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Some Comparative Performance and Emission Studies on DI Diesel Engine Fumigated with Methanol and Methyl Ethyl Ketone Using Microprocessor Controlled Fumigator

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Abstract: The main objective of this study is to improve the performance and cleaning up of diesel engine's exhaust by fumigating known quantity of methanol and methyl ethyl ketone individually using a custom made Electronic fuel injector controlled by a microprocessor. To control the emission from diesel engine and to improve performance, alternate fuel and in-cylinder control techniques are used. The experimental study has been carried out in a single cylinder diesel engine. The experimental set-up is such that known quantity of methyl ethyl ketone is fumigated in the intake manifold using a microprocessor controlled electronic fuel injector. Results of the experimental study of a DI Diesel engine are presented, which show the influence of partial premixing fumigation of the intake air with methanol and methyl ethyl ketone fuel on the exhaust emissions and the engine performance parameters The result shows an appreciable reduction of emissions, such as, oxides of nitrogen, smoke density and marginal increase in the performance in fumigation mode for both the fuels and are compared with those of normal diesel engine.

INTRODUCTION

Reducing the emissions and fuel consumption are no longer future goals; instead they are the demands of the day. Alcohols are examples of the most attractive alternative non-petroleum fuels used in internal-combustion engines. Although there are a lot of studies on the use of alcohols in spark ignition engines, in the past, little attention has been given to the utilization of alcohols in diesel engines. This is due to the difficulties encountered while attempting to use alcohols in diesel engines, especially at high alcohol ratios, which are summarized as follows [1-5]:

1. Alcohols have very poor lubricating characteristics.
2. The heating value of alcohol is less than that of diesel fuel; therefore, more alcohol than diesel fuel is required by mass and volume.

Although replacing diesel fuel entirely by alcohols is very difficult, an increased interest has emerged for the use of alcohols, and particularly the lower alcohols such as methanol and ethanol, with different amounts and different techniques in diesel engines as a dual fuel operation during recent years [4]. These techniques can be generally classified into three categories:

1. Alcohol-diesel fuel blend: mixing fuels in the fuel tank, displacing up to 25% of diesel fuel demand.
2. Dual injection: separate injection system for each fuel, displacing up to 90% of diesel fuel demand.
3. Alcohol fumigation: the addition of alcohols to the intake air charge, displacing up to 50% of diesel fuel demand.

The most attractive and the simplest one of these techniques we are concerned with in this study is alcohol fumigation for diesel engines. Fumigation is a technique by which alcohol is introduced in the intake air flow by a simple carburetor and vaporizing it or injecting alcohol in the intake air stream. This requires the addition of a carburetor, a vaporizer or an injector, along with a separate fuel tank, lines and control [4]. However, using a simple carburetor requires a simple modification on the engine intake system, and thus, this method is fairly cheap. Thus, it is considered that instantaneous burning of air and LF mixture could form swirl motions and additional gas motions in the cylinder and this could mix rather well diesel fuel, air and LF mixture. As a result, engine performance could improve and nitrogen oxides could decrease because of faster and efficient burning of the fuel [6]. Most of these studies are focused on to calculate the dimensions of carburetor for fumigation as there is no specific device in any model to find the volume of LF inducted. In this work the performance and emissions are studied by adapting a microprocessor controlled electronic pump with injector to control the LF flow rate. Experiments were conducted for various fumigation rates of two different LF (methanol and methyl ethyl ketone) and the results were compared.

ELECTRONIC FUEL INJECTOR

An electronic fuel injection kit as shown in Fig. (**1**) is used for fumigation. The fumigating fuel is pumped in to the injector by an electronic pump and the number of pulses of the injector is controlled by an AT-89C52 microprocessor.

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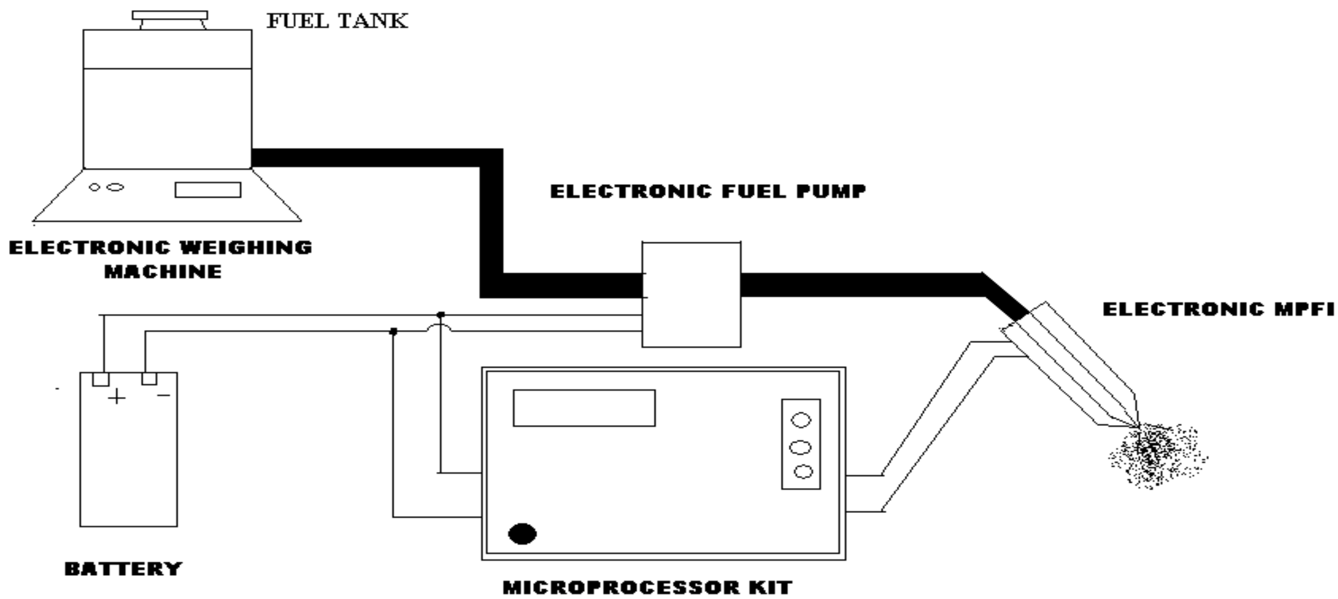


Fig. (1). Layout of Electronic Fuel Injection Kit.

The quantity of fuel injected per pulse can be calibrated by adjusting the number of pulses per minute and hence a constant volume of LF can be fumigated at any working condition

Table 1. Specification for Kirloskar Diesel Engine

Type of engine	Single cylinder DI Diesel engine
Type of cooling	Air
Engine power	5hp
Bore and stroke	87.5X110 mm
Compression ratio	17.5:1
Speed	1500 rpm

Table 2. Properties of Methanol and Methyl Ethyl Ketone

Properties		
Molecular Formula	$C_4H_8OCH_3COC_2H_5$	CH_3OH
Molar mass	72.11 g/mol	32.04 g/mol
Appearance	Colourless liquid	Colourless liquid
Density	952 kg/m3	791.8 Kg/m³
Melting point	−86 °C	-97 °C
Boiling point	80 °C	64.7 °C
Solubility in water	29 g/100 ml (20 °C)	Fully miscible
Calorific Value	13228 kJ/kg	11778 KJ/Kg

EXPERIMENTAL SETUP

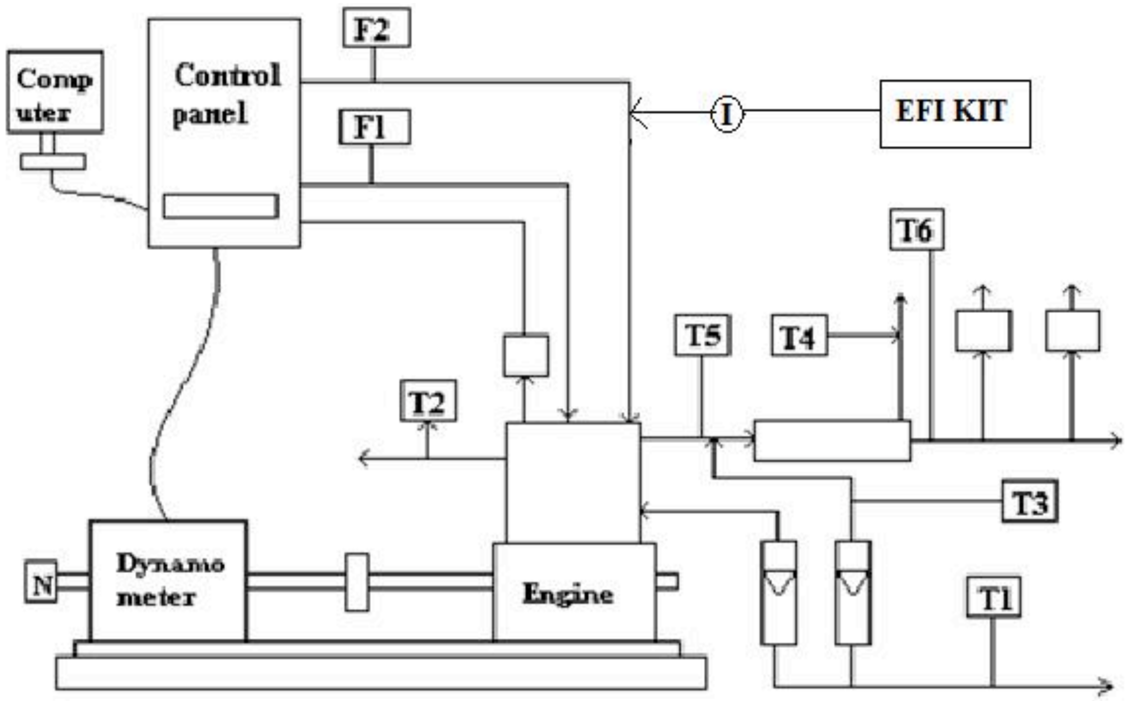
The experimental set up is shown in Fig. (**2**). The experimental system includes the engine, air flow and emission measurement system. The engine is connected to an eddy current dynamometer. Airflow rate was measured by means of anemometer. An exhaust gas analyzer (AVL Five gas analyzer) was used for measuring the exhaust emissions like oxides of nitrogen, hydrocarbons, carbon monoxide and carbon dioxide (NOx, HC, CO, CO_2) Exhaust gas temperature was measured by means of a K - type thermocouple. The LF is injected in to the inlet manifold through microprocessor injection kit. Experiments were conducted with neat diesel and fumigating with Methanol and Methyl ethyl ketone individually at a rate of 0.2, 0.4, 0.6, 0.8, 1.0 gm/min by adjusting the pulse setter in the microcontroller and the optimum value of each LF for performance was found out at 50%,75% and 100% of load. The emission at various loads for optimum flow of LF were studied and compared.

RESULTS

The variation of Brake thermal efficiency at 50%, 75% and 100% load for base diesel fuel and for various fumigation rates with methanol and methyl ethyl ketone is shown in Figs. (**3**) and (**4**). It can be observed that the brake thermal efficiency is maximum at 0.4 gm/min of methanol fumigation and 0.8 gm/min of methyl ethyl ketone fumigation. The increase in efficiency for methanol is high comparing with methyl ethyl ketone as the number of C and H atoms are more in methyl ethyl ketone

Fig. (**5**). shows the variation of brake thermal efficiency at various loading conditions for neat diesel and optimum fumigating conditions for metanol and methl ethyl ketone. The efficency is increased in fumigating mode and a maximum of 3.3% at full load is recorded for methanol fumigation.

The variation of oxides of nitrogen with load for base diesel fuel and optimum fumigating conditions for metanol and methl ethyl ketone is depicted in Fig. (**6**) Both the fumigators reduces NOx concentration almost in equal manner and the maximum reduction is 48% at full load for metanol fumigation when compared to base diesel fuel.



T1&T3 - Inlet water temp in ˚C
T2-Outlet engine water temp in ˚C
T4-Outlet calorimeter water temp in ˚C T5-Exhaust gas temp˚C before calorimeter
T6-Exhaust gas temp ˚C after calorimeter
N - RPM decoder
F1 - Fuel flow differential weight unit
F2 - Air flow differential velocity unit
I - Electronic Injector

Fig. (2). Experimental setup.

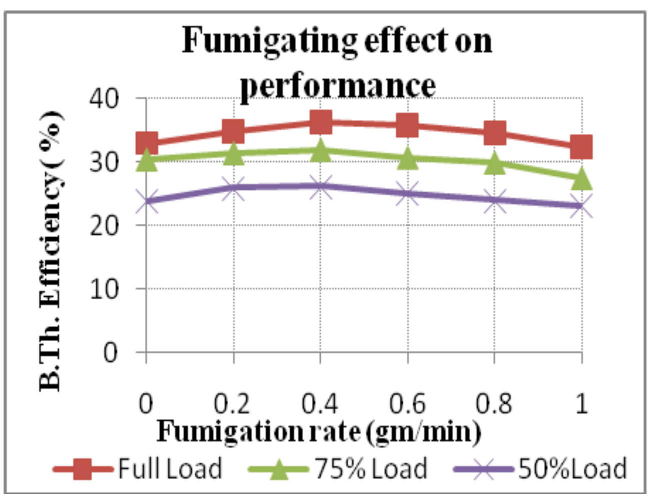


Fig. (3). variation of brake thermal efficiency for methanol fumigation.

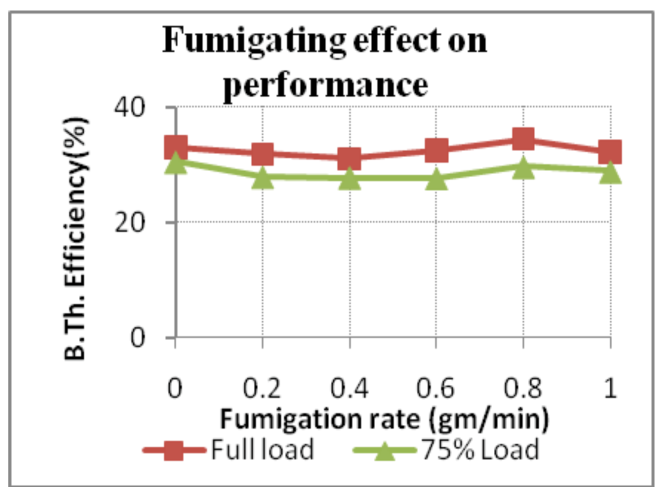


Fig. (4). variation of brake thermal efficiency for methyl ethyl ketone fumigation.

Fig. (7) depicts the variation of smoke opacity with load for base diesel fuel and optimum fumigating condition. The smoke in the engine exhaust is gradually reduced during loading for fumigating condition compared to base diesel fuel. 34% reduction was obseved at full load for MEKfumigated and 25% for metanol fumigated fuel comparing with neat diesel.

It can be observed from the Fig. (**8**) that HC emission increased by 67.5% and 48% respectively at no load for methanol and MEK fumigated fuel when compared to the base diesel fuel. The increase in HC may be due to the quenching layer generated on the wall surface of the combustion chamber by the LF mixture as in SI engine. However as invented by Daniel (1967) the generated quench

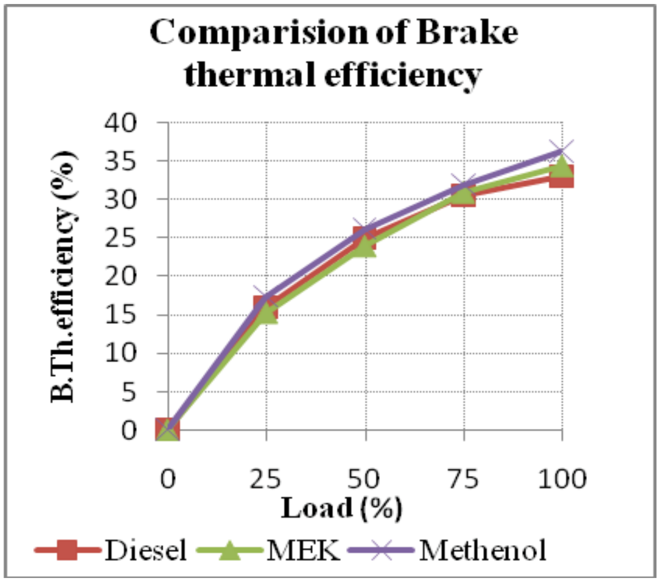


Fig. (5). Variation of brake thermal efficiency with load.

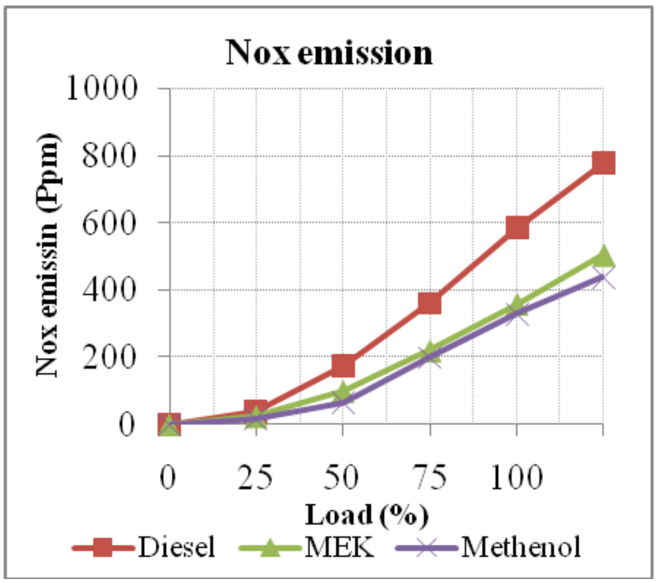


Fig. (6). Variation of NOx with load.

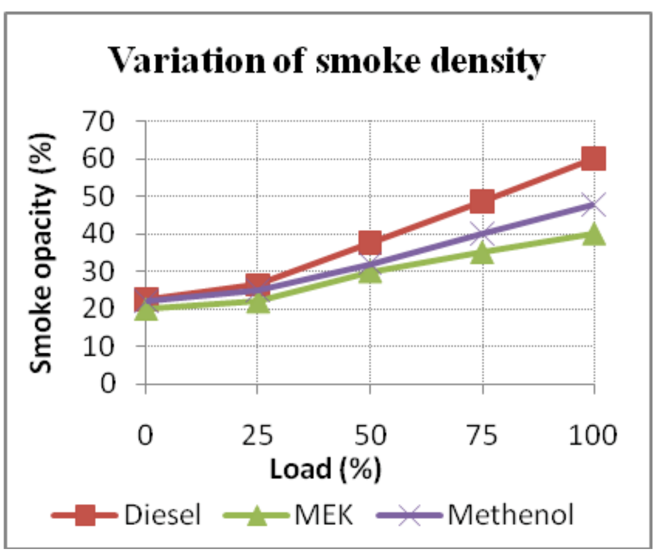


Fig. (7). Variation of smoke opacity with load.

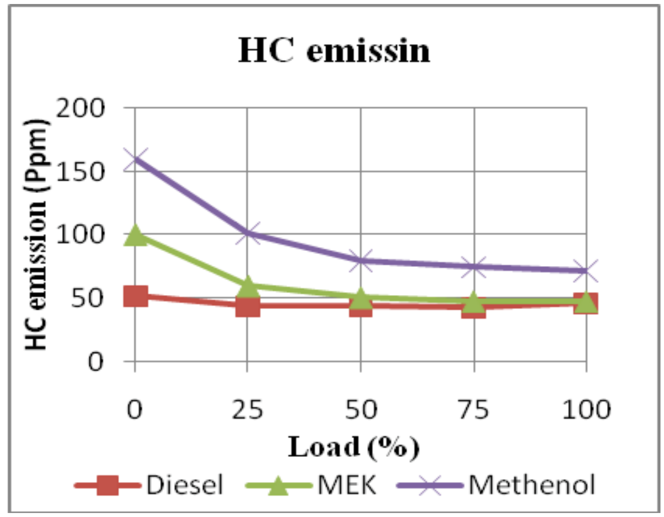


Fig. (8). Variation of HC with load.

layer is oxidized by diffusion after expansion, and hence the amount of HC reduces during loading. It can also be due to the loss of some of the fumigated charge through exhaust valve during the overlap period. The difference is reduced to 20% and 3% respectively at full load.

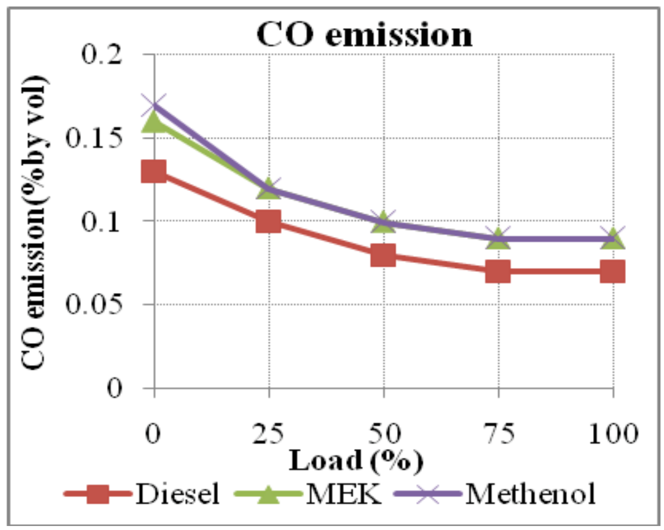


Fig. (9). Variation of CO with load.

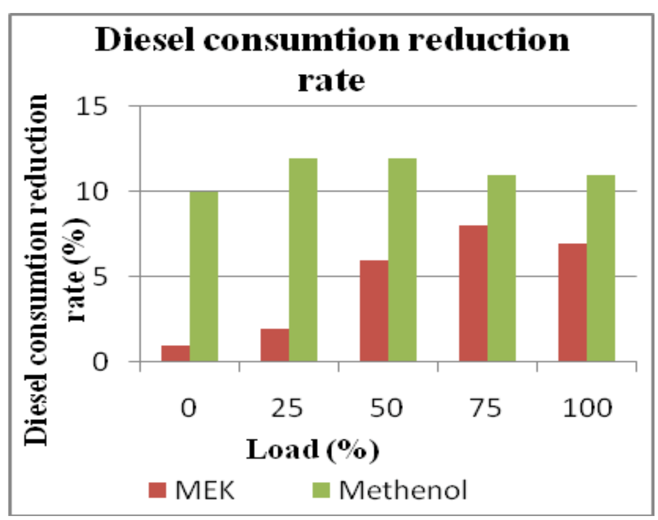


Fig. (10). Diesel consumption.

The variation of CO emission with load for base diesel fuel and optimum fumigating condition with metanol and MEK is shown in Fig. (**9**). It can be observed that CO emission increased by 22% at full load in the case of fumigation for both the fuels when compared to the base diesel fuel. This may be due to the combustion of fumigated methenol is more like a homogeneous charge.

It is also observed from Fig. (**9**) that11.5%, 7% of diesel consumption is reduced when it is fumigated with 0.4 gm/min of methenol and 0.8gm/min of MEK respectively.

DISCUSSION AND CONCLUSIONS

The results obtained in this investigations are as follows:

Brake thermal efficiency at 50%, 75%, Full load is maximum at 0.4 gm/min of methanol mixture and 0.8gm/min of MEK mixture then decreases indicated that the optimum fumigation is 0.4 gm/min 0.8 gm/min for metanol and MEK mixture respectively

- Oxides of nitrogen emissions can be substantially reduced in fumigation with both the fuels
- Carbon monoxide emission increased in fumigation mode
- Unburned hydrocarbons increased greately with fumigated fuel and is relatively high for methenol fumigation
- Smoke emission is considerably reduced at high loading conditions for fumigated fuel and the reduction is high for MEK fumigation compared with metanol
- Diesel consumption rate is greately reduced in fumigated mode for metanol than the MEK

ABBREVIATIONS

^oC	=	Degree centigrade
bhp	=	Brake horse power
KJ/Kg	=	Kilo joules per kilogram
Ppm	=	Parts per million
LF	=	Light fuel
LFM	=	Light fuel mixture
MEK	=	Methyl ethyl ketone

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