LPG as fuel on Diesel engine

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Abstract: - Air pollution is a condition triggered by the presence of air borne pollutants that affect the quality of air we inhale. These pollutants could either be the result of chemical emissions or the particulate material from biological waste. Primary air pollutants are those that are directly emitted via some processes like the ash from volcanoes or the carbon monoxide and sulfur dioxide emissions from vehicles and factories respectively. Secondary air pollutants are the result of the reactions or interactions of the primary pollutants. An example of secondary air pollutant is photochemical smog. In nowadays the condition has reached alarming proportion with large scale industrialization and vehicle emissions being the primary culprits. The main pollutants from car emissions are carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter. This work examines the conversion of Diesel engine to an engine that use for it's function the mixture of diesel - gas as fuel. The engine was examined from the side of operation and from the side of gas emissions (CO, HC, NO, smoke) in different rpm.

Key-Words: - Gas emissions, LPG

1. Introduction

The primary focus in today's culture is efforts to reduce pollutants and greenhouse gases. Alternative or renewable energy sources show significant promise in helping to reduce the amount of toxins that are by-products of energy source. Moreover, alternative energy use can help preserve the delicate ecological balance of the planet and help us conserve the non renewable energy sources like fossil fuels. In order to replace the fossil fuels with other fuels more efficient, economical and less harmful to the environment in terms of the transportation sector, the technology of conversion engine has been evolved so that the engines can run on LPG. In these conversions is common to be used CNG (compressed natural gas) or LPG (liquid petroleum gas) and even hydrogen for conversions types of bi-fuel and dual-fuel. Lately, it has been used the biogas. LPG is a mixture of gaseous hydrocarbons that is produced from the extraction of natural gas and diesel (66%) and cleaning diesel (34%) [1,2,3,4,5,6]. It is automatically created during the production of methane and during the cleaning process in two forms: propane and butane, thus it is a sub product of the clearing diesel industry. If LPG was not hold at this point, it will be destroyed during the combustion or ventilation. This would be an unacceptable lost of an available and excellent source of energy. LPG properties present a great interest, classified in the cleanest fuel but with very high efficiency. It is odorless and colorless, but it is imparted with some substances of osmosis in order to understand any potential leakage. It has high octane content (over 110). Also it has higher ignition temperature than gasoline, 410 – 450 °C (opposite 257 °C) [34]. LPG does not contain lead. However, the greatest advantage of LPG is that it has low content of carbon dioxide, which classifies it to the least polluting fuels. When it is placed in a relatively low pressure, the gas becomes liquid and then can easily be stored in various tanks. However, this is not happening with other gas fuels for vehicles, such as CNG and LNG, which either must be cooled to extremely low temperatures (LNG) or come from very high pressure (CNG) to be stored.

LPG is simpler and cleaner hydrocarbon fuel than gasoline and diesel. If a vehicle is properly converted to run on this fuel, it will produce fewer exhaust emissions. Thus, governments have set lower taxes for LPG (in Greece Unleaded gasoline: 610€/1000lit, Diesel: 382€/1000lit and LPG: 125€/1000lit) [7,8]. The reference to legislation on vehicle emissions is stated due to the fact that each vehicle must not exceed the statutory limits even after its conversion. The emitted pollutants from a vehicle must be equal or lower than those emitted before engine's conversion to LPG[9,10,11].
The United Nations has legislations that relates to each sector. What it needs to be taken under consideration are the regulations given by the ECE (Economic Commission for Europe) regarding to the engines conversion to LPG.
The regulation R67 provides guidance on the specifications of each one of the engine conversion components to LPG [12,13,14,15,16,17]. It lists in detail all the components contained in a kit conversion, determines the safety regulations that must be fulfilled and all the typical, such as request statement to the manufacturer, statement of any conversion to the equipment, display manufacturer's name and other elements in any piece of kit etc.
Similarly, the regulation R10 has exactly the same content with the previous one, with the exception that it refers to engine conversion to CNG. The specifications of kit components change as CNG is stored and operated at different pressure and temperature conditions. Both of these regulations provide the requirements for the design, installation and testing of the following:

- Storage system and fuel distribution.
- Fuel tanks that include testing, inspection and characterization of cylinders. For both CNG and LPG, fuel tank must be designed and constructed according to the specified instructions.
- Position of fuel tank (LPG requires that fuel tanks should be higher from the vehicle's lower point).
- Pressure gauges and valves.
- Piping connections
- Supplying fuel connections
- Electrical equipment related to system supplying.

Finally, the regulation R115 refers to vehicle emissions after the conversion. Moreover, it determines which exhaust gases are considered as pollutants and it also compares the engine emissions before and after the conversion (for both LPG and CNG) calculated by the equations listed in the regulation.
It is important to mention that in any case the vehicles to be converted should maintain the original operating conditions, in which they have been approved. The question that arises is how a diesel engine behaves when it uses Diesel – LPG as fuel simultaneously.

2 Instrumentation and experimental results

It has been used a turbo diesel common rail multijet engine, 16 valve, four cylinder (in series), with total capacity 1248cc. From its production it became a very popular engine, which was adopted by other companies too. The maximum power of this engine is 70 ps. For the measurements it has been also used an oscillograph named OTC vision, exhaust gas analyzer Bosch BEA350. In order to filter and measure the pollutants, it was necessary to place a sensor λ. The sensor was also connected to the new brain of gas that was placed in the engine in order to measure the mixture and to adjust the amount of gas injected. The supplying system of gas fuel that it has been used is designed to be placed in gasoline engines (figure 1). The infusion of LPG with nozzle was made from the air inlet of the engine (figure 3). The initial conversion of the engine was made in LPG with continuous gas flow. The engine modification started with the installation of new tank (shape of cylinder) for the gas on the metal base of the engine (figure 2).

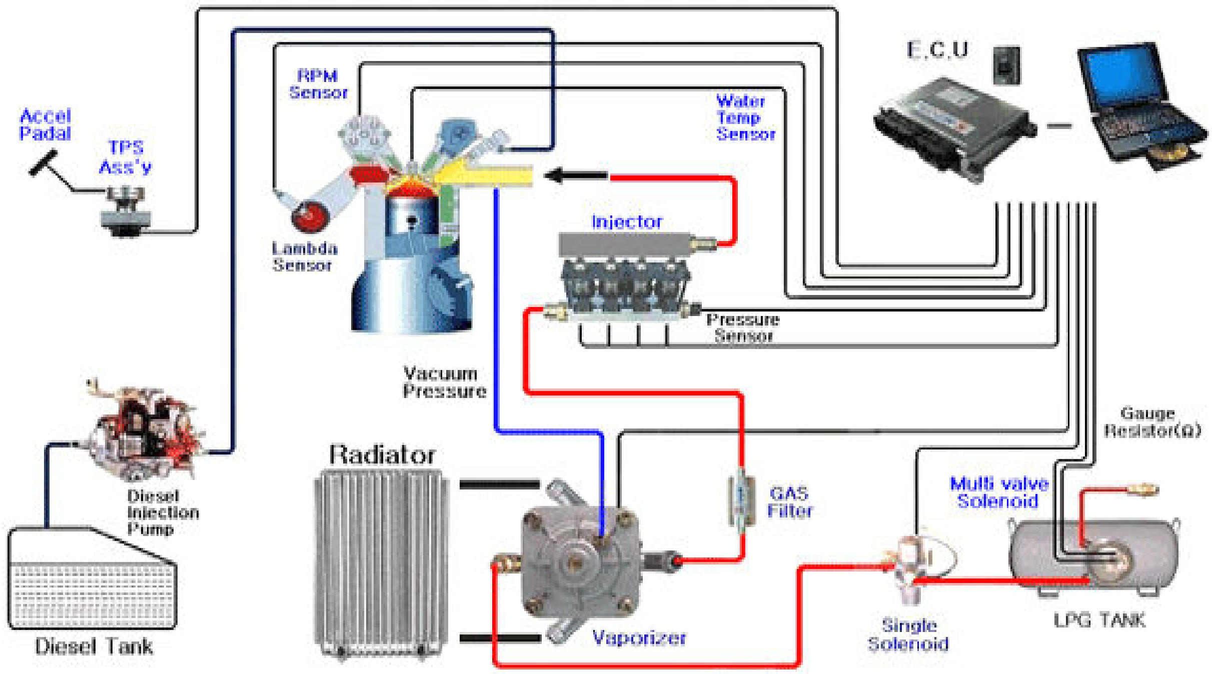

Figure 1. Experimental layout

Figure 2. Gas fuel tank

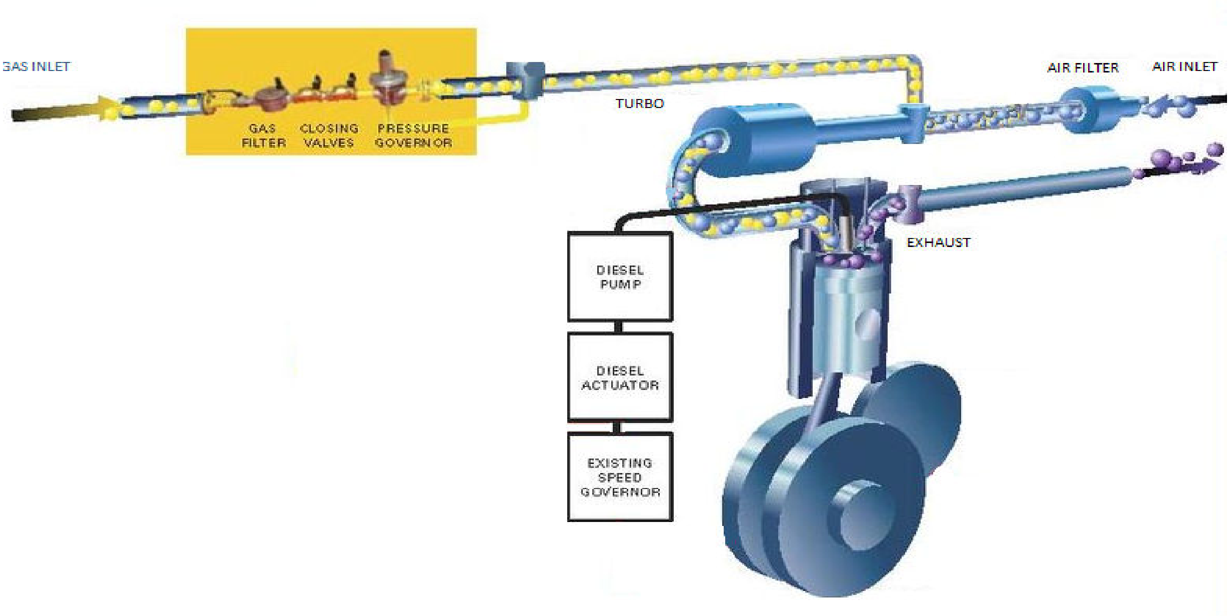

Figure 3. System of continuous flow of gas

It has been made a measurement (figure 4), in which it is shown the engine rounds and the percentage (%) of pressure regulator fuel. The measurements have reached the maximum value of 12.0% of the rate pressure fuel regulator, in where the turbo engine reached 2300 rpm and the maximum number of rounds at 4200 rpm. After 3.9% of the fuel pressure regulator, rounds have been increased significantly due to no load condition of the engine.

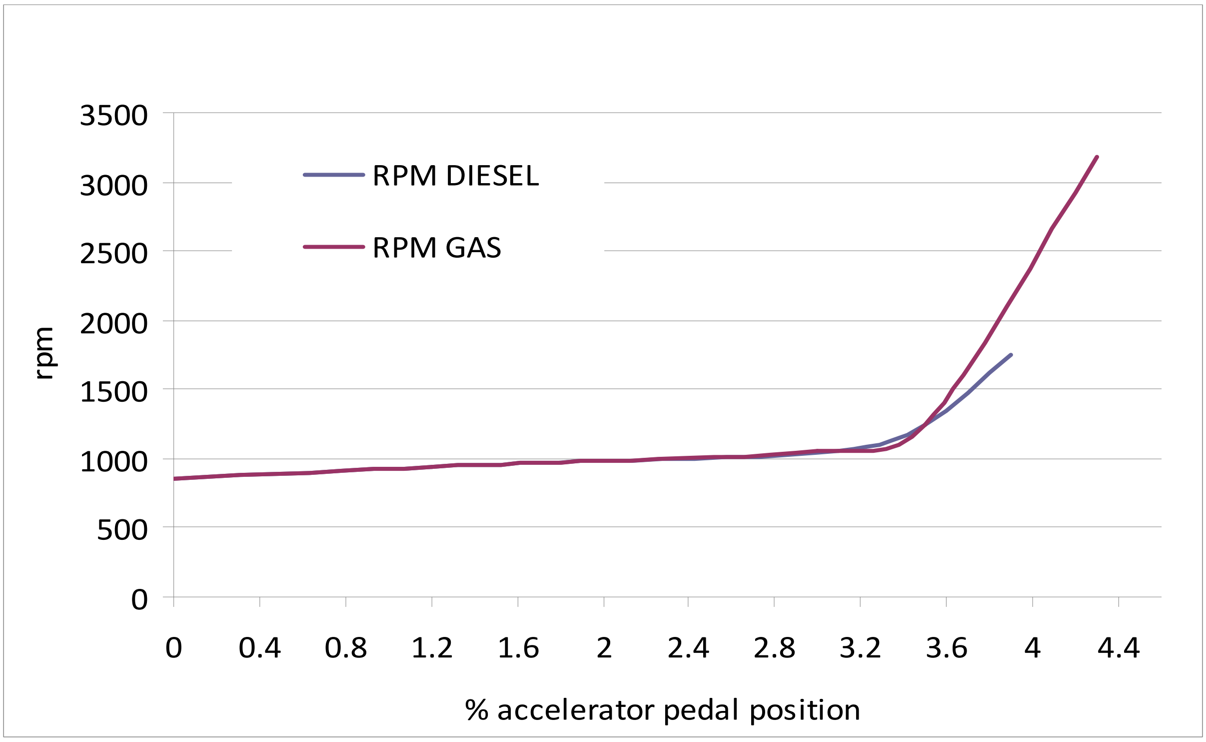

Figure 4. The Engine rpm in relation to the percentage of accelerator pedal position (%)

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At the following figure, it can be seen the percentage of CO emission in relation to the percentage of accelerator pedal position.

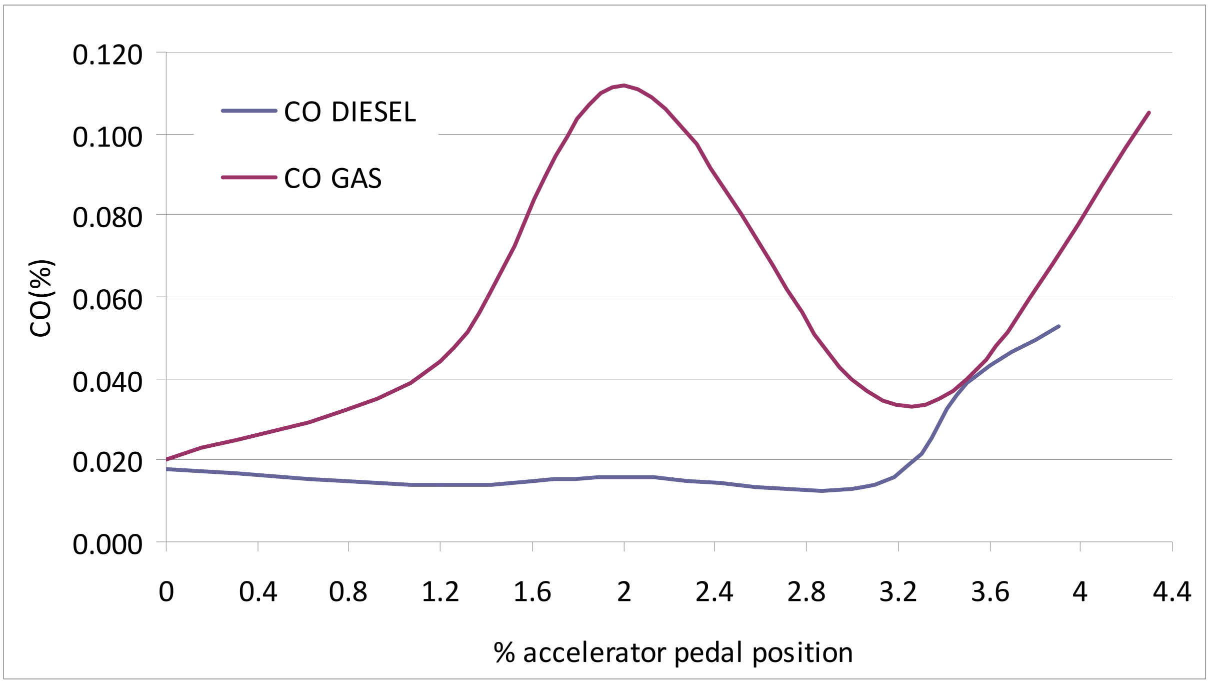

Figure 5. The % CO emission in relation to the percentage of accelerator pedal position (%)

Similarly, at the following figure, it can be seen the HC emissions in relation to the percentage of accelerator pedal position.

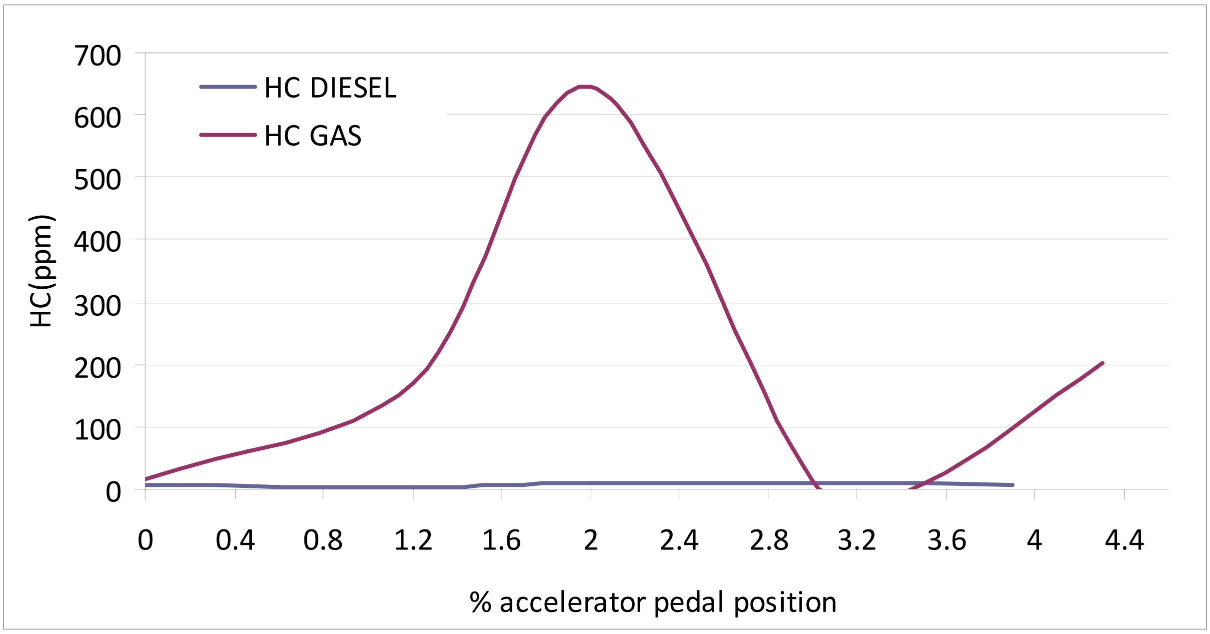

Figure 6. The HC emission in relation to the percentage of accelerator pedal position (%)

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In figure 7 it can be seen the percentage of CO_2 emissions regarding to the percentage of accelerator pedal position.

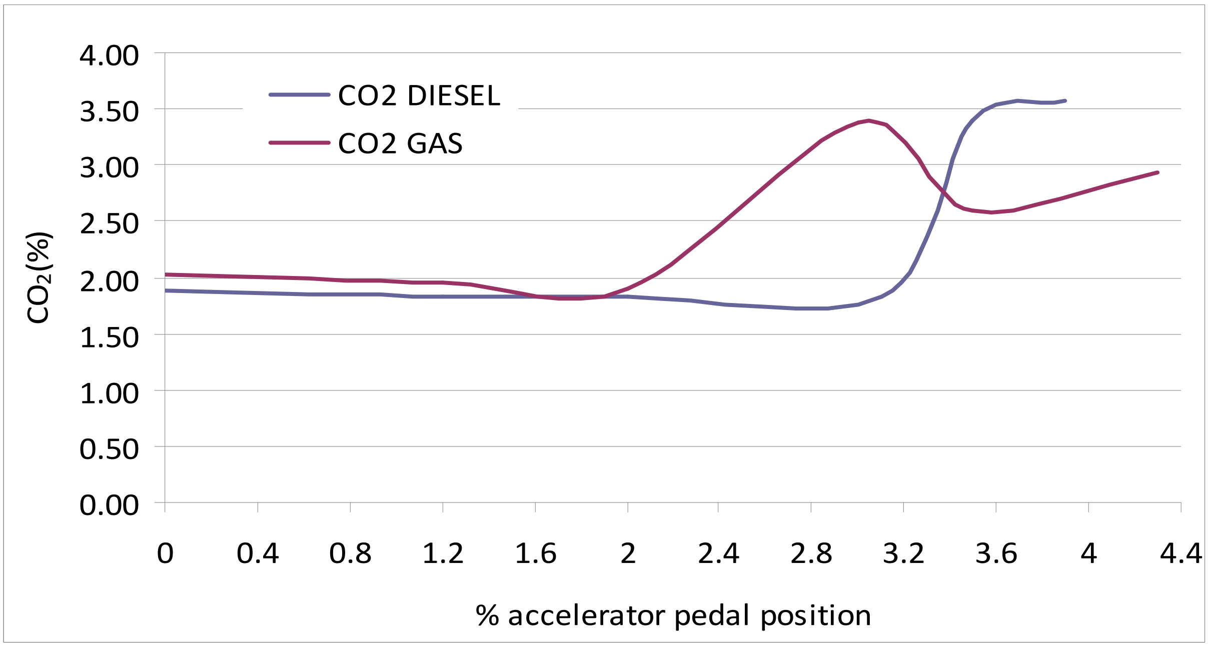

Figure 7. The CO_2 emission regarding to the percentage of accelerator pedal position (%)

Additionally, in figure 8 it can be seen the percentage of O_2 emission regarding to the percentage of accelerator pedal position

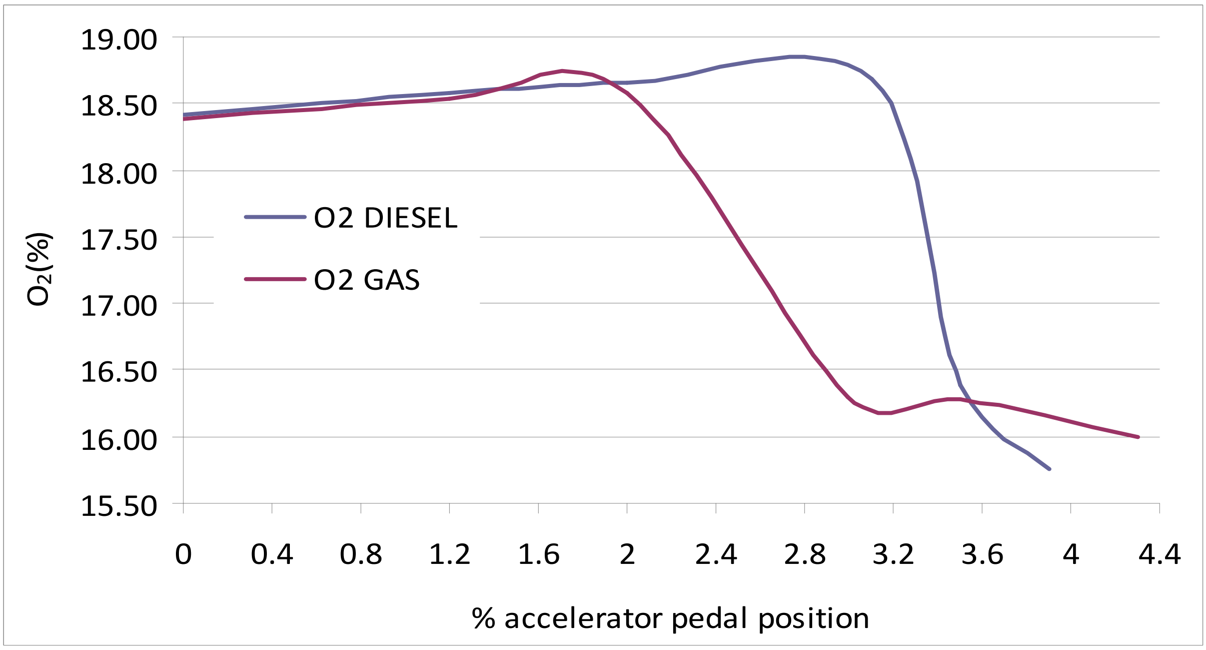

Figure 8. The percentage of O_2 regarding to the percentage of accelerator pedal position (%) .

The last figure presents the variation of engine lamda (λάμδα) regarding to the percentage of accelerator pedal position.

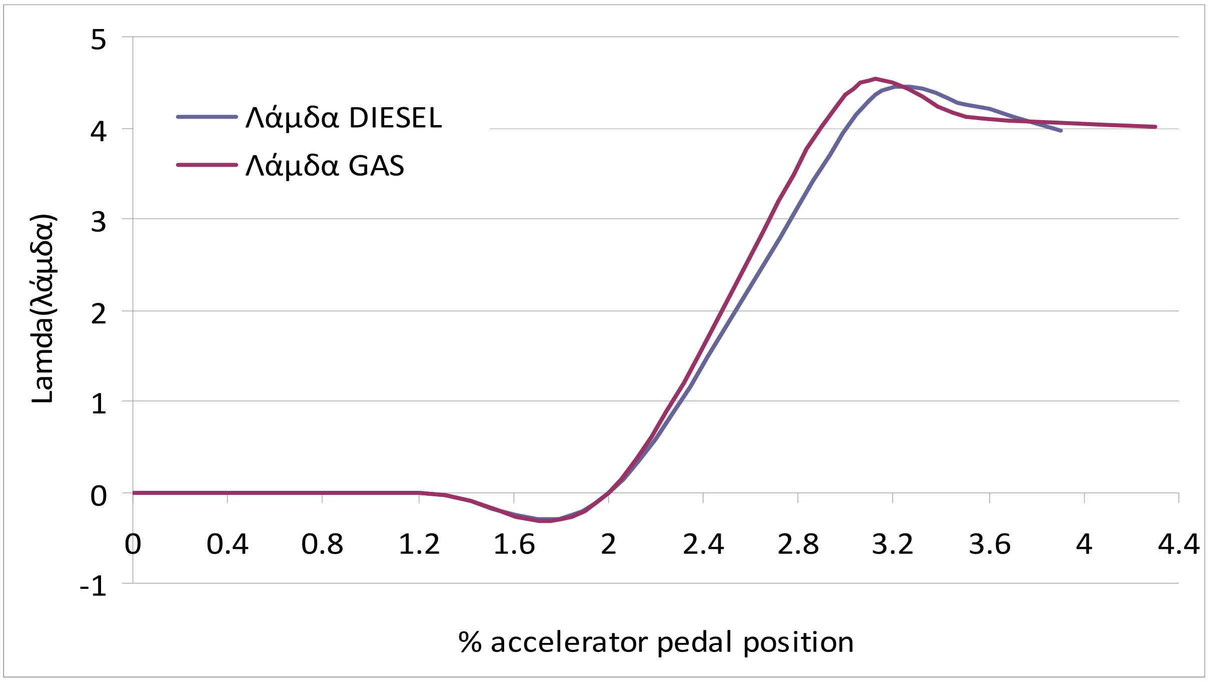

Figure 9. The variation of engine lamda (λάμδα) regarding to the percentage of accelerator pedal position (%)

The engine rounds followed an upward path up to the rate pressure regulator fuel. They have reached the point of 3.1%, in where it is observed a sharp increase of their values. It can be noticed that the increase of rounds is steeper when the engine operates with the combustion of diesel-gas combination. Also the values of the rounds that reached the engine were significantly increased with the parallel use of the two fuels (diesel: 1900 rpm, gas-diesel: 3300 rpm).

From figure 5, it can be observed that when the rate of pressure regulator fuel is increased, in case that it is used only diesel as fuel, CO emissions remained at low levels. However, due to the increased number of rounds, CO emissions are increased by reaching a maximum of 0.040% vol. In case of simultaneously combustion of diesel and gas, CO emissions from the rate of 1.2% (when the gas started to enter in the engine) followed an upward path, which at 3.1% pressure of accelerator pedal reached the value of 0.054 % vol. This is the point that there was a small increase in rounds. That leaded to the conclusion that there was gas combustion but it was incomplete, thus had to exit unburned emissions from the exhaust. Then significantly CO emissions were reduced until the pressure rate of accelerator pedal reached 3.5% in where there were no changes in the engine operation. From 3.5% and then begun the upward path culminating in 3.9% of the pedal, in where there was the leap in engine rounds as mentioned above.

Regarding to HC emissions (Figure 6), it can be observed that during the combustion of diesel only, there were not HC emissions, with an average of 6 ppm as it was expected. On the other hand, during the combustion of the diesel and gas fuel, there were HC emissions that followed an upward path from 1.2% onwards, with most of this time to 2.0% of the rate pressure regulator fuel with 110 ppm value, which it is quite high. This is the point where it was observed a small decrease in diesel consumption; therefore there was gas combustion. From that point there was drop of the values in the percentage of 3.1% of fuel flow controller due to the EGR operation.

During the operation of diesel fuel, CO_2 emissions (Figure 7) ranged at 1.93% vol, thus it is reasonable for a diesel engine operation. After the 2.0% pressure rate of pedal, it appeared an upward trend in values till 3.9%, due to EGR operation. When operating with the combination of diesel and gas as fuel, in the initials positions of the pedal there were low and stable CO2 emissions. At 2.0% CO_2 emissions started to increase with a maximum value of 3.38 % vol to 3.9% of controller. It can be mentioned that there was normal gas combustion at this point of the operation. It followed a small decrease in the values and then an increase due to the final experiments that have been made under high engine rounds. Regarding to O_2 emissions during engine operation with diesel only, it is observed an increase of the emissions as the rounds of the engine were increased too. At the rate of 2.0% of pedal O_2 emissions were reduced. This is due to the fact that in that point started the ERG operation, as a result there was a fall in the rate of incoming air.

3. Conclusion

During the measurements it has been find out that a diesel engine could operate by using simultaneously diesel and gas as fuel. Under low engine rpm the gas flow does not exist. As soon as the rounds of the engine are increased (940 rpm and over) there is a simultaneously combustion of both fuels. The settings of the conversion system parameters that it has been used, were based on the low emissions according to the limits of the European Union (euro 4 for the particular engine). However, the emissions from the combination of these two fuels were not ideal in all engine operating conditions. It is estimated that with the proper control of the inlet liquid gas in the engine there will be an improvement of the emitted pollutants. The experiments were made under no load engine conditions. It will be advisable to conduct some experiments in the particular engine with the combination of diesel and gas as fuel, under load engine conditions. By placing such a circuit in each sprayer's engine it will be possible to check the pulse signals to the injectors and to give the appropriate expression in the brain controls of the gas injection LPG system installed.

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