Emission and performance investigation of LPG and DEE as ignition improver fuelled diesel engine

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Abstract : ***Need of an appropriate supportable fuel for existing internal burning motors is by and large frantically felt nowadays, when oil holds are soon going to vanish from the surface of earth Biodiesel proposes one such choice*** *The purpose of this article is to provide the physicochemical properties and characteristics of exhaust emissions from a DEE and LPG-fueled diesel engine. Fundamental properties of DEE and LPG are described and compared with the properties of the conventional diesel fuel. In addition, the applicability of DEE fuel is presented in terms of its potentials as an alternative fuel for compression ignition engines. The exhaust emission characteristics of a DEE and LPG-fueled engine are described using experimental results of different DEE and LPG with diesel blends. The most important properties of DEE and LPG are the presence of oxygen in the fuel molecule, lower ignition temperature, and high cetane number. The kinematic viscosity of DEE is significantly lower than that of diesel. However, low lower hating value (LHV), low viscosity, and low lubricity are some of the major disadvantages of DEE.* ***LPG is considered to be one of the most promising alternative fuels not only as a substitute for petroleum but also as a means of reducing nox, soot and particulate matter. Fuels like vegetable oils, which have a high cetane number, can be directly used in neat form in a conventional diesel engine. Alcohols like ethanol also can be used in a neat form with ignition improvers like dimethyl ether (DEE) or by employing hot surfaces for ignition LPG has a high octane rating and is therefore well suited for SI engine. But when LPG is burnt in the conventional diesel engine there is a difficulty in self-ignition because of its lower cetane number. If LPG is to be used as an alternative to diesel the cetane rating needs to be improved with additives or other positive means of initiating combustion. Adding a cetane number improver to LPG is one method to improve its cetane number and its ignition quality.*** *Emission characteristics of different DEE and LPG and diesel blends are investigated, which shows low soot, CO,* NO_X *and other hydrocarbon emissions.*

Index Terms - HC, CO, NO_X***, BP, BSFC, Vol Efficiency***

I. INTRODUCTION

Internal combustion engine continues to dominate many fields like transportation, agriculture and power generation. Conventional hydrocarbon fuels used by these engines lead to pollutants like hydrocarbons (HC), Carbon Monoxide (CO), Nitric Oxides (NO), Soot and Particulates which are harmful to human health, animal and plant life. Hence automobiles in the recent years are being subjected to increasingly stringent regulations. The product of complete combustion CO_2 is a green house gas that contributes to global warning. Thus there has been a need to find suitable alternatives to conventional hydrocarbon fuels, which can reduce pollution levels, especially from C.I. engines. Promising alternative fuels for internal combustion engines are natural gas, liquefied petroleum gas (LPG), hydrogen, biogas, alcohols and vegetable oils (Nagarajan et al 2002). Gaseous fuels have been found to be attractive because of their wider ignition limits and capability to form homogeneous mixture. Even very lean mixture of these fuels can be burned in air and in addition they have lower hydrogen to carbon ratio. Thus very low emissions are possible when they are used in I.C. engines. One of the major challenges of diesel engine development is the simultaneous reduction of nitric oxide and particulate emissions. This is especially true for smaller engines, where the possibilities of using beneficial measures such as turbo charging, electronic engine control, particulate traps, etc., are expensive in relation to the fundamental cost of the engine.

A. HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINE

Homogeneous Charge Compression Ignition operation is relatively a new combustion technology, which is a hybrid of the traditional spark ignition process and the compression ignition process (George Kontarakis et al 2001). A homogeneous fuel-air mixture is formed in the inlet system as in SI engine and during the compression stroke the temperature of the mixture increases and reaches the point of auto ignition, i.e. the mixture burns without the help of any ignition system, just as in a CI engine. The combustion in HCCI engine does not rely on maintaining a flame front. Rather, combustion occurs as a result of spontaneous auto-ignition at multiple points throughout the combustion chamber. The main advantage of HCCI engine is its unparalleled reduction of NO_x emissions by about 90-98 % in comparison to conventional diesel combustion. The HCCI engine undergoes an auto-ignition process throughout the combustion chamber that can eliminate the high temperature flames and thus NO_x emissions from HCCI engines can be very low. HCCI engine also produces low levels of smoke and particulate emissions. This is attributed to the absence of diffusion-limited combustion and localized fuel-air regions, which discourages the formation of soot.

B. LIQUEFIED PETROLEUM GAS (LPG)

LPG as engine fuel provides a number of benefits when compared with conventional fuels. LPG produces fewer harmful emissions that have an impact on the local air quality and also reduces carbon dioxide emission. With the government enforcing tough emission laws and ban on high emission vehicles, LPG has been found to be a logical alternative fuel for cars and vans particularly in cities. LPG also has the advantages like low cost, and lower maintenance as fewer deposits build-up in the engine (Baxter et al 1968). Typical properties of important liquid and gaseous fuels are given in Table 1.1 and other properties of liquid and gaseous fuels are given in Appendix 1. (Kajitani et al 1998, Brent Bailey et al 1997 and Mitsuru Konno et al 1999). LPG's flame velocity is higher, and due to its higher density than air, any leakage causes it to settle near the ground. Thus combustible mixtures, which lead to fire risks, can be formed near the ground when LPG leaks. However, it is feasible to use LPG as a clean alternative fuel if proper safety regulations are considered.

C. IGNITION IMPROVERS AND ADDITIVES

The main problem associated with all the alternative fuels is that they have high octane ratings, and hence require high compression ratios for HCCI operation. Alternatively ignition promoters can be added to the fuel to broaden the HCCI operating range. The same fuel additives used in gaseous fuels to increase the cetane rating can also be used in gasoline, or any of the alternative fuels, to promote ignition in HCCI engines. There are a number of additives that have been added to gaseous fuels, and in particular the use of nitrate compounds have been widespread. While many different organic nitrates have been evaluated over the years, only 2-ethylhexyl nitrate (2-EHN) is currently commercially available and has been added to diesel fuels for over 30 years. Ethers and oxygenates are known to be effective cetane improvers. Oxygenates that are widely used are dimethyl ether (DEE) (Ofner et al 1998), dimethoxy methane (DMM), dimethyl ether (DEE), and di-tertiary butyl peroxide (DTBP). The boiling points, heating value and chemical structures for these additives are listed in Table 1.2 (Fuquan Frank Zhao et al 2003).

TABLE I
Properties of Fuel Additives

Additives	Chemical Formula	Cetane No	Boiling Point (°C)	LHV (MJ/kg)
DEE	CH_3-O-CH_3	55-60	-25	28.8
DMM	CH_3-O-CH_2-O-CH_3	25-30	42	22.3
DEE	CH_3-CH_2-O-CH_2- CH_3	> 125	34	33.9

II. EXPERIMENTAL SET-UP AND TECHNIQUES

D. Experimental set-up

The schematic view of the experimental test set-up used in the present investigation is shown in Figure 3.1. A photographic view of the entire experimental setup is shown in Figure 3.2. The test facility includes the following arrangements:

1 Test engine coupled to an alternator with electrical resistance loading device.

2 Burette and stop watch arrangement for diesel and DEE flow measurements.

3 Orifice plate and U-tube manometer for air flow measurements.

4 Thermocouple for measuring the temperature of exhaust gas, intake charge, cylinder head and cooling water.

5 Digital platform type electronic weighing machine for LPG flow measurements.

6 Piezo-electric pick up for cylinder pressure measurements.

7 Needle valve and intra venous needle valve for the control of LPG and DEE flow respectively.

8 Electromagnetic inductive pick up for TDC position.

9 Arrangement for maintaining the LPG cylinder at constant temperature for ease of flow.

11 Exhaust-gas sampling arrangements for measuring HC, CO and NO with online analyzers.

12 Smoke meter for measuring the exhaust smoke.

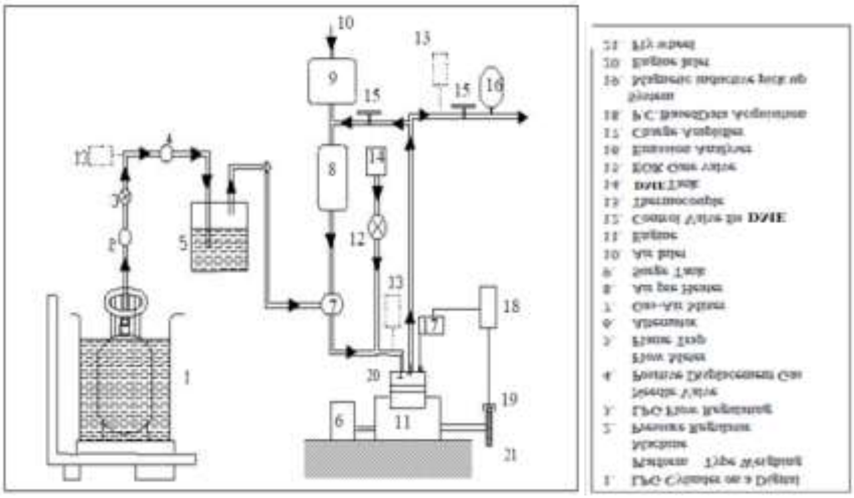

Figure 1.1 Schematic diagram of the experimental set-up

III. Test Engine Details

The engine employed for the experimental work was a single cylinder, four stroke, water-cooled, vertical, naturally aspirated DI diesel engine developing power of 3.73 kW at 1500 rpm with compression ratio of 16.5:1. The engine was modified to operate in HCCI engine mode by mounting gas-air mixture arrangement in the intake manifold to supply LPG. The technical data of test engine is given in Appendix 2.

E. Inlet Mixture Preheating System

Electric heater of capacity 2 kW was provided in the intake air pipeline to preheat the air. A thermocouple was inserted just before the intake port to monitor the intake temperature and was connected to a temperature controller. The temperature controller was used to control the set temperature.

F. Exhaust Gas Recirculation System

A schematic diagram of the EGR arrangement is shown in Figure 3.6. A spring type flexible metal pipe was installed between the exhaust pipe and the intake pipe, to route the exhaust gases back to the engine inlet system, where the hot gases were inducted into the succeeding cycles.

G. Temperature Measurement

The temperature of exhaust gases, intake charge, and cylinder head were measured by means of a K-type (chromel-alumel) thermocouples. The thermocouples were connected to a 12-channel selector switch and digital panel indicator.

H. LPG Supply and Measurement System

The LPG cylinder was kept in a bath maintained at a constant temperature of 40°C. Since the gas flows from the cylinder, the temperature of the contents in the cylinder falls, which leads to reduction in the vapour pressure of LPG and hence the flow rate gradually decreases. LPG from the cylinder was allowed to flow through a regulator in order to bring the pressure to atmospheric value. LPG from the regulator was fed into fine control needle valve and passed into flame trap before being admitted into the gas carburettor in the intake manifold. The needle valve was used to control the desired quantity of LPG flow rate.

I. Air, Diesel and DEE Flow Measurements

The airflow rate was measured with the help of a U-tube manometer. Surge tank with volume fixed at approximately 500 times the swept volume was used to reduce the fluctuations in the airflow. Diesel and DEE flow rate were measured from the time taken for a fixed volume of diesel and DEE from the respective burette.

J. TDC Position Sensor

The reference point used for determining the crank position was the Top Dead Center (TDC). An electromagnetic inductive pick up was used to give a voltage pulse exactly when the piston reached the TDC position. In order to find the TDC position, the cylinder head was removed and a dial gauge was used to determine the highest position of the piston. To locate the exact position of TDC, the flywheel was rotated until the dial indicator indicates highest point of piston travel.

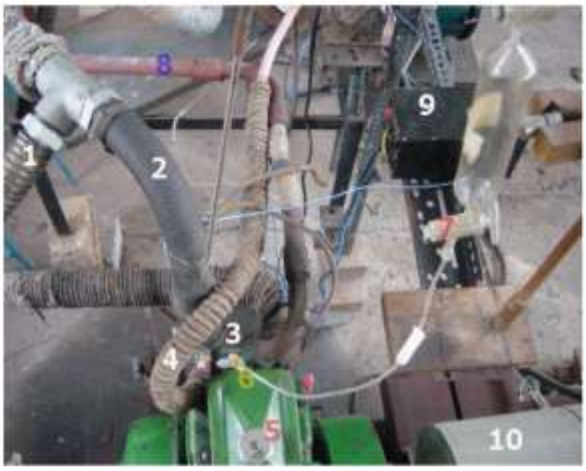

Figure 1.2 Photographic view of LPG-DEE port admission

IV RESULTS

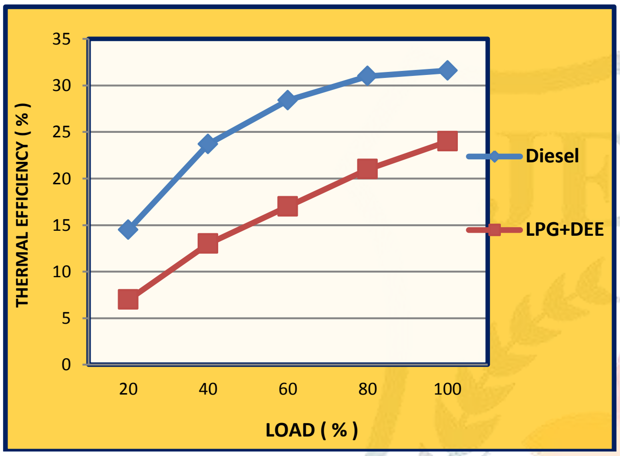

Figure 1.3 Variation of Brake Thermal Efficiency

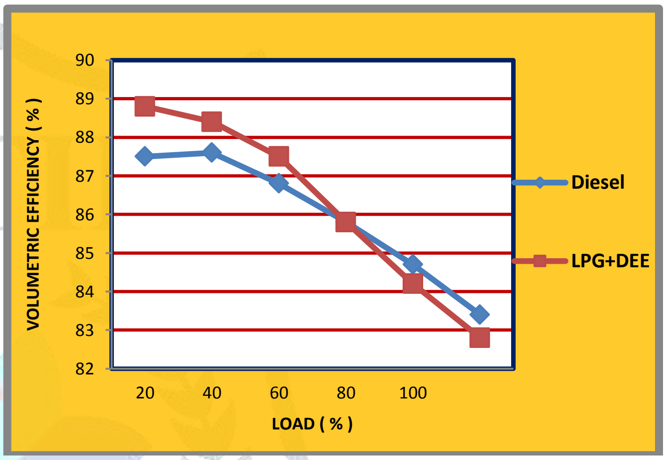

Figure 1.4 Variation of Volumetric Efficiency

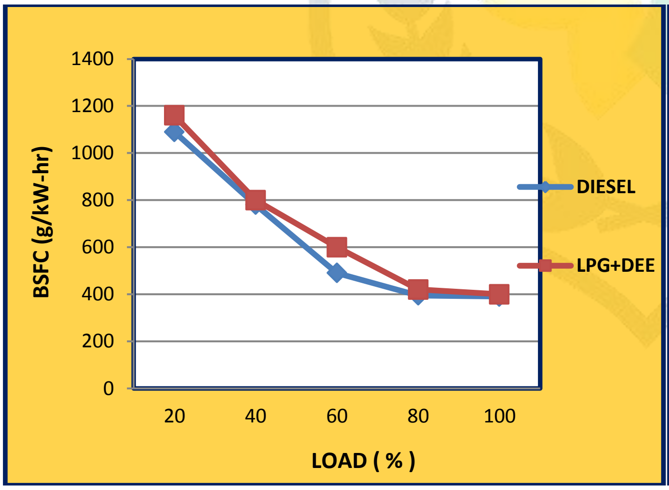

Figure 1.5 BSFC against load at different Diesel-LPG modes

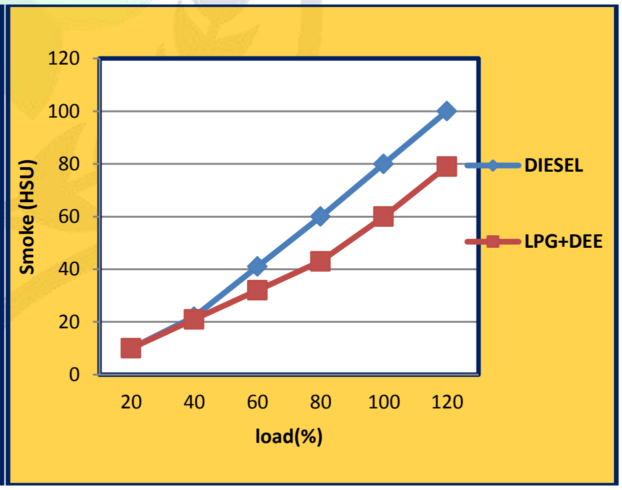

Figure 1.6 Smoke emissions against load at different Diesel-LPG modes

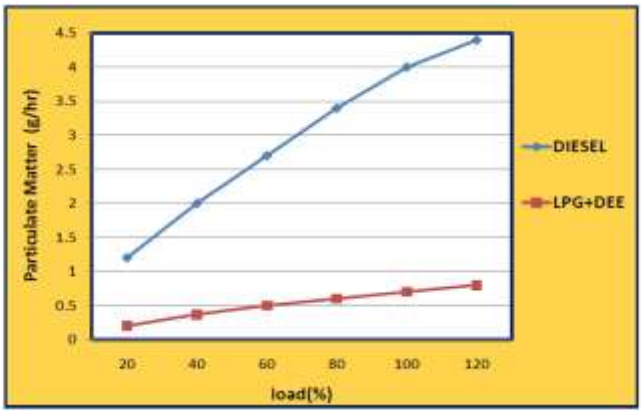

Figure 1.7 Variation of Particulate Matter

V. Conclusion

- At higher power outputs admitting too rich mixture reasons a very fast combustion and reason severe knock, which might affect the engine overall performance and the engine itself.
- Brake thermal efficiency in LPG mode is lower (7.7 % to 24.2 %) throughout the load spectrum than the diesel operation (14.6 % to 31.5 %).
- Smoke reduces by about 80 % to 85 % throughout the load spectrum for LPG operation compared to diesel operation
- The volumetric efficiency is found to be higher at lower loads (> 40 %) and beyond this result in lower efficiency.
- BSFC decreases with load but DEE give better BSFC than diesel
- The reduction in particulate matter is because, DEE is mixed in the form of vapour with LPG-air mixture and Inducted into the cylinder in the state of homogeneous mixture, which can eliminate fuel-rich diffusion combustion and can reduce the particulate emissions.

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