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Technical Assessment of Two Alcohol Generator Sets

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Abstract: *This study aimed to evaluate the performance of two gensets, using as fuel, alcohol from fuel station and farm distillery. Specifically, to evaluate the power generation, the specific fuel consumption as well as the efficiency of the two gensets. The alcohol fuel from farm distillery was produced from residues of sugar cane aguardiente (head and tail), with an alcoholic content of 91%. It was used a single-phase generator of 10 kVA and three-phase generator of 42 kVA. For the generator 1 the specific fuel consumption was 0.93 L kWh-1 and 0.90 L kWh-1 and for generator 2 was 0.62 L kWh^{-1} and 0.71 L kWh^{-1} for alcohol from fuel station and farm distillery, respectively. With the increasing of power, the specific fuel consumption decreased and the efficiency increased. When the working power generator set increase, the efficiency increased. It was determined that the efficiency for the generator 1 was greater when it was used alcohol from farm distillery for the same load. In the case of the generator 2, the efficiency was higher with the ethanol fuel station for power values between 22.27 and 25.99 kW.*

Keywords: *energy generation, alcohol, alternative fuel, generator, bioelectricity*

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I. INTRODUCTION

The sugar cane industry is longtime a mainstay of the Brazilian economy. From the introduction of the first plants in the country, in 1532, for over two centuries sugar was the main Brazilian product. For nearly 40 years began the transformation of the sector. Besides sugar, the mills began to focus on the production of ethanol and, more recently, attention has turned to bioelectricity, the alcohol-chemicals and marketing of carbon credits. This is a new level of business, where competition is the order of the day [1].Ethyl alcohol, or ethanol, is a substance having molecular formula C_2H_6O which can be used as fuel in internal combustion engines with spark ignition (Otto cycle) of two ways, namely: 1) mixtures of gasoline and anhydrous ethanol; or 2) as pure ethanol, generally hydrated.In the Brazilian case, the specifications that must be met by producers and respected throughout the supply chain, are defined by ANP Portaria 57/2011, for gasoline with anhydrous ethanol, and the ANP 7, 09/02/2011, for anhydrous and hydrous ethanol, called respectively, anhydrous ethanol fuel (AEF) and hydrated ethanol fuel (HEF). According to this legislation, considering contents by mass anhydrous ethanol should not exceed 0.4% water, whereas the hydrous should not exceed 4.9%. The alcoholic content to be 99.3% for the AEF, and between 92.5 and 93.8% for HEF, considering the mass percentages [2]. According to CIMA Resolution 37/2007, 25% is the percentage of mandatory addition of anhydrous ethanol to gasoline fuel [3].Ethanol is a chapter in the recent history of internal combustion engines. The first engines were developed for use in gasoline and diesel. Nowadays, the interface fuel-engine technology reveals interest in biofuels, particularly by ethanol. It must be taken into account that in the world, 97% of the fuels consumed are derived from petroleum. This is relevant because it makes the commercial viability of any alternative fuel dependent utilization of infrastructure for transportation, storage and distribution of gasoline and diesel. In this sense, thecompatibility of ethanol mixed with gasoline or pure, is a great advantage against other energy options [4].

The pure hydrated ethanol to be used in engines manufactured or adapted specifically for this purpose, in particular with the adoption of higher compression ratios in order to properly utilize the higher octane of ethanol compared to gasoline and efficiency gains of 10%. In other words, the higher octane of ethanol allows the engines to get more useful energy from the heat of the fuel compared to gasoline. Other modifications should be made to the fuel supply system and ignition to compensate for differences in air-fuel ratio and other properties. Moreover, modifications are required in some materials in contact with the fuel, as anticorrosion treatment of metal surfaces of tanks, filters and fuel pumps and replacement of pipes or adoption of most resistant materials to ethanol. Today, after decades of development of ethanol engines specially manufactured for the automotive technology is sufficiently developed to allow vehicles to have pure hydrated ethanol performance, drivability, cold starting conditions and durability absolutely similar to gasoline engines, especially in countries with moderate winters [5].Due to the oil crisis of 1973, two years later, was developed by the federal government the National Alcohol Program (Proálcool). The culmination of the program was in 1979, with the second oil price shock. The Proálcool aimed to replace petroleum products with alcohol, since that time, the oil crisis has spread across the world, and the price of the product climbed increasingly being required to seek another source of energy to replace it.At the time, what mattered most was the development of an alcohol engine technology that increases energy efficiency, which came to be 16% higher than for gasoline vehicles. Environmental considerations were not a priority, although the quality "green" ethanol as a renewable fuel, it was already recognized. It was only in the 1980s, when the vehicles reached 90% of alcohol sales, which are now valued environmental and social characteristics of ethanol, not seldom pushed into the background in the energy efficiency of fuel utilization. From the 1990s, with the fall in oil prices, the auto industry again invest more in technological upgrading of the vehicle with gasoline, which reduced to about 4% of the energy advantage of ethanol vehicles [4].According to the Ministry of Agriculture, Livestock and Supply (MAPA), the production of sugar cane in the calendar year 2011 totaled 565.8 million tons. This amount was 9.8% lower than in the previous calendar year, when the grinding was 627.3 million tons. In 2011, there was a reduction of 18.1% in the manufacture of ethanol, yielding the amount of 22,892,504 m^3. About 62% of this total refers to hydrous ethanol: 14,217,182 m^3. In comparative terms, fell by 28.7% in the production of this fuel compared to 2010. Regarding the production of anhydrous ethanol, which is blended with gasoline A to form gasoline C, there was an increase of 7.9%, totaling 8,675,322 m^3 [6].Renewable fuels now represent 19% of the fuel energy used in the transportation sector in Brazil, which also intends to exercise certain international leadership and set an example for other countries in the production and use of renewable fuels. It is, therefore, the challenge for the Brazilian engineering: not only adapt to ethanol technologies developed for use of petroleum, but also perform technological developments based on specific properties of ethanol for use as fuel become more competitive, helping to avoid new laws that limit the use of ethanol in the global market [7].This study aimed to evaluate the performance of two gensets, using as fuel, alcohol from fuel station and farm distillery. Specifically, to evaluate the power generated, the specific fuel consumption as well as the efficiency of the two gensets.

II. MATERIALS AND METHODS

The work was conducted at the Department of Agricultural Engineering, Universidade Federal de Viçosa, Viçosa, MG.

In developing the work were used the following components:

• Genset 1 (GG 1): an ethanol monophasic generator, consisting of a four-stroke combustion engine V2, associated with a generator B4T-10000 BRANCO®.

• Genset 2 (GG 2): an ethanol three-phase generator, consisting of a gasoline combustion engine, with six cylinders inline equal to a truck FORD® F1000, modified to operate with ethanol, associated to a generator WEG® , GTA162AIVD model, with the output terminals connected in star configuration, equipped with field excitation systems and automatic control speed.

• Fuel: ethanol from fuel station and alcohol fuel from farm distillery with an alcoholic content of 91%, produced from residues of sugar cane aguardiente (head and tail).

• Heatsinks energy: incandescent lamps and electric heaters.

2.1 Measuring fuel consumption

GG 1: measurement of fuel consumption was achieved by the consumption of fuel, which were placed a measuring cylinder of equal volume, measuring the time taken by the generator to consumption of fuel volume.GG 2: To examine the fuel system utilizing a system meter comprising a transparent hose placed in the fuel tank, with a range previously calibrated with the aid of a measuring cylinder. As fuel was added to the reservoir, the level of the hose was recorded on a scale which, according to Pascal's principle, equivalent to the volume of fuel in the reservoir. Importantly, the lower end of the hose is connected to the base of the fuel tank and the top is in direct contact with air. It was determined fuel consumption for a set time of 2 h.

The calculation of the specific fuel consumption of the engine is defined by the volume consumed in one time interval to a power determined as follows in Equation (1):

$$C_{ec} = \frac{V}{t\ P} \tag{1}$$

wherein:

C_{ec} fic fuel consumption, L kWh^{-1};

V ne of fuel, L;

t h;

P :, kW.

2.2 Efficiency of the generator

The efficiency of generator group was determined as follows:

$$\eta = \frac{3600}{C_{ec}\ P_{CI}} \qquad (2)$$

wherein:

η : Efficiency of the system, decimal;

C_{ec} : Specific consumption of fuel, L kWh^{-1};

P_{CI} : Net calorific value of the fuel, kJ L^{-1} (in this case, 22350 kJ L^{-1}).

2.3 Testing the genset

GG 1: tests were done initially with the generator running without load. After, tests were performed by placing two different loads of 3.5 and 7.1 kW. To dissipate the energy produced was assembled a structure consisting of incandescent lamps of 200 W and a set of resistors. The structure was divided into two parts. The first consisted of an electrical circuit with incandescent lamps for a total power of 3.5 kW. The second consisted of an electrical circuit with incandescent lamps and electric heaters for a total power of 7.1 kW. It was used the ethanol from fuel station and farm distillery in the tests and three repetitions were performed.GG 2: tests were done on the generator with five different loads of 4.5, 10.5, 16.5, 22.5 and 27 kW. To dissipate electricity was a bank of resistors mounted in a water tank. The stock consisted of five sets of resistors, two sets of three 4.5 kW and 6 kW, totaling 27 kW. It was used the alcohol ethanol fuel station and farm in the tests conducted in three replications.In the tests, information was obtained about quantities such as voltage, current, power factor and frequency thereof using the device Universal Quantities Meter (MUG), which enables the collection of data and its storage in internal memory and transfer to computer.

2.4 Statistical analysis

With the collected data was performed an analysis of the significance of the use of alcohol from fuel station and from farm distillery, applying the Student's t-test at a significance level of 95%..

III. RESULTS AND DISCUSSION

Tests were carried out with the generator 1 (GG 1) with the alcohol from fuel station and farm distillery. In Figure 1 shows the power generated by each fuel. The generated power to the loads 1 and 2 using alcohol from fuel station was 3.45±0.01 and 7.02±004 kW, respectively. When using alcohol from the farm distillery; the generated power was 3.45±0.02 and 6.86±0.03 kW for loads 1 and 2, respectively. For load 1 gave the same power with both fuels, but for loading 2 reached to a higher power when the alcohol from fuel station was used. It was determined by Student's t test, there is a significant difference to the power generated to the load 2 in GG 1.

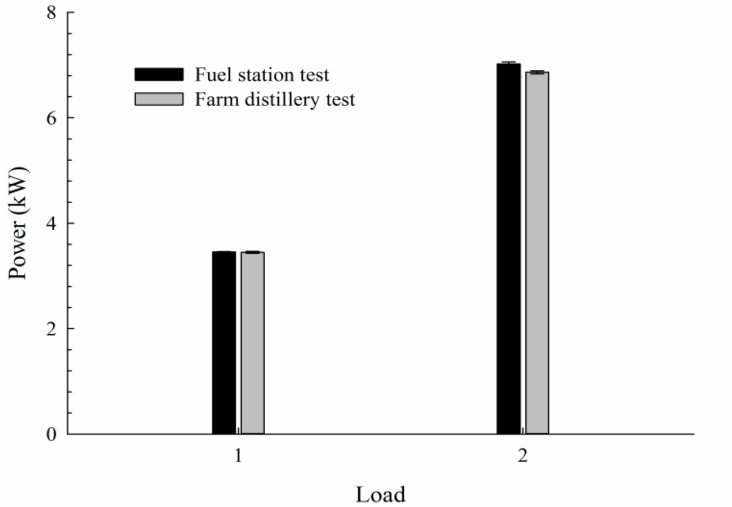

Figure 1. Electrical power generated in function of load in generator set 1 using alcohol from fuel station and alcohol from the farm distillery.

Figure 2 shows the power generated by the generator 2 (GG 2). In this case the power generated with the alcohol from fuel station for the load 1, 2, 3, 4 and 5 was 4.44 ± 0.01, 10.37 ± 0.07, 16.33 ± 0.14, 21.72 ± 0.77 and 25.99 ± 0.98 kW, respectively. Tests were performed using alcohol from farm distillery only for the load 4 and 5 and these were not repeated. The results obtained for the loads 4 and 5 were 22.27 and 26.85 kW, respectively. Higher powers were obtained for loads 4 and 5 with alcohol from farm distillery, but this power increase was not significant.

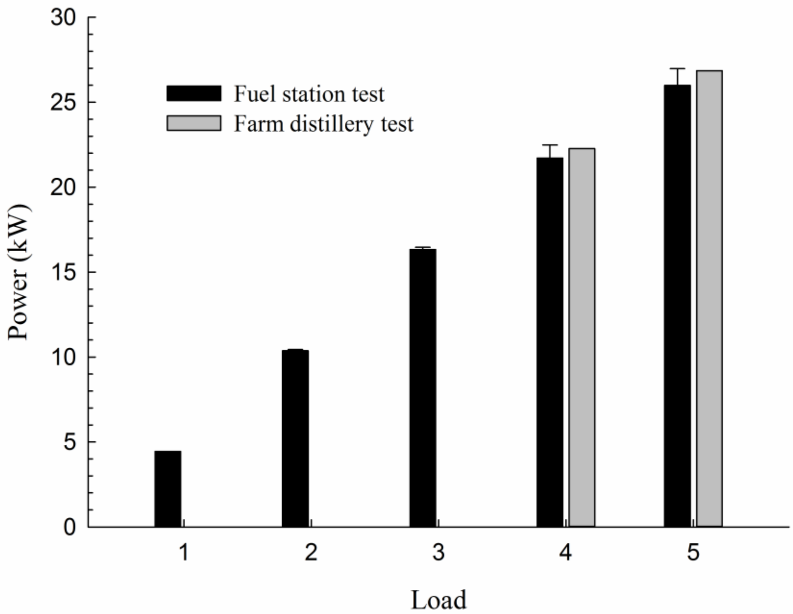

Figure 2. Electrical power generated as a function of the load on the generator set 2 using alcohol from fuel station and alcohol from the farm distillery.

The voltages obtained from the generator 1 are shown in Table 1.By analyzing data contained in Table 1, it can be seen that as the load demanded of the generator increases, the mean voltage value is reduced. This happens with both alcohols as the fuel station with farm distillery. The voltage values for both fuels in the load 2 has differences greater than 10% with respect to nominal voltage of 220 V. There is also the stability of voltage to each load used with each fuel, with a difference not exceeding a value of 2 V.

Table 1 - Voltages obtained with the generator 1

Load (kW)	Test	Mean voltage (V)	Standard deviation (V)	Minimum mean voltage (V)	Maximum mean voltage (V)
		Fuel station			
	1	211.77	0.5579	211.00	212.60
3,45	2	212.12	0.2438	211.90	212.60
	3	212.23	0.1337	212.00	212.40
	1	195.56	0.2186	195.30	196.00
7,02	2	195.00	0.1658	194.80	195.20
	3	194.27	0.2830	193.90	194.80
		Farm distillery			
	1	212.86	0.3307	212.30	213.20
3,45	2	211.94	0.2186	211.70	212.40
	3	211.80	0.2000	211.50	212.20
	1	192.50	0.4082	191.80	193.20
6,86	2	191.94	0.3688	191.50	192.50
	3	191.56	0.1856	191.20	191.80

The voltages obtained with the generator 2 are shown in Table 2.

Table 2 - Voltages obtained with the generator 2

Load (kW)	Test	Mean voltage (V)	Standard deviation (V)	Minimum mean voltage (V)	Maximum mean voltage (V)
		Fuel station			
	1	126.33	0.0459	126.30	126.40
4,44	2	126.36	0.0495	126.30	126.40
	3	126.64	0.0506	126.60	126.80
	1	125.10	0.2359	124.60	125.50
10,37	2	126.06	0.2307	125.10	126.40
	3	126.28	0.2822	125.20	126.50
	1	125.18	0.3925	123.00	125.60
16,33	2	126.29	0.1645	125.20	126.50
	3	126.00	0.2020	123.30	126.20
	1	121.93	0.5616	120.60	125.50
21,72	2	126.07	0.0911	125.90	126.20
	3	125.62	0.3319	124.50	125.90
	1	121.02	1.1507	123.00	125.60
25,99	2	117.23	0.5507	125.20	126.50
	3	117.14	0.7506	123.30	126.20
		Farm distillery			
22,27	1	126,19	0.0264	126.10	126.20
26,85	2	120,34	0.3103	119.20	120.90

By analyzing the data in Table 2 is possible to verify that as the generator load increases, the average voltage value is reduced. For all load values used tension was maintained within the tolerance range of 116 V to 133 V, around the nominal value of 127 V, and this tolerance range of the contractual terms of supply of electricity applied by Cemig (Companhia Energetica de Minas Gerais), the company responsible for electricity supply in the region of Viçosa [8].The voltage variation is due to fluctuations of frequency in the system. This reveals the deficiencies in the system speed control, since this should promote a frequency regulation to 60 Hz, which was not observed in the system in question. The most critical case was for the load of 27 kW, to which the working frequency reached values of 48 Hz.In both generators reports that have similar behavior when it increased the workload for both, alcohol from fuel station and from the farm distillery. It appears that both have a stable behavior in the production of energy in each of the loads used. There is also the possibility that the regulation of the rotation system is outside the established ranges due to the decrease in the rotation with the increased workloads.Figure 3 shows the specific fuel consumption.In both generators, electric power generated increases as the specific fuel consumption decreases. For the generator 1, the specific fuel consumption was 1.86 ± 0.01 L per kWh for the load 1 of 3.45 kW using the alcohol from fuel station and 1.78 ± 0.01 L per kWh using alcohol from the farm distillery for the same power. It was determined by Student's t-test that there is a significant difference between the fuel consumption of the load 1.For the load 2, the fuel consumption was 0.93 ± 0.01 L per kWh using alcohol from fuel station and 0.93 ± 0.01 L per kWh using alcohol from the farm distillery. It was determined by Student's t-test that there is no significant difference between the fuel consumption of the load 2. In this case, the consumption was lower with alcohol from farm distillery.Independently of charge, the consumption was 6.47 L h^{-1} for ethanol from fuel station and 6.15 L h^{-1} for alcohol from farm distillery, which represents a significant difference according to the Student's t-test.

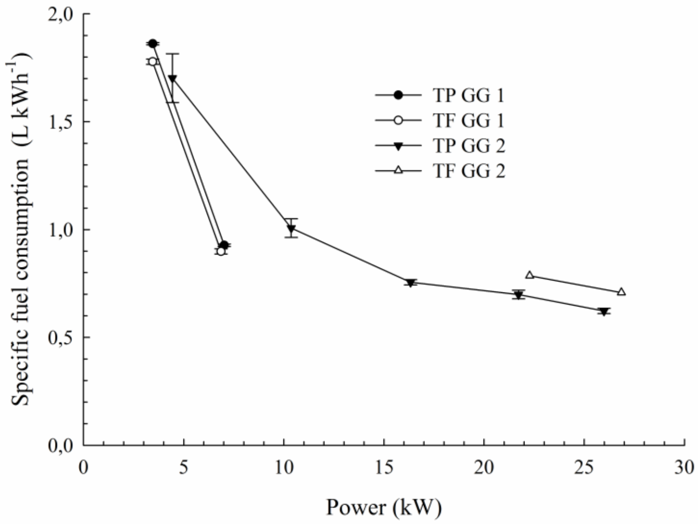

Figure 3. Specific fuel consumption for the generator 1 (GG 1) and the generator 2 (GG 2), using alcohol from fuel station (EP) and alcohol from farm distillery (EF).

For the generator 2, the specific fuel consumption of alcohol from fuel station, for loads 1 to 5 was 1.70 ± 0.11, 1.01 ± 0.04, 0.76 ± 0.01; 070 ± 0.02 and 0.62 ± 0.01 L per kWh, respectively. For alcohol from farm distillery, specific consumption was 0.79 kWh per L and 0.71 for the loads 4 and 5, respectively.It were determined by Student's t-test, there is significant difference to the loads 4 and 5 in specific fuel consumption. In this case, the consumption was greater for alcohol from farm distillery, but the increase was not greater than 15%.Figure 4 shows that, as the working power generator set increase, the efficiency increased. Values were obtained up to 25.88% to 22.99 kW of power, with alcohol from fuel station in generator 1. It was also observed that the efficiency for the generator 1 was greater when it was used alcohol from farm distillery for the same load. In the case of the generator 2, the efficiency was higher with the ethanol fuel station for powers between 22.27 and 25.99 kW.

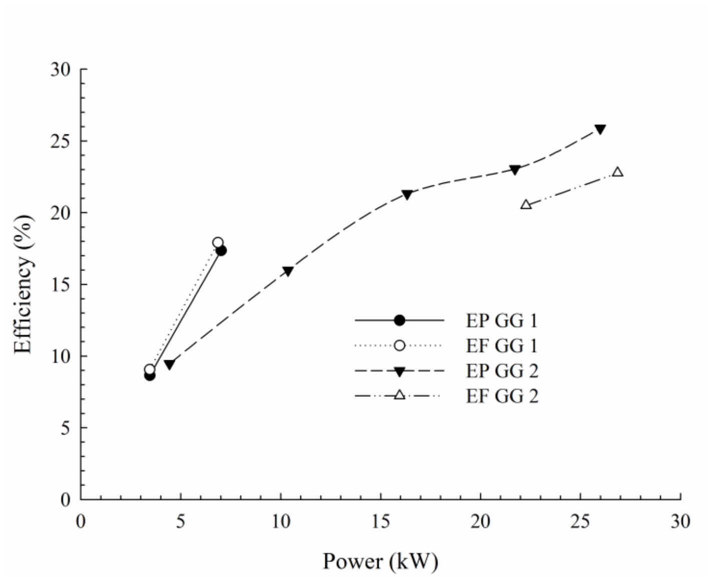

Figure 4. Efficiency of the generator 1(GG 1) and generator 2 (GG 2), using alcohol from fuel station (EP) and alcohol from farm distillery (EF).

IV. CONCLUSIONS

Under conditions in which the tests were performed and according to the results obtained, it can be concluded that it is feasible the use of alcohol fuel produced on the farm distillery for the gensets used.There was a decrease in the values of the specific fuel consumption with increased power. The best result for the genset 1 was a specific fuel consumption of 0.90 L per kWh for a load of 6.86 kW when used ethanol fuel from farm distillery. The best result for the genset 2 was a specific fuel consumption of 0.62 L per kWh for a load of 25.99 kW when used the ethanol from fuel station.There was an increase in the values of the efficiency with increasing power. The best result for the genset 1 was an efficiency of 17.91% for a load of 6.86 kW when used the ethanol fuel farm. The best result obtained for the genset 2 one efficiency was 25.88% at a load of 25.99 kW when used the alcohol from fuel station..

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