"Performance and Emission Analysis on Single Cylinder Diesel Engine Using Dual Fuels"

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ABSTRACT

Biodiesel is an alternative fuel to diesel derived from vegetable oils by transesterification process. It can be used in diesel engines with/without any modification in the engine system. Biodiesel engines emit slightly higher NOx emissions, as compared to that of diesel engines, as higher cylinder temperatures achieved during combustion.

A single cylinder diesel engine was modified to use LPG in dual fuel mode to study the performance, emission, and characteristics. The primary fuel, liquefied petroleum gas (LPG), was mixed with air, compressed, and ignited by a small pilot spray of diesel. The kirloskar (AV1 model) 4-stroke single cylinder water cooled diesel engine in made to work as Dual Fuel Engine by attaching a mixing chamber to the engine and giving the LPG gas connections to supply LPG. The engine performed satisfactorily with LPG - Biodiesel, so that the PAME can be used as an alternative fuels in existing Dual Fuel Engine without any hardware modification in the system.

The engine has been properly modified to operate under dual fuel operation using LPG as the primary fuel and Diesel, POME as an ignition source. From the experimental results obtained with LPG - Diesel, LPG - POME in dual fuel engine, it was concluded that the brake thermal efficiency of the engine under dual fuel mode is less compared to normal diesel operation at lower and part loads. But at higher loads the efficiency of the engine with LPG - Diesel in a dual fuel mode is comparable with normal diesel operation. It was also noticed reduction in emissions of diesel engine with dual fuel mode.

Key words:

Diesel engine, dual fuel, biodiesel, LPG gas, performance, emissions.

1. Introduction:

Literature on log and biodiesel has been collected and grouped in the following sections.

[1] In this investigation, the characteristics of combustion of natural gas in an unmodified diesel engine using pilot injection ignition method. They identified that the engine speeds, load, and delay period, system temperature, mixture composition and turbulence in the cylinder as the factors influencing the combustion characteristics of dual fuel engines. [2] In this investigation the suitability of Mahua oil methyl ester as alternative fuel for diesel engine. They found that trans-esterification of Mahua oil with alcohol provided a significant reduction in viscosity, thereby enhancing the physical properties of the renewable fuel to improve engine performance. They reported in their paper that the engine performance with Mahua oil methyl ester differed a little from engine performance with diesel fuel. They concluded that the engine with methyl ester of Mahua oil gives lower HC, CO emission and smoke than conventional diesel at optimum conditions. [3] In this investigation, the suitability of Mahua oil methyl oil ester as alternative fuel for diesel engine. They mentioned that Mahua oil be easily substituted up to 20% diesel without any significant difference in power output, BSFC, and brake thermal efficiency. The performance of engine with Mahua oil blends increased with the increase in compression ratio from 16:1 to 20:1. They found that the increase in concentration of Mahua oil in diesel revealed that the power output decreases at all compression ratios. However, at compression ratio of 20:1, the blends up to 60% Mahua oil did not reveal any significant difference at 5% level of significance in power output. [4] In this investigation, the test conducted on a single cylinder DI Diesel engine, which has been properly modified to operate under dual fuel conditions. The primary amount of fuel is the gaseous one, which is ignited by a pilot Diesel liquid injection. Comparative results are given for various engine

speeds and loads for conventional Diesel and dual fuel operation, revealing the effect of dual fuel combustion on engine performance and exhaust emissions. [5] In this investigation, the use of non-edible oil (Pongamia oil) as an alternative to diesel fuel. They varied the fuel injection pressures from 140 to 220 bars on single cylinder air cooled vertical diesel engine of 6hp at 1500 rpm. They adopted blends of 10, 20, 30, 40 and 50% Pongamia oil and diesel oil. They observed smooth running of the engine at 50% blend of Pongamia oil and also observed that the 20% blend of Pongamia with 80% diesel gave the better performance with lower emissions compared to all other blends. They encountered no cold start problems and observed 200 bar as the optimum injection pressure for 20% Pongamia oil. [6] In this investigation, the combustion model for direct injection dual fuel compression ignition engine in which the biogas is supplied through the inlet manifold and the diesel fuel through fuel injection system. Their results shown that introduction of biogas reduce the rate of combustion due to the presence of carbon dioxide which brings down engine performance. [7] In this investigation, the performance and emission characteristics of a compression ignition engine fuelled with Karanja oil and its blends (10%, 20%, 50% and 75%) visa- vis mineral diesel. A series of engine tests, with and without preheating/pre-conditioning have been conducted using each of the above fuel blends for comparative performance evaluation. The performance parameters evaluated include thermal efficiency, brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC), and exhaust gas temperature whereas exhaust emissions include mass emissions of CO, HC, NO and smoke opacity. [8] In this study the effect of cycle by cycle variations on the performance of the LPG-Diesel dual fuel engine. They found for LPG flow rates between 0.2-0.3 Kg/hr, fluctuation in various parameters like peak pressure, rate of pressure rise and IMEP is minimum because the combustion is mainly due to diesel fuel. At LPG flow rate beyond 0.3 Kg/hr, the fluctuation in parameters increases due to the fact that combustion of LPG is not efficient because of mixture being very lean. They finally concluded that at full load fluctuation in IP, Indicated thermal efficiency and peak pressure remains steady at low value for most of the LPG flow rates. [9] In this study, an experimental investigation conducted on a single cylinder DI Diesel engine, which has been properly modified to operate under LPG–Diesel blended fuel conditions, using LPG–Diesel blended fuels with various blended rates (0%, 10%, 20%, 30%, 40%). Comparative results are given for various engine speeds and loads for conventional Diesel and blended fuels, revealing the effect of blended fuel combustion on engine performance and exhaust emissions. [10] In this research has shown that biodiesel-fueled engines produce less carbon monoxide (CO), unburned hydrocarbon (HC), and particulate emissions compared to mineral diesel fuel but higher NOx emissions. Exhaust gas recirculation (EGR) is effective to reduce NOx from diesel engines because it lowers the flame temperature and the oxygen concentration in the combustion chamber. However, EGR results in higher particulate matter (PM) emissions. [11] In this study, the combustion characteristics and emissions of two different petroleum diesel fuels (No. 1 and No. 2) and biodiesel from soybean oil were compared. The experimental results compared with No. 2 diesel fuel showed that biodiesel provided significant reductions in PM, CO, and unburned HC, the NOx increased by 11.2%. Biodiesel had a 13.8% increase in brake-specific fuel consumption due to its lower heating value. However, using No. 1 diesel fuel gave better emission results, NOx and brake-specific fuel consumption reduced by 16.1% and 1.2%, respectively. [12] In this investigation Gasification is a process in which solid biomass is converted into a mixture of combustible gases, which complete their combustion in an IC engine. Hence, producer gas can act as a promising alternative fuel, especially for diesel engines by substituting considerable amount of diesel fuels. Downdraft moving bed gasifiers coupled with IC engine are a good choice for moderate quantities of available biomass, up to 500kW of electric power. Hence, bio derived gas and vegetable liquids appear more attractive in view of their friendly environmental nature. Since vegetable oils produce higher smoke emissions, dual fuel operation could be adopted for improving their performance. [13] In this investigation the effect of variation in LPG composition on emissions and performance characteristics in a dual fuel engine run on diesel fuel and five gaseous fuel of LPG with different composition. To quantify the best LPG composition for dual fuel operation especially in order to improve the exhaust emissions quality while maintaining high thermal efficiency comparable to a conventional diesel engine, a two-cylinder, naturally aspirated, four-stroke, DI diesel engine converted to run as pilot-injected dual fuel engine. From the results, it is observed that the exhaust emissions and fuel conversion efficiency of the dual fuel engine are found to be affected when different LPG composition is used as higher butane content lead to lower NOx levels while higher propane content reduces CO levels. [14] In this investigation, on single cylinder vertical air-cooled diesel engine was modified to use LPG in dual fuel mode to study the performance, emission, and combustion characteristics.

2. EXPERIMENTAL SETUP AND PROCEDURE:

Fig.1 shows the schematic diagram of the complete experimental setup of LPG-Diesel/Vegetable oil dual-fuel engine. It is a single cylinder four-stroke, and water cooled diesel engine test rig which is modified to work in dual fuel mode (see Appendix A for Engine Specifications) and is directly connected to mechanical loading. It is provided with temperature sensors for the measurement of jacket temperature, calorimeter water and calorimeter exhaust gas inlet and outlet temperature. Pressure sensors are provided for combustion gas pressure and fuel injection pressure and an encoder is fixed for crank angle plots. Provision is also made for volumetric liquid fuel flow measurement. A differential pressure transducer detects the air pressure across the orifice. The LPG cylinder is connected to the inlet manifold through a rubber hose provided with a control valve. The volumetric LPG flow rate is measured by a rotometer.

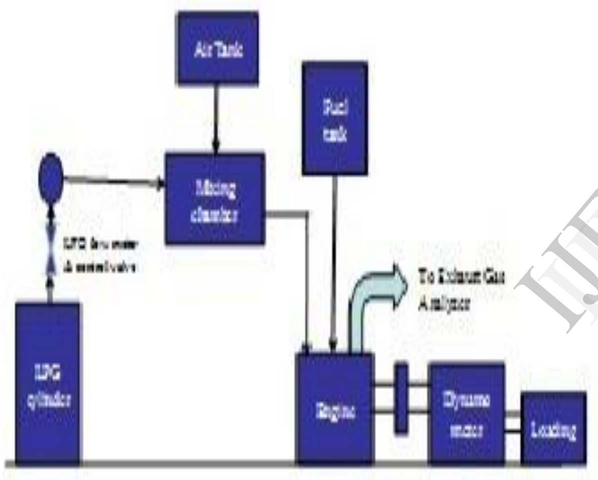

Fig.1 Experimental Setup

The experiment is conducted for various loads viz. 4, 6, 8, 10, 12 and with 190,210and 230 bar injection pressures. At each load, the corresponding performance parameters are recorded. The set of experiments are repeated for the next dual-fuel combination of LPG – Methyl esters of palm oil and various observations were noted down.

- **The specifications of the diesel engine are given in table 1.**

Make	Kirloskar model AV1
No. of Strokes per cycle	4
No. of Cylinders	1
Combustion chamber position	vertical
Cooling method	Water cooled
Starting condition	Cold start
Ignition technique	Compression ignition
Bore (D)	80 mm
Stroke (L)	110 mm
Rated speed	1500 rpm
Rated power	5 hp (3.72 kW)
Compression ratio	16.5 : 1

The various views of experimental set up, exhaust gas analyzer and smoke meter are shown in below figures 2, 3 and 4.

Fig 2 Engine Setup

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Fig 3 Exhaust Gas Analyzer

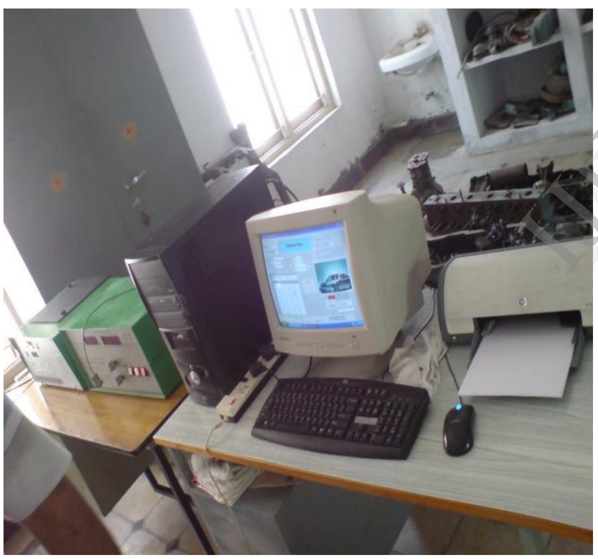

Fig 4 Emissions test setup

3. RESULTS AND DISCUSSIONS:

The variation of brake thermal efficiency with load at different injector opening pressures, when diesel was used as pilot fuel, is shown in Fig 5. At full load, for the injector opening pressure of 190 bar, 210 bar and 230 bar, the LPG flow rate of 1.5 LPM, 1.5 LPM and 2.0 LPM respectively, results in higher brake thermal efficiency. At higher LPG flow rate, the higher flame speed of LPG might have resulted in better combustion of the fuel.

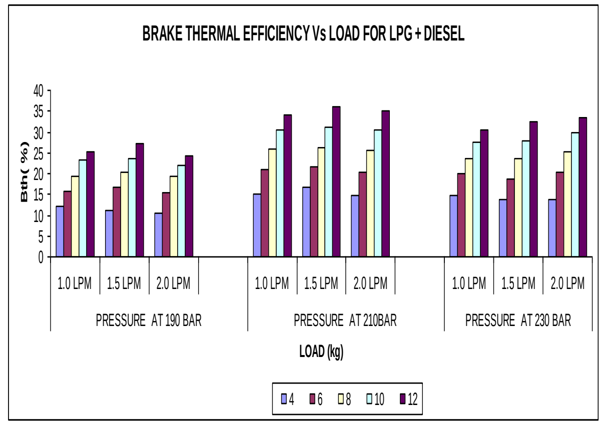

Fig.5 Brake Thermal Efficiency Vs Load

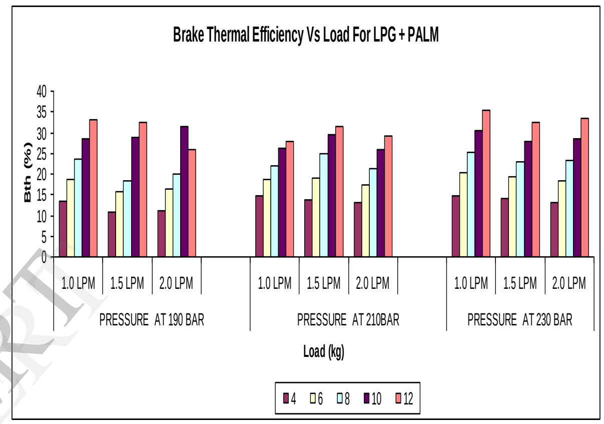

Fig.6 Brake Thermal Efficiency Vs Load

The variation of brake thermal efficiency with load at different injector opening pressures, when biodiesel was used as pilot fuel, is shown in Fig. 6. At full load, for the injector opening pressure of 190 bar, 210 bar and 230 bar, the LPG flow rate of 1.0 LPM, 1.5 LPM and 1.0 LPM respectively, results in higher brake thermal efficiency. Since the viscosity of the biodiesel is high, it requires large heat source for the combustion of fuel at lower injector opening pressure. But at higher injector opening pressure, atomization and penetration of pilot fuel is good and hence the injector opening pressure of 230 bar results in higher brake thermal efficiency at the LPG flow rate of 1.0 LPM

- **Brake specific energy consumption Vs Load:**

The variation of brake specific energy consumption with load at different injector opening pressures is shown in Fig. 7 & Fig. 8.

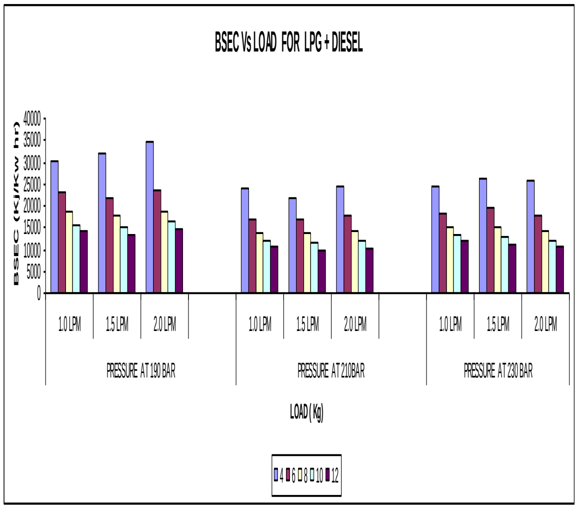

Fig.7 Brake specific energy consumption Vs Load

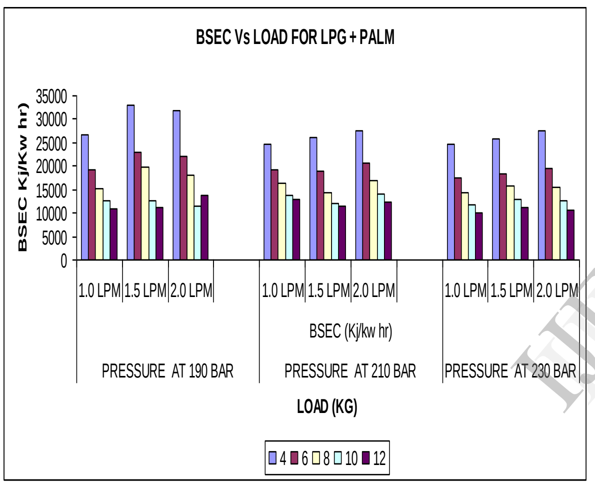

Fig.8. Brake specific energy consumption Vs Load

- **Emission Characteristics:**
- **CO Emission characteristics:**

The variation of carbon monoxide (CO) emission with load at different injector opening pressures, when diesel was used as pilot fuel, is shown in Fig. 9. At full load, for the injector opening pressure of 190 bars, 210 bars and 230 bar, the LPG flow rate of 2.0 LPM, 1.5 LPM and 1.0 LPM respectively, results in lower CO emission. The variation of carbon monoxide emission with load at different injector opening pressures, when biodiesel was used as pilot fuel, is shown in Fig. 10. At full load, for the injector opening pressure of 190 bar, 210 bar and 230 bar, the LPG flow rate of 1.0 LPM, 2.0 LPM and 1.5 LPM respectively, results in lower CO emission.

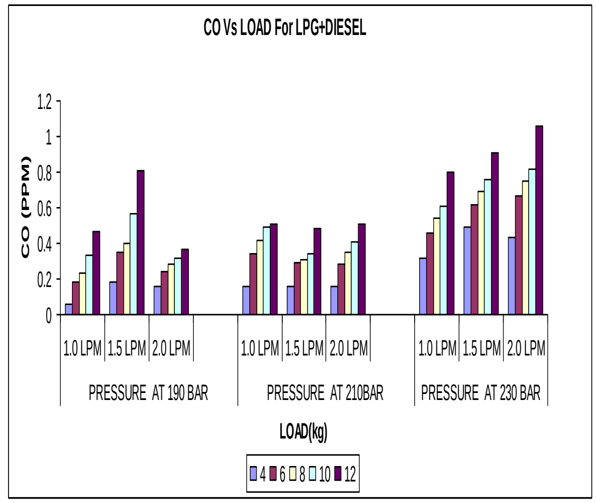

Fig.9. Carbon monoxide Vs Load

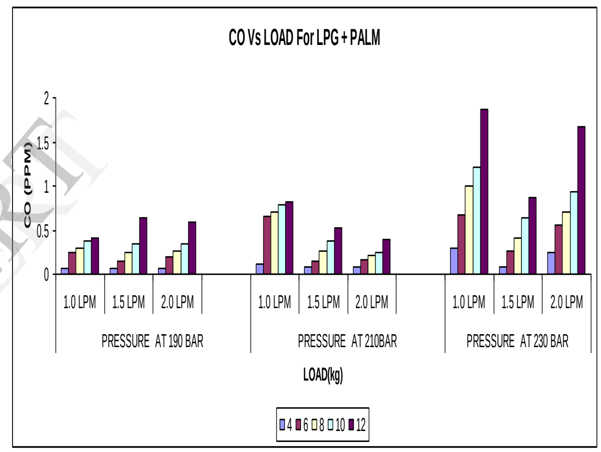

Fig.10. Carbon monoxide Vs Load

- **UBHC Emission characteristics:**

The variation of un burnt hydrocarbon (UBHC) emission with load at different injector opening pressures, when diesel was used as pilot fuel, is shown in Fig.11. At full load, for the injector opening pressure of 190 bars, 210 bars and 230 bar, the LPG flow rate of 2.0 LPM, 2.0 LPM and 1.0 LPM respectively, results in lower UBHC emission. The variation of UBHC emission with load at different injector opening pressures, when biodiesel was used as pilot fuel, is shown in Fig. 12. At full load, for the injector opening pressure of 190 bar, 210 bar and 230 bar, the LPG flow rate of 1.0 LPM, 1.5 LPM and 2.0 LPM respectively, results in lower UBHC emission.

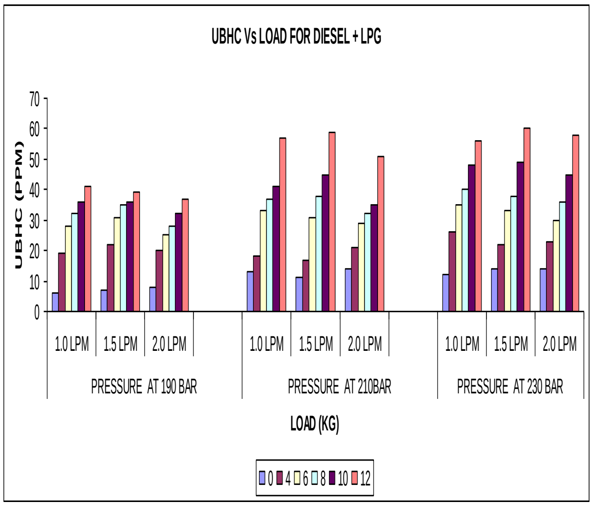

Fig.11. UBHC Vs Load

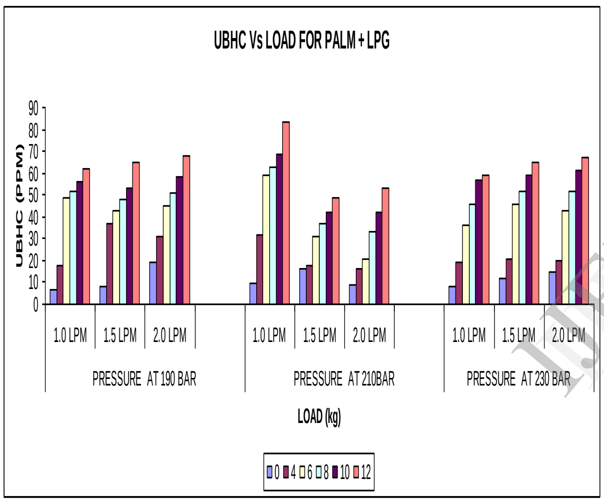

Fig.12. UBHC Vs Load

- **Smoke Emission characteristics:**

The variation of smoke emission with load at different injector opening pressures, when diesel was used as pilot fuel, is shown in Fig. 13. At full load, for the injector opening pressure of 190 bars, 210 bars and 230 bar, the LPG flow rate of 2.0 LPM, 2.0 LPM and 1.5 LPM respectively, results in lower smoke emission. The variation of smoke emission with load at different injector opening pressures, when biodiesel was used as pilot fuel, is shown in Fig. 14. At full load, for the injector opening pressure of 190 bar, 210 bar and 230 bar, the LPG flow rate of 1.0 LPM, 2.0 LPM and 2.0 LPM respectively, results in lower smoke emission.

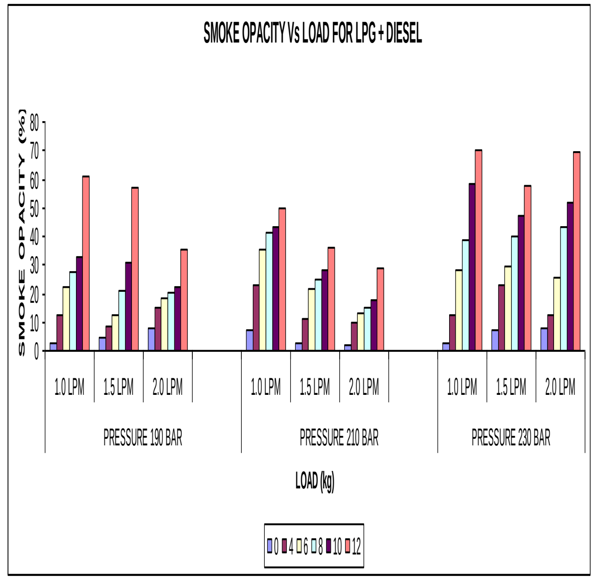

Fig.13. UBHC Vs Load

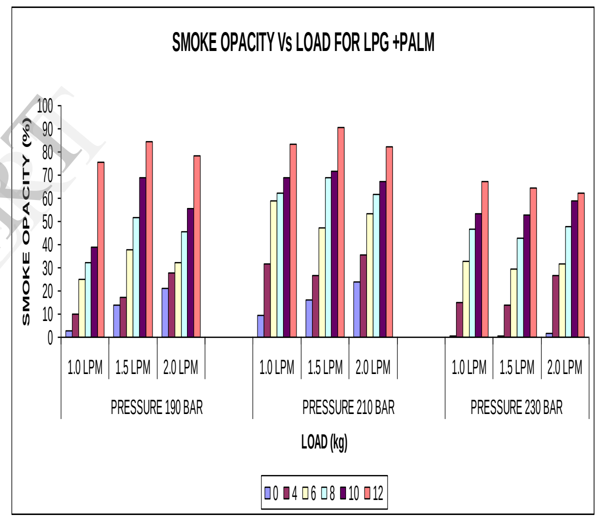

Fig.14. UBHC Vs Load

- **NO_X Emission characteristics**

The variation of NOx emission with load at different injector opening pressures, when diesel was used as pilot fuel, is shown in Fig. 15. At full load, for the injector opening pressure of 190 bar, 210 bar and 230 bar, the LPG flow rate of 1.5 LPM, 2.0 LPM and 2.0 LPM respectively, results in higher NOx emission. The variation of NOx emission with load at different injector opening pressures, when biodiesel was used as pilot fuel, is shown in Fig. 16. At full load, for the injector opening pressure of 190 bars, 210 bars and 230 bar, the LPG flow rate of 2.0 LPM, 1.5 LPM and 2.0 LPM respectively, results in lower NOx emission.

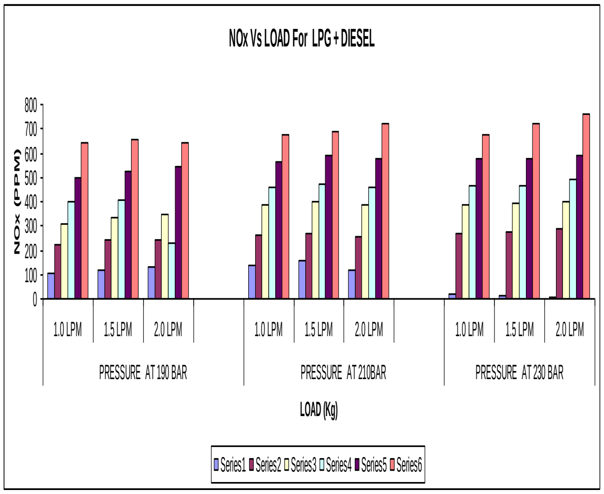

Fig.15. NOx Vs Load

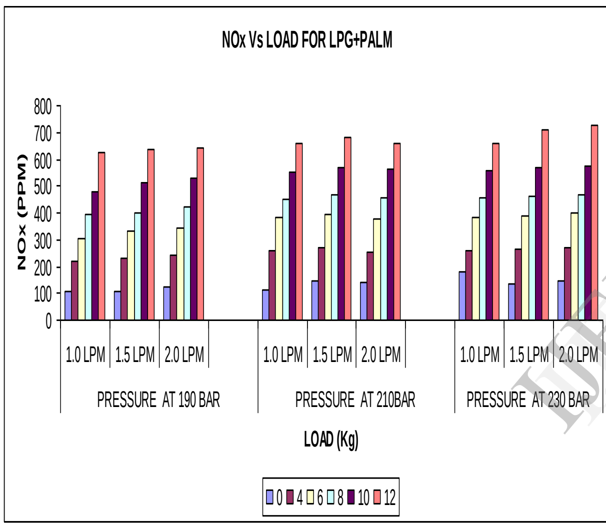

Fig.16. NOx Vs Load

4. Conclusions:

In the present work, an experimental investigation has been conducted to perform the optimization studies on the dual fuel engine using LPG as primary fuel and POME as pilot fuel on a CI Diesel Engine. The engine has been properly modified to operate under dual fuel operation using LPG as the primary fuel and Diesel, POME as an ignition source.

From the experimental results obtained with LPG - Diesel, LPG - POME in dual fuel engine the following conclusions are drawn:

- The kinematic viscosity and specific gravity of the Palm oil have reduced to a great extent by the esterification process.
- The existing diesel engine in made to work as Dual Fuel Engine by attaching a mixing chamber to the engine and giving the LPG gas connections to supply LPG. The engine performed satisfactorily with LPG - Biodiesel, so that the PAME can be used as an alternative fuels in existing Dual Fuel Engine without any hardware modification in the system.
- The brake thermal efficiency of the engine under dual fuel mode is less compared to normal diesel operation at lower and part loads. But at higher loads the efficiency of the engine with LPG - Diesel in a dual fuel mode is comparable with normal diesel operation.
- The highest obtained brake thermal efficiency with biodiesel was 35% and that for diesel operation was found to be 36%. This may be due to high viscosity and less calorific value of POME compared to that of diesel.

- The exhaust emissions like smoke opacity, CO, CO2, UBHC and NOx are higher for LPG - POME compared to LPG- Diesel operation which may be due to higher viscosity and lower volatility of biodiesel which leads to improper atomization and thus higher exhaust emissions.

- It was found that NOx emission is not effected much by the change in the flow rates of LPG at lower injection pressure of 190 bars but it has been significantly affected at higher injection pressures. It has also been observed that the amount of smoke in the exhaust is much lower at higher injection pressures of 230 bars which might be due to the better atomization of the fuel at higher injection pressures and at the same time NOx emissions are found on the higher side for higher LPG flow rates. An LPG flow rate of 1.0 LPM was found to the worst emission characteristics for most of the cases.

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