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Performance, Emission and Combustion Evaluation of Diesel Engine Using Methyl Esters of Sunflower Oil

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ABSTRACT: Inflation in fuel prices and unprecedented shortage of its supply has promoted the interest in development of the alternative sources for petroleum fuels. In the present study, investigations were carried out on single cylinder, four stroke and water cooled diesel engine. The evaluation of performance, emission and combustion characteristics of sunflower methyl esters blended with diesel fuel were carried out. To characterize the performance at different blending, four blending percentages by volume like 25%, 50%, 75% and 100% were chosen and are named as B25, B50, B75 and B100 respectively. Tests were conducted over entire range of engine operation with varying loads. The engine performance parameters such as specific fuel consumption, brake thermal efficiency, exhaust gas temperature and exhaust emission (CO, CO_2, HC, O_2 and NOx) were recorded. From the performance characteristics it is noted that, the lower the blend percentage of sunflower methyl esters increases the brake thermal efficiency and reduces the specific fuel consumption. The exhaust gas emissions are reduced with increase in sunflower methyl esters concentration. The experimental results proved that the use of sunflower methyl esters in compression ignition engine is a viable alternative to diesel.

KEYWORDS: Performance; Emission; Diesel engine; Blending; Sunflower methyl esters.

INTRODUCTION

Increasing petroleum prices, increasing threat to the environment from exhaust emissions and Global warming have generated intense international interest in developing alternative non-Petroleum fuels for engines. The use of vegetable oil in engines is not a recent innovation. Diesel said the use of vegetable oils as engine fuel may seem negligible today. Nevertheless, such oils may become, in the passing years, as important as oil and coal tar. In the present scenario, oil has become a finite resource and its price tends to increase exponentially, as its reserves are fast depleting [1]. Recent Report says that lower smoke levels and higher thermal efficiencies can be obtained by the sunflower ester of vegetable oils than neat vegetable oils [2]. Further, it has been reported that the thermal efficiency of the engine increases with an increase in the methanol fraction in diesel. This is because of the increased fraction in the premixed combustion phase with marked reductions in CO and HC emissions [3]. It has been found that vegetable oils have proved to be more feasible alternative, because they can be produced from the plants grown in rural areas. In the past, serious efforts have been taken by several researchers [4-9] to use different vegetable oils as fuel in existing diesel engines without any modifications. Intensive research is going on throughout the globe for a suitable diesel substitute. In this race among different alternatives, vegetable oils have attained primary place as some of their physical, chemical and combustion related properties are nearly similar to that of diesel fuel. In a developing country like India, major concentration has been focused on non-edible vegetable oils as the fuel alternative to diesel because edible vegetable oils have their use in our day-to-day life. Vegetable oils can be used directly or can be blended with diesel to operate compression ignition engines. Use of blends of vegetable oils with diesel has been experimented successfully by various researchers in several countries [10-14, 20]. Vegetable oil fuels resulted in lower thermal efficiency, lower NOx emission, higher CO and HC emissions [14-17]. The chemical composition of vegetable oil helps in reducing the emission of unwanted components when they are burnt [18]. The performance and emission test on a direct injection diesel engine with methyl ester of Sunflower oil. It was observed that BSFC is 20% higher and brake thermal efficiency was 13% lower than that of diesel, while HC, CO, O_2 emissions reduced and NOx emissions were increased [19]. In the present work, investigations were carried out by blending the diesel with sunflower oil methyl esters. The performance, emission and combustion characteristics of bio diesel blends were evaluated.

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TRANSESTERIFICATION

This process involves heating the sunflower oil approximately to 65 to 70°C, from which the biodiesel fuel is extracted. During heating the oil will be held at a constant temperature for about 25 minutes. In the preparation process, 300 ml of methanol and 30g of potassium hydroxide are added per 1000ml of sunflower oil. The sunflower oil chemically reacts with alcohol in the presence of catalyst to produce methyl esters. The whole mixture will be stirred for one hour and let it settle for about 24 hours. After 24 hours the glycerin gets settled down at the bottom and esters get separated to the top. After separation of the methyl esters, it is washed in order to get clear solution of methyl esters, obtained by the spraying of distilled water.

EXPERIMENTAL SET UP AND PROCEDURE

Experimental Set Up

The engine shown in Figure 1 is a 4 stroke, vertical, single cylinder, water cooled, diesel engine coupled to a rope brake dynamometer, specifications were written in Table 1. Cooling water lines are fitted with temperature measuring thermocouples provided for engine cooling. A measuring system for fuel consumption consisting of a fuel tank, burette, and a 3- way cock mounted on stand and stop watch are provided. Air intake is measured using an air tank fitted with an orifice meter connected to a water U-tube differential manometer. A digital temperature indicator and a digital rpm indicator are provided for temperature and speed measurement on the panel board. A governor is provided to maintain the constant speed. All the experiments were conducted at the engine speed of 1500 rpm. Initially, the tests were conducted on the engine by using diesel as fuel then the tests were conducted on the engine with different blends like engine was run on B25, B50, B75, and B100. All the test values were noted down thrice and average value was taken to avoid the errors in readings. Some of the properties of sunflower oil, sunflower methyl esters and its blends are given in Table 2. It is very important to know the properties of fuel with blends. Different blends were tested and the properties are noted down in the table 2.

Table 1. Specifications of the Test Engine.

Particulars	Specifications
Make	Kirloskar
Rated Power	3.7 kw(5hp)
Bore	80 mm
Stroke Length	110 mm
Swept volume	562 cc
Compression ratio 16.5:1	Compression ratio 16.5:1

Figure 1. Diesel Engine Test Rig.

Table 2. Properties of sunflower oil, sunflower methyl esters and its blends.

FUEL	VISCOSITY mm^2/s at 45^0C	Calorific value MJ/kg	Density kg/m^3 at 45^0C	Flash point at ^0C
B100	3.94	37.1	876	108
B75	3.91	38.4	867	96
B50	3.86	40	857	92
B25	3.82	41.2	842	88
DIESEL	3.8	42.6	830	58
SUNFLOWER OIL	17.8	36.4	916	202

RESULTS AND DISCUSSION

The variation of fuel consumption with brake power is shown in Figure 2. From the graph it is observed that as the load increases, fuel consumption increases for all the fuels. This variation is less at part load compared to that of full loads. As the concentration of biodiesel increases, the fuel consumption tends to increase. Figure 3 shows the variation of specific fuel consumption with brake power. From the graph it is observed that as brake power increases, specific fuel consumption decreases for all the fuels. The value of B25 fuel approximates that of the diesel. The minimum specific fuel consumption is observed for blends B25 and B50, 0.2929 kg/kW-hr and 0.2967 kg/kW-hr against 0.2741 kg/kW-hr of diesel fuel. Specific fuel consumption of B75 is 0.3102 kg/kW-hr and for B100 are 0.3699 kg/kW-hr against 0.2741 kg/kW-hr of diesel.

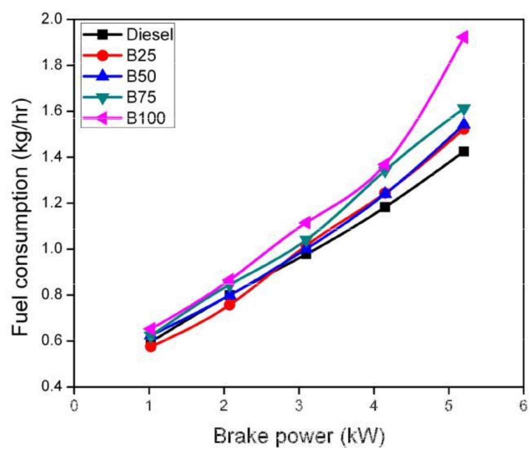

Figure 2. Variation of Fuel Consumption with Brake Power.

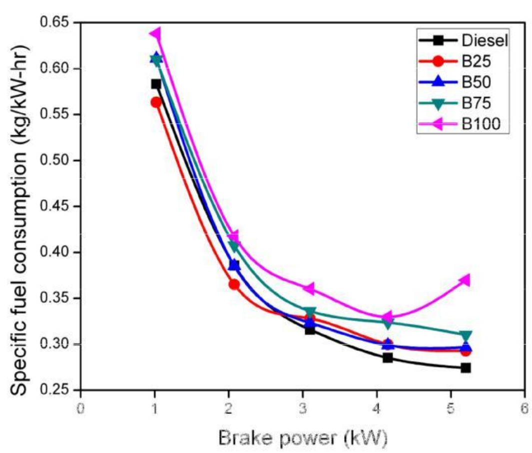

Figure 3. Variation of Specific Fuel Consumption with Brake Power.

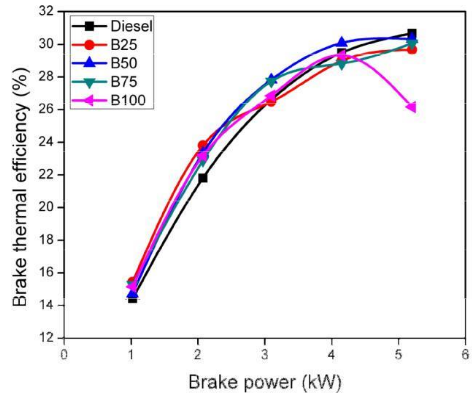

Figure 4. Variation of Brake Thermal Efficiency with Brake Power.

The variation of brake thermal efficiency with brake power is show in Figure 4. From the figure it is observed that the brake thermal efficiency for fuel with blend B25 is very close to that of diesel. At full load condition, the maximum Brake thermal efficiency are for 30.68% , 29.68%, 30.33%, 30.06% and 26.26% for diesel fuel, blend B25, B50, B75 and B100 respectively. This decrease in thermal efficiency with increase in blend may be because of poor combustion, low volatility, high viscosity and density.

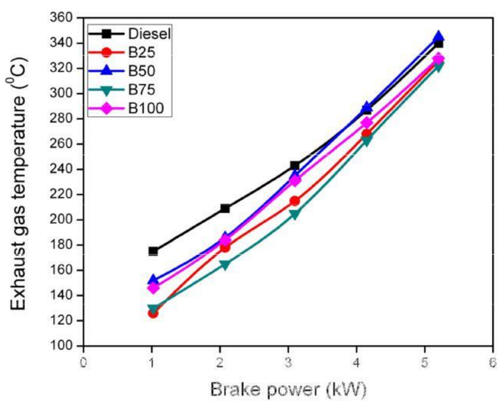

Figure 5. Variation of Exhaust Gas Temperature with Brake Power.

The variation of exhaust gas temperature with brake power is shown in Figure 5. Exhaust gas temperature is an indication of the extent of conversion of heat into work. It is noted that the exhaust gas temperature using different fuels at different loads are nearly the same. Exhaust gas temperature increases with increase in power for all the fuels. As the biodiesel fuel concentration increases, the exhaust gas temperature also increased. The pure sunflower oil methyl esters, B100 assumes higher exhaust gas temperature than other blends and diesel fuel. This increase in the exhaust gas temperature may be due to the high viscosity of the biodiesel.

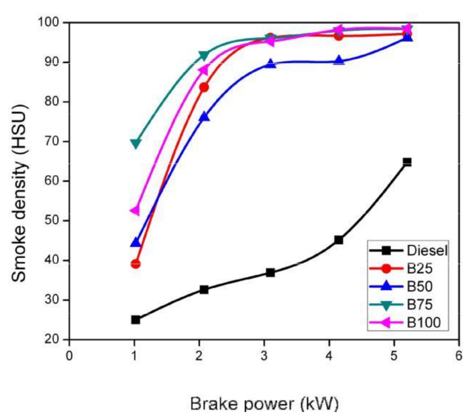

Figure 6. Variation of Smoke Density with Brake Power.

Figure 6 represent the variation of smoke density with brake power. The increase in smoke density of the sunflower oil methyl ester blends is due to the presence of residual gases which affects the efficiency of the combustion process. The smoke density increases with increase in viscosity which results in decrease of fuel air mixing rate. It was observed that B100, B75 and B50 blends have high smoke density compared with that of diesel. It also observed that the smokes density obtained with B20 blend closely match with diesel at high power.

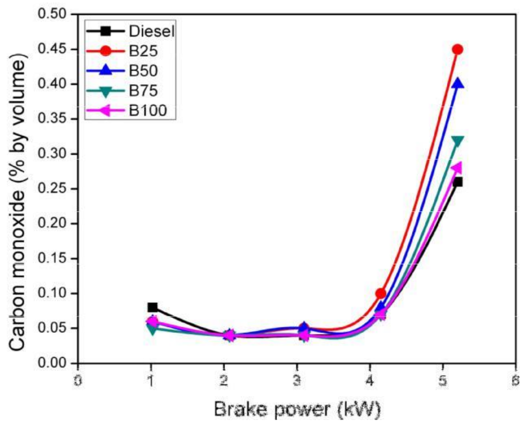

Figure 7. Variation of Carbon Monoxide with Brake Power.

The variation of carbon monoxide with Brake power is shown in Figure 7. The carbon monoxide emissions are found to be increasing with increase in load. It was noted that at low and medium loads, the carbon monoxide emission for B25, B50, B75 and B100 fuels are closely matching with diesel. At full load, the carbon monoxide emissions of the blended fuels increase significantly when compared with diesel except B25 which is fairly close to diesel fuel. At full load, the carbon monoxide emission for B100 fuel is about 23% higher than that of diesel. It is also observed that the carbon monoxide emission increase as the fuel air ratio becomes greater than the stoichiometric value.

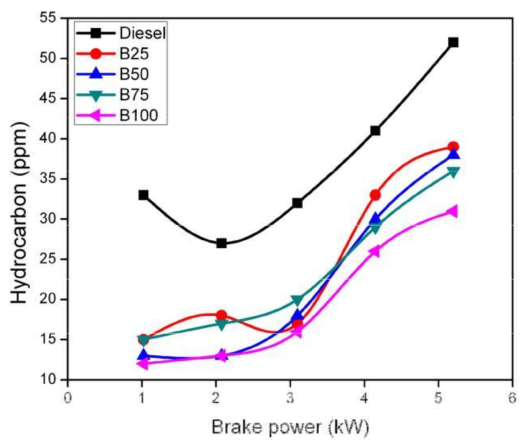

Figure 8. Variation of Hydrocarbon with Brake Power.

Figure 8 shows the variation of hydro carbon with brake power. It is observed that the hydro carbon emission of various fuels is low in low at part load but high at full loads. This is because, as the load increases, more fuel is injected into the engine cylinder leading to availability of free oxygen is relatively less for the reaction. The variation of carbon dioxide with brake power is shown in Figure 9. As expected, it is noted that the carbon dioxide emission increases with increase in load. The carbon dioxide emission is found to increase with increase in the concentration of biodiesel blends as the fuel. B100 emits more carbon dioxide which indicates the complete combustion of the fuel. The carbon dioxide emission from biodiesel engines can be absorbed by the plants for photosynthesis. The carbon dioxide level in the atmosphere may be kept in balanced condition due to the increased greenery and plants cultivated to yield bio fuels.

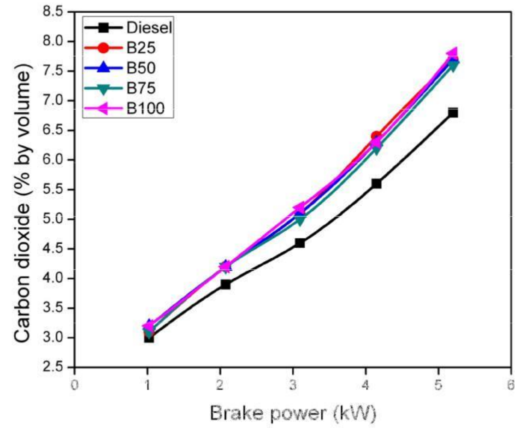

Figure 9. Variation of Carbon Dioxide with Brake Power.

Figure 10 shows the variation of oxides of nitrogen with brake power. Increase in the NOx emission is due to lower cetane number. It is observed that the NOx emission is increased with increase in the load. At full load, B100 gave 0.5% lower NOx emission compared to that of diesel. This reduction in NOx emission is due to the reduced rate of heat release. It is observed that oxygenated fuel blends can result in increase in NOx emission. It is also observed that complete combustion causes higher combustion temperature which results in higher NOx formation. Figure 11 shows the variation of cylinder pressure with crank angle. The maximum pressure is for diesel 67.46 bar and for biodiesel B25, B50, B75 and B100 are 65.64 bar, 65.01 bar, 64.53 bar and 63.76 bar respectively. The variation of heat release rate with crank angle is shown in Figure 12. It can be observed that heat release rate is high for diesel. This is due to premixed and uncontrolled combustion phase. The value of heat release rate is 122.07 for diesel and is 60.705 for B100.

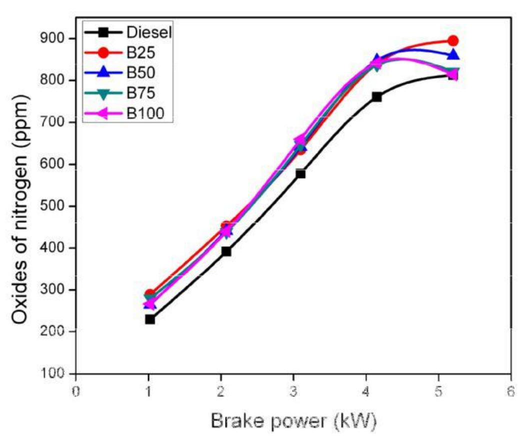

Figure 10. Variation of Oxides of Nitrogen with Brake Power.

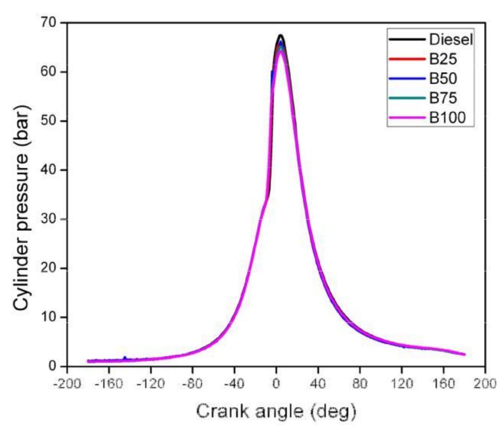

Figure 11. Variation of Cylinder Pressure with Brake Crank Angle.

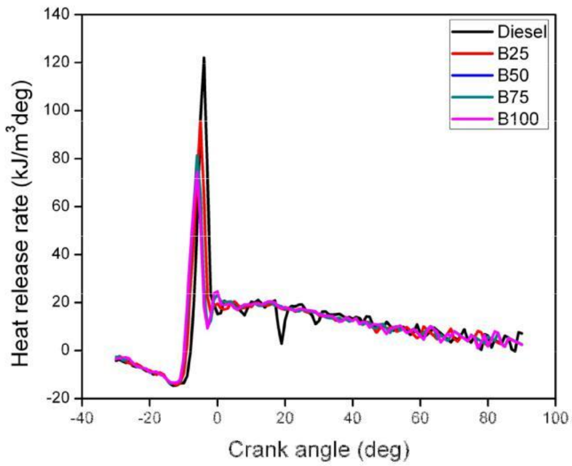

Figure 12. Variation of Heat Release Rate with Crank Angle.

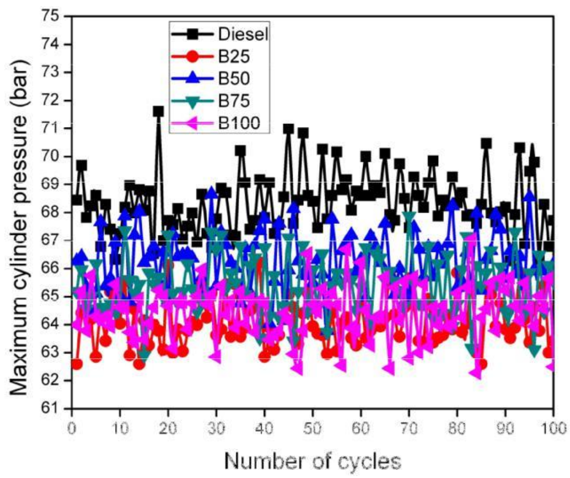

Figure 13. Variation of Maximum Cylinder Pressure with Number of Cycles.

Figure 13 shows the variation of maximum cylinder pressure with number of cycle, varying from 1 to 100. In this graph, the data for 100 consecutive cycles are shown. The maximum cylinder pressure is assumed for diesel during entire cycle followed by B50 and B75 blends. The blend B25 and B100 assumes lower cylinder pressure.

CONCLUSIONS

The experiments were carried out on a single cylinder diesel engine using biodiesel derived from sunflower oil. The performance, emission and combustion characteristics of blends are evaluated and compared with diesel. From the above results, the following conclusions are drawn. It is observed that at part load operation the fuel consumption is low and the brake thermal efficiency is 5.1% more than the diesel for B25. From the emission characteristics of blends, it is found that HC reduces by 11% and NOx reduced by 1% whereas CO and smoke slightly increases by 19% and 33.7% respectively. From the combustion analysis, it is found that the performance of the biodiesel blend is comparable as that of diesel. The present experimental results show that methyl esters of sunflower oil can be used as an alternative fuel in diesel engine.

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