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Effect of addition of Oxygenated fuels on combustion and emission performance of diesel engine

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Abstract

Oxygenates blended into diesel fuel can serve at least two purposes. Components based on renewable feedstock make it possible to introduce a renewable component into diesel fuel. Secondly, oxygenates blended into diesel fuel might help to reduce emissions. Particulate matter (PM) and oxides of nitrogen (NOx emissions) are the two important harmful emissions in diesel engine. Fuel modification, modification of combustion chamber design and exhaust after treatments are the important mean to reduce such emissions. Among different alternative fuels, oxygenated fuel is a kind of alternative fuel. Diethylene glycol dimethyl ether (DGM), dimethoxy methane (DMM), dimethyl ether (DME), methyl tertiary butyl ether (MTBE), dibutyl ether (DBE), dimethyl carbonate (DMC), methanol, ethanol and diethyl ether (DEE and DME-a Cetane Improver) have played their role to reduce diesel emissions. These fuels can either be used as a blend with conventional diesel fuel or as a neat fuel. The presence of oxygen in the fuel molecular structure plays an important role to reduce PM and other harmful emissions from diesel engine. It has been found that the exhaust emissions including PM, total unbrunt hydrocarbon (THC), carbon monoxide (CO), smoke and engine noise were reduced with oxygenated fuels. NOx emissions were reduced in some cases and were increased depending on the engine operating conditions. The reductions of the emissions were entirely depended on the oxygen content of the fuel. It has been reported that the combustion with oxygenated fuels were much faster than that of conventional diesel fuel. This was mainly due to the oxygen content in the fuel molecular structure and the low volatility of the oxygenated fuels. The presence of DEE and DME increases the volatility and decrease the boiling point in comparison to diesel fuel. The blended fuel retains the desirable properties of diesel fuel but includes the cleaner burning capability of DEE/DME.

***Keywords** – Diesel Fuel, DEE, Combustion Performance, Emission Performance, CI Engine*
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I. INTRODUCTION

For many years the use of alternative fuels has play important and special role in the area of internal combustion development. The family of alternative fuels is defined by many types and the alcohols represent a significant percent due to the following aspects as: - adequate properties for internal combustion engines use; good conditions of producing process from agriculture products, for the next decades the liquid fuels shall continue to have an important share in transportation activities so the storage and transportation can be realized in safe conditions using the existing infrastructure for fuel distribution. Particulate matter (PM) and oxides of nitrogen (NOx emissions) are the two important harmful emissions in diesel engine. Fuel companies and the researchers around the world are devoted to reduce such emissions with different ways. Fuel modification, modification of combustion chamber design and exhaust after treatments are the important mean to alleviate such emissions. Among different alternative fuels, oxygenated fuel is a kind of alternative fuel. Diethylene glycol dimethyl ether (DGM), dimethoxy methane (DMM), dimethyl ether (DME), methyl tertiary butyl ether (MTBE), dibutyl ether (DBE), dimethyl carbonate (DMC), methanol, ethanol and diethyl ether (DEE-a Cetane Improver) have played their role to reduce diesel emissions. These fuels can either be used as a blend with conventional diesel fuel or as a neat fuel. The presence of oxygen in the fuel molecular structure plays an important role to reduce PM and other harmful emissions from diesel engine. The present work reports on the effect of oxygenated fuel on diesel combustion and exhaust emissions. It has been found that the exhaust emissions including PM, unburnt hydrocarbon (HC), carbon monoxide (CO), smoke and engine noise were reduced with oxygenated fuels. NOx emissions were reduced in some cases and were increased depending on the engine operating conditions. The reductions of the emissions were entirely depended on the oxygen content of the fuel. It has been reported that the combustion with oxygenated fuels were much faster than that of conventional diesel fuel. This was

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mainly due to the oxygen content in the fuel molecular structure and the low volatility of the oxygenated fuels.

A. OXYGENATED FUELS

Oxygen compounds used as components of oxygenated fuels must demonstrate properties that are required for all components of motor fuels. Not all oxygenates are suitable for the use as an additives to diesel fuel, but the potential oxygenated compounds must meet the following requirements

- be able to mix with diesel fuel in the whole range of engine operating temperatures,
- low-temperature parameters of diesel fuel and oxygenated compounds mixtures must be suitable for the climate where they will be used,
- mixtures of diesel fuel and oxygenated compounds should not be susceptible to stratification as a result of contamination with water,
- Oxygenated compounds should have a sufficiently high cetane number,
- Oxygenated compounds should not have a too high volatility or too low flash point.

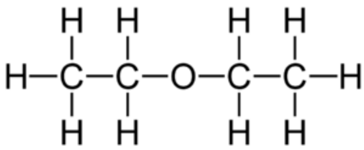
Additional important requirements for potential oxygenates of diesel fuels should include:

- high oxygen content in the molecule allowing for small concentrations of oxygenated compounds to achieve sufficient amount of oxygen in the final fuel mixture; lower concentrations also have a lesser impact on the physical properties of fuel,
- no negative impact on fuel system components: no corrosive effect on metals or swelling effects on plastics
- low own toxicity of the oxygenated compound,
- Competitive price and availability.

It should be noted that the fulfilment of these criteria will often depend on the amount of oxygenated compound added to the fuel composition.

After initial selection on the basis of three parameters, such as oxygen content, density, and flashpoint temperature, oxygenated compounds were addressed for further analysis, where they have been evaluated in terms of miscibility with diesel fuel and water tolerance.

Di Ethyl Ether (DEE): Di Ethyl Ether ,also known as ethoxy ethane, ethyl ether, sulphuric ether or simple ether is an organic compound in the ether class with the formula $(C_2H_5)_2O$. It is colourless, highly volatile flammable liquid. It is commonly used as a general anesthetic.



II. TEST FUEL AND ITS PROPERTIES

The experiments were carried out on a naturally aspirated, water-cooled, 4-cylinder, direct-injection diesel engine. The specifications of the engine are shown in Table 1. The major properties of the fuels are shown in Table 2. In Table 2 the lower heating values of biodiesel were determined with bomb calorimeter. The densities of the fuels were measured at 20 °C. Other properties of the fuels were obtained either from the literature or from fuel specifications.

Table 1. Engine specifications

Type:	Vertical, water cooled, Four stroke
Make:	KIRLOSKAR AV-1
Number of cylinder:	One
Bore:	87.5 mm
Stroke:	110 mm

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Displacement Volume: 661 CC
Compression ratio: 17.5:1
Maximum power: 3.7 kW
Speed: 1500 rpm
Dynamometer: Eddy current dynamometer
Injection opening angle: 23° b TDC

Table 2. Fuel properties

Properties	Diesel	Diethyl Ether
Density at (Kg $^{-3}$)	830	713
Kinematic Viscosity @ 40 □C (cSt)	2.0 to 4.5	0.23
Calorific value (kJ/kg)	42000	32000
Flash Point (□C)	80	138
Fire Point (□C)	86	136
Ash content (%)	0.01 to 0.1	0.01

III. EXPERIMENTAL SETUP

The experimental setup is shown in Fig.1. The engine was connected to an eddy current dynamometer, and a control system was used for adjusting its speed and torque. The engine was run at a constant speed of 1000 rpm. The NOx, CO and HC emission were measured with gas analyser. The gas analyzer is calibrated with standard gases and zero gas periodically. Experiments were conducted at the engine speed of 1000 rpm and at five engine loads. At each engine operating mode, experiments were carried out for the diesel (D100), diethyl ether (DEE) namely DEE5, DEE10, DEE20 respectively. In this study, the diesel engine was not modified during all the tests. Before each test, the engine was allowed to operate with the new fuel for five minutes to clean the fuel system which is used in the previous running. The data were recorded continuously for 5 min to reduce experimental uncertainties, and average values were presented.

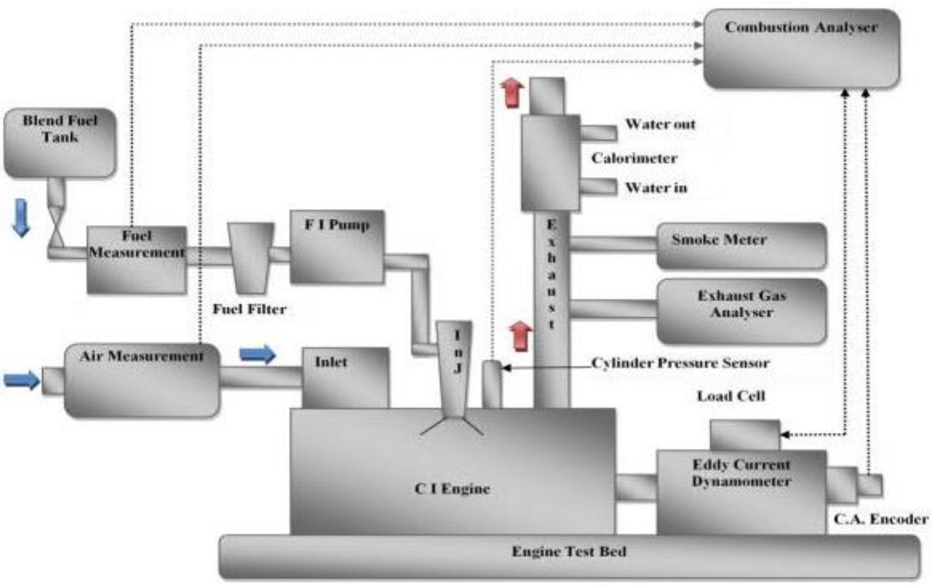

Figure 1.1 Schematic block diagram of experimental set up

IV. RESULT AND DISCUSSION

a) Brake Thermal Efficiency

Figure 2 shows the variation of the brake thermal efficiency with brake power for diesel, and DEE fuels. The brake thermal efficiency is increased for DEE20 as compared to Diesel full load. The thermal efficiency obtained for diesel and DEE20 are 30.45%, 28.72% respectively at full load,

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whereas for DEE20 it is 29.12% at full load. The increase in BTE may be due to better evaporation of DEE that mixes with air and forms a homogeneous mixture, and results in combustion, creating a hotter environment to assist the combustion of DEE20 fuel, which leads to higher thermal efficiency.

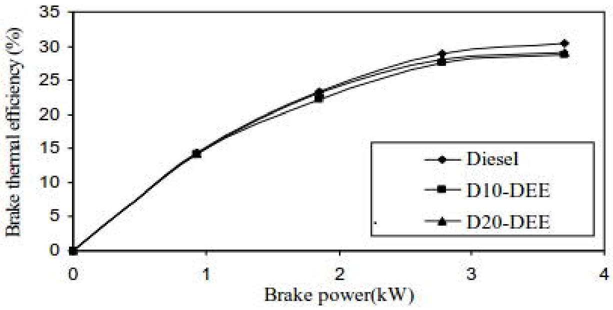

Figure 2 Variation of Brake thermal efficiency with BP

b) Brake Specific Fuel consumption

Figure 3 depicts the variation of the brake thermal efficiency with brake power for diesel and DEE fuels. The BSFC values obtained for diesel with DEE20 are 0.240 kg/kWh and 0.267 kg/kWh respectively, whereas for the DEE20 it is 0.256 kg/kWh at full load. The increase in BSFC for DEE20 may be due to high density and viscosity, which affects the mixture formation, leading to slow combustion.

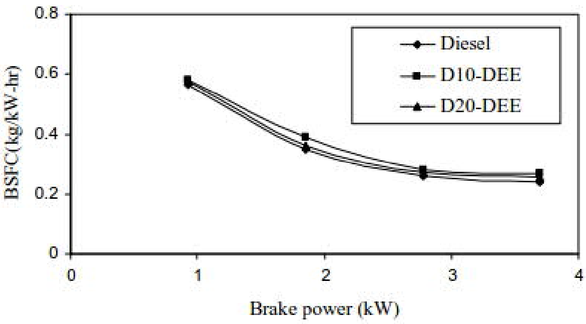

Figure 3 Variation of BSFC with BP

c) Carbon monoxide emission (CO)

Figure 4 depicts the variation of the carbon monoxide emission with brake power for diesel, and DEE fuels. The CO values obtained for diesel and DEE20 are 0.06%Vol and 0.045 %Vol respectively at full load, whereas for DEE20 it is 0.035 %Vol at full load. The decrease in CO with DEE may be due to better evaporation of DEE that mixes with air and forms a homogeneous mixture and results in better and complete combustion, creating a hotter environment to assist the combustion of DEE20 fuel, which leads to lower CO emissions.

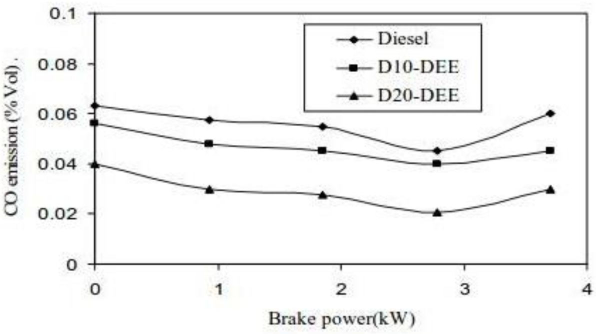

Figure 4 Variation of CO emissions with BP

d) Hydrocarbon emission (HC)

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Figure 5 shows the variation of the hydrocarbon emission with brake power for Diesel and DEE fuels. The hydrocarbon emission for diesel and DEE20 are 29 ppm and 42 ppm respectively for the base engine at full load. For the ceramic coated piston with DEE20, it is 24 ppm at full load. The reduction in HC emission is due to addition of DEE that makes the mixture homogeneous, which results in better combustion. The ignition improver (DEE) forms a number of ignition centers in the combustion chamber, which results in complete combustion.

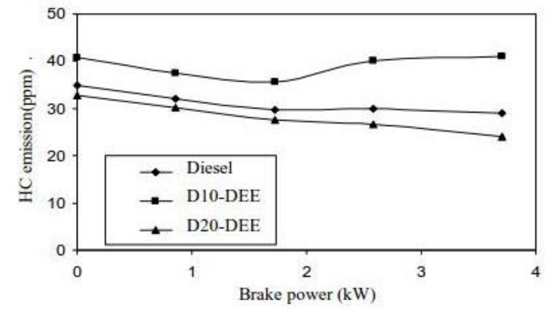

Figure 5 Variation of HC emissions with BP

e) Nitrogen oxide emission (NO)

Figure 6 illustrates the variation of the nitrogen oxide emission with brake power for diesel DEE fuels. The NO forms by oxidation of atmospheric nitrogen at sufficiently high temperatures. The NO values obtained for diesel and DEE20 are 486 and 536ppm, respectively at full load, whereas for DEE20, it is 512ppm at full load. The decrease in NO level for DEE20 may be due to the evaporation of DEE and it has lowered the charge temperature, resulting in decreased the NO level compared to DEE20 at full load.

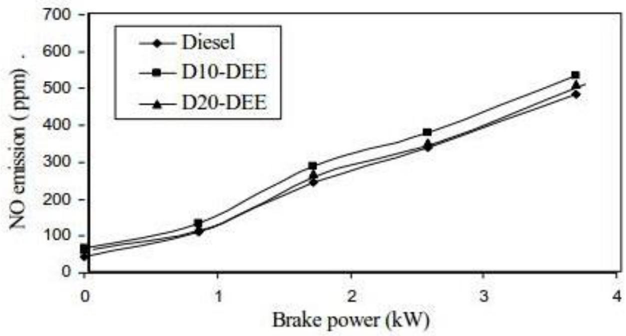

Figure 6 Variation of NO emissions with BP

V. CONCLUSION

The experiments were conducted with Diesel using Diethyl ether (DEE) has been studied extensively through performance, emissions and combustion parameters. The following are the important conclusions drawn from the present investigations with the effect of DEE additives with biodiesel on a direct injection diesel engine.

The brake thermal efficiency for 10% DEE additive increased by about 1.4 %.

The CO emissions decreased by 42% and the HC emissions decreased by about 26 % for 10% DEE additive at full load compared to that of the base engine with diesel at full load.

The NO emissions were almost equal for 10% DEE additive at full load conditions compared to that of diesel fuel at full load, while the smoke emissions decreased by about 17% for 10% DEE additive at the full load compared to that of diesel with the base engine.

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