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Research Article

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Utilization of biofuel blends in a direct injection diesel engine for the prediction of engine performance parameters and exhaust emission characteristics

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ABSTRACT

Increased petroleum prices, fast depletion of conventional fuel resources, stringent emission norms and increased environmental concern led to search for suitable alternative fuels for diesel engines. An oxygenated fuel is a chemical compound seems to be a possible source of alternative fuel received great attraction for diesel engines. In this work an experimental investigation is conducted to study the effect of di-methoxy methane blends with diesel fuel in a single cylinder four stroke naturally aspirated direct injection diesel engine. The engine was operated with diesel fuel and two levels of diesel/DMM blends: 6% and 12%.Blends were subjected to undergo engine performance and emission tests and the results were compared with diesel fuel. Results showed that, the addition of di-methoxy methane (DMM) blend to diesel fuel decreases the emissions of carbon monoxide (CO), hydrocarbon (HC) and smoke intensity. DMM blends slightly increases the specific energy consumption and nitrogen oxide emissions. From the test results it was found that the selected oxygenated fuel can be used for running the diesel engine successfully.

Keywords: Diesel engine, Di-methoxy methane, Engine Performance and Emissions.

INTRODUCTION

An intense research effort is on-going in the engine combustion and pollutant emission of diesel engines due to better fuel economy, widespread use in agricultural, power generation and transportation sectors. In compliance with the limited oil reserves and governmental regulations to meet emission standards, there has been an active research for alternate fuels. Oxygenated fuels can be considered as an alternative fuels due to its availability, cetane number and oxygen content. Oxygenated fuels can be either synthetically prepared oxygenates or biomass products which can be produced from both fossil and renewable sources. When these compounds are blended with diesel fuel the oxygen content of the fuel increases which results in better combustion. It also leads to reduction in emissions of hydrocarbon, carbon monoxide and smoke intensity. In the present research work, single cylinder, direct-injection diesel engine running on ignition improver blend was instrumented for the measurement of in-cylinder pressure-crank angle history, the engine performance and emissions. Ren *et al.* (1) investigated the combustion and emissions characteristics of a DI diesel engine fuelled with diesel-diglyme blends. They observed that at high engine load, smoke decreases by 3.7% for a 1 wt% increase of the oxygen mass fraction in the blends and NO_x concentration shows a slight decrease or remains unchanged. Yanfeng *et al.* (2) conducted experiments with a new kind of oxygenated fuel, 2-methoxyethyl acetate. Authors concluded that the cylinder pressure, the rate of pressure rise and the ignition delay change little and the smoke density could be reduced by more than 50% respectively. The emissions of CO and HC also decreased with an increase in MEA in the blends. The blends have almost no effects on the NOx emissions and the thermal efficiency of the engine increases by 2%. Srinivasan *et al.*(3) investigated the performance and emission characteristics of two kinds of oxygenates 2-Ethoxy ethyl acetate and 2-Butoxy ethanol with three different blends. They observed that a considerable reduction of smoke emission, carbon monoxide and unburned hydrocarbon is obtained and nitrogen oxide emissions are increased when the oxygen content is increased from 5% to 15%. Kapilan *et al.* (4) conducted experiments with 5 % DEE and found lower carbon monoxide, total hydrocarbon and smoke emissions while a slight improvement in thermal efficiency was observed. Chen *et al.* (5) investigated the effect of blended ethanol and biodiesel on diesel emissions and performance. The blending percentages of ethanol to diesel fuel were 10%, 20% and 30%, while the biodiesel percentages were 5% and 10%. Engine torque was reduced and brake specific fuel consumption was increased with blended fuels. NO_x emissions were slightly increased or the same as baseline diesel fuel. HC emissions with oxygenated blends were reduced under most operating conditions. CO emissions were increased at low to medium load conditions, but reduced at high load condition. Zhu *et al.* (6) conducted an experiment in a diesel engine to study the combustion, performance and emission of a direct-injection diesel engine fuelled with the blends of dimethoxymethane. Results showed that, without changing the fuel supply system and the combustion system of a diesel engine, when using blended fuel with increased DMM percentage, BSFC is higher for a smaller lower heating value of DMM, while thermal efficiency increased a little. For exhaust emission, smoke and CO emission decrease and NOx remained almost unchanged, while hydrocarbons increased. They observed that the diesel engine fuelled with 30% DMM blending fuel could obtain satisfactory fuel efficiency and emission level. Sudeshkumar *et al.* (7) studied the combustion, performance and emission characteristics of a DI compression ignition engine fuelled with ignition improver blends. It is observed that addition of ignition improvers reduce the smoke intensity at all loads. They have concluded that 12% 2ME blend with diesel fuel is found to be the best proportion in improving the diesel engine combustion, performance and emissions compared to 6% blended fuels. Xiangang *et al.*(8) conducted experiments on a 4-cylinder direct-injection diesel engine using ultralow sulphur diesel blended with ethanol, biodiesel and diglyme to investigate the particulate emissions of the engine under five engine loads. Four diesel–ethanol blends with oxygen concentrations of 2%, 4%, 6% and 8%, five diesel–biodiesel blends and five diesel–diglyme blends with oxygen concentrations of 2%, 4%, 6%, 8% and 10% were studied. Results show that the particulate matter (PM) emission decreases with the increase of oxygenate content in the blends. Ethanol addition into diesel fuel increases HC, CO, NOx and NO2 emissions and decreases particle number concentration. Balasubramaniam *et al.* (9)investigated the exhaust emissions from the diesel engines using fuel additives. The additives used in this work are 1-2 Di methoxy ethane. It was mixed with diesel in the concentration of 1%, 3%, &5% by volume. The result showed that by using the above said fuel additives the percentage of smoke, NOx and particulate matter (PM) in the engine exhaust was reduced.Sandeep *et al.* (10) studied the effects of DMC and DBM on the emission characteristics of a diesel engine with all load ranges of the engine. All tests were conducted at steady state and were set at constant engine speed of 1500 RPM. The smoke content reduces by 35% at full load conditions using DMC20 blend, the oxygen content in theemission increases by 39% with DBM15, the decrease in the % of unburnt hydrocarbons and carbon monoxide is respectively 19 and 21. The blends of diesel with 15% DMC and DBM by volume is the best fraction for reduction of smoke and CO emissions without much affecting the performance of the engine. Krishnasamy *et al.*(11) tested an oxygenated blend fuel containing volumes of 15% bio-diesel and 5% ethanol on a direct injection diesel engine with diesel oxidation catalyst as after treatment device. Test results reveal no significant change in engine combustion characteristics and fuel economy but appreciable reduction in particulate matter emissions. Hansdah*et al.* (12) tested the possibility of utilizing bioethanol obtained from Madhuca Indica flower as an alternative fuel in a direct injection (DI) diesel engine. Three different percentages of bioethanol (5%, 10%, and 15%) on volume basis were emulsified with diesel proportionality with the help of a surfactant. The emulsions were designated as BMDE5, BMDE10, and BMDE15 where the numeric value refers to the percentage of bioethanol. It is suggested that the bioethanol produced from Madhuca Indica flower can be used as a potential alternative fuel replacing 5% of petroleum diesel.Prajapati*et al.* (13)compared the performance and emissions characteristics of diesel, EGM05 and DMC-EGM05 blends with experimental study on CI engine. Test results show that brake thermal efficiency for the DMC-EGM05 blend is higher than that of EGM05 blend. BSEC of DMC-EGM05 blends show decreasing trend for increasing brake power or load. CO emissions can be remarkably reduced with the addition of DMC and EGM to diesel compared to only EGM added blend. All these results indicate the potential of the DMC-EGM blend for clean combustion in diesel engine.Venkatraman *et al.* (14) carried out an experimental investigation on low heat rejection engine with raw jatropha oil, methyl ester of jatropha oil, methyl ester of jatropha oil–kerosene blend in the proportion of 70:30 and the results obtained shows better performance and emission characteristics of the engine with methyl ester of jatropha oil.

PROPERTIES OF DIESEL AND DI-METHOXY METHANE

Dimethoxymethane ($C_3H_8O_2$) is a potential alternative oxygenated diesel fuel or blend component for diesel engines. DMM has a high oxygen fraction; high cetane number; and exists in a liquid state in normal conditions, making it convenient for storage and transportation. DMM can be manufactured by oxidation of methanol or by the reaction of formaldehyde with methanol. It can also be produced via the catalytic oxidation of dimethyl ether (DME). Table 1 shows the properties of DMM and diesel fuel

Table 1 Properties of Diesel and Oxygenated fuel

Properties	Diesel	DMM
Density (g/cc)	0.826	0.86
Oxygen Content (wt %)	-	42.1
Cetane Number	45	30
Boiling Point (°C)	317	42
Heat of Combustion kJ/kg	42000	23260
Viscosity @ 40°C	2.51	2.0

EXPERIMENTAL SECTION

Engine tests were performed in a single cylinder, four stroke, naturally aspirated, water cooled direct injection diesel engine with bowl type piston. The engine was operated at a constant speed of 1500 rpm and standard injection pressure of 220 bar. The engine was coupled to an eddy current dynamometer for load measurement. A complete description of the engine specifications are presented in Table 2. The main measuring instruments were: electronic flow meter for fuel consumption, air flow measurement system, a TDC marker, an rpm indicator and a Kistler piezoelectric transducer for the combustion chamber pressure. A fast data acquisition system was used to record the pressure diagrams obtained by the piezoelectric transducers. The crank angle encoder was mounted on the engine shaft for crank angle measurement. Exhaust emissions of CO, HC and NO_x were measured with krypton 5 gas emission analyser. The analyser was calibrated according to the instructions of the manufacturer. Smoke level was measured using diesel tune DX.230 smoke meter. The hardware for pressure measurement consists of a high speed data acquisition system and a digital signal processor. The inbuilt software performs the thermodynamic analysis of the pressure data. Before starting the measurements the engine was allowed to run for sufficient time to ensure emissions and fuel consumption had stabilized. All the engine tests were carried out in the fair constant ambient conditions. Experiments were carried out by using neat diesel as the base line fuel after that base line data were generated and the corresponding results were obtained. The engine was then operated with blends (6% and 12% by volume) of Di-methoxy methane.Figure.1 and Figure.2 shows the schematic and photographic view of experimental setup.

Table 2 Specifications of a Diesel Engine

Make and Model	Kirloskar DM 10
Bore and Stroke	102 × 116 mm
Compression Ratio	17.5:1
Cubic Capacity	0.948 Litres
Rated Speed	1500 rpm
Rated Power	7.5 kW @ 1500 rpm
Injection Timing	26° BTDC
Injector Opening Pressure	200-205 bar
Valve Timing Inlet valve opens BTDC Inlet valve closes ABDC Exhaust valve opens BBDC Exhaust valve closes ATDC	 4.5 Deg. 35.5 Deg. 35.5 Deg. 4.5 Deg.

The test standards followed for this research work are BIS: 10003 – 1981.Initially engine tests were performed using diesel fuel for all engine loads and the same tests were performed for each blend assuring the best possible repeatability.

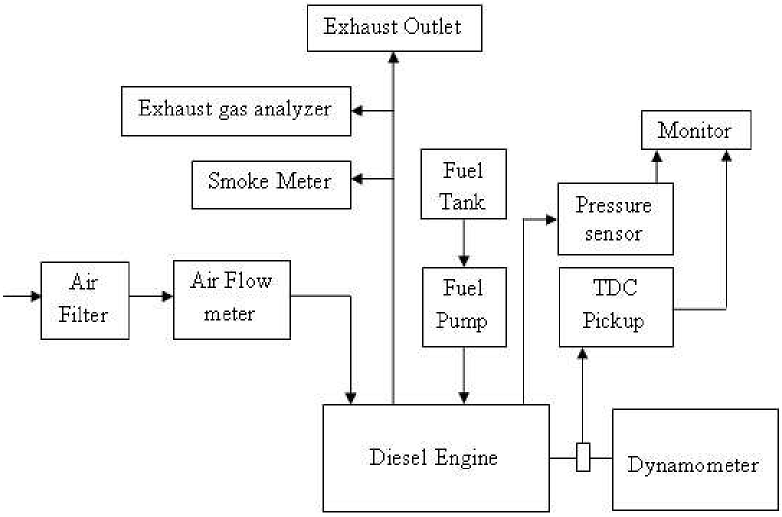
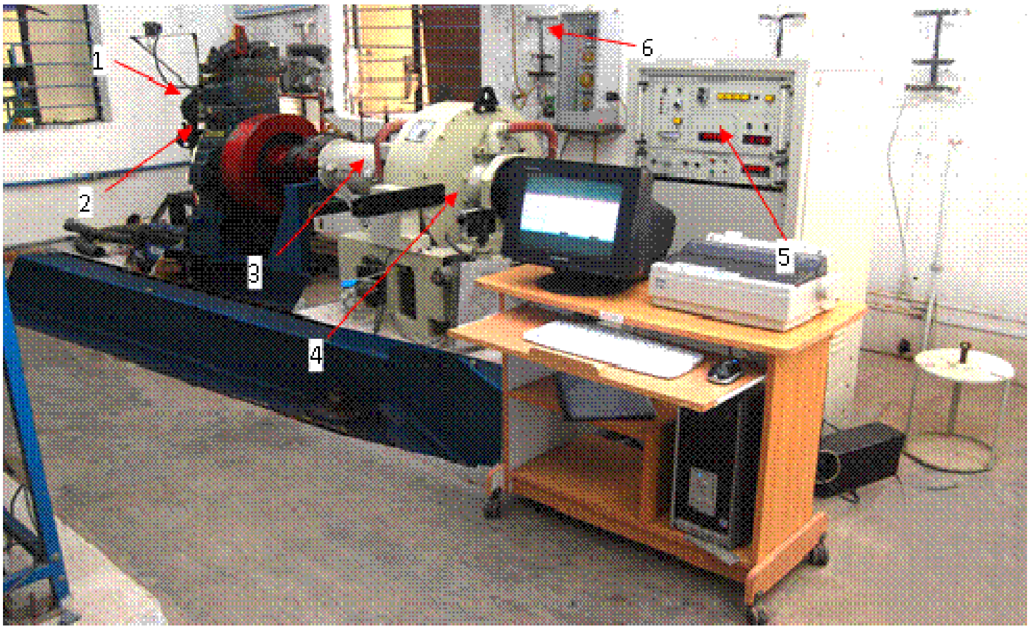


Figure.1 Schematic Arrangement of Experimental Setup



1. Engine	**2. Flywheel**
3. Dynamometer	**4. Data acquisition system**
5. Control unit	**6. Fuel flow meter**

Figure.2 Photographic View of the Experimental Set up

RESULTS AND DISCUSSION

Cylinder pressure characterizes the ability of the fuel to mix well with air and burn. The cylinder pressure changes because of cylinder volume change, combustion rate, heat transfer to the cylinder walls and flow in and out of crevice region. Figure.3 shows the comparison of cylinder pressure traces of diesel and oxygenated blends with respect to crank angle at 80% load condition. It is seen from the results that the addition of DMM blends increases the peak value of cylinder pressure for the same speed and load compared to diesel fuel. It is observed from the results that the peak value of cylinder pressure increases with the increased proportions of DMM blends. Peak pressures of 67 bar, 69 bar and 69.5 bar are recorded for diesel fuel, 6% DMM blend and 12% DMM blend respectively. The presence of oxygen in the oxygenated fuel makes combustion complete and hence higher peak pressure is obtained.

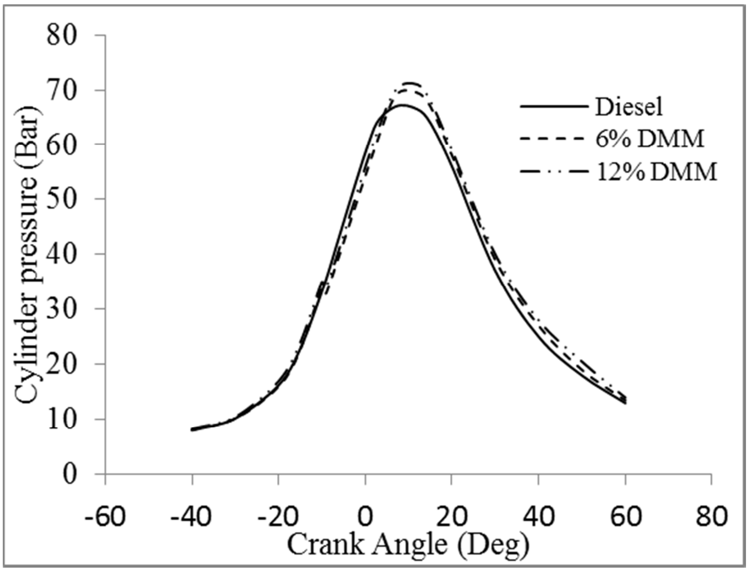


Figure.3 Variation of Cylinder Pressure Traces

Figure.4 shows the variation of cumulative energy release with respect to crank angle for diesel and oxygenated blends. Addition of DMM blends to diesel fuel slightly increases the cumulative energy release compared to diesel fuel. 6% and 12% DMM blend increases the cumulative energy release by 2.24%, 3.03% and compared to diesel fuel due to improved spray characteristics and faster burning characteristics of the blended fuel.

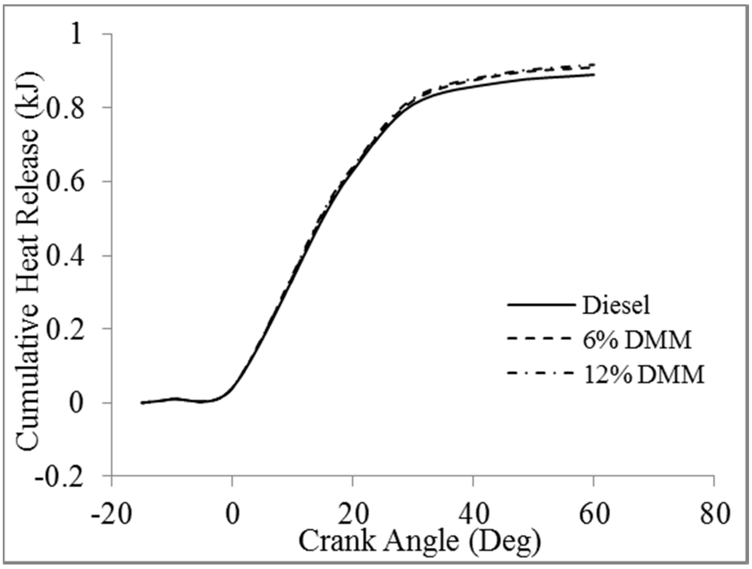


Figure.4 Variation of Cumulative Heat Release

Brake specific energy consumption is the energy consumed per unit power. It is an ideal variable because it is independent of the fuel and hence it is easy to compare energy consumption rather than fuel consumption. The effect of Di-methoxy methane fuel blends on the brake specific energy consumption for different load conditions are shown in Figure.5. Addition of Di-methoxy methane blends to diesel fuel increases the brake specific energy consumption compared to diesel fuel at all loads. 12% and 6% Di methoxy methane increases the specific fuel consumption by 20% and 15% compared to diesel fuel at 80% load. The increase in brake specific energy consumption for the DMM blend to diesel fuel is due to lower calorific value per unit mass of the DMM blend.

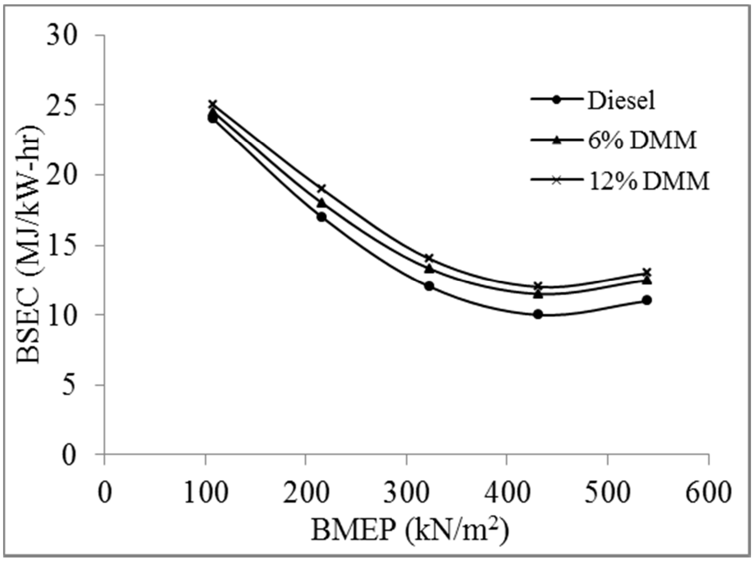


Figure.5 Variation of BSEC with BMEP

CO emission is mainly due to oxygen insufficiency inside the combustion chamber. Figure.6 shows the comparison of carbon monoxide emissions with respect to brake mean effective pressure. It is observed from the results that the carbon monoxide emission decreases as the BMEP increases. This is due to the oxygen content of blended fuel which makes better combustion resulting in reduced CO emission in the exhaust. 6% DMM decreases the CO emission by 22.4% and 12% DMM decreases the CO emission by 27.5% at 539.3 kN/m^2respectively.

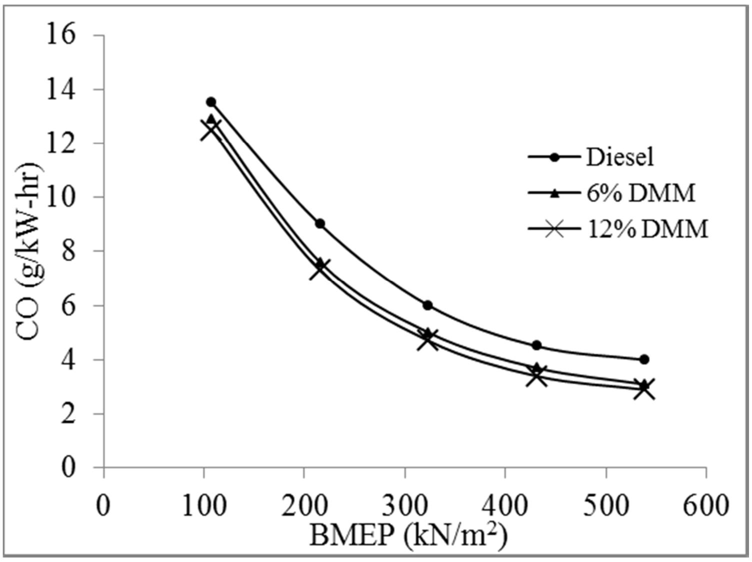


Figure.6 Variation of CO with BMEP

Figure.7 shows the comparison of hydrocarbon emissions with respect to brake mean effective pressure for diesel and DMM blend for different loads. Unburnt HC emissions consist of fuel that is incompletely burnt. The hydrocarbon emissions are reduced with the addition of DMM blend compared to diesel fuel. Due to higher oxygen content proper mixing of air and fuel takes place inside the combustion chamber. Therefore HC emission of oxygenate was reduced. The emission of HC was lowered by 15% and it was reduced by 21.4% with 6% and 12% DMM blend. The oxygen present in the blended fuel reduces the emissions of hydrocarbon.

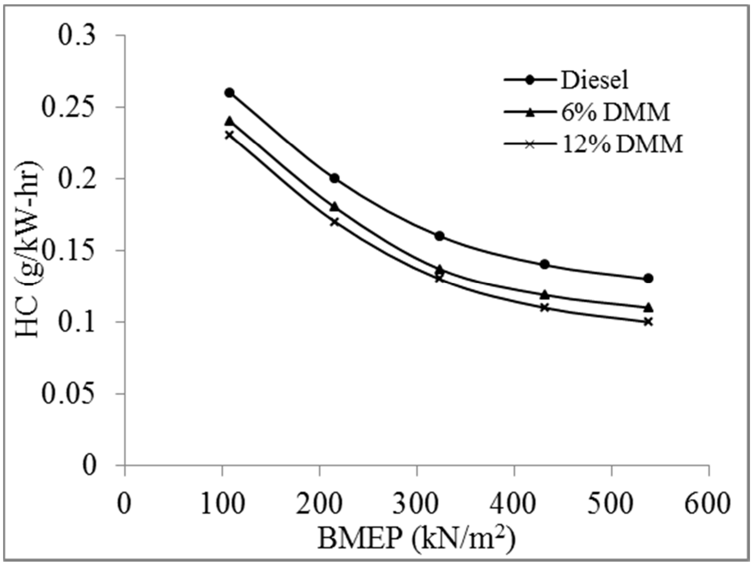


Figure.7 Variation of HC with BMEP

The variation of nitric oxide emission with respect to brake mean effective pressure for diesel fuel and DMM blends is shown in Figure.8. The formation of oxides of nitrogen is highly dependent on in cylinder temperatures, the oxygen concentration and residence time for the reaction to take place. Addition of DMM blends to diesel fuel slightly increases the nitric oxide emission compared to diesel fuel for all the loads. The slight increase in NOx emission of the blended fuel is due to decrease of the local temperature as a result of lower fuel heating value. 12% DMM blend has comparable NO_x emissions than that of 6% DMM blend and diesel fuel for all the loads.

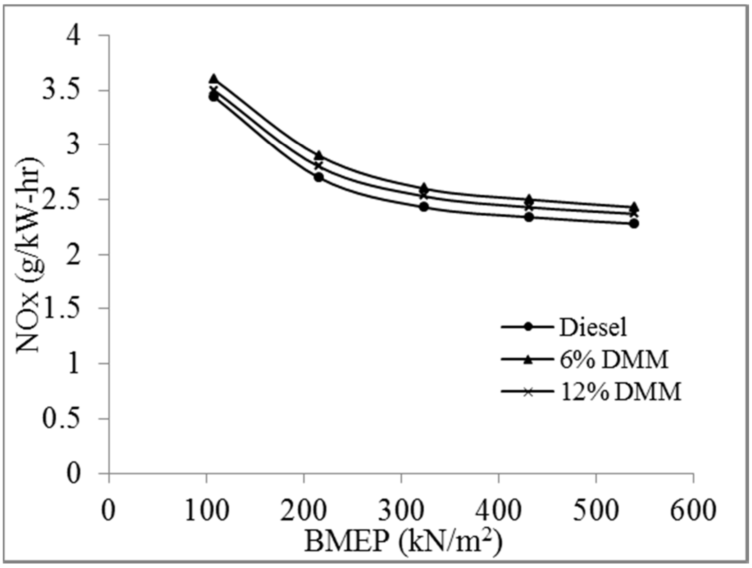


Figure.8 Variation of NOx with BMEP

Figure.9 shows the comparison of smoke intensity with respect to brake mean effective pressure. Smoke is the net result of soot formation and the subsequent oxidation during the combustion process before the exhaust valve is open. It is evidenced from the results that the smoke intensity of DMM blend increases with increase in load. Addition of DMM blend to diesel fuel decreases the smoke emissions in the exhaust considerably compared to diesel fuel. 6% DMM blend reduces the smoke intensity by 12.6% and 12% DMM blend reduces the exhaust smoke by 16.67% compared to diesel fuel. The smoke content in the exhaust is reduced due to the presence of oxygen content in the blended fuels compared to diesel fuel.

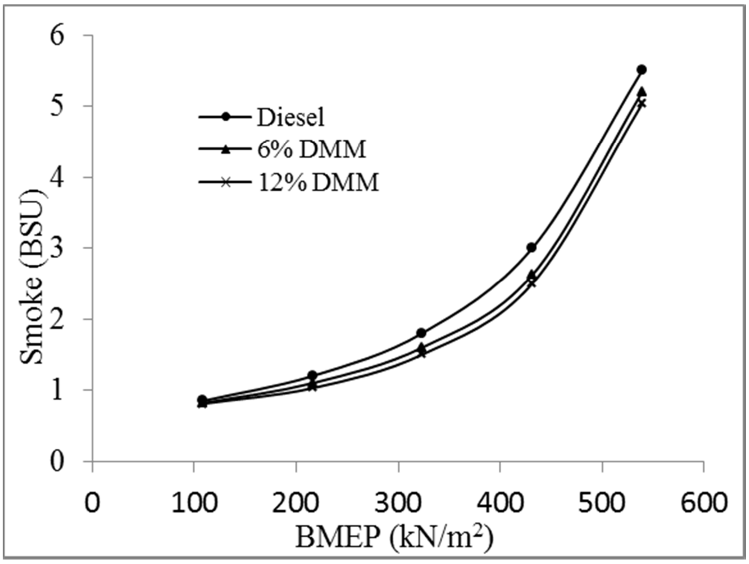


Figure.9 Variation of Smoke with BMEP

CONCLUSION

Experiments have been conducted on a diesel engine usingdiesel-DMM blends to study the performance and emission characteristics and the conclusions of the investigation are as follows:

Peak value of cylinder pressure and cumulative energy release is increased for DMM blends at 80% load compared to diesel fuel.

Addition of DMM blend to diesel fuel increases the specific energy consumption.

Emissions of Carbon monoxide, hydrocarbon and smoke intensity decreases with the addition of blended fuel to diesel fuel.

Nitrogen oxide emission increases slightly for the blended fuels and it is also observed that the NOx emissions may reduce with the higher proportions of selected oxygenated fuel.

From the above results it is conclude that the selected Di-methoxy methane blends can be effectively used in diesel engines as an alternative fuel.

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