PERFORMANCE OF A COMPRESSION IGNITION ENGINE USING CANOLA (BRASSICA NAPUS) BIODIESEL

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Abstract

The fuel consumption in the world, particularly in developing countries has been growing at an alarming rate. Also the petroleum prices are approaching record high and they are in the state of depletion within few decades. So in regard to this one alternate solution for overcoming these problems related to commonly available fossil fuels is usage of biodiesel derived from non-edible stocks such as Canola (Brassica Napus). Canola biodiesel (canola oil methyl esters) is a non toxic and biodegradable alternative fuel that can be obtained from canola base oils by transesterification process and its properties are similar to that of diesel. Moreover the Canola oil Biodiesel (canola oil methyl esters) can be blended with diesel fuel in different ratio and can be used directly without any further modification in the existing diesel engine. This paper tries to investigate the performance characteristics of a diesel engine using the various blends of Canola oil biodiesel (B20 & B40) by running the engine in steady state conditions. The various performance parameters such as brake power, brake thermal efficiency, specific fuel consumption and exhaust gas temperature were measured to evaluate and compute the behaviour of the diesel engine running on biodiesel. B20 shows a better performance characteristic than B40 which makes it more suitable to replace the conventional petroleum fuels and qualify as an effective alternative fuel.

Keywords: Alternative fuel, diesel engine, Canola oil biodiesel, transesterification, Performance characteristics.

1. Introduction

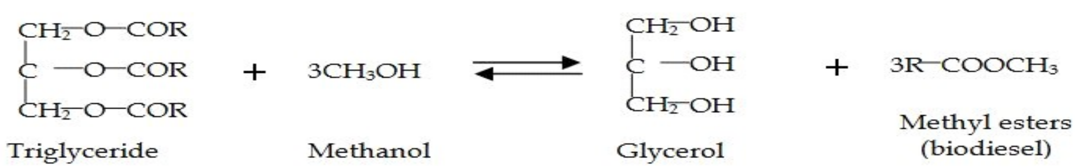
The world is confronted with the twin crises of fossil fuel depletion and environmental degradation [1-2]. Alternative fuels, promise to harmonize sustainable development, management, energy conversion, environmental preservation and efficiency. One of these alternatives is the use of biodiesel produced from vegetable oils [3-4]. Vegetable oils are non-toxic, renewable sources of energy, which do not contribute to the global CO2 build up. Biodiesel contains no petroleum but it can be blended at any level with petroleum diesel to greater biodiesel blend. It can be used in CI engine with no major modifications in the existing engine. It is simple to use, bio degradable, non-toxic and essentially free of sulphur and aromatics. The fuel properties of biodiesel such as cetane number, specific gravity, heat of combustion, and viscosity influence the combustion and so the engine performance characteristics because it has different physical and chemical properties than petroleum-based diesel fuel. The choice of vegetable oil as engine fuel naturally depends upon the local conditions prevalent availability of a particular vegetable oil in excess amount. There are various oils which are being considered worldwide for use in the engines. One of the promising biodiesel option among all these is the Canola biodiesel (Canola oil methyl ester). India is the third largest producer of rapeseed-mustard after China and Canada [5-6].Out of these 30 percent is used in the total production of oilseeds [5-6]. Canola quality varieties are commonly developed from species of Brassica napus, Brassica Campestris and Brassica Juncea. Out of these species cultivation of Brassica Napus is majorly found in India [7].Canola quality form Brassica Napus is an edible variety of rapeseed with a low percentage of erucic acid (< 2%) and low levels of glucosinolates (less than 30 micro mole/g) [7].

In this paper, experiments is being conducted in the diesel engine using blends of Canola oil Biodiesel in percentage of 20 % and 40 % at variable load condition of 40 kg, 80kg, 120 kg, 160 kg and 200 kg load at engine and a comparative investigation have been done on the various performance parameters using those blends in order to provide an effective replacement for diesel fuel.

2 . Biodiesel Processing

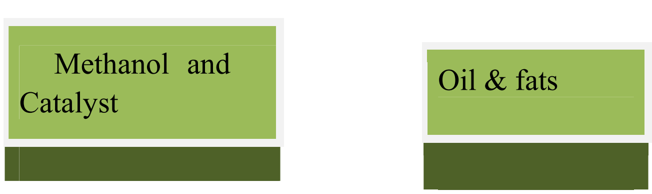
The methods of producing biodiesel can be divided into “physical” and “chemical” methods according to processing method and biodiesel characteristics. Further physical methods can be subdivided into the “direct mixed method” and the “micro emulsion method” while the chemical methods can be subdivided into the “pyrolysis method” and the “transesterification method.” Transesterification being the most used method. The process of converting the raw vegetable oil into biodiesel, which is fatty acid alkyl ester, is named as transesterification. Conversion is complicated if oil contains higher amounts of Free Fatty acids (FFA) (>1% w/w) such as in the cases of non-edible vegetable oils such as Olive oil, Jatropha and Cotton seed oil, etc. which in turn will form soap with alkaline catalyst. The soap thus formed can reduce the ability to separate the crude biodiesel from the glycerin fraction in the later stages of transesterification process. Crude oil contains about more than 30 % FFA, which is far beyond the 1% level [8-9]. For determining whether the raw vegetable oils can be transesterified directly, the acid value is the most important property that must be determined. If the acid value <3 then the raw vegetable oil can be directly trans-esterified. If the acid value >3 then there is slight change in the production of biodiesel process. At first the oil undergoes esterification and then followed by transesterification. Few researchers have worked with feedstock having higher FFA levels using alternative processes [10].Pretreatment step to reduce the free fatty acids of these feed stocks to less than 1% before transesterification reaction was completed to produce biodiesel [11]. The reduction of FFA <1% is best if esterification followed by Transesterification. In the esterification process the excess of the free acid gets reacted. The remaining acid content in the oil undergoes trans-esterification process. So this method is effective for oils that contain high free fatty acid (FFA) content.

Transesterification also called alcoholysis is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis, except that an alcohol is worked instead of water. Suitable alcohols include butanol, methanol, ethanol, propanol, and amyl alcohol. Ethanol and methanol are utilized most frequently. This process is mostly used to reduce the viscosity of triglycerides, thereby enhancing the chemical and physical properties of biofuel and improve engine performance. Thus fatty acid methyl ester (also known as biodiesel) is obtained by transesterification. This reaction can be shown as:-



3. Biodiesel Production

The Canola Oil was procured from local source. The traces of water present in the oil is removed before transesterification process by initial heating .The base oil is boiled for 20 minutes to ensure the minimal presence of water in the oil and to use it for further process. Figure1shows the schematic sketch of the preparation of biodiesel



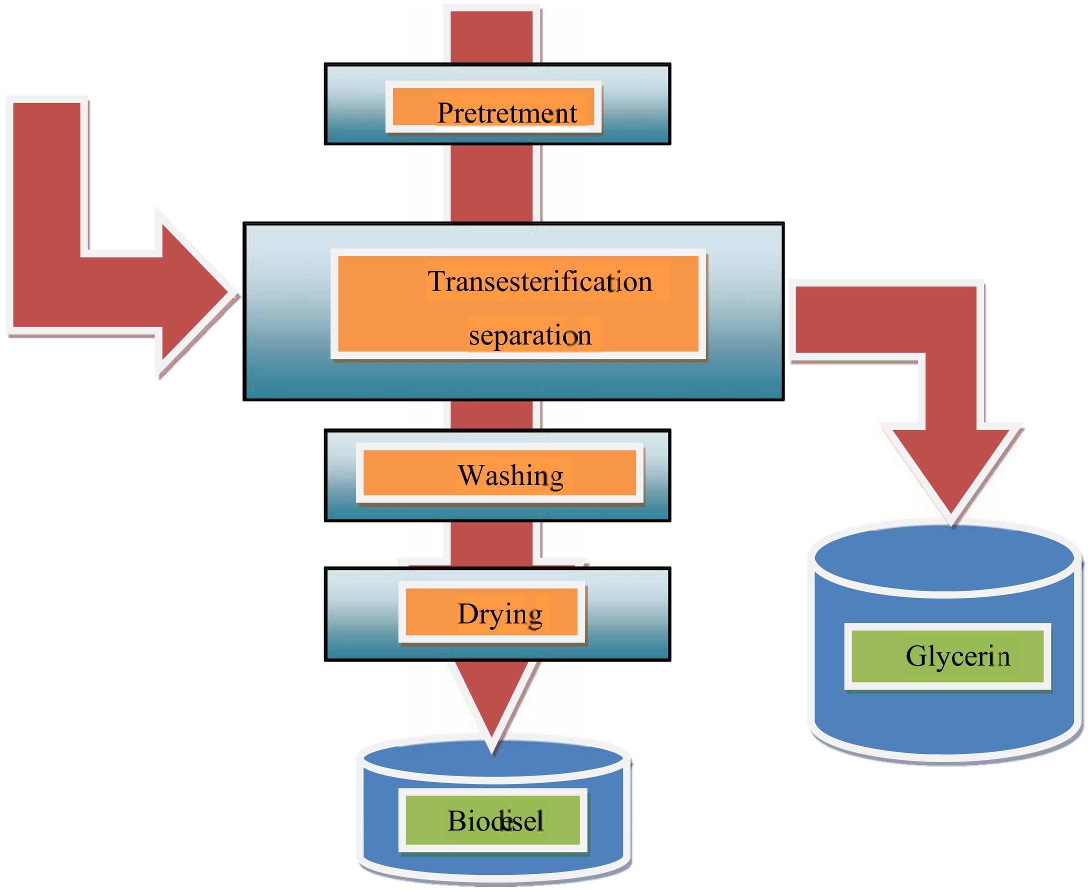


Figure 1: Schematic diagram of preparation of biodiesel

An alkali catalyst is required for transesterification due to the presence of FFA in base oil. The reaction is performed close to the boiling point of alcohol (methanol: 60-70 ^{0}C) at atmospheric pressure for a given time. Pre-treatment is not required if the reaction is carried out under high pressure (900 KPa) and high pressure (240^{0}C), where simultaneous esterification and transesterification takes place with maximum yield obtained at temperature ranging from 6080^{0}C at a molar ratio of 6:1. An increase in temperature is reported to have an adverse effect on the biodiesel recovery. The base oil was heated up to 60'C in a flat bottom flask in order to prevent evaporation of methanol from the solution. The amount of NAOH required (in grams) to be poured into reaction vessel is obtained by adding FFA neutralization to a NAOH solution. A solution C is prepared with this NAOH weight in 200ml water. Then 1 litre of filtered base oil is poured into the reaction vessel and heated with continuous stirring using a magnetic stirrer. When the temperature reaches 60C 120ml of solution C is poured into the reaction vessel and constant temperature is maintained for 1hr.The entire solution is put into separating funnel for 6hrs to retrieve glycerol and base oil methyl ester layer wise. Figure2 shows the traces of layers of canola oil and fatty acids. Recovered methyl ester is again subjected to the same procedure with 80ml of solution C to remove traces of glycerol in order to achieve rich quality of biodiesel (B100). The Canola biodiesel blends were then prepared in proportion of 20% and 40% of biodiesel with diesel. These blends, B20 (20% Canola biodiesel with 80% diesel) and B40 (40% Canola biodiesel with 60% diesel) were run on a CI engine to investigate its performance parameters.

Figure 2: Layer of Canola oil and fatty acids

4. Experimentation

4.1 Experimental Fuels.

In this research investigation two blends were prepared 20% (v/v) canola biodiesel with 80% (v/v) diesel fuel denoted by B20 (Canola biodiesel blend) and 40% (v/v) biodiesel with 80% (v/v) diesel fuel denoted by B40(Canola biodiesel blend).

The pour point and cloud point of Canola biodiesel is higher so it can perform better work at cold condition as compare to diesel. The properties of Canola biodiesel blends (B20 & B40) prepared is checked in a quality test so that its properties satisfies the standards of ASTM D6751 and then it is proceeded for use in a direct injection diesel engine. The table shows the various comparative properties of diesel and Canola Biodiesel blends

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Table1: Properties of diesel and Canola biodiesel blends

SL.No.	Properties	Diesel	B20	B40
1.	Density at 15°C (kg/m^3)	830	839	855
2.	Viscosity at 40°C (cST)	270	3.13	3.71
3.	Flash point (°C)	58	82	113
4.	Fire point (°C)	77	87	118
5.	Calorific value (MJ/kg)	43.09	40.95	38.62
6.	Pour point (°C)	3.1	3.7	4.83
7.	Cloud point (°C)	6.8	7.87	10.21

Figure 3: Blends of Canola biodiesel (B20 & B40)

4.2 Experimental Setup and Procedure for Performance test

Experiments were conducted on a four cylinder, four stroke, and DI diesel engine at varying loads. The major specifications of the test engine are presented in Table-2. Fuel used for testing was blends of Canola biodiesel, B20 & B40.

Table2: Test Engine Specification

Engine:	Mahindra & Mahindra
Make &Type:	Four cylinder, four stroke, water cooled diesel engine.
Displacement volume(cc):	1895
Density of fuel (kg/m^3):	720-780
LHV of Diesel (MJ/kg):	42.11
Density of air, ρ_{air} (kg/m^3):	1.17 to 1.20
Number of cylinders:	Single
Bore/Stroke:	85/80
Compression ratio:	16.1
Rated Power:	46.55 kW
Rated Speed:	1800 rpm
Injection Pressure:	200 bar

The performance test were conducted at variable load of 40 kg, 80kg, 120 kg, 160 kg and 200 kg load with the speed of engine was constant at 1500 rpm. For the application of load, engine was coupled to a DC Shunt dynamometer. The Figure 4 shows the experimental test rig that is used for investigation Initially the test engine was operated with base fuel- diesel for about 30 minutes to attain a normal working temperature condition and after that a base line data was generated to obtain the corresponding results. The following parameters are noted down during the experimentation:

a) Brake power, kW.

b) Dynamometer load, kg.

c) Fuel consumption, kg/sec.

Figure 4: Experimental Test rig

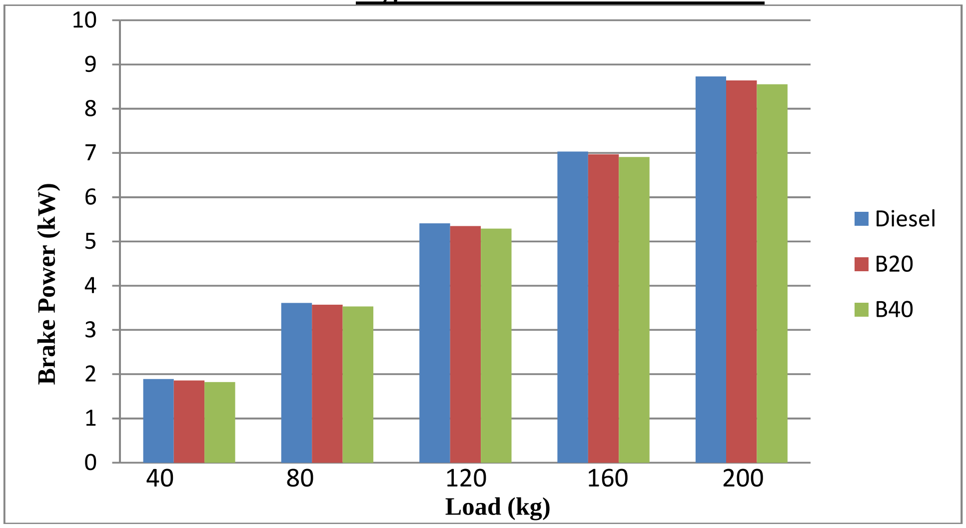
5. Results and Discussions

5.1 Performance Characteristics

5.1.1 Brake power

The brake power (BP) is the power that is available at the crankshaft of the engine. Figure 5 shows the effect of load on the brake power of the engine with the use of diesel and different blends of Canola biodiesel. It can be observed from the figure that with increase in load the brake power of the engine is monotonically increasing for all types of fuels that are being used. It is also seen from the figure that the blend B20 has a higher brake power than B40 for all the load conditions operated for the test rig, though it is still less than that of the BP obtained from diesel fuel. This is because with the increase in concentration of Canola biodiesel in the blend the heating value or calorific value decreases. Hence it results in lower brake power. At maximum load the BP of the engine using diesel, B20, B40 was found out to be 8.73 kW, 8.64kW and 8.55kW respectively.

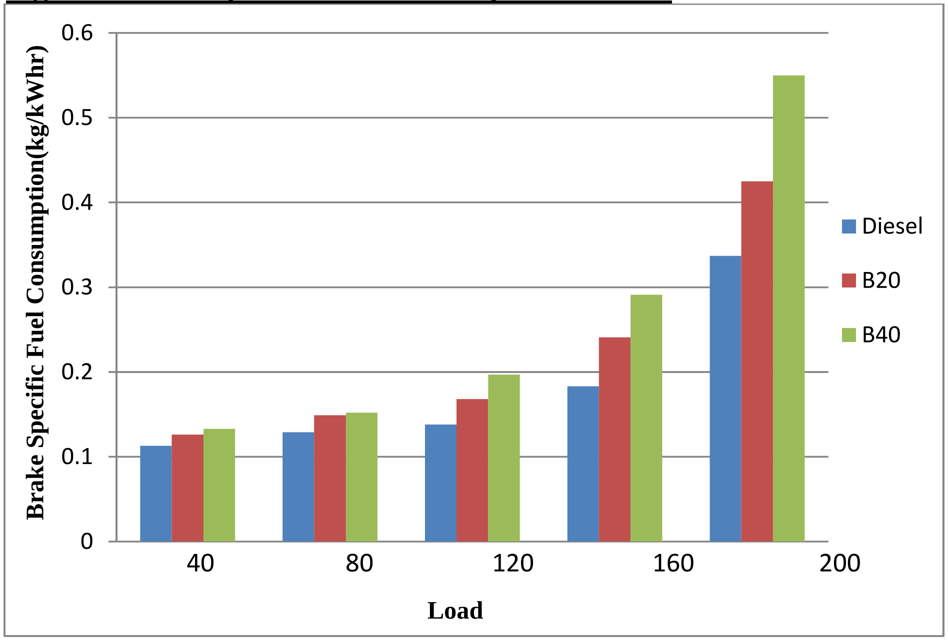
Figure 5: Brake Power Vs Load



5.1.2 Brake Specific Fuel Consumption

It is seen from the Fig.6 that brake specific fuel consumption (bsfc) is less for diesel when compared to biodiesel blends B20 and B40 for all varying loads. For the fuels tested, brake specific fuel consumption increases with increase in load. As the proportion of biodiesel blend increases, the bsfc was also observed to be increasing and the bsfc of B40 was found to be higher than all other blends for all the load conditions. The bsfc of the engine at maximum load using diesel, B20 and B40 was found to be 0.337 kg/kWhr, 0.425 kg/kWhr and 0.55 kg/kWhr. The bsfc of B40 is higher than all the other tested blends. This is due to the higher density of biodiesel and lower calorific value. As the percentage of blend increases the density also increases. The higher densities of biodiesel blends caused higher mass injection for the same volume. The results obtained from the figure suggest that B20 performs the best in less fuel consumption at lower loads and higher loads condition.

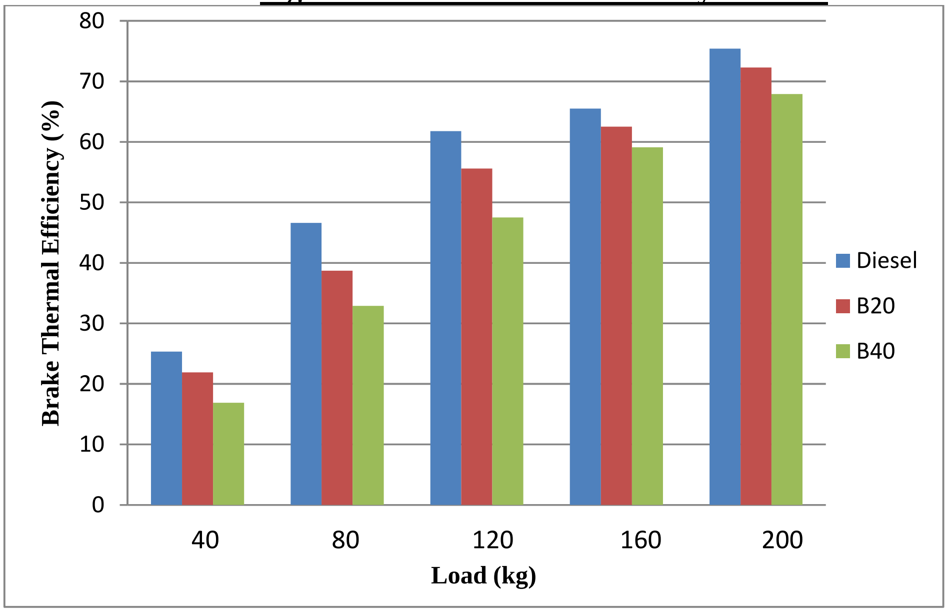
Figure6: Brake Specific Fuel Consumption Vs Load



5.1.3 Brake Thermal Efficiency Vs Load

The brake thermal efficiency is the ratio of power output of the engine to the rate of heat liberated by the fuel during combustion. Fig.7 shows the variation of Brake thermal efficiency (BTE) of diesel and different blends of biodiesel, B20 and B40 with load. In all the cases BTE increases with increase in load. However B20 has a relatively higher brake thermal efficiency than B40 for all increasing load conditions. This is because with the increase in concentration of biodiesel in blends, the properties of the blend result in lower calorific value, higher viscosity and poor volatility that accounts for poor atomization and spray pattern. The poor spray pattern results in non homogeneous fuel distribution in combustion chamber, hence poor combustion and lower thermal efficiency. The BTE of diesel and biodiesel blends B20 and B40 at maximum load are found out to be 75.4%, 72.3% and 67.9% respectively.

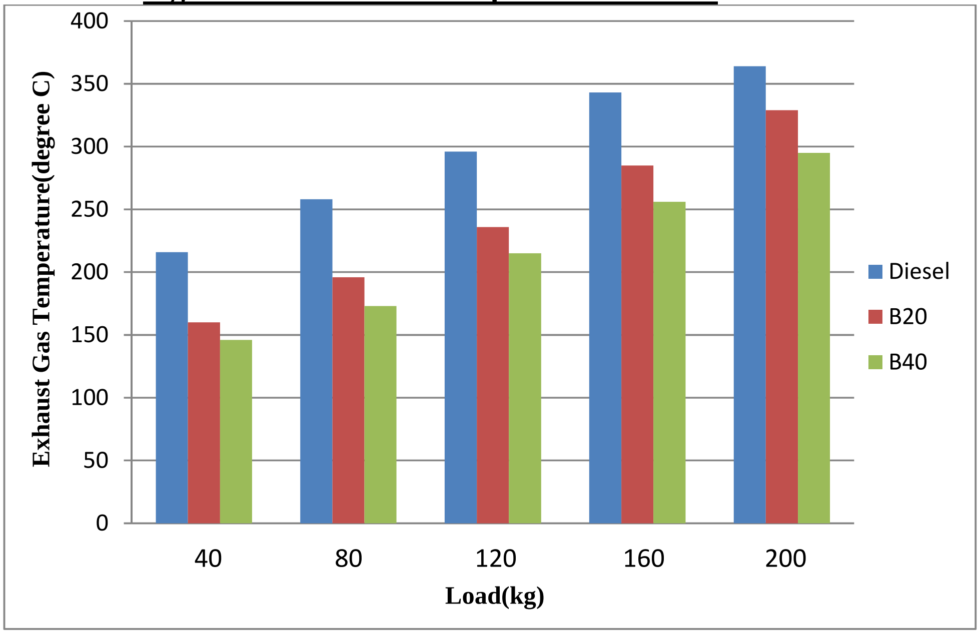
Figure7: Brake Thermal Efficiency Vs Load



5.1.4 Exhaust Gas Temperature

The variation of exhaust gas temperature depending upon variation of 40%, 80%, 120%, 1600%, and 200% loads at engine is shown in the Figure 8. The results showed that the exhaust gas temperature increased with increase in load for every tested fuel. It can also be observed from the figure that the exhaust gas temperatures of the blends B20 & B40 are less than that of diesel. However B40 has a lesser exhaust gas temperature than B20 for all the varying load conditions. The combustion characteristics of the blends were improved by increasing the percentage of diesel fuel in the biodiesel fuel. All the test fuels exhibited lower exhaust gas temperature as compared to diesel fuel and this phenomenon can be understood that poor bsfc can be because of poor combustion efficiency. The exhaust gas temperatures of diesel, B20 and B40 are found out to be 364°C, 329°C and 295°C respectively.

Figure8: Exhaust Gas Temperature Vs Load



Conclusion

The Canola biodiesel (Canola oil methyl ester) blends B20 and B40 worked successfully in the four cylinder direct injection Compression Ignition engine and the engine resulted in acceptable engine performance when compared to the performance index of a diesel fueled engine. The following conclusions are obtained on the base of experimental results:

1. The properties of Canola biodiesel blends (B20 & B40) have satisfied the results obtained as per ASTM D-6751 standards of biofuels policy.

2. At all varying load conditions, the blends of Canola biodiesel tends to show an increase in brake power though it is less than that of diesel. Amongst the blends used, B20 has the maximum power because of high heating value than B40.

3. B20 performs the best in less fuel consumption at lower loads and higher loads condition in comparison to B40 biodiesel blend. This is due to the higher density of biodiesel and lower calorific value.

4. For all varying load condition, the Canola biodiesel blends have higher brake thermal efficiency. This happens because Canola biodiesel have containing 10% more oxygen content than diesel. Out of the two blends tested, B20 performs the best with a much higher brake thermal efficiency and its value is near about to that of pure diesel.

5. It is observed that at all loads condition exhaust gas temperature of B40 is minimum and hence it also results in less NOx emission.

The overall analysis has shown that Canola biodiesel has the potential to be used as an alternative fuel to diesel fuel in conventional compression ignition engine without any modifications on it. The property of the biodiesel blends and the tests performed on it suggests that the values obtained from it are near about to the values of the conventional pure diesel.

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