CASE STUDY ON MAIN POLLUTANTS MONITORING CONCERNING COMBUSTING LPG AND PETROL FUEL IN A GENERATOR WITH A SPARK IGNITION ENGINE

Florin. IACOBESCU
Faculty of Mechanical Engineering,
Politehnica University of Timisoara

Prof.dr.ing.habil Ioana IONEL
Faculty of Mechanical Engineering,
Politehnica University of Timisoara

REZUMAT. În lucrare sunt descrise activităţile de monitorizare pentru HC, CO, CO2, şi NOX, în raport cu procesul de ardere a combustibilului GPL şi benzină în interiorul unui generator cu motor cu aprindere prin scânteie. Concluziile sunt în raport cu influenţa a două tipuri diferite de combustibil, cu accent pe impactul GPL asupra benzinei. Chiar daca GPL este un gaz mai puţin poluant, pentru o sarcină anume a motorului 2 kW valoarea de poluare este crescută.

Cuvinte cheie : GPL,ardere de benzină , motor cu aprindere prin scânteie

ABSTRACT. The paper describes the monitoring activities for HC, CO, CO_2, and NO_X, relative to the combustion process of LPG and petrol fuel inside a generator with a spark ignition engine. Conclusions are taken relative to the influence of the two different fuel types with accent on the impact of LPG over petrol fuel. Even the LPG is a less pollution gas for a certain charge of the engine (2 kW) the pollution amount is increased.

Keywords: LPG, petrol combustion, spark ignition engine

1. INTRODUCTION

The calculation of combustion is important in the design of combustion, but also to have a tool for assessing their environmental impact.

In contrast to environmentalist slogan "a clean man in a clean world ", it appears that there are undesirable impact of internal combustion engines because it pollutes the environment through harmful emissions mainly and noise, but also by other disadvantages, apparently of a lesser importance (such as oil and fuel spills, waste from manufacturing or recycling of vehicles and induced electromagnetic interference [1].

The effect of the most important pollutant in internal combustion engines is due to the presence of harmful emissions in the combustion gases, emissions that occur due to incomplete and imperfect combustion (attested by the presence of CO species, CmHn in the flue gas) fuel in internal combistion engine, but following the standard mechanisms of genesis (where NOx).

Burning fuel in an ideal Otto cycle would lead to stable and nontoxic compounds only in the combustion gases (O_2, N_2, H_2O), together with the presence of CO_2. However, in real conditions, the emissions contain food pollutants: NOx, SO_2, CO, CH_4, N_2O, etc. and greenhouse gas (CO_2), as shows Figure 3.

The installation conceived applies the principle of simultaneous change in two distinct forms of energy of a single primary energy source (LPG or Petrol). Primary energy is energy that feeds the engine fuel introduced and the two forms of energy are electricity at a voltage between 215-230 V at 50 Hz and an output of up to 4 kWh and heat. The fuel used is LPG [1].

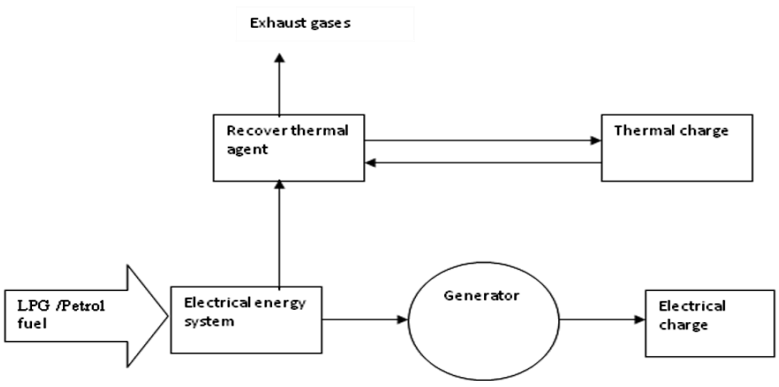

Fig. 1. *Cogeneration with spark ignition engine by burning Lpg/Petrol fuel*

The main components of the installation are:
- spark ignition engine which, based on chemical energy of fuel combustion, generates mechanical energy, and which is connected directly, without reducing speed, power generation system;
- the generator itself, which converts mechanical energy into electrical energy;
- heat exchanger, which converts the energy of combustion of the spark ignition engine;
- reostat group load generator to simulate electric charge;
- data acquisition system that continuously monitors the thermodynamic parameters of the installation during the experiments [2].

Generator group is the main component of the cogeneration plant. The group is produced by Honda. The BCS-type generator is GE 6000 Plus. The group consists of: Otto engine; General Electric: Otto engine is the latest generation of production in 2007, single cylinder type, fuel, ignition and air cooling Hall effect. Turning is done exclusively by hand, like the case of the saw.

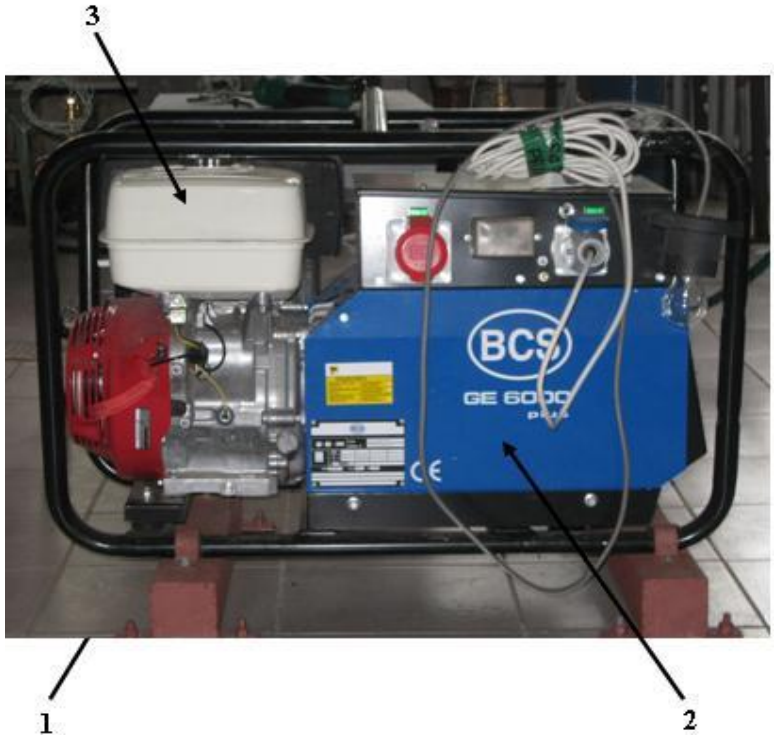

Fig. 2 *Generator group left view: 1-engine, 2-generator, 3-tank*

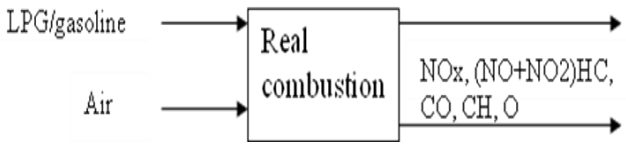

Fig. 3 *The real combustion of LPG/Petrol fuel*

2. POLLUANT DESCRIPTION

In the next rows are presented the main pollutants form an internal combustion engine:

2.1 Hydrocarbons – HC

These include gas products of incomplete and imperfect combustion. They identified about 400 individual compounds, representing most classes of organic compounds, including saturated and unsaturated aliphatic hydrocarbons, aromatic hydrocarbons and polycyclic compounds, oxygenates such as aldehydes, ketones, alcohols, ethers, acids and esters, as well as nitrogen, sulfur and organometallic compounds. It was found that benzpripenul, who is a cyclic hydrocarbons extracted from tar, exert a powerful carcinogen action. Especially as secondary substances are harmful because they are a main component of photochemical smog formation reactions [2].

Hydrocarbons, seen as a set of numerous chemical compounds are considered primary substances resulting from the combustion process in an internal combustion engine. They are very harmfull, including non-toxic compounds such as methane, but also highly toxic compounds such as 4-hydroxyphenyl [18]. Some are irritating and have reduced systemic effects, while others may have serious toxicological effects such as central nervous system failure and respiratory tract failure, or even carcinogenic effects [4].

2.2 Carbon monoxide – CO

Carbon monoxide is a colorless, odorless and tasteless gas, which is less dense than air. It is a relatively stable compound and participates in atmospheric chemical reactions. CO is an intermediate product, through which all compounds containing Care passing when they are oxidized. In the presence of sufficient O_2 during combustion, CO is produced which is then immediately oxidized, resulting in CO_2. This does not happen if the engine is running under load or deceleration.

However it is known that in normal operation, diesel engines produce lower amounts of CO compared to petrol engines [3].

CO affinity to combine with hemoglobin is 220 times greater than for O_2, resulting carboxyhemoglobin, which produce even in small doses, very serious disease of the nervous system, respiratory and cardiovascular systems.

CO poisoning results in headache, fatigue, dizziness, blurred vision, irritability, palpitations, vomiting, fainting, coma and even death.

2.3 Nitrogen oxides - NOx (NO, NO2)

Nitrogen oxides are formed by reaction with atmospheric oxygen at high temperatures and pressure specific to a burning chamber, in oxygen rich atmosphere and at higher changes of residence time. Nitrogen comes from either fuel or the air introduced for combustion. As temperature increases, increases also the share of the genesis mechanism of NOx and gas concentration exhaust. NOx is actually a symbol that includes multiple chemical species of nitrogen oxides [4].

Among the oxides in the exhaust gases is present and a certain amount of nitrogen dioxide (NO_2), which increases the amount of gas output in the atmosphere, by further oxidation of nitric oxide (NO).

NO_2 is generally considered the most harmful nitrogen oxide to human health. Such statistics point to the risk of disease correlated with ambient concentrations. Allowable limits and standards are often expressed with direct reference to NO2 and more general to NOx.

Nitrogen dioxide is considered harmful, toxic effects resulting from inhalation and producing lung dysfunction, acute respiratory diseases, irritation of eyes and of mucous membranes in general. NO_2 produce harmful effects on the environment. It mentions acid rain, with adverse consequences for vegetation. NO_x are essential in the formation of ground ozone. When ultraviolet radiation is subject to solar NO_2, an oxygen atom is separated from the oxide molecule, combined with a molecule of oxygen and forming ozone (O_3) [3].

N_2O (nitrous oxide) is an oxide that is criminalized as greenhouse gas emissions, but also with contributions to ozone depletion. It has extremely long lifetime. Because of ozone holes generated at high altitude and which unfortunately extend, ultraviolet radiation is no longer filtered, leading to increased incidence of skin cancer in recent years [4].

NO_2 emissions are the second component as a percentage, which contributes to the greenhouse effect, after CO_2, and they also have an important contribution to photochemical smog.

2.4 Polluant measurement with LPG combustion

Depending on the chosen target for monitoring parameters of an installation, this examines the phenomena to be relevant conclusions. If cogeneration is intended to assess the efficiency of generating two forms of energy.

Action Plan therefore aims to monitor all parameters necessary to determine the effectiveness of co-generation. The study took shape around the influences of two major parameters:

-Workload of the group,

-Type of fuel used.

Simultaneously altering these two thermodynamic parameters, was determined and the environmental impact of co-generative group

- To do a simulation as close to the real situation, they chose a loading condition of 2 kW.

The specific method of continuous sampling was determined following dependencies:

1. CO concentration variation depending on load and fuel type used;
2. NO and NOx concentration changes depending on load and fuel type used;
3. O2 and CO2 percentage changes depending on load and fuel type used.

In the next graphics is presented the variation of the CO, NO, NOx, O2 and CO2 for a charge of the 2 kW with LPG.

Step 2 kW is the result of many consumers connect to the generator terminals. For this stage of loading, as in the previous case were measured thermodynamic parameters of the plant with continuous data acquisition program, namely fuel flow were recorded manually by reading the time unit of digital scales (for fuel) and meter (for heat - in our case water) in the flue gas emissions were monitored continuously using flue gas analyzer TESTO 350 M / XL.

Increasing the electrical load cogeneration plant, burning mechanism involves the intensification of internal combustion engine inside. Enhancing the thermal regime translates into increased flue gas temperatures. An increasing amount of heat leaving the combustion engine will find and simultaneously heat is circulated flue gas heat exchanger. So, in other words, the thermal component will increase the overall efficiency of the plant. At the same time fuel consumption will increase and that its degree of harm.

In this reference fuel was replaced with alternative fuel. Alternative fuel used in determining the comparative parameters liquefied petroleum gas. From the literature it is known that internal combustion engine that uses liquefied petroleum gas has the thermal regime intensified. Taking this into account, attempts were made some preliminary steps in order to determine the load.

In order to compare the thermodynamic parameters for the two cases were tried in the simulation of loads made for the situation when the engine was fueled with petrol.

Below are the results of measurements in graphical form.

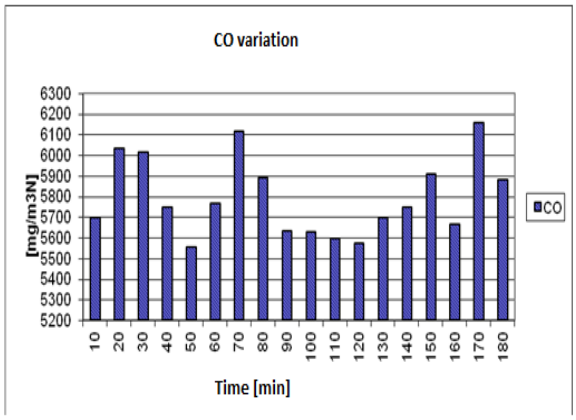

Fig. 4. *Variation of CO for 2kW charge for LPG*

In Figure 4 the results of measurements of CO emission, expressed in mg/m3N and related to reference oxygen. The average value is 5700[mg/m3N]. Observe an increase in the emission of carbon monoxide.

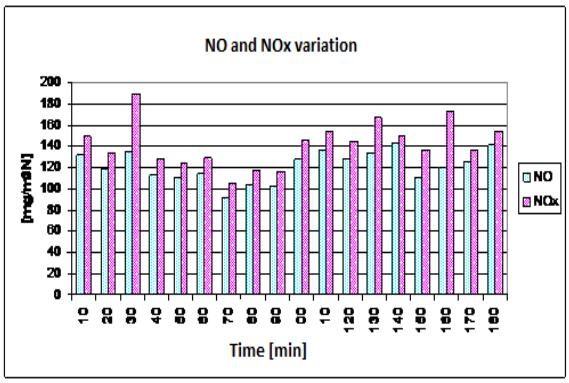

Fig. 5. *Variation of NO, NOx, for 2kW charge for LPG*

Figure 5 shows measured values for NO and NOx emissions expressed in mg/m^{3}N and reported to the 3 % oxygen. Intensification mechanism inside burning internal combustion engine, is also reflected in increased emissions of NO and NOx. Average values obtained for these species polluting mg/m^{3}N NO 121 and 142 mg/m^{3}N for NOx is higher than in the case load of 1 kW.

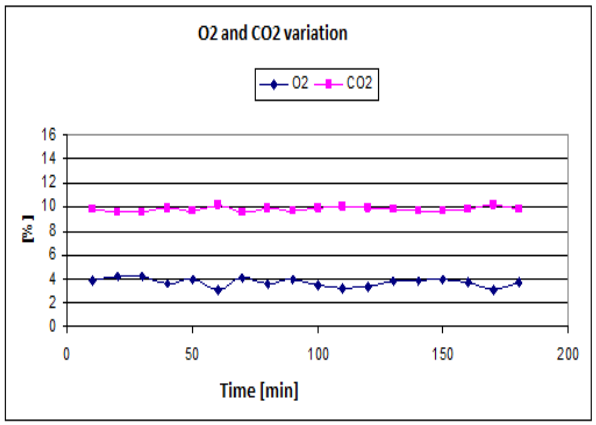

Fig. 6. *Variation of O_2, CO_2, for 2kW charge for LPG*

Figure 6 shows values for oxygen and carbon dioxide expressed as a percentage. The average values for these species were 3 % and 9.8 % oxygen for carbon dioxide.

2.5 Polluant measurement with Petrol combustion

A very important parameter in calculating combustionis air excess ratio [λ] . Gas analyzer is not directly measure this parameter, it is calculated as the ratio of $CO_{2\ max}$ and CO_2.

$$\lambda = \frac{L_{min}}{L} \qquad [-] \quad [1]$$

L_{min} - the minimum air nccesary for burning in m ^{3}N/kg,
L - the actual quantity of air in m ^{3}N/kg

Combustion calculation is done in several stages and is based on:
a) Mass percentage composition of gasoline:
c = 85%
h = 14.9%
s = 0.05%
o = 0.04%
h = 0.01%
b) Petrol lower heating value H guaranteed by the analysis and verified experimentally by calorimetric bomb test:
H = 43 698 MJ / kg

To test the engine loaded with 2 kW , using a single dimmer, connected directly to the generator through socket. At the end of the tests were generated by data acquisition program, two separate files. A file showing the tempreature values and the second one showing the values of pollutant emissions. Fuel flow and water flow were recorded manually, because the type of sensor, according to the remaining measurements. The results are presented in graphical form, to be more intuitive analysis measurements.

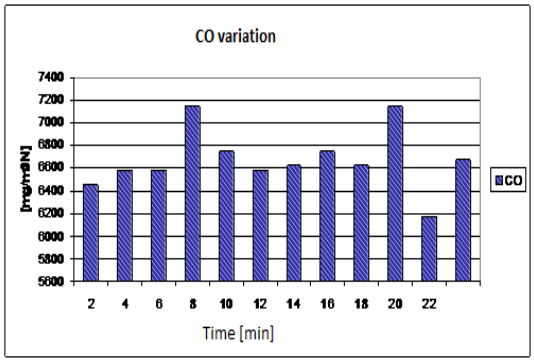

Fig. 7. *Variation of CO for 2kW charge for petrol*

CO concentrations in Figure 7 obtained from this system are high. Value recorded for this species is "normal" for a gasoline engine, air cooled, single cylinder, with the power system through carburetion and 4-stroke operation. .

Values indicate that on the one hand burning is not perfect, the lack of oxygen resulting in significant CO concentrations. On the other hand, combustion is intensified, increasing the temperature inside the combustion chamber resulting in higher levels of NO concentrations. From the graph we can see that the values are constant.

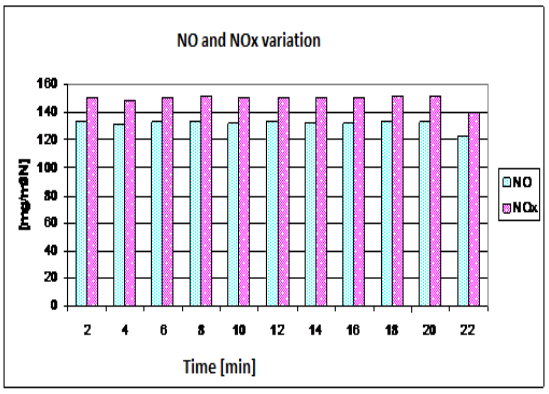

Fig. 8. *Variation of NO, NOx, for 2kW charge for petrol*

The same increased values are found and emitted NOx and NO_2 concentrations are also high.

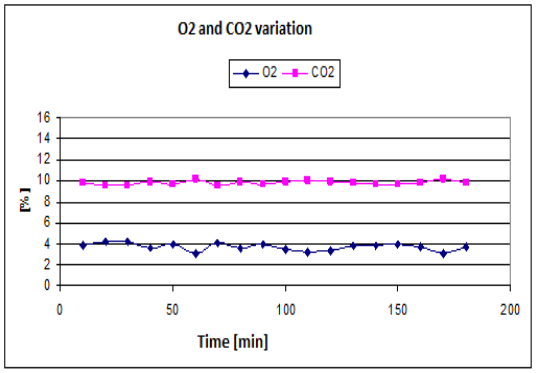

Fig. 9. *Variation of O2, CO2, for 2kW charge for LPG*

For O_2 and CO_2 were obtained values shown in Figure 9. He obtained a constant around 8.73 % (volume parts) for the emission of CO_2 and oxygen was an average of 5.5 % parts by volume.

3.RESULTS AND DISCUSSIONS

In Figure 10 are the average values of carbon monoxide emissions expressed in [mg/m3N] reported the oxygen reference. Values were recorded at a frequency of 10 minutes due to the installation system has been constantly subjected. Reference Oxygen has two values in this case, because the plant was fed with two types of fuel.

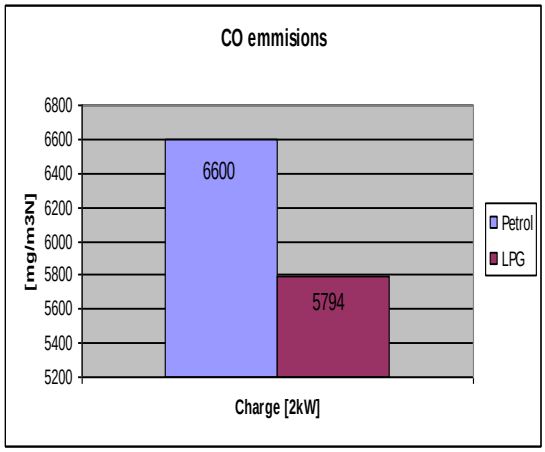

Fig. 10. *Comparison of CO for petrol and LPG for 2 kW charge*

For liquid fuel the oxygen reference value is 5 % and gas fuel is 3 %. From the figure we see that level of 2 kW load pretru power specials carbon monoxide mg/m3N 6600, which is higher than the value obtained for the electrical load of 2 kW (5794 mg/m^3N). Although electrical power is the difference in terms of assessing the degree of pollution we can say that the species of carbon monoxide, the value loaded cogeneration plant of 2 kW is cleaner when using liquefied petroleum gas. Reducing pollution is blamed on elementary composition of liquefied petroleum gas which consists only of propane and butane in various proportions by volume, depending on the season in which it is delivered to recipients.

For the Figure 11 in which the facility was charged at 2 kW, for the two types of fuel, the emission of NO gas fuel, resulting in a lower value of 10 units.

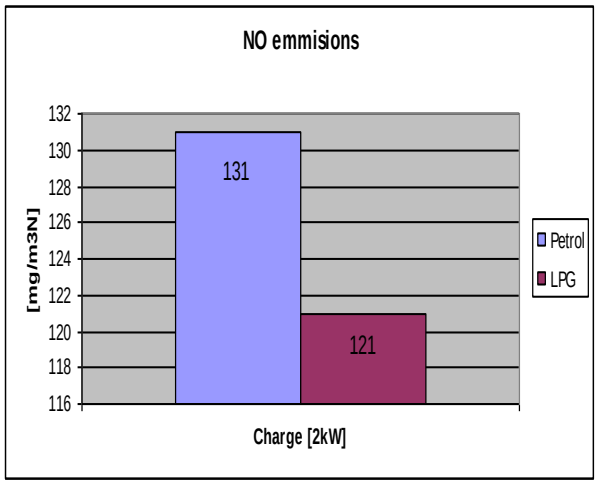

Fig. 11. *Comparison of NO for petrol and LPG for 2 kW charge*

For the load of 2 kW petrol and - 2 kW LPG, the NOx emission is located on the same beach, the differences between the two loads are small, about 7 units as is it showed in the figure 12.

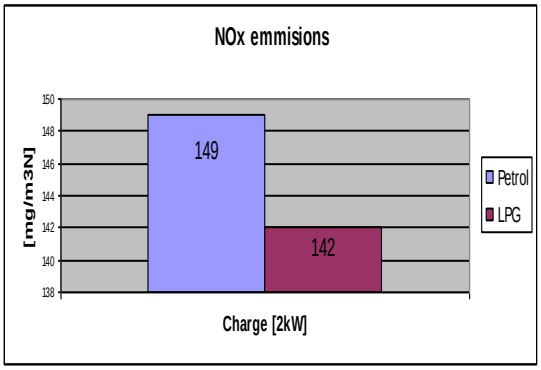

Fig . 12. *Comparison of no_x for petrol and lpg for 2 kw charge*

Table 1 *Comparison of CO_2 amount for Petrol and LPG for 1 unit and 1000 units*

Fuel	Charge [kW]	CO_2 [mg/m3N]	Flow CO2/units [t/year]	Flow CO2/1000 units [t/year]
Petrol	2	17,66	7,25	7245,54
LPG	2	20,04	8,22	8222,00

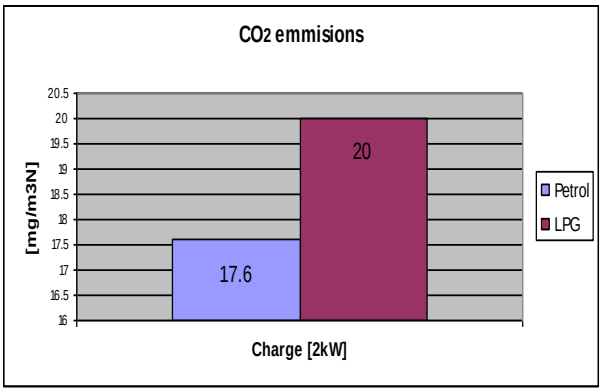

Fig. 13. *Comparison of CO_2 for petrol and LPG for 2 kW charge*

The emission of CO_2 is a pollutant species requiring strict control any activity from either industry or energy sector. Carbon dioxide gas is not toxic; it contributes to the greenhouse effect on earth installation. The only method of annihilation of the species is through photosynthesis. The process of obtaining heat and power cogeneration, reduce CO_2 emissions by lowering fuel consumption would be needed to produce heat and power separately.

Another thing to note is that the amount of CO_2 will be reduced in direct proportion to the percentage by volume of fuel used in combustion of organic nature. For example, if the primary fuel used to produce electricity and heat in cogeneration, should be at 100% of organic nature, then the CO_2 emission would be zero. Research by the cogeneration plant in question have so far highlighted the advantages and disadvantages of using gasoline and lpg as primary fuel, both fossil nature. Future research will explore the future possibility of cogeneration power of small groups with biogas, CO_2 reduction principle is fully applied in this way.

In Table 1 are the CO_2 emissions for the two fuels considered when producing heat and electricity cogeneration. To determine the amount of carbon dioxide in tonnes per year for a single unit similar to that achieved in the multifunctional laboratory of the Faculty of Mechanical. I have also presented a scenario for 1000 such small cogeneration plants, similar with the laboratory that experiments were carried out. It is worth mentioning that the annual operating period was set at 365 days.

From the table it is noted that the thermal energy production in cogeneration power of 2 kW for charging when the primary fuel used to produce heat and power cogeneration was petrol, CO_2 emissions for a single cogeneration plant was 7, 25 tons.

For alternative fuels, power generation situation in CO_2 emission cogeneration, results negative changes.

At this charge the CO_2 emmisions were increased.

CONCLUSIONS

Even the LPG is a less pollution gas for a certain charge of the engine (2 kW) the pollution amount was increased. The measurement of the emmisons was done for 2 kW charge and most of the emmisons were less for GPL (NO, CO, NO_x). For CO_2 the emmisons were increased significantly.

REFERENCES:

[1] **V., D., Negrea**. *Procesees in Internal combustion Engines*, Economy, Pollution avoidance. Vol 1, Ed. Politehnica (2001).

[2] **D. Iorga**, *Supply of Internal Combustion engines*, Ed. Politehnica, (1995)

[3] **R. Bosch Gmbh**: – *Automotive handbook*, Stuttgart, (2000).

[4] **Tyson, K. Shaine**, *Biodiesel Handling and Use Guidelines*, National Renewable Energy Laboratory, USA, September (2001).