EXPERIMENTAL STUDY ON EMISSION ANALYSIS OF OXYGENATED FUELS DIMETHYL CARBONATE (DMC) AND DIBUTYL MALEATE (DBM) IN A CI ENGINE

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Abstract

The biggest challenge in front of energy scientists is to find the alternative to diesel engine fuel due to depletion of fossil fuels and the environmental pollution, which is increasing alarmingly. Oxygenated fuel is one of the viable solutions to the global environmental changes. Dimethyl carbonate (DMC) and Dibutyl Maleate (DBM) are two hopeful fuel additives to reduce emission in diesel engine, due to their high oxygen content, 53.3 and 28 % respectively. This paper presents an experimental study of their effects on the emission characteristics of a diesel engine. DMC and DBM was used with diesel in different blends for all load ranges of the engine viz. at no load, 25%, 50% and 75% of full load and at full load. All tests were conducted at steady state and were set at constant engine speed 1500 RPM. The smoke content reduces by 35% at full load conditions using DMC20 blend, the oxygen content in the emission 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. On the basis of the results obtained, these additives are effective method for reducing the emission of diesel engine.

Keywords- *Dimethyl carbonate; Dibutyl Maleate; Oxygenated fuel, Diesel engine; Engine emission; Exhaust smoke*

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1. INTRODUCTION

The lesser fuel consumption, relatively longer life span, lesser repairs and great consistency are the few properties of a diesel engine which results in its extensive use in transportation, power generation and many more industrial and agricultural applications. But in spite of its many advantages, the diesel engine is inherently dirty and is the noteworthy contributor of exhaust emissions, which contributes to serious health problems. In view of increased concerns regarding the effects of diesel engine particulate and emissions on human health and the environment, reducing the emission from diesel engines is one of the major challenges today, due to continuing stringent emission requirements. Research work is going on to develop after treatment and in-cylinder control techniques to reduce the emission, but in this work, attention is focused on the use of oxygenated fuels to reduce particulate smoke emissions from diesel engine. Oxygenated additive is nothing more than fuel that have a chemical compound containing oxygen. It is used to help fuel burn more efficiently and cut down on some types of atmospheric pollution. Dimethyl carbonate (DMC) and Dibutyl Maleate (DBM) are two expectant additives to decrease smoke emission in diesel engine, due to their high oxygen content.

DMC is an organic compound with the formula $C_3H_6O_3$. It is a colour less, flammable liquid. It is classified as a carbonate ester. DBM with the formula $C_{12}H_{20}O_4$ is a clear colorless flammable liquid with a low boiling point, low viscosity and an excellent dissolving power. It has a chloroform-like odor and a pungent taste. The chemical structure of the two chemicals is shown in figure 1.

Figure1. Chemical structure of DBM and DMC

Table 1 shows the different properties of diesel, DBM and DMC. Dimethyl carbonate and Dibutyl maleate are non-toxic and also 100 per cent miscible in diesel fuel. The two oxygenated fuels used in the study has comparative values when compared to diesel. The cetane number and the calorific value of the oxygenated fuels is no doubt less than diesel but the oxygen percentage in the fuels make the combustion better in combustion chamber. The improvement in the combustion of fuel helps in increasing the performance and improving the emission characteristics of the engine.

Table1. Properties of different fuels used

Abbreviation	Diesel	DMC	DBM
Formula	$C_{10.8}H_{18.7}$	$C_3H_6O_3$	$C_{12}H_{20}O_4$
Molecular wt (g/mol)	148.3	90	228.29
Oxygen content (wt %)	0	53.3	28.0
Carbon content (wt %)	86	40	42
Liquid density (g/cm3)	0.86	1.0694	0.9880
Boiling point (°C)	154	90	281
Calorific value (MJ/kg)	42.5	13.5	29
Cetane number	40-55	35-36	35-36

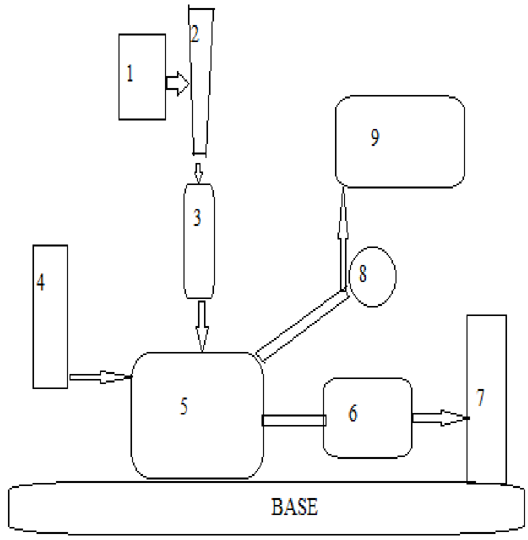
2. EXPERIMENTAL SETUP AND PROCEDURE

The diesel engine selected for the experimentation is widely used for commercial activities in agriculture sector and small scale industries. Engine selected is the make of the Kirloskar Oil Engines Limited, India. It is a single-cylinder, 4-Stroke, water-cooled diesel engine of 3.7 kW rated power. Important engine specifications are shown in Table 2. A generator was attached to the engine and load cell is designed to load generator. The output power of the engine was calculated based on the data of the current and voltage generated, while the brake thermal efficiency was obtained by using the data of the engine output power and the fuel consumption is measured using burette method.

Table 2 Specifications of the engine

Engine type	**Vertical, 4stroke, Single cylinder, DI**
Cooling	**Water cooled**
Rated power	**3.7 kW at 1500 rpm**
Horse power	**5**
Bore/Stroke	**80/110 (mm)**
Compression Ratio	**16.5:1**
Volts	**240 V**
Amps	**17.5**

The schematic arrangement of the experimental setup is shown in Fig. 2. Exhaust gas temperatures were also recorded for all loads. Content of smoke is measured using smoke meter and Airrex exhaust gas analyzer (German Make) is used to measure % of CO, CO_2 and HC in the exhaust gases at all loads and graphs are drawn to analyze the emissions.



Parts of the experimental setup

1. Fuel tank
2. Burette (for fuel measurement)
3. Fuel filter
4. Air filter
5. Diesel engine
6. Generator
7. Load cell
8. Thermocouple
9. Emission gas analyzer

Figure2. Schematic Arrangement of the Experimental Setup

The experimental procedure consisted of the following steps;

a) To begin with, the different blends were prepared and the blends containing 5, 10, 15, and 20 percent DMC fuel by volume were denoted as DMC5 (D95), DMC10 (D90), DMC15 (D85) and DMC20 (D80) respectively. Similarly DBM5, DBM10, DBM15 and DBM20 were denoted.

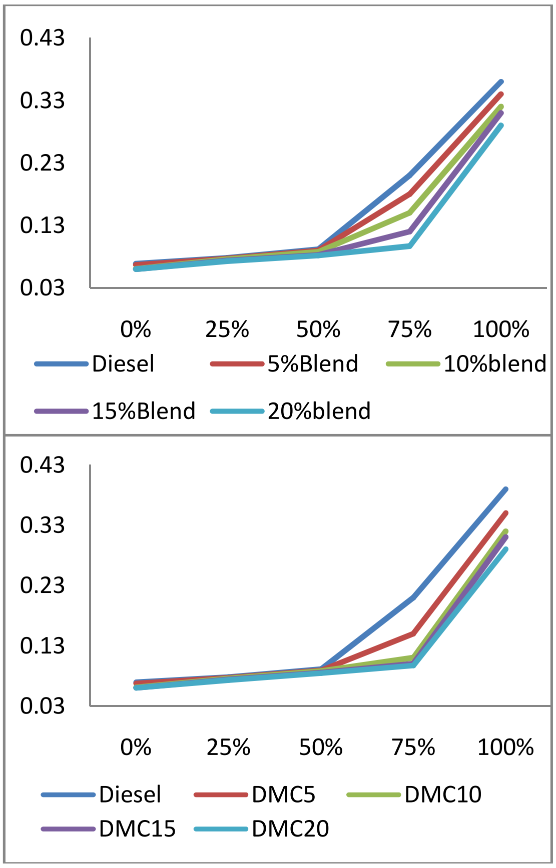
b) The engine tests were performed using the pure diesel fuel as base without any blending covering all engine loads to determine the engine operating characteristics and pollutant emissions to set a base line.

c) Then the readings were recorded at the same operating conditions with the engine fueled with different blends prepared in the beginning.

d) In the last the graphs were plotted to analyze the effect of the blends on the emission of the engine.

3. RESULTS AND DISCUSSION

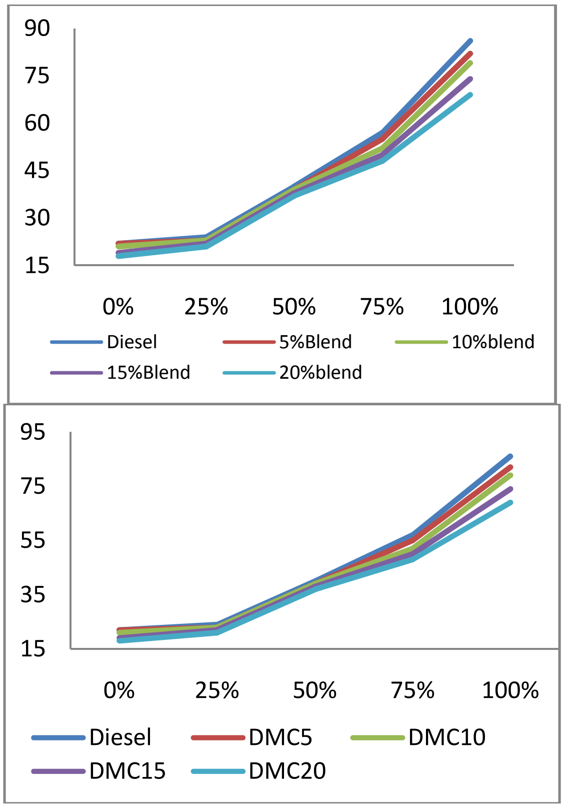
The key findings from the experimental testing are analyzed and summarized below by using graphs:



Graph1 Variations in CO % under Various Load Conditions using DBM and DMC blends

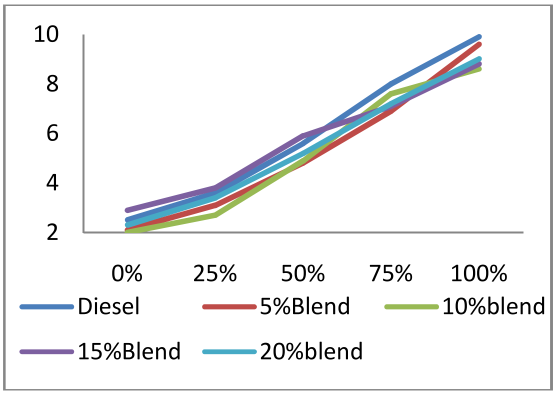
It is clear from Graph 1, that the addition of Dimethyl carbonate and Dibutyl maleate has significant reduction in CO emissions from diesel engines. Readings suggests that DBM and DMC addition improves the post-flame oxidation during the expansion stroke and reduce the locally fuel rich regions where CO is mainly formed, especially under high load operating conditions when the temperature inside the cylinder is much higher comparing with that at low load operation.

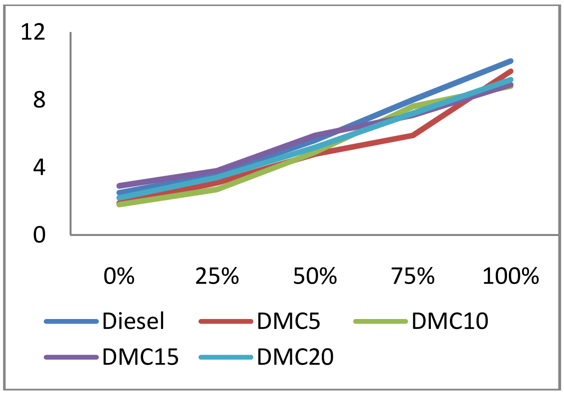
As seen in graph 2, the oxygenated additives reduce the HC emission. This is due to the oxidation of the lean mixture, especially at low load when the in-cylinder temperature is low and also due to the lower boiling point and ignitability of additives comparing with that of diesel.



Graph2. *Variations in HC % under Various Load Conditions using DBM and DMC blends*

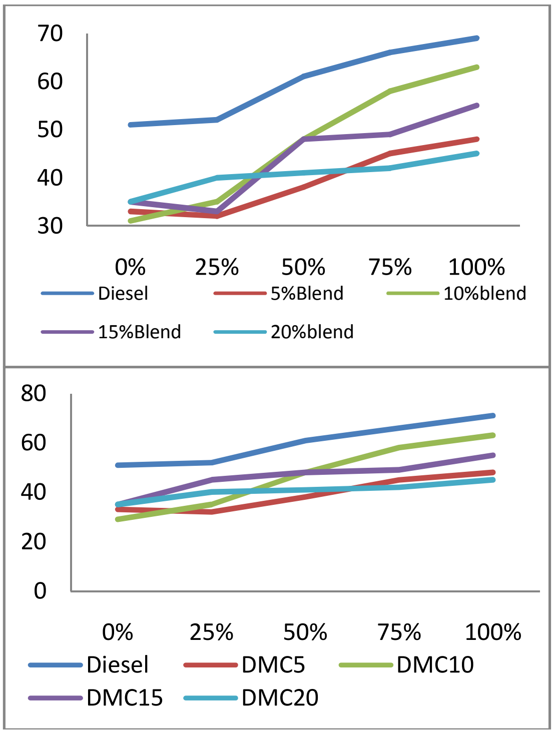
The CO_2 emission increases with increase in load for all blends. Graph 3 shows the effect on CO_2 emission with changing load conditions. In general the % of CO_2 reduces with the increase in the amount of oxygen content in DMC or DBM -diesel blend.





Graph3. Variations in CO_2 % under Various Load Conditions using DBM and DMC blends

This is due to the fact that with more oxygen content going into the cylinder for combustion with the fuel helps in complete burning of the fuel and decreases the level of unburnt carbons in emission.



Graph4. Variations in smoke content under Various Load Conditions using DBM and DMC blends

Graph 4 shows typical smoke levels for various engine loads with different blends. It is possible to see that all the oxygenated fuels produce lower smoke levels than their diesel counterparts for corresponding speed and load conditions. Comparing the DMC or DBM blends with pure diesel, it is also plausible that as fuel-borne oxygen levels increase, smoke levels go down.

CONCLUSIONS

In this research a investigation was carried out to study the effects on exhaust emissions by DBM and DMC blends in a single cylinder direct injection diesel engine. The oxygen contents of DBM and DMC is different, and consequently, their effectiveness as diesel fuel blending agents to reduce emissions, should be comparable. Their chemical structures and associated physicochemical properties are distinctly different. The results obtained for constant engine speed with various engine loads can be summarized as follows:

- ➢ The effect of oxygenated additives on performance of engine is not significant as there are marginal differences in the performance characteristics.
- ➢ Both DBM and DMC blends substantially lowers the exhaust gas opacity. The maximum reduction nearly of 35% was observed by DMC15 and DBM20 blends as compared to base reference diesel fuel.
- ➢ The oxygenated diesel fuel blends has shown significant reduction in CO and HC emissions with only a slight penalty in NOx emissions, which can be controlled by exhaust gas recirculation (EGR).
- ➢ The exhaust gas temperature increases which shows the complete burning of the fuel in the combustion chamber.

So it can be concluded that oxygenated additives addition in diesel fuel in appropriate proportion will reduce the emission characteristics. If the proportion of these additives is more than engine performance declines because the additives have lower calorific value compared to diesel. Other barriers in the use of oxygenated fuel additives are their high price and poor availability.

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