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Investigation on the Effect of Diethyl Ether Additive on the Performance of Variable Compression Ratio Diesel Engine

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Abstract— T**he performance of the diesel engine is increased with the addition of oxygenates to the fuel prior to the combustion. This paper presents the effect of blending of Diethyl ether (DEE) with diesel at various proportions (5%,7.5% and 10%)on the performance of diesel engine. The experimental results indicated that with the increase in the concentration of DEE to diesel increases the brake thermal efficiency, mechanical efficiency and decreases the specific fuel consumption. The performance of diesel engine at different compression ratios (18, 16 and 14) for diesel with 5% DEE blend was also evaluated in this work. The data obtained from experimentation is presented analyzed in this paper.**

Keywords—**Variable Compression, Diethyl ether, blends, Diesel.**

I. Introduction

Diesel engines though enjoying higher fuel economy than gasoline engines suffer from inherent higher Particulate Matter (PM) and Nitride Oxide (NOx) emissions. Currently there are many techniques that are capable of improving the combustion processes of diesel engines, such as the fuel injection retarding, exhaust gas recirculation (EGR), high pressure injection, and air intake super charging. The reduction of diesel engine emissions could be considered from three aspects: the combustion improvement technique, the exhaust after treatment technology**,** and the fuel melioration. However, the relevant research on fuels especially on liquid fuels was still less investigated until very recently. Many researchers indicated that the performance of diesel engine can be improved by adding additives. The research on diethyl ether (DEE) as an alternative fuel produced great enlightenment. DEE contains oxygen element and has no C–C bonds, which therefore helps to achieve smokeless combustion that is superior than with a diesel fuel even without high-pressure injection or turbocharger.DEEcan be produced by de hydration of bio ethanol,a renewable fuel.DEE has long been recommended as a cold starting additive in diesel engines and gasoline engines due to it's low auto ignition temperature and high volatility(Gupta, 1988). The properties of DEE permit it to be used as a compression ignition engines either as a neat fuel or as a blend with diesel. The auto ignition temperature of DEE is lower than diesel. DEE has high cetane number of greater than 125. Its heating value is comparable to that of diesel. The latent heat of vaporization is higher than diesel.DEE is liquid at room temperature which reduces handling and storage problems.DEE is also non-corrosive compared to alcohols. The properties which need concern are high flammability and poor storage stability.DEE also poses human health problems due to its anesthetic effect. Ohta and Takahashi (1,2) reported the stages of flame propagation for DEE. DEE has low heat release rates during early cool flame generation, but has typical heat release rates for mid stage blue flame oxidation. The blue flame is followed by a conventional red flame with constant heat release during full combustion. P.Q.E Clothier et al.,(3) reported that DEE ignition is inhibited by diesel fuel and that adding DEE to diesel fuel will actually decrease the cetane number of the diesel fuel. Experiments suggested that DEE may interact with aromatics in diesel fuel, delaying the onset of ignition. A mixture of 4% toluene in DEE resulted in an ignition delay of 4 to 5 milliseconds before the ether ignited. Used as a cold starting aid, DEE apparently acts as a neat fuel and not in combustion with the diesel fuel.The objective of the present work is to investigate the effect of DEE additive on the performance of Diesel engine. In the present work different blends of diesel with DEE additive are prepared and their comparative performances are evaluated with pure diesel. Based on the result the effect of compression ratio on the performance of best blended diesel is also studied in this work.

II. Material and Methodology

Experimental setup:

In this work experiments are conducted on computerized Variable Compression Ratio (VCR) engine test rig as shown in Fig.1. The setup consists of single cylinder four stroke VCR (Variable Compression Ratio) Diesel engine connected to eddy current type dynamometer for loading. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The experimental set up consist two pressure sensors, one placed inside the combustion chamber to measure the combustion pressure and the other placed in the injection nozzle to find the injection pressure. The digital encoder is placed to place the crank angle movement. The gas calorimeter is fixed to the exhaust gases to measure the heat loss through the exact gases. The test rig also equipped with airflow, fuel flow, temperatures and load measurement sensors. All the sensors are interface with computer through LABVIEW software and data acquisition card. The specification of the test rig is shown in Table.1.

Figure.1. Engine test rig

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In this work different blends of diesel with DEE additive are prepared. The fuel properties for diesel and different proportions of DEE with diesel are shown in the Table 2. The diesel is thoroughly mixed with DEE and Due to lower density difference, blending is not difficult and also no separation observed. The properties determined by performing basic tests for different blends. The additive is having higher cetane value and lower density, lower auto ignition temperature and boiling point indicates that it starts ignition and initiates ignition of the main fuel. All this combinations of diesel and DEE was prepared in the laboratory itself by mixing appropriate volume of diesel with DEE. First the experiments were conducted in single cylinder, Variable Compression Ratio diesel engine (Kirloskar make) at compression ratio 18 with pure diesel as well as different blends of diesel and di ethyl ether additive (5% ,7.5% and 10% DEE).A set of readings were obtained first by running the engine with diesel at CR of 18 and varying the load from idle to full load in the steps of 3kg to 12 kg. The engine performance characteristics were recorded by using the software Engine Soft (LABVIEW base) and instrumentation provided by the National Instruments. After completion of the experiments with pure diesels then, the engine was run on different diesel and DEE combinations and the parameters were recorded as above. Similar sets of readings were recorded for the Diesel-5% DEE fuel for the compression ratio of 16 and 14. For the changing the compression ration first the engine was started at compression ratio of 18 and then the compression ratio was changed by using the tilting head arrangement as shown in Fig. 2.

Table 1 Specification of Test rig

Specifications of the Engine
Number of Strokes -4
Fuel type – Diesel
Rated Power – 3.5KW
Speed – 1500 rpm
Cylinder Diameter – 87.5mm
Stroke – 110mm
Connecting rod length – 234mm
Compression ratio – 12 to 18:1

Table 2.Properties of different blends of diesel with DEE

Properties	Diesel	DEE	5% DEE	7.5% DEE	10% DEE
Viscosity (cst)	2.7	0.23	1.80	1.415	1.01
Density (Kg/m^3)	830	713	812	788.6	774.4
Cetane number	49	125	55.2	54	53
Flash point (°C)	46	40	38	36	35
Fire point (°C)	52	44	42	40	37
Calorific value (KJ/Kg)	42,800	33,900	43,100	43,047	42,994

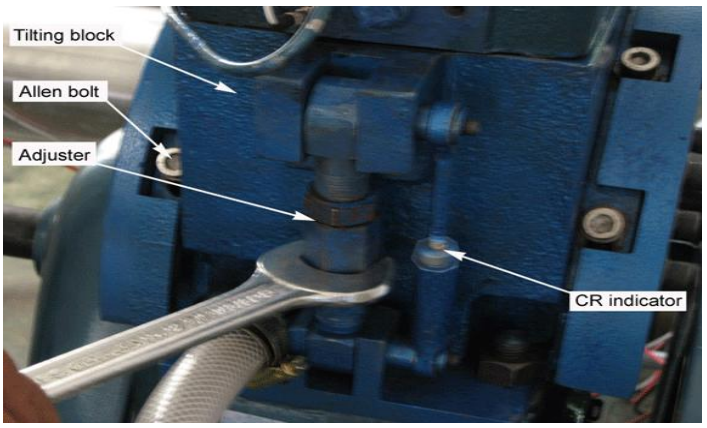

Figure. 2. Compression ratio adjustment

III. Results and Tables

In this work the comparative performance of different blends of Diesel and Diethyl ether were analyzed by varying the loads in terms of brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, fuel flow and specific fuel consumptions.
The effect of compression ratios on the performance of 5% DEE blend was evaluatedinterms of brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, fuel flow and specific fuel consumptions.

Effect of DEE additive:

Brake thermal efficiency:

The variation in Brake thermal efficiency at different load for different blends is shown in Fig.3. With the increase in the load, the Brake thermal efficiency (BTE) increases at higher loads for all the blends. The addition of DEE increased the BTE. The presence of oxygen in the DEE helps in the complete combustion of the fuel raising the BTE. The BTE is almost same at the lower loads for all combinations of diesel and DEE and then increases slightly with increase in concentration of DEE to diesel. At higher concentration of DEE, the increase in BTE may be due to the ability of DEE to reduce the surface tension or interfacial tension between two or more interacting immiscible liquids helped the better atomization of fuel, which improves the combustion of diesel.

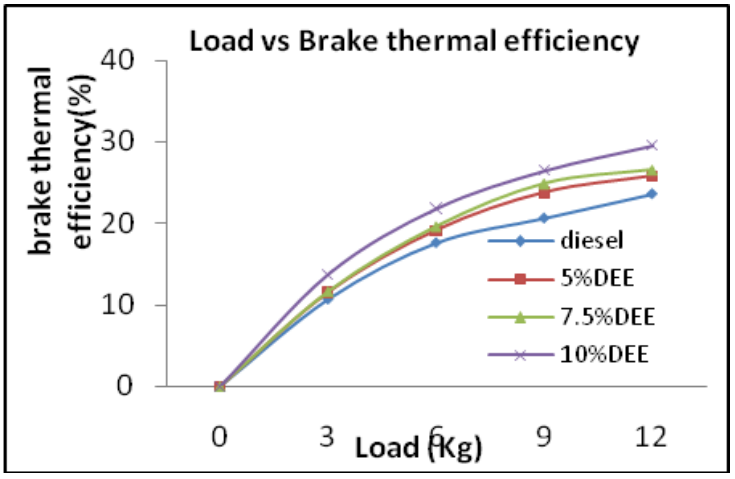

Figure.3. Variation in Brake thermal efficiency with load for different blends

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Indicated thermal efficiency:

The variation in Indicated thermal efficiency for different blends of fuel at different loads is shown in Fig.4. The Indicated thermal efficiency (ITE) increases with the increase in the load and decreases slightly at full loads. The ITE increases with the increase in the concentration of DEE to diesel. And it is higher for diesel and 10%DEE combination and minimum for diesel.

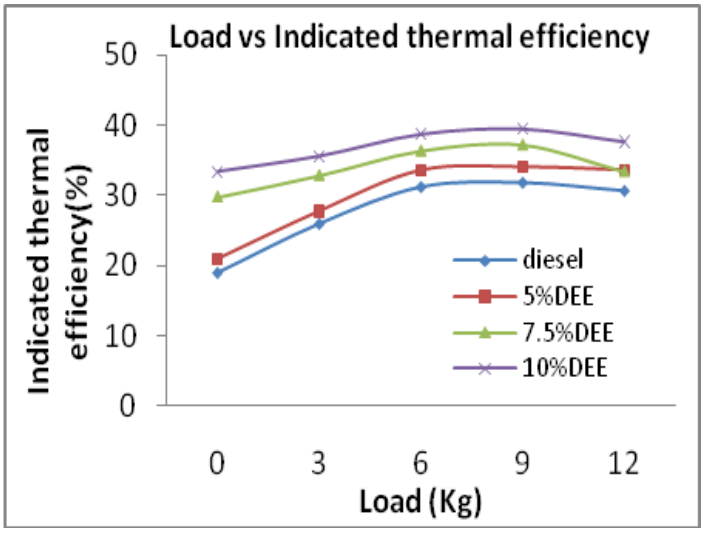

Figure.4 Variation in Indicated thermal efficiency with load for different blends

Mechanical efficiency:

The variation in mechanical efficiency at different loads for different blends is shown in Fig.5. It is observed that mechanical efficiency increases with the increase in the load due to increase in the BP and IP.with the increase in the concentration of DEE, the mechanical efficiency also increases.

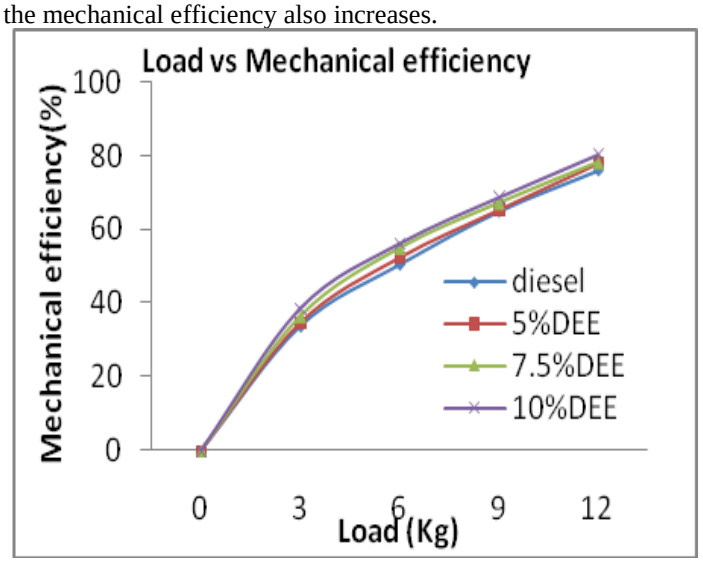

Figure.5 Variation in mechanical efficiency with load for different blends

Fuel flow:

The variation in fuel flow at different loads for different blends is shown in Fig.6. With the increase in the load, the amount of fuel consumed per unit time is increasing for all blends. With the addition of DEE to the diesel, the total fuel flow decreases.

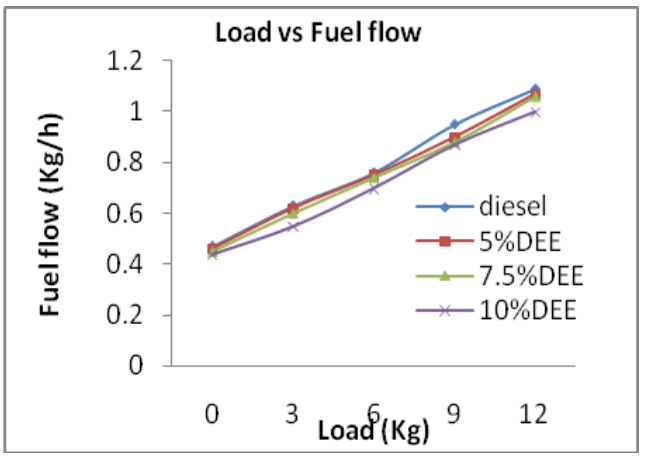

Figure.6 Variation in fuel flow with load for different blends

Specific Fuel Consumption:

The variation in Specific Fuel Consumption (SFC) at different load for different blends is shown in Fig.7. The SFC is higher for lower loads and it decreases rapidly with increases in loads. At higher loads the SFC is decreasing linearly with load. The SFC is lower fordiesel with 10% DEE blend. This is due to better combustion of diesel fuel, which results in higher heat release. The SFC decreases with increase in concentration of DEE.

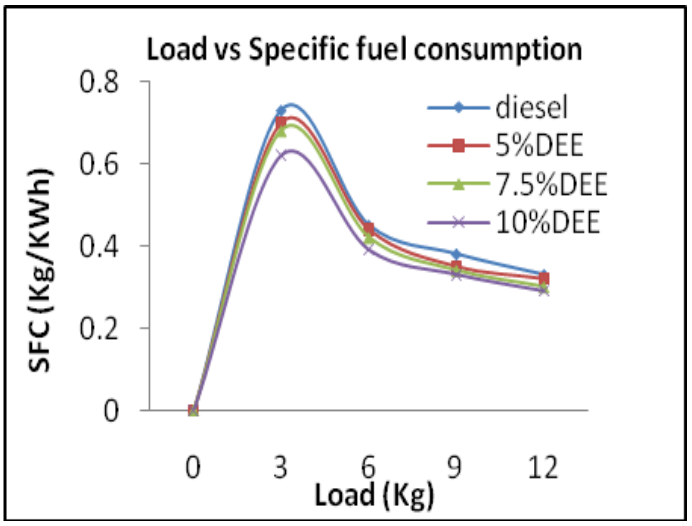

Figure.7 Variation in Specific fuel consumption with load for different blends

EFFECT OF COMPRESSION RATIO FOR 5% DEE FUEL

The effect of compression ratio for diesel with 5% DEE is investigated. The variation in brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, fuel flow and specific fuel consumptions at different compression ratios at different loads are shown in Fig. 8 to Fig.12. From the figures it is observed that compression ratio 18 gives the best performance results when compared to remaining compression ratios. All these efficiencies increase with increase in compression ratios.

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Brake thermal efficiency:

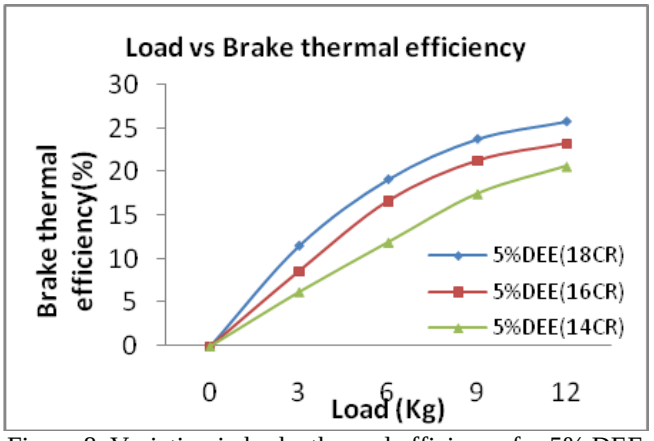

Figure.8. Variation in brake thermal efficiency for 5% DEE blend at different compression ratios

Indicated thermal efficiency:

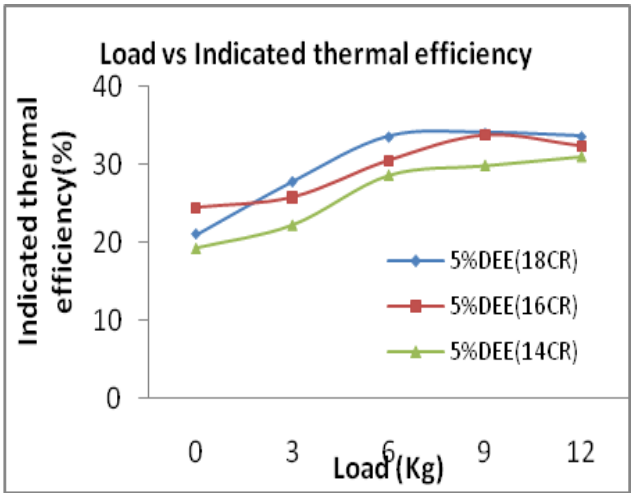

Figure.9. Variation in indicated thermal efficiency for 5% DEE blend at different compression ratios

Mechanical efficiency:

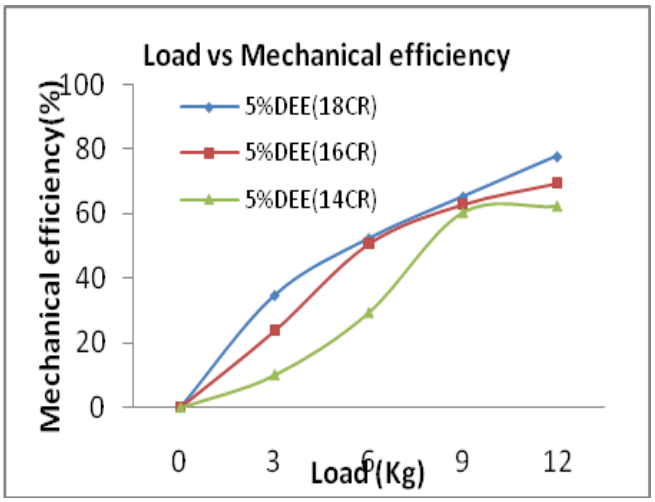

Figure.10. Variation in mechanical efficiency for 5% DEE blend at different compression ratios

Fuel flow :

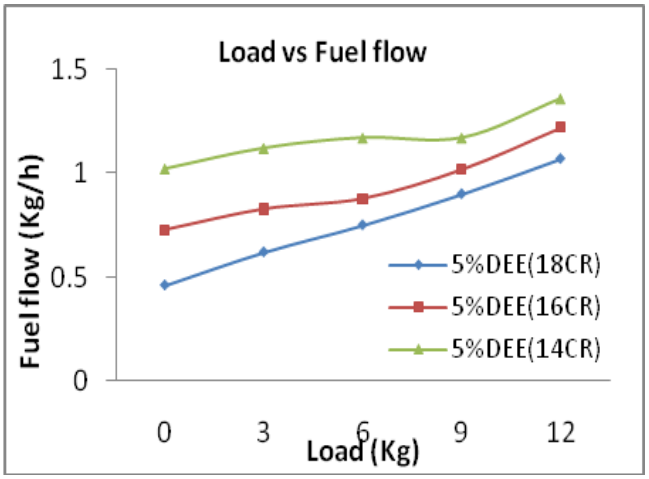

Figure.11. Variation in fuel flow 5% DEE blend at different compression ratios

Specific fuel consumption:

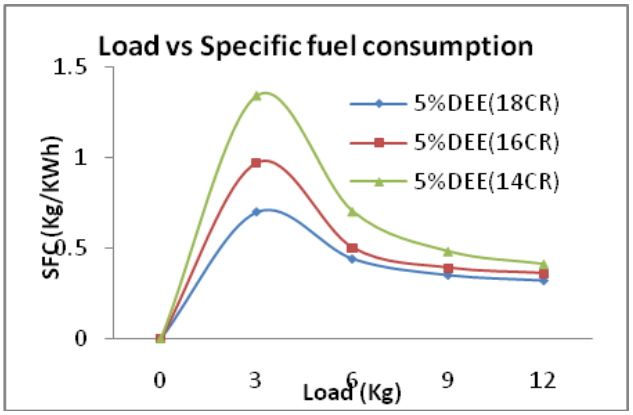

Figure.12. Variation in specific fuel consumption for 5% DEE blend at different compression ratios

IV. Conclusion

Based on the experimental investigation the following conclusions are drawn;

- With increase in the concentration of DEE to diesel increases the brake thermal efficiency, indicated thermal efficiency.
- Mechanical efficiency is higher for blen of diesel with 10%DEE fuel and decreases with decrease in the concentration.
- SFC is less for blend of diesel with 10%DEE combination fuel which is the desired for efficient running of the engine.
- Increase in the concentration of DEEto the diesel decreases the viscosity of the fuel.
- Compression ratio 18 gives the best performance results than compression ratios 16 and 14 for blend of diesel with 5%DEE fuel.
- As the cost of the DEE is less, so it can be used as a diesel fuel additive in engines.
- High knocking sounds were observed in the engine when the concentration of DEE increases more than 15% to diesel

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