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Research Article

Experimental Investigation on Performance and Emission characteristics of DI Diesel Engine using Canola oil as Bio-diesel fuel

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Abstract

Experiments are carried out to study performance and emission characteristics of a diesel engine fuelled with diesel fuel, a Canola Biodiesel and its blends 10% by volume(BD10),20%(BD20),30%(BD30),40%(BD40),50%(BD50) and 100%(BD100).Tests have been conducted on four stroke, single cylinder, vertical, water cooled, cold start, compression ignition high speed diesel engine with different loading conditions at a constant speed of 1500 rpm. The results are presented in the form of Brake specific fuel consumption, mechanical efficiency, brake thermal efficiency and emission characteristics of CO, CO_2, UHC and NO_x. From the results it is observed that BD10, BD20, BD100 biodiesel blends given better Brake specific fuel consumption, mechanical efficiency, brake thermal efficiency than pure diesel. HC, CO, CO_2 emissions are lower for BD10 and BD20 blends and NO_xemissions are lower for BD100 except at 20% load. Also HC, CO_2, NO_xemissions are lower for pure biodiesel (BD100) compared to pure diesel and a reverse behavior is observed with respect to CO emissions. The results revealed that the Canola biodiesel showed comparable performance and can be a good replacement to diesel fuel.

Keywords: *Biodiesel, Canola oil, Blending, DI diesel engine, Performance, Emissions.*

1. Introduction

Biofuels are drawing increasing attention worldwide as substitutes for petroleum-derived transportation fuels to help address energy cost, energy security and global warming concerns associated with liquid fossil fuels. The term biofuel is used here to mean any liquid fuel made from plant material that can be used as a substitute for petroleum-derived fuel. Biofuels can include relatively familiar ones, such as ethanol made from sugar cane or diesel-like fuel made from soybean oil, to less familiar fuels such as dimethyl ether (DME) or Fischer-Tropsch liquids (FTL) made from lingo cellulosic biomass.

In addition, biodiesel has very low sulphur content and high flash and fire points than the diesel fuel, hence it is very environment friendly and safe to operate. A lot of research work revealed that biodiesel can be used as an alternate fuel for diesel engine without any modifications in the existing engine.

V. Amosu and S.K. Bhatti performed the investigations on performance and emissions characteristics of DI diesel engine operating with Rapeseed methyl ester (RME) and concluded that RME blends were good alternative for diesel without modifications in the Engine. The Brake Thermal efficiency decreases with increase in percentage of RME. The Brake Thermal efficiency of RME B20 at full load is 42.38% which is slightly lower than the diesel fuel. The exhaust temperature for diesel fuel and RME B20 was comparable. The NO_x emissions of RME B20 higher than the diesel fuel due to high oxygen content. The CO and CO_2 emissions of RME blends were comparable with the Diesel fuel. Hydrocarbon emissions were low for all RME blends and ranges between 4 and 16 ppm.

M.Harinathareddy *et al* conducted experimental investigations on 4-stroke,Single cylinder Diesel engine to know the performance of the engine using Cotton Seed Oil(CSO) Methyl ester as alternate fuel at full load conditions. Comparisons of CSO with Diesel and Jatropha biodiesel were made and concluded that brake thermal efficiency and indicated thermal efficiency of CSO biodiesel was slightly higher than that of diesel fuel and Jatropha oil. The study revealed that the use of cotton seed biodiesel oil improves the performance parameters of CI engine compared with pure diesel.

Experimental tests were carried out by ShyamPandey*et al*to study the performance and emissions of DI engine fuelled with Ethanol, Diesel and Jatropha based Biodiesel blends. The blends used for

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this study were BOD95E5, BOD95E10, BOD95E15 and BOD95E20.The physic-chemical properties of all blends showed good resemblance with that of diesel except the flash point. From the performance tests, it was concluded that the BOD95E5 fuel blend has maximum brake thermal efficiency and minimum brake specific fuel consumption at higher loads. The overall emission characteristics of BOD95E10 were found to be best over the entire range of engine operations.

DragosTutunea and IlieDumitru analyzed the sunflower methyl ester (SFME) and its blends as an alternate fuel for diesel engines. Biodiesel was prepared from sunflower oil by transesterefication and tested on 4 cylinder Deutz F4L912 diesel engine. The EGT was found to be highest for pure diesel. The emissions of CO, HC were found to be lower for all blends tested than the diesel fuel and NO_xwere higher due to high volatility and high viscosity of biodiesel.

Amit Agrawal *et al* conducted experimental investigation on Single cylinder 4s diesel engine to study performance characteristics using duel vegetable oil blends (mixture of Mustard oil and Palm oil) with diesel. The blends of BB10(Combination of Diesel 90% by volume, Mustard oil 10% by volume and Palm oil 10% by volume),BB20,BB30,BB40 and BB50 were considered for study. Out of these blends, BB10 and BB20 gave better brake thermal efficiency, lower total fuel consumption and lower brake specific fuel consumption than other blends.

Experimental investigations were conducted by K.Srithar *et al* on single cylinder DI diesel engine using two biodiesels from Pongamiapinnata oil and mustard oil to study the performance and emissions characteristics at various engine loads with a constant speed of 3000 rpm. From the results, the thermal efficiency and mechanical efficiency of blend A (90 % diesel, 5 % Pongamia and 5% Mustard all by volume) were slightly higher than diesel and blend B and blend C were very close to the diesel values. The emissions of smoke, hydrocarbon and nitrogen oxides of duel biodiesels were higher than that of diesel. But the exhaust gas temperature for duel biodiesel blends was lower than diesel.

Vijittra Chalatlon *et al* conducted studies on DI diesel engine using diesel, Jatropha oil and blends of Jatropha oil and diesel in different proportions to know the performance of the engine. A wide range of engine loads and Jatropha/diesel ratios of 5/95 %(J5), J10, J20, J50 and J80 by volume were considered. Brake Thermal efficiency and brake specific fuel consumption were not affected up to J20 ratios. However, higher blends suffered from deterioration in efficiency and fuel consumption about 10 to 25 %.CO_2 emissions were lower for Jatropha blends than that of diesel at low loads, where as higher at high loads with a higher percentage of Jatrapha oil in the blends. However, CO emission with blends was much higher than that of diesel.

Experimental investigations were conducted by Nitin Shrivastava *et al* to study performance parameters and exhaust emissions of a 4 cylinder DI diesel engine fuelled with diesel oil, Jatropha oil methyl ester (JOME), its 20 percent (B20) and 50 percent (B50) blends. From the results, a fuel blend of 20 % JOME showed approximately same brake thermal efficiency as that of neat diesel fuel. The emission of JOME and its blends showed reduction in carbon monoxide, Hydrocarbon and smoke emissions whereas NO_X emission was higher compared to diesel. The 20% blend of JOME showed higher average reduction in CO, HC and Smoke in comparison to average increase in $NO_{X.}$

Hemanandh Janarthanam and Narayanan K V conducted experimental investigations on Kirloskar DI 4s diesel engine to study performance and emission characteristics fueled with Refined Palmolein, Refined Corn, Refined sunflower oil and pure diesel. Methyl esters of refined vegetable oils were transesterified with sodium meta oxide as catalyst before blending with diesel. It was concluded that brake thermal efficiency of the Refined Pamolein biodiesel was marginally higher than the pure diesel. It was also observed that CO, HC, CO2 &NOx were less in Refined Palmolein than Refined Corn and Refined Sunflower oil. Also Brake Specific Fuel Consumption of Refined Palmolein was reduced by 28.57% compared to pure diesel.

Experimental investigations on the performance and emission characteristics of 4s single cylinder CI engine were conducted by Dinesha P and Mohanan P using preheated Pongamia Methyl Ester as Fuel. Here two blends of B20 and B40 were used for testing and compared the performance & emission characteristics of preheated B40 blend of pongamia biodiesel with B20 biodiesel. The B40 blend was preheated at 60, 75, 90 and 110°C temperatures using waste heat exhaust gas in a shell and tube heat exchanger. B40 blend preheated to 110°C showed maximum 8.97% increase in brake thermal efficiency over B20 blend at 75% load. Also it was observed that UBHC emission and smoke opacity values reduced by 78.12% and 73.54% respectively over B20 blend for B40 blend preheated to 110°C at 75% load. Thus preheating of higher biodiesel blend at higher temperature improves the viscosity and other properties and improves the performance and emission.

From the literature, it was observed that a lot of research work done on diesel engines using various alternate fuels to study the performance and emission characteristics of the engine. A little literature was found using the Canola biodiesel as the fuel in the engine. The present work describes the performance and emission characteristics of DI diesel engine using Canola oil as biodiesel. Here Canola Biodiesel and its blends are considered for performance and emission analysis and the results are compared with diesel.

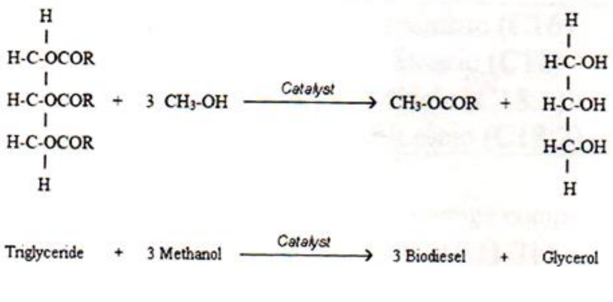
2. Materials and methods

The basic process for making fuel from organic matter has not changed since it was invented in the nineteenth century. E process, called transesterification, forces vegetable oil or animal fat to react with a catalyst (usually sodium hydroxide) and methanol or ethanol to produce glycerol and fatty acid esters, the latter being the actual chemical name for biodiesel.

2.1 Overview of Canola oil Biodiesel

Oil Canola, an oleaginous tropical plant, has the highest oil productivity per unit of land on earth. In terms of its usage, Canola oil has various uses as a food, (oils, margarines, bread, mayonnaise, feeds, ice cream, cookies etc), in industry (soap, lubricants, detergents, plastics, cosmetics, rubber etc), in steel making, the textile industry, pharmacology, etc.

Canola oil blended diesel has emerged as an alternative fuel for an internal combustion engine satisfying certain criteria, such as requiring minimum engine modification offering uncompromised engine life and not being hazardous to human health and environment during production, transportation, storage and utilization. Direct use of crude Canola oil has been shown feasible in the Elsbett engine. However, a problem of clogging of the filter by impurities is observed, which can be eliminated by using processed liquid canola oil (PLCO) directly or in blends with petroleum diesel to overcome this problem. The chemical formula for biodiesel Transesterification is:



2.2 Trans-esterification Process

Conversion of oil to its fatty and then to biodiesel trans- esterification reaction is a stage of converting oil or fat into methyl or ethyl esters of fatty acid, which constitutes to biodiesel. Biodiesel (methyl ester) is obtained through the reaction of triglycerides of vegetable oils with an active intermediary, formed by the reaction of an alcohol with a catalyst. The general reaction for obtaining biodiesel through trans-esterification is:

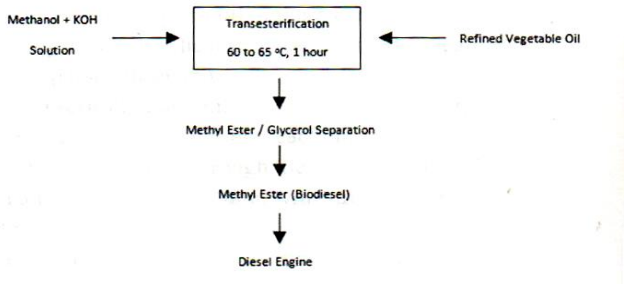
Oil or Fat + Methanol = Methyl Esters + Glycerol

Or

Oil or Fat + Ethanol = Ethyl Esters + Glycerol

Trans- esterification reactions may employ various types of alcohols, preferable, those with low molecular weight, with the most studied ones being the methylated and ethylated alcohols. Studies have shown that trans- esterification with methanol is more viable technically than with ethanol. Ethanol may be used as long as it is anhydrous (with a water content of less than 2%), since the water acts as an inhibitor reaction. Another advantage in using methanol is the separation of glycerin (obtained as a by-product of the reaction) from the reactive medium, since, in the case of synthesis of the methylated ester, this separation may be easily obtained through simple decantation.

This reaction can be catalyzed by alkalis, acids, or enzymes. Alkalis include sodium hydroxide, potassium hydroxide, carbonates, and corresponding sodium and potassium alkoxides such as sodium meth oxide, sodium ethoxide, sodium prop oxide, and sodium but oxide. Sulphuric acid, sulfonic acids, and hydrochloric acid are usually used as acidic catalysts. In the industry, transesterification is generally done with alkali mediums, because they present better yield and lower reaction time. The production of biodiesel by transesterification of vegetable oil uses the following steps: Mixing of alcohol and catalyst: Potassium hydroxide (KOH) and sodium hydroxide (NaOH) are generally used as alkaline catalysts with methanol (CH_3OH) for production of biodiesel.



2.3 Blends

The Canola oil and its blends with various proportions by volume basis taken for experimental investigations are as follows. Fuel properties are given in the Table1.

- 10% canola oil and 90% pure diesel **(BD10)**
- 20% canola oil and diesel 80% pure **(BD20)**
- 30% canola oil and 70% pure diesel **(BD30)**
- 40% canola oil and 60% pure diesel **(BD40)**
- 50% canola oil and 50% pure diesel **(BD50)**
- 100% canola oil**(BD100)**
- 100% pure diesel **(DIESEL)**

Table1. Properties of Canola oil Biodiesel comparison with diesel

Properties	Pure diesel	BD10	BD20	BD30	BD40	BD50	BD100
Density at 15°C(kg/m³)	830	833	839	848	857	864	872
Viscosity at 40°C(centi Stokes)	2.7	3.09	3.13	3.37	3.94	4.82	5.94
Pour point(°C)	3.1	3.4	3.7	4.25	4.84	5.04	5.26
Cloud point (°C)	6.8	7.55	7.87	9.78	10.95	11.32	12.44
Flash point (°C)	58	75	82	95	115	136	156
Fire point (°C)	77	84	87	111	132	156	175
Calorific value(KJ/Kg)	43,090	41,110	40,750	40,830	39,960	38,004	37,450

3. Experimental investigation

In order to evaluate the performance and emission characteristics of DI diesel engine using canola oil as biodiesel, experiments are conducted in the mechanical engineering thermal laboratory. This section deals with description of test rig, engine specifications, test methodology and description of the gas analyzer used for testing.

3.1 Description of test rig

Kirloskar make diesel engine is used for experimentation. The water–cooled single cylinder diesel engine is coupled to a rope pulley brake arrangement to absorb the power produced. Necessary weights and spring balance are included to apply load on the brake drum. Suitable cooling water arrangement for the brake is provided. Separate cooing water lines filled with temperature measuring thermocouples are provided for engine cooling. A fuel measuring system consists of a fuel tank mounted on stand, burette, three way cock and stop watch provided. Air intake is measured using an air tank fitted with orifice and water manometer. The test rig is shown in the Fig.1 and Fig.2.

Fig.1: Diesel engine test rig

Fig. 2: Four stroke single cylinder diesel engine

3.2 Specifications of the engine

Four stroke, single cylinder, vertical, water cooled, cold start, compression ignition high speed diesel engine. Specifications of the engine are given in the Table2.

Table 2: Specifications of the engine

Make	Kirloskar
Bore	80mm
Stroke	110mm
R.P.M	1500
B.H.P	5 (Single Cylinder)
Compression ratio	16:5:1
Loading type	Mechanical
Brake drum diameter	0.315m
Fuel	High Speed diesel oil

3.3 Test methodology

Load test is conducted to study the performance of single cylinder diesel engine at various loads under constant speed maintained at 1500 rpm. At a constant speed, power loss due to friction i.e., frictional power at a particular speed is obtained between brake power and the fuel consumption per hour, the tangent drawn to the curve between brake power and the fuel consumed per hour is called WILAN'Ss line. An intercept made by the line on the negative side of the brake power axis will give frictional power of engine.
For further study of performance of the engine, the parameters such a brake thermal efficiency, indicated thermal efficiency, mechanical efficiency at different loads are determined by calculating brake power and indicated power at the respective loads. The engine is started and allowed to run at different loads and at each load, time taken for 10 cc fuel consumption and emission readings are noted down for diesel fuel. The experiment is repeated for Canola biodiesel and its blends.

3.4 Description of 5 gas analyzer

INDUS model PEA205 is a 5-gas analyzer meant for monitoring CO, CO_2, HC, O_2 and NO in automotive exhaust. It meets OIML, class specifications CO, CO_2 and HC are measured by NDIR technology and O_2 and NO by electro chemical sensors. It has many control features to prevent faulty measurements. A built in dot matrix printer is provided to print out a hard copy of the results. It conforms to CMVR 115/116 and is certified by ARAI, PUNE. 5 gas analyzer is shown in the Fig.3.

Fig.3: Five gas analyzer

Features of Gas Analyzer

- Selection of fuel type
- Automatic fresh air intake during auto zero
- Line leak check facility
- CO correction

4. Results and discussion

Fig.4 shows the relation between the brake specific fuel consumption and brake power for different proportions of Canola biodiesels i.e. BD10, BD20, BD30, BD40, BD50, BD100 and pure diesel. It is noticed that brake specific fuel consumption decreases as the brake power increases for almost all the biodiesel blends and diesel. Lowest brake specific fuel consumption values are observed for BD10 and BD20 blends. Also it is observed that brake specific fuel consumption values are reduced by 7.7 % at all brake power points for pure diesel compared to BD100.Hence it is concluded that brake specific fuel consumption increases as the blend proportion increases. This is due to lower calorific values of biodiesel and its blends when compared with diesel.

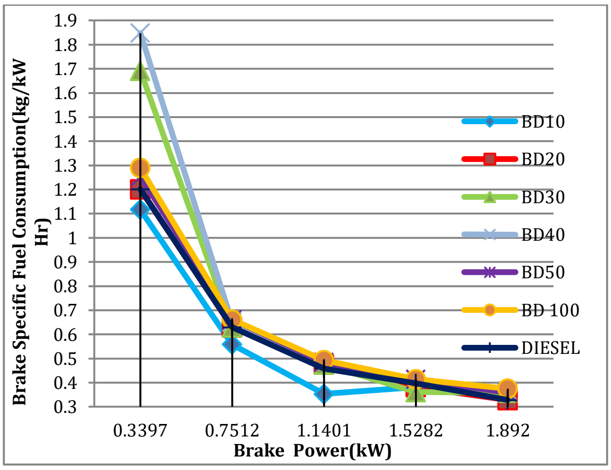


Fig.4: Relationship between the brake specific fuel consumption and brake power for different biodiesels and diesel

Fig.5 shows the relation between the mechanical efficiency and brake power for different proportions of Canola biodiesels i.e. BD10, BD20, BD30, BD40, BD50, BD100 and pure diesel. It is noticed that mechanical efficiency increases as the brake power increases for almost all the biodiesel blends and diesel. Mechanical efficiency is high for BD20 and low for BD10 at all points of brake power. Also it is observed that mechanical efficiency values are increased by 16.67 % at almost all the brake power points for BD100 compared to pure diesel.

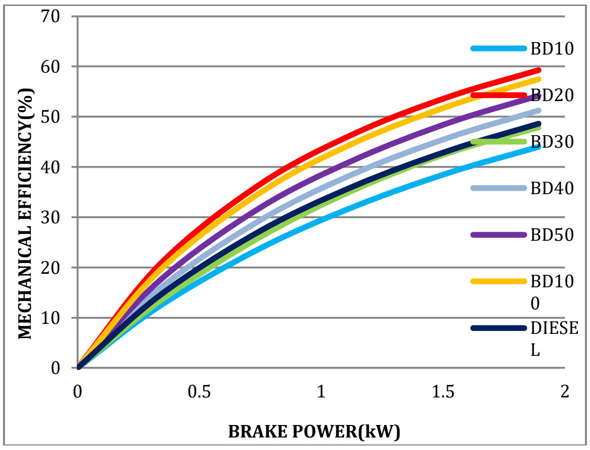


Fig.5: Relationship between the mechanical efficiency and brake power for different biodiesels and diesel

Fig.6 shows the relation between the brake thermal efficiency and brake power for different proportions of Canola biodiesels i.e. BD10, BD20, BD30, BD40, BD50, BD100 and pure diesel. It is noticed that brake thermal efficiency almost increases as the brake power increases for almost all the biodiesel blends and diesel. Brake thermal efficiency is high for BD10 and BD20 biodiesel blends at higher brake power points. Also it is observed that brake thermal efficiency values are higher at all the brake power points for BD100 compared to pure diesel and brake thermal efficiency increases by 17.5% at a brake power of 1.5282 kW for BD100 compared to pure diesel.

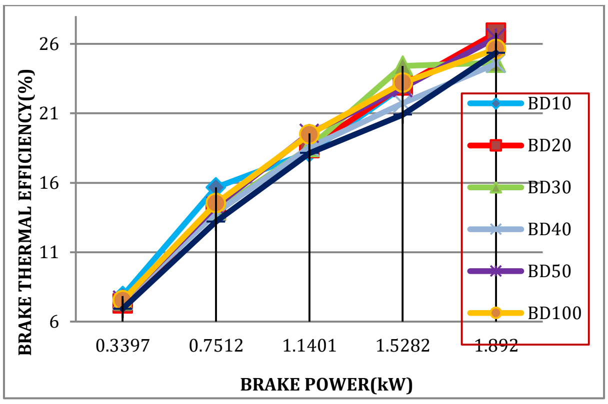


Fig.6: Relationship between the brake thermal efficiency and brake power for different biodiesels and diesel

Emissions of hydro carbons (HC)

Fig.7 shows the relation between the hydrocarbons and % of load for different proportions of Canola biodiesels i.e. BD10, BD20, BD30, BD40, BD50, BD100 and pure diesel. It is noticed that hydrocarbon emissions are increased as the % of load increases for almost all the biodiesel blends and diesel. As the % of blend increases HC emission increases due to lower calorific value and higher viscosity. Out of all the blends B10 and B20 have given lower HC emissions at almost all the loads. HC emissions are low for pure biodiesel (BD100) compared to pure diesel at loads of 60%, 80% and 100% but reverse is the case with other loads. Hence pure Canola biodiesel is a better alternative to diesel fuel with respect to HC emissions at higher loads.

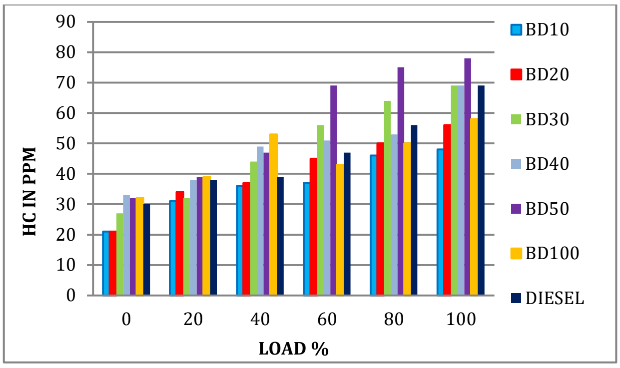


Fig.7: Relationship between the hydrocarbons and % of load for different biodiesels and diesel

Emissions of carbon monoxide (CO)

Fig.8 shows the relation between the CO emissions and % of load for different proportions of Canola biodiesels i.e. BD10, BD20, BD30, BD40, BD50, BD100 and pure diesel.

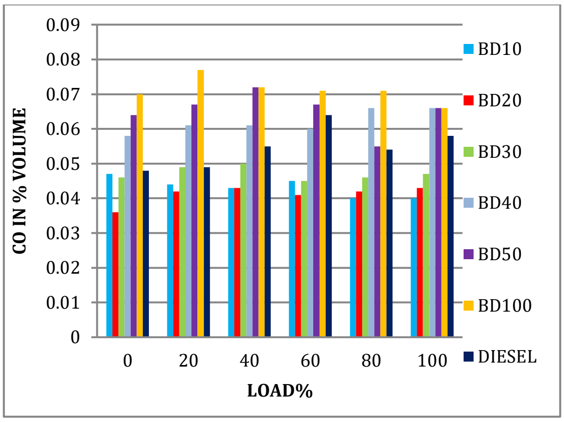


Fig.8: Relationship between the CO emissions and % of load for different biodiesels and diesel

It is noticed that there are slight variations in CO emissions as the % of load increases for almost all the biodiesel blends and diesel. Out of all the blends B10 and B20 have given lower CO emissions at 80% and 100% loads and also they are low at other loads compared to other blends and diesel. This is due to the oxygen content in B10 and B20 blends which makes easy burning at higher temperature. CO emissions are higher for pure biodiesel (BD100) compared to pure diesel at all loads. Hence pure diesel is better compared to 100 % Canola biodiesel with respect to CO emissions at all loads.

Emissions of carbon dioxide (CO_2)

Fig.9 shows the relation between the carbon dioxide and % of load for different proportions of Canola biodiesels i.e. BD10, BD20, BD30, BD40, BD50, BD100 and pure diesel.

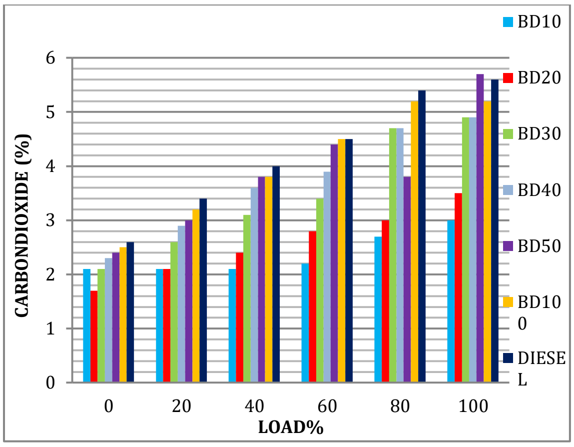


Fig.9: Relationship between the carbon dioxide and % of load for different biodiesels and diesel

It is noticed that CO_2 emissions are increased as the % of load increases for almost all the biodiesel blends and diesel. Out of all the blends B10 and B20 have given lower CO_2 emissions at almost all the loads compared to other blends, except at 0 % load the CO_2 emission is slightly higher for B10 blend. Also CO_2 emissions are low for pure biodiesel (BD100) compared to pure diesel at all loads. Hence pure Canola biodiesel is a better alternative to diesel fuel with respect to CO_2 emissions at all loads.

Emissions of nitrogen oxides (NO_x)

Fig.10 shows the relation between the NO_X and % of load for different proportions of Canola biodiesels i.e. BD10, BD20, BD30, BD40, BD50, BD100 and pure diesel. It is noticed that NO_X emissions are increased as the % of load increases for pure diesel. Out of all the blends, BD100 has given lower NO_X emissions at almost all the loads compared to other blends, except at 20 % load. Also NO_X emissions are low for pure biodiesel (BD100) compared to pure diesel at all loads except at 20 % load. Hence pure Canola biodiesel is a better alternative to diesel fuel with respect to NO_X emissions.

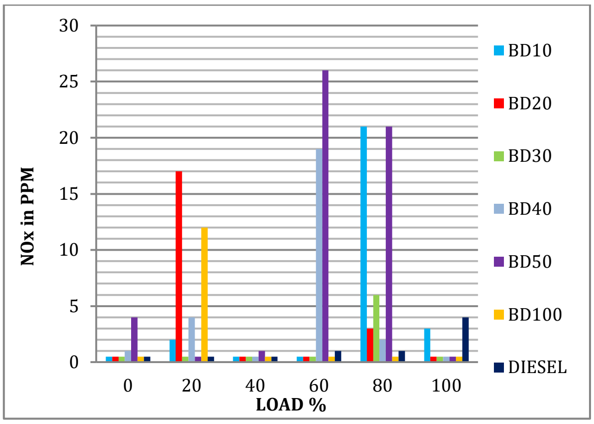


Fig.10: Relationship between the NO_X and % of load for different biodiesels and diesel

Conclusions

A single cylinder, 4s, CI high speed diesel engine is operated successfully using Canola oil and its blends with diesel as fuel. The following conclusions are drawn based on experimental results.

1) Lowest brake specific fuel consumption values are observed for BD10 and BD20 blends.
2) Mechanical efficiency of engine is high for BD20 blend out of all blends and diesel. Mechanical efficiency values are increased by 16.67 % at almost all the brake power points for BD100 compared to pure diesel.
3) Brake thermal efficiency values are higher at all the brake power points for BD100 compared to pure diesel and brake thermal efficiency increases by 17.5% at a brake power of 1.5282 kW for BD100 compared to pure diesel.
4) Out of all the blends B10 and B20 have given lower HC emissions at almost all the loads. HC emissions are low for pure biodiesel (BD100) compared to pure diesel at loads of 60%, 80% and 100% but reverse is the case with other loads
5) B10 and B20 have given lower CO emissions compared to other blends of biodiesel and diesel. CO emissions are higher for pure biodiesel (BD100) compared to pure diesel at all loads. Hence pure diesel is better compared to 100 % Canola biodiesel with respect to CO emissions at all loads.
6) CO_2 emissions are low for pure biodiesel (BD100) compared to pure diesel at all loads. Hence pure Canola biodiesel is a better alternative to diesel fuel with respect to CO_2 emissions at all loads.
7) NO_X emissions are low for pure biodiesel (BD100) compared to pure diesel at all loads except at 20 % load. Hence pure Canola biodiesel is a better alternative to diesel fuel with respect to NO_X emissions.
8) With the use of Canola biodiesel, there is a little bit increase in BSFC, increase of mechanical & brake thermal efficiencies and reduction of exhaust emissions. So Canola biodiesel is a best substitute especially in automotive industries in the coming future.
9) Use of biodiesel oil reduces green house gas emissions and there by reduces the impact of emissions on the environment.

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