MICROGENERATION OF ELECTRICITY WITH PRODUCER GAS IN DUAL FUEL MODE OPERATION

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ABSTRACT: Among the alternatives to meet the increasing of world demand for energy, the use of biomass as energy source is one of the most promising as it contributes to reducing emissions of carbon dioxide in the atmosphere. Gasification is a technological process of biomass energy production of a gaseous biofuel. The fuel gas has a low calorific value that can be used in Diesel engine in dual mode for power generation in isolated communities. This study aimed to evaluate the reduction in the consumption of oil Diesel an engine generator, using gas from gasification of wood. The engine generator brand used was a BRANCO, with direct injection power of 7.36 kW (10 HP) coupled to an electric generator 5.5 kW. Diesel oil mixed with intake air was injected, as the oil was injected via an injector of the engine (dual mode). The fuel gas was produced in a downdraft gasifier. The engine generator was put on load system from 0.5 kW to 3.5 kW through a set of electrical resistances. Diesel oil consumption was measured with a precision scale. It was concluded that the engine converted to dual mode when using the gas for the gasification of wood decreased Diesel consumption by up to 57%.

KEYWORDS: gasification, biomass, Diesel engine generator.

MICROGERAÇÃO DE ELETRICIDADE COM GÁS DE GASEIFICAÇÃO NUM MOTOR GERADOR DUAL

RESUMO: Dentre as alternativas à crescente demanda energética mundial, o uso da biomassa como fonte de energia é uma das formas mais promissoras, pois contribui para a redução das emissões de dióxido de carbono na atmosfera. A gaseificação é uma tecnologia de transformação energética da biomassa num biocombustível gasoso. O gás de gaseificação é um combustível de baixo poder calorífico que pode ser utilizado em motor ciclo Diesel no modo dual para geração de energia elétrica em comunidades isoladas. Este trabalho teve por objetivo avaliar a redução no consumo de Diesel num motor gerador, com a utilização de gás da gaseificação da madeira. O motor avaliado foi da marca BRANCO, com injeção direta e potência de 7,36 kW (10 cv) acoplado a um gerador elétrico de 5,5 kW. O gás de gaseificação foi produzido num gaseificador tipo concorrente, sendo injetado no motor misturado com o ar de admissão e o Diesel injetado pelo injetor do motor (modo dual). O motor gerador foi submetido a cargas que variaram entre 0,5 kW e 3,5 kW, com o auxílio de um banco de resistências elétricas. O consumo de Diesel foi medido por meio de uma balança de precisão. Concluiu-se que o motor convertido para o modo dual, ao utilizar o gás de gaseificação de madeira, apresentou uma redução no consumo de Diesel de até 57%.

PALAVRAS-CHAVE: gaseificação, biomassa, motor gerador Diesel.

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INTRODUCTION

The use of biomass as an alternative source of energy is a current topic, since it is a less intermittent source of energy when compared to wind and solar sources, and for having a "zero balance" of CO_2, i.e., the CO_2 emitted from burning biomass is reabsorbed in the next life cycle of the plant by the photosynthesis process (GALVÃO, 2006). There are many advantages of using biomass as energy source, regarding socio-environmental factors. According to SOARES et al. (2006), biomass is a form of energy, which can be used as a mechanism to promote development in rural areas.

In 2007, 46% of the total energy supplied in Brazil was obtained from renewable energy sources, in which biomass represented approximately 28%, and sugarcane products accounted for 16%. Thus, Brazil is a country that has one of the cleanest energy matrixes in the world (BRASIL, 2007).

One form of thermochemical conversion of biomass into biofuel is the gasification technology, which provides poor-quality gas. The gasification process is a process in which biomass is subjected to drying, pyrolysis, oxidation (combustion) and reduction. In the drying area, the biomass loses its moisture as it passes through the pyrolysis zone, where it is decomposed into volatile gases, charcoal, tar and acids. The pyrolysis products react with oxygen at high temperature in the combustion zone and are converted into gas in the reduction zone (SHARMA, 2009; LORA et al., 2008).

Gasifiers can be updraft, downdraft, cross-flow and fluidized bed. According to SHETH & BABU (2009), when using alternating engines and gas turbines, the downdraft gasifier is the most widespread type because it produces low tar. Figure 1 shows a downdraft gasifier.

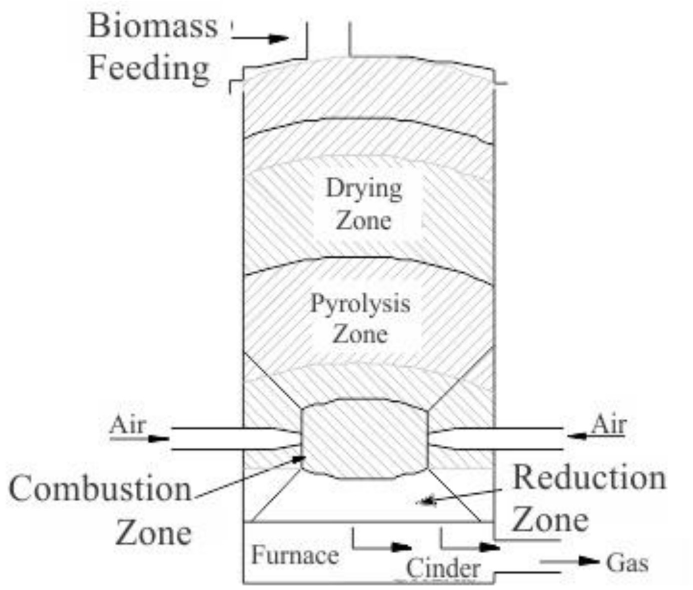

FIGURE 1**.** Downdraft gasifier (LORA et al., 2008).

In regions where there is availability of wood and its processing residues, gasification technology is recommended for generation of electricity. The gas produced from wood has a calorific value of 5.7 MJ m^{-3} and is composed (by volume) of 17% H_2, 21% CO, 13% CO_2, 1% CH_4, and 48% N_2 (BRIDGWATER, 2003).

A Diesel-cycle engine generator can be adapted to use producer gas as a primary source to generate electricity. The diesel oil acts as a pilot fuel, being injected through the injection system of the engine, while the gas is dragged with the atmospheric air in a venturi tube attached to the air intake, forming an engine referred as dual.

Alternatives to diesel oil have been studied in a partial or total fuel replacement. BEDOYA et al. (2009) tested a diesel cycle engine of direct injection coupled to an electricity generator, 1,800 rpm and 20 kW nominal power using biogas as a primary fuel (60% methane and 40% carbon dioxide) associated with a pilot diesel injection. RAMADHAS et al. (2008) used gas produced from biomass as primary fuel associated with a pilot biodiesel injection to generate electricity. In these reports, MCI - Diesel cycle was used to reflect changes to operate in dual mode.

HENHAN & MAKKAR (1998) tested a dual engine with diesel cycle and direct injection, a model Lister Petter LPWS2. They used as a primary fuel natural gas mixed with carbon dioxide, i.e., simulating biogas (poor-quality gas) to different methane concentrations. They varied the percentage of natural gas between 0 and 100% air and mixed with a T-type mixer before entering the combustion chamber and ignited with the pilot diesel. They obtained the result that 60% of diesel can be replaced without ignition of the engine.

To use the operation systems in the generation of electricity, it is possible to convert these to operate in dual mode, however the MCI - Diesel cycle must have derivation with the aspiration of the engine, combining air with gas. Nevertheless, a "pilot" injection of diesel oil is required, which has a function to the initial ignition, since the gas plus air does not burn at the normal compression ratio of the engine (SCHLOSSER et al., 2004).

Law nº 12,111 of December 9, 2009, ratified the bill of fuel consumption (BFC) of isolated systems of energy, which corresponds to the sector fund administered by ELETROBRÁS, whose purpose is to reimburse the costs of energy supply by public or private companies in isolated areas in northern Brazil. BFC is paid for by all energy consumers in Brazil and represents a large expenditure of public funds to secure energy to isolated regions. Thus, the implementation of viable solutions of energy generation through renewable energy with biomass in isolated areas represents economical savings to country.

Currently, in Brazil the biomass gasification for power generation may potentially contribute to assist rural communities isolated from the electricity transmission grid. In these regions, the electric power is usually obtained with diesel generators. One of the problems is the cost of diesel oil to generate electricity, which when coupled with the difficult access to these regions by the transport systems; it is a product with higher cost compared to other regions. In this regard, the use of primary energy from biomass for energy transformation in a gasification plant for electricity generation partially replaces the consumption of diesel oil. Besides, alternative technologies for power generation and gasification are renewable and contribute to sustainable development.

The purpose of this study was to measure the reduction of oil consumption in a dual-fuel diesel engine using diesel as pilot associated with gasification gas. The generator engine used was a Branco type, with direct injection and power of 7.36 kW (10 hp) and 5.5 kW generator coupled to a downdraft gasification unity with a processing capacity of 10 kg h^{-1} of wood.

MATERIALS AND METHODS

The gasification/generation of electric power was installed in the Bioenergy Laboratory, located at the Universidade Estadual do Oeste do Paraná (UNIOESTE), Cascavel, PR Campus.

The tests were performed on a generator-engine Diesel set operating in two situations: in dual mode (mixture of diesel and wood gasification gas) and standard or conventional mode (only diesel). Thereby to allow reducing diesel consumption by mixing diesel with gasification gas.

The gasifier used here is a downdraft type, which produces low levels of tar, a compound present in the gas and that in large amounts restricts its use in internal combustion engines, because it damages the motor when it condenses on the moving parts of the engine.

The biomass used in the gasifier was wood residue from a sawmill located in the city of Cascavel, PR. The mill works with *Mezilaurus itauba* wood, locally known as Itaúba. The higher calorific value of Itaúba, according to QUIRINO et al. (2005), is 22.00 kJ kg^{-1}.

Figure 2 shows the gasification unit. Some specifics in the generation of gas were followed, as the wood moisture fed to the gasification system, which, according to FÁVERO et al. (2007), should not be greater than 20% wb, to avoid major losses in the energy efficiency of the gas produced. Another specification was related to the dimensions of the wood pieces that feed the reactor, being no larger than 4.0 cm to ensure a smooth flow in the reactor.

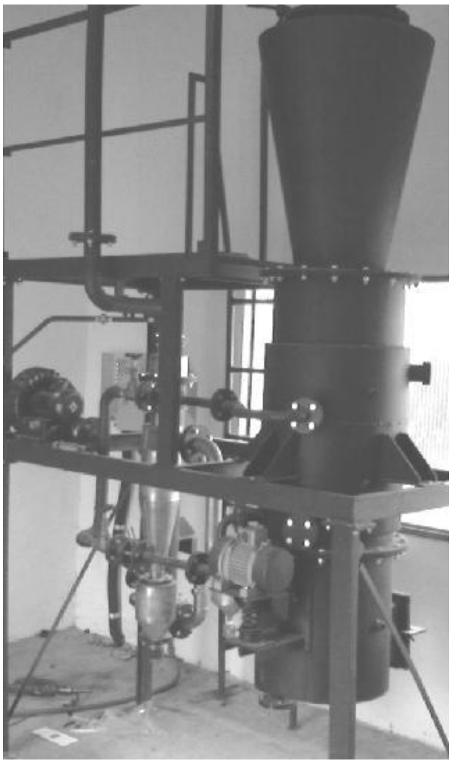

FIGURE 2. Gasification unit.

The diesel generator engine, which was coupled to the gasifier was a Branco type with 7.36 kW (10 hp) power and 5.5 kVA/5.0 kW nominal power and a single-phase output voltage of 120/240 V. For the diesel generator engine to work in a dual-fuel system, it was necessary to make an adjustment with air aspiration through a venturi, so that the engine receives air plus gasification gas during the air intake phase. With this mix, the combustion cylinder is compressed until the final compression stage, when it receives a pilot injection of diesel or biodiesel to start the combustion phase.

The function of the venturi, which is a tube with a reduced area in a section, is to increase the speed of the mixture and reduce the suction pressure, causing the combination to be uniformly mixed and dragged into the engine cylinders prior to combustion. The control of gas flow into the venturi was performed by a gate-type valve. Air suction was controlled by increasing or reducing the area and the intake air into the venturi.

Load simulation on the generator was performed by a set of resistors, with power controlled through a panel. The set simulates power ranges spaced each 0.25 kW i.e., from 0.25 kW, 0.5 kW, 0.75 W, 1.0 kW, 1.25 kW … 4.0 kW, up to 4.25 kW.

Figure 3 shows the experimental setup. The gasifier is shown with its accessories (filter, cyclone and cooler), the generator engine and the set of resistors.

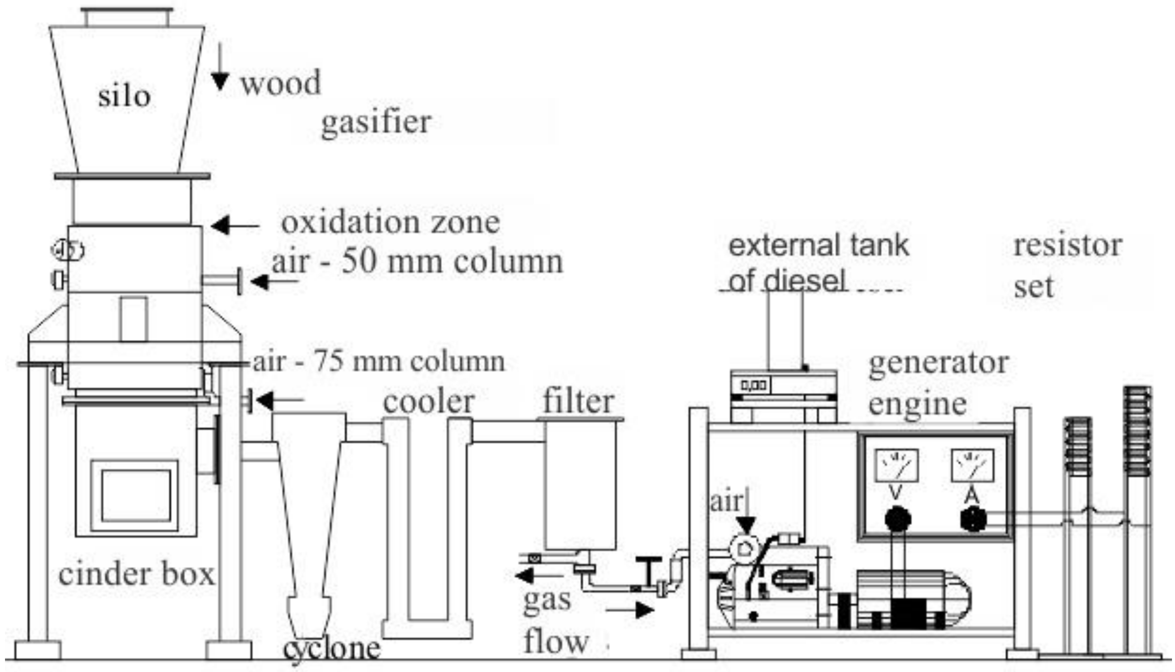

FIGURA 3. Experimental setting.

As the engine does not work only with gasification gas, the fuel injection system of the engine pumps diesel oil. To measure the mass of diesel, a storage tank was used, which was weighed by a precision scale to obtain the consumption during the tests with diesel generator engine set. A digital timer was used to time the interval between a measurement and the next in order to get the hourly diesel consumption (mass flow). Equation 1 shows the calculation of diesel consumption in a time interval during the test.

$$\text{Cons} = ((\text{Mr} + \text{Mi}) - (\text{Mr} + \text{Mf})) \quad (1)$$

where,

Cons - fuel consumption, kg;
Mr - mass of the fuel container, kg;
Mi - initial fuel mass, kg, and
Mf - final mass of fuel, kg.

The chosen loading cycle began to be applied from smaller loads: 0.25 kW, 0.5 kW, 0.75 W, 1.0 kW, 1.25 kW; ... 4.0 kW, 4.25 kW. This loading cycle was repeated for cases studied, with the consumption of diesel with the engine in normal mode and with the engine in dual mode. The time versus power consumption in a given power provided the specific consumption of diesel (CED). CED evaluation was determined by varying the load of the generator engine operating in conventional mode with diesel and with diesel plus wood gasification gas.

$$\text{CED} = \left(\frac{3600\ \text{Cons}}{\text{V I T}} \right) \quad (2)$$

where,

CED - specific fuel consumption, kg kWh^{-1};
V - output voltage, V;
I - electrical current, Å, and
T - test time, s.

The difference between diesel fuel consumption operating in conventional mode and dual-mode can be expressed by the formula:

$$\text{diesel economy}(\%) = \left(\frac{(\text{Cons}_{\text{conventional}}) - (\text{Cons}_{\text{dual mode}})}{(\text{Cons}_{\text{conventional}})} \right) 100 \quad (3)$$

RESULTS AND DISCUSSION

Figure 4 shows the specific fuel consumption in the two cases studied. It was observed that only the generator engine operating with diesel (conventional mode) under lower loads showed an increase in CED, i.e., the performance of the generator engine at low loads is lower. This is also true for the engine operating in dual mode, but larger loads tends to decrease CED until reaching stabilization.

The higher conversion efficiency of the generation engine with diesel was between loads 2.00 and 3.5 kW, being obtained in this load range an average CED of 450 g kWh^{-1} for the lowest diesel generation. In the generation with diesel plus gasification gas, the best results observed for the conversion efficiency of the engine were with loads between 2.54 and 3.36 kW, which produced the best result with an average CED of 214 g kWh^{-1} (Figure 5).

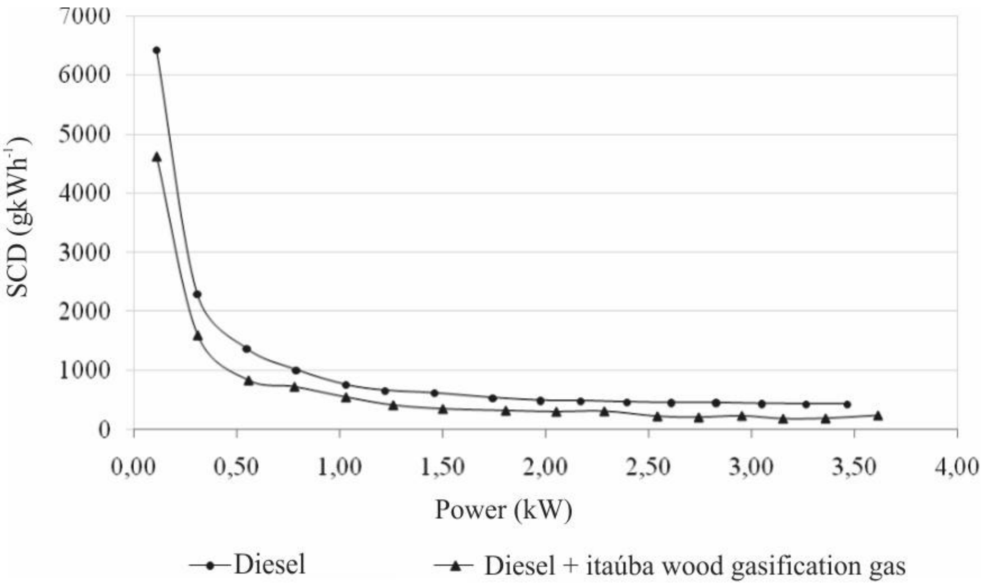

FIGURE 4. Specific consumption of diesel fuel.

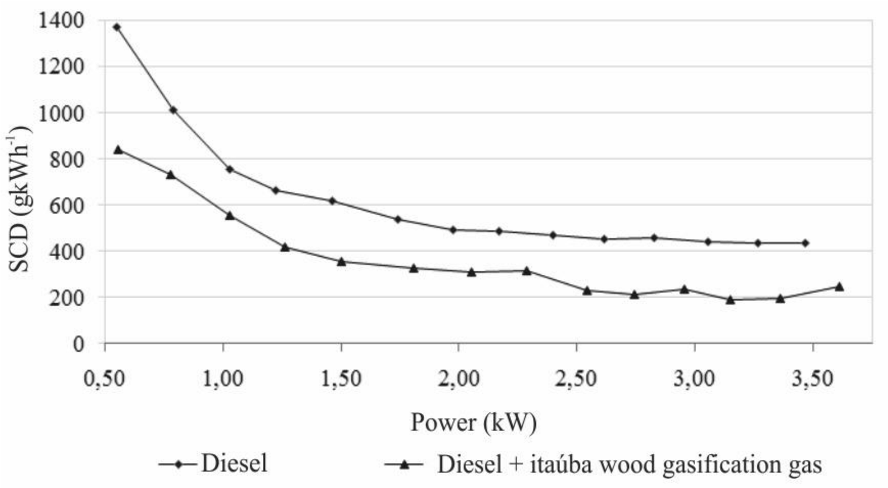

FIGURE 5. Load range with a lower specific fuel consumption.

During the tests, it was noted that at loads ≥ 4.0 kW, the motor presented ignition accompanied by white smoke in the exhaustion of combustion gases at regular intervals. This behavior was associated with a mixture rich in gas and diesel oil.

Figure 6 shows the economy obtained with the use of gas on partial substitution of diesel oil. The best result obtained in diesel economy was 57% at the load of 3.25 kW. DESHMUKH et al. (2008), obtained 60% reduction in consumption of diesel when combined with gasification gas with an engine operating in dual mode under similar conditions. RAMADHAS et al. (2006) obtained 72% economy in diesel oil in studies with gasification gas.

It was found that at lower loads, the reduction in diesel consumption was lower, with less than 30% reduction at the lowest loads. This behavior was also noticed by RAMADHAS et al. (2006), which explains it as having insufficient oxygen in the system to complete combustion in operations with lower loads, and that for much larger loads, the authors conclude that the gas flow in these cases may be insufficient to boost the diesel fuel economy. As seen in Figure 6, the situation described by the author was not observed at loads near the nominal power of the engine. In applications of the generator engine set with loads above 1.25 kW, substitution of diesel oil by gasification gas is more significant.

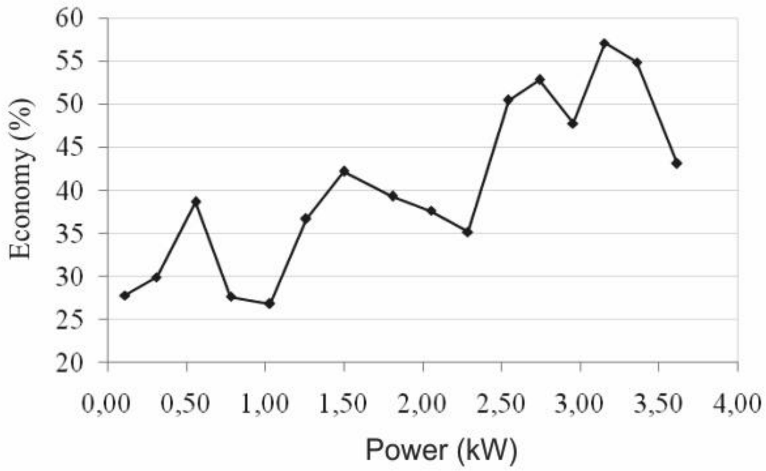

FIGURE 6. Reduction in Diesel fuel consumption, expressed in porcentage**.**

As observed in Figure 6, there were several fluctuations in the reduction values of diesel consumption. This behavior was attributed to the high sensitivity to inconsistencies occurred in the MCI interface and flow of air plus gasification gas. Even though, good results were obtained for the reduction in fuel consumption. The worse results obtained in loads larger than 3.25 kW were attributed to the difficulty of finding an appropriate air + gas ratio, being observed in these charges a pre-ignition behavior.

CONCLUSION

It was concluded that with the use of gasification gas from wood as the main fuel, savings of up to 57% of diesel oil were achieved at a load of 3.5 kW.

This type of system can be used to generate electricity in isolated locations that are not served by electric grids, which could represent substantial savings of diesel fuel with its replacement.

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