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Effect of a New Design Electronic Control System on the Emissions Improve for Diesel Engine Operation by (Diesel + LPG)

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ABSTRACT

Diesel engines are important and widely used in many fields in industry, agriculture, transportation, and electricity, but the disadvantages of these engines are environmental pollution due to exhaust gas emissions as well as the high cost of diesel fuel. These defects made the topic an important research topic to search for less polluting and less expensive fuel to use it in diesel engines, and this makes LPG a good candidate for diesel supplements because it contains several technical advantages in this regard, being environment friendly and has a high heat value to increase energy production And also its price is cheap compared to diesel fuel. In this study, an electronic system was designed to control the LPG injector and a magnetic sensor was installed on top of a single-cylinder and air-cooled diesel engine head. Tested using at two-stage first diesel fuel D-100 and second stage, dual-fuel in three modes (LPG-25, LPG-50, and LPG-75). The test was under loads (0%, 25%, 50%, 75% and 100%) at different speeds (1000, 1500 and 2000 rpm). A decrease in emission ratios (NOx, HC, CO, and CO_2) is observed in all operating modes with LPG, and the best emission reduction mode is LPG-75. As for O_2 gas, the results showed almost the same in diesel case.

1. INTRODUCTION

Due to the rapid increase in the population around the world increased demand for internal combustion engines, especially for diesel engines compared to other types of engines in the same size range it has a large capacity for high use in transportation, irrigation, electricity generation, and heavy industries. Based on the widespread use of diesel engines and the protection placed on the production of diesel engines is increasing year on year and the transport sector is accountable around 35% of pollutant emissions [1] and approximately 20–30% of all consumption of energy [2]. Significant research is being carried out on diesel engines which develop fuels. CI engines release different types of pollutants like NOx, HC, CO2, CO, particles, soot particles, etc. [1, 3-5]. Regardless of the other parameters of the engine, the emission results from the phenomenon of the combustion process and the chemistry of the fuel used. By using biodiesel and gaseous fuel additives. There are several studies on diesel engines to boost engine efficiency and reduce harmful emissions by using alternative fuels. Exhaust emissions from the CI engine are harmful to our respiratory system, and also effective on environment pollution [4, 6-14]. In addition to engine parameters, the emission depends on the combustion process and the chemistry used for the fuel. The use of biodiesel and gaseous fuel additives will significantly reduce these emissions. LPG is one of the leading alternative fuels. LPG is safer than petrol and diesel, as it consists mainly of simple hydrocarbon compounds. LPG contains very little sulfur and is free of lead and most additives [15-17]. Compared with vehicle emissions of petrol and diesel, LPG-driven vehicle emissions include lower levels of hydrocarbon compounds (HC), nitrogen oxides (NOx), sulfur oxides, Air toxics, and particulate matter [18].

There are two ways to keep pollution under control [1]. The first approach is to monitor emissions after combustion, using different devices at the exit point such as catalytic converters, thermal converters, etc. The second method, which is to regulate emissions during combustion. This can be accomplished either by modifying the fuel injection timing or by adding some external additives that can operate inside the combustion chamber and produce clean exhaust. Typically only about 82 percent of fuel burns entirely in typical diesel engines [19] by adding LPG to the combustion process, it is possible to burn nearly 98 percent of fuel. Emissions issues such as Particulate Matters (PM) and NO× are now well known to be mainly associated with diesel engines. These emissions can be reduced substantially with the use of LPG. Compared to natural gas, LPG has the advantage of low-pressure fuel, ease of transport, and better handling. LPG can be used as an alternative fuel in spark-ignition engines as well as in dual-fuel usage as an alternative fuel for the compression ignition engines with diesel. The relatively high auto-ignition temperature of the LPG is an advantage that allows the compression ratio of conventional diesel engines to be maintained and minimal modifications to the engine to be made. It has the potential for significant savings in diesel fuel and increased system power [20, 21]. The response of the engine is smoother and faster when the gas is added and the replacement is high. The service schedule may be extended due to the fumigation of gaseous fuel, reduced injection service, and longer oil change intervals due to less contamination of engine oil [15].

The extraction of many natural gas liquids (NGL) in many gas fields in increased the country's capacity to produce liquefied petroleum gas. In the spark ignition engines investigated by Chiriac et al. [22] and Ehsan et al. [23], LPG was successfully used, but the dual-fuel operation in the diesel engine was relatively less investigated. Jian, et al. [24] A new type of dual system has been developed that could effectively turn traditional diesel engines into dual-fuel engines (LPG+Diesel engines and CNG+Diesel engines), using either only diesel or dual-fuel, A diesel and LPG as well as diesel and CNG engines. These diesel-LPG engines were applied to the diesel busses in Guangzhou City's public transport, one of China's largest cities. Compared to the diesel baseline engine, it was found that soot emissions were significantly reduced and fuel consumption improved with the diesel+LPG engine. The LPG commodity strategy is also tackled to meet the demands of soot emission, fuel efficiency, transient performance, and output power simultaneously. Rao and others [6, 25, 26]. Experimental tests were performed on a single-cylinder water-cooled ignition compression engine operating in dual-fuel mode with diesel as pilot fuel and LPG as the main fuel. The engine was run under different operating conditions and for the best efficiency, the optimal combination of the proportions induced to inject fuel energy is calculated in each case [8, 27, 28].

Salman et al. [29] investigated the reduction in the emission of exhaust gas from a dual-fuel diesel engine. For this reason, a single-cylinder, the direct-injection diesel engine was converted into dual-fuel operation (70% diesel and 30% LPG by weight). The engine speed was maintained constant (1650 rpm) during the experiments and the load was changed. In several studies carried out by Qi et al. and Vijayabalan et al. [30, 31], about 40 to 65 percent of diesel replacement by LPG was observed depending on engine specification. Studies have shown that Diesel+LPG dual operations can achieve the rated capacity of traditional diesel engines, up to a point of diesel replacement [30, 31]. Saleh [32] has shown that both environmental and economic benefits of dual fuel service with LPG. Kumar and Azad [11] Modified diesel genet for operation with dual fuel, LPG and diesel genet. In addition to emissions testing, the engine performance test was carried out on the updated diesel genet at different quantities of diesel and LPG including 100% diesel. The test result showed that the BTE and BSFC are increased by 30% at full load condition at a blend of 30% LPG and 70% diesel, while the fuel consumption cost is 22% lower than the peak load cost of a 100% diesel._In addition, emissions such as NO_x & Smoke decreased at full load condition by 33% and 28%. Yuvaraj [12] experiment done on a traditional dual fuel CI engine using diesel and LPG. The experiment by a diesel engine , direct injection, single cylinder, 4-stroke,water cooling. The LPG tank is sent into the inlet manifold at a rate of 0.25 kg/hr using LPG valve with the help of the pressure regulator. The results of the experiment showed reduction of Carbon monoxide(CO), Carbon dioxide (CO_2) Hydrocarbon (HC), Nitric oxide (NO_x), Oxygen (O_2) emissions than the diesel engine. Reduced the emission. The brake thermal efficiency for LPG-diesel mode increases as load increases gives more than 3% of better performance compare to the pure diesel engine. Specific fuel consumption reduced when compared to the pure diesel fuel (the pure diesel consume of 0.8 kg/Kw.hr, the blend fuel consume fuel 0.78 Kg/Kw.hr). Karim [33] stressed the importance of understanding the mechanisms of combustion at dual-fuel engines in terms of increased engine performance and reduced air pollution. Given that Iraq produces primarily accompanying natural gas and that its production of crude oil reached 4.4 million barrels per day (MMb/d) in January 2018 (the second producer of crude oil in OPEC) [34]. Using LPG as an alternative motor fuel requires relatively small and not costly adaptations in spark-ignited motors. They found the economic and ecological benefits of using these engines, and more often sell vehicles with Autogas systems built in the factory. It creates a positive image of Autogas as an environmentally friendly, cost effective and fully safe fuel [16, 35]. This is a very positive indication of the possibility of using liquefied gas as a dual fuel with diesel being available in this country Iraq as well as from material and economic foreigners and it can be produced according to what the combustion process requires in internal combustion engines [13].

In this study, dual-fuel engine is used where diesel is used as an elementary fuel and LPG is used as a subsidiary fuel. Here a diesel+LPG engine is addressed which can either use single diesel fuel or use diesel-LPG fuel. LPG is operated by a new electronic system designed to suit the diesel engine's function–LPG after making an engine change and installing a magnetic sensor on the engine's head. The engine was initially run on the base diesel mode and the test engine was operated with four different fuel types as D-100, LPG-25, LPG-50, and LPG-75 using an air valve to enter the LPG with the air into the combustion chamber and at the pressure 1 bar. The pure quantity of diesel was modified by is the flow rate of the injectors (100%, 75%, 50%, and 25%) and replaced by LPG. The test was for each condition loads (0%, 25%, 50%, 75% and 100%) at different speeds (1000, 1500 and 2000) rpm.

2. MATERIALS AND METHODS

Table 1. The characteristics of commonly used fuels

S. No.	Properties	Diesel	LPG
1	Normal state	Liquid	Gaseous
1	Formula	C9.12H16.85	C3.34H8.68
2	Density(kg/m3) @ 15°C	870	550
3	Boiling Point, °C	160-320	-34
4	Flashpoint, °C	>52	-140
5	Auto Ignition Temperature, °C	242-257	525

Table 2. Specifications of the engine used

Brand		LOMBARDINI, ITALY
Type		15LD315
Injector type		Direct injection
Engine type		Single-cylinder 4-stroke
Cooling type		Air-cooled
Cylinders	N	1
Displacement	cm^3	315
Bore	mm	78
Stroke	mm	60
Compression ratio		20.3:1
Max. Power		5.0 kW/6.8 HP
Dryweight	kg	33
Max.Torque	Nm	15@2400
Rated speed	rpm	3600
Dimension (LxWxH)	mm	295x374x445
Method of starting		Hand cranking

In the experiment, was diesel and LPG fuel used as test fuels. LPG content was Iraqi liquefied petroleum gas (LPG) is a three-gas mixture of 0.05 C_2H_6 (Ethane), 0.5 C_3H_8 (Propane), and 0.45 C_4H_{10} (Butane). The properties of the test fuels (diesel and LPG) are given in the Table 1. The engine used in this experiment is a single-cylinder direct-injection four-stroke, the air-cooled diesel engine was used to experiment. Brief specification at a Table 2.

2.1 Diesel injection system

The amount of diesel fuel entering the combustion chamber is controlled by special nozzles worked according to the proportions (25%, 50%, 75%, and 100%) as shown in Figure 1 and in each special experiment, the type of nozzles was used where the engine is running in each one of the above cases, and the LPG is entered by the electronic control unit.

2.2 Electronic control unit for LPG

This electronic system controls the time and amount of gas entering the engine via the injector and takes the signal through a magnetic sensor installed on the motorhead as shown in Figure 2 and connected to a source 12-volt DC. The engine is modified by a magnetic sensor installed mount that signal the electronic control unit of the LPG system that controls the amount and time of the LPG at the intake manifold and mixes it with the air entering the combustion chamber of the engine at pressure 1 bar as shown in the Figure 3.

Figure 1. Types of injectors the pure diesel used

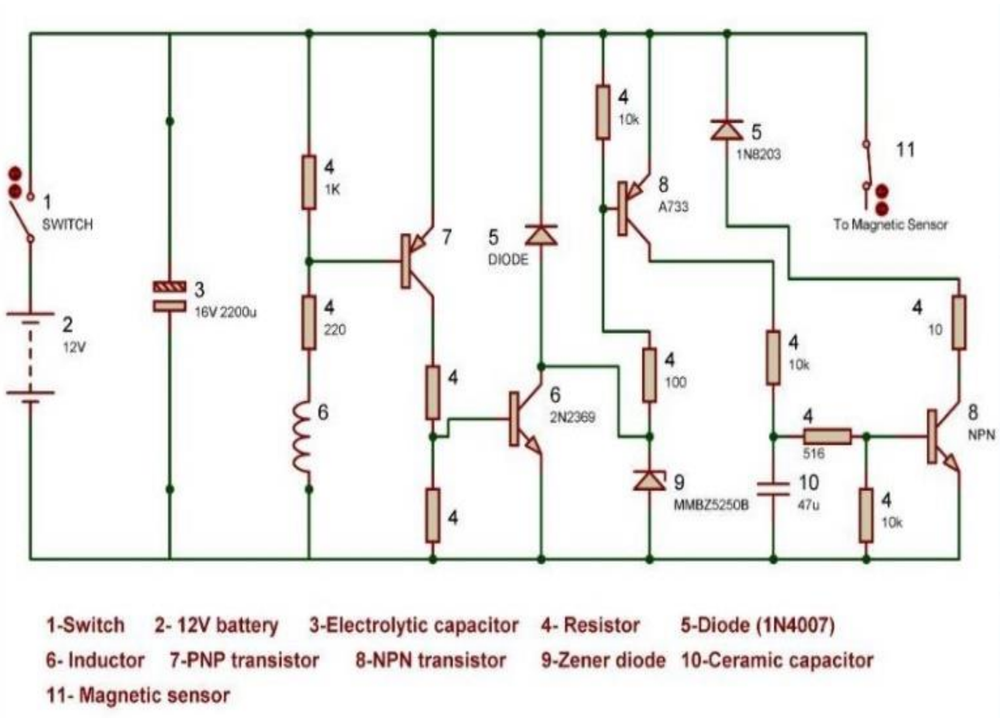


Figure 2. Diagram of electronic control unit

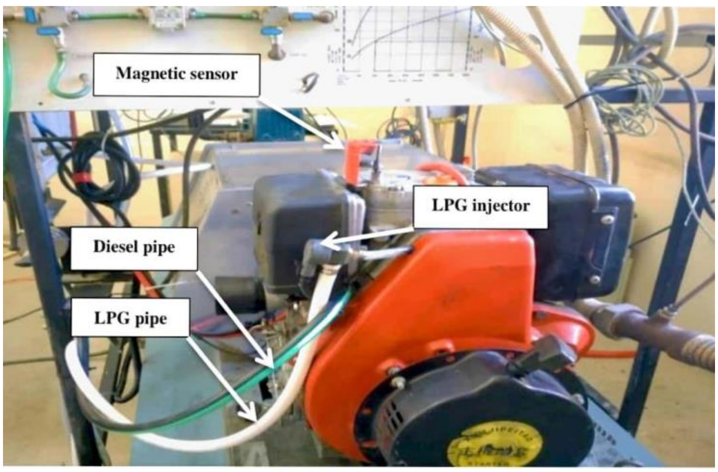
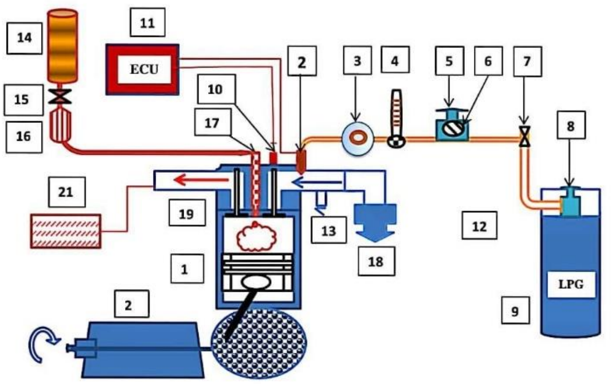


Figure 3. Experiment engine with parts

3. EXPERIMENTAL METHODOLOGY

A schematic setup diagram is shown in Figure 4. This explains the parts of the experiment and a special electronic system was designed for LPG, then the set was run in the mode of diesel fuel only and the readings were taken, and then the engine was started using LPG. Therefore, a partial engine modification of the gas vaporizer was applied. Crossflow mixing chamber before the inlet valve is combined to mix LPG with air.



1-Test engine; 2- LPG injector; 3- Vaporizer; 4-Flow meter for LPG; 5-Pressure regulator; 6- Pressure gage; 7-Valve for LPG; 8-Pressure valve; 9-LPG cylinder; 10-Magnetic sensor ;11- Electronic control unit for LPG; 12-Air filter; 13-Air manometer; 14- Diesel flow meter; 15- Diesel valve; 16-Diesel filter; 17- Diesel injector; 18- Intake; 19-Exhaust; 20- Dynamometric unit; 21- Gas Analysis Unit

Figure 4. Block diagram of the experimental setup

4. RESULTS AND DISCUSSION

At the beginning of the experiment, the diesel engine was started in pure diesel fuel (D-100), and exhaust gas emissions were recorded in this mode, and then LPG was used in different proportions LPG-25, LPG-50 and LPG-75 at different loads (0%, 25%, 50%, 75%, and 100%) and at different engine speeds (1000, 1500 and 2000) rpm and the amount of LPG are controlled by an (ECU) and the readings were recorded as shown below:

4.1 Nitrogen oxide emissions (NOx)

Nitric oxide is a colorless, toxic gas that causes harmful hazards to the environment hence its emission from the dual-fuel engine should be limited [12]. The emission of NOx from LPG of dual-fuel engine is lower than that compared to the pure diesel. Figure 5 shows the variations of NOx. High NOx emissions were observed under higher loads due to the temperature that decreased during expansion and exhaust strokes. The largest amount of nitrogen oxides appears in the exhaust at the highest elevation of loads and with an increase in engine speeds. where the results showed the highest increase in pure diesel D-100.

Figure 5 a, b, and c show the differences in nitrogen oxides in different loads (0%, 25%, 50%, 75% and 100%). Where it increases when the load increases in NOx at (LPG-25, LPG-50, and LPG-75). As explained below in detail:

(1) Figure 5 a show the difference in nitrogen oxides at (1000 rpm), from the calculations, and the figure shown below, that nitrogen oxides decrease by (3.8%, 3.198%, and 7.65%) at mode LPG-25, LPG-50, and LPG-75 respectively compared with the D-100.

(2) Figure 5 b show the difference in nitrogen oxides at (1500 rpm), from the calculations, and the figure shown below, that nitrogen oxides decrease by (7.57%, 18.18%, and 22.7%) at mode LPG-25, LPG-50, and LPG-75 respectively compared with the D-100.

(3) Figure 5 c show the difference in nitrogen oxides at (2000 rpm), from the calculations, and the figure is shown below, that nitrogen oxides decrease by (4.82%, 10.38 %, and 21.5%) at mode LPG-25, LPG-50, and LPG-75, respectively compared with D-100.

These findings are consistent with other studies [6, 12, 26].

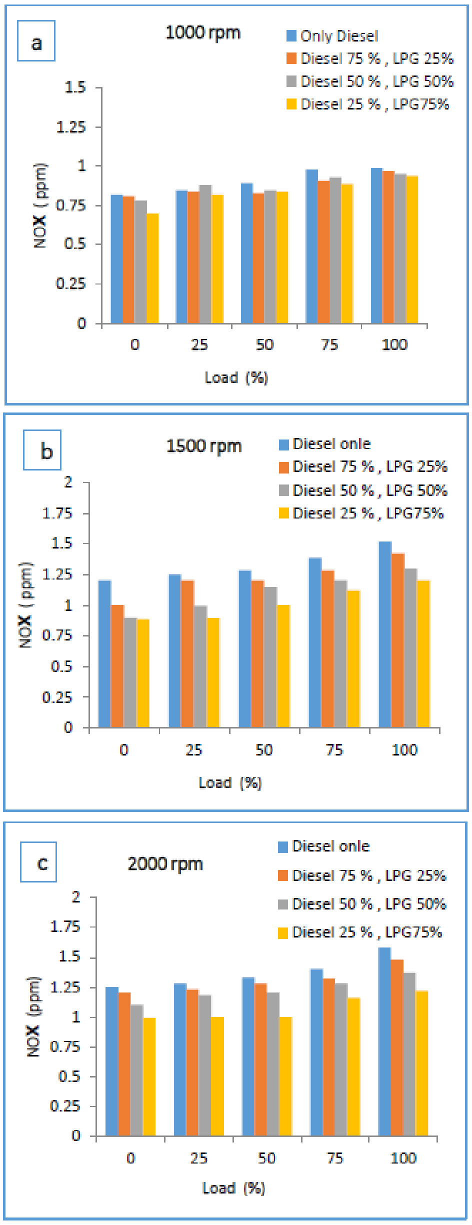


Figure 5. NOx emission variance, depending on engine load

4.2 Hydrocarbon emissions (HC)

The emission of unburned hydrocarbon (HC) comes from the combustion of part of the fuel injected into the engine. HC emissions rely on many mechanisms such as oil layer adsorption and desorption of fuel, flame quenching, fuel leakage into crevices, and fuel deposition in engine deposits, etc. HC emission values depend on the speed engine and load between (1000-2000) rpm and (0%-100%) respectively are given in Figure 6. HC emissions using different LPG ratios have decreased through improved combustion reactions with diesel pilot fuel and more effective combustion reactions with the help of LPG. As explained below in detail:

(1) Figure 6a shows the difference in HC at (1000 rpm), from the figure shown below, that HC decrease by (6.75%, 12.93%, and 18.3%), respectively at the mode LPG-25, LPG-50 and LPG-75 compared with the D-100.

(2) Figure 6b shows the difference at (1500 rpm), from the calculations, and the figure is shown below, that HC decrease by (8.3%, 13%, and 26%), respectively at the mode LPG-25, LPG-50 and LPG-75 compared with the D-100.

(3) Figure 6c shows the difference in HC at (2000 rpm, from the calculations, and the figure is shown below, that HC decrease by (11.94%, 18%, and 23.6%), respectively at the mode LPG-25, LPG-50, and LPG-75 compared with the D-100.

Similar results were obtained by other studies [7, 36-38].

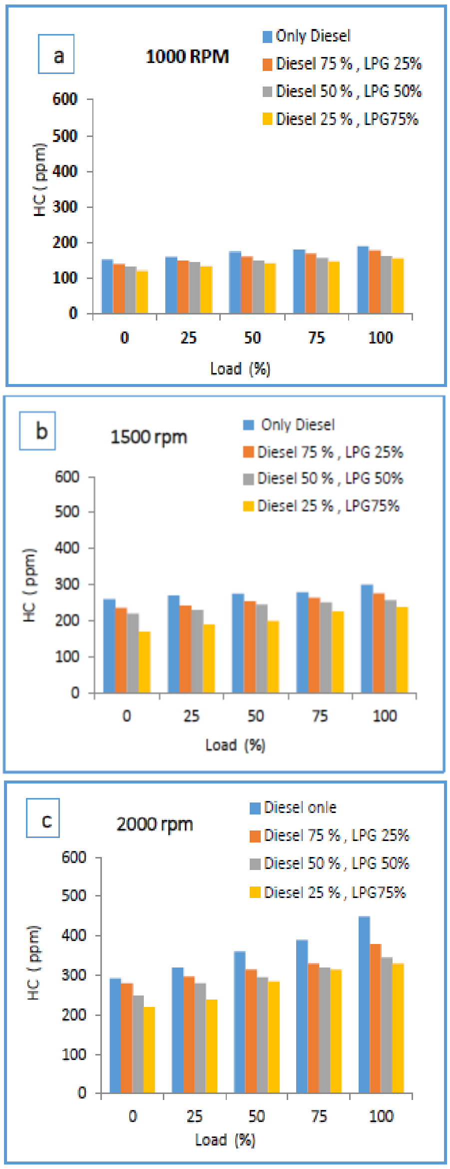


Figure 6. the HC emission range by depending on engine load

4.3 Carbon monoxide emissions (CO)

Carbon monoxide, which is the combination of one carbon atom and one oxygen atom is a poisonous gas that causes harmful hazards to the environment hence its emission from the dual-fuel engine should be limited. The emission of CO from LPG of the dual-fuel engine is less as compared to the pure diesel and as shown in Figure 7 where we note the following:

(1) Figure 7a shows the difference in CO at (1000 rpm), from the calculations, and the figure is shown below, the CO at the mode LPG-25, LPG-50, and LPG-75 decrease by (21.875%, 42.96%, and 44.14%), respectively compared with the D-100.

(2) Figure 7b shows the difference in CO at (1500 rpm), from the calculations, and the figure is shown below, the CO at the mode LPG-25, LPG-50, and LPG-75 decrease by (16%, 23.21%, and 42.5%), respectively compared with the D-100.

(3) Figure 7c shows the difference in CO at (2000 rpm), from the calculations, and the figure is shown below, the CO at the mode LPG-25, LPG-50, and LPG-75 decrease by (9.8%, 14.84 %, and 21%), respectively compared with the D-100

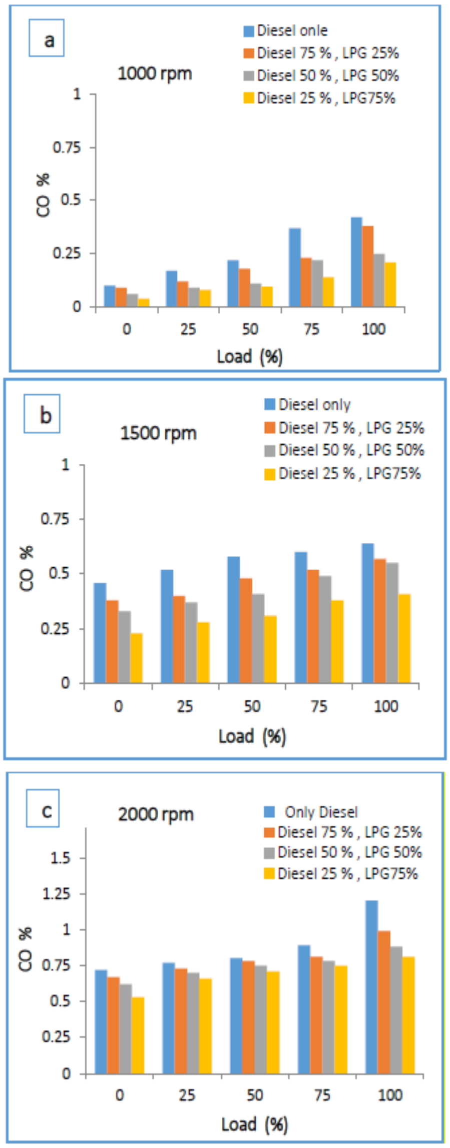


Figure 7. Variation of CO emission range by depending on load

4.4 Carbon dioxide emissions (CO_2)

Carbon dioxide is a poisonous gas that causes harmful hazards to the environment and emission from the dual-fuel engine should be limited. The emission of CO_2 from LPG of the dual-fuel engine is lower than that compared to the pure diesel. Figure 8 shows the variations of CO_2 emissions. As the loads on the engine and engine speed were increased the percentage of CO_2 at diesel fuel and it reduces the increase in the percentage of LPG, as follows:

(1) Figure 8a shows the difference in CO_2 at (1000 rpm), from the calculations, and the figure is shown below, that decrease by (16%, 22.37%, and 27.76%) at the mode LPG-25, LPG-50, and LPG-75 respectively compared with the D-100

(2) Figure 8b shows the difference in CO_2 at (1500 rpm), from the calculations, and the figure is shown below, that CO2 decrease by (9.41%, 24.7%, and 29.41%) at the mode LPG-25, LPG-50, and LPG-75 respectively compared with the D-100

(3) Figure 8c shows the difference in CO_2 at (2000 rpm), from the calculations, and the figure is shown below, that CO_2 decrease by (9.5%, 16.5%, and 25%) at the mode LPG-25, LPG-50, and LPG-75 respectively compared with the D-100.

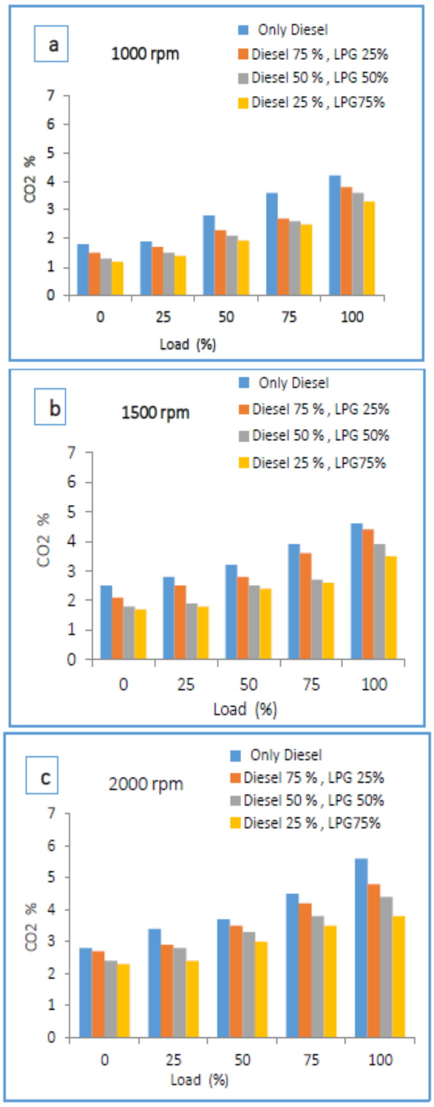


Figure 8. Variation of CO_2 emission range by depending on load

In general, CO_2 emissions were caused by the full combustion of a large amount of fuel at the cylinder and on the other hand, the CO emissions that occurred in the remaining fuel from all combustion were burned insufficiently. The non-combustible part of the fuel produced using HC emissions. The reasons why CO and HC emissions are produced are very similar. The direct injection of LPG fuel in the cylinder by an injector under is pressure enabled the LPG to achieve a better atomization level compared to the pure diesel fuel. Improving the combustion reaction with the use of the LPG fuel, thus produced a reduction in CO emissions. Better combustion and higher LPG calorific value enhance the flaming propagation and oxidation reactions which slightly reduce HC and CO emissions. Also, the lower LPG C/H ratio decreases HC and CO emissions, and CO_2 emissions. Those findings indicate with other studies [4, 32, 36, 39].

4.5 Oxygen (O_2)

Oxygen is the most abundant element on the earth. The emission of O_2 from LPG of a dual-fuel engine is the same as compared to the pure diesel at low load, but at maximum load and engine speed running condition of the engine, the emission of O_2 in LPG diesel decreases than pure diesel operation. As shown in Figure 9 a, b, and c.

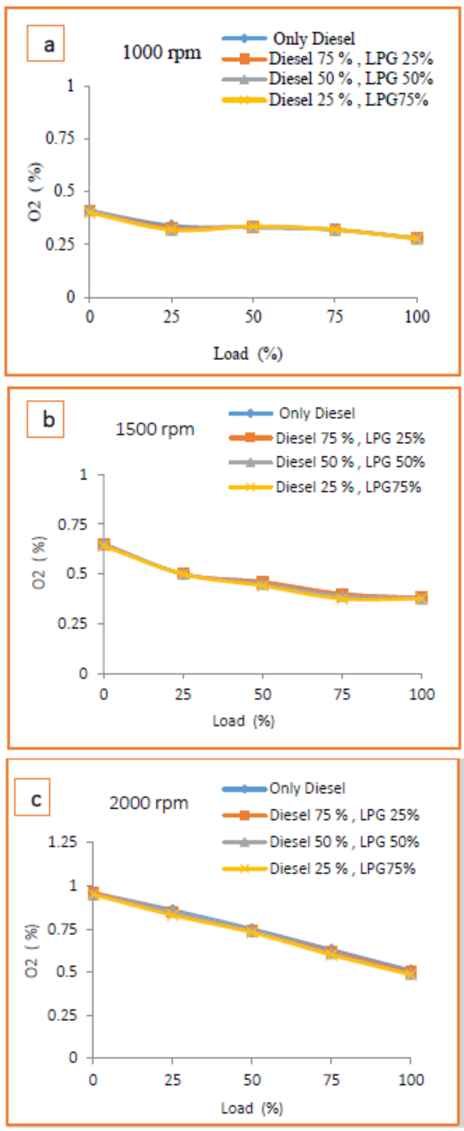


Figure 9. Variation of O_2 emission depending on loads

5. CONCLUSIONS

The following conclusions can be taken from the current study:

(1) A diesel engine can be successfully produced to run on dual fuel (Diesel + LPG) and a dual-fuel engine is ideal for all applications that a diesel engine can satisfy.

(2) When the engine runs on the dual-fuel show results in better emissions than diesel.

(3) The design of the electronic system contributed to controlling the amount of liquefied petroleum gas and injecting gas promptly, and this led to a reduction in fuel consumption and the implementation of safety requirements in the experiment.

(4) The best operating mode to reduce emissions is (LPG-75), as it contributed to reducing emission ratios by proportions as shown below for each gas.

A-NOx reduced (7.65% at 1000 rpm, 22.7% at 1500 rpm and 21.5% at 2000 rpm)

B- HC reduced (18.3% at 1000 rpm, 26% at 1500 rpm and 23.6% at 2000 rpm)

C- CO reduced (44.14% at 1000 rpm, 42.5% at 1500 rpm and 21% at 2000 rpm)

D-CO2 reduced (27.76% at 1000 rpm, 24.41% at 1500 rpm and 25% at 2000 rpm)

(5) The emission of O_2 from LPG of the dual-fuel engine is the same as compared to the pure diesel.

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NOMENCLATURE

CNG	Compressed natural gas
LPG	Liquefied petroleum gas
D-100	Diesel fuel
LPG-25	LPG 25% + Diesel 75%
LPG-50	LPG 50% + Diesel 50%
LPG-75	LPG 75% + Diesel 25%
ECU	Electronic control unit
GDI	Gasoline direct injection
HC	Hydrocarbon
NOx	Nitrogen oxide
CO_2	CARBON DIOXIDE EMISSIONS
CO	CARBON MONOXIDE EMISSIONS
O_2	Oxygen