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EXPERIMENTAL INVESTIGATION OF THERMAL PERFORMANCE, EMISSION AND COMBUSTION CHARACTERISTICS OF CIDI ENGINE USING BLENDS OF BIODIESEL, METHANOL AND DIESEL.

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***Abstract*- In this study mineral diesel fuel, biodiesel (Pongamia), and methanol– biodiesel blends were tested in a 4 stroke single cylinder direct-injection diesel engine to investigate the combustion characteristics and particulate emissions of the diesel engine under six engine loads at the maximum torque engine speed of 1500 rpm. Test has been conducted on 200 bar fuel injection pressure. BTE, BSFC, emissions like CO, HC and NOx are measured. Overall, biodiesel-methanol diesel blends show higher brake specific fuel consumption than mineral diesel. As methanol proportions in blends increase, NO_X emissions increase, while CO emissions are reduced. Also, biodiesel-diesel blend with 10% of methanol is more effective than biodiesel blend with 20% for reducing CO emissions. Blend B20 gave better outcomes than other blends, but at little higher BSFC than diesel. In all biodiesel blends drop is witnessed in CO, HC but has more NOx emission. From investigation it is concluded that bio-diesel methanol and diesel blends can be used securely as alternative fuel to substitute diesel without any alteration in engine.**

***Index Terms*- Combustion characteristics, Emissions, Methanol, Pongamia and Thermal performance**

I. INTRODUCTION

The natural petroleum derived fuels are depleting at the faster rate due to the increased number of automobiles and improved economy of the different nations. If the petroleum fuels are consumed as of today, it is going to last only for few decades. Hence finding the alternate fuels which can be used in the existing diesel engines without or with little modification is the need of the hour. So it is must situation for the researchers and technocrats to find the alternate fuels to prolong the availability of natural petroleum fuel.

The vegetable oils can be one of the alternate fuels which can be used in the diesel engines. Prolonged use of vegetable oils can cause the engine problems such as carbon deposits on cylinder wall, piston, piston ring sticking, nozzle cocking, etc due to their higher density and viscosity. The viscosity of vegetable oils can be reduced by different process, transesterification is one of the process widely used to reduce the viscosity of vegetable oils. The processed vegetable oil is called biodiesel. Biodiesel is one of promising fuel for the future, which can be used in existing diesel engines.

There are about 15 non edible oil crops that are being developed and cultivated in India. Among the crops identified as potential sources of biodiesel are Simmondsia chinesis, Pongamia (derris indica), Garcinia indica, Moringa oleifera, Madhuca indica, Ricinus communis, Simarouba glauca, Citrullus colocynthis, algae, Mahua, Hezel nut etc. Concern about energy security, dependence on foreign oil, finite oil and gas resources, and the negative consequences associated with global warming due to continued greenhouse gas emissions have prompted significant interest in the development of low carbon and sustainable bio fuels like biodiesel from nonfood feedstock. From algae and wood chips to grasses and solid waste, scientists are looking far and wide range of raw material that will yield a new generation, advanced bio fuel a source that doesn't divert food into energy, and is abundant enough to make a significant dent in the oil market.

The government is trying to reduce the country's dependence on oil and gas imports, which account for 80% of all petroleum products and 70% of the total natural gas consumed "Recently, the Ministry

II. OBJECTIVES

It is observed from the literature that lot of work has been carried out using variety of oil seeds but little work has been carried out using pongamia as fuel with methanol. In this project performance and emission characteristics of CI engine are studied exhaustively. However the objectives are summarized as below.

1. Investigating the properties of the neat biodiesel (Pongamia) with diesel.
2. Investigating the properties of the biodiesel as well as blends of biodiesel with methanol and diesel.
3. To study various emission characteristics.
4. Evaluating the maximum efficiency and minimum emissions.

III. EXPERIMENTAL SETUP

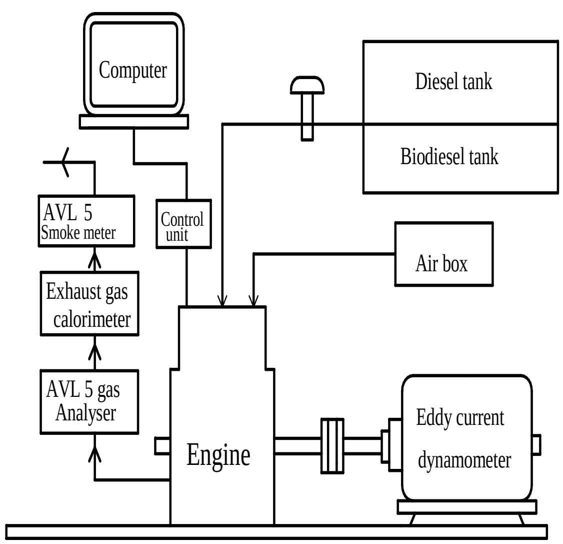

Fig. 1. Line diagram of experimental Setup

The experiments are conducted in laboratory on a fully advanced computerized experimental engine. Testing consisting of single cylinder, direct injection, 4 stroke diesel engines. The arrangement of testing and its instrumentation is shown in figure. It has rated power of 5.2 kW at 1500rpm, having 87.55 mm bore and

of Petroleum and Natural gas has permitted direct sale of Biodiesel (B100) to bulk consumers like Railways, shipping and State Road Transport Corporations etc. Also, Ethanol Blended Petrol program (EBP) is being promoted, where ethanol blending in petrol is going from 5 to 10 % based on the availability of ethanol. 110mm stroke, injection pressure of 200bar and 230 b TDC injection timing. It test bed consist of a diesel engine, eddy current dynamometer, and other measuring systems. An AVL444 gas analyzer (5 gas analyzer) used to measure the exhaust emission. A computer with an engine soft software, pressure sensor to measure cylinder pressure, TDC sensor records pressure for every 2 degrees of rotation of crank with curve P-Ɵ plotted.

Rotameters is provided for measurement of water flow to the engine and calorimeter. The water flow to the engine and calorimeter are adjusted accordingly. For combustion pressure measurement piezoelectric type sensor with water cooled adapter fitted in cylinder head. This sensor is connected to an engine indicator which is fitted in control panel and scans pressure and crank angle data is interfaced with computer through comport. To convert information from one format to another the encoder is used. Encoder is a device, transducer, circuit, software, program, algorithm that converts from one format to other. To measure the speed and crank angle rotation, encoder is used. The sensor is fitted on dynamometer shaft and connected to engine indicator. Thermocouples are used to measure the temperature, water inlet and outlet temperature to the engine and calorimeter and exhaust gas temperature of engine. These temperatures are digitally indicated on control panel. AVL-437 Smoke meter is used to measure the smoke density. AVL-444 di gas analyzer is used to measure the gaseous emission in the exhaust.

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Fig. 2. electric stirrer

The computer is interfaced with engine. The PCI 1050 IC card is connected to COM port of CPU. Engine soft is the software used to control the entire engine readings. It is lab view based software. Experiments are conducted on the engine at different loads from 0kg to 18kg (rated load). Blends B0, B20, B40, B60, B80 and B100 are tested for 200bar injection pressure and engine performance is studied. In diesel engine, diesel is used as base line fuel and then PMD blends are used as alternate fuel. For each blend the engine performance and emission characteristics are measured and examined.

The blends of biodiesel, methanol and diesel are prepared in the required proportion. These mixtures are prone for their separation due to their different density. The mixture is stirred with the help of stirrer which is operated by electrical motor. The schematic of stirrer along with the control system is shown in the above figure. The speed of stirrer is varied by electronic regulator.

IV. RESULTS AND DISCUSSION

1. Comparison of thermal performance of biodiesel and Methanol and diesel Blends:

1.1 Brake specific fuel consumption (BSFC):

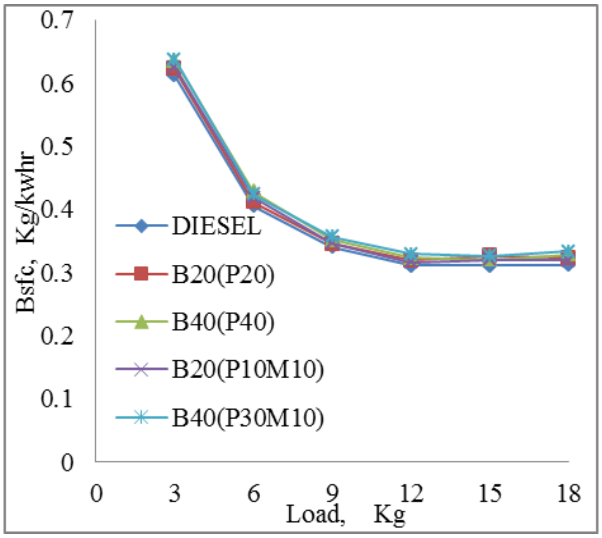

Fig.1.1. Variation of BSFC with load for PMD blends

Brake specific fuel consumption may be defined as fuel consumed per unit of power produced and their variation with power produced for different fuels and loads are presented in fig.1.1.Brake specific fuel consumption of different blends of Pongamia biodiesel and diesel, biodiesel methanol and diesel and pure diesel fuel for different loads and different percentage of blends are B0 (diesel), B20 (P20, P10M10) B40 (P40, P30M10) are considered for the comparison. It can be seen that as the load on the engine increases there is increase in BSFC for all the fuels considered. The increase in BSFC with increase in load is to produce more power to carry the increased load on the engine and may be also due to lesser heating value of biodiesel. Conversion of heat of energy in to the mechanical work increases with rise in combustion temperature and that may causes the decrease in BSFC with increase in load on the engine. BSFC of diesel fuel is the least and for all the B20 blends are more than diesel fuel and B40 (P30M10) is the highest. The difference in the BSFC indicates the difference in the fuel properties such as heating value, density, volatility of different fuels used. The heating value is the predominant factor in influencing the BSFC of the engine. Diesel fuel is having higher heating value and has least BSFC and Pongamia is having lesser heating value and has highest BSFC.

1.2 Brake Thermal Efficiency:

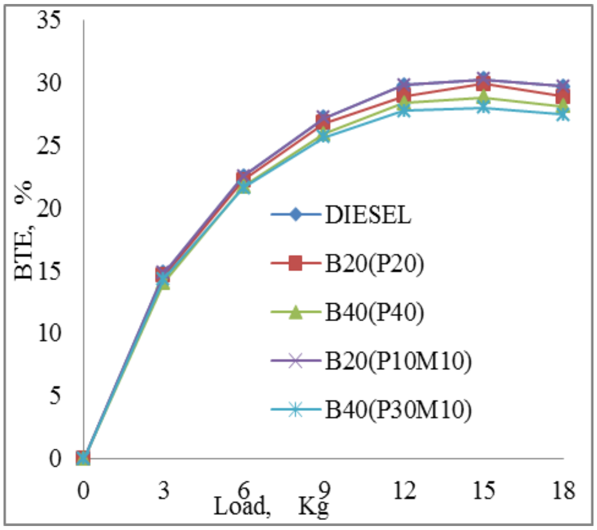

Fig 1.2 Variation of BTE with load for PMD blends

Brake thermal efficiency indicates the conversion of chemical energy of fuel in to heat energy in to the mechanical work. The change in brake thermal efficiency for increasing load on the engine for various blends of biodiesel and diesel, biodiesel methanol and diesel blends and pure diesel fuels are presented in fig.1.2. It is seen that brake thermal efficiency for B20 (P10 M10) is higher compared to other fuels as well as diesel fuel, this may be attributed to the rapid premixed combustion stage of methanol and diesel blend compared to the other fuels used in the experimental work. The diffused combustion phase improvement may be the reason for higher efficiency for the methanol B20 (P10M10) blended diesel fuel. BTE for the blends of biodiesel methanol and diesel B20 (P10M10) blends are higher, it may be due to the reduced density and viscosity of biodiesel methanol and diesel blends (P10M10), leads to the faster combustion compared to B40 (P30M10) and diesel fuel.

1.3. Exhaust gas temperature:

Variation of exhaust gas temperature for biodiesel and diesel, biodiesel methanol and diesel blends, and pure diesel fuel are presented in the fig.1.3. Exhaust gas temperature for the biodiesel and diesel, biodiesel methanol and diesel blends and for pure diesel fuels are increasing with increase in load. Increase in temperature may be due to increased fuel supply with

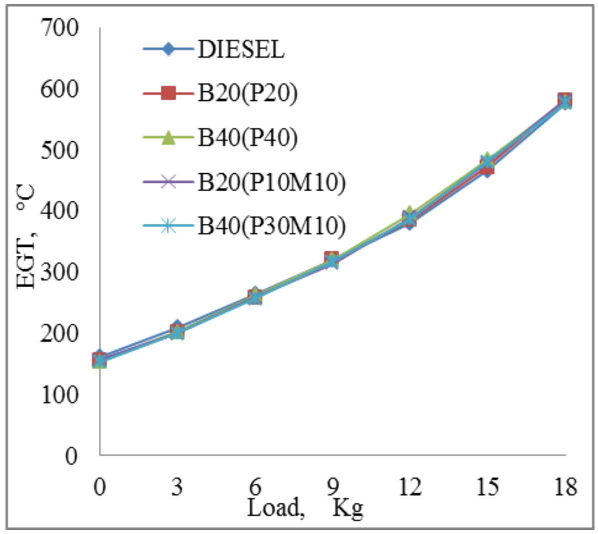

Fig1.3 Variation of Exhaust gas temperature with Load for PMD blends

increase in loads. It can be seen that there is no much variation in the exhaust gas temperature of the blends and diesel fuel. At higher loads exhaust gas temperature for biodiesel methanol blends and diesel blends are higher than pure diesel fuel, may be due to lean burning and delayed combustion of methanol blended fuels. The higher exhaust gas temperature of biodiesel methanol and diesel blends is due to better combustion of biodiesel methanol blended fuel compared to the other fuels, because of oxygen content in biodiesel and methanol fuel. The shorter combustion duration of biodiesel methanol and diesel fuel may have slightly higher exhaust gas temperature compared to diesel fuel at higher loads.

1.4. Carbon monoxide:

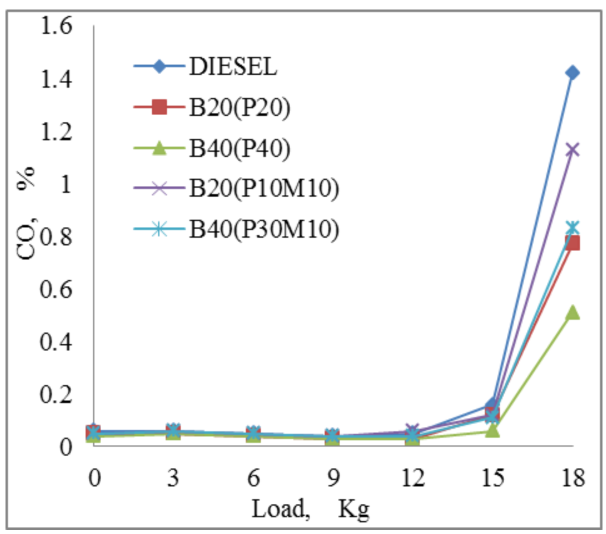

Fig 1.4 Variation of Carbon monoxide with Load for PMD blends

Fig.1.4. shows the variation of CO emissions with change in load for the blends of biodiesel and diesel, biodiesel methanol and diesel blends and pure diesel fuel. It can be seen from the figure as the load on the engine increases CO emission decreases, may be due to faster combustion for all the fuels used in the experimental work. It can be indicated from the figure that that emission of CO at the lower loads and mid-range loads are less for all the fuels used. CO emission for B40 (P30M10) is lesser compared to diesel fuel, may be due to the oxygen present in the biodiesel fuel may reduce the CO emission by converting it to CO_2. At rated load CO emission increases drastically compared to other loads may be due to the higher air fuel equivalence ratio. The difference in the CO emissions at lower loads is insignificant for the different blends as well as diesel fuel. CO emissions for biodiesel methanol and diesel B20 (P10M10) blends are higher compared to other blends as well as pure diesel fuel.

1.5. Hydrocarbon

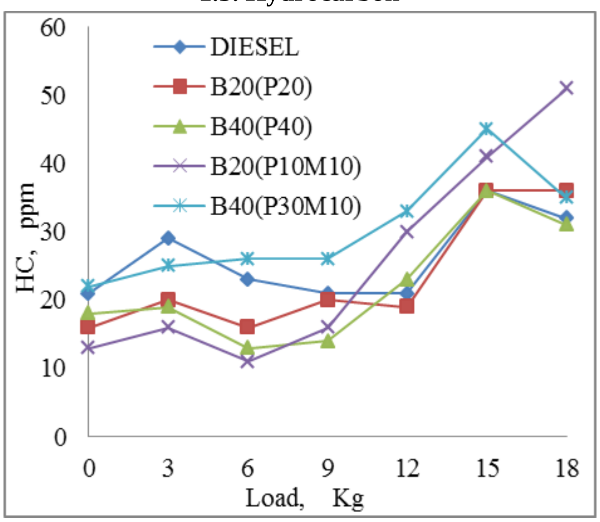

Fig 1.5.Variation of Hydrocarbon with Load for PMD blends

Fig.1.5 shows the emission of HC with change in load for the blends of biodiesel and diesel, biodiesel methanol and diesel blends and pure diesel fuel. It is seen that HC emission increases with increase in load may be due increased fuel supply to generate more power to carry the increased load on the engine. It is clear from the graph that for biodiesel and diesel (B20) blend HC emissions are the least for all the loads compared to diesel and other blends may be due to the oxygen in biodiesel and methanol actively involved in the combustion process and hence reduction of HC emission. For all the blends HC emissions are lesser at lower loads may be due to the better combustion of the blended fuels than diesel fuel. HC emissions for B40 (P30M10) blends are higher compared to other blends and diesel fuel at higher loads, they are lesser at the lower loads.

1.6. Oxides of nitrogen:

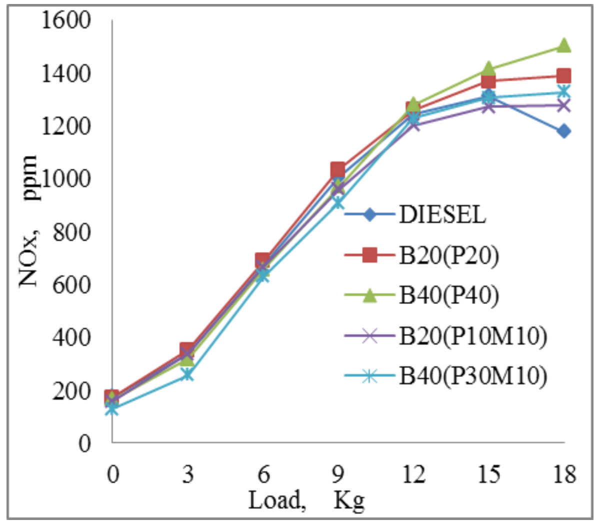

Fig1.6.Variation of Oxides of nitrogen (ppm) with Load (kg) for PMD blends

Emission of NO_x for different blends of biodiesel and diesel, biodiesel methanol and diesel and pure diesel fuel with change in load is shown in fig 1.6. NO_x emission increases with increase in engine load is due to the more amount of fuel is supplied to carry the increased load on the engine. The main factors which contribute for the NOx formation are combustion temperature, oxygen availability and the residence time during the combustion. It is seen that emission of NO_x for B20 (P10M10) and B40 (P30M10) is lesser compared to diesel fuel at lower loads. NOx emission for biodiesel and diesel blends are higher compared to diesel fuel may be due to the oxygen availability and higher combustion temperature increases the NOx. According to the experimental results methanol in the blend decreases the NOx emissions. It can be seen from the graph that emission of NOx for B20 (P10M10) and B40 (P30M10) blends are lesser than diesel fuel.

1.7. Pressure crank angle diagram at 12 Kg:

The variation of in cylinder pressure with crank angle at 12 Kg load is shown in Fig. 1.7. It can be seen from the graph that the ignition delay for the blends are lesser for the blends compared to diesel fuel. Decrease in delay period may be due to the higher Cetane number of biodiesel in the blends of biodiesel and diesel ie B20 (P20D80).For the biodiesel methanol and diesel blends may reduce density and viscosity of the blends may enhance combustion due to the increased rate of mixture formation and ignites the air fuel mixture earlier than the diesel fuel, hence reduced ignition delay for the fuels considered for test compared to diesel fuel. Pressure for B40 (P30M10) blend is higher among all the blends used and it is 67.65 bars at 7^0 aTDC. For B0 (diesel) peak pressure is 68.32bar at 7^0 aTDC. For B20 (P20) peak pressure is

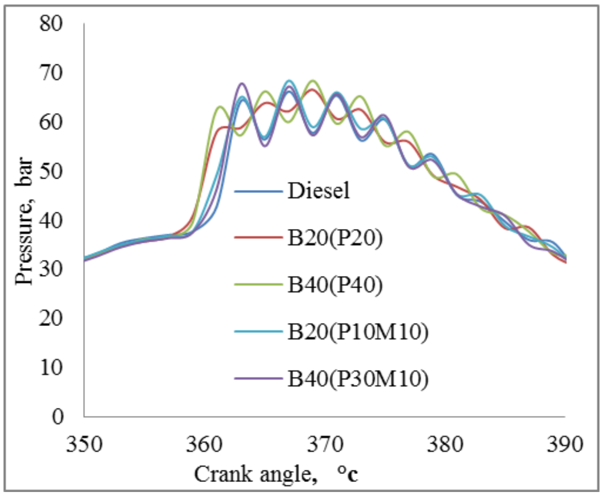

Fig 1.7. P-Ɵ diagram at 12 Kg for PMD blends

63.77 bar at 5^0 aTDC, it seen that the variation pressure for this fuel is less compared to the other fuel.

1.8. Pressure crank angle diagram at 15 Kg

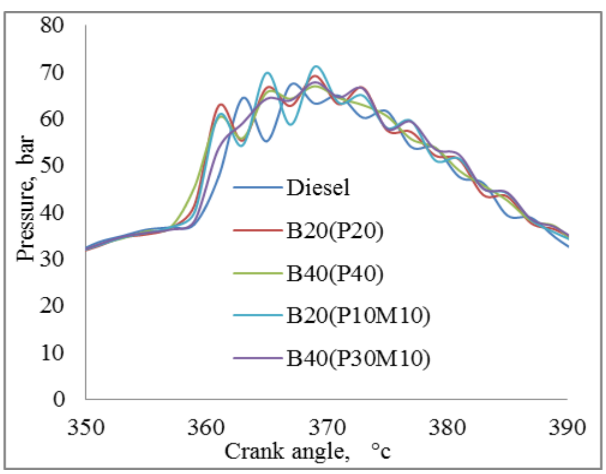

Fig 1.8. P-Ɵ diagram at 15 Kg for PMD blends

Fig.1.8. shows the variation of pressure with change in crank angle for biodiesel methanol and diesel blends and pure diesel at 15 Kg load. It is observed that the maximum pressure is for B20 (P10M10) biodiesel methanol and diesel blends compared to B0 (diesel) fuel. The highest pressure for B20 is 68.32 bar 3^0 aTDC, whereas for B40 (P30M10) the peak pressure is 64.28 bar 5^0 aTDC. For the diesel fuel the peak pressure is 66.13 bars at 7^0 aTDC. The peak pressure for B20 is attained earlier than other blends. For B40 the peak pressure is attained next to B20 blend. But for all other blends the peak is attained later than B20 and B40 blends. Ignition delay period for the biodiesel methanol and diesel blends are lesser compared to diesel fuel. Ignition delay for the B40 (P40) biodiesel blend is lesser than any other blends and pure diesel fuel. This may be due to the faster evaporation of biodiesel diesel blends.

V .CONCLUSIONS

The main aim of this study is to investigate the thermal performance, emission and combustion characteristics of diesel engine using the blends of biodiesel and diesel blend and biodiesel methanol and diesel blends and comparing these results with base line petroleum diesel fuel. Based on the tests carried out using the blends following conclusions are drawn

- Fuel consumption with biodiesel and biodiesel methanol blends, fuel consumption is even higher than biodiesel and diesel blends and pure diesel fuel.
- Brake thermal efficiency for biodiesel and diesel blends are lesser compared to diesel fuel.
- Brake thermal efficiency for biodiesel methanol and diesel blends are higher compared to pure diesel fuel.
- Emission of CO, HC are lesser for biodiesel and diesel blends.
- Emission of CO, HC are higher for biodiesel methanol and diesel blends compared to biodiesel and diesel blends as well as pure biodiesel fuel.
- NOx emissions are higher for biodiesel and diesel blends compared to diesel fuel.
- NOx emissions are lesser for biodiesel methanol and diesel blends compared to other fuels.

- Exhaust gas temperature are comparable for all the fuels considered for the experimental work.
- From all these results, it could be concluded that the blends of Pongamia with methanol, diesel up to 10% by volume could replace diesel for running the diesel engine with less emissions.
- Methanol blended fuel gives lesser NOx emissions compared to the pure diesel fuel and as well as blends of biodiesel and diesel.

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