Liquid Petroleum Gas (LPG) and Natural Gas (NG) as fuels on Diesel engine –Dual fuel engine

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Abstract: - 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) for conversions types of dual-fuel. This work deals with the examination of a four stroke Diesel engine from the viewpoint of pollution and funcion, using as fuels diesel-LPG and diesel-CNG. A series of laboratory instruments were used for the realisation of the experiments.

Key-Words: Gas emissions, Diesel engine, Dual fuel engine, LPG, CNG.

1. Introduction

Named for the liquid state used primarily for its transportation and storage, LPG or liquid petroleum gas is either a liquefied gas such as propane, propylene, butane, and butylenes, or a mixture of the above. It is used as a fuel in heating appliances and various vehicles, and nowadays as a refrigerant and an aerosol gas replacement for chlorofluorocarbon refrigerants and aerosol propulsion gases. LPG is obtained mainly from gas wells and to a lesser extend as an oil by-product from refineries and is stored and transported as a liquid at moderate pressures. As a heating fuel it is commercially available either as a propane liquid gas or a butane liquid gas specially scented to allow for leakage detection[1]. It has been in use since the 1920s either as pressurized metal canisters (hence the name bottle gas) either through a network of pipelines throughout cities and industrial areas supplement or replacing natural gas usage. As a vehicle fuel the most common application is that of liquid propane gas or a mixture of propane and butane. LPG has high octane rating which enables higher compression ratio to be employed & hence gives higher thermal efficiency. It is widely thought as a "green" fuel, as it decreases exhaust emissions as it reduces CO_2 emissions by around 35% compared to petrol and lately also preferred for its lower price over other petroleum fuels. Finally, there are high-purity grades of LPG available for laboratory work, for use as aerosol propellants and as refrigerants. As such, blends of pure, dry propane and isobutene they have negligible ozone depletion potential and very low global warming potential and serve as a functional replacement chlorofluorocarbon or hydrofluorocarbon refrigerants in conventional stationary refrigeration and air conditioning systems but not in motor vehicle air conditioning systems, the more flammable hydrocarbons presenting significant risks[2]. The typical heating values of the above gases are 90,500 British thermal units per gallon (Btu/gal) for typical home-use propane and vehicle propane, and about 97,400 Btu/gal for butane mixtures. The largest market is the domestic heating market used throughout the world in various heating applications. This is followed by the use in chemical industry applications and the various uses in the agricultural field. Lately the emerging area of vehicle use has given a boost to that area of application as an alternative to gasoline and other petroleum products. Similar to those of natural gas, LPG combustion processes in both commercial and industrial applications usually require a vaporizer[3]. This provides the proper fuel-air mixture for the burner and has different fuel injector tips and fuel-air ratio settings than the ones for natural gas burners due the different requirements of LPG combustion. As mentioned above, LPG is considered a “clean” fuel because of the reduction in emissions compared to other petroleum fuels and the absence of visible emissions. In reality gaseous pollutants such as nitrogen oxides (NOx), carbon monoxide (CO), and organic compounds are present in LPG emissions, as well as heavier organic compounds and small amounts of sulfur dioxide (SO_2) and particulate matter (PM). The emission of such undesirables as NOx, CO, and organic compounds is affected by burner design, burner adjustment, operating parameters and flue gas venting. As is evident, inefficient design, improper adjustment and operating parameters and flue vent clogging will lead to something common to all combustion processes, partial or improper combustion, followed by the emission of aldehydes, CO, hydrocarbons, and other organics. On the same page, NOx emissions are a function of a number of variables, including temperature, excess air, fuel and air mixing, and residence time in the combustion zone[4]. On the other hand, SO_2 emissions are directly proportional to the amount of sulfur in the fuel. Finally, particle mater emissions are very low and result from soot, aerosols formed by condensable emitted species, or boiler scale dislodged during combustion. Earlier it was mentioned that undesirable emissions as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions are all produced during LPG combustion. Almost all of the fuel carbon (99.5 percent) in LPG is converted to CO_2 during the combustion process and is relatively independent of the firing configuration. Even if the formation of CO acts to reduce CO_2 emissions, the amount of CO produced is insignificant compared to the amount of CO_2 produced. The majority of the 0.5 percent of fuel carbon not converted to CO is due to incomplete combustion in the fuel stream. The formation of N_2O during the combustion process is a result of a complex series of reactions and is dependent upon many factors. With combustion temperatures kept high (above 800^oC) and excess air is kept to a minimum (less than 1 percent) the formation of N_2O is minimized. Additionally, methane emissions are highest at the start-up or shut-down cycle for boilers and burners i.e. during periods of low-temperature combustion or incomplete combustion and in general conditions that favor formation of N_2O also favor emissions of CH_4. As is with every gasoline fuel alternative, LPG has been extensively investigated. The disadvantages of it use include the following. As LPG is stored under pressure, an LPG tank is heavier and requires more space than a gasoline tank. There is a reduction in power output for LPG operation compared to gasoline operation[5]. The starting load on the battery for an LPG engine is higher than gasoline engine, so a higher-powered ignition system is required. Due to the flammability of LPG, the system requires more safety. In case of leakage LPG has tendency to accumulate near ground as it is heavier than air making a potential hazard as it may catch fire. As a final point, the volume required by LPG is more by 15 to 20% as compared to gasoline. Concluding, the benefits of LPG use include the following. The relative fuel consumption of LPG is about ninety percent of that of gasoline by volume and as LPG has higher octane number of about 112, it enables higher compression ratio to be employed and gives more thermal efficiency[6]. Due to gaseous nature of LPG fuel distribution between cylinders is improved and smoother acceleration and idling performance is achieved. Generally fuel consumption is better and engine life is increased for LPG engines as cylinder bore wear is reduced and combustion chamber and spark plug deposits are reduced. Furthermore, LPG operation increases the durability of an engine and the life of the exhaust system is significantly increased. The lower carbon content of LPG, compared to gasoline or diesel, produces less CO2 which plays a major role in global warming during combustion. Finally, LPG powered vehicles have lower ozone forming potential and air toxic concentrations making it a “greener” fuel choice[7].

One of the alternative fuels that can be used is natural gas. Natural gas is a mixture of hydrocarbon and non-hydrocarbon gases which occurs naturally and is found in porous geological formations that are called reservoirs, beneath the earth's surface[8]. The chemical composition and the Btu content of natural gas varies with the reservoir source, processing / conditioning steps and the kind of pipeline used. Processed natural gas is primarily a mixture of paraffinic hydrocarbons with the following median composition: methane (93%), ethane (3,1%), propane (0,5%), isobutane (0,06), n-butane (0,05), isopentanes (0.02), n-pentane (0,02), hexanes (+ 0,04), along with N_2 (1,2%), and CO_2 (0,6%). Odorants (tert-butyl Mercaptan) are added for safety purposes. Low levels of H_2O vapor, H_2 CO, He, O_2 and C_6-C_{14} hydrocarbons are normally considered "negligible" constituents of most processed natural gas streams[9]. In order to increase Btu content of processed natural gas it can be blended with reformed gas on a seasonal basis. Besides the use of natural gas as fuel, natural gas is a feedstock (hydrogen source) for ammonia production and a source of light hydrocarbons (ethane, propane, butane) for chemical synthesis or LG products[10]. The question that is examined in this paper is how the dual fuels diesel –LPG and diesel - NG behaves in a four-stroke diesel engine from the aspect of gas emissions and function.

2. Instrumentation

It has been used a turbo diesel common rail multijet engine, 16 valve, four cylinder (in series), with total volume 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. The sensor was also connected to the new brain of gases 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 fuels that it has been used is designed to be placed in diesel engines (figure 1). The engine modification started with the installation of new tanks (shape of cylinder) for the gases(LPG and NG) on the metal base of the engine. The experimental unit is shown at figure 2.

The fuels that have been used contained Diesel-LPG and Diesel-CNG, where the percentage of gas in the mixture was 3%.

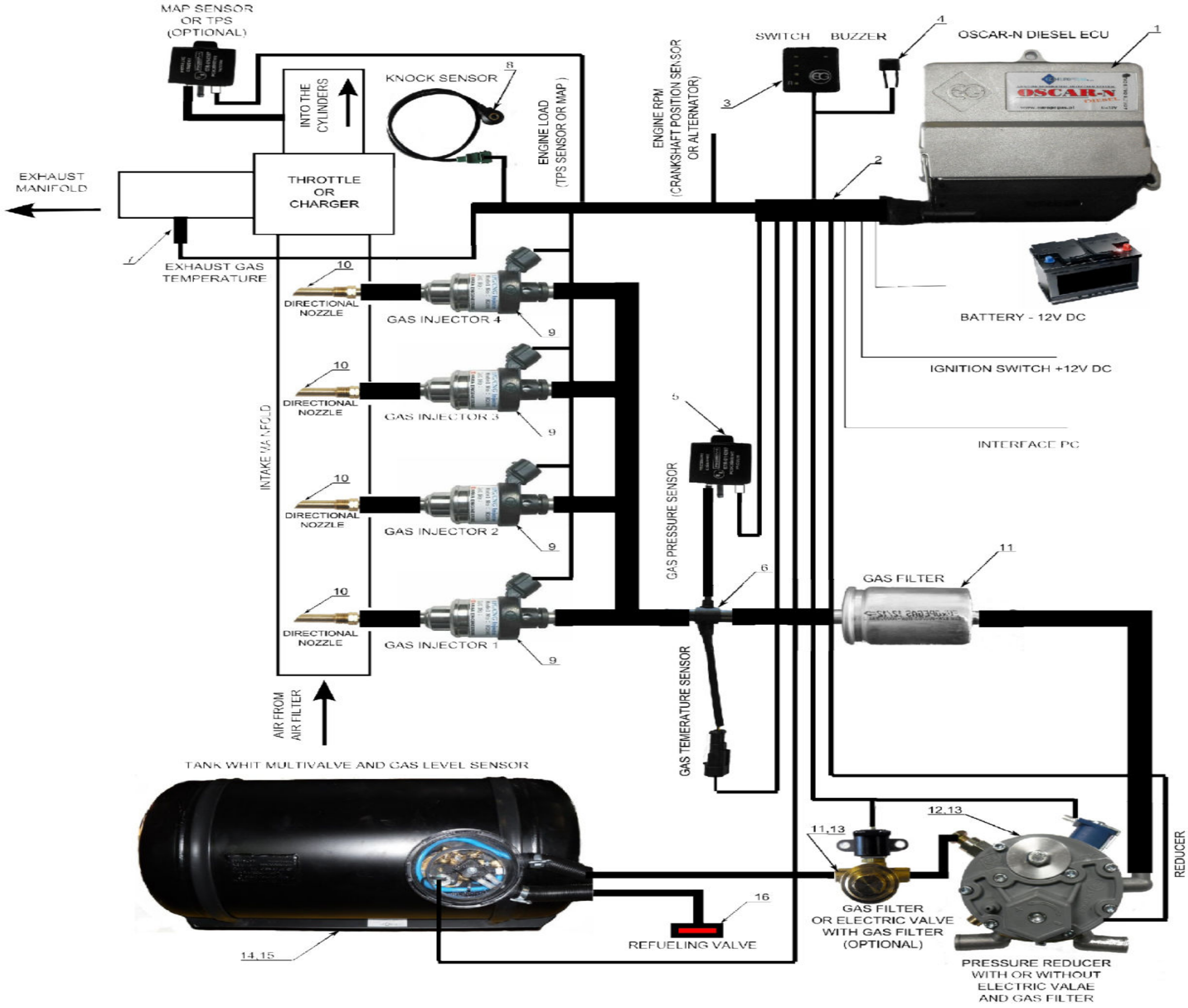

Figure 1. The supplying system of gas fuels

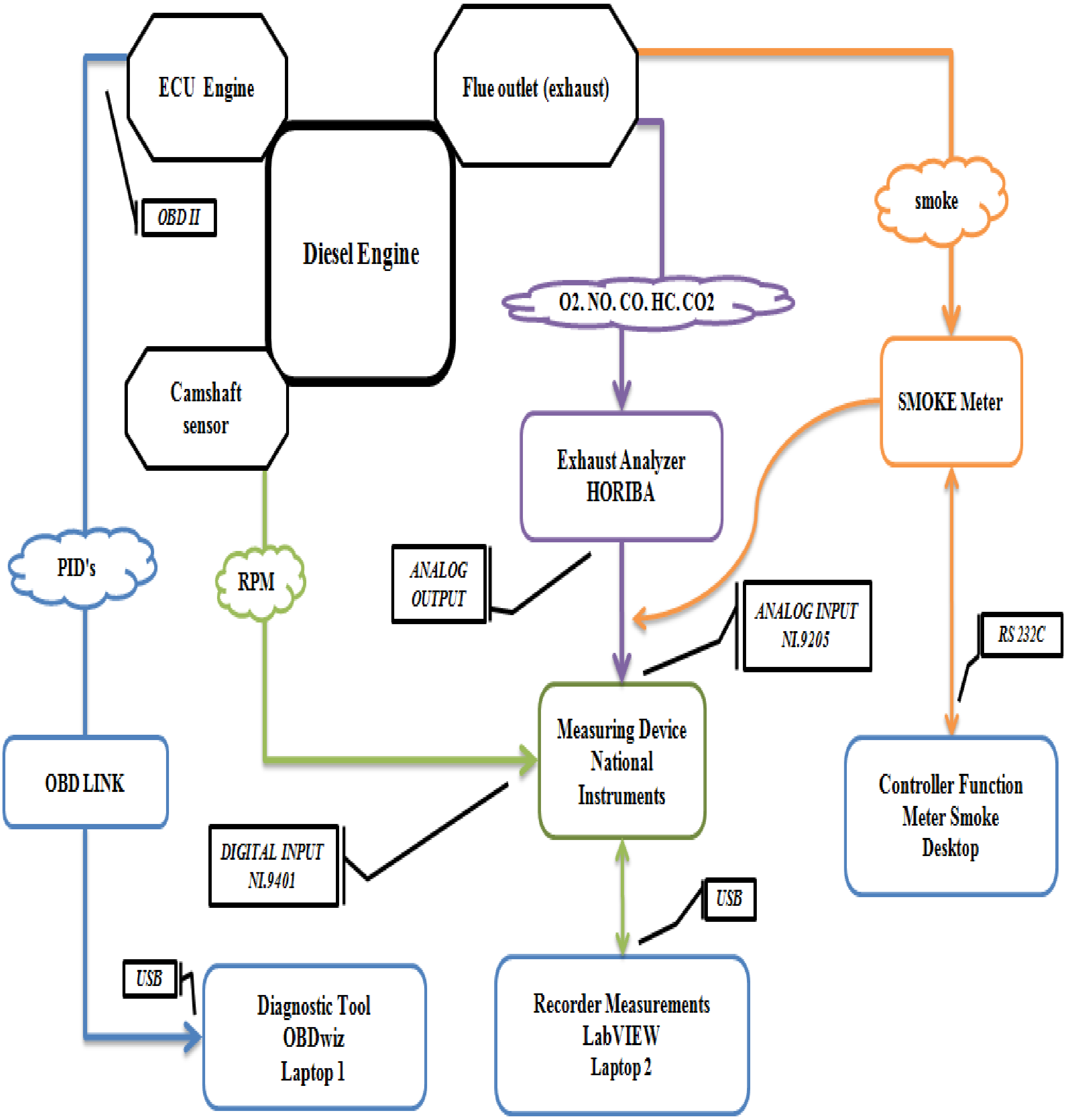

Figure 1. The experimental unit

Figure2 shows the objects that have been used in the experiments, the magnitudes measured in each, and the connection between these parts. More specifically illustrated:

- The Diesel engine around which the experiments took place.
- The measuring instruments and how they were ordered in space.
- The measurement capabilities of the measuring instruments.
- The connection types between sensors and instruments.
- The operating programs used for the processing, storage and display of measurements.

Figure 3 shows the pressure emulator connections about the diesel common rail system:

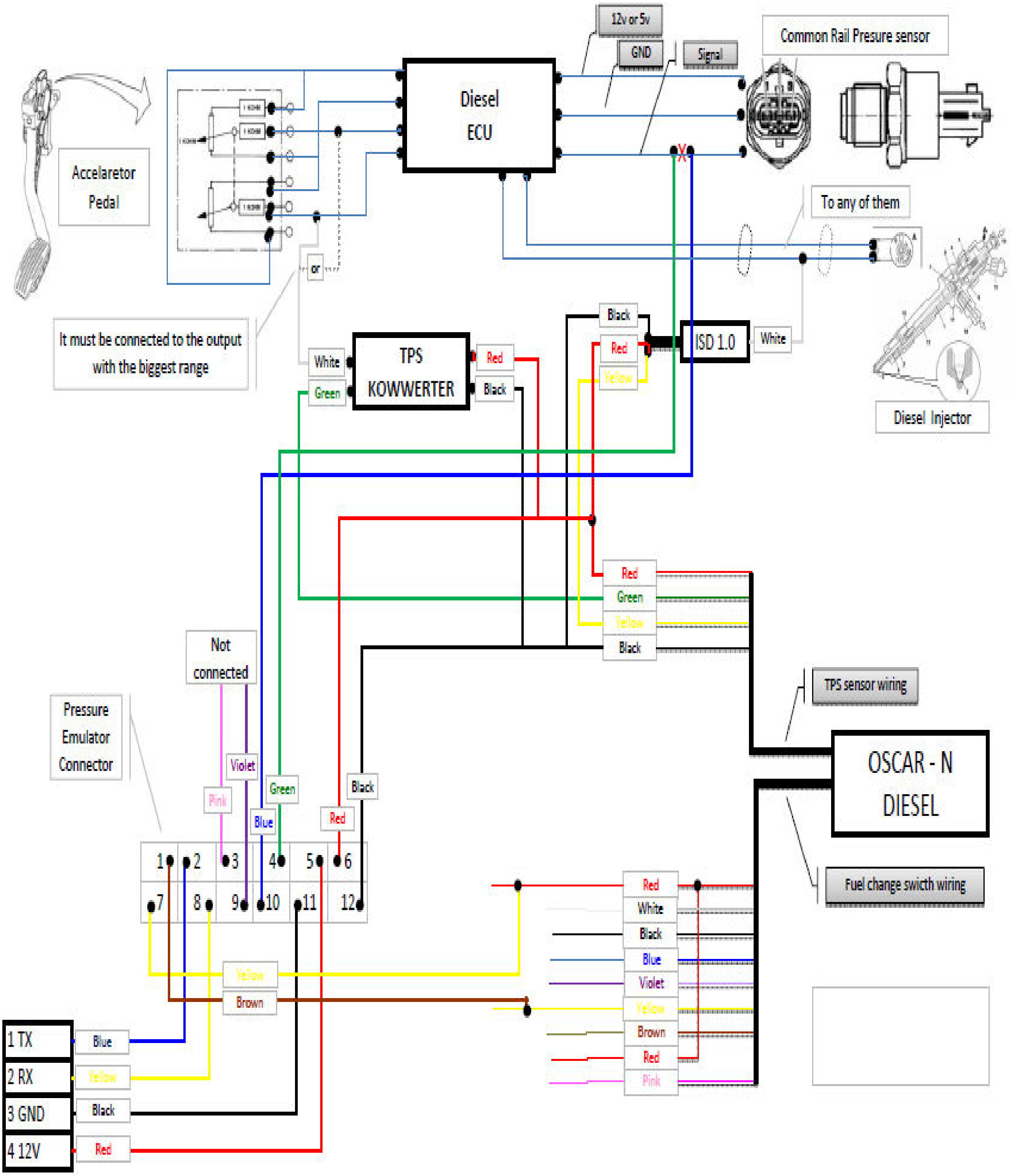

Figure 3. Pressure emulator connections of diesel common rail system

3. Experimental results

The experimental results are shown at the following figures:

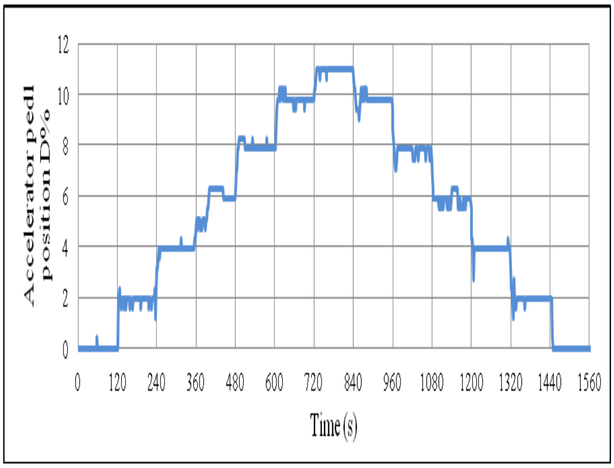

Figure 4. The percentage of accelerator pedal position (%)

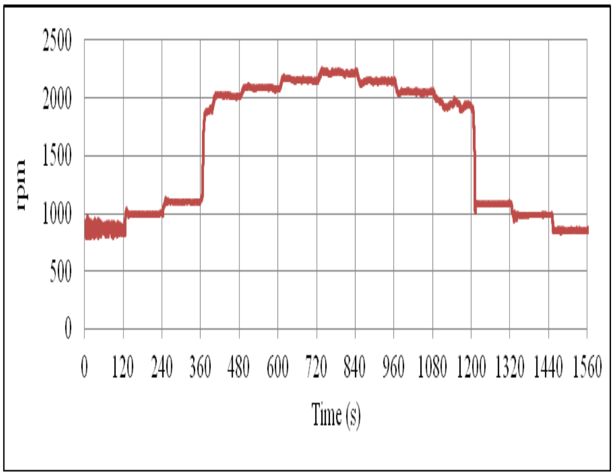

Figure 5. The engine rpm variation

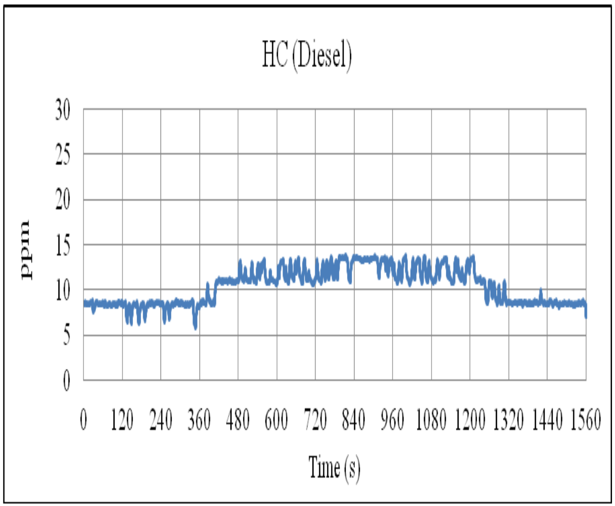

Figure 6. The HC variation when used as fuel diesel

Figure 7. The HC variation when used as dual fuel diesel -LPG

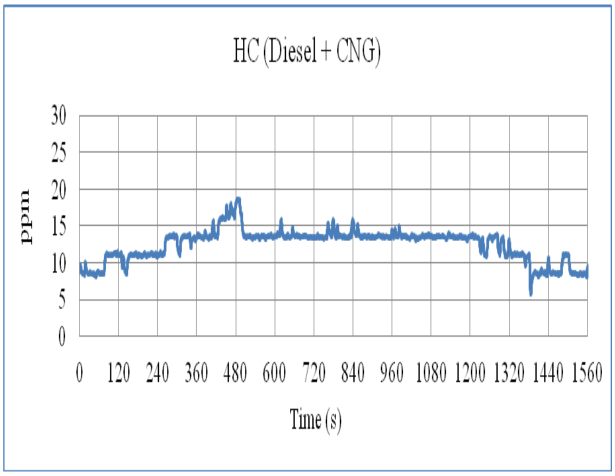

Figure 8. The HC variation when used as dual fuel diesel –CNG

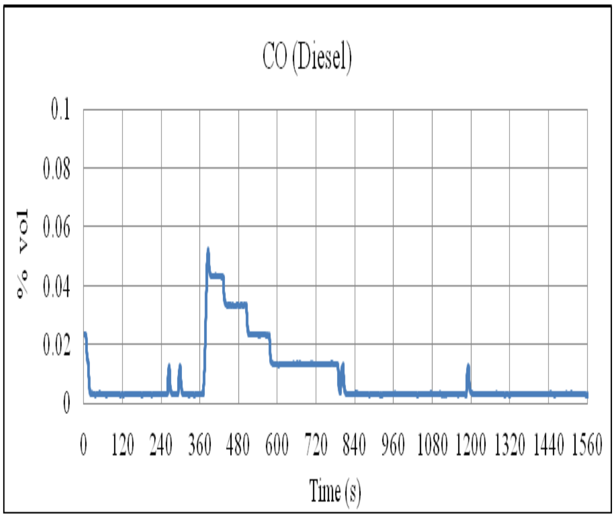

Figure 8. The CO variation when used as fuel diesel

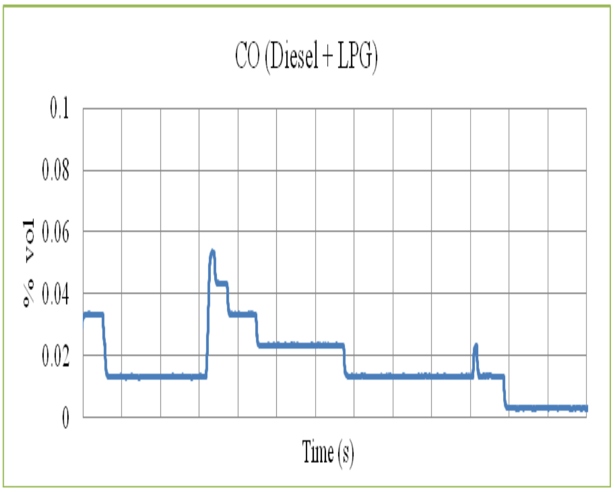

Figure 9. The CO variation when used as dual fuel diesel -LPG

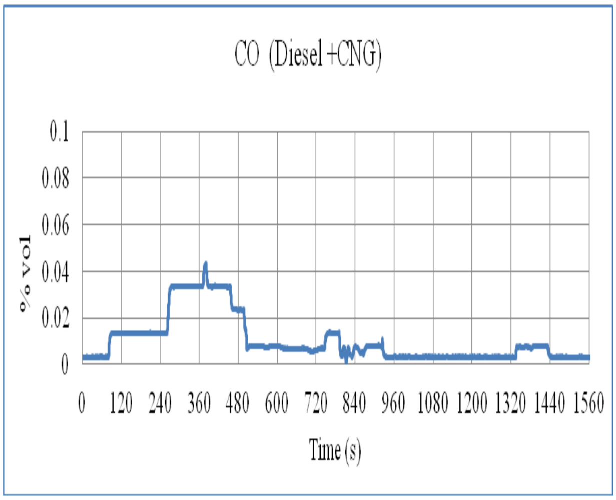

Figure 10. The CO variation when used as dual fuel diesel –CNG

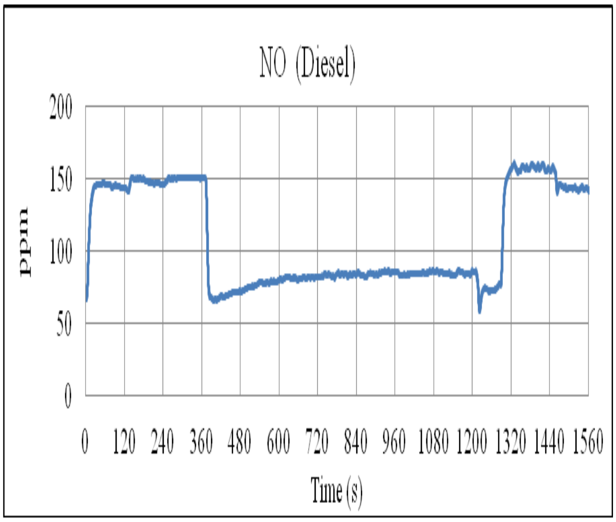

Figure 11. The NO variation when used as fuel diesel

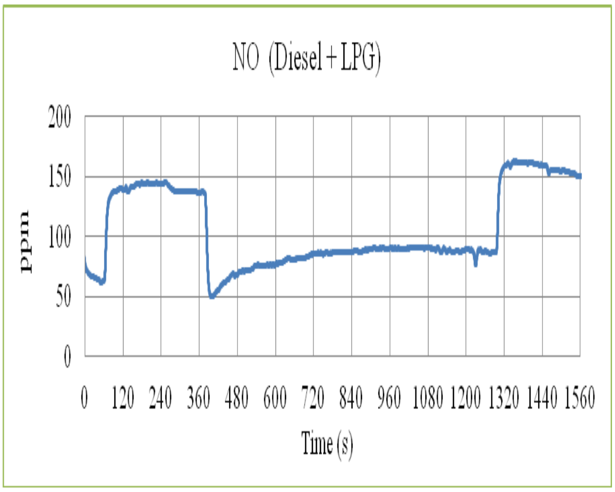

Figure 12. The NO variation when used as dual fuel diesel -LPG

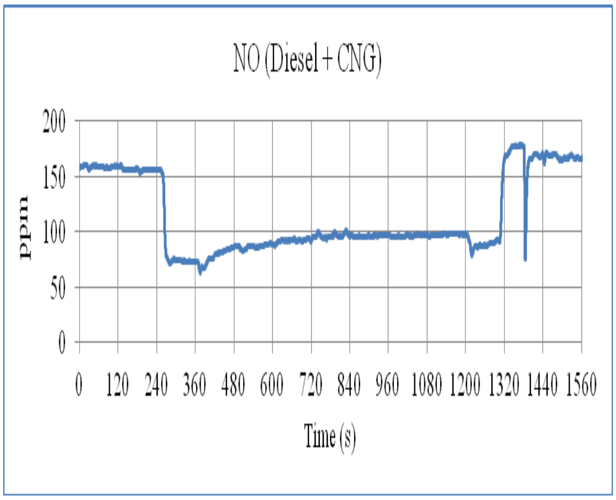

Figure 13. The NO variation when used as dual fuel diesel -CNG

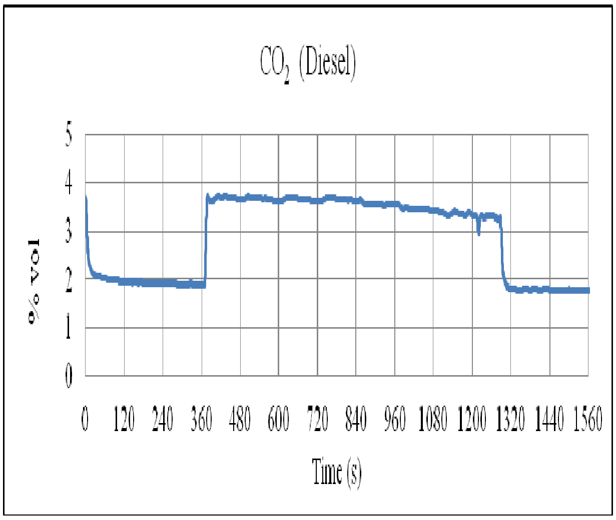

Figure 14. The CO_2 variation when used as fuel diesel

Figure 15. The CO_2 variation when used as dual fuel diesel -LPG

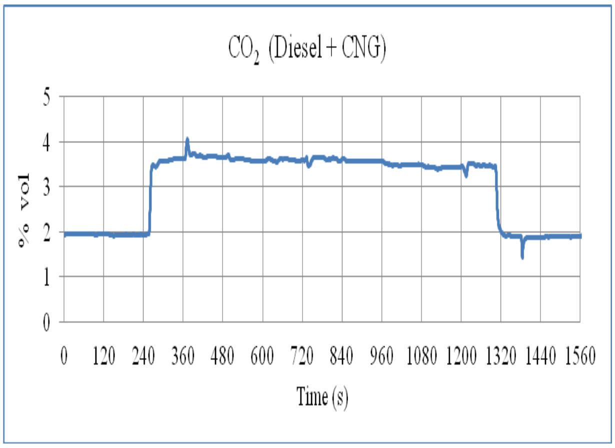

Figure 16. The CO_2 variation when used as dual fuel diesel -CNG

4. Conclusion

By taken into consideration the above results, it can be said that:

-The HC emissions were increased in the case of diesel-LPG

The CO emissions were decreased in the case of diesel –CNG

The NO emissions have not changed.

The CO_2 emissions have not changed significantly.

Finally, it is important to be mentioned that with the use of diesel-LPG and diesel-CNG the engine was functioned better than the case of diesel.

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