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Effect of Hydroxy (HHO) Gas Injection in a Gasoline Electric Generator for Rural Areas

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Abstract

This study aimed to evaluate how the HHO gas injection from an electrolyser, conventional bipolar type, works inside a motor-generator fueled with gasoline for utilization in rural areas. After the injection of HHO gas together with gasoline, the parameters of exhaust gases, exhaust temperature, pollution expelled, specific consumption of the engine and excess air, were checked and compared. The main results allowed the evaluation of the engine, when it was fueled with gasoline and HHO gas, which had a better performance than that when fed only with gasoline. The results showed that the engine consume less gasoline and generate fewer pollutant gases when in operation with the injection of HHO gas without the need of radical changes in the engine design.

Keywords: HHO gas, specific consumption, motor-generator

1. Introduction

There are in Brazil approximately 25 million people living outside urban areas. Among them, 15% still live without access to the electricity in their homes and the vast majority lives in rural communities or in areas of difficult access. It has been estimated that there are 100,000 rural properties still without electricity in our country, depending, in large majority, on diesel generators for the production of electricity. To provide electric power for this population it would be necessary transport this energy in long transmission lines, but the cost of doing it, is too expensive. A solution for this impasse would be the generation of electric energy on a small scale, through distributed generation, supplied by small local hydroelectric plants or even internal combustion generators (Walter, 2000).

In places where there is no power grid from distributed generation and nor centralized generation, generation systems are used by internal combustion engines, also called motor-generator, where each unit generates from a few kilowatts to hundreds of watts, usually powered by gasoline, diesel, natural gas and others (Walter, Faaij, & Bauen, 2000). These motor-generators are also very common in rural areas where biodigester systems are used to that produce fuel gas for production of electric energy (Oliveira, 1997). However, these systems can produce harmful and pollutant gases to the environment, which can contribute to the reduction of the ozone layer of the planet.

The increasing demand for oil-based fuels and the reduction around the world of its production has led to the increase of the prices, promoting the search for other solutions that did not depend on hydrocarbons (Souza et al., 2003; Maizonnasse, Plante, & Laflamme, 2013). Researchers seek for an alternative fuel that can be used in engines without the need for major mechanical changes (Bose, Banerjee, & Deb, 2011). An alternative, would be gaseous hydrogen, pressurized, to be used as fuel for internal combustion engines (Saravanan & Nagarajan, 2011) or hydrogen from electrolytic reactions by separation of the water molecules (Verhelst & Wallner, 2009; Vandenborre, Sierens, & Greenbus, 1996; Rimkus et al., 2013).

According to recent studies, there are some advantages, such as improved engine power, reduction in pollutant concentrations expelled in the exhaust and the reduction in specific consumption (Maken, 2003). An alternative for obtaining hydrogen gas is through relatively simple process called electrolysis of water in which hydrogen gas can be removed from water by an endothermic reaction. In this reaction, oxygen is also detached from the water and it can be used together with hydrogen and the base fuel (gasoline, diesel or natural gas) in internal combustion engines. As some types of electrolyzers have no separation of oxygen and hydrogen, this mixture is called HHO gas (El-Kassab et al., 2016; Santilli, 2006).

The purpose of this article is to verify the effects of mixture of the HHO gas in a gasoline motor-generator. The HHO gas comes from the water, through the process of electrolysis, in an electrolyser built in an acrylic box, conventional bipolar type, in which the gases from the reaction of H_2 and O_2, are led to a combustion chamber that will be burn with gasoline inside the motor-generator (Al-Rousan, 2010) and consequently serving as a proposal for rural electrification.

2. Material and Method

In the development of the experiment was used a motor-generator Toyama, model TF1200 (Figure 1) and its technical description, as shown in Table 1, is provided by the manufacturer (Toyama, 2011).

Table 1. Technical characteristics of themoto-generator

MOTOR		**GENERATOR**		**GROUP**	
Type	Mono-cylindrical, 4	Maximum Power CA	1.2 KVA	Tank Capacity	5 L
Type	Time, OHV 25º	Rated Power CA	1 KVA	Autonomy at Nominal Power	9 h
Engine model	TF25FX	Output Voltage	115 V	Noise Level Within 7m Distance	67 dB
Cilindrada	87 cc	Nominal Chain CA	9.5 A	Voltmeter	Yes
Cilindro (diameter × course)	54 × 38 mm	sockets	2 × 115 V	Fuel level indicator	No
Rated Power/Rotation	2,4HP/3600RPM			Overload protector	Yes
Compression ratio	7,7:1	Type/Phases	single-phase	Oil level warning	Yes
Fuel	Gasoline	Power factor	Cos ϕ=1	Structure	Tubular Steel
Starting system	Retractable manual	Frequency	60 HZ	Dimension (W × L × H)	460 × 365 × 390 mm

Note. Where OHV = Over Head Valve; CA = Alternating Current; A = Amperes; V = Volt; HZ = Hertz; RPM = Revolutions per minute; dB = Decibels; h = Height; W × L × H = Width × Length × Heigth.

In the experiment, 8 lamps of 100 Watt (W) were used as the charge in the generator and, as shown in Figure 2, in the way that each lamp was turned on by independent switches, composing the charge needed in each test.

To monitor the voltage generated by the motor-generator a voltmeter was used, and it was installed on the generator panel, as seen above in Figure 1.

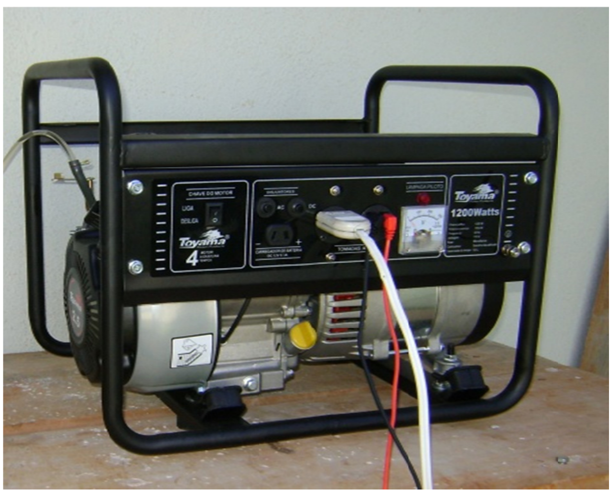

Figure 1. Motor-generator, Toyama, model TF1200

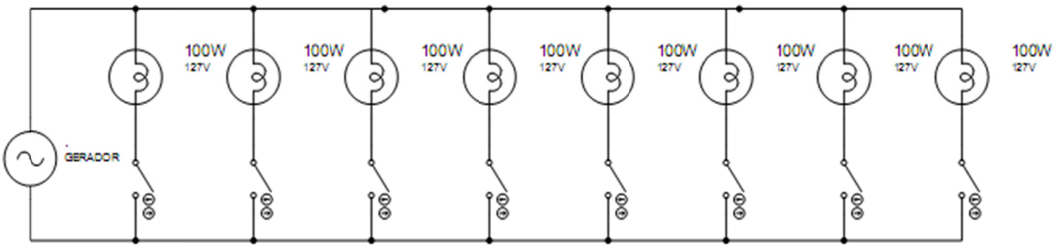

Figure 2. A resistive load connected to the generator

To register the frequency of the voltage generated by the motor-generator set, equipment called multimeter was used with the frequency analysis function, Minipa, model ET-2053, which were written down the values to be evaluated later (Figure 3a).

To determine the output temperature of the exhaust gases, a thermocouple sensor was used, K type, Kalimex Tools Professional, model M890T (Figure 3b), positioned and fixed on the exhaust output, where the exhaust gases from the internal combustion engine were expelled, as Figure 3b.

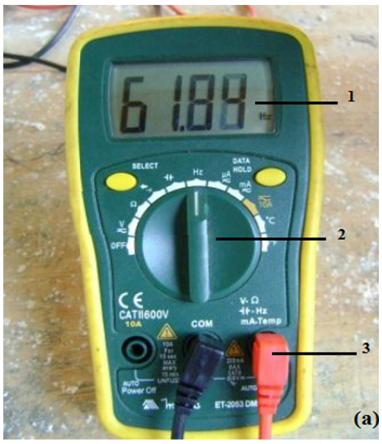

Figure 3. (a) Frequency analysis, Minipa, model ET-2053 (1-Display: Displays the reading value; 2-Rotary Switch: Turns on and off and select a function and measure range; 3-Input Terminals: Terminals for connection of the probes. (b) Termometer, Kalimex, model M890T (1-Display: Displays the reading value; 2, 3-Rotary Switch: regulation of electrical resistance and electrical voltage)

To register the amount and current requested by the charge of the lamps to the motor-generator, an ammeter was used, Instrutherm, model Va-750, once the equipment does the readings, through the electric field that circulates around the conductor without the necessity of open the circuit to read their values, as shown in Figure 4a.

To quantify the gases generated by the engine, an emission and combustion analyzer was used. The analyzer was manufactured by Homis, model PCA3, as Figure 4b.

Figure 4. (a) Ammeter, Instrutherm, model VA-750 (1-Meter-contact area; 2-Rotary Switch: Turns the instrument on and off and selects the function and measuring range; 3-Display: Displays the reading value; 4-Input Terminals: Terminals for connection of probes). (b) Mission and combustion analyzer, HOMIS, model PCA-3 (1-meter up to 4 gases simultaneously; 2-control of functions)

The experiment was executed with a Lctrical generator linked with a combustion engine, called motor-generator or generator group, with some alterations in the original structure, which was necessary the removal of the original tank, replaced by a graduated beaker to determine consumption in short time intervals. The original carburettor had to be moved in order to enable the insertion of the HHO gas injector, which remained between the carburettor and the intake valve of the combustion engine during the tests performed on HHO gas (Figure 5a).

Due to the moving of the carburettor, the connection rod had to be disconnected (Figure 5b), because it was in between the automatic regulator of rotation (ARR), as shown on Figure 4c. Furthermore, manual adjustments were needed in relation to the acceleration, in order to keeping the motor speed velocity around 3600 RPM, for every charge used, adjustments in the carburettor were made (Figure 5a).

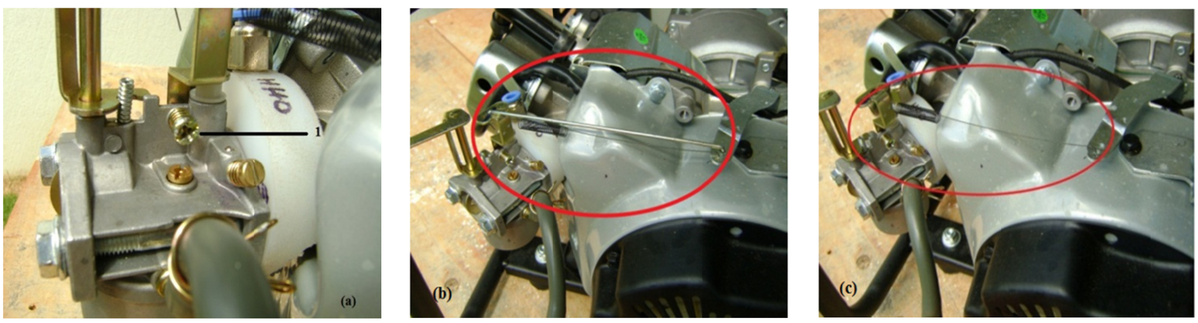

Figure 5. (a) Manual acceleration and rotation adjustments (1-Acceleration adjustment). (b) Connection rod with ARR. (c) Without rod in the connection of the carburettor with ARR

To measure the consumption of gasoline in the motor-generator, 100 ml capacity milliliters measuring cylinder was used. The amount of fuel spent in every minute was recorded, and this process was repeated 10 times for each one of the nine powers. Electric charges were 0 W (empty or no load), 100 W, 200 W, 300 W, 400 W, 500 W, 600 W, 700 W and 800 W.

The mass of gasoline correspondent to each milliliter of fuel used in the engine was determined, using a precision scale of six decimal places, calculating, subsequently, the density (specific weight) in grams per milliliter, because the specific consumption of the engine is given in g/kWh.

For the HHO gas to be admitted by the motor-generator, a nylon gun was developed as shown in Figures 6a and 7.

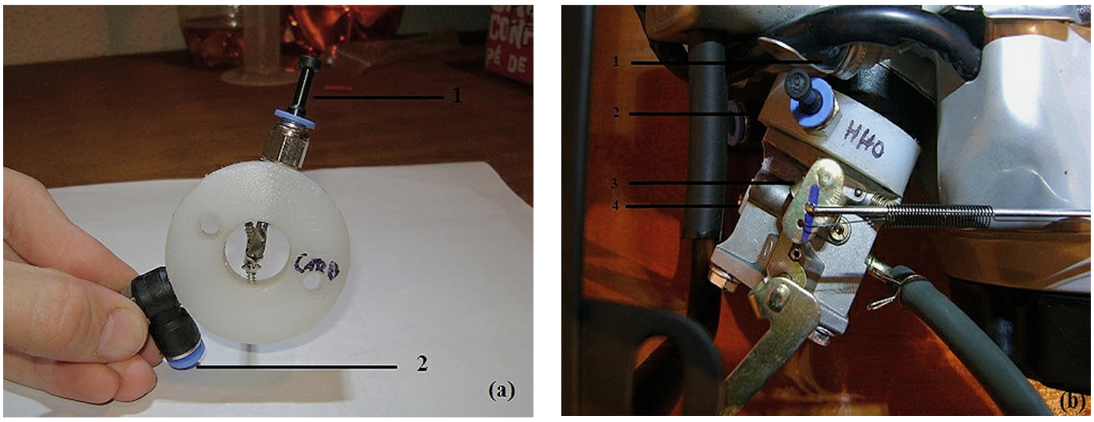

Figure 6. (a) Prototype of HHO gas gun (1-HHO intake; 2-Air intake). (b) Gas gun prototype installed on motor-generator gasoline (1-Intake valve; 2-Intake HHO; 3-Accelerator; 4-Carburador)

The injector was installed between the intake valve and carburetor, as can be seen in Figure 6b, and its design can be seen in Figure 7.

Figure 7. Design HHO gun

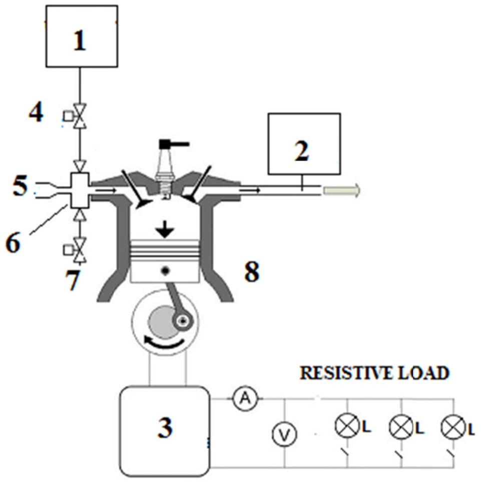

Figure 8. Complete system HHO gas injection installed in motor-generator gasoline (1-Electrolytic reator; 2-Combustion analyzer; 3-Electric generator; 4-Inlet valve HHO; 5-Carburetor; 6-Intake HHO; 7-Air inlet valve; 8-Internal combustion engine

The installation of the injector was executed this way to ensure the admission of HHO gas and to make is the closer as possible to the engine intake chamber, ensuring that HHO was directed to the chamber when the air was sucked into the intake chamber, avoiding any possible wastes of the gas inside the system, reducing this way, the dragging and the fuel consumption (gasoline), through the main input of the carburetor. The whole scheme can be observed in the Figure 8.

To simulate the electrical charge demanded by the motor-generator, 8 incandescent lamps of 100 W were used, individually activated by switches according to the level of the charge to be simulated. The simulations could vary since the empty or no-charge mode (0 W), to the power rating of 800 W, as shown earlier at Figure 2.

For determining the specific fuel consumption in the motor-generator, both gasoline and the mixture of gasoline and HHO gas, a graduated cylinder from 0 to 100 ml was used, to quantify the consumption in every minute, with 10 repetitions for each of the simulated charges.

To quantify the exhaust gases, an emission and combustion analyzer was used, with the gas input inserted in the engine exhaust, in order to collect only the gases that really were present in the exothermic reaction occurred in the engine combustion chamber.

The analyzer was kept collecting data throughout the experiment, quantifying the amount of gas in each charge connected to the generator, as when the engine was fueled only by gasoline, as when fueled with the mixture of gasoline and HHO gas. Thus, determining the variation on the gases released from the engine. Variations in the nitrous oxides (NOx), carbon dioxide (CO_2), excess air (EA) and temperature of exhaust gases were measured.

3. Results and Discussion

In Figure 9, it was observed that the specific fuel consumption at no-charge mode, which means 0 W charge, was 4.8 g/k Wh and 4.4 g/k Wh supplied to motor-generator, respectively, with gasoline and gasoline with gas HHO. The difference in this charge corresponded to 8.3% less fuel consumption for the motor-generator when supplied with the mixture of gasoline and HHO gas.

The fuel consumption difference, when the motor-generator was fueled by gasoline and HHO gas, was more significant as the simulated charge increased. To each 800 W, the specific consumption of fuel, corresponded to a 16.6% less consumption when fed with gasoline and HHO gas, with specific consumption values of 8.6 g/kWh and 7.2 g/kWh to the motor-generator fed, respectively, with gasoline only, and gasoline with HHO gas, as can be seen at Figure 9.

According to Musmar and Al-Rousan (2011) in a study conducted in order to evaluate the effect of HHO gas in gasoline engines, the obtained results, where the specific consumption of gasoline was reduced by 20%, however, the authors have their focus on the engine speed.

Other authors report that when hydrogen or HHO gases were inserted into the engines, its efficiency in combustion is increased (Akansu, 2004).

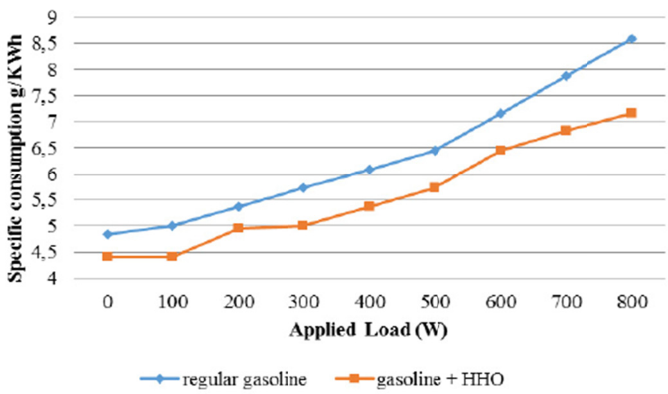

Figure 9. Specific motor-generator consumption depending on the load applied

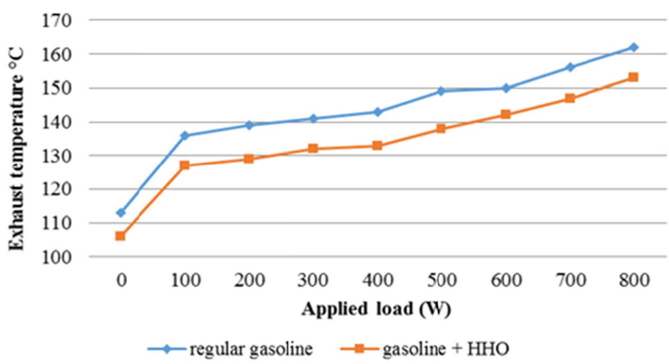

Figure 10. Temperature range in engine exhaust

As shown in Figure 10, the temperature was less when inserted HHO gas with gasoline. This behavior can be found throughout the graph, from the charge in the empty mode, meaning that it was empty, it was 113 °C and 106 °C for powered "motor-generator", with pure gasoline and gasoline with HHO, respectively. The variation in this charge corresponded to 6.2% less than the temperature of motor-generator when supplied with the mixture of gasoline and HHO gas.

It was observed that the difference between the temperature when the motor-generator is fed with gasoline and HHO gas became more significant when connected to charges 100 to 800 W. To the load 100 W the temperature of the exhaust gases had 6.6% lower than when fed with gasoline and HHO gas with temperature values 136 °C and 127 °C for powered motor-generator, respectively, with gas and gasoline and HHO gas, where this difference remained about the same throughout the experiment, as can be seen in Figure 10.

Musmar and Al-Rousan (2011), Al-Janabi and Al-Baghdadi (1999), and Thurnheer et al. (2009) in a study conducted with the objective of evaluate the effect of hydrogen in gasoline engines, obtained similar results to variations in temperature of the exhaust gases found, however with engine speed-related approach.

When the motor-generator works with fuel in the uncharged mode (0 W), the amount of NO was 34 ppm, and after insertion HHO, this amount was 20 ppm, representing a reduction of 41%. As seen in Figure 11, where the exhaust gases are shown, it was found that when inserted HHO gas together with the gasoline, this behavior was observed throughout the graphic from the load to the unloaded mode until the equivalent load the rated motor (800 W).

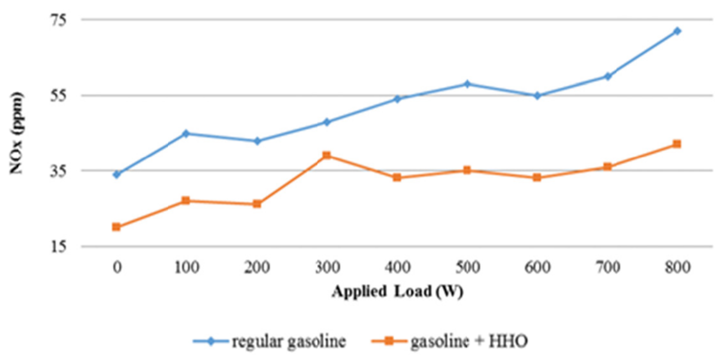

Figure 11. Nitrous oxide exhaustion data

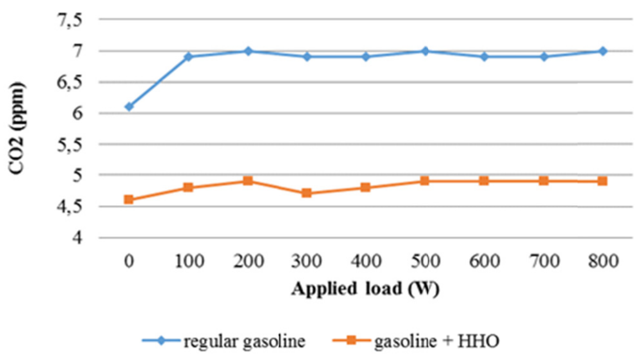

Figure 12. Carbon dioxide exhaustion data

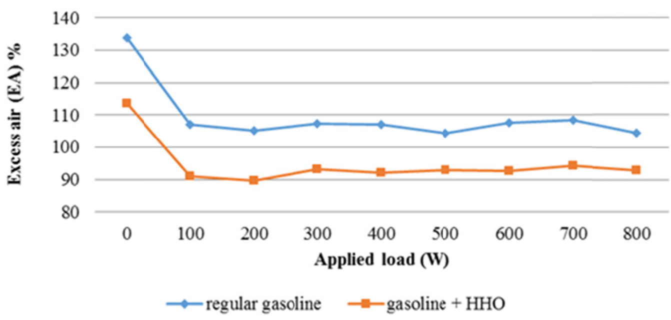

Figure 13. Variation of excess air

When analyzed CO_2 emissions, shown in Figure 12, the behavior was similar after insertion of the HHO gas, when the motor-generator worked with fuel in the empty mode (0 W), the amount of CO_2 was 6.1 ppm, and after HHO insertion this amount was only 4.6 ppm, a reduction of 24%. It was found that when inserted HHO gas with gasoline, this behavior can be seen in virtually all the graphic from the load to the empty mode (0 W) to the rated motor load (800 W).

It is observed in Figure 12 the carbon dioxide has a more constant behavior from 400 W of power, while running at regular gasoline has slight variations and remains more constant from the load 500 W.

These results were compared to Musmar and Al-Rousan (2011), and Yilmaz, Uludamar, and Aydin (2010) in a study conducted with the objective of evaluating the effect of the HHO gas in combustion engines, obtaining similar results to variations of nitrous oxides and carbon dioxide exhaled during combustion, in which, according to these authors carbon dioxide reduction was 40%, however, these authors have a related approach to rotation of the motor. According to Sulatisky, Hill, and Lung (2006), Saravanan and Nagarajan (2009), and Huang et al. (2007) reached values close to this work with reduction of CO and NOx, the values 20 to 28% under similar conditions.

As the reading of the data collected from the combustion analyzer, the motor worked with excess fuel when added HHO gas in the combustion chamber together with fuel, as shown in Figure 13 because it was a mixture composed of gas enriched with hydrogen.

If the carbon dioxide release is low, consequently, slower is the release of excess air, since the excess air comprises the gases that constitute the atmospheric air as CO_2, O, N (Mohammadia et al., 2007; Al-Janabi & Al-Baghdadi, 1999).

As can be seen in Figure 13, there was a reduction in excess air in the engine running on gasoline and HHO gas, and was compatible such as the reduction of CO_2 presented in Figure 12.

The following Table 2 summarizes the main values found in the survey. In it is present the minimum results for 0 W for the applied load, and maximum values for when the applied load is of 800 W, respectivel.

Table 2. Summary table of results found by applied load

Type of Fuel	Applied Load		Parameter Studied
	0 W	800 W	
Regular Gasoline	4.83 g/kWh	8.6 g/kWh	Specific Fuel Consumption
Gasoline + HHO	4.40 g/kWh	7.2 g/kWh	
Regular Gasoline	116 °C	162 °C	Extraust Temperature
Gasoline + HHO	106 °C	153 °C	
Regular Gasoline	34 ppm	72 ppm	NOx
Gasoline + HHO	20 ppm	42 ppm	
Regular Gasoline	6.1 ppm	7 ppm	CO_2
Gasoline + HHO	4.6 ppm	4.9 ppm	
Regular Gasoline	133.8 %	104.3%	Execess Air
Gasoline + HHO	113.7%	92.8%	

Results with gasoline with HHO addition were satisfactory for all the parameters verified in the study. It is worth noting the reduction of specific fuel consumption when adding HHO gas in gasoline.

4. Conclusion

They were obtained in this study the effects of HHO gas to be injected into a Toyama motor-generator, model TF1200. The gas was generated through an electrolyser and inserted directly into the intake valve with the aid of a gas gun. The gases expelled by the engine were quantified by gas analyzer, which enabled the following conclusions:

There was increasing the engine speed after insertion of the HHO gas, due to the increase of the calorific value of the fuel mixture, air and HHO.

There was an increase in combustion efficiency, while reducing specific fuel consumption reached 16.6%.

In conclusion, there was a reduction in the temperature of the exhaust gases.

After insertion, HHO decreased concentration of the exhaust gases.

With HHO gas injection engine remain in working arrangements with excess fuel or rich burning.

HHO gas when injected into a Toyama motorcycle generator TF1200 is a good alternative for rural areas, especially in isolated regions.

It is suggested that in motors with mechanical control system be made the adjustment of the carburetor to achieve the reduction in specific consumption.

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