PERFORMANCE AND EXHAUST EMISSION CHARACTERISTICS OF A DIESEL ENGINE RUNNING WITH LPG

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Abstract

This paper investigates the effects of LPG composition, Which is injected during air inlet period, on emissions and performance characteristics. The engine has modified to determine the best LPG composition for dual operation in order to improve the emissions quality while maintaining high thermal efficiency in comparison to a conventional diesel engine, a single cylinder, naturally aspirated, four-stroke, DI diesel engine converted to run as dual fuel engine. LPG injection rate were selected as 5%, 10%, 15% and 25% on a mass base. It has been that although maximum increase in brake power and brake torque were found as 21.59% and NOx emission decreased by 44.7% at 1200 rpm with 25% LPG, brake specific consumption (SFC) and smoke emission drastically increased by 16.7% and 80%, respectively. Minimum SFC and maximum brake efficiency obtained with 15%LPG between 1400 and 1800 rpm engine speeds. Optimum injection rate is found at 5% LPG in terms of exhausts emissions and performance. At this injection rate SFC, NOx and smoke emissions decreased by 9%, 27.6% and 20% at 1600 rpm, respectively.

Keywords: Diesel engine; Dual fuel; LPG; NOx, Smoke

1. Introduction

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. Therefore, it is more economical and of environmental advantage to use gaseous fuel in Diesel engines that use the dual fuel concept. However, when LPG is used in the conventional diesel engine, a difficulty is encountered in self-ignition because of its lower cetane number. Thus, 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. Various studies on alternative fuels have been conducted for reducing the consumption of Diesel fuel and important pollutant emissions such as nitrogen oxide (NOx) and particulate emissions[1-4].

LPG can be used in dual fuel compression ignition engines as a primary fuel[5-7]. In dual fuel compressed ignition system (CI) engine is operated with LPG as primary fuel and a pilot amount of diesel fuel is used as an ignition source. The LPG is inducted along with the intake air and is compressed like in a conventional diesel engine. The mixture of air and LPG does not auto-ignite due to its high auto-ignition temperature. A small amount of Diesel fuel is injected near the end of the compression stroke to ignite the gaseous mixture. The Diesel fuel auto-ignites and creates ignition sources for the surrounding air–LPG mixture. The pilot Diesel fuel, which is injected by the conventional diesel injection equipment, normally contributes only a small fraction of the engine power output[8, 9].

Karim et al.[10, 11] has reported that in dual fuel engines under low loads, when the LPG concentration is lower, the ignition delay of the pilot fuel increases and some of the homogeneously dispersed LPG remains unburned, resulting in poor emission performance. Poor combustion of LPG under low loads because of a dilute LPG–air mixture results in high CO and unburned HC emissions. Whereas, at high loads, increased admission of LPG can result in uncontrolled reaction rates near the pilot fuel injection and lead to knock.

Qi et al.[12, 13] conducted an experimental investigation on a single cylinder DI Diesel engine, which has been properly modified to operate under LPG–Diesel dual fuel conditions, using LPG–Diesel blends of various rates; 0%, 10%, 20%, 30% and 40%. They compressed LPG by pressured N_2 gas to mix with the diesel fuel in a liquid form. They found that LPG-Diesel blended fuel combustion is a promising technique for controlling both NOx and smoke emissions even on existing DI Diesel engines.

The purpose of the present study is to investigate the effects of proportion LPG composition in the fuel mixture, which is injected during air inlet period, on emissions and performance characteristics in a dual fuel engine running on diesel fuel. The optimum LPG proportions for dual fuel operation are investigated in order to improve the emission quality while maintaining high thermal efficiency in comparison to a conventional diesel engine. The amount of LPG was determined on the basis of mass base with the parentages of 5, 10, 15 and 25 of standard engine fuel consumption for all over the engine speed tested for full load condition.

2. Experimental

The engine used is a single cylinder, naturally aspirated, four-stroke, and water cooled, direct injection Diesel engine with a bowl in piston combustion chamber. Fig. 1 shows the experimental setup and the specifications of the engine are given in Table 1.

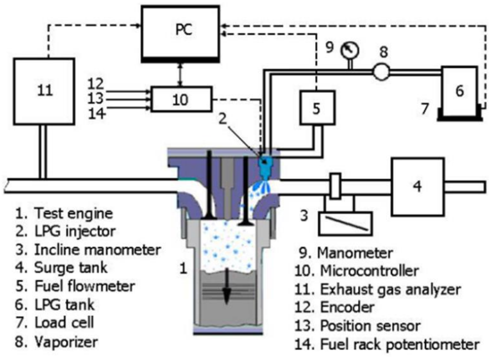

Figure 1. Block diagram of the experimental setup

Table 1 Specification of the test engine

Engine type	Super Star water cooled
Bore [mm]	108
Stroke [mm]	100
Cylinder number	1
Stroke volume [l]	0.92
Power – 1500rpm, kW	14.7
Injection pressure, [bar]	175
Injection advance, [CA bTDC]	35
Maximum speed [rpm]	2500
Cooling type	Water
Injection type	DI

In order to measuring to brake torque the engine is coupled with a hydraulic dynamometer of 50 kW absorbing capacity. Using a load cell with the precision of 0.1 N. full load tests were conducted at the engine speeds of 1200, 1400,1600, 1800,2000, 2200 and 2400 rpm. Fuel consumption was measured by an electronically controlled balance with the precision of ±0.1 g.

An electronically controlled LPG injection system was developed for dual fuel operation. The system composes of a rail, solenoid type injector, electronic control unit and an absolute encoder. The encoder gives a reference pulse signal (5V) to determine the engine top dead centre (TDC). The TDC sign on the flywheel of the test engine was matched with the reference output of the encoder by using digital oscilloscope before testing.
NOx, CO and HC emissions were measured with MRU Spectra 1600 L gas analyzer. Smoke emissions were measured with Bilsa Mode 5000 opacimeter.

3. Results and discussion

The main scope of the present work is to examine the effect of different rates of LPG injection into the engine manifold during inlet period on performance and the pollutant emissions. In the following pent ions, the results are given comparatively for all test cases examined.

3.1 The effects on performance parameters

Figs. 2 compares brake torques of the diesel engine working with diesel fuel and LPG mixtures respectively. LPG injections into the engine through inlet manifold affect the brake power and torque considerably. The figures show that as the injection rate of LPG increases, the power and the torque increase considerably. While maximum brake torque was obtained as 65.2 Nm at 1800 rpm with standard diesel operation; the torque were reached to a maximum at the speeds of 1200 rpm and 1800 rpm with the mixture of 15% LPG. Maximum increase in power and torque is obtained with 25% LPG injection at this engine speed. However, specific fuel consumption (SFC) rises compared to that of standard diesel engine as can be seen from Fig. 4. Maximum improvement in SFC is %9 with 15% LPG injection rate and at the engine speed of 1600 rpm. When the LPG injection is cut-off at 1200 rpm, it is shown that fuel savings (in SFC) changes between 4.5% and 9%, and brake thermal efficiency varies from 1.5% to 3.5%.

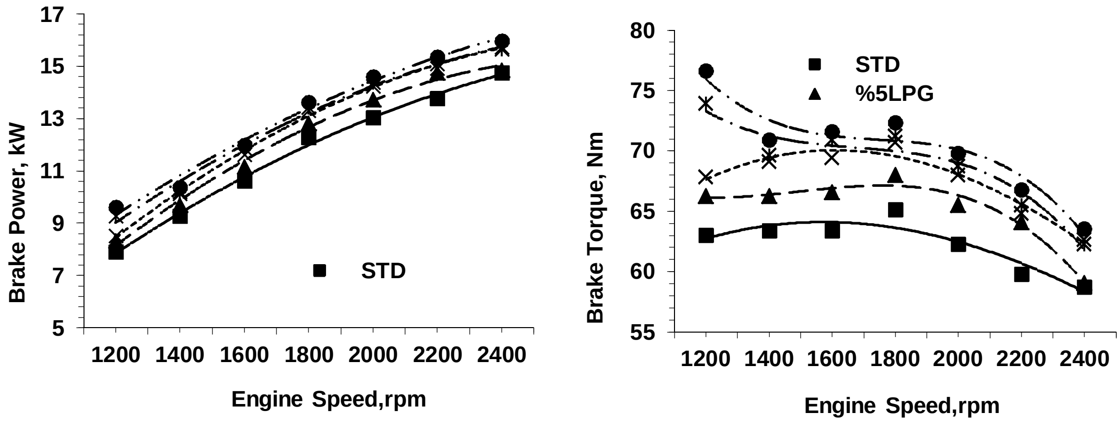

Figure 2. Variations of the brake power and torque depending on various LPG injection rates

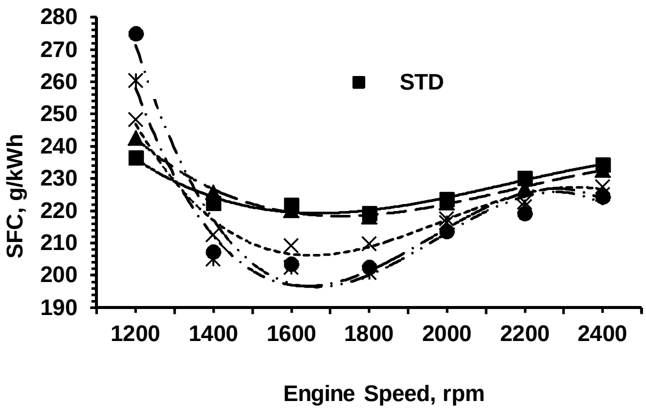

Figure 3. Variations of the brake power and torque depending on various LPG injection rates

3.2 The effects on pollutant emissions

3.3.1 NOx emissions

At the full load conditions the variations of NOx emissions from the engine exhaust when using both Diesel fuel and various LPG-Diesel fuel mixtures are given in Fig.4a. Maximum decrease was observed at the speed of 1200 rpm which is 44.7% with the 25% LPG injection rate.

3.3.2 Carbon monoxide emissions

The results for CO emissions of the engine, which was operated under both Diesel fuel and diesel fuel with different LPG compositions, are shown in Fig. 4b for all the speeds tested under full load condition. It is seen from the Figure that CO emissions significantly increased at 1200 rpm for 15% and 25%LPG rates. While CO emissions were measured as %0. 6 with the diesel fuel operation at this speed, the emissions with the other LPG compositions at the same speed are 0.7 % for 5% LPG, 0.8% for 10% LPG, 1.9% for 15%LPG and 2.2% for 25% LPG. The increase rate for 15% and 25% at this speed were 206% for 15% LPG and 250% for 25% LPG.

3.3.3 Unburned Hydrocarbon Emissions

The variation of unburned HC emissions of the engine, which was operated under both Diesel fuel and with different diesel fuel- LPG compositions are shown in Fig. 4d. The HC emissions increased with increase of the LPG mass fraction at all the engine speeds tested. It is obviously seen from the Figure that the increase rate were to be higher at 1200 rpm for 15% and 25% LPG rates compared to the other speeds. In general, the emissions increased with the increase of engine speed.

3.3.4. Smoke emissions

Figures 4b shows the smoke emission behavior of the engine operated with LPG compared to the standard diesel operation. It can be observed that the engine operated with 5% LPG exhibits a significant reduction in smoke emissions at all loads.

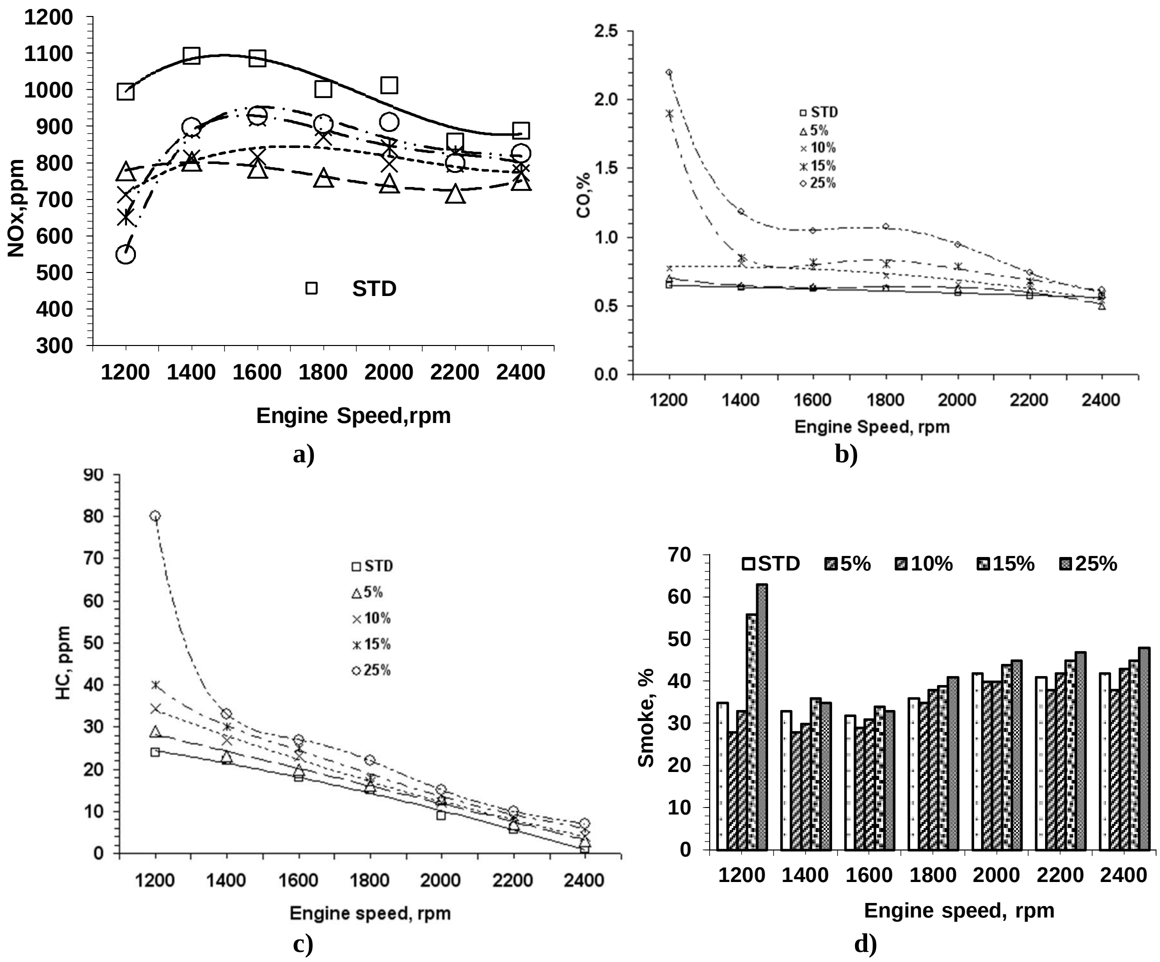

Figure 4. Variations of emissions depending for various LPG injection rates

4. Conclusion

In the present work, an experimental investigation has been conducted to examine the effect of injection of LPG into the engine manifold (just adjacent to inlet valve) during inlet period has been investigated in terms of the performance and the pollutant emissions. From the analysis of the experimental data, it is revealed that injection LPG during inlet period of the engine considerably improved the brake power, specific fuel consumption, brake efficiency and brake torque with increase of LPG fraction in mixture for the engine speeds tested but 1200 rpm at the full load conditions. NOx emissions also decreased in a big scale at this speed. When exhausts emissions and performance trade-off considered, optimum injection rate is found at 5% LPG injection rate. Minimum SFC and maximum brake efficiency obtained with 15%LPG between 1400 and 1800 rpm engine speeds. Although CO and HC emissions increased slightly with 5% LPG, these can be tolerated when it is considered significant improvements in performance, NOx and smoke emissions

5.References

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