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Performance and Emission Study on Diesel Engine using Waste Cooking Oil with Methanol as Additive

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ABSTRACT:

As the years are passing by, the number of vehicles used for transportation is increasing. Due to this the environment is degrading and also the fossil fuels are depleting. This paper presents the performance and emission study on diesel engine using waste cooking oil with methanol as additive in various proportions. The properties such as the flash point, fire point, kinematic viscosity and the calorific values of the blends with and without additive are determined. Then all the biodiesel blends are used as fuel separately in the diesel engine. The engine performance as well as emission characteristics have been determined and compared at different blends. The blends with additive showed better properties and reduction in emission characteristics compared to diesel. The emission of CO is decreasing with increasing waste cooking oil and methanol quantity in the blends. Fuel consumption was more for the higher percentage blends with respect to increasing brake power. The emission of un-burnt hydrocarbon and oxides of nitrogen are reduced significantly with addition of methanol to fuel mixture due to higher oxygen and heat of vaporization.

KEYWORDS:

Waste cooking oil; Biodiesel; Emissions; Engine performance; Methanol

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1. Introduction

The alarming rate of consumption of hydrocarbon reserves present in fossil fuels has led to many new developments into finding a close replicate of the gasoline family [8]. With pushing the need to curb global warming on one hand and escalating crude oil prices due to excessive depletion on the other hand has a lead researcher to ensure bio-diesels are an apt replacement for crude oil and also want it to exceed expectations [1-3]. The keen aspect for interest in biodiesel is that it is made from fat content of various types of oils and hence can be considered renewable [9-10]. Although the CO_2 levels after combustion remain the same, in order to adhere to the Kyoto protocol, the harmful emissions including SO_x, NOx, Carbon monoxide (CO), Un-burnt Hydrocarbons (UBHC) should be reduced [4-7].

There are two methods of doing this. The first is to stop production and usage of gasoline run vehicles which is an impossible task. The second being slowly shift the spot light from gasoline to other alternatives, which seems somewhat convincing. Keeping these facts, various permutations and combinations have been tried to increase the percentage of biodiesel in the diesel blends in this study. This work is ambitious to establish a percentage or proportion of bio-diesel that can be blended with diesel to ensure sustained or enhanced efficiency and undoubtedly termed as the best blend. The blends are being prepared by using transesterification process through which the waste cooking oil can be made glycerol free and suitable for blending with diesel and using it as bio-diesel [12]. The nomenclature used in this work depicts B50 blend as a blend which has 50% by weight of diesel and 50% by weight of biodiesel.

The usages of alcoholic type of additives are very much popular in the preparation of bio-diesels. The reason for this is mainly because of its mutability with the pure bio-diesel [11]. An experiment is underway to establish the chemical nature of methanol used in the blends and its burning characteristics in the diesel engine. Methyl alcohol (CH3OH) is a derivative from organic compounds called Alcohols and it is popularly known as Methanol [13]. The production of this methyl alcohol is very easy as such it can be obtained from biomass, synthesis gas, coal gasification etc. As these resources are ample the extraction of methanol is simple [16-17]. By experimentation of methanol blends many researchers have established that the harmful pollutants of UBHC and NO_x are reduced drastically [15]. They have also established that brake thermal efficiency (BTE), brake power (BP) and engine torque have meagrely exceeded expectations [14].

The densities of diesel and biodiesel are similar [18]. The factor which makes methanol different from other hydrocarbon fuels is its higher laminar flame speed [19]. The biodiesel-methanol blends will be more oxygenated due to the oxygen atoms present in the methyl alcohol [20]. In this work an attempt is made for the practice of biodiesel-diesel-methanol blends in CI engine as a fuel. The engine parameters of performance and emission were tested at different loads. The performance parameters like BTE, total fuel consumption (TFC), brake specific fuel consumption (SFC) and BP are evaluated. The emission characteristics like CO, CO_2, NO_x, UBHC, O_2 and smoke density were also evaluated. It was observed from the results that there was a decrease in the emissions of UBHC and CO. There is also an increase in the BTE.

2. Means and methods

The main objective of this project is to find an optimum blend which can be used as fuel in diesel engines. For that purpose the waste cooking oil was used. It contains glycerol and biodiesel. In this the fat content will have been used up in the cooking process. Now we have to separate the biodiesel from the glycerine content through transesterification process. In this process the filtered oil was heated unto 60°C. Then a mixture of 2.5 grams of Sodium hydroxide was dissolved in 100 ml of methanol was poured into the oil. This mixture was stirred for 3hours at a speed of 600RPM using a magnetic stirrer. After stirring, the mixture was poured into a separation funnel to separate the glycerine content from the bio-diesel. Due to density difference, the glycerine settles in the bottom which can be removed. Fig. 1 shows the flow chart for preparation of biodiesel.

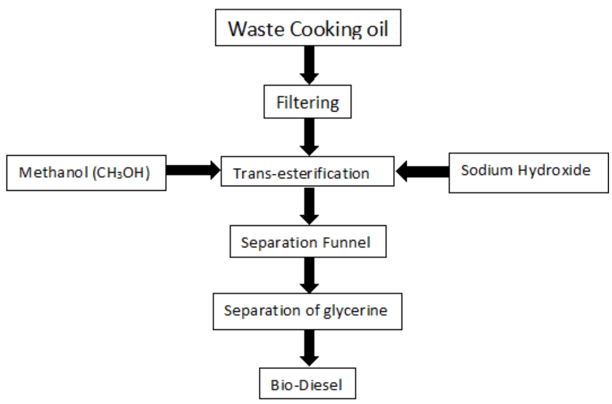

Fig. 1: Biodiesel production

The biodiesel is prepared by a chemical reaction as depicted in Fig. 2. This reaction exactly contemplates as to what happens in the stirring process. The glycerol chain breaks free from the alcohol chain giving rise to biodiesel. Then the blends with different compositions of methanol, biodiesel and diesel were prepared on mass analysis. The fuel blends prepared are DBD50, DBDM1, DBDM2, DBDM3, DBDM4, and DBDM5. DBDM4 depicts 50% of diesel 46% of bio-diesel and 4% of methanol. DBD50 is the mixture of 50% diesel and 50% transesterified oil. The blends were prepared for the net content of 1000ml.

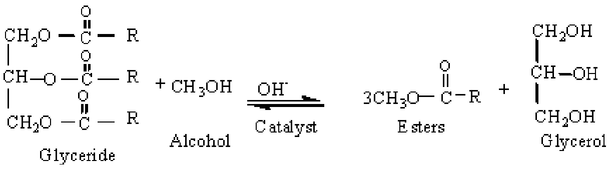

Fig. 2: Chemical reaction of biodiesel

The prepared fuel blends are tested for all chemical characteristics like calorific value, flash and fire point and viscosity. The calorific value was tested using a bomb calorimeter. 1 gram of fuel was burnt and the calorific value is determined by principle of conservation of energy. The performance characteristics are tested using a single cylinder Kirloskar compression ignition engine with rated power of 3.75 kW at 1500 rpm. The emission parameters such as CO, HC, NO_x and smoke are obtained from INDUS Five Gas Analyser and INDUS Smoke meter. The setup of the diesel engine for testing is schematically shown in Fig. 3.

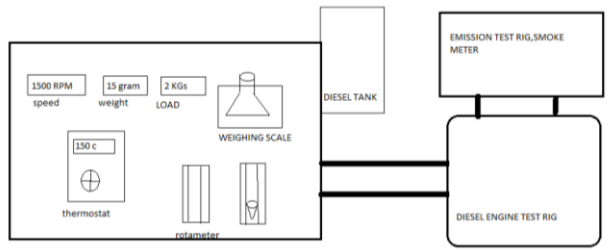

Fig. 3: Schematic diagram of engine setup

3. Results and discussions

4.1. Fuel test results

The Cleveland open cup tester was used for the determination of flash and fire points of the fuels. Fig. 4 shows the flash point and fire point of the various biodiesel blends. DBD50 blend gave the highest flash and fire point. DBDM5 blend gave the lowest. Due to addition of methanol there is a reduction in flash and fire point. As there is no methanol in DBD50, it gave the highest flash and fire point. The less volatility of waste cooking oil when compared to diesel is also a significant factor. Another important factor for the rise of flash and fire point is that the boiling point of diesel is less than that of the oil. Addition of methanol lowers the boiling point of the oil. As the methanol blend percentage increases, there is a reduction in flash and fire points.

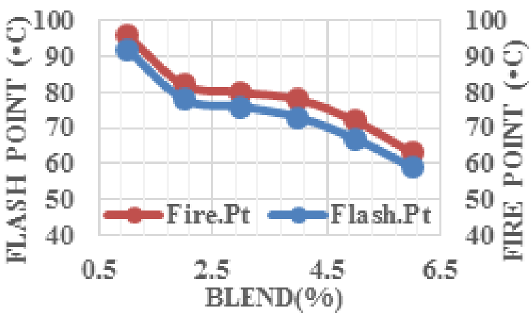

Fig. 4: Flash point and fire point of blends

The kinematic viscosity of all blends was calculated by say bolt viscometer. Fig. 5 depicts the kinematic viscosity obtained for different blends with respect to the blend percentage. The highest viscosity was observed for DBD50 which was 0.00000585m^2/s. This is due to the high density of oil. The lowest viscosity was observed for DBDM5. This is due to the density of the methanol which is almost equal to that of diesel. Hence by adding more methanol to the diesel, the viscosity of biodiesel decreases. The calorific value was calculated by using bomb calorimeter. Fig. 6 shows the calorific value obtained for different blends. The highest calorific value is obtained for DBD50 as 30565.1 kJ/kg. The lowest is for DBDM5. This is because of the lower calorific value of methanol than diesel and oil. Hence on addition of methanol, the calorific value of the blends goes down with the increasing percentage of methanol.

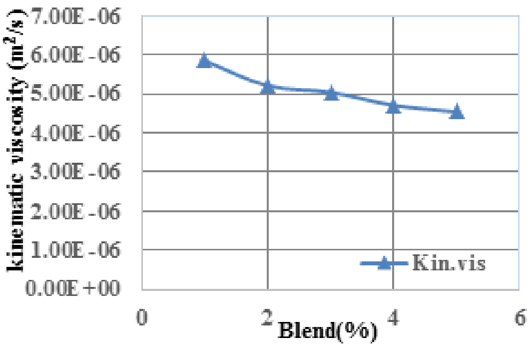

Fig. 5: Kinematic viscosity of blends

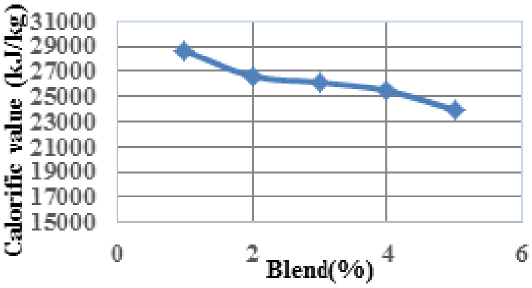

Fig. 6: Calorific value of blends

4.2. Performance characteristics

The amount of fuel used up by the engine per unit time is called TFC. It is calculated by taking the time taken for consuming 10 grams of fuel by using a stop watch. Fig. 7 depicts the TFC obtained for various blends at different loads. As the load increases the TFC also increases along with it. The highest TFC was obtained for DBDM5. The lowest TFC was obtained for DBD50. This is due to the very low calorific value of methanol when compared to oil and gasoline. In order to overcome the loss of power, more fuel is consumed. Thus, TFC for biodiesel is more when compared to pure diesel. BSFC is the ratio of the total fuel consumption to the brake power. Fig. 8 depicts the BSFC obtained for various blends with respect to the brake power. Since the brake power is inversely proportional to the BSFC as per the definition, the curve obtained depicts that as the load increases the BSFC decreases and vice versa. The highest BSFC was obtained for DBDM5 at the very initial load. The lowest was obtained for the DBD50 at the higher load. BTE is the effective usage of heat energy from the fuel to mechanical energy. Fig. 9 depicts the BTE for various biodiesel blends with respect to the brake power. The highest BTE was obtained for DBDM5 at higher load. The lowest BTE was obtained for DBD50 at lower load. This is due to the fast completion of combustion process and thereby the reduction in heat losses of the cylinder. Therefore due to the addition of methanol the BTE is higher.

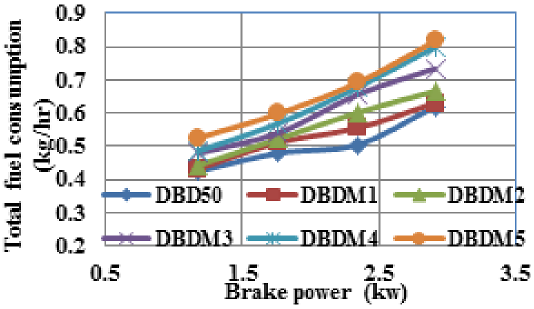

Fig. 7: TFC vs. BP

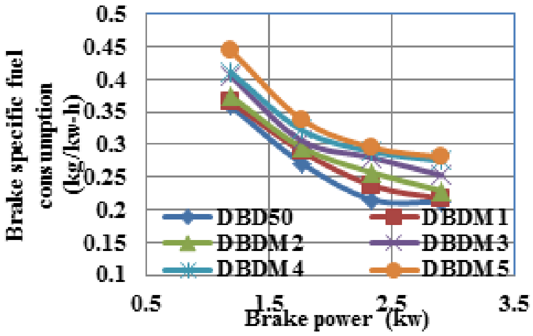

Fig. 8: BSFC vs. BP

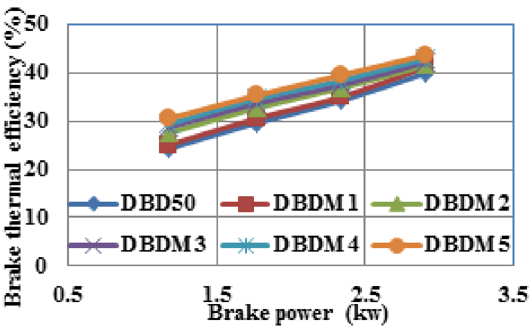

Fig. 9: BTE vs. BP

4.3. Emission characteristics

The gas analyser was used to evaluate the CO emission of various blends. Fig. 10 depicts the CO emission with respect to the different loads. The lowest CO emission was observed for the blend DBDM5. This is because the methanol-biodiesel blends are oxygenated due to the presence of oxygen atoms in methyl alcohol. Due to the absence of methanol in DBD50 it showed the highest emission of CO. But this emission of CO in this blend DBD50 is less than emission in pure diesel. When the engine is operated at higher operating temperatures, the oxidation of CO increases. Hence its emission decreases. This is also a reason for the reduction in CO emission. Fig. 11 depicts the emission of CO_2 with respect to the different load conditions for various blends. The highest emission was observed for the blend DBDM5. As the load increases the amount of CO_2 emission also increases. Many studies have proved that the emission of CO_2 is dependent on the carbon and hydrogen bond ratio in the compound [21-23]. In this case it is due to the conversion of carbon into CO_2 instead of leaving it in the form of CO. The lowest CO_2 emission was observed for the blend DBD50 which has no sign of methanol in it.

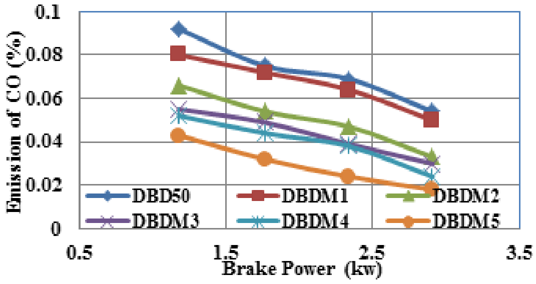

Fig. 10: CO emission vs. BP

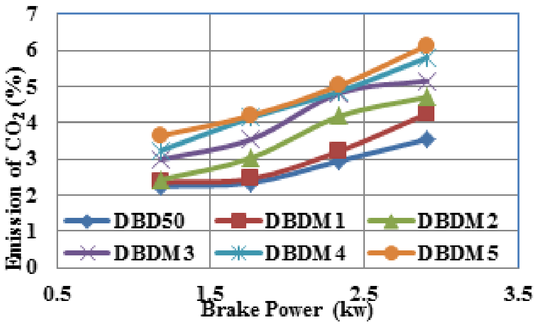

Fig. 11: CO_2 emission vs. BP

Fig. 12 depicts the emission of UBHC with respect to the different load conditions for various blends. The highest UBHC emission was observed for the blend DBD50. The lowest UBHC emission was observed for the blend DBDM5. The reason for the existence of hydrocarbons is incomplete combustion. Since there is complete combustion happening in the case of blends having higher percentage of methanol, so there is low emission observed. The emission of HC is reduced for the higher loads. The reason behind this is because of the higher operating temperatures and moreover the enriched oxygen present in the methanol decreases the HC emission. From many other studies which list the different reasons for the emission of UBHC are deposition of lubricating oil on the combustion chamber walls, valve overlapping, misfire and crevices [7, 24].

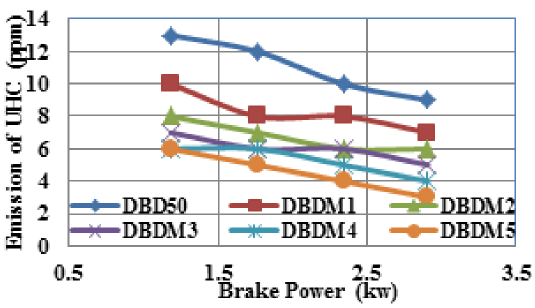

Fig. 12: UBHC emission vs. BP

Fig. 13 depicts the emission of NO_x with respect to the variation of loads for different blends. The highest NO_x emission is observed for the blend DBD50. The lowest NO_x emission is observed for the blend DBDM5. The reason behind this is the high heat of vaporisation of methanol present in blend. This will cause a reduction in the combustion temperature thereby resulting in the reduction of engine intake temperature. Hence the emission of NO_x is less in the case methanol rich blends.

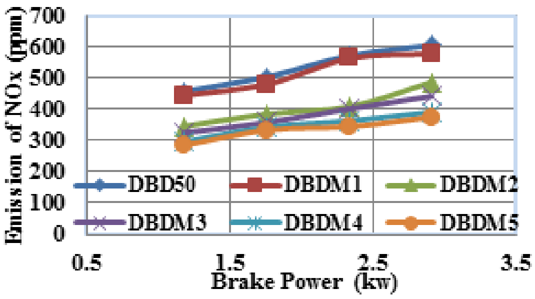

Fig. 13: NO_x emission vs. BP

Fig. 14 depicts the emission of oxygen with respect to the variation of different loads. The highest oxygen emission was observed for the blend DBDM5. The lowest oxygen emission was observed for the blend DBD50. As the methanol is rich in oxygen hence the methanol rich blends have highest emission of oxygen. As the load increases the emission of oxygen is reduced because of the higher operating temperatures resulting in the oxidation of carbon to carbon dioxide. Hence reduction in oxygen emission was observed with increasing load. Fig. 15 shows the smoke density of various blends with respect to the different loads. The smoke density is evaluated with smoke meter. The highest smoke density is observed for the blend DBD50. The lowest smoke density is observed for the blend DBDM5. It can be inferred, the increase of methanol content reduces the smoke density as the emissions of HC and CO are low.

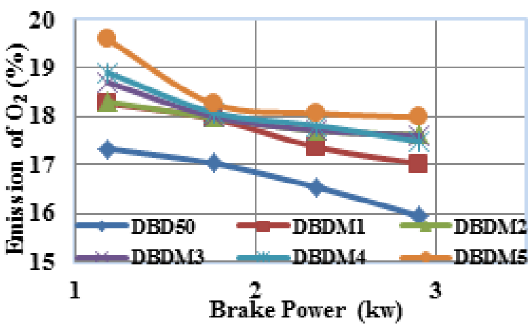

Fig. 14: O_2 emission vs. BP

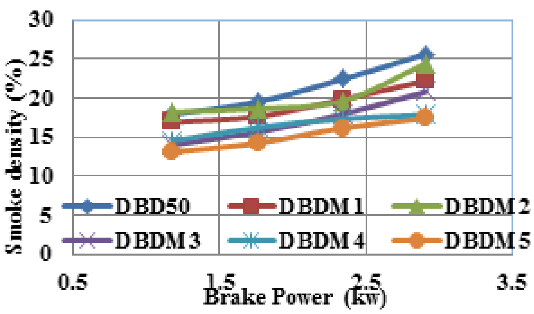

Fig. 15: Smoke density vs. BP

5. Conclusion

In this paper the work was performed in order to find out the optimum blend for biodiesel that can be used as an alternative to the diesel in the CI engine. The blends were prepared and its performance, emission parameters were evaluated through experimental tests. From the test results, it can be inferred that the blends with increasing methanol content show optimum characteristics high brake thermal efficiency, low smoke density, high emission of oxygen, low emissions of CO, NO_x and UBHC. It was also observed that the fuel consumption increases along with the methanol content due to its lower calorific value.

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