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Effect of Oxygenated Fuel Diethyl Malonate Additive on Diesel Engine Performance and Emission

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ABSTRACT

This improvement of fuel properties essential for suppression of pollutant and optimization of engine performance. One way is use of additives. Oxygenated additives were conventionally recommended for gasoline. But now day's oxygenated additives are widely considered for diesel fuel also. The present work is set to explore the performance characteristics, emissions of Diethyl Malonate-diesel blends run diesel engine. Parameters considered to optimize the diesel engine are brake thermal efficiency (BTE), Brake specific fuel consumption (BSFC), smoke opacity (OP), NOx, CO, HC and CO_2. Experiments are carried out in water cooled, single cylinder DI Diesel Engine at constant speed of 2300 rpm under varying load with maximum capacity of 3.5 kW. The study involves four different DEM-diesel blends of B05, B10, B15 and B20 (BX% where X is volumetric percentage of DEM-diesel blend). A CR of 16.5, BX of 20%, was found to be optimal values for the DEM-diesel blends with diesel fuel operation in the test engine of 3.25 kW at 2300 rpm. The results of this study revealed that at optimal input parameters, the values of the BTE, BSFC, EGT and OP were found to be 36.24%, 0.234 kg/kW h, 458^{0}C and 71 HSU respectively.

Keywords— Tachometer, Thermocouple, Single cylinder 4 stroke engine, Additives (diethyl malonate).

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I. INTRODUCTION

Due to low cost of Diesel fuel , diesel engine are more common and economical than gasoline engines but suffer from inherent higher Particulate Matter(PM) and nitride oxide (NOx) emissions. Reduction of exhaust emissions is extremely important for diesel engine development in view of increasing concern regarding environmental protection and stringent exhaust gas regulations. Diesel engines are the major contributors of air polluting exhaust gases such as particulate matter, carbon monoxide, oxides of nitrogen and other harmful compounds. Increasingly stringent regulations governing particulate emissions, nitric oxides from diesel engines have prompted research directed toward methods for reducing the in-cylinder formation of pollutants by modifying fuels or controlling particles by after treatment technologies. The diesel fuel properties have become even more stringent controlling diesel exhaust emissions through fuel modification seems to be promising because it would affect both the new and old engines. Modification of diesel fuel to reduce exhaust emission can be performed by increasing the Cetane number, reducing fuel Sulphur, reducing aromatic content, increasing fuel volatility and decreasing the fuel density to have the compromise between engine performance and engine out emissions, one such change has been the possibility of using diesel fuels with oxygenates. These blends usually enhance the combustion efficiency, burn rates, power output, and the ability to burn more fuel, but first of all, these blends offer the reduction of exhaust emissions. 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. The research on Diethyl Malonate (DEM) as an alternative fuel produced great enlightenment. DEM contains oxygen element, which therefore helps to achieve smokeless combustion that is superior than with a diesel fuel even without high-pressure injection or turbocharger, however, the use of DEM requires significant modifications on the fuel supply, delivery, and injection systems, which largely limits its application. The blending of oxygenates into a diesel fuel could effectively reduce the smoke emission from diesel engines, which has a strong synergy to the use of methanol, ethanol, or dimethyl carbonate (DMC). The results indicated that the smoke emission decreased when the oxygen content was higher than 20%.

Amba Prasad Rao et al. investigated the effect of supercharging on the performance of a direct injection diesel engine with the use of untreated cottonseed oil under varying injection pressures [1]. It was observed that a reduction in BSFC of about 15% when cottonseed oil is used as fuel. It was reported that the performance deteriorated with increased injection pressure under naturally aspirated and supercharged conditions due to fuel impregnation on the cylinder wall and hence the effective amount of fuel undergoing complete combustion was reduced. Small droplets would also undergo thermal cracking at the temperature attained in the engine operation. They concluded that by raising the injection pressure no improvement in performance could be obtained with cottonseed oil under naturally aspirated condition. With an increase in supercharging pressure, the performance of the engine was improved. The investigation revealed that cotton seed oil, in general vegetable oils, can be best utilized if super charging is employed at the recommended injection pressure of the engine. Purushothaman and Nagarajan investigated the effect of the injection pressure on the combustion process of a DI diesel engine fueled with Orange Skin Powder Diesel Solution (OSPDS) [2]. The injection pressure was varied (21.5, 23.5 and 25.5 MPa) with 30% OSPDS, and the combustion and performance characteristics were compared with those of diesel fuel. The results showed that the cylinder pressure with 30% OSPDS at 23.5 MPa fuel injection pressure is higher than that of diesel fuel as well as at other injection pressures. Similarly, the ignition delay was longer with shorter combustion duration at 30% OSPDS, 23.5 MPa injection pressure. The brake thermal efficiency was better at 23.5 MPa than those of other fuel injection pressures with OSPDS and lower than that of diesel fuel. The combustion and performance characteristics of the engine at 23.5 MPa injection pressure were better than other injection pressures. Gumus and Kasifoglu studied the performance and emissions of a compression ignition diesel engine without any modification, using neat apricot seed kernel oil methyl ester and its blends with diesel fuel and found that lower concentration of apricot seed kernel oil methyl ester in blends give a better improvement in the engine performance and exhaust emissions [3]. Huzayyin et al. conducted experiment using jojoba oil as an alternate Diesel engine fuel. Measurements of jojoba oil chemical and physical properties have indicated a good potential of using jojoba oil as an alternative Diesel engine fuel [4]. Blending of jojoba oil with gas oil has been shown to be an effective method to reduce engine problems associated with the high viscosity of jojoba oil. Experimental measurements of different performance parameters of a single cylinder, naturally aspirated, direct injection, Diesel engine have been performed using gas oil and blends of gas oil with jojoba oil. Measurements of engine performance parameters at different load conditions over the engine speed range have generally indicated a negligible loss of engine power, a slight increase in BSFC, a reduction in NO_X and soot emission using blends of jojoba oil with gas oil as compared to gas oil. The reduction in engine soot emission has been observed to increase with the increase of jojoba oil percentage in the fuel blend. Further enhancement in the engine performance parameters are expected using minor modifications in the engine operating conditions, such as injection timing and pressure that can be optimized as a function of the jojoba–gas oil blend ratio.

II.PROBLEM STATEMENT

As seen in the literature oxygenated diesel blend have influence on performance (such as BTE and BSFC) and emission (such as NOx, CO, CO_2, and HC) characteristics of diesel engine. Most of the studies are conducted considering oxygenated diesel blend with various % of blend. However, the optimization of diesel engine performance and emission at different RPM is not studied.

III.OBJECTIVE

The objectives of this work is to establish DEM blends as alternative fuel to diesel. To accomplish this objective, experimental analysis of DEM-diesel blended fuel on diesel engine is done. These objectives are achieved completing following steps.

a) To procure DEM and to prepare DEM-diesel blends in various volumetric proportion viz. B5 (05% DEM, 95% diesel), B10 (10% DEM, 90% diesel), B15 (15% DEM, 85% diesel), B20 (20% DEM, 80% diesel) etc.
b) To upgrade the test engine rig to carry out experimental analysis.
c) To study the effect of BSFC, BTE on the emission and performance of the CI engine using DEM-diesel blends experimentally using research engine test rig.

IV.EXPERIMENTAL TEST SETUP AND PROCEDURE

Keeping the specific features of diesel engines in mind, a typical engine system widely used in India has been selected for the present experimental investigation. This is a single cylinder, direct injection, water cooled, portable diesel engine of 3.5 kW rating with a rope brake dynamometer. The engine is provided with suitable arrangements, which permitted a wide variation of controlling parameters. The experimental setup consists of a single cylinder diesel engine, fuel measuring equipment, exhaust gas analyzer and thermocouples with a temperature indicator. The schematic diagram of test setup is shown in Fig. 4.1.

Engine type	Vertical, 4stroke, Single cylinder, DI
Cooling	Water cooled
Rated power	3.5 kW at 2300rpm Horse power 5
Compression Ratio	16.5:1
Bore/Stroke	80/110 (mm)

Table 4.1.Engine Specifications

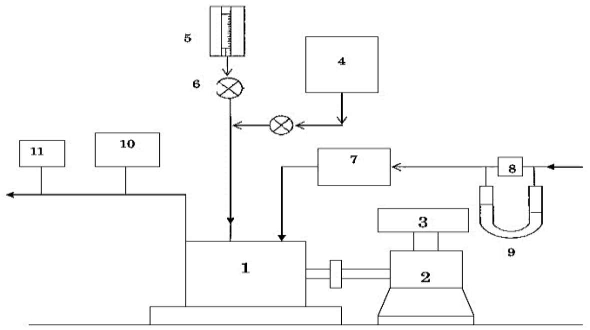


Figure 4.1 Schematic diagram of experimental setup

(1) Engine (2) rope brake dynamometer (3) spring load (4) fuel tank (5) burette (6) two way control valve (7) air box (8) orifice plate (9) U-tube manometer (10) smoke meter and (11) exhaust gas thermocouple.

V.PREPARATION OF TEST FUEL

Oxygenated fuel used in this study is DEM. The legend BX represents a blend including X% Oxygenated fuel, i.e. B5 indicates a blend including 5% DME in diesel. The fuels prepared for the testing purpose were B5 (5% Oxygenated fuel + 95% mineral diesel), B10 (10% Oxygenated fuel + 90% mineral diesel), B15 (15% Oxygenated fuel + 85% mineral diesel), B20 (20% Oxygenated fuel + 80% mineral diesel) and B0% (100% mineral diesel).

All the tests with different fuels were conducted for a constant engine speed of 2300 rpm and with varying loads on engine. The load was varied from 2.5 – 12.5 kg. The engine was first tested with diesel fuel for 2.5 kg load for 10 min at a rated speed of 2300 rpm until cooling water exit temperature is constant. The same conditions were maintained throughout the experiment for different fuels. After the baseline test with diesel, no load test was conducted for batches of DEM prepared with different blends. The specific fuel consumption was calculated by measuring the time taken for a fixed volume of fuel to flow into the engine. The torque was measured using a rope brake dynamometer. The engine speed (rpm) was measured by an electronic digital counter. The reading was taken for five run times for each run and the average value was used to calculate performance parameters. The performance parameters, brake thermal efficiency and brake specific fuel consumption was calculated from measured data. The exhaust gas temperature was measured by using a thermocouple installed in setup. The Smoke was measured by using smoke meter and smoke is measured in Hartridge Smoke Unit (HSU).

VI .EXPERIMENTAL ANALYSIS

A. TEST PROCEDURE

Initially the experiments were conducted on the engine with diesel to find optimum cooling rate and further all the experiments are conducted on the engine by maintaining this optimum rate of engine cooling.

The performance test is conducted using Diesel as fuel. The following step by step procedure is adopted for the test:

1. Give the necessary electrical connections to the panel.
2. Check the lubricating oil level in the engine.
3. Check the fuel level in the tank.
4. Allow the water to flow to the engine and the calorimeter and adjust the flow rate.
5. Release the load if any on the dynamometer.
6. Open the fuel flow cock so that fuel flows to the engine.
7. Start the engine by cranking.
8. Allow the engine to run under idling condition (no load) for 10 minutes to ensure warm and steady operating conditions.
9. Record all the thermal performance parameters for no load condition through a data acquisition system.
10. Repeat the experiment for different loads of 2.5kg, 5 kg, 7.5 kg, 10 kg, 12.5 kg and note down the readings.
12. After the completion release the load and then switch of the engine.
13. Allow the water to flow for few minutes and then turn it off.

The performance tests on the engine was conducted one by one with diesel and DEM blends (B5, B10, B15, and B20) and compared. The experiments replicated for 5 times and mean values of the readings are recorded. Each and every time, when the DEM or blend proportion is changed the engine was run with diesel fuel for few minutes to wash the fuel lines. The performance of the engine is evaluated in terms of Brake thermal potency, Brake specific fuel consumption, Exhaust gas temperature, Smoke density and the emissions of HC, CO, CO_2 and NOx.

B. EXPERIMENTAL CALCULATIONS AND RESULTS

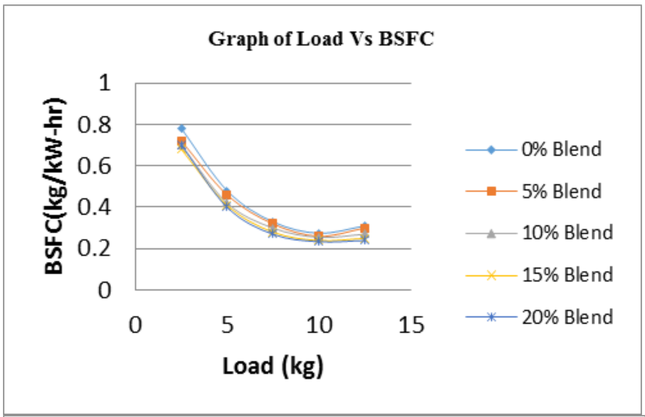
For 10 kg load and all blends

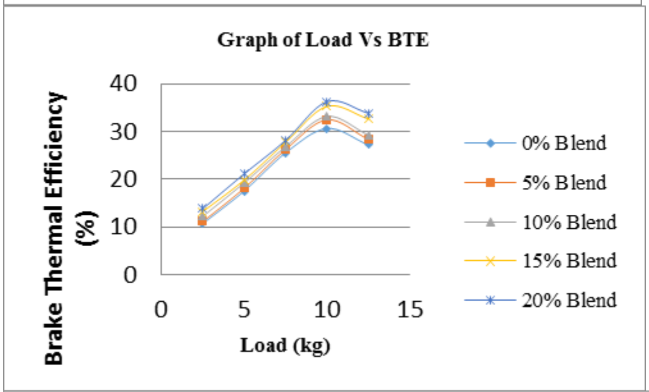
Sr. no	% Blend of DEM	Time (s) for 10 ml fuel	$\dot{m}\ (kg/hr)$	η_{BTH} %	BSFC (kg/kWhr)
1	0	41.6	0.7095	30.6	0.275
2	5	44.32	0.6708	32.43	0.26
3	10	45.52	0.6579	33.12	0.255
4	15	48.95	0.6192	35.25	0.24
5	20	50.56	0.6037	36.24	0.234

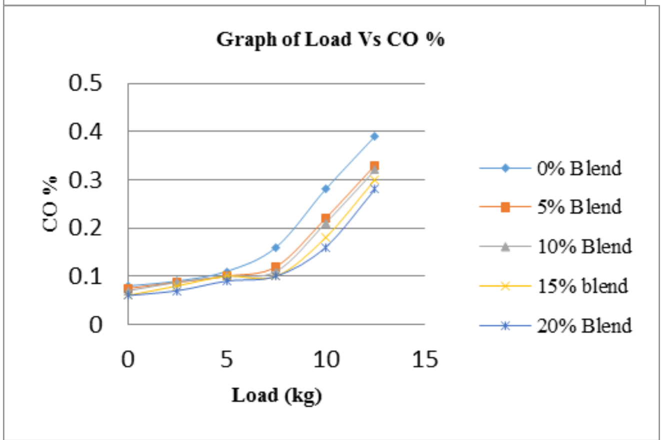
Table 6.1 Optimal solution at 10 kg load

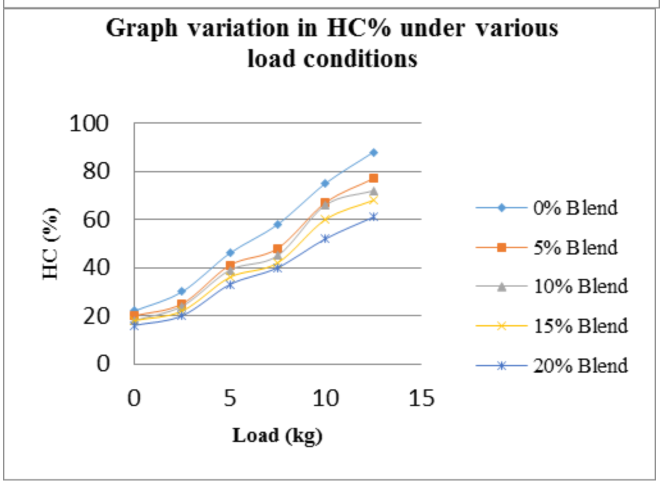
Type of emission	Diesel	B20	% Reduction
NO_x	1800 ppm	1540 ppm	15
HC	88%	61%	30
CO	0.39%	0.28%	28
CO_2	9.2%	6.1%	34
Smoke	75 HSU	71 HSU	5

Table 6.2 Analysis of diesel and B20









VII. CONCLUSION

In this research an investigation was carried out to study the effects on exhaust emissions by DEM diesel blends in a single cylinder direct injection diesel engine. The oxygen contents of DEM effect the diesel emission and hence different DEM blends is compared The results obtained for constant engine speed with various engine loads can be summarized as follows:

a) The effect of oxygenated additives on performance of engine shows significant differences in the performance characteristics.
b) DEM blends substantially lowers the exhaust gas opacity. The maximum reduction nearly of 15% was observed by B20 blends as compared to base reference diesel fuel.
c) 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).
d) 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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