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INFLUENCE OF INJECTION PRESSURE ON THE PERFORMANCE AND EMISSIONS OF A DUAL FUEL ENGINE

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ABSTRACT:

The conventional fuels, petrol and diesel for internal combustion engines, are getting exhausted at an alarming rate. Further, these fuels cause serious environmental problems as they release toxic gases into the atmosphere at high temperatures and concentrations. Some of the pollutants released by the internal combustion engines are HC, CO, NO, smoke and particulate matter. In view of this and many other related issues, these fuels will have to be replaced, completely or partially, by less harmful alternative and eco-friendly fuels for the internal combustion engines.

At low engine load of 20%, at an injection pressure of 180 bar, the brake thermal efficiency was found to be 13.5% on diesel fuel mode, and reduced to 9.1% on dual-fuel mode with 50% LPG energy. When the fuel injection pressure was increased to 220 bar, the corresponding values were recorded to be 13.2% and 8.8%. The brake specific fuel consumption was measured to be 0.6017 kg/KWh on diesel fuel mode, and increased to 0.8971 kg/KWh on dual-fuel mode with 50% LPG energy, under the same operating conditions.

Key Words Dual-Fuel, Diesel, Emissions, Injection Pressure, LPG, and Performance

Introduction:

The purpose of internal combustion engines is to generate mechanical power from the chemical energy contained in the fuel. In internal combustion engines, as distinct from external combustion engines, this energy is released by burning the fuel inside the engine cylinder. The fuel-air mixture before combustion and the burned products after combustion are the actual working fluids. The work transfers which provide the desired power output occur directly between these working fluids and the mechanical components of the engine. Because of their simplicity, ruggedness and high power-to-weight ratio, the internal combustion engines have found wide range of applications in agriculture, transportation and power sectors.

In the present work, LPG, a by-product of petroleum refining process, is used to partly replace conventional diesel fuel for improved combustion efficiency and clean burning. A four-stroke, single-cylinder diesel engine, most widely used in agricultural sector, has been considered for the purpose of experimentation. The fuel injection pressure has been varied by adjusting the spring stiffness of the fuel pump.

Experimental Set Up:

The experimental setup consists of a single-cylinder, four-stroke diesel engine connected to an eddy-current dynamometer for loading of the engine. It is provided with necessary instruments for combustion pressure and crank angle measurements. The signals are interfaced to a computer through an engine indicator to obtain pressure-crank angle diagram. Provision is also made for interfacing air flow, fuel flow, temperatures and load measurement.

The schematic layout of the experimental set up is shown in figure 1.

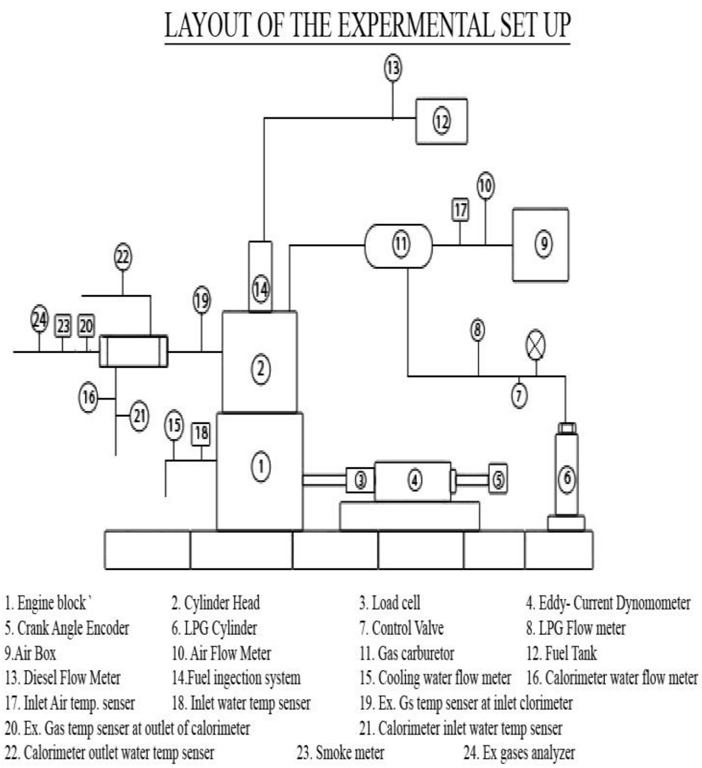

Figure 1 Layout of the Experimental Set-up

Fuel Injection Pressure Measurement

The fuel injection pressure has been measured by using a mechanical type of hand operated pressure gauge. The injection pressure was varied by adjusting the spring tension of the fuel injector. The spring tension was adjusted for the required fuel injection pressures of 180 bar to 220 bar with a step of 10 bar. The positions of the spring for these pressures have been marked on a template, to avoid frequent removal of the fuel pump assembly. These markings were cross-checked for several times, by running the engine.

Results and Discussion 5.1 20% Engine Load

The effect of fuel injection pressure on the brake thermal efficiency of the engine for different proportions of LPG, at 20% engine load, is shown figure 1 At any injection pressure, it is higher for diesel fuel operation, and it is reduced with an increase in the LPG content. For instance, at the injection pressure of 200 bar, the brake thermal efficiency was 14.4% on the diesel fuel mode and went down to 9.8% on the dual-mode with 50% LPG on energy basis, a drop of almost 32%. This could be due to high ignition temperature requirements of air-LPG mixture. Gettel et al (50), have reported the same results in their investigations.

The fuel injection pressure has a strong influence on the smoke density under all operating conditions. The variation of smoke density with the fuel injection pressure at 20% engine load is illustrated in figure 3. From this figure it may be observed that, the smoke density is reduced with an increase in the fuel injection pressure, on both diesel fuel and dual-modes of operation. Further, at any injection pressure, it has increased with an increase in the LPG content. At an injection pressure of 200 bar , the smoke density has been observed to be 9.5 HSU on the diesel fuel mode and as high as 3.6 HSU on the dual-fuel mode with 50% LPG energy.

Figure 4 represents influence of the fuel injection pressure on the emissions of NO, at low engine load of 20%. It is evident from the figure that the emissions of NO have increased with an increase in the fuel injection pressure, on both the modes of operation. However, at any injection pressure, the addition of LPG content has resulted in a decrease in the emissions of NO. This is a favorable aspect with regards to dual-fuel operation at low engine loads. The emissions of NO were found to be 278 ppm on diesel fuel mode and as low as 158 ppm on the dual-fuel mode with 50% LPG energy. At 20% engine load, LPG substitution could be done up to 50%, implying that precious diesel could be conserved by 50%, without sacrificing the engine power.

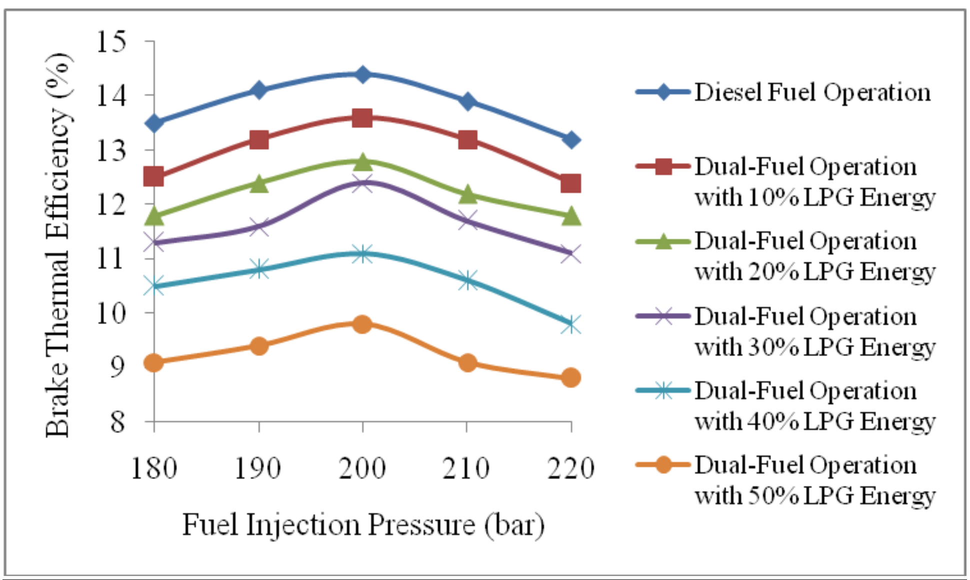

Figure 2 Effect of Fuel Injection Pressure on the Brake Thermal Efficiency on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 20% Load

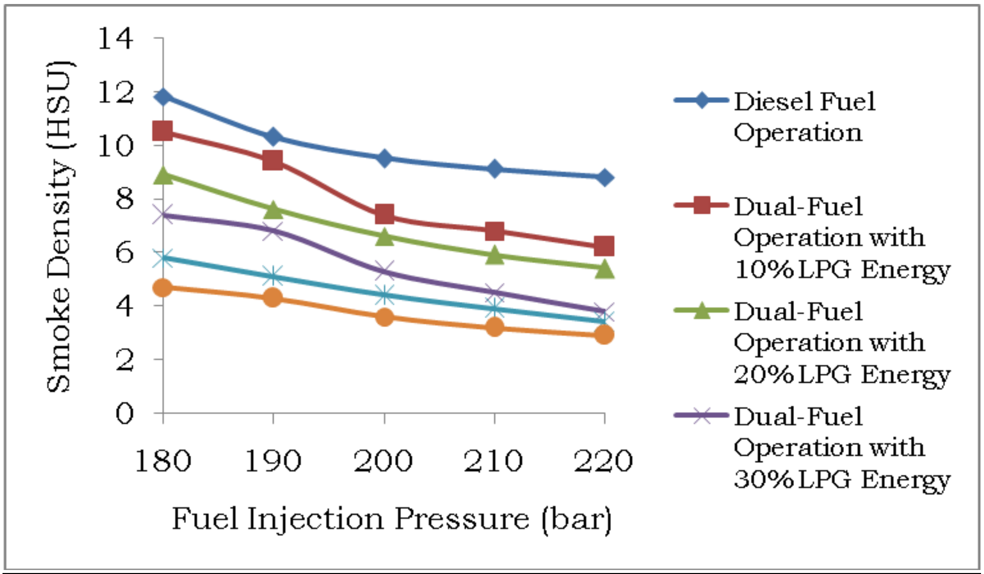

Figure 3 Effect of Fuel Injection Pressure on the Smoke Density on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 20% Load

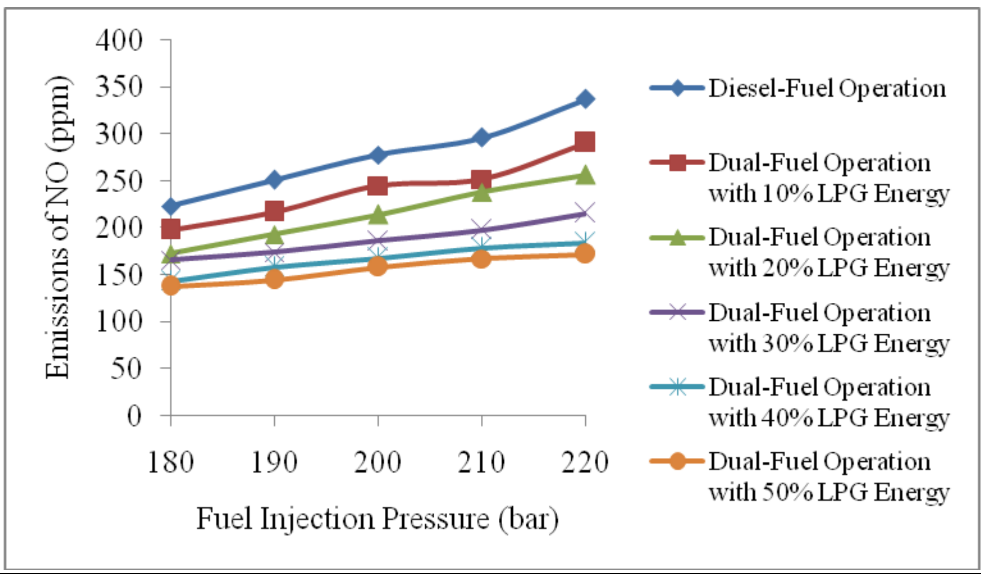

Figure 4 Effect of Fuel Injection Pressure on the Emissions of NO on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 20% Load

5.2 60% Engine Load

The effect of fuel injection pressure on the brake thermal efficiency of the engine at 60% load, for various modes of operation is shown in figure 5. At any fuel injection pressure, brake thermal efficiency is observed to increase with an increase in the LPG content. Further, on any mode of operation, it is found to increase with an increase in the injection pressure. This could be due to improved combustion characteristics of air-LPG mixture at 60% engine load. At an injection pressure of 200 bar the brake thermal efficiency has been observed to be 22.3% on the diesel fuel mode and 26.6% on the dual-fuel mode with 40% LPG energy. The hike in the brake thermal efficiency is 19.3%.

The variation of smoke density with the injection pressure for various proportions of LPG, at 60% engine load, is described in figure 6. It is evident from the figure that, the smoke density is reduced with an increase in the fuel injection pressure, on both the modes of operation. Further, at any injection pressure, it is significantly reduced with the addition of LPG. This could be due to improved combustion properties of air-LPG mixture at 60% engine load. For instance, when the fuel injection pressure was 200 bar, the smoke density was observed to be 27.6 HSU on the diesel fuel mode of operation and as low as 10.6 HSU on the dual-fuel mode of operation with 40% LPG energy. The drop is about 62%, whuch is a sginificant advantage of dual-fuel operation.

The variation of emissions of NO with fuel injection pressure at 60% engine load for diesel fuel and dual-fuel modes of operation is represented in figure 7. At any injection pressure, the emissions of NO are observed to decrease with an increase in LPG content. On any mode of operation, NO emissions are found to increase with an increase in the fuel injection pressure. This is a set back as far as the dual-fuel operation is concerned at mid and high engine loads. At an injection pressure of 200 bar, the emissions of NO have been found to be 453 ppm on diesel fuel operation and as high as 986 ppm on the dual-fuel operation with 40% LPG by energy.

At 60% engine load, diesel could be substituted by LPG upto 40% on the energy basis. Beyond 40% LPG, the engine operation has been observed to be rough, jerky and inconvenient.

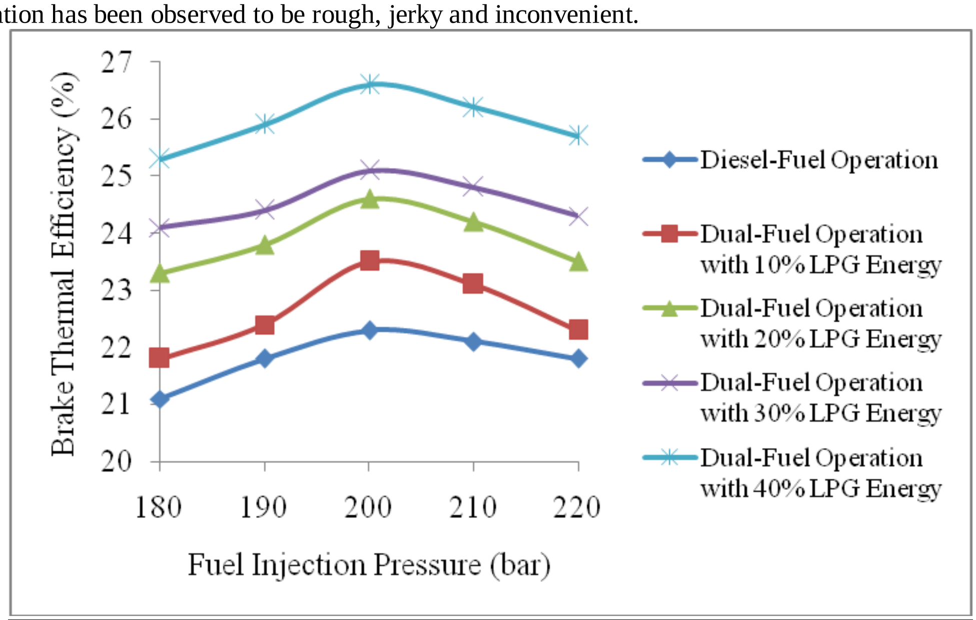

Figure 5 Effect of Fuel Injection Pressure on the Brake Thermal Efficiency on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 60% Load

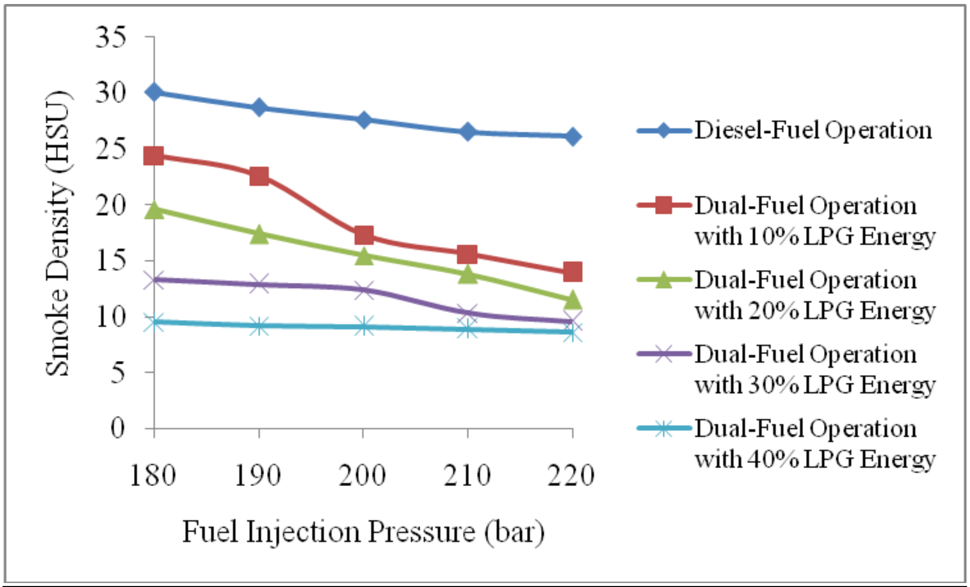

Figure 6 Effect of Fuel Injection Pressure on the Smoke Density on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 60% Load

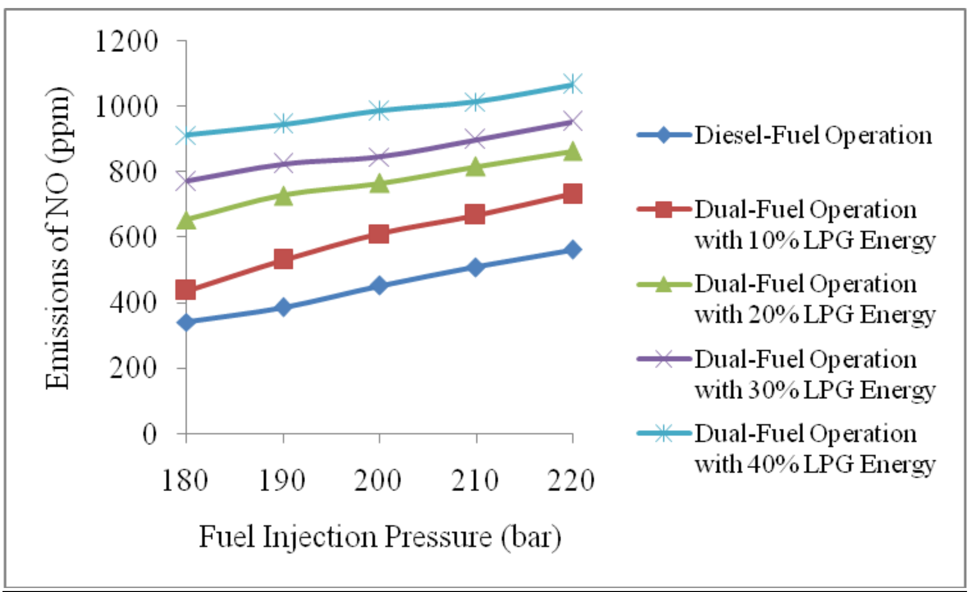

Figure 7 Effect of Fuel Injection Pressure on the Emissions of NO on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 60% Load

5. 3 80% Engine Load

The fuel injection pressure has a strong effect on the brake thermal efficiency of the engine at high engine loads. This is true on both diesel fuel and dual-fuel modes of operation. Figure 8 represents this trend at 80% engine load. It is clear from this figure that, brake thermal efficiency is highest at an injection pressure of 200 bar for the diesel fuel operation and for the dual-fuel operation with 20% LPG content, the ideal fuel injection pressure is 210 bar. From figure 8, it can be seen that at an injection pressure of 200 bar, brake thermal efficiency of the engine is 25.7% on diesel fuel mode of operation, and it is increased to 26.8% on dual-fuel mode of operation with 20% LPG by energy.

The effect of fuel injection pressure on the smoke density on various modes of operation is shown in figure 9, at 80% engine load. It can be seen from the figure that, an addition of LPG resulted in a decrease in the smoke density, on both the modes of operation. Further, on any mode of operation, the smoke density is reduced with an increase in the fuel injection pressure. The reduction in the smoke density could be due to improved combustion characteristics of air-LPG mixture at high engine loads. From figure 9, it may be seen that the smoke density at an injection pressure of 200 bar is 34.8 HSU on diesel fuel mode of operation and as low as 18.2 HSU on dual-fuel mode of operation with 20% LPG by energy. The decrease in smoke density is almost 48%.

The emissions of NO are observed to increase with an increase in the fuel injection pressure at 80% engine load. This is true on diesel fuel and dual-fuel modes of operation, as can be seen in figure 10. Further, there was a steep reduction in the emissions of NO, with an addition of LPG, at all the fuel injection pressures. This is the major drawback of dual-fuel mode of operation. At an injection pressure of 200 bar, emissions of NO were found to be 954 ppm on the diesel fuel mode of operation and as high as 1208 ppm on the dual-fuel mode of operation with 20% LPG by energy. The increase in the emissions of NO is almost 27%.

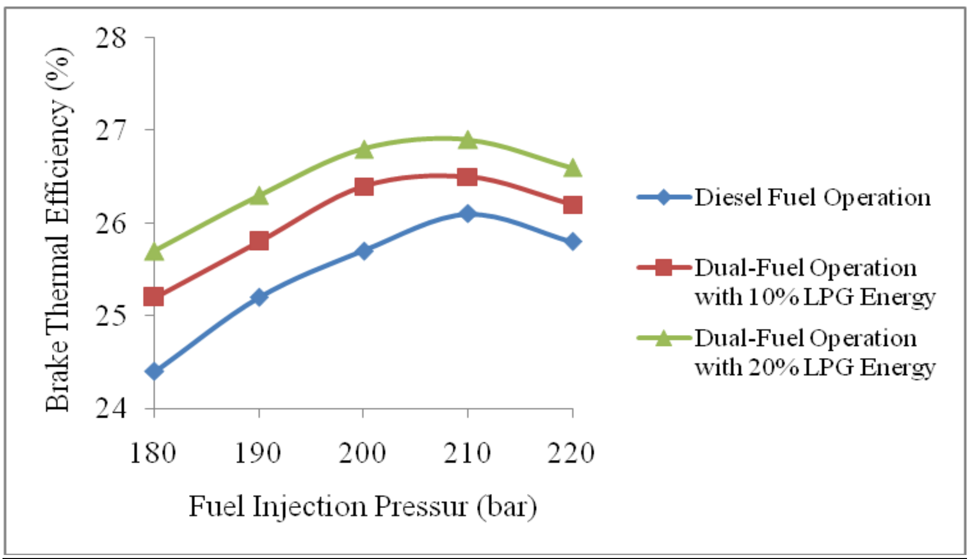

Figure 8 Effect of Fuel Injection Pressure on the Brake Thermal Efficiency on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 80% Load

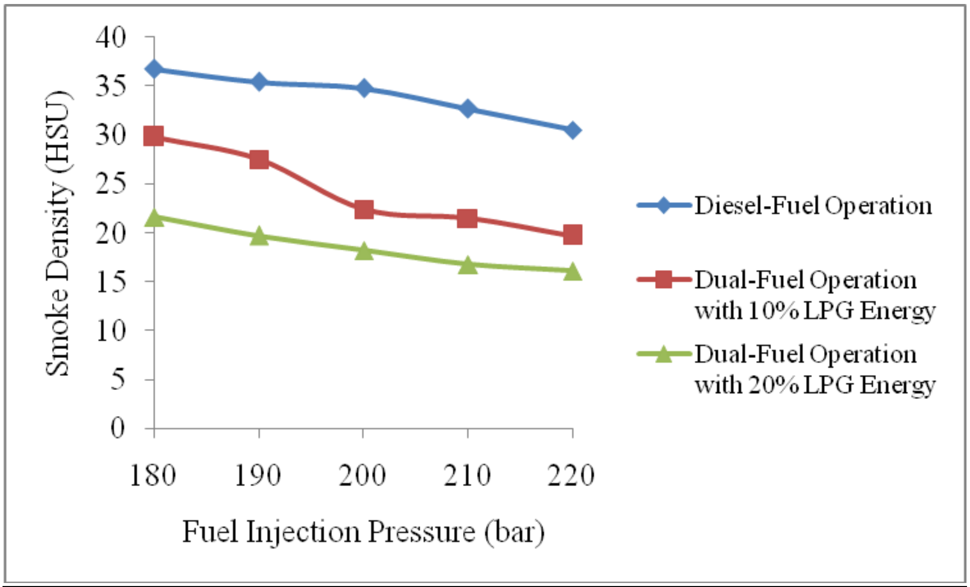

Figure 9 Effect of Fuel Injection Pressure on the Smoke Density on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 80% Load

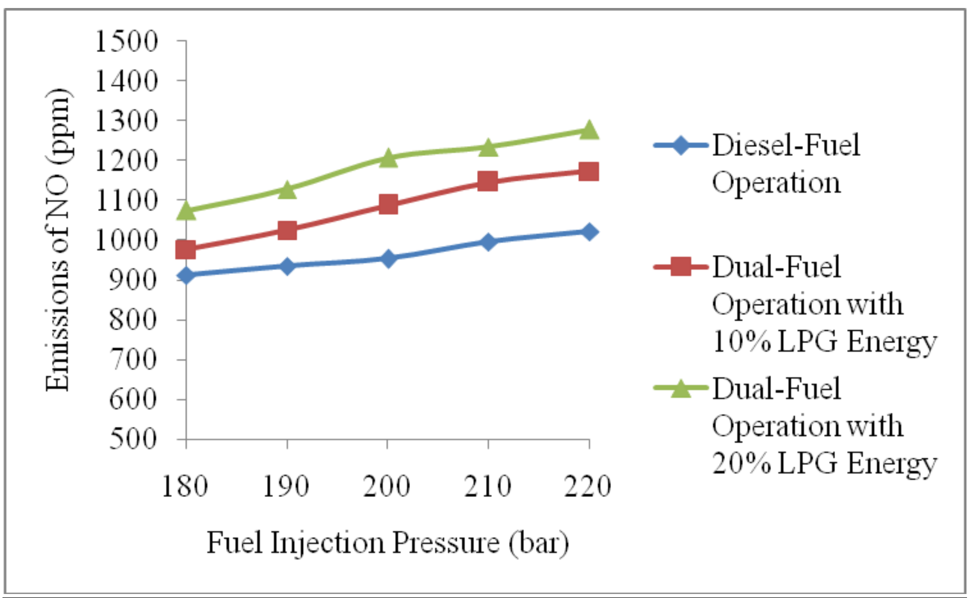

Figure 10 Effect of Fuel Injection Pressure on the Emissions of NO on Dual-Fuel Mode of Operation for Different Levels of Substitution of LPG at 80% Load

CONCLUSIONS:

- The brake thermal efficiency of the engine at low engine load of 20% was found to decrease with an increase in the LPG content. This could be due to poor combustion characteristics of air-LPG mixture at low load conditions. High auto-ignition temperature of LPG might be the basis for the poor combustion characteristics of air-LPG mixture.

- At low engine load of 20%, at an injection pressure of 180 bar, the brake thermal efficiency was found to be 13.5% on diesel fuel mode, and reduced to 9.1% on dual-fuel mode with 50% LPG energy.

- At mid engine load of 60%, the fuel injection pressure has a significant effect on the brake thermal efficiency of the engine. On diesel fuel mode of operation, it has increased from 21.1% at an injection pressure of 180 bar, became maximum of 22.3% when the fuel was injected at 200 bar and then reduced to 21.8% with further increase in the injection pressure to 220 bar. Same trend was observed on the dual-fuel mode of operation.

- At 80% engine load, the brake thermal efficiency was found to vary with the fuel injection pressure. On dual-fuel mode of operation with 20% LPG energy, it was found to be 25.7% when the fuel injection pressure was 180 bar, and increased to 26.8% when fuel was injected at 200 bar.

- The smoke density has been observed to decrease with an increase in the fuel injection pressure on both the modes of operation. Further, at any injection pressure, it was found to reduce with the addition of LPG.

- Lowest smoke was observed when the fuel injection occurred at 220 bar, obviously due to better combustion of air-LPG mixture, being 8.8 HSU on diesel fuel mode and 2.9 HSU on dual-fuel mode with 50% LPG. Similar trend was observed at mid and high engine loads.

- Reduction in the smoke density at all the engine loads is one of the salient features of dual-fuel operation.

- Emissions of NO were observed to increase with an increase in the fuel injection pressure on both the modes of engine operation. At any injection pressure, at low engine load, they were found to decrease with an increase in the LPG content.

- At mid and high engine loads, emissions of NO were found to increase with an increase in the LPG content.

- At lower engine loads, the engine performance on dual-fuel mode is found to be inferior compared to that of the diesel fuel mode.

- At mid and higher engine loads, the dual-fuel mode of operation was found to be superior compared to that of the diesel fuel mode of operation.

- At low engine loads, the engine may be operated on the diesel fuel mode, and at higher engine loads, the engine could be switched over to the dual-fuel mode.

- The engine operation was observed to be smoother on the dual-fuel mode of operation, due to better mixing of air and LPG and thus improved combustion.

- With an increase in LPG energy, the engine performance was found to reduce at lower loads, and it was found to increase at mid and higher loads.

- Diesel could be replaced by LPG on energy basis up to 50% at lower load of 20%, up to 40% at mid-load of 60%, but at higher load of 80% it could be done only up to 20%.

- At low engine loads, further addition of LPG resulted in ignition failure and starting difficulties.

- At higher loads, with the addition of more LPG energy, the engine operation has become more noisy and rough. This could be considered as the on-set of engine knock.

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