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Performance Study of Mustard Oil Bio-diesel Blend in a Single Cylinder 4-stroke Diesel Engine

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Abstract: In this article the performance study of mustard oil bio-diesel blended with commercially available diesel has been conducted on the single cylinder engine. The bio-diesel was extracted from the mustard oil by transesterification process. The percentage yield of the biodiesel was ≈82%. The extracted bio-diesel was blended with commercially available diesel in different fractions for the study. The performance study and emission analysis were calculated on single cylinder four stroke diesel engine. According to analysis brake specific energy consumption there was decreasedand there is slight increase in brake thermal efficiency. The exhaust analysis showed that there was considerable drop in the engine emission like carbon dioxide, carbon mono oxide and hydrocarbons, resulting in lower smoke opacity. The oxides of nitrogen were present at a higher percentage in the engine emissions when the bio-diesel blend was used.

Keywords: Green fuel, Engine emissions, Smoke opacity, Brake specific energy consumption, Mustard oil bio-diesel, Brake thermal efficiency.

1. Introduction

Diesel engine has been used as one of the most reliable sources for producing power in various fields due to its low installation cost, high operational life, simple in operation, versatility and lesser thermal and mechanical losses[1-3].Beside the conventional diesel the alternative duels can also be used in the diesel engine[4-5]. The fuel used is hydrocarbon which goes through combustion and produces the required power[6-7]. The prime concern for the use of diesel engine is availability of fuel and the environmental pollution[8-9]. The petroleum-based diesel or conventional diesel has limit sources which are depleting day by day hence may result in a huge power crisis one day[10-12]. The diesel is a hydrocarbon which when burnt in presence of oxygen results in emission of harmful gasses which are adding to environmental pollution[13-14]. The increased power demand resulted in the over use of diesel engine. The gasses like CO and NO_x released form the diesel engine are highly dangerous for the living beings. The particulate matter released form the diesel engine is making the condition even worse[15-16]. The researchers have been trying to produce cleaner to fuel to reduce such hazardous effects[17-18]. Such alternate fuels either blended in some proportion in the conventional diesel or used as it in the engine depending upon the various physio chemical properties[19-20]. The alternative fuels for the diesel engine are produced mainly form the biological compounds making the system sustainable. The diesel produced from the eatable or non-edible oils, starch, algae has high yield and desirable performance[21-22]. The methyl ester synthesized in non-thermal plasma reactor show considerably high yield and performance[23].

The yield of bio diesel reactor depends on several factors. The replacement of nitrogen by carbon dioxide as carrier gas resulted in heat emissivity and yield on the other hand the method more economical[24-25]. The carbon dioxide emissions and water requirement for commercial bio-diesel productions has been studies, the large demand of water can be met from the natural sources like rain[26]. The yield of bio diesel depends on various factors like temperature and reaction time[27], outdoor temperature[29], mass flow rate of carrier gas[30].

The versatility of diesel engine has made it one of the primary choice for energy generation under different applications. The major issue for using diesel engine has been the availability of fossil fuel and the carbon foot prints. The recent developments in the field of bio-fuels have attracted the researches to check the potential of different oils that could be converted to bio-diesel. The

objective of current research is to utilize the mustard oil for developing the bio-diesel. The developed bio-diesel was blended with the conventional diesel to reduce the carbon footprints. The thermal performance and emission study of the single cylinder diesel engine was studied using the bio-diesel blend as fuel and compared with the conventional diesel to predict the most suitable bio-diesel blend.

2. Biodiesel Production

Transesterification process is used for production of bio diesel from mustard oil. The methanol was added to mustard oil in (mol/mol 1:6). NaOH (1% w/w) was used as the base catalyst to enhance the rate of reaction. The rate of reaction was increased by mechanical mixing at elevated temperature. The blend was maintained at 60°C and 500 rpm using a hot plate magnetic stirrer. Due to centrifugal action methyl ester and glycerol were separated after the stirring for 2-3 hr. The NaOH was washed using the DI water. The inverter beaker was used to separate out bi-product from the bio diesel because of very high-density difference. The high-density bio-product settle down and drained out. The excess of methyl alcohol was removed by the vaporization process.

The freshly prepared bio diesel was blended with convention diesel (mineral diesel) in different v/v ratios of 10%, 15%, 20% and 25%. The various blends and bio diesel were used as fuel for performance measurement of 4 stroke diesel engine and comparison is done with the conventional diesel.

Table 1: Percent yield of produced bio diesel.

Molar ratio (alcohol/oil)	Quantity of oil	Quantity of bio diesel produced	Percentage Yield
1:6	400 g	328 g	82 %

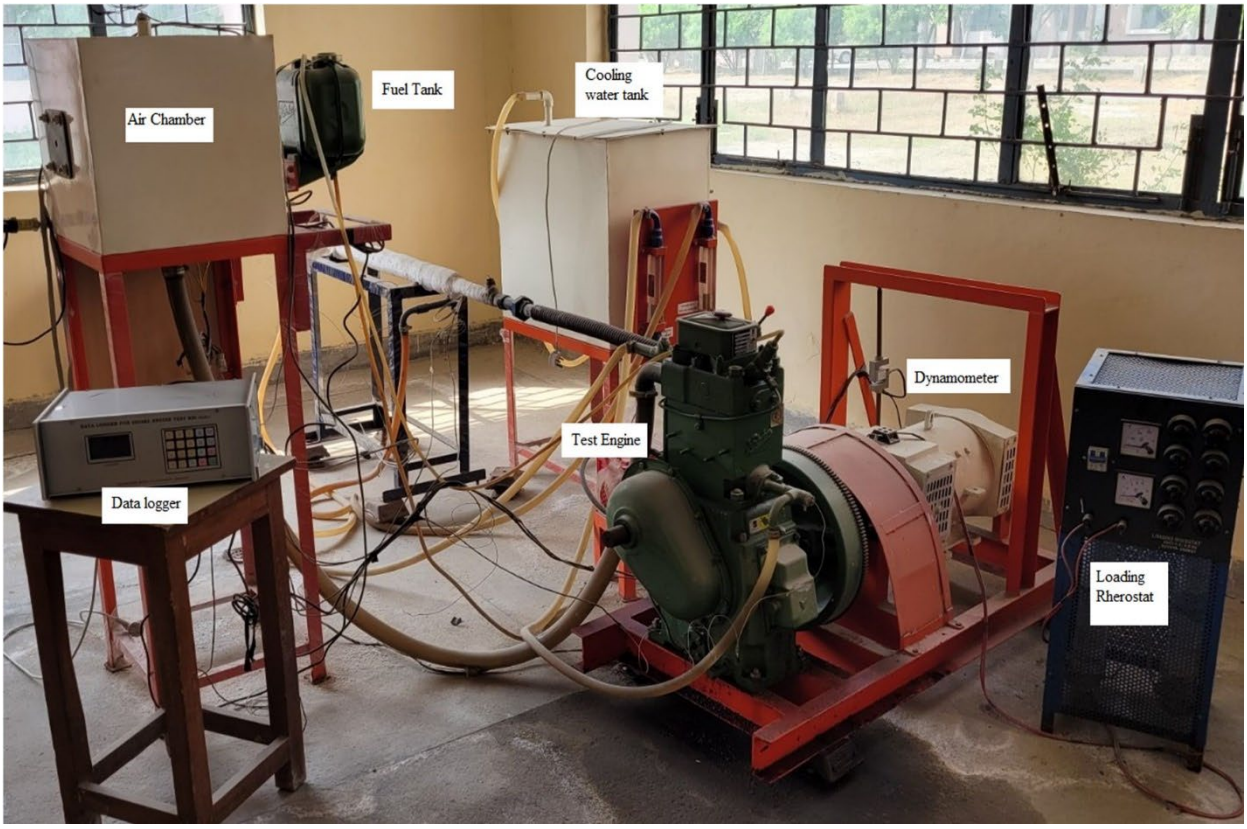

Figure 1: Engine test rig

3. Experimental setup

3.1 Single cylinder diesel engine

The Kirloskar internal combustion single cylinder diesel fueled four stroke engine is used for performance analysis as shown in Figure 1. This light duty, water cooled, vertical engine diesel engine generally used for irrigation purpose by the farmers. Table 2 provides the test rig's characteristics.The engine and the eddy current dynamometer are connected.Data loggers was used for the measurement ofthe engine performance characteristics such as brake thermal efficiency, emissions, and brake-specific fuel consumption.Exhaust gasses were studied by using of smoke meter and gas

analyzer.

Table 2: Enginespecifications for the Test

Parameter	Description
Name	Kirloskar
Number of strokes	Four stroke
Model	AV1-5.0
Type of cooling	Water cooled engine
Fuel	Diesel
Lubricating oil	15W40
Compression Ratio of engine	16.5:1
Bore	80 mm
Cubic Capacity	553 cc
Engine Rated Power	3.7 kw per 5 hp @ 1500 rpm
Number of cylinders	Single cylinder
Displacement	110 mm

4.Performance Study of IC Engine

The engine's performance was evaluated under various load conditions.The consumption of brake specific energy and the brake thermal efficiency were measured along with the emissions.

$$\text{Brake Power (BP) (kW)} = \left(\frac{2 \times \prod \times \text{rpm} \times \text{load} \times 9.81 \times \text{l}}{60 \times 1000}\right) \ldots\ldots\ldots (2)$$

$$\text{BMEP (bar)} = \left(\frac{120 \times \text{BP}}{\text{L} \times \text{A} \times \text{N} \times 101.325}\right) \ldots\ldots\ldots (3)$$

$$\text{BTE} = \left(\frac{\text{BP}}{\text{mf} \times \text{CV}}\right) \ldots\ldots\ldots (4)$$

$$\text{BSEC} = \left(\frac{\text{m} * \times \text{CV} \times 3600}{\text{mf} \times \text{CV}}\right) \ldots\ldots\ldots (4)$$

4.1 Brake specific energy consumption (BSFC)

The ratio of the total energy produced by the metered fuel quantity to the brake power is known as brake-specific energy consumption.As it considers the calorific value and density of the fuel, BSEC is a more reliable parameter when studying the multi-fuel system than brake-specific fuel consumption.It is the indication of measurement of the fuel efficiency at prime mover by combustion of fuel and produce shaft power. The BSEC was very high at lower loads or BMEP. The BMEP increased as per engine's load increased. There was a sudden drop noticed in the value of BSEC up to BMEP of 1 bar. After that the slop of curve was not that steep still it showed a continuous decrement as shown in Figure 2. Hence at higher loads the BSEC showed lesser value. The BSEC was higher for the conventional diesel and it decreased as the composition of bio diesel in the blend increased up to 15% due to the superior combustion quality of the bio diesel blend. As the composition of bio diesel in the blend increased the density of fuel increased resulting in higher mass flow rate of fuel inside the engine. As a result, the BSEC increased beyond 20% bio diesel in the blend.

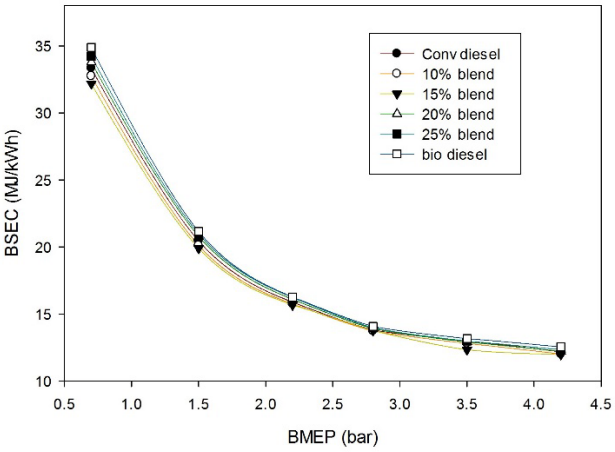

Figure 2: Graph Between BMEP and BESC

4.2 Brake Thermal Efficiency (BTE)

The BTE was very low (around zero) at lower loads or BMEP. There was a sudden increment noticed in the value of BTE up to BMEP of 3 bar. After that the slop of curve was not that steep still it showed a continuous increment. Hence at higher loads the BTE showed higher value indicating better performance of engine. The BTE of the blend was higher compared to the conventional diesel upto 15% bio-diesel in the blend as shown in Figure 3. This is due to the fact that the bio-diesel contains free oxygen which enhance the combustion quality of fuel resulting in higher thermal efficiency. As the amount of bio diesel in the blend was increased further the BTE started to drop because of the lower calorific value of the bio-diesel compared to the conventional diesel.

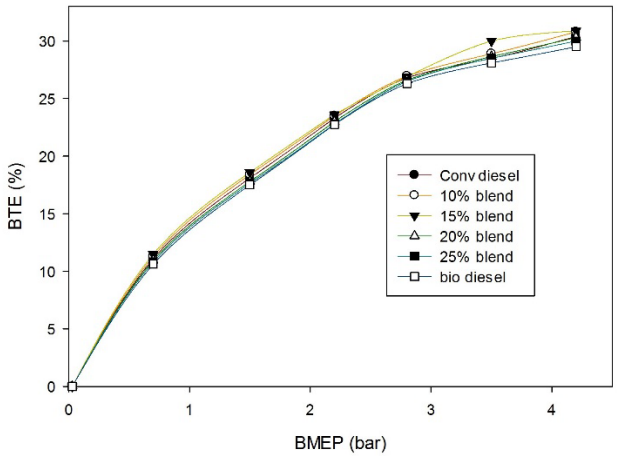

Figure 3: Graph Between BTE and BMEP

4.3Temperature of Exhaust gas (EGT)

The exhaust gas temperature was measured under various load conditions, that are varies fromnil load to full load.With increasing engine load, the temperature of the exhaust air rose.This pattern was followed by the conventional diesel as well as the bio-diesel blends. The exhaust air temperature for bio diesel blend was less than the conventional diesel, this goes on decreasing as the composition of bio diesel in the blend increased as shown in Figure 4. Compared to conventional diesel, bio diesel burns more quickly and has a lower heating value.

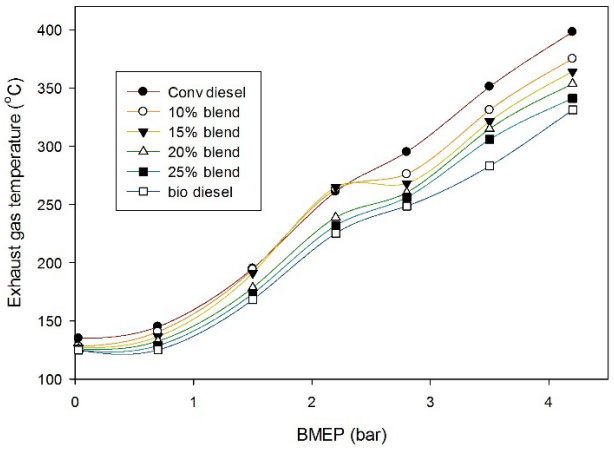

Figure 4: Graph Between EGT and BMEP

4.4 CO Emissions

The CO emission was very low (around zero) at lower loads or BMEP. There was a sudden increment noticed in the value of CO emission up to BMEP of 3 bar. After that the curve was steep showing continuous increment. Hence at higher loads the CO emission showed higher value indicating poor performance of engine. As demonstrated in Figure 5, the CO emission was higher for conventional diesel and decreased as the amount of bio diesel in the blend increased. This is because of the fact that the bio-diesel blend had excess of oxygen which resulted in further oxidation of the CO.

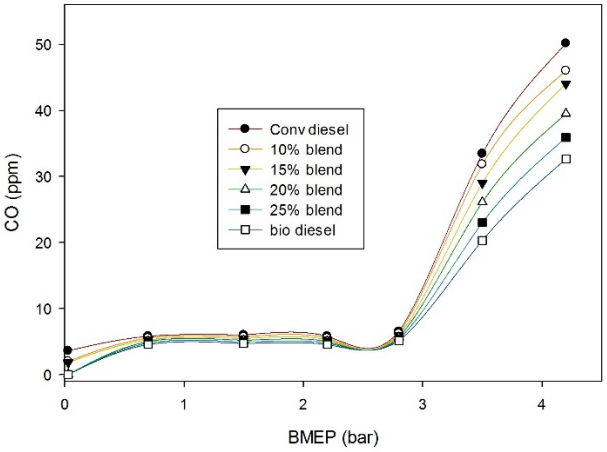

Figure 5: Graph Between CO and BMEP

4.5Hydrocarbon emission

The HC emission was very low at lower loads or BMEP. The value of HC emissions up to BMEP of 2.2 bar was not too high; however, they did grow with an increase in engine load.After 2.2 bar that the HC emissions continues to increase with steep slope as shown in Figure 6. The flow rate of the mass of fuel inside the engine improved at greater loads.The fuel inside the engine at higher loads has not been completely combusted as a result the unburn hydrocarbons goes out of the engine. As the proportion of biodiesel in the blend increased, the HC emission reduced from the higher levels for conventional diesel.This is due to the fact that the bio-diesel blend had excess of oxygen which increased the combustion quality of fuel resulting in lower hydrocarbon emissions [27].

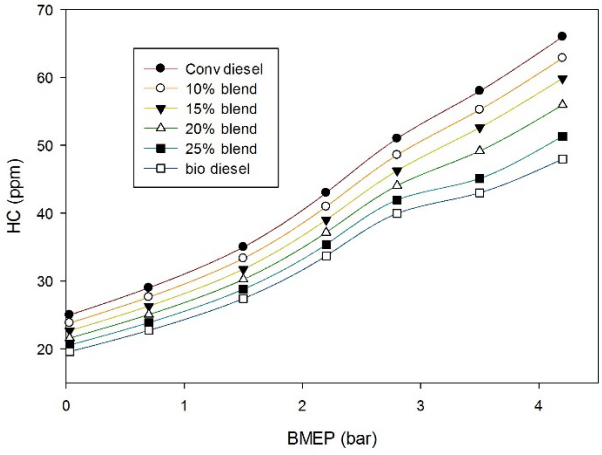

Figure 6: Graph Between HC and BMEP

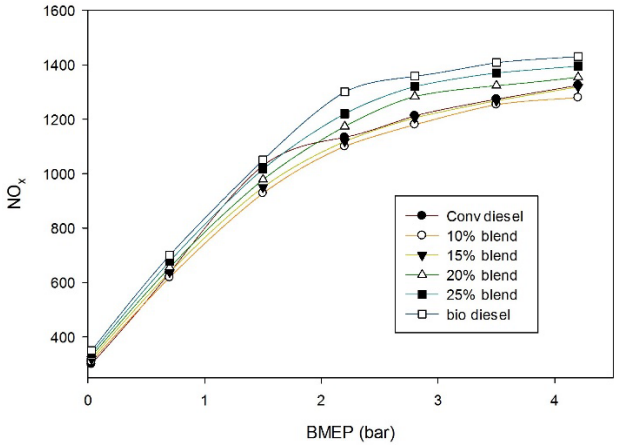

Figure 7: Graph Between NOx and BMEP

4.5 Oxides of Nitrogen emission

The NOx emission were very low at lower loads or BMEP. There was a sudden increment noticed in the value of NOx emission as the BMEP increased up to 1.6 bar as shown in Figure 7. After that the curve had constant slope showing continuous increment. Hence at higher loads the NOx emission showed higher value indicating poor performance of engine. The NOx emission was higher for the conventional diesel and it increased as per the composition of bio diesel in the blend decreased.

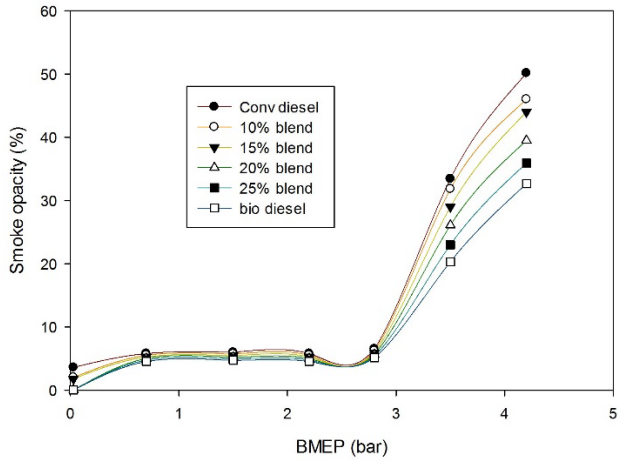

Figure 8: Graph Between Smoke opacity and BMEP

4.6 Smoke Opacity

The Smoke opacity was very low at lower loads or BMEP. There was a sudden increment noticed in the value of Smoke opacity up to BMEP of 3 bar as shown in Figure 8. After that the curve was steep showing continuous increment. Hence at higher loads the Smoke opacity showed higher value indicating poor performance of engine. The Smoke opacity was more for the conventional diesel at lower loads whereas at higher loads the bio diesel blend showed higher smoke opacity, similar results have been observed by Sugeng et.at. [30]. As the percentage of bio diesel in the blend decreased, the opacity of the smoke also reduced.

5. Conclusions

The bio diesel was produced successfully from the mustard oil with a yield of ≈82%. The bio diesel blends were prepared and compared with conventional diesel. The BSEC was lower for the conventional diesel and it increased as the composition of bio diesel in the blend increased. The BTE was higher for conventional diesel and fell as the percentage of bio diesel in the mixture increased.Performance of conventional diesel was better than the bio diesel blend still up to a composition of 15 % the variation was less than 10 %, so the blend with bio diesel up to 15% can be used without much effect on the performance. The bio diesel blend showed little considerable better emission characteristics in case of HC, CO and smoke. But the NOx emission were slightly on the higher in case of bio diesel blend.

Nomenclature

CO	Carbon Monoxide
NO_x	Oxides of Nitrogen
BP	Brake Power
HC	Hydrocarbon
BMEP	Brake Mean Effective Pressure
BTE	Brake Thermal Efficiency
CO_2	Carbon Dioxide
BSFC	Brake Specific Fuel Consumption
BSEC	Brake Specific Energy Consumption

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