ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

EFFICIENCY ANALYSIS OF GENERATOR SET OPERATING WITH BIODIESEL-DIESEL BLEND

Tito Britto Santos[1]
Vitor Pinheiro Ferreira[2]
Ednildo Andrade Torres[3]
Universidade Federal da Bahia, Escola Politécnica, PEI – Rua Prof. Aristides Novis, nº 2, 40.210-630, Salvador – Bahia.
titobs@gmail.com[1]; vitorpferreira@gmail.com[2]; ednildo@ufba.br[3] and ednildotorres@gmail.com[3];

Abstract.

Several changes to leverage energy supply systems implementing global standards of efficiency and reduced pollution levels have taken place in Brazil. In a country as large as Brazil, electricity generators are an important way to supply electric power to remote areas, distant from urban centers. It is an equally important subject for farmers and industries located in rural regions that normally use a number of diesel generators connected to the main system, in order to reduce excessive spending on mains electricity. Due to the importance of biodiesel and the wide range of types of generators in Brazil, the aim of this article is to provide an analysis and diagnosis focused on a generator operating on fuel blends of biodiesel-diesel. This work was carried out using a generator set of 60 kVA using different percentages of fuel blends, biodiesel concentration in diesel oil, and varying engine loads from 9 to 27 kW. The performance related to the consumption fuel, the specific consumption and energy efficiency were studied. The results show that the addition of biodiesel to the fuel increases the fuel consumption and decreases the efficiency of the system.

Keywords: *generator set, performance, biodiesel, diesel, blend.*

1. INTRODUCTION

The global regulations regarding the emissions of pollutants have been made increasingly restrictive due to the growth of population concern about environment issues. In many countries several actions have been taken to comply with law requirements, especially the use technological advances to improve equipment and systems. In this context, biodiesel was inserted in the energy market of many countries with a goal of assisting in the reduction of environmental impacts (Talebian-Kiakalaieh, A. et al. 2013; Baranescu, R. 1994; R.D. Misraa, M.S. Murthy, 2011; Dwivedi, G. et al., 2011). It is important to know the performance of the biofuel to establish its feasibility. (Fazal, M.A. et al., 2011). The standard generally adopted is the supply of biodiesel to consumers through blends of conventional diesel and biodiesel.

In the case of Brazil, the percentage of the current blend (2013) circulating in the market is at the legal ratio of 5% of biodiesel to diesel, a value established by the “National Program for Production and Use of Biodiesel” (*Programa Nacional de Produção e Uso de Biodiesel* – PNPB). In order to implement the biodiesel in Brazil's energy market, and to ensure the end consumer the validity of their insurance coverage of vehicles and equipment, a framework was created to run tests on engines and vehicles with biodiesel to provide technical support to assess the feasibility of the use of B5 on a national scale (MCT, 2009). To provide basis for advances in the use of blends with a higher proportion of biodiesel, and improve specific studies with generators, this present paper has analyzed the performance of a generator with a diesel engine, in which the measurements were made during the operation using biodiesel blends at different ratios (B5, B25, B75 e B100), in the context of a simulation of different regimes of output load (9kW, 18kW, 27kW).

The components of biodiesel are oxygen moieties, free fatty acids, degree of unsaturation and hygroscopic nature, which contribute to the degradation parts of equipment and engines, and also influence the performance and engine warranty while biodiesel is the fuel used to partially or completely.

Studies were conducted to demonstrate the impact that may occur in a vehicle engine if used a blend of biodiesel added over 5% (NBB, 2005), but also to demonstrate that it is still possible to use it with a higher percentage without modifying the current diesel engines – since certain technical recommendations are met.

The purpose of this study was to collect data to show the performance of a generator with diesel engine. The efficiency of a motor can be understood in terms of fuel consumption (W. J. Lee et al., 2011). Considering also that this consumption varies according to the load amount that is requested in relation to its nominal power (Taylor, C. F., 1985), a sequence has been established of methods of data acquisition over the total consumption and the respective load generated within a test cycle.

ISSN 2176-5480

2. MATERIALS AND METHODS

The experiment was performed by testing a generator, engine model described in Table 1 and connected to alternator that model is Negrini type ATE of 60KVA, three-phase, 220/380 VCA, 60 Hz, with 48 kW of real power.

The test was conducted with the generator with low and medium load with 9 kW increment (9kW; 18kW e 27kW) keeping in constant rotation (1800 rpm), and using different compositions of biodiesel blends.

Table 1. Description of engine MWM D225

DESCRIPTION	FEATURE
Model	MWM / D225
Engine	5.7
Fuel	Diesel
Version	6 cylinders
Displacement	5.658
Bore x Stroke	100 x 120 mm
Construction type	4 strokes
Type of injection	Direct
Aspiration	Natural
Maximum rated power	130 cv / 95.61 kW a 2400 rpm
Weight	570 kg
Compression	17.0 : 1

Data measurement produced the total fuel consumption, specific fuel consumption and the energy efficiency (fuel conversion efficiency).

The generator is connected to a load bank to dissipate electricity generated. This load bank consists of a carbon fiber water tank of 2000 liters, installed in a very open and ventilated area, and three electrical resistors (9 kW capacity of each) with the possibility of two-phase or three-phase configuration, stainless steel tubular shielded, with 3 elements, welded in brass flanges, intended for industrial low viscosity product. To maintain a uniform voltage across the resistance elements, and to obtain similar currents to produce the same power at each resistance, it was established for each phase configuration and interconnection resistance between similar poles of each generator resistance.

For greater reliability of the data collected some steps were taken: before collecting consumption data, the generator was operated for 15 minutes to establish a full state due to heating of the engine components. The time between the cycles of the experiment involving the change of blend was determined with reference to the total amount of fuel to be injected into the combustion chamber at the time of maximum load of the set of tests included here (27 kW). Therefore, the interval between cycles involving the exchange of mixture composition was set at approximately 15 minutes. This step was taken to reduce the degree of influence of a blend still present in the internal parts of the engine to collect data from a new composition of other mixture. Another step to ensure repeatability was to perform three cycles and the establishment of a interval between the cycles with the same mixture composition in the amount of 10 minutes.

The biodiesel (B5) was obtained in one of the Petrobras BR petrol stations. The blend to produce B5 was made with conventional diesel, with soybean biodiesel (B100), processed from soy vegetable oil in their biofuel plants. To obtain the soy biodiesel (B100) a special request was made directly to the Petrobras BR company's plant in Candeias.

The blends used in this experiment were B5, B25, B75 and B100. To create the B25 and B75 blends, the proportion was calculated according to the volume factor, considering how much of B100 would be necessary to add in B5 to obtain such blends. Given these values, the mixture underwent a continuous manual stirring for 2 minutes.

2.1 Total consumption and specifc fuel consumption

The measurement of total fuel consumption is crucial to develop other important data in the analysis of the engine's performance. This value makes possible to obtain specific consumption values that indicate the consumption depending on the demand required by that generation. Another important factor is to know the efficiency with which the engine converts the chemical energy of the fuel into useful work.

The collection of fuel consumption was carried out by a system comprising a digital scale brand Toledo, model 9094-I, maximum load of 15 kg, with a resolution of 0.005 kg.

The calculation of the specific fuel consumption can be seen in Equation 1, which is calculated for different modes of operation, depending on the output load increased.

ISSN 2176-5480

$$\mathbf{SFC} = \frac{\dot{m}}{P} \tag{1}$$

Where the specific fuel consumption, SFC, is expressed in [g.kW^{-1}.h^{-1}], ṁ (mass flow rate) in [g.h^{-1}] and P (power) in [kW].

2.2 Energy Efficiency

To determine the efficiency, also known as fuel conversion efficiency, the Equation 2 was used (Heywood, J.B., 1988).

$$\eta = \frac{3600}{\text{sfc. LHV}} \tag{2}$$

Where η = efficiency of converting fuel and sfc (specific fuel consumption) is expressed in [g.kW^{-1}.h^{-1}] and LHV (lower heating value) in MJ.kg^{-1}.

To determine the lower heating value it was used the comparison of means test, considering the higher heating value of the oil determined by "Laboratory Research and Development in Chemistry - Federal University of Bahia" (*Laboratório de Pesquisa e Desenvolvimento em Química – Universidade Federal da Bahia*). Table 2 shows the values used in this work.

.

Table 2. Lower heating value of differences blends

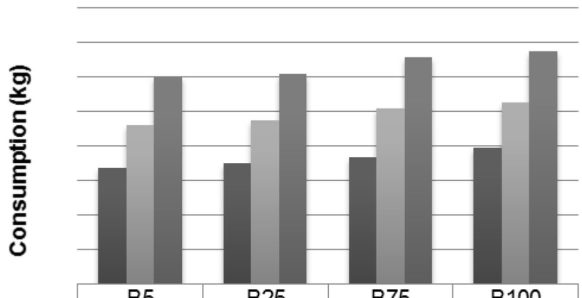
LHV (MJ kg-1)			
B5	**B25**	**B75**	**B100**
41.13	40.78	38.59	36.20

3. RESULTS AND DISCUSSION

The test results were presented in graphics for comparison, showing the variations of both the proportions of the blend as different types of output loads used in the experiment.

Analyzing the Figures it can be observed that there was a significant increase of total and specific consumption as more biodiesel was added. With the analysis of energy efficiency was possible to verify that the values have fluctuated.

3.1 Total consumption and specific fuel consumption



	B5	B25	B75	B100
9 kW	0.672	0.698	0.735	0.788
18 kW	0.922	0.95	1.017	1.055
27 kW	1.202	1.222	1.318	1.352

Figure 1. Total consumption

ISSN 2176-5480

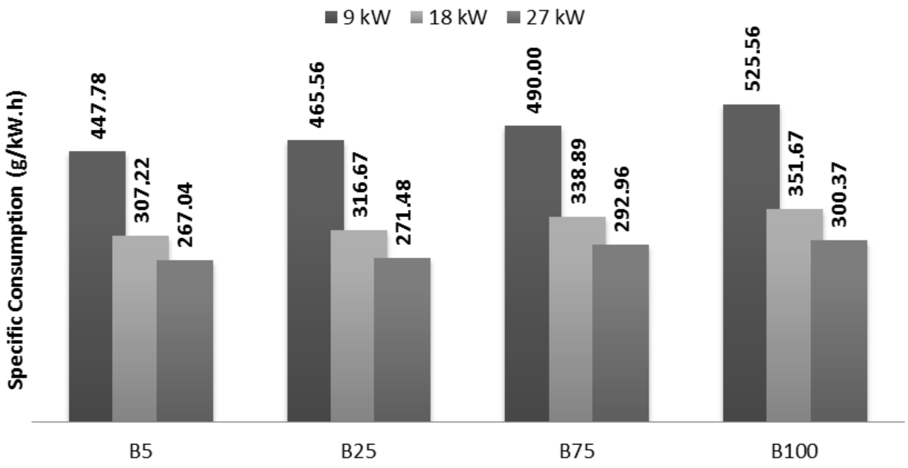


Figure 2. Specific fuel consumption

The Figure 2 shows better efficient results when higher loads are used, due to an improvement in thermal efficiency caused by an optimization of combustion. The engine transforms proportionally fewer mass of fuel to generate more useful work.

3.2 Energy Efficiency

The efficiency of the generator is unknown, so the efficiency shown in Figure 3 comprises the total system (generator set) efficiency.

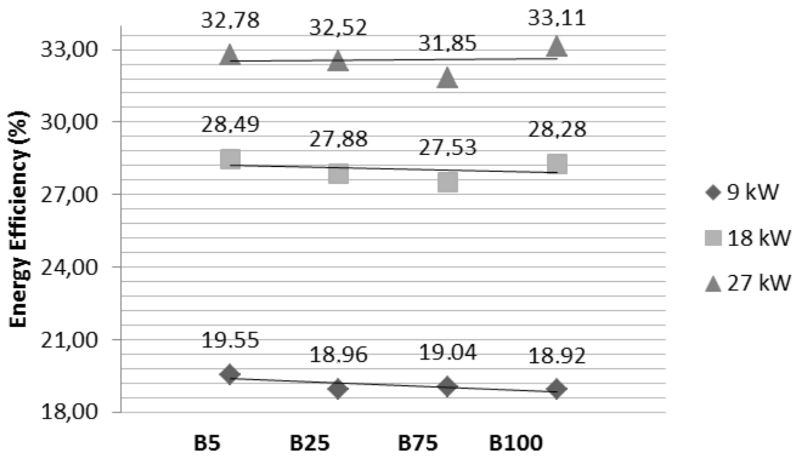


Figure 3. Energy efficiency

With regard to the results of energy efficiency, a reduction is expected along with the addition of biodiesel in the blend, because the energy efficiency is related to heating value (the amount of thermal energy that can be fully utilized by a certain amount of mass) and biodiesel has lower heating values than conventional diesel or blends. Thus, it is expected that the blends with less biodiesel require a higher consumption of fuel mass.

In the case studied here, it was identified an increase in efficiency when using the B100 biodiesel, especially when operating with loads of 18kW and 27 kW. The tendency found in the literature studied was to obtain the highest efficiency with B20 (Xue, J., et al. 2011; da Silva, MJ et al., 2011; Atabani, AE et al., 2013), in the experiment performed here, the highest efficiency was obtained at 33.11% with B100 at 27 kW. It is important to note that this test used only low and medium output load demands.

ISSN 2176-5480

4. CONCLUSIONS

Experimental results showed a reduction in efficiency when the percentage of biodiesel in the blend is increased, only in cases of load with 18 kW and 27 kW composition of B100 showed an increase in energy efficiency. When the load variation occurs with the same fuel composition it is possible to perceive a considerable increase in efficiency, with 9 kW of output load, the energy efficiency is 19% on average, with the 18 kW of output load the efficiency is increased to 28% on average and the best average efficiency was 32% when used with 27 kW of load.

By analyzing only the total consumption is possible to verify that consumption increases with the addition of biodiesel into the blend. The diesel fuel has a higher heating value than biodiesel. The blend of diesel with biodiesel presents a progressive reduction of the heating value when is added higher proportions of biodiesel.

The data presented here can serve as a basis for economic studies and for the preparation of considerations in determining the best operating point for diesel engines using biodiesel.

5. ACKNOWLEDGEMENTS

The authors thank CAPES for the support to this project.

6. REFERENCES

Atabani, A. E. et al., 2013 “Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production” In *Renewable and Sustainable Energy Reviews*, Volume 18, Pages 211-245.

Baranescu, R. 1994, “Biodiesel research-engine warranty policy”. Presented at *commercialization of biodiesel: establishment of engine warranties*, University of Idaho National Center for Advanced Transportation Technology.

da Silva, M. J. et al., 2011. “Motor gerador ciclo diesel sob cinco proporções de biodiesel com óleo diesel”. In *Revista Brasileira de Engenharia Agrícola e Ambiental*. v.16, n.3, p.320–326.

Dwivedi, G. et al., 2011. “Impact analysis of biodiesel on engine performance—A review”. In *Renewable and Sustainable Energy Reviews*, Volume 15, Issue 9, Pages 4633–4641.

Fazal, M.A. et al., 2011. “Biodiesel feasibility study: An evaluation of material compatibility; performance; emission and engine durability” In *Renewable and Sustainable Energy Reviews* Volume 15, Issue 2, pages 1314–1324.

Heywood, J.B., 1988. “Internal combustion engine fundamentals”. McGraw-Hill International, New York.

MCT, 2009. “Testes e ensaios para validação do uso da mistura biodiesel B5 em motores e veículos”. Ministério da Ciência e Tecnologia. Secretaria de Desenvolvimento Tecnológico e Inovação. Brasília, Brazil.

NBB, 2005. “OEM Warranty Statements and Use of Biodiesel Blends over 5% (B5)” *National Biodiesel Board*. 12 May 2013 <http://www.biodiesel.org/docs>

R.D. Misraa, M.S. Murthy, 2011. “Performance, emission and combustion evaluation of soapnut oil–diesel blends in a compression ignition engine”. In *Fuel* vol. 90, pages 2514–2518.

Talebian-Kiakalaieh, A. et al. 2013. “A review on novel processes of biodiesel production from waste cooking oil”.In *Applied Energy* Volume 104, Pages 683–710.

Taylor, C. F., 1985. “The Internal Combustion Engine in Theory and Practice”. Vol. 1, T*he Mit Press-id*.

W.-J. Lee et al., 2011. “Assessment of energy performance and air pollutant emissions in a diesel engine generator fueled with water-containing ethanol-biodieselediesel blend of fuels”. In *Energy* vol. 36, pages 5591 - 5599.

Xue, J. et al., 2011 “Effect of biodiesel on engine performances and emissions” In *Renewable and Sustainable Energy Reviews*, *Volume 15, Issue 2*, *Pages 1098-1116.*

7. RESPONSIBILITY NOTICE

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