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Effect of Dimethyl Carbonate on Performance and Emission Characteristics of a Diesel Engine

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ABSTRACT

The exhaust from vehicles pollutes the environment and contributes to global warming, acid rain, SMOG, respiratory and other health problems. In this work, Dimethyl Carbonate (DMC) is mixed as an additive to the diesel as pilot fuel, with focus on reduction of harmful exhaust emissions and maintaining high Brake Thermal Efficiency. The performance and emission characteristics of the diesel engine operated with diesel fuel mixed with DMC (5%) was studied. These results were compared with the neat diesel as base fuel. The experimental study found that diesel engines fueled with DMC had improved the combustion and emission performances without significant increase in NOx emissions. By using biodiesel, there are some disadvantages such as higher density, lesser heating value, high fuel consumption and high oxides of nitrogen. To avoid above disadvantages, the fuel additives help in playing a very important role in minimizing the drawbacks of biodiesel and in maintaining international fuel standards. Additives can be considered toward to improve combustion, fuel economy and to decrease the emissions. In particular, DMC may be a promising additive for diesel fuel owing to its high oxygen content, no carbon-carbon atomic bonds, suitable boiling points and solubility in diesel fuel.

Key Words: Global warming, DMC, NOx, Biodiesel

INTRODUCTION

In the past, the world energy demand has relied on non-renewable fossil fuels for energy generation, transportation and industrial applications. Due to excess use of petroleum-based fuels for industry and automobile application in present time, the world is facing severe problems like global energy crisis, environmental pollution and global warming. The gaseous emissions from the combustion of these fuels are the principal causes of many environmental consequences. Many research programs are going on in order to reduce the harmful exhaust emissions from diesel engine.

In this work, Dimethyl Carbonate (DMC 5%) is mixed as an additive to diesel and the performance and emission characteristics of a diesel engine is studied. The fuel properties play an important role for engine performance and emission testing, important properties such as cetane number or index, calorific value and viscosity [1]. So, the addition of additives helps in playing a very important role in minimizing the drawbacks of diesel and in maintaining international fuel standards.

Some preliminary results have been obtained by the researchers. But there are still many aspects worth investigating, especially on a quantitative level. These quantitative parameters are expected to supply more information on engine combustion with oxygenated fuels and provide more practical measures for improving the combustion and reduction in emissions. Based on the authors' previous study, the objectives of the present study are further to investigate the combustion and emissions in a diesel engine, and to conduct a systematic analysis of the heat release parameters of a diesel engine operating on diesel fuel blends [2].

ADDITIVES

An additive plays a magnificent task in increasing the performance of the diesel engine, improving the combustion

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and reducing the emissions. A metal based additive will minimize the viscosity and increase the flash point properties of diesel. The brake specific fuel consumption decreases significantly because the additives have capability to reduce hydrocarbon (HC) and smoke emission. At present for vehicular fuels, combustion of numerous chemical additives is used to improve the quality of diesel fuel to convene up the most wanted performance level. The additive selection will be based on the drawbacks of diesel fuel such as density, toxicity, viscosity, economic feasibility, additives solubility, auto ignition temperature, flash point, and cetane number for the fuel blending process.

The reasons for using additives in diesel engine are listed below:

- Enhanced the nagging properties and immovability of the fuel.
- Shrinking the harmful emission from fuel combustion.
- Developing the combustion and performance properties of the fuel.
- To afford engine protection and cleanliness.
- Saving the fuel from optimized engine economy and performance [3].

The most important additives for diesel engine are oxygenated additives. The fuels that are containing oxygen and blending components contain at least one oxygen atom by the molecules at the side of the hydrogen and carbon atoms. The oxygenated additives are very useful to develop the combustion process and octane rating. The generally used oxygenated are alcohols, ether and ester. The few names of alcohols contain butanol, propanol, methanol and ethanol and ether includes diethyl ether, di-isopropyl diethyl ether, dimethyl ether and esters contain dimethyl carbonate are included in the efficient groups. By addition of oxygenated additives, the ignition temperature of biodiesel will be minimized and also reduction in smoke emission is observed in the diesel engine. According to the composition of diesel, the oxygenated additives will affect directly the properties such as cetane number, density, viscosity, volatility, flash point and calorific value. To ignite the fuel more efficiently oxygenated additives will support and as well as diminish environment pollution. The engine fuels will burn more completely due to the presence of oxygenated additives.

LITERATURE SURVEY

It was shown that the use of additive diesel blend is rapidly increasing around the world. Reason behind this is that the petroleum reserves are depleting rapidly and blended fuel mixture give the better performance which is investigated by researchers.

1) An experimental study by R. Rama Udaya Marthanda had been carried on 4 stroke CI engine with different blends of ethyl alcohol and diesel with n-butanol as an additive.
2) Experimental results were found out by Nasarullah. M and Raja Gopal. K on Kirloskar, AV-1 4 stroke, single cylinder, CI engine with variable compression ratio fuelled with diesel. Methyl ester of jatropha oil(MEJO) and MEJO with ignition improver and ethanol is used as fuel [4].
3) An experimental study was carried out by Mojtaba Saei Moghaddam, Abdolsamad Zarringhalam Moghaddam. The experimental study was carried out on on ECE R-96 8- modes cycle the engine used in this study was commercial Di, water cooled 4 cylinders diesel engine. The nitromethane (10%) and nitroethane (10%) were blended with diesel fuel [5].
4) Fleisch [6], Kapus and Ofner [7] and Sorenson and Mikkelsen [8] have studied dimethyl ether in modified diesel engines, and their results show that the engines can achieve ultralow emissions without any fundamental change to the combustion systems.
5) Huang investigated the combustion and emissions characteristics in a compression ignition engine with DME and found that the DME engine has high thermal efficiency and fast diffusion combustion, with the added advantage of low noise and smoke-free combustion [9].
6) Kajitani studied the DME engine with injection time delay to reduce both smoke and NOx [10].
7) Huang tested gasoline oxygenated blends in a SI engine and obtained satisfactory results on emission reduction [11].
8) Murayama studied the emissions and combustion with EGR and dimethyl carbonate [12].
9) Wang made a preliminary study of engine combustion and emissions on diesel DMC blends, and their results revealed a high possibility of smoke reduction with DM addition [13].

EXPERIMENTAL SETUP

The experiments were conducted on a Kirloskar single-cylinder, 4 stroke, direct injection diesel engine coupled with electrical dynamometer. The specifications of the engine are given in Table 1.

Table 1: Specifications of the engine

Properties	Description
Engine make	Kirloskar
Engine model	TV 1
Engine rated power	5.2 KW @ 1500 rpm
No. of cylinders	1
No. of strokes	4
Cooling type	Water
Engine type	Diesel
Bore diameter	87.5 mm
Stroke length	110 mm
Connecting rod length	234 mm
Compression ratio	17.5
Swept volume	661.45 cc

The engine develops the rated power of 5.2 KW and run at a constant speed of 1500 rpm. The engine has a bore diameter of 87.5 mm and stroke length of 110 mm. The combustion parameters are given in Table 2.

Table 2: Combustion parameters

Particulars	Description
Specific gas constant	1 KJ/KgK
Air density	1.17 Kg/m³
Adiabatic index	1.41
Polytrophic index	1.24
No. of cycles	5
Cylinder pressure reference	6
TDC reference	0
Smoothing	2

The fuel pipe diameter is of 12.4 mm and the experiment is conducted at an ambient temperature of 27˚C and the density of the fuel is 845 Kg/m3. The performance parameters of the engine are given in Table 3.

Table 3: Performance parameters

Particulars	Description
Orifice diameter	20 mm
Orifice coeff. of discharge	0.60
Dynamometer arm length	185 mm
Fuel pipe diameter	12.4 mm
Ambient temperature	27° C
Pulses per revolution	360
Fuel type	Diesel
Fuel density	845 Kg/m3
Calorific value of fuel	43245 KJ/Kg

In this experiment, the DMC (5%) is added as an additive to the diesel fuel. The properties of diesel fuel and DMC are given in Table 4. The fuel properties shows that DMC has a high oxygen content, while its heat value is lower and its cetane number is slightly lower compared with diesel fuel. The pressure is maintained at 200bar and the performance and emission characteristics were analysed.

Table 4: Properties of diesel and dimethyl carbonate (DMC)

Properties	Diesel	Dmc
Chemical formula	$C_{10.8}H_{18.7}$	$CH_3O(CO)OCH_3$
Molecular weight	148.3 g	90.1 g
Density	0.86 g/cm³	1.079 g/cm³
Boiling point	180-330 K	90.9 K
Heat of evaporation	270 KJ/Kg	369 KJ/Kg
Lower heating value	44.8 MJ/Kg	15.78 MJ/Kg
Stoichiometric air- fuel ratio	14.4	4.185
Cetane number	45	35
Carbon content	87.4%	40%
Hydrogen content	12.6%	6.7%
Oxygen content	0%	53.3%

RESULTS & DISCUSSION

A. *Brake Thermal Efficiency*

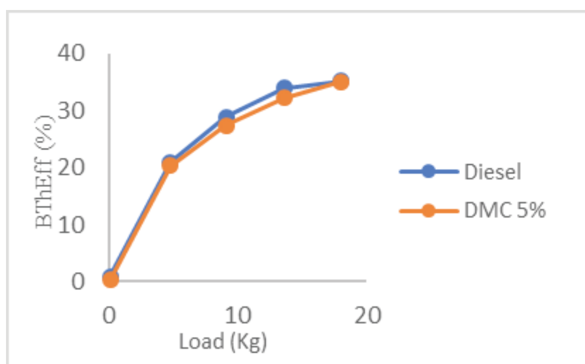

Figure 1: Variation of Brake Thermal Efficiency with load.

The Figure 1 shows the variation of Brake Thermal Efficiency(BTE) in case of diesel and DMC 5%. It is clearly seen that the BTE increases with increase in load. From the result we can observe that diesel has the highest BTE than the other fuels. This is because of its higher heat content, lower viscosity, lower density and higher volatility in comparison with other fuels [14]. But by increasing the percentage of additive with the diesel the BTE increases with respect to the load and shows very close behaviour to that of diesel because of increase in heat content, reduction in viscosity, density and increase in volatility which leads to better combustion of the test fuels [15-17].

B. *Mechanical Efficiency*

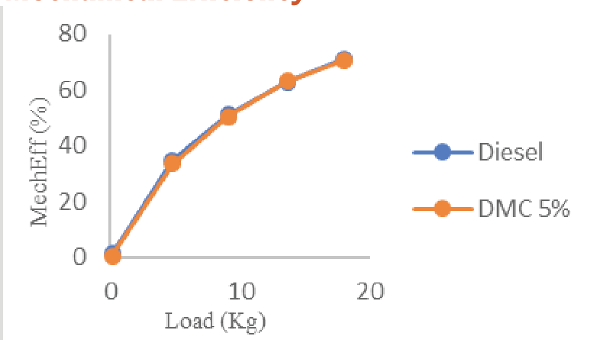

Figure 2: Variation of Mechanical Efficiency with load.

The Figure 2 shows the variation of mechanical efficiency for diesel and DMC 5%. It is observed that the mechanical efficiency increases with increase in load and it is almost same as that of the diesel. It is due to the effective combustion of the fuel. If we add more amount of additive to the diesel, then we obtain higher mechanical efficiency.

C. *Brake Specific Fuel Consumption*

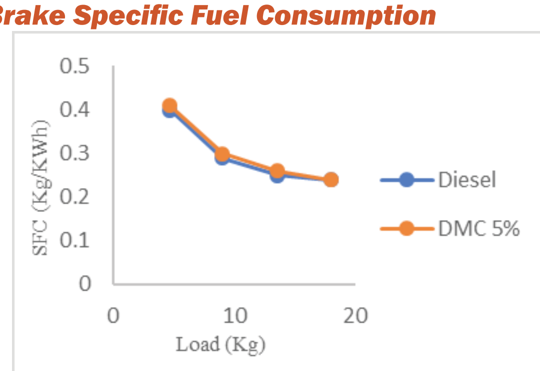

Figure 3: Variation of Specific Fuel Consumption with load.

The Figure 3 shows the variation of SFC for diesel and DMC 5%. It is observed that SFC first decreases abruptly up to 75% load and gradually at 100% load. The reason for the decreasing trend of SFC for blends at higher loads is due to the better reactivity of oxygen at higher average temperature of combustion chamber leading to more complete combustion [18]. It is seen that SFC is highest for blended diesel and lowest for pure diesel. This is because of high viscosity, density, low volatility and low heat content of blended diesel when compared with that of pure diesel [9,20]. However, increasing the additive percentage with the diesel, SFC decreases with respect to load and shows close results to that of diesel. This may be due to improved combustion, low viscosity, high volatility of the test fuels using additive [15,16].

D. *Exhaust Gas*

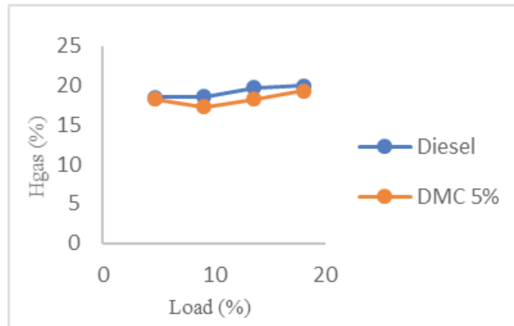

Figure 4: Variation of Exhaust Gas with load.

The Figure 4 shows the amount of Exhaust Gas(EG) for diesel and DMC 5%. It is observed that EG increases gradually as load increases. It can be seen that the EG of blended diesel is lower than the pure diesel. This may be due to calorific value of DMC, oxygen content and low cetane number. Having oxygen content and a low calorific value, causes lower combustion temperatures [1].

E. *Pressure Crank Angle Diagram*

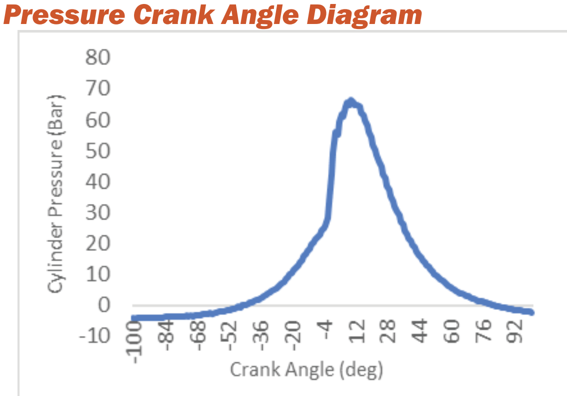

Figure 5: Variation of Cylinder Pressure with Crank Angle.

The Figure 5 shows the variation of Cylinder Pressure with respect to the crank angle of the blended diesel fuel. It is observed that there is a maximum pressure for the diesel fuel blended with DMC. This is due to rapid combustion of the accumulated fuel as the temperature of the combustion increases at higher loads. The reason is due to higher cetane number and lower heat of vaporization compared with the blend containing 5% DMC [18].

F. *Heat Release Rate*

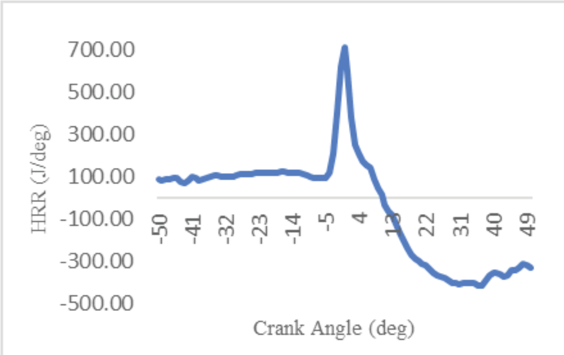

Figure 6: Heat Release Rate at full load.

The Figure 6 shows the Heat Release Rate(HRR) of the blended fuel. It is observed that the diesel containing 5% DMC has higher HRR than the diesel fuel. This is due to the better reactivity of oxygen at higher loads as the combustion chamber temperature is higher. The angle of occurrence of maximum heat release rate for the blends are -3˚CA to 2˚CA. This shows that the maximum heat release occurs away from Top Dead Center(TDC) [18].

CONCLUSION

The subsequent results and future scope research were able to be concluded from this literature work. An additive is playing a magnificent task in increasing the performance of the diesel engine, improving the combustion and reducing the emissions. The combustion characteristics and heat release of a diesel engine fuelled with DMC have been investigated and the main results can be summarized as follows:

- The BTE increases with increase in the percentage of additive added to the diesel fuel. This is due to the increase in heat content, reduction in viscosity, density and increase in volatility.
- The Mechanical Efficiency of the diesel engine blended with DMC is higher than that of engine with pure diesel fuel which is due to the complete combustion of the fuel.
- The BSFC decreases rapidly at 75% load condition and gradually at full load condition. This is because of better reactivity of oxygen at higher temperature of the combustion chamber.
- The amount of EG is lower in case of DMC blended diesel engine and comparatively higher in pure diesel fuel. The reason is that due to addition of DMC, the calorific value of the fuel decreases and it causes lower combustion temperatures.

Finally, it can be concluded that the DMC is one of the best suitable additives in order to increase the performance of the engine and helps in controlling the pollution and other environmental consequences.

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