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Use of an Ethanol-powered Motor-generator to Electricity Generation for Countryside Population and Small Isolated Communities

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Abstract

Due to the growing demand in the global energy mix and the constant concern about the use and the scarcity of fossil fuels, the study of cleaner, cheaper, easy-obtaining and environment-friendly alternative fuels has become a matter of general interest. In Brazil, the sugar-cane-based ethanol is a good alternative for the use of gasoline, since the country has a land fit for cultivation of this crop, skilled labor and suitable climatic conditions, and has low emissions of greenhouse gases. In this study it was used a four-cylinder Otto-cycle engine powered by gasoline with no adjustments. It was evaluated the system performance, power, voltage, and specific fuel consumption using mixtures of gasoline and ethanol in the following proportions: E0, E5, E10, E15, E20, E30, E35, E40, E45, E50, E55, E60, E65, E70, E75, E80, E85, E90, E95 e E100. The amount of harmful exhaust gases expelled by the engine (CO2 and NOx), was also analyzed, and it was observed a reduction in the amount of CO2 expelled by the engine due to the increase of ethanol concentration in the mixture. In contrast, the amount of NOx increased due to the fact that the temperature in the combustion chamber is higher for ethanol. As a result it was observed that the motor-generator provides 800 W of power, which is enough to allow the operation of refrigerator, television and electric bulbs in a small home.

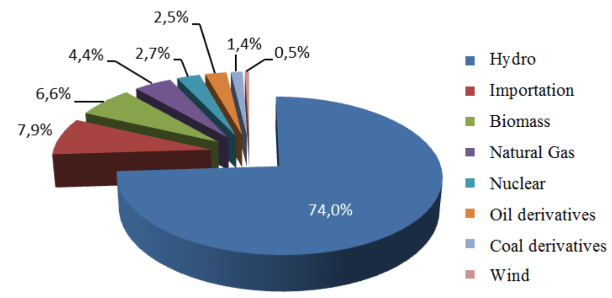
Key words

Small motor-generators, gasoline, ethanol, electricity, energy, exhaust gases.

1. Introduction

Energy is one of the most important inputs for humanity; the quality of life, economic growth, public health and sanitation are related to the energy availability for a specific population, industry or any other tangible area. The great challenge for the mankind is to find out the best ways to extract this energy without damaging the environment or, at least, to reduce such aggression.

The great need of electricity and easiness to obtain it from fossil fuels supported the great energy development during the industrial revolution. Its advantages such as high energy content, availability on the earth's crust, easiness of transport and handling, led the mankind to explore it in a continuous and devastating way. Brazil has abundant natural resources applicable for the generation of renewable energy. Considering the production of electricity, 74% of its energy matrix consists of energy generated from hydro resources. The second one is the biomass with 6.6% in 2012 (it was 4.7% in 2011). Figure 1 shows the sources of electricity generation in 2011. (MME, 2012)



Source: EPE
Fig. 1 – Brazilian sources of electricity generation (2011)

Such great availability of resources highlights Brazil globally and emphasizes the responsibility of creating new technologies for efficient use of renewable resources, creating opportunities for energy and environmental improvements. In 2011, a survey held by the Energy Research Company (EPE) showed that Brazil count on 88.8% of renewable electricity, while the rest of the world uses only 19.5%, numbers that put the country in a prominent position when compared to the rest of the world. The Brazilian sugarcane industry has a great importance on the renewable energy generation in the country. The sugarcane, raw material for the production of ethanol and bioelectricity, is the second largest source of energy in the country, accounting for 18% of the whole amount of energy consumed in Brazil, as reported by the Sugarcane Industry Union Cane (UNICA, 2010).

Brazil is the worldwide greatest producer of sugarcane. It is expected to produce more than 596.6 million tons in the 2012/2013 harvest, count on a planted area intended of 8.5 million hectares available for the sugarcane sector. (CONAB, 2013)

The large territory, the diversity of soil suitable for planting, the influence of different climates and the secular domination of the technologies used in sugarcane production justify the position reached by Brazil in the global context of the production of ethanol and sugar. According to an agro-ecological zoning conducted by the Ministry of Agriculture, Livestock and Provision (MAPA), Brazil has about 64.7 million of hectares suitable for expansion and cultivation of sugarcane, and 37.2 million of hectares used for pasture. This scenario demonstrates that there is no need for new areas or clearing of native forest to increase production rate.

In recent years the share of biomass in the Brazilian energetic matrix was 31.0%, and the sugarcane accounted for 17.7%, according to the Ministry of Mines and Energy (MME). Studies show that up to 2020 this number should exceed 35%. In this regard, there is a government concern that the production of sugarcane must grow in a productive and environment-friendly way, analyzing the environmental and socioeconomic impacts. In order to reach this goal there are studies in the areas of regular production, biofuel production, cogeneration, conservation of soil and water and reduction of greenhouse gases emissions.

Other aspects of the production of ethanol through sugarcane is the generation of clean energy, income generation all the yearlong throughout the cycle of planting and harvesting of sugarcane, organization of sugarcane producers cooperatives aiming the mechanical harvesting technology stimulation in the production and harvesting of sugarcane, qualification of local labor and investment in agro-industrial complex.

The processing of sugarcane is technologically simple, in a way that can be done even on small units at home farms, for their own consumption or to supply electricity for small isolated communities. The production of sugar, ethanol, sugarcane brandy (cachaça) and other derived food is presented as an option for wide exploration of sugarcane. The bagasse originated from this process can be used for steam generation, aiming to drive electrical energy generators to produces electricity that can be used by the home farm or be sold in case of energy surplus (SANTOS, 2012).

A survey conducted by the National Electric Energy Agency (ANEEL) among electricity distribution companies in the country showed that the percentage of homes that are not provided with electricity in Brazil is approximately one million. According to the Brazilian Institute of Geography and Statistics (IBGE), 2,749,243 Brazilians do not takes the benefit of electricity availability. According to IBGE the most affected region due to the lack of energy is the countryside, where about 2,352,949 people live without electricity in Brazil. In the northern area only 62 % of homes have electricity. (COPEN, 2011)

2. Materials and Methodology

The tests were conducted in the campus of UNESP Guaratinguetá in different weather and temperature conditions. For each test were used 100 mL of fuel for the engine drive, whereas information as power, current, voltage, speed, power factor, exhaust gases and activation time were recorded and monitored until the total fuel consumption. Five replicates were performed for each experiment.

For the experiments it was used a motor-generator brand Buffalo, composed of an electric generator with 115V output coupled to a 2.8 cv (2060 W) internal combustion Otto-type engine, gasoline-powered, attached to an electrical loads panel as shown in figure 2.

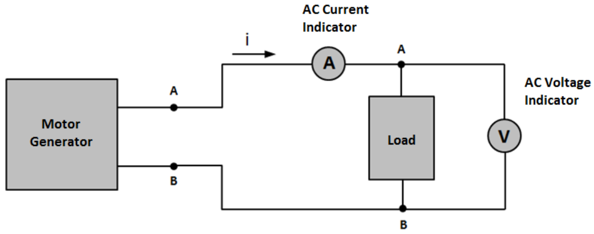


Fig. 2 – Electrical scheme of the motor-generator and the electrical loads panel

The experiment was performed using mixtures of hydrous ethanol and pure gasoline, both obtained from commercial market, ready for consumption. It was started from 0% ethanol, that is, pure gasoline and finished with 100% ethanol, in a 5% increment ratio.

For each ratio of fuel mixture were accomplished 500 measurements during the motor-generator operation cycle related to the consumption of 100 ml of fuel, considering the average value of all 500 points for each electrical parameter that was monitored. This procedure was repeated five times for each mixture in order to reduce the propagation of experimental errors.

For the analysis of exhaust gases it was used the combustion analyzer Chemist 300 model ASO 630 AE. A hole was adopted in the end of the exhaust duct aiming to minimize the influence of the air in the results and determine only the gases found in the exothermic reaction that occurs in the combustion chamber of the engine.

It was determined the variation of the engine exhaust gases by measuring the amount of nitrous oxides (NO_x) and carbon dioxide (CO_2), the temperature of exhaust gases and the air surplus. Figure 3 shows the assembly of the gas analyzer used in the experiment.

Fig. 3 – Combustion gas analyzer for the ethanol-gasoline mixture

3. Results

In order to allow a good comparison of the 21 fuel blends, statistical analyzes were used to evaluate the data and to qualify the appropriate experiments relating to the tests. Generally speaking, the variation of the experimental data is expressed by four forms of dispersion: the mean standard error, the variance (S^2) or standard deviation (S) and the coefficient of variation (CV), which is the most widely used statistical measure by researchers in the experiments accuracy assessment (AMARAL, 1997).

The CV allows comparisons among items of different natures and provides an outline of the data accuracy. The CV is the ratio of the standard deviation (S) expressed as a percentage of the mean (m).

$$C.V. = \frac{100.S}{m}$$

According to Pimentel Gomes (1991), the lower the CV, the more homogeneous are data and values. Table 1 shows the classification of the coefficients of variation according to Pimentel.

Tab. 1 – Classification of variation coefficients

Level	Variation Coefficient
Low	below 10%
Intermediate	between 10% and 20%
High	between 20% and 30%
Upper High	above 30%

The classification of the variation coefficient is inversely proportional to the accuracy level of the experiment - the larger the coefficient of variation, the lower the experiment accuracy, that is, the higher the coefficient of variation, the lower the test accuracy.

Figure 4 shows a graphical comparison of the measured values of power for each ratio of mixture used in the experiment. Based on it is possible to confirm the feasibility of ethanol utilization in the motor-generator. It is also possible to observe that the increase of ethanol concentration in the mixture does not cause a big influence on the motor-generator performance.

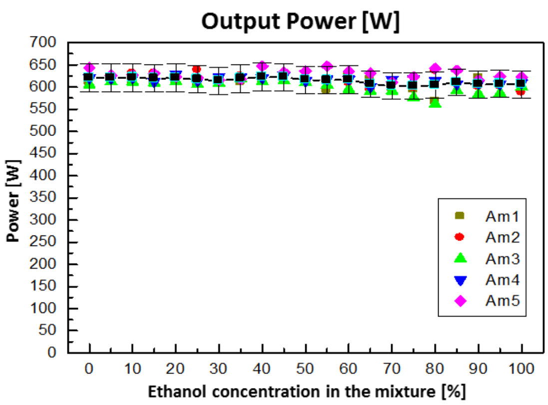


Fig. 4 – Electrical power output variation according to ethanol concentration in the mixture.

Another essential figure to be analyzed is the engine fuel consumption, which does not present a big distortion as per the ethanol increase in the mixture, as showed in figure 5.

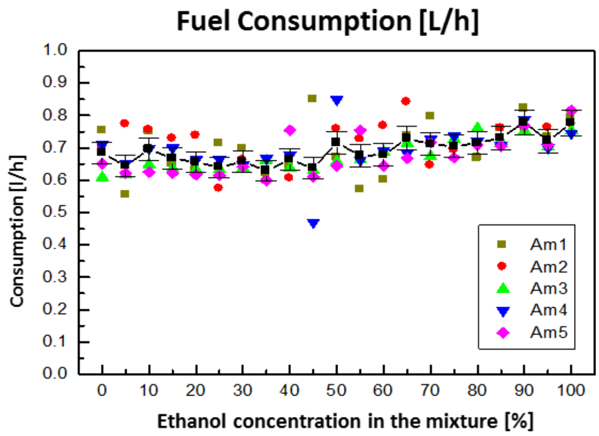


Fig. 5 – Motor-generator fuel consumption variation according to ethanol concentration in the mixture

The engine presented specific fuel consumption of 0.63 liter per hour when using C-type gasoline. For an 85%-concentration of ethanol its consumption rose to 0.73 liter per hour. Such fuel consumption increase was expected because ethanol presents lower net heating value (NHV) (NHV = 36.8 MJ/kg) when compared to gasoline (NHV = 43.0 MJ/kg). This means that, in order to release the same amount of energy than gasoline, ethanol requires a larger mass, which results in a higher specific consumption of fuel.

According to Heywood (1988), besides the fact that the flame temperature increases with the increase of ethanol, there is also an increase in the rate of nitric oxide (NO) formation, as shown in Figure 6. The formation of NO_x is the dissociation and combination of N_2 and O_2 found in the atmosphere and not in the fuel and it caused by the high temperatures and pressures in the combustion chamber (VILANOVA, 2009).

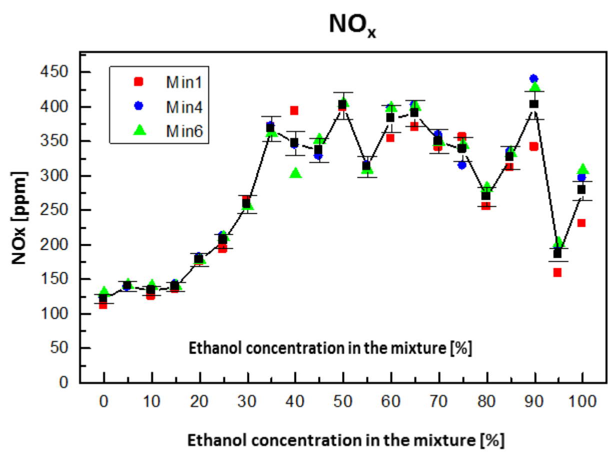


Fig. 6 – Values in ppm of nitrogen oxide exhaust according to the percentage of ethanol in gasoline

Figure 7 shows the emission of CO_2. It is possible to notice the reduction of emission as per the gradual addition of ethanol when the power generator operated with 100% gasoline, the amount of CO_2 emitted was 12.8% vol. After insertion of ethanol, this value went to 11.0% vol. for a mixture of 85% ethanol. This absolute reduction of 1.8%, indicates a relative reduction of 14%.

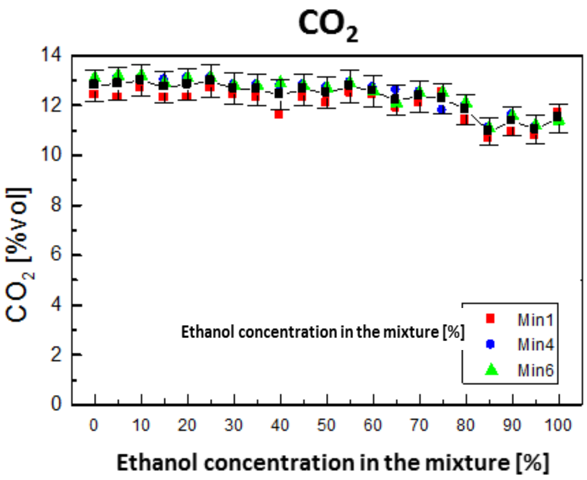


Fig. 7 – Values of carbon dioxide exhaustion according to the percentage of ethanol in gasoline

Ethanol has a tolerance to combustion with air surplus. So, the greater the percentage of ethanol, the greater the amount of air surplus. This factor allows the complete burning with lower emissions of CO (GUARIEIRO, 2011). The lower molecular complexity of ethanol enables combustion with the formation of small carbon particles, resulting in negligible emission of particulate material (TEIXEIRA, 2008).

4. Conclusion

Based upon the tests is possible to affirm that the engine operates fully with large percentages of ethanol. There was no need for physical modifications to the engine, except for the original fuel mixture defined by the engine manufacturer, (C-type gasoline). The mixture did not show aqueous phase at any percentage of ethanol.

As a conclusion, is possible to say that this study scenario economically feasible, that is, it is a low cost project. A motor-generator system requires an average investment of approximately USD 400.00 and does not need other expense unless fuel. The equipment has low cost and great portability.

The optimum mixture ratio observed for the fuel is 85% of ethanol, since this point showed the highest power for the same fuel consumption. In order to obtain this ratio in the mixture would be necessary to add four liters of ethanol in one liter of C-type gasoline, which can be purchased in any gas station.

In addition to these benefits, another factor of great importance is the reduction in the amount of greenhouse gases from fossil fuels burning. It has been found in tests with the power generator that the amount of CO_2 emissions decreases with the increase of ethanol.

Ethanol presents the carbon balance much close to zero, since the plantations of sugarcane absorb carbon dioxide in the process of photosynthesis. Rather, gasoline promotes large emission of greenhouse gases into the atmosphere.

A disadvantage of ethanol is the increase of aldehyde emissions. However, acetaldehyde from ethanol is less aggressive to human health and the environment than the formaldehyde produced by the combustion of gasoline (TEIXEIRA, 2008).

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