of CO_2 emissions. The 220 bar FIP with 100B shows a lowest CO_2 emission than the pure diesel.

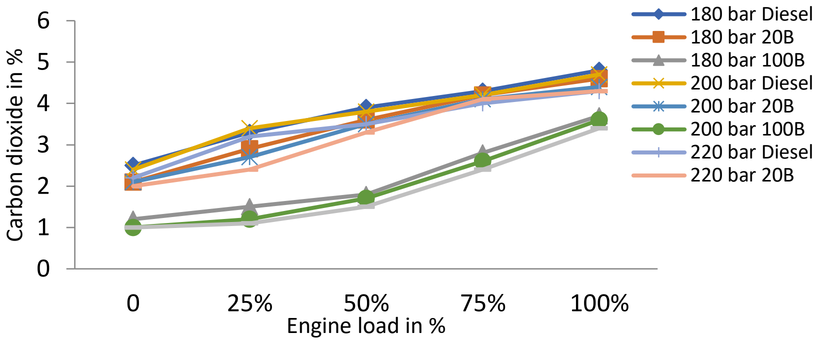

Figure 10: Effect of engine load and FIP on CO_2 emissions

3.2.4 Effect on oxygen emission:

The variation in oxygen emission with varied load and FIP is illustrated in Figure 11. It's clear from the graph that, a continuous decrease in oxygen emission with increased load. The diesel shows lowest oxygen emissions compared to WOME blends B20 and B100. The higher biodiesel content results in increased oxygen emission. The B100 shows more oxygen emission due available oxygen in the biodiesel as well increased FIP leads to increased oxygen.

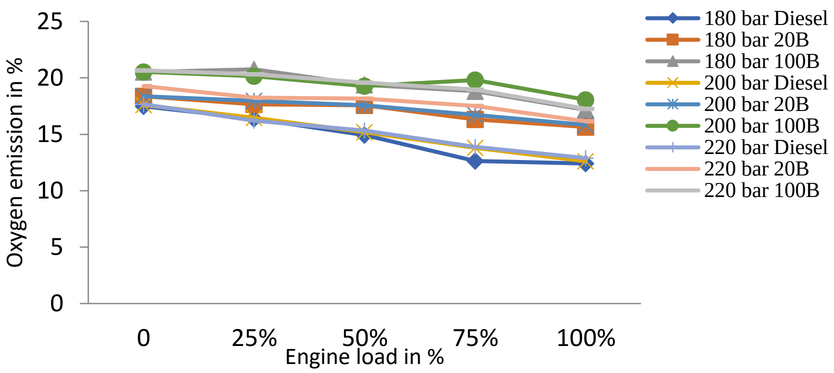

Figure 11: Effect of load and FIP on Oxygen emissions

3.2.5 Effect on NOx formation:

The Nitrogen oxide (NOx) emissions with varied load and FIP are seen in Figure 12. The B100 fuel tested resulted higher NOx than B20 and diesel, this may be attributed by increase in EGT and the biodiesels have inherent oxygen, which facilitated NOx generation. In general the NOx formations vary with engine load. Further, the Figure 12 illustrates the enhanced combustion temperature and NOx formation. This is, because the NOx formation is strongly the temperature dependent. From the result graph can be shown that 220 bar has less NOx emission.

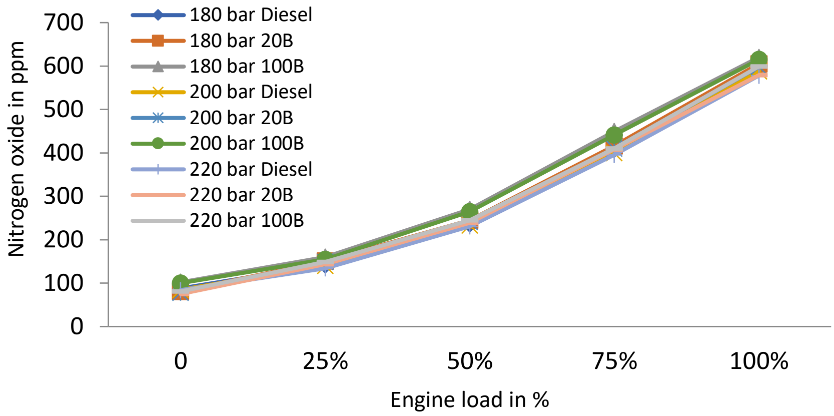

Figure 12: Effect of load and FIP on Nitrogen oxide emissions

Conclusions

The intension of this paper is to exhibit the effect of load and the FIP on the usage of WOME blends on engine behavior.

- The engine tests were done with WOME blends with base line fossil diesel with adjustment to raise the FIP from 180 to 220 bar.
- It's noticed that the engine BTE with WOME blends were marginally better than 180 bar than 220 bar with increased load, but found low efficiency for biodiesel blends and diesel.
- BSFC is lower for diesel than WOME blends tbut it increases with load and decreases with increased injection presuure.
- From the result it shown that WOME exhibit less NOx emission.
- The pure diesel has lowest oxygen emissions compared to WOME blends. Further, the increased biodiesel content results increased oxygen outputs.
- The higher blend shows lower CO_2 emissions.

From the extensive experimentation with increased load and FIP it's recorded that, the WOME blends are marginally better than neat diesel fuel and there is improved emissions and performance with the increased injection pressure.

References

[1] Azmi Yahya and Stephen J. Marley, "Performance and exhaust emission of a compression ignition engine operating on ester fuels at increased injection pressure and advanced timing", Biomass and Bioenergy, 6, 1994, pp 297–319.

[2] J. Narayana Reddy and A. Ramesh, "Parametric studies for improving the performance of a Jatropha oil-fuelled compression ignition engine", Renewable Energy, 31, 2006, pp 1994-2016.

[3] Agarwal D. and Agarwal A. K., "Performance and emission characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine", Appl. Thermal Eng, 27, 2007, pp 2314–23.

[4] Ghazikhani M., Zangooee, M. R. and Darabandi, A., "Performance and emission characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine", Applied Thermal Engineering, 27, 2007, pp 2314-2323.

[5] Sharma Y. C., Singh B. and Upadhyay S. N., "Advancements in development and characterization of bio diesel: A review", Fuel, 87, 2008, pp 2355-2373.

[6] Rosli Abu Bakar, Semin and Abdul Rahim Ismil, "Fuel Injection pressure effect on performance of Direct Injection Diesel Engines based on Experiment", American Journal of Applied Sciences, 5, 2008, pp 197-202.

[7] Rehman, A., Pandey R. K., Dixit S. and Sarviya, R. M., "Performance and Emission Evaluation of Diesel Engine Fueled with Vegetable Oil", Int. J. Environ. Res., 3, 2009, pp 463-470.

[8] K. Purushothaman and G. Nagarajanan, "Effect of injection pressure on heat release rate and emission in CI engine using orange skin powder diesel solution", Energy conversion and Management, 50, 2009, pp 962-969.

[9] Satish Kumar Sharma, Dilip Sharma, S.L.Soni and Kamal Kishore Khatri, "Optimization of Injection Timing and Pressure of Stationary C.I. Engine Operated on Pre-Heated Karanj-Diesel Blend", Indian Journal of Air Pollution Control, Vol. 9, 2009, pp 79-89.

[10] Sukumar Puhan, R. Jegan, K. Balasubbramanian and G.Nagarajan, "Effect of injection pressure on performance, emission and combustion characteristics of high linolenic linseed oil methyl ester in a DI diesel engine", Renewable Energy, 34, 2009, pp 1227-1233.

[11] Mustafa Canakci, Cenk Sayin, Ahmet Necati Ozsezen and Ali Turkcan, "Effect of Injection pressure on the Combustion, Performance and Emission Characteristics of a Diesel Engine Fueled with Methanol-blended Diesel Fuel", Int. Jr. of Energy & Fuels, 23, 2009, pp 2908-2920.

[12] Suryawanshi J G & Deshpande N V-"Overview of EGR, Injection Timing and pressure one missions and performance of CI engine with Pongamia Methyl Ester." SAE paper 2005, 26-346.

[13] Chennakesava Reddy, M V S Murali Krishna et al.-"Potential of a low Heat Rejection Diesel engine with crude Pongamia oil". IJMERVol.1 issue 1, pp-210-224.