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Performance and Emission Characteristics of Direct Injection Diesel Engine Running On Canola Oil / Diesel Fuel Blend

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ABSTRACT : *The increase of petroleum price and environmental problems has triggered the finding of alternative and renewable energy. In this study, biodiesel produced by transesterification of triglycerides with alcohol. Canola oil was used as raw oil to produce biodiesel by transesterification reaction. The prepared biodiesel was then subjected to performance and emission tests in order to evaluate its actual performance, when used as a diesel engine fuel. A single cylinder direct injection diesel engine was used for this work to investigate the engine performance and emission characteristics of the biodiesel, The brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were calculated from the recorded data. From the emission tests, it is observed Hydrocarbon and* NO_X *pollutants are decreased along with the percentage of biodiesel.*

KEYWORD : *Canola biodiesel, Diesel Engine, Emissio, Engine performance, Esterification*

I. INTRODUCTION

The exponential growth of world population would ultimately lead to increase the energy Demand in the world. Petroleum is a non-renewable energy source, which means that the resources of this kind of fossil fuel are finite and would be run out upon continuous use. Both of the shortage of resources and increase of petrol price have led to the findings of new alternative and renewable energy sources. Apart from these situations, environmental issues are also the driving forces for the development of alternative energy sources, since the burning of fossil fuels would cause various environmental problems including global warming, air pollution, acid precipitation, ozone depletion, forest destruction, and emission of radioactive substances [1]. The alternative energy sources of fossil fuels including hydro, wind, solar, geothermal, hydrogen, nuclear, and biomass [2]. Among these alternative energy sources, biofuels derived from biomass are considered as the most promising alternative fuel sources because they are renewable and environmental friendly. Like canola oil, it can be directly used in diesel engines as they have a high cetane number and calorific value very close to diesel [3]. Canola oil is environment friendly and does not produce Volatile organic Compounds as atmospheric pollutants. The aim of the study was to check the performance and the emission of fuel properties of canola oil (biodiesel), diesel and its blends of direct injection diesel engine.

II. MATERIALS AND METHODS

Preparation of biodiesel

Biodiesel was prepared in the laboratory using the seed oil of the Canola. 1.5g of NaOH per litre of oil was mixed with 200 ml of methyl alcohol to produce methoxide [4]. Oil was heated to 60^0C and the prepared methoxide was poured into the oil. The reaction was allowed for one hour and the final products were allowed to settle in the separating funnel overnight to produce two distinct liquid phases: crude ester phase at the top and glycerol phase at the bottom. The crude ester phase separated from the bottom glycerol phase was transferred to a clean conical flask. The biodiesel produced contains some residues including excess alcohol, excess catalyst, soap and glycerin. It was purified by washing with distilled water to remove all the residual by-products. The volume of water added was approximately 30% (volume) of the biodiesel. The flask was shaken gently for 1 minute and placed on table to allow separation of biodiesel and water layers. After separation, the biodiesel was transferred to a clean conical flask. The washing process was repeated for several times until the washed water became clear. The clean biodiesel was dried in incubator for 48 hours, followed by using sodium sulphate. The final products were analyzed to determine related properties including viscosity, total acid numbers (TAN). The properties of biodiesel are listed in Table 1. The experiments were conducted in different loads like 25%, 50% and 75% of full load and full load. Similar experiments were done with diesel and biodiesel so as to make a comparison.

Experimental setup and procedure : The performance tests for the stable Diesel-biodiesel are carried out on a computerized single cylinder four stroke direct injection variable compression ratio engine. The Table 2 shows the specification of the engine. No modification or alteration has been made in the engine. The experimental setup consists of a variable compression ratio engine is coupled to an eddy current dynamometer. A computerized data acquisition system is used to collect, store and analyze the data during the engine testing. A Kistler piezoelectric pressure transducer and a crank angle encoder is used to measure the in-cylinder gas pressure and the corresponding crank angle. The load applied on the engine is measured by the load cell connected to the eddy current dynamometer. A burette with two infra red optical sensors measures the fuel flow rate, an air flow sensor measure the inlet air flow rate, K type thermocouples measure the inlet air and exhaust gas temperatures. AVL DIGAS analyzer is used to measure the exhaust gas constituents such as CO, HC, NO and the smoke is measured using the AVL smoke meter. All the experiments are conducted at the compression ratio of 17.5 and the results are recorded under steady state conditions.

The fuels which have been used in this study are: Commercial diesel (D) and a blend of 20% biodiesel (B20), 40% biodiesel (B40), 60% biodiesel (B60) and100% biodiesel (B100).The main properties of the test fuels are given in Table 3. The test engine were fueled with diesel, B20, B40, B60 and B100 to conduct the experiments on an electrical dynamometer earlier, experiment were performed by using different blends of biodiesel and diesel. In this study, speed characteristics tests have been carried out for wide open throttle (WOT), while load characteristics tests have been conducted at 1500 rev/min speed at 220bar injection pressure. Following major parameters were measured: Fuel flow rate, Crank angle, Instantaneous pressure in cylinders, Combustion characteristics.

III. RESULTS AND DISCUSSIONS

Performance characteristics

Brake Thermal Efficiency (BTE)

The Brake thermal efficiency is the true indication of the efficiency with which the chemical energy input in the form of fuel is converted into useful work [5]. In the present study BTE of the diesel engine is measured using different blends of biodiesel and diesel. The variations of brake thermal efficiencies at different loads for various combinations have been shown in figure 1. Brake thermal efficiency increases with the increasing load. However, the load reaches 75% and above, it almost constant. The brake thermal efficiency of biodiesel (B100) is 98.2% same compared with diesel(D100), which is clearly shown in the figure 1.BTE for D100 is maximum compared with blends and biodiesel, this may be due to lower heat value of the fuel. It is well known that the lower heat value of the fuel affects the engine power. The effective power decreases with the increase of blends and biodiesel. Thus, the engine needs more fuel consumption to maintain the same amount output power[6].

Brake Specific Fuel Consumption : Brake specific fuel consumption is the ratio between mass fuel consumption and brake power. Figure 2 shows the variations of brake specific fuel consumption with load for different fuels. For all fuels tested, brake specific fuel consumption is found to decrease with increase in the load also it is lower than the blends of biodiesel(B20, B40, B60 and B100) compared with diesel(D100). The BSFC of pure biodiesel (B100) is 113% higher than that of diesel (D100). The BSFC will appear when the rate of increase of fuel consumption is larger than that of engine power output with the increase of engine speed.

Exhaust Gas Temperature : The exhaust gas temperature (EGT) increases while the load is increased. The EGT of biodiesel is lower than that of diesel. It is shown in the figure 3.

Emissions characteristics : The emissions of HC and NO_x are illustrated in figures 4 and 5. Figure 4 demonstrates HC emissions at different loads for various fuels. HC gradually decreases with biodiesel-diesel blends although, there is no significant change is observed for B40. which is due to almost even mixer of biodiesel and diesel. The higher load , the lower the HC emissions expect diesel(D100) is observed. This phenomenon can be attributed to better mixing of air and fuel at higher load.

The higher the biodiesel percentage in biodiesel-diesel blends, the lower the HC emissions are observed. This is due to the fact that the higher O_2 concentration in the air-fuel mixture can help enhance oxidation of unburned hydrocarbons. Figure 5 illustrates NO_x emissions at different loads for various fuels. NOx emissions of biodiesel blends and neat biodiesel are higher than diesel at all loads. This is the opposite tendency with the results reported by Geo et al., 2008 [7]. Smoke emissions decreased with increase in biodiesel concentration in the biodiesel blends with diesel. In general, NO_x emissions is increases if load is increases with all fuels. In light loads emission is slightly lower for biodiesel and blends compared with diesel. At light load operations, the engine runs at a very lean state and with a small biodiesel or canola oil blends. Extra O_2 in biodiesel and canola oil blends in this case does not help produce higher NO_x, because the mixture is already very lean. This might be a reason why no NO_x increase with 2–5% blends is observed. Higher NO_x emissions are obtained with higher percentage of biodiesel and canola oil in the blends. This is common trend in NOx emissions with biodiesel blends. This is mainly attributed to O_2 content in biodiesel and higher combustion temperature. Higher canola oil–diesel blend produces much higher NO_x probably because of lower cetane number and its consequence of longer ignition delay; NO_2 production at high idling operations is very significant and even higher than NO production and its share in total NO_x is more than 50%. This is ignored most of the times as in describing the state that in most high temperature combustion processes, the majority (95%) of NO_x produced is in the form of NO. Even some gas analyzer has used the same principle to calculate the NO_x emissions from NO measurements and considering that NO is 95% of total NO_x. This might be true for gasoline engine, however, diesel engine emits much higher NO_2. NO formed in the flame zone can be rapidly converted to NO_2 via reactions such as

$NO + HO_2 = NO_2 + OH$

Subsequently, conversion of this NO2 to NO occurs via

$NO_2 + O = NO + O_2$

unless the NO2 formed in the flame is quenched by mixing with cooler fluid. Under light load operating conditions, there are many cooler regions and NO_2 formed in the flame is quenched and could not be converted back to NO. Hence, higher amount of NO_2 is produced at light load operations. This suggests that a proper care be needed to report NO_x emissions from biodiesel combustion, especially at high idling operation. This also suggests that NO_x abatement technology must include a system to address both NO_2 and NO reduction.

Smoke opacity : The variation of fuel smoke opacity of the engine with various fuels is demonstrated in figure 6. The smoke opacity of biodiesel is lower than the smoke opacity of diesel. Agarwal et al., 2008[8] reported that 20% biodiesel blend showed maximum lowest smoke opacity compared to all other biodiesel blends (10, 30, 50 and 100%, v/v). In the present study the same trend was observed. B20 blend having lower smoke opacity compared with other blends and diesel. An important observation is that all biodiesel blends have higher thermal efficiency than diesel fuel.

IV. CONCLUSIONS

Biodiesels have been produced and their fuel characteristics have been investigated. An experimental investigation has been conducted to explore the performance and emissions of biodiesel and its blends at high idling operations on a small DI diesel engine. The results obtained suggest the following conclusions:

[1] The fuel properties of canola oil are slightly different from those of diesel. The BSFC and exhaust gas temperature for canola oil are higher than that for diesel fuel while BTE for canola oil is generally lower than that for diesel fuel. This is probably resulting of lower heat value of canola oil, which is distinctly lower than that of the diesel fuel.

[2] HC emissions for all blends and biodiesel fuels are lower at different loads, and the higher the biodiesel percentage in biodiesel– diesel blends, the lower the HC emissions. Higher blends of canola oil and higher loads deteriorate HC emissions.

[3] Up to 5% biodiesel and canola oil in the blends, there is no increase in NO_x emissions, in fact canola oil up to 5% in the blends shows a little reduction of NO_x emissions than diesel. However, B20 has 12–26% NOx increase at different engine loads. Canola oil and diesel fuels exhibit different combustion and emission characteristics with the variation of engine load due to their different properties. Based on the exhaustive engine tests, it can be concluded that biodiesel can be adopted as an alternative fuel for the existing conventional diesel engines without any major modifications required in the system hardware. The use of canola-based biodiesel solves the problem of the toxic organic pollutant emissions from the diesel engines. Indian government should increase the rate of canola oil production to produce more biodiesel. Furthermore, not only for India, the conclusion of this study also applies to many other countries in the world.

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Table 1. Properties of biodiesel (canola oil)

Viscosity	5.38(cst)
Density	886.5(Kg/m^3)
Flash point	172^{o}c
Fire point	186^{o}c
Calorific Value	38758 KJ/Kg

Table 2. Specification of the single cylinder four stroke direct injection engine

Brake Power	3.7 kW
Speed	1500 rpm
Compression ratio	17.5 (Variable)
Bore	80 mm
Stroke	110 mm
Ignition	Compression ignition
Cooling	Water cooled
Loading System	Eddy current dynamometer

Table 3 Properties of test fuels

Acidity as mg of KOH/gm	0.01
Density (kg/m^3)	886.5
Viscosity at 40 ºC	5.38
Gross calorific value (KJ/kg)	38758
Cetane number	48
Sulfur content (mg/L)	< 50ppm
Flash point	172^{o}c
Fire point	186^{o}c

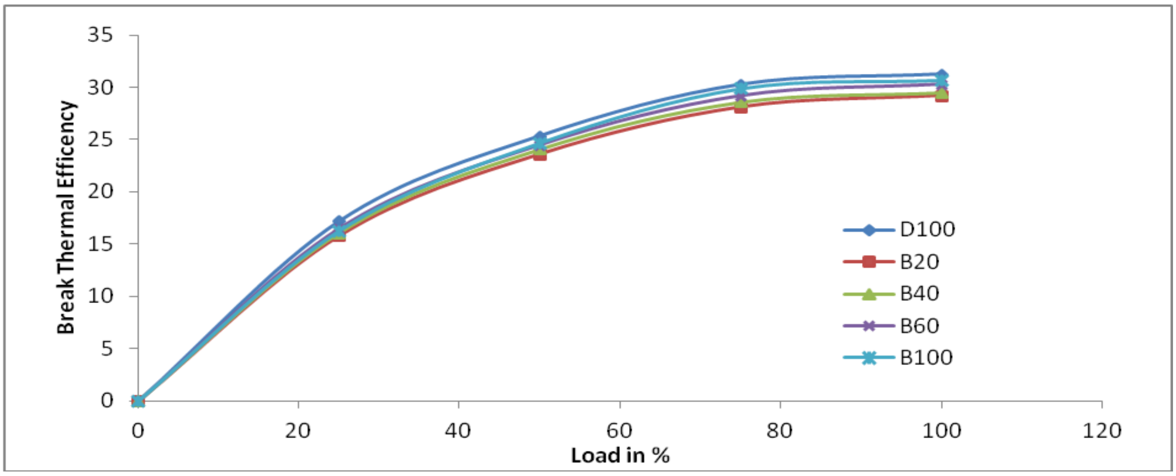

Figure 1. Load Vs Break Thermal Efficiency for different blends of biodiesel and diesel

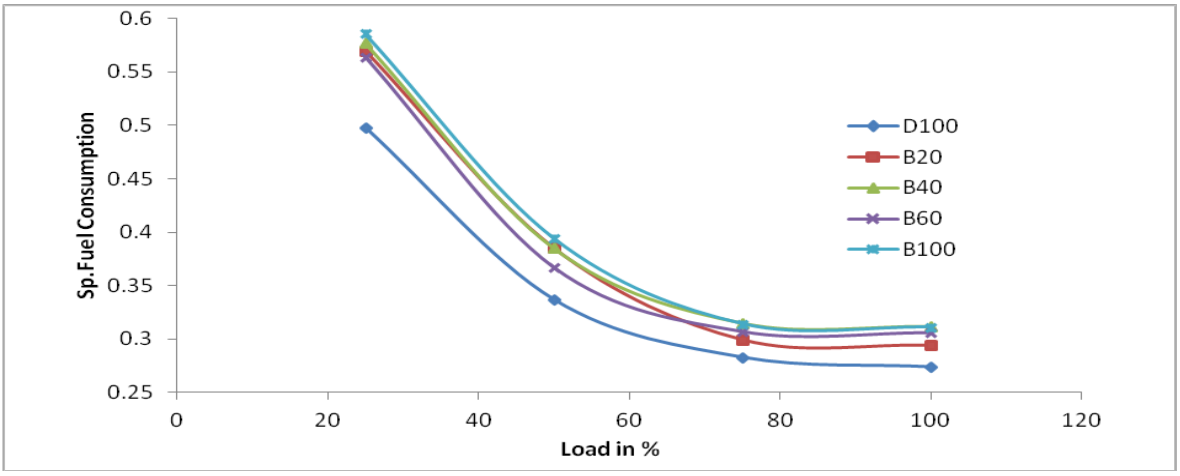

Figure 2. Load Vs Brake specific fuel consumption for different blends of biodiesel and diesel

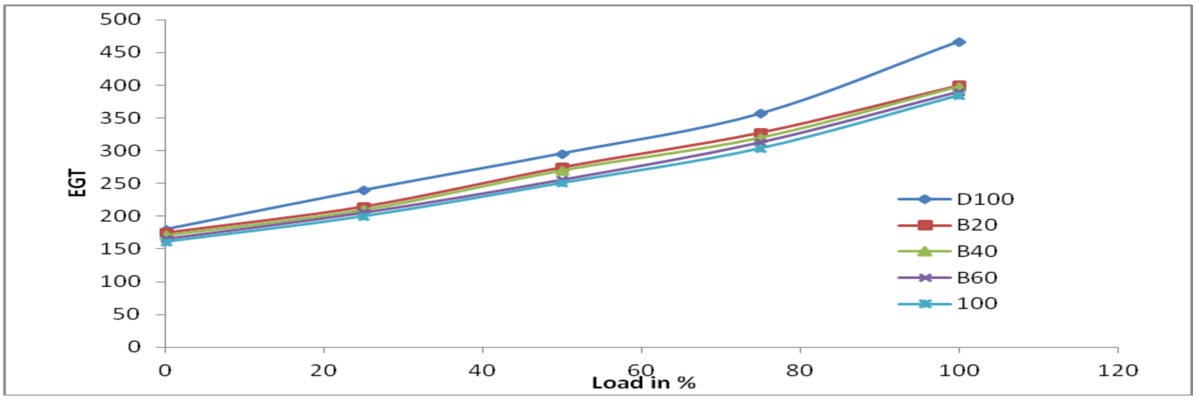

Figure 3. Load Vs Exhaust Gas Temperature for different blends of biodiesel and diesel

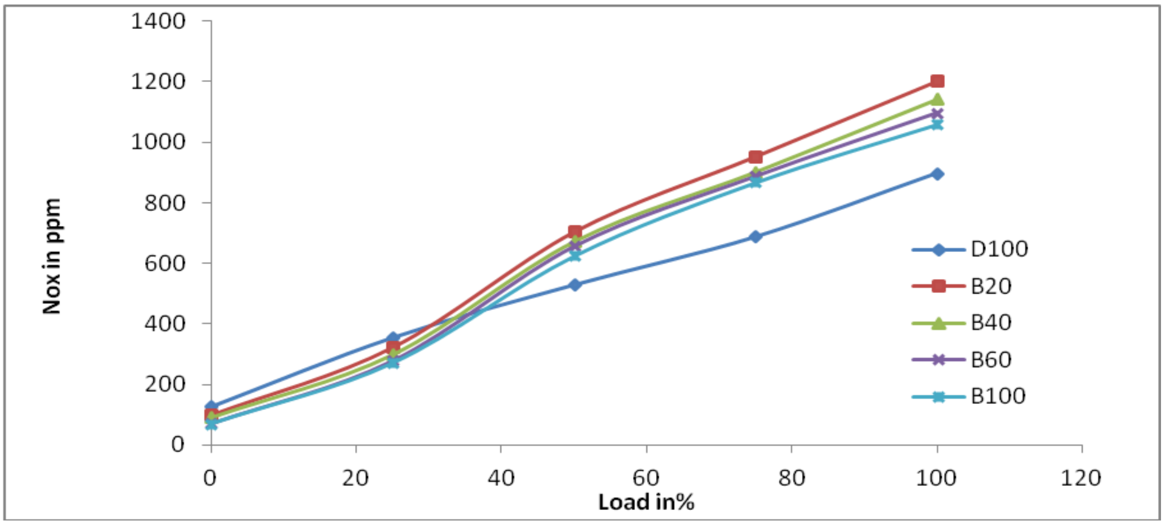

Figure 4. Load Vs Hydro carbon emission for different blends of biodiesel and diesel

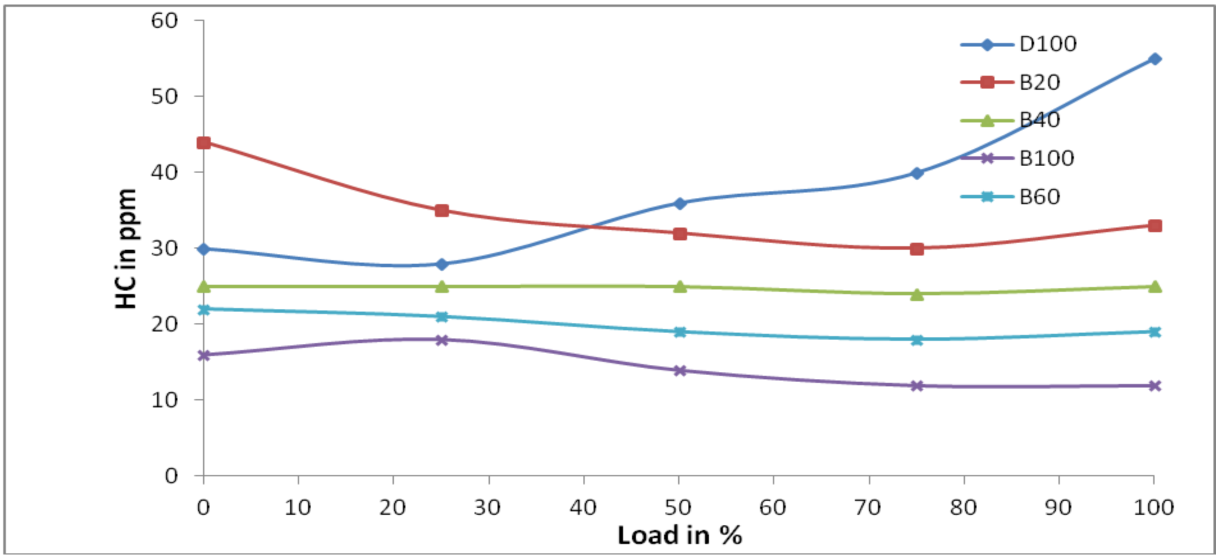

Figure 5. Load Vs NOx emission for different blends of biodiesel and diesel

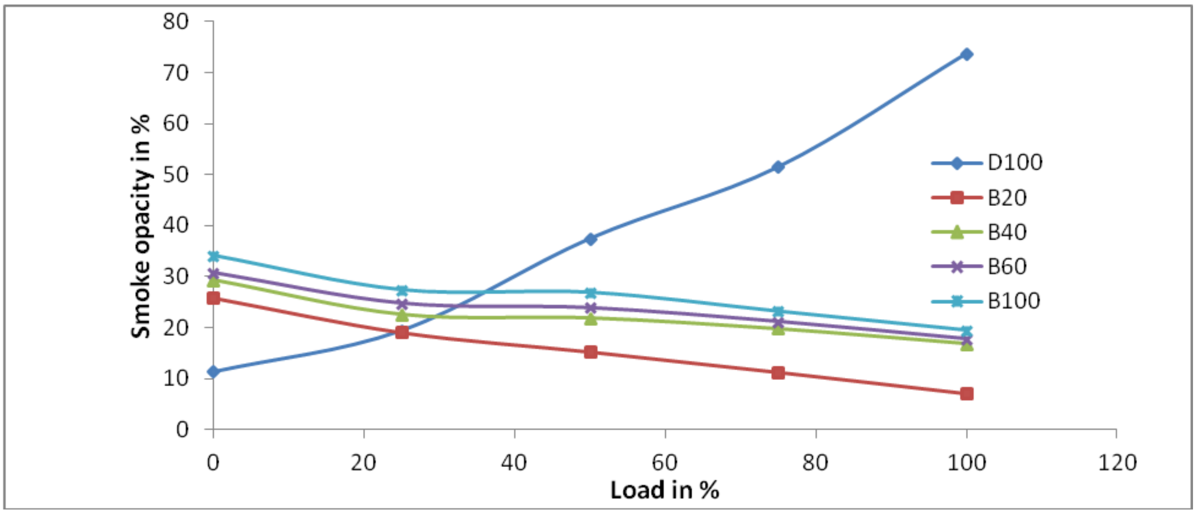

Figure 6. Load Vs smoke opacity for different blends of biodiesel and diesel