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Investigation on parameters of methanol fuel and its blend on a diesel dual fuel engine

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Abstract: An experimental investigation has been performed on a 4 cylinder (turbocharged and intercooled) 62.5 kW gen-set dual fuel diesel engine. Break specific fuel consumption (bsfc), break thermal efficiency (bte) along with HC, CO, CO_2 and NO_x at various mixture ratios of methanol substitutions and loads have been investigated. The minimum and maximum BSFC were found to be 0.18 and 1.01 at 40 and 10% of full engine load and 40 and 60% of methanol substitution compared to pure diesel operation where the minimum and maximum BSFC were found to be 0.26 and 0.434 at 20 and 10% of full load condition. The minimum and maximum BTE were found to be 7.19 and 40.8 at 60 and 40% methanol substitution and at 10 and 40% load conditions whilst for pure diesel operation it was found to be 19.7 and 40.4 at 10 and 40% load conditions respectively. A two factor, three-level full factorial design was employed and the experimental results are in accordance with the results obtained.

Keywords: methanol blend, oxygen concentration, break specific fuel consumption, break thermal efficiency

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1 Introduction: Ever increasing petroleum demands as well as increasing air pollution from the combustion of the petroleum products has generated curiosity among many researchers to develop alternative methods to reduce the pollutants or search for an alternate eco-friendly fuel. Methanol-diesel blends can help reduce the smoke and PM emissions of diesel engine. The higher this reduction is, the higher the percentage of methanol is in the blends. The oxygen content in blends can promote the combustion of fuel **[1–4]**. Slightly reduced NOx emissions can be obtained with the use of the methanol-diesel fuel blends with respect to those of the diesel. The hydrocarbons (HCs) emissions increased with the use of methanol-diesel blends. The higher the percentage of methanol in the blend could increase the HC emissions; however, the HC emissions of blends can still meet the emission standards due to low HC emissions of diesel engine. The CO emissions decreased at low load and increased at high load of methanol-diesel blends were. Additionally, the CO_2 emissions were decreased due to the low C/H ratio of ethanol-diesel blends **[5, 2]**.The required levels are very difficult to achieve solely through engine design alone. With the shortage of conventional energy together with the increasingly stringent emission standards, it is very important to develop new and innovative internal combustion engines with minimum emissions, high fuel efficiency and high specific power **[6]**. Alcohols have been widely used in compression ignition engines as alternative fuels. Although alcohols are cheaper than standard diesel fuel, but there exist challenges with respect to utilization of alcohols in diesel engines and blending these fuels with diesel. Over the past years the worldwide interest in application of alternative fuels, especially those produced from biomass, may very well be experimented. Such type of a fuel is methyl alcohol (methanol), which can be manufactured from corn, sugarcane and biomass. Methanol is a renewable and oxygenated bio-fuel and furthermore could be a potential alternative fuel for vehicles, which can be blended with diesel in the tank or injected into the cylinder directly and burned with diesel in order to reduce the exhausted pollutants [6]. Diesel engines are an important part of the public and private transportation sector and their use will continue and grow into the future. But their smoke has become biggest threat to health and environment.

2. Experimentation:

The present investigation required a test diesel engine setup which has been personalized according to the essential conditions for experimentation. The lay-out of the test setup used throughout the experimentation is schematically presented in Fig. 1. A model of Ashok Leyland ALU WO 4CT, four stroke, compression ignition engine, turbocharged with intercooler, coupled with gen-set was used for the present experimental investigation [7]. Table 1 showcases the engine geometry and working parameters for the present work. The diesel engine was personalized to work on dual fuel mode to cater methanol along with diesel. The engine was coupled to a D.C. generator of 62 .5 kW [14]. Five water pumps and 12 (3 kW) industrial water heaters in a set of four each, were used to vary the load on the engine. The engine was run at constant speed of 1500 rpm. The quantity of diesel fuel was automatically controlled with the help of governor whilst the flow of fuel mixture was automatically controlled using control values embedded with the fuel inlet.

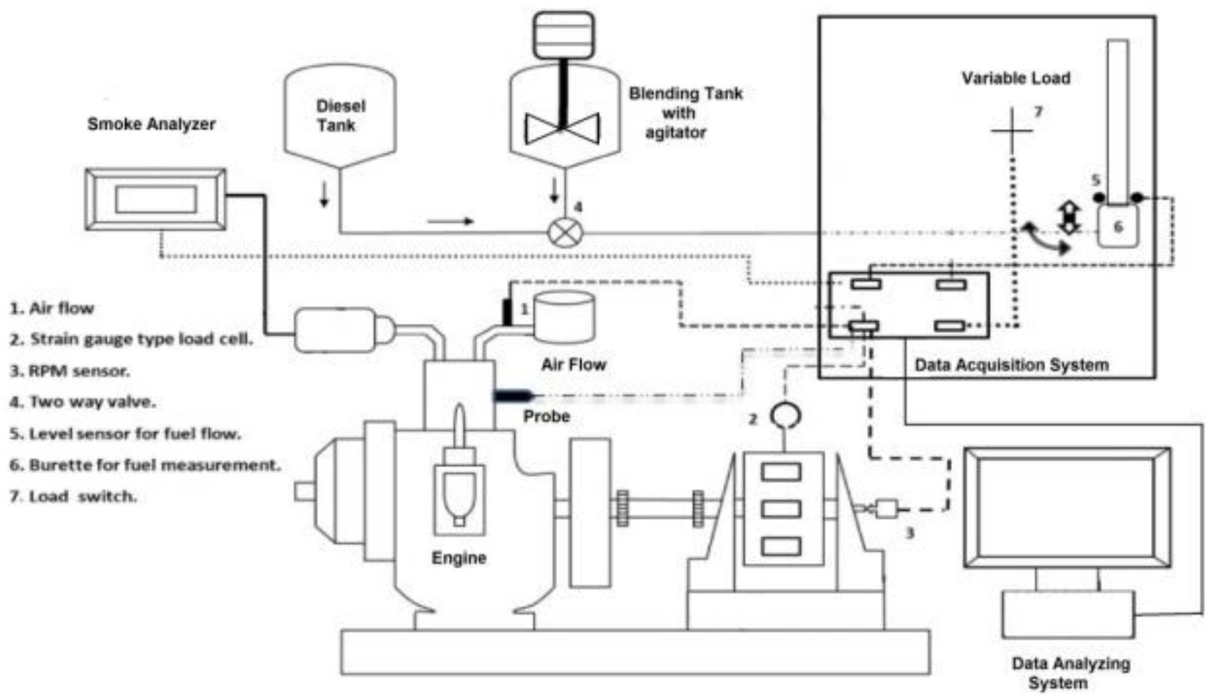

Figure (1): Experimental Setup

The predetermined amount of mixture and diesel and methanol was introduced into the intake manifold through the fuel supply system. High accuracy optical crank angle encoder (Kistler make) was used to ascertain the location of the top dead center (TDC) position precisely and then correlate cylinder pressure data with cylinder volume. Since the engine was personalized to run simultaneously with mixture of fuels, fuel induction, metering and measurement systems were used. The liquid fuel measurement system for the test rig was based on the gravimetric principle. For this purpose a 1000 cc glass bulb apparatus with a control valve was placed in between the fuel tank and engine fuel supply system [8]. For fuel mixture, the mixture was premixed and automatic values for controlled flow of mass flow meters were used. The cylinder pressure was measured by piezoelectric pressure transducer (pressure range 0-250 bars) along with a charge amplifier. The pressure data were transferred to data acquisition system for further analysis. A crank angle encoder (Kistler make) with an accuracy of 1degree was used for angle measurement. After 20 min of engine operation on stabilized conditions, pressure data were obtained for an average of 100 cycles. The mass flow rate of fuel mixture was measured by mass flow meters in ml per minute. To ensure reproducibility of the results, the experiments were repeated for five times. The experiments were performed under the following conditions: (i) Case I: engine runs on diesel only. (ii) Case II: engine runs on mixture of 20% methanol and 80% diesel. (iii) Case III: engine runs on mixture of 40% methanol and 60% diesel and (iv) Case IV: engine runs on mixture of 60% methanol and 40% diesel.

TABLE 1: TEST ENGINE SPECIFICATIONS

S. No.	Parameter	Specification
1	Make and model	Ashok Leyland ALU - WO4CT Turbocharged, Intercooler, gen-set
2	General Details	Four stroke, compression ignition, Constant speed, vertical, water-cooled, direct injection, turbo charger, intercooler, gen-set
3	No. of cylinder	4
4	Bore (mm)	104
5	Stroke (mm)	113
6	Rated speed (rpm)	1500
7	Swept volume (cc)	3839.67
8	Clearance volume (cc)	84.90
9	Compression ratio	17.5:1
10	Injection pressure (bar)	260
11	Injection timing BTDC	16
12	Rated power kW at 1500 rpm	62.5
13	Inlet pressure (bar)	1.06
14	Inlet temperature (K)	313
15	Nozzle diameter (mm)	0.235
16	Number of holes	6

3. Results and discussion:

3.1 Design of Experiment: A two factor, three-level full factorial design was employed using Design-Expert software. The investigated factors (independent variables) were amount of mixture ratio (X_1) and the engine load (X_2). Levels for these factors were determined from preliminary trials. The response variables in the present investigation were HC (Y_1), CO (Y_2), CO2 (Y_3) and O2 (Y_4). The polynomial equation generated by this design is as follows:

$$Y_i = b_0 + b_1X_1 + b_2X_2 + b_{12}X_1X_2 + b_{11}X_1^2 + b_{22}X_2^2 \qquad (1)$$

The response variables in the present investigation of load and the mixture ratio are HC (Y_1), CO (Y_2), CO_2 (Y_3), O_2 (Y_4) and NOx (Y_5). The equations represent the quantitative effect of process variables X_{1-2} on Y_{1-2}. Mathematical equation generated by the software relating the independent variable and dependable responses. The algebraic signs of each coefficient represent the antagonistic and prognostic effects of the corresponding terms, i.e. X_{1-2} respectfully, with the Y_{1-2} term. In case of Y_1, X_{1-2} have negative algebraic sign, indicating its antagonistic response over the overall response.

The above equations represent the quantitative effect of process variables X_{1-2} on Y_{1-6}. Mathematical equation generated by the software relating the independent variable and dependable responses. The algebraic signs of each coefficient represent the antagonistic and prognostic effects of the corresponding terms, i.e. X_{1-2} respectfully, with the Y_{1-6} term. In case of Y_1, X_{1-2} have negative algebraic sign, indicating its antagonistic response over the overall response.

3.2 Experimental Investigations: The experimental results at rated speed of 1500 rpm, injection pressure 260 bar and injection timing 16 BTDC are presented. The mixture of methanol with diesel fuel substitution is mainly presented at no load, 10%, 20% and 40% of full load condition. The 10% of full load was selected to represent engine performance at light load condition, whereas 20% of full load condition was selected for medium and 40% of full load for high load operation, respectfully. 60% and above load condition has not been taken into consideration due to knocking.

The mixture of diesel and methanol was automatically catered through fuel metering and governing system at various load conditions. Zero percent fuel substitution represents pure diesel operation. Adding methanol to diesel, engine emissions can be improved. Methanol has higher stoichiometric fuel/air ratio compared to diesel. Methanol is present as an oxygenated fuel, therefore blending it into diesel leads to the leaner operation. Physical and chemical properties of methanol, namely density, flame speed etc., also vary with that of diesel combustion.

Engine performance parameters such as brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) and exhaust emissions such as HC, CO, CO_2 and NOx are presented in this paper.

BSFC: Figure 2 shows BSFC with brake power for diesel fuel and methanol fuel blends at various load conditions. The minimum and maximum BSFC were found to be 0.18 and 1.01 at 40 and 10% of full engine load and 40 and 60% of methanol substitution compared to pure diesel operation where the minimum and maximum BSFC were found to be 0.26 and 0.434 at 20 and 10% of full load condition.

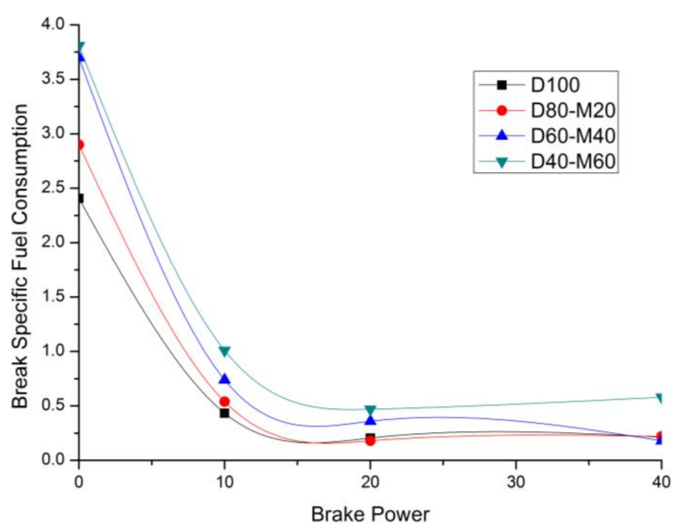

Figure (2): Break Specific Fuel Consumption vs. Brake Power.

BTE: The minimum and maximum BTE were found to be 7.19 and 40.8 at 60 and 40% methanol substitution and at 10 and 40% load conditions. For pure diesel operation the minimum and maximum BTE were found to be 19.7 and 40.6 at 10% load and 40% substitution conditions. Fig. 3 shows the change in BTE compared to brake power. The changes in BTE may be due to the difference in heating values of the methanol and diesel.

HC: The minimum and maximum HC emissions were found to be 16 and 51ppm at 20 and 40% load, 20 and 60% methanol substitution whereas for pure diesel operation it was found to be 2 and 4ppm at 20 and 40% load conditions. Methanol blends show higher HC emission compared to diesel run because of the unburned methanol **[9-12].** Fig.4 shows the HC emission with varying loads. The more the amount of HC, the more may be the unburned methanol being exhausted out from the combustion chamber.

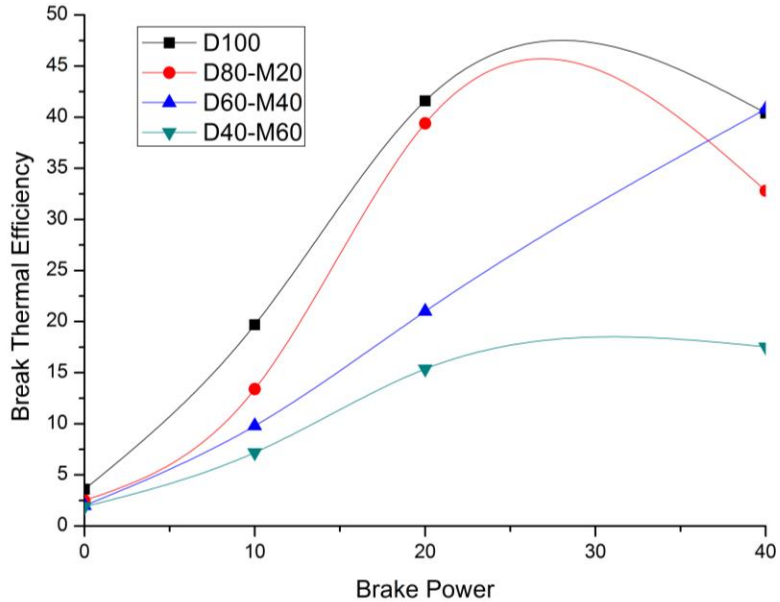

Figure (3): Break Thermal Efficiency vs. Brake Power.

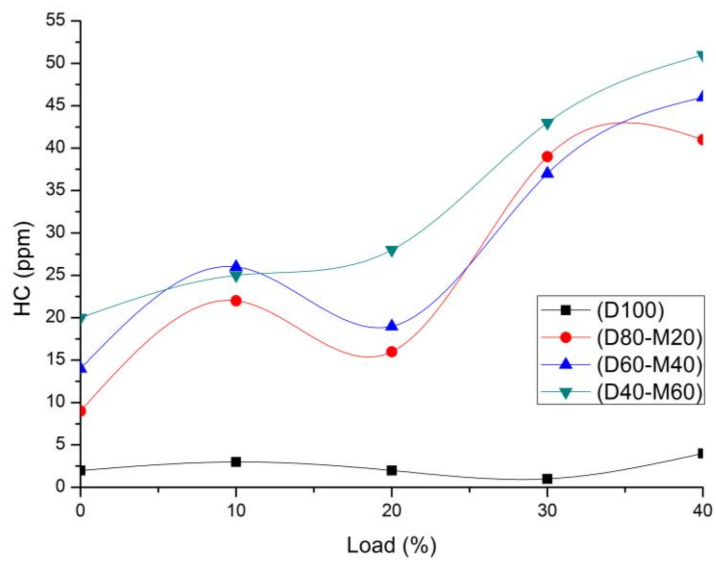

Figure (4): HC vs. Load.

CO

The CO emissions at various load conditions have been shown Fig. 5. The minimum and maximum CO emissions were found to be 0.025 and 0.219% at 10 and 40% load conditions, 60% methanol substitution. The minimum and maximum CO emissions for pure diesel operation were found to be 0.026 and 0.222% at 10 and 40% load conditions. At lower load condition, the CO emission increases and decreases at higher load condition. Due to high heat of vaporization the cylinder gas temperature get decreases while due to the delayed combustion process, the CO increases and later on it reduces at higher load condition **[13-15].**

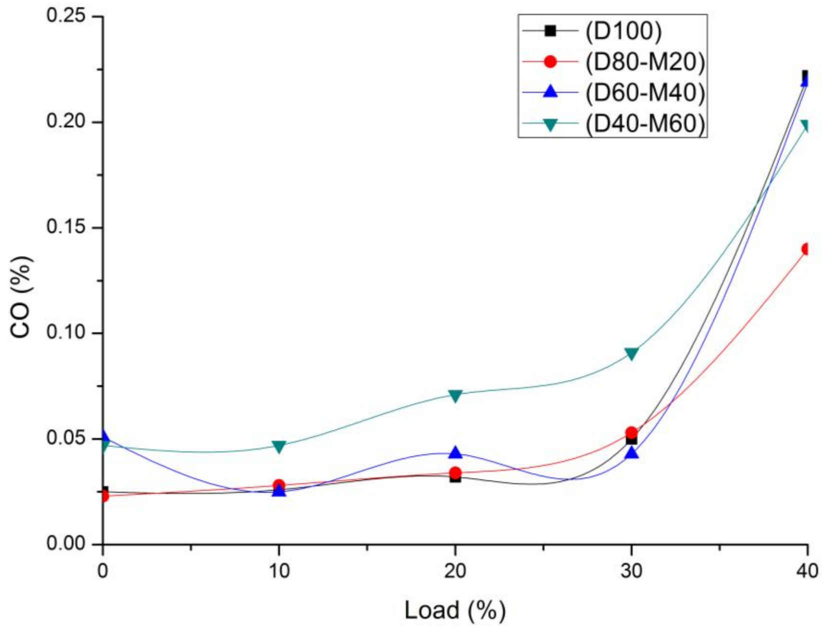

Figure (5) : CO vs. load.

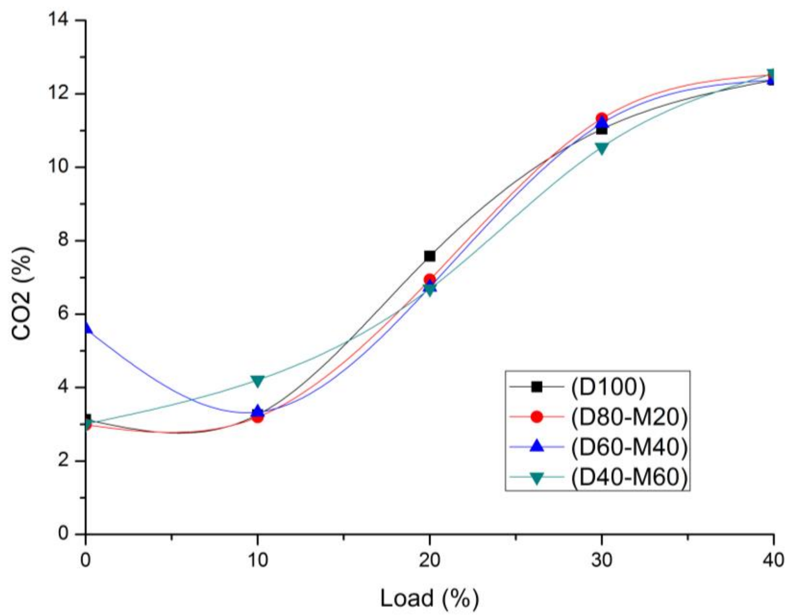

FIG 6 : CÖ$_2$ VS. LOAD

CO_2: The emission trends were found to be comparatively closer to pure diesel operation. CO_2 is a product of combustion. The minimum and maximum Figure (6) shows the CO_2 emissions at different load conditions CO_2 emissions were found to be 3.2 and 12.56 % at 10 and 40 % load, 20 and 60 %

methanol substitution. If CO_2 amount increases while HC and CO emission amounts increases, then it indicates a incomplete combustion. CO_2 emissions are higher due to more presence of methanol to accomplish complete combustion and more fuel consumption is due to lower calorific value of methanol **[16-18].** The minimum and maximum CO_2 emissions for pure diesel operations were found to be 3.26 and 11.04 % at 10 and 40 % load condition. It is found that as load increases CO_2 emissions increases as more and more fuel burns at higher load condition and complete combustion also been achieved due to high temperature. This trend was found to be similar for all fuel blends.

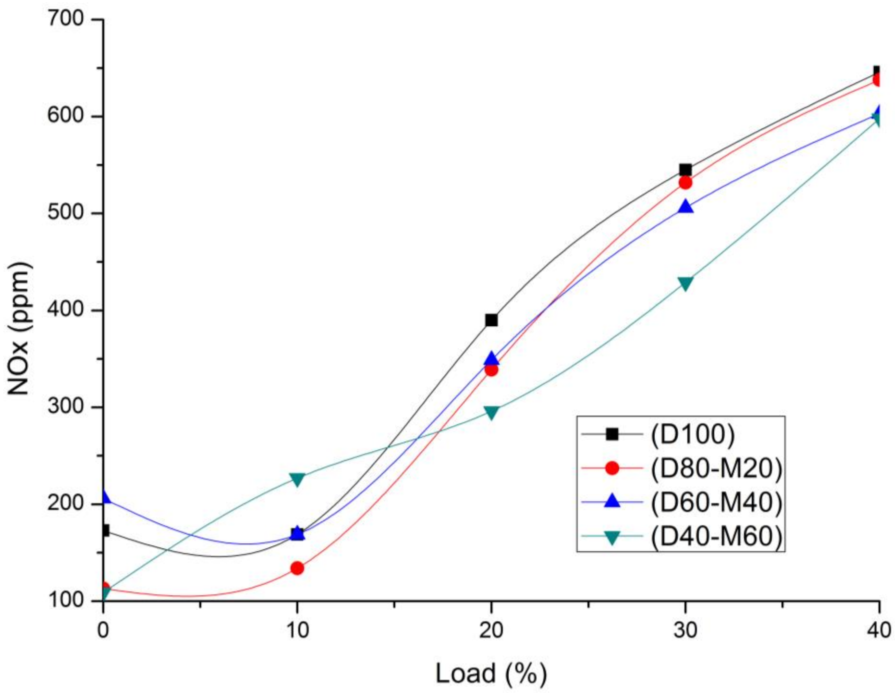

FIG 7 : NO_X VS. LOAD

NO_X: The emission trends were found to be lower than that of pure diesel operation. This maybe because of the presence of methanol as it lowers the temperature inside the combustion chamber **[19-20].** Fig.7 shows the NO_x emissions results. The minimum and maximum NOx emissions were found to be 134 and 227ppm at 10% load condition, and 20 and 60% methanol substitution whereas for pure diesel operation the minimum and maximum emissions were found to be 169 and 545 ppm at 10 and 40% load conditions.

4 Conclusions: BSFC was found to increase whereas BTE was found to decrease compared to pure diesel operation. The addition of methanol improved the combustions process and this was confirmed by using the exhaust gas analysis. Increase in CO2 and also the increase in HC and CO amounts showed that the combustion was near completion. At lower loads the CO emissions increases whilst it decreases at higher loads. Methanol blends showed higher HC emission compared to diesel.

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