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STUDY OF THE THERMAL EFFICIENCY OF AN ICE-DIESEL USING DIESEL FUEL, BIOFUEL AND MIXTURE

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Abstract. The concern with the global warning and the renewable fuel search has made many studies emerge addressing this topic and the use of sustainable energy to cover the human need has been growing a reason for study. Improve the thermal efficiency is a king of fuel economy that comes upon to the reduction of the generating greenhouse effect gases emission, as well as producing fuel from a renewable source is something of extreme importance for the future. Here, we will address the thermal efficiency alterations happened in a diesel internal combustion engine, which was originally prepared to operate with Diesel S500, when we use it without any change of motor regulation, different fuels, as the S10, the Farnesano and this fuels blend. Farnesano is a new fuel produced from sugar cane, through the fermentation by a bacterium developed in laboratory, which produces oil, not alcohol, in its fermentation. This bacterium created by Amyris, a US company, allows us work with a renewable fuel produced from non-competing cultivation with human being feeding. To this end, we use a generator group, that will produce electric energy which will be consumed by a resistive system, in this case, incandescent lamps, where will be obtained the power generated to calculate the desired thermal efficiency in this study.

Keywords: global warming, fuel, efficiency, Farnesano, renewable.

1. INTRODUCTION (TIMES NEW ROMAN, BOLD, SIZE 10)

The use of diesel cycle motor is very usual in several world economic sectors, where it stands out in the transport either road, or maritime and in the generation of electrical energy. This highlighting is easily understood when evaluated the durability and thermal efficiency of the Diesel cycle compared to other internal combustion motor.

With the huge concern descendant from the possible shortage of petroleum and the effects generated by the greenhouse gases emitted in the atmosphere, made the search for forms of renewable energy a constant, being largely developed the use of biofuels, as well as the demand for other renewable energy sources with less impact on the environment.

Knowledge of the possibility of using vegetable oils in Diesel cycle engines isn't a new and with the embargo imposed by the OPEC (Organization of the Petroleum Exporting Countries) to the United States and Europe in the 1970s, created a real interest in developing technologies that enabled the use of these fuels then called of biofuel.

Within this constant search is that it was developed by Amyris, a north American company that works on the development of synthetic biology, the Farnesano; a fuel derived by sugarcane that can't be obtained by the cracking process, esterification or trans esterification, can't be treated as a biodiesel. This new fuel that will be studied here, produced by the fermentation of sugarcane juice using a bacterium genetically developed in laboratory, in which through a comparison with S10 diesel oil and S500, today supplied in the national market will be evaluated its

performance using for this a motor-generator group, that when consuming the fuel will generate electricity, which energy will dissipate through a set of lamps of the type of thermal efficiency calculation.

2. MATERIAL AND METHODS

2.1 Motor generator Group

The experimental tests were performed in a motor generator set, model BD-600 CFE allocated in DCTEF Motor Laboratory. Its characteristics are defined in Table 1. Being a motor of aspirated type with injection of mechanical fuel, having the discharge been elongated in 1,2m with steel tube of same diameter of the original, allowing the gases to be sent to the outside of the laboratory.

Table 1- Main characteristics of the BD-9500 CFE motor set

Number of cylinders	Single Cylinder
Cylinder Capacity	400 cm^3
Compression ratio	19:1
Cooling	Air
Effective rated potency (Ne)	9,1 HP (6700 W)
Revolutions per minute (rpm) at Ne	3600
Fuels	Diesel Oil, Biofuel or mixture
Air-fuel formation	Air admitted by the valve and direct injection of fuel
Motor start	Manual or electric

Source: BRANCO, A Cia. Caetano, 2008

The original fuel tank was removed in order to allow the use of the volumetric consuption measurer erlenmeyer, as shown in fig. 1.

Figure 1. BP 6500 CFE generator motor after modification. Source: Author.

2.2 Dynamometric workbench

The dynamometric bench installed in the DCTEF laboratory is responsible for consuming the eletrical energy generatec by the generator motor set, creating resistance to the system.

The energy consumption is achieved through the use of two incandescent lamp panels which are connected to the alternating current output of the generator set, gouped together of 3 lamps of 200W each, connected in parallel with the light switch to which glamps group. Incandescent lamps have been used because they have a potency factor of 1. Then measuring the power generated by the current measuring, through a pliers ammeter and supply voltage measured by a digital multimeter. In fig. 2 is possible to see the lamp panels mounted.
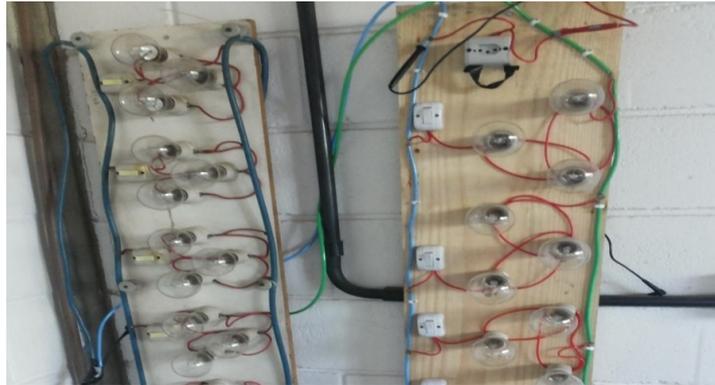
Figure 2. Energy-consuming lamp panel. Source: Author

2.3   Volumetric consumption measurer panel

The panel contains four 2 liters pet tanks, interconnected through hoses, the fuel is brought to the motor passing by na erlenmeyer, as shown in fig. 3. Its flow can be blocked through a valve that the motor starts to consume only the contents present in the erlenmeyer (8 ml, 16 ml or 24 ml). The time spent is timed and the valve is opened again to continue feeding the motor and refill the Erlenmeyer column to do a new test.

Figure 3. Volumetric Consuption Measurer Panel. Source: Author

2.4 Calculation methodology

2.4.1   Power calculation

The eletric potency is calculated using the voltages and currents values that are obtained in the tests to make a comparison in terms of yield next to the generator-group. For the values of the potencies to be in KW, it was necessary to divide the valeus obtained by thousand. According to Eq. 1.

$$P = V . I \qquad (1)$$

Where:
P is potency in W (watts);
V is the voltage in V (volt);
I is the electric current in A (amperes);

2.4.2   Calculation of consumption and/or flow

The fuel consuption was calculated by dividing the volume consumed by the time spent consuming it. The fuel volume that was analyzed in the test was 8 mL and the time analyzed was in seconds, so, the longer the time to consume the 8 mL of fuel, the higher the efficiency of the generator-group. As can be seen in Equation 2 of consumption or flow (Q):

$$Q = \frac{V}{t}$$

(2)

Where:
Q is the flow in mL/s;
V is the volume consumed in mL;
T is the time taken to consume the volume under study in s;

2.4.3 Calculation of horary mass consumption

For the calculation of horary mass consumption was necessary the fuel density, which was measured in laboratory for each of the fuels used, as shown in fig. 4, and the flow as definrf in subheading 2.4.2.

Figure 4. Fuel Densimeter. Source: Author

In the mass calculation as a function of time, which was necessary for the calculation of specific time consumption, used Eq. 3.

$$M = d \,.\, Q \,.\, 3600$$

(3)

Where:
M is the horary mass consumption in g/h;
D is the density in g/cm3;
Q is the flow in mL/s;

2.4.4 Specific horary consumption

The specifc fuel consumption is the ratio of the fuel mass by the average potency dissipated over a given period of time. In other words, the specific fuel consumption indicates the fuel mass needed to dissipate a unit of energy. Calculated using Eq. 4.

$$m = \frac{M}{P}$$

(4)

Where:
M is the specific horary consumption in g/h kW.

2.4.5 LCP calculation

Obtained through experiment using a calorimeter, avoiding erros. The values obtained are shown in Table 2.

Table 2: LCP and Specific Mass values of fuels and mixture used.

Fuel	LCP (J/gr)	Specific Mass (gr/ml)
S10	42,612	0,847
S500	42,791	0,836
F100	43,910	0,768

F120	42,872	0,824

2.4.6 Calculation of thermal yield

The thermal efficiency of the system is the ratio of the amount of energy generateed by the system to the amount of energy available. By means of the thermal yield is possible to determinate which of the mixtures presented greater use of the chemical energy of the fuel. The amount of available energy was calculated taking into account the LCP of each of the mixtures. Using Eq. 5.

$$\eta = \frac{360.000}{PCI \cdot m}$$

(5)

Where:
LCP is the Lower Calorific Power in J/g.

2.5 Types of fuels used

2.5.1 Diesel S10

Fuel sold ate Brazilian gas stations, being the most current composition of Diesel oil, where it has 10 ppm of sulfur and 5% of biofuel as determined by current Brazilian legislation.

2.5.2 Diesel S500

Fuel also marked at Brazilian gas stations, which in the future will be retired from the market being replaced by S10, in the S500 the sulfur composition is 500 ppm and 5% biofuel as determinated by current Brazilian legislation

2.5.3 Farnesano

Biofuel produced from sugarcanem using yeasts genetically modified in laboratory to produce oil in its fermentatio, not generating alcohol, after the fermentation undergoes a hydrogenation process. Because it is a product of plant origin, it is free of sulfur in its composition. We will treat this fuel as F100 in this paper.

2.5.4 Mixture (F20)

For a comparative analysis, a mixture composed of 80% of S10 and 20% of Farnesano, which we will call in this paper of F20, will be made becausa S10 in its compositions has sulfur, but was not possible to measure the proportion

3. RESULTS AND DISCUSSIONS

Three different fuels and one mixture were analyzed:
  – Diesel oil S10, purchased at a gas station in the city of São João Del-Rei/MG;
  – Diesel oil S500, purchased at a gas station in the city of São João Del-Rei/MG;
  – Farnesano, acquired from Amyris, the producer of this fuel in the city of Campinas/SP;
  – Mixture of 80% S10 oil and 20% of Farnesano.

Carrying out the tests using the dynamometric bench, using it for all batteries tests the same load conditions, that is, first charge condition by lighting 4 groups of lamps containing each group 3 lamps of 200W totaling 2,400W. Second charge condition by lightning 6 groups of lamps containing each group 3 lamps of 200W totaling 3,600W and third charge condition by lighting 9 groups of lamps containing each group 3 lamps of 200W totaling 5400W. From where we obtained the results that ar presented and commented here.

For all tests a 10-minute interval between measurements was given so that the generator set stabilized with the new condition, thus allowing reliable readings of the results to be analyzed.

Density analysis was carried out for each fuel and the measurement of the ICP to be used in the calculations presented in the table was performed.

The results obtained in the tests were published in spreadsheets that served as the basis for the generation of graphs used in the comparative analysis of the results, the comments will be carried out together with the graphs, seeing this way it is easier to understand the analyzes performed.

The tables were represented only as an illustrative way from which other information can be collected for better clarification

3.1 Results obtained with S10

The results obtained with the diesel oil S10 were presented in Table 3 for power calculation, consumption and efficiency.

Table 3: Calculation of power and consumption for the Diesel S10.

Battery tests	Group of 3 lamps on	Time (s)	Volume (ml)	Consumnption (ml/s)	Hourly consumption (g/h)	Hour. Espec Consumption (g/(kW.h))	Thermal efficiency (%)	Voltage (V)	Current (A)	Power (kW)
1	4	25,00	8	0,320	975,74	468,97	0,180	206	10,10	2,081
	6	21,40	8	0,374	1139,89	431,94	0,196	182	14,50	2,639
	9	17,40	8	0,460	1401,93	463,48	0,182	152	19,90	3,025
2	4	25,20	8	0,317	968,00	476,85	0,177	203	10,00	2,030
	6	21,80	8	0,367	1118,97	442,70	0,191	178	14,20	2,528
	9	18,00	8	0,444	1355,20	481,76	0,175	145	19,40	2,813
3	4	24,80	8	0,323	983,61	507,02	0,167	200	9,70	1,940
	6	21,80	8	0,367	1118,97	450,91	0,187	176	14,10	2,482
	9	18,20	8	0,440	1340,31	490,72	0,172	143	19,10	2,731
MEDIA	4	25,000	8,000	0,320	975,786	484,279	0,175	203,000	9,933	2,017
	6	21,667	8,000	0,369	1125,944	441,850	0,191	178,667	14,267	2,549
	9	17,867	8,000	0,448	1365,813	478,655	0,177	146,667	19,467	2,856

3.2 Results obtained with the S500

The results obtained with S500 diesel oil were presented in Table 4 for calculation of power, consumption and efficiency.

Table 4: Calculation of power and consumption for the Diesel S500

Battery tests	Group of 3 lamps on	Time (s)	Volume (ml)	Consumnption (ml/s)	Hourly consumption (g/h)	Hour. Espec Consumption (g/(kW.h))	Thermal efficiency (%)	Voltage (V)	Current (A)	Power (kW)
1	4	22,20	8	0,360	1084,54	396,25	0,212	230	11,90	2,737
	6	18,20	8	0,440	1322,90	353,62	0,238	215	17,40	3,741
	9	15,20	8	0,526	1584,00	500,95	0,168	155	20,40	3,162
2	4	24,20	8	0,331	994,91	490,22	0,172	205	9,90	2,030
	6	21,20	8	0,377	1135,70	447,48	0,188	180	14,10	2,538
	9	17,00	8	0,471	1416,28	484,20	0,174	150	19,50	2,925
3	4	25,20	8	0,317	955,43	482,64	0,174	202	9,80	1,980
	6	21,80	8	0,367	1104,44	432,10	0,195	180	14,20	2,556
	9	17,80	8	0,449	1352,63	471,87	0,178	147	19,50	2,867
MEDIA	4	23,86	8	0,336	1011,626	456,371	0,186	212,333	10,533	2,249
	6	20,40	8	0,395	1187,680	411,066	0,207	191,667	15,233	2,945
	9	16,66	8	0,482	1450,971	485,674	0,173	150,667	19,800	2,985

3.3 Results obtained with the Farnesano

The results obtained with Farnesado were presented in Table 5 for calculation of power, consumption and efficiency.

Table 5: Calculation of power and consumption for Farnesano

Battery tests	Group of 3 lamps on	Time (s)	Volume (ml)	Consumnption (ml/s)	Hourly consumption (g/h)	Hour. Espec Consumption (g/(kW.h))	Thermal efficiency (%)	Voltage (V)	Current (A)	Power (kW)
8	4	26,00	8	0,308	850,71	406,78	0,202	194	10,78	2,091
	6	22,40	8	0,357	987,43	374,74	0,219	170	15,50	2,635
	9	17,80	8	0,449	1242,61	408,08	0,201	150	20,30	3,045
2	4	29,00	8	0,276	762,70	405,80	0,202	179	10,50	1,880
	6	23,40	8	0,342	945,23	365,35	0,224	168	15,40	2,587
	9	18,20	8	0,440	1215,30	407,13	0,201	150	19,90	2,985
3	4	30,00	8	0,267	737,28	425,19	0,193	170	10,20	1,734
	6	23,80	8	0,336	929,34	371,26	0,221	168	14,90	2,503
	9	18,6	8	0,430	1189,16	406,51	0,202	147	19,90	2,925
MÉDIA	4	28,333	8,000	0,283	783,564	412,591	0,199	181,000	10,493	1,902
	6	23,200	8,000	0,345	954,001	370,449	0,221	168,667	15,267	2,575
	9	18,200	8,000	0,440	1215,688	407,242	0,201	149,00	20,033	2,985

3.4 Results obtained with the mixture of 80% S10 and 20% Farnesano (F20)

The results obtained with the mixture F20 were presented in Table 6 for calculation of power, consumption and efficiency.

Table 6: Calculation of power and consumption for F20

Battery tests	Group of 3 lamps on	Time (s)	Volume (ml)	Consumnption (ml/s)	Hourly consumption (g/h)	Hour. Espec Consumption (g/(kW.h))	Thermal efficiency (%)	Voltage (V)	Current (A)	Power (kW)
1	4	26,00	8	0,308	912,74	413,21	0,203	199	11,10	2,209
	6	23,00	8	0,348	1031,79	375,54	0,224	175	15,70	2,748
	9	18,80	8	0,426	1262,30	412,52	0,204	150	20,40	3,060
2	4	26,60	8	0,301	892,15	408,49	0,206	195	11,20	2,184
	6	23,20	8	0,345	1022,90	374,22	0,224	173	15,80	2,733
	9	19,00	8	0,421	1249,01	421,96	0,199	148	20,00	2,960
3	4	26,80	8	0,299	885,49	412,82	0,203	195	11,00	2,145
	6	23,40	8	0,342	1014,15	373,39	0,225	173	15,70	2,716
	9	19,20	8	0,417	1236,00	423,29	0,198	146	20,00	2,920
MÉDIA	4	26,467	8,000	0,302	896,794	411,507	0,204	196,333	11,100	2,179
	6	23,200	8,000	0,345	1022,947	374,382	0,224	173,667	15,733	2,732
	9	19,000	8,000	0,421	1249,103	419,255	0,200	148,000	20,133	2,980

3.5 Generated power

In all the graphs presented the fuels were represented with the same colors used in the tables presented in previous item, in order to facilitate the understanding and facilitate the verification of the presented information.

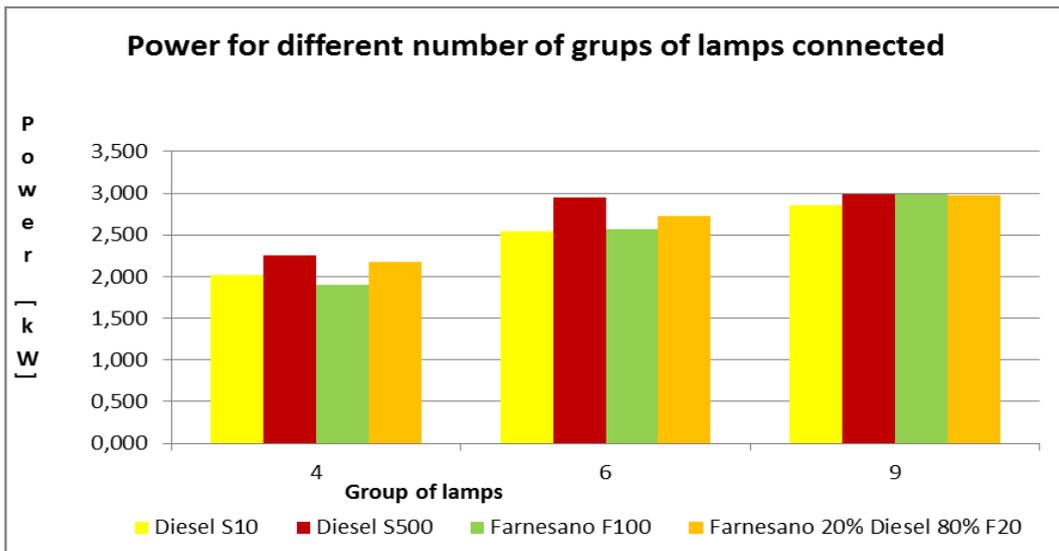Figure 5 shows the results of the power for each fuel.

Figure 5. Generated power. Source: Author.

It was observed that, for loads close to the maximum load supported by the equipment, all fuels had very similar yields and the lowest generation was of the order of 4%.

For medium and small loads, there was a greater difference in power generation of the order of 14%. Satisfactory results were obtained for all types of fuels used.

3.6 Hourly consumption analysis

From fig. 6, it was verified that Farnesan and F20 presented the lowest consumption for small and medium power generation and that with the increase of power generation, consumption tends to close values.

Note that for the S500, there is a significant increase in average consumption for high power.
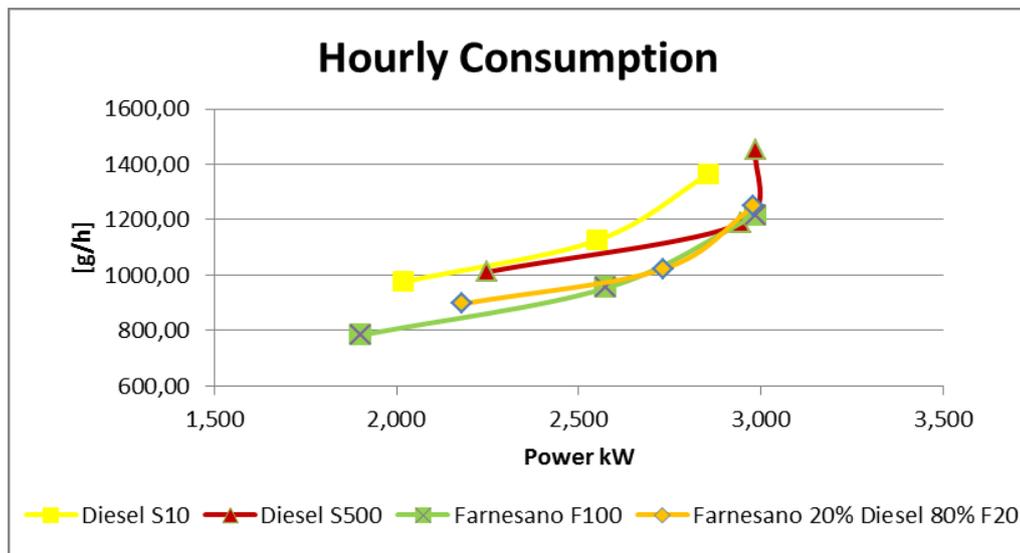

Figure 6. Hourly consumption. Source: Author.

3.7 Thermal yield analysis

For the thermal yield, the characteristic curve showed that the best performance was for the F20 mixture, as also observed in fig. 7.

It has been observed that the yield of the F20 mixture is higher than the Farnesan, which has a higher ICP and higher than the S10 that composes it in greater quantity. It should be noted that S10 was the worst of all the results analyzed.
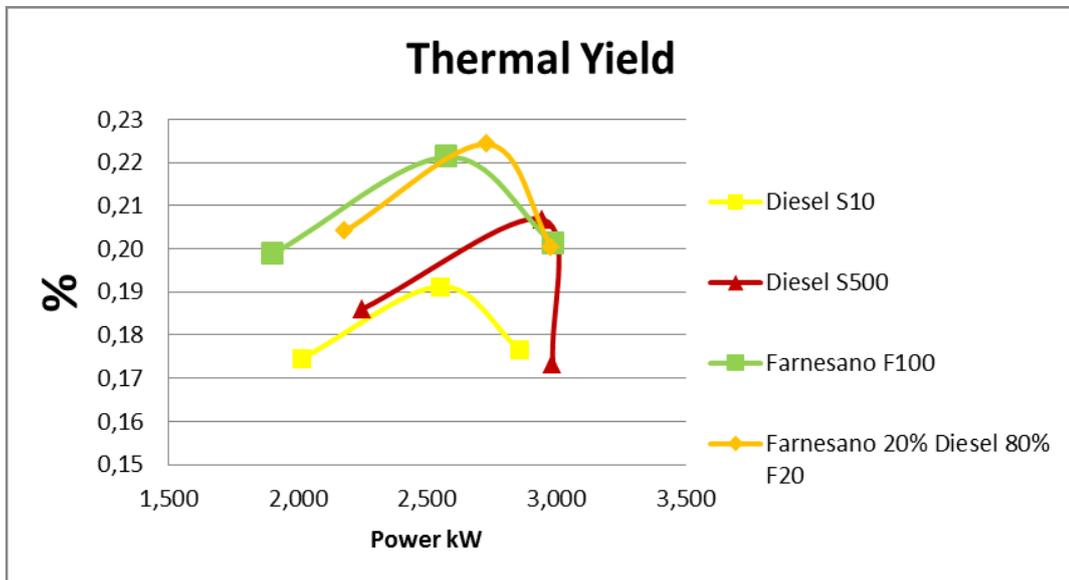

Figure 7. Thermal yield. Source: Author.

4. CONCLUSIONS

Farnesano has proved to be suitable for use in Diesel cycle engines without changes in engine settings, and the engine can be supplied with any of them without detriment to its performance.

The power developed with the use of all fuel variations remained satisfactory, with no variation greater than 14% between the fuels tested. It is noted that the S10 and 20% Farnesano blend greatly improves the power supply.

It can be said that Farnesano is an excellent fuel option when compared to petroleum-based fuels.

5. REFERENCES

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The authors are the only responsible for the printed material included in this paper.