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SIZE EFFECT OF WOODEN PIECES ON THE PERFORMANCE OF A BIOMASS GASIFIER

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Abstract. *The scientific community is concerned with preserving the environment, to prevent general life degradation. Nowadays, it is evident that such an aim cannot be achieved without the aid and development of new and clean technologies. Biomass, is probably, the main weapon in this crusade, given that: residual biomass is renewable, it is a low carbon source of fuel, it is cheaper than the fossil fuel, and it is available in many countries like Brazil (Nogueira, 2012). On the other hand, gasification is one of the most efficient processes to turn the internal energy of biomass available, requiring a relatively simple technology. In the present work a co-current open top downdraft gasifier, having a 4 kW thermal power capacity is used. The poor gas from the gasifier fuel an 18 Hp Otto cycle engine, is coupled to an electrical generator. In order to improve the knowledge of parameters related to the performance of a biomass gasifier, the present paper discusses the importance of the size of the wooden pieces, which fuel the gasifier, on the system global efficiency. It was noticed that the maximum value of the temperature of the reactor combustion zone was a consequence of the biomass in Sample 4.*

Keywords: *Gasifier, Residual Biomass, Size of Wooden pieces, Producer gas.*

1. INTRODUCTION

Biomass gasification relies on renewable energy sources. Its technology is relatively simple and efficient, having less carbon emissions than those from natural gas and propane fuels. Gasification is a process that converts carbonaceous material through thermal decomposition into combustible gas (Krause, 1990). In other words, gasification consists of the conversion of the biomass into poor gas by means of a partial oxidation at high temperature. Poor gas is a gas mixture of carbon monoxide, hydrogen, methane and carbon dioxide. Its heating value depends on the gasification agent, but, in general, it is ten times lower than that of natural gas. Some properties of the feeding biomass may influence the gasification process, such as moisture, volatile matter, and ash contents, as well as the size of the biomass pieces, the latter being one of the most important parameters affecting the composition, quality and final application of

poor gas, cf. Dasappa et al. (2003). The present work investigates the influence of the size of the pieces of wood serving to feed a co-current gasifier, on the efficiency of a system formed by a biomass gasifier, and an electrical generator coupled to an Otto cycle engine.

2. EXPERIMENTAL PROCEDURE

All tests were carried out in a co-current downdraft gasifier, of 4 kW thermal capacity in the Laboratório de Inovação at the Technology Center of the Federal University of Paraíba. The engine used in the system was a gasoline VANGUARD V-Twin, 2 cylinders, 18-hp Otto cycle, adapted to run on poor gas. The generator, coupled to the engine, is from Toyama (model TG2500MX), single phase, 220 V and 60 Hz.

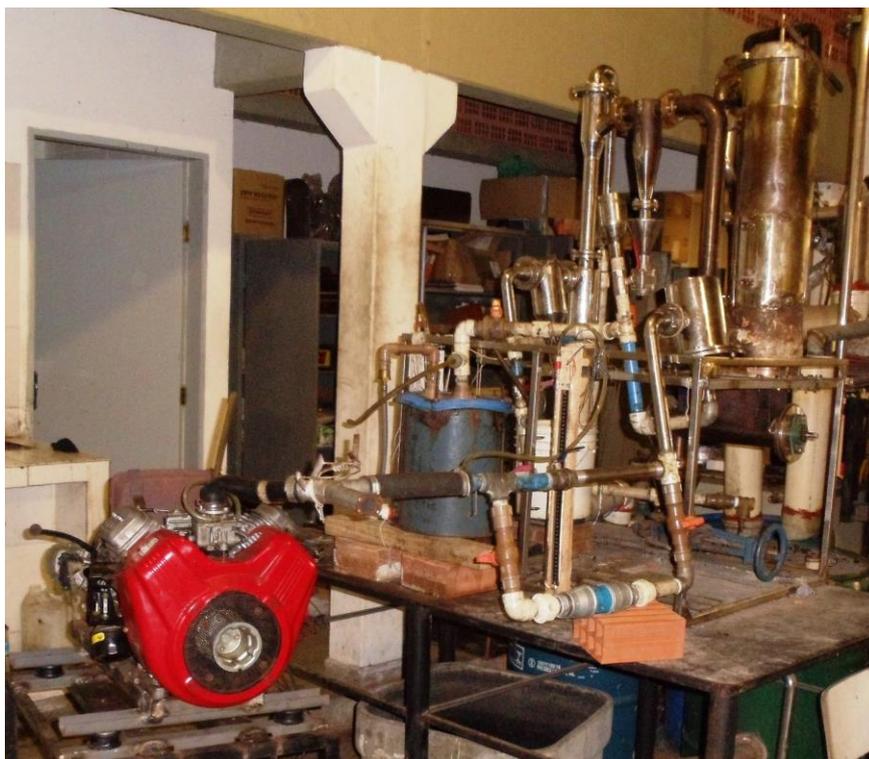


Figura 1. Experimental bench.

Wooden waste materials brought from the University campus dump, have served as residual biomass to feed the gasifier. They were cut into uneven cubic form with approximately, 13 mm³, 16 mm³, 20 mm³ and 27 mm³, each referred to as Samples 1, 2, 3 and 4, respectively, see Figure 2. The reactor internal diameter of the gasifier is 160 mm. For each test it was feed with a different kind of sample.

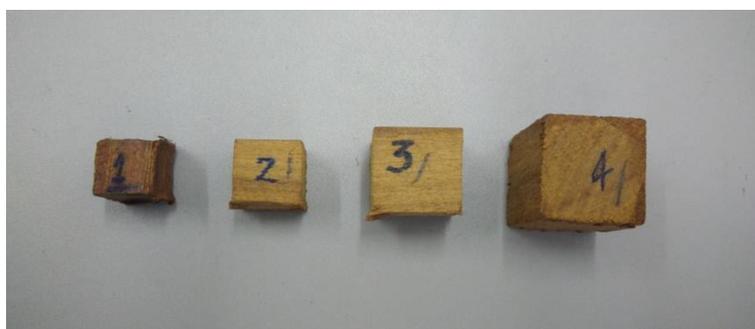


Figure 2. Biomass samples used to feed the gasifier

Initially, the specific mass and moisture content from the different samples were determined. Then, using Eq. (1) (Garcia, 2002) the low heating value of the samples was determined

$$PCI_{Mad} = 4756 - 53,418 \cdot (\%UM) \quad (1)$$

Where:

%UM is the moisture content of biomass.

To start running the system, first the biomass, inside the reactor, was ignited with a gas torch burner, and then the flare was lit. After some minutes, the intensity and the color of the flare, as well as, the CO level of the poor gas were checked. To run the engine, the CO level was examined to see if it was over 10 %. To guarantee that the engine could work having mixtures of air/poor gas at, approximately, stoichiometric conditions, the mixture was controlled through a Y shape mixing apparatus, see Figure 3. A set of eight lamps, six of 250 - 280 W and two of 150 W - 180 W, was used to simulate the resistive load of the generator, see Figure 4. Each sample reached a maximum power, being: 2.15 kWe for sample 1, 2.17 kWe for sample 2 and 2.16 for samples 3 and 4.



Figure 3. The Y shaped mixture air/gas controller



Figure 4. Electrical load simulating module

Having stabilized the engine, lamp by lamp was lit and all the data (power, biomass consumption, gases composition, elapsed running time, etc.) was registered. The consumption was checked by means of a digital scale. (In the beginning the reactor was completely full with of biomass. During the operation new quantities of weighted biomass - kg - were used to feed the gasifier and the elapsed time was registered). The composition of the poor gas as well that

of the exhaust gases was evaluated using a Discovery G4 vehicle gas analyzer, from Alfatest. The whole procedure was repeated for each of the four samples of wooden pieces.

In order to determine the low heating value of the poor gas, (J / Nm³), Eq. (3), Rumão (2013), which correlates low heating value with carbon monoxide from wood gasification, was used.

$$PCI_{Gás} = -0,004738 \cdot (\%CO)^2 + 0,3149 \cdot (\%CO) - 0,1057 \quad (3)$$

Equation (4) was used to determine the efficiency of the system (gasifier/electrical generator)

$$\eta_G = \frac{P_e}{M_s \cdot PCI_{Bio}} \cdot 100(\%) \quad (4)$$

Where:

P_e is the useful electrical power (W).

M_s is the mass flow of biomass serving to feed the gasifier (kg/s)

PCI_{Bio} is the calorific value of the biomass (J/kg).

3. RESULTS AND DISCUSSIONS

3.1 The Moisture Content and the Biomass Density of the Wooden Pieces

Table 1 shows experimental results of the moisture content for the four biomass samples used to feed the gasifier. Table 2 shows the density values of the wooden pieces, experimentally determined.

Table 1. Moisture content results of the wooden pieces, determined in triplicate, for each one of the four samples

Sample	Moisture Content 1 (%)	Moisture Content 2 (%)	Moisture Content 3 (%)	Average (%)
1	10.992	10.442	9.042	10.159
2	8.280	10.149	9.304	9.244
3	9.868	9.793	10.670	10.110
4	8.274	9.752	9.544	9.190

Table 2. Density experimental results of the wooden pieces, determined in triplicate.

Sample	Density 1 (kg/m ³)	Density 2 (kg/m ³)	Density 3 (kg/m ³)	Average (kg/m ³)
1	1083.754	1073.243	1063.308	1073.435
2	704.696	743.469	796.531	748.238
3	814.968	863.694	908.6684	862.444
4	762.917	664.674	802.483	743.358

As can be seen, the values of the moisture content in Table 1 are all very similar, having magnitudes lower than 10.2 %. In Table 2, it is remarkable the fact that Sample 1 presents a density 19.7 % larger than that of Sample 3, the one with the second larger density among all samples. Samples 2 and 4 have very similar densities.

3.2 Temperature Distributions Inside the Reactor

Table 3 shows the temperature inside the reactor, in the drying, pyrolysis, combustion and reduction zones.

Table 3. Temperature distributions inside the reactor, related to the different samples.

	Sample 1	Sample 2	Sample 3	Sample 4
Drying (°C)	40.5	52.5	61.5	45.6
Pyrolysis (°C)	463.2	698.5	544.0	701.0
Combustion (°C)	954.4	1028.0	1079.0	1162.0
Reduction (°C)	860.0	844.0	952.7	1014.0

3.3 The Gas composition of the Poor Gas

Figure 5 shows, for the four samples, the levels of CO, CO₂ and O₂, registered when the engine was running at maximum power,

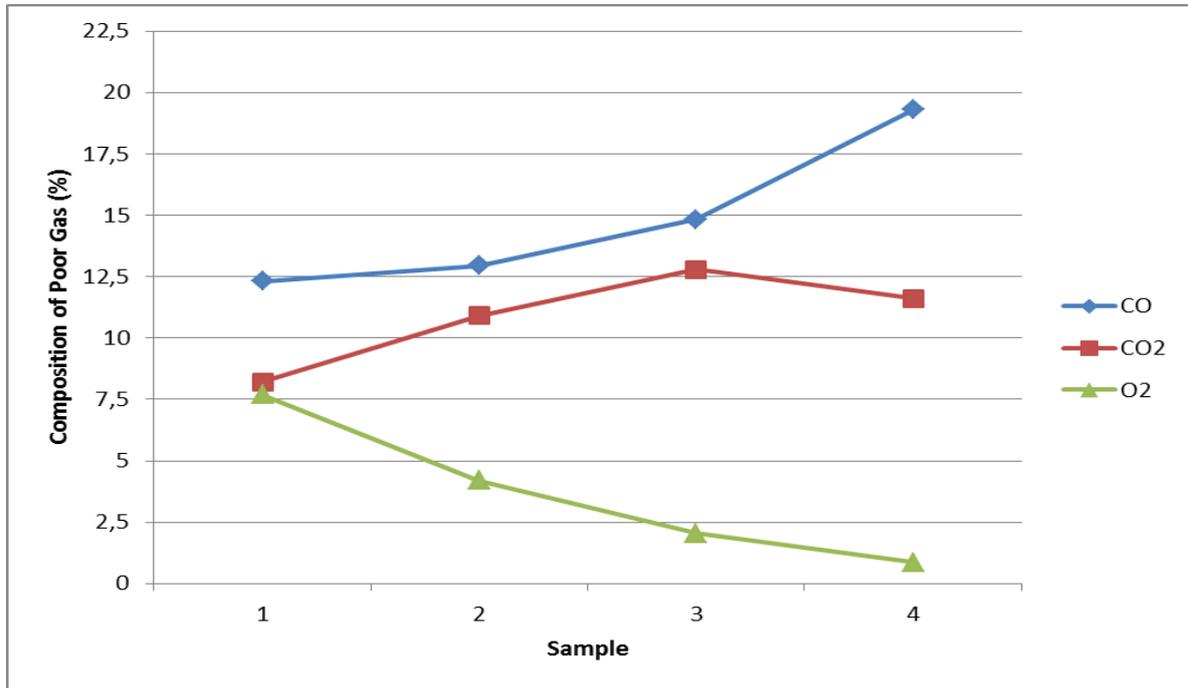


Figure 5. Level of CO, CO₂ and O₂ of the poor gas.

As expected, the generated poor gas was mainly a mixture of H₂, CO, and CO₂. The CO level variation went up from 12.32 to 19.29 %, responding to the increasing values of the temperatures on the Combustion zone, see Table 3. On the other hand, the CO₂ level went from 8.2 to 12.8%, indicating that it was converted (reduced) to CO. The O₂ concentration went from 0.86 to 7.68 %, following an inverse trend of the temperatures of the Combustion zone, which shows that the greater the sample size the better the combustion efficiency of the wooden pieces. Again, it gives Sample 4, the best feeding condition.

3.4 Low Heating Value (LHV)

3.4.1 Determination of the Biomass LHV

The heating values of the biomass used in the tests are showed in Table 4, and they are in agreement with the ones mentioned by Quirino et al. (2004).

Table 4. Dates of the biomass LHV.

Sample	PCI _{Mad} (kJ/m ³)
1	17628,63
2	17832,99
3	17639,44
4	17845,13

3.5 Determination of the Poor Gas LHV

Figure 6 shows the heating values of the poor gas as a function of the electric power generated, for the four sample types.

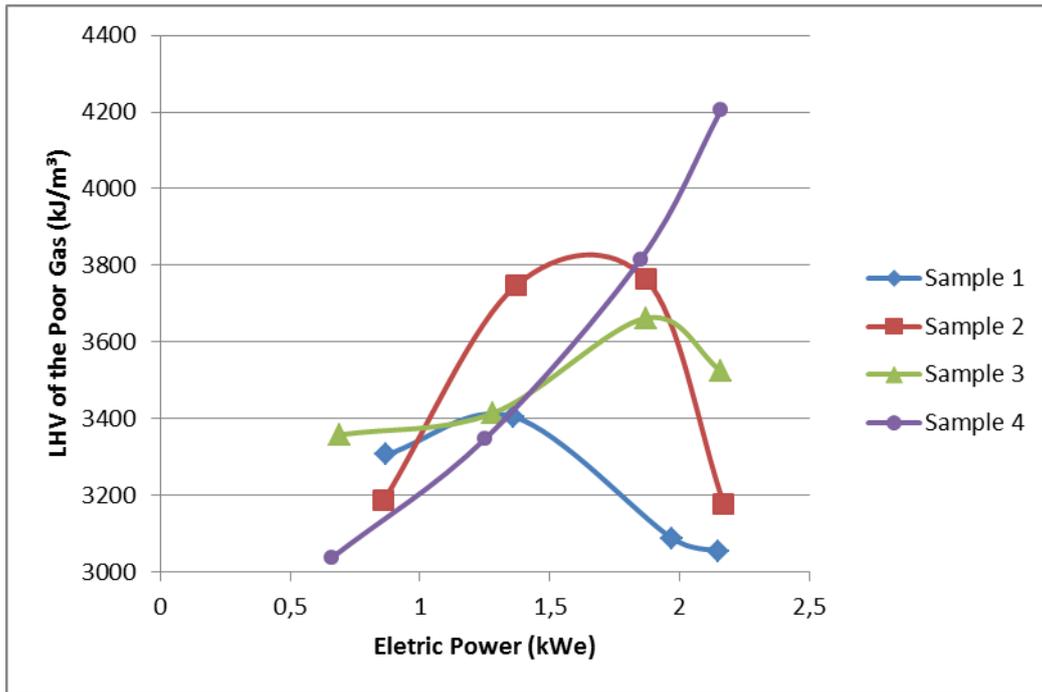


Figure 6. LHV of the poor gas

As we see, on the whole, Samples 2 and 4 came to reach the larger outcomes of LHV, i.e., Sample 4 in terms of fourth generated electrical power whereas Sample 2, concerning the second and third generated electrical power. It should be observed that, in addition, Sample 4 and 2 presented both the lowest density and moisture content, with Sample 4, showing the largest volume.

3.6 Biomass Specific Consumption

Figure 7 presents the specific consumption of biomass as a function of the electric power generated, for the four different sizes of biomass used. The lowest consumption was related to Sample 4, with Sample 2, coming next.

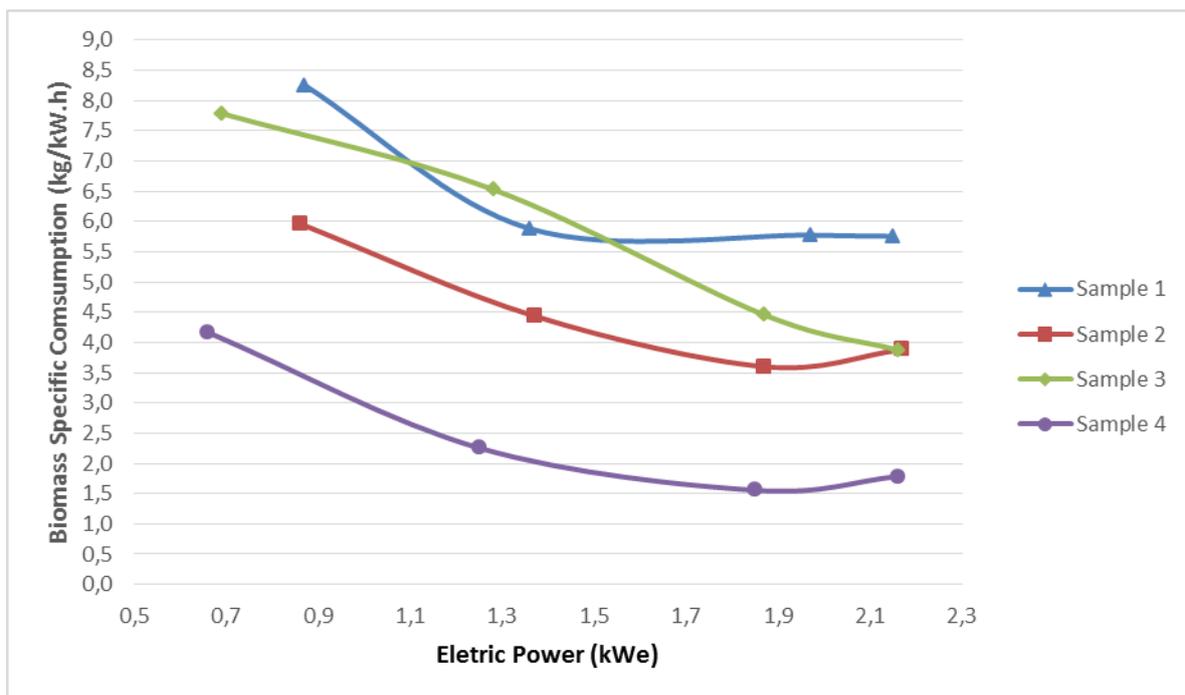


Figure 7. Biomass specific consumption.

In Fig. 7 we see that, in general, the specific consumption of the biomass decreases with the increase of the power generated level, the lowest consumption being achieved by Sample 4, with Sample 2, coming next.

When the system was generating the maximum electrical power using biomass from Sample 4, the consumption was 1.78 kg/kWh. For the same electrical power, the consumption raised to 5.76 kg/kWh, when fueled with biomass from Sample 1.

3.7 Efficiency of the system Gasifier/ Otto Cycle engine/Generator

Figure 8 presents the plot of the efficiency of the system formed by gasifier, Otto cycle engine and generator, see Eq. (4) over the electrical power generated.

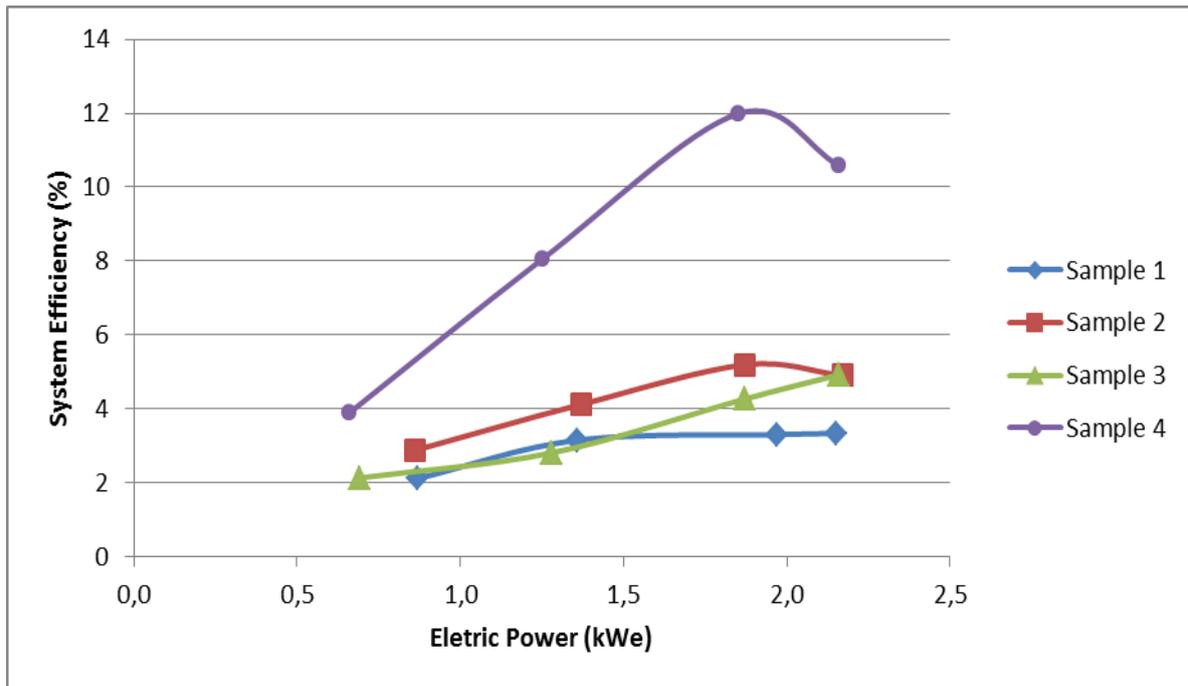


Figure 8. Efficiency of the gasifier/cycle Otto engine/generator system vs Electrical power

In Fig. 8 it is seen that no matter the sample, the efficiency of the system goes up as the electrical power increases. However, the highest efficiency (11.99%) resulted from the biomass from Sample 4, when the electrical power generation reached 1.85 kWe.

4. CONCLUSIONS

Considering that the gasifier has operated no matter the size of the biomass pieces, in a similar fashion, the consequent experiment results should be explained by the physical or chemical conditions of each different sample. In this regard, probably the most distinguishable fact registered in several essays was the maximum value of the temperature of the reactor combustion zone, brought about by Sample 4. Analyzing its averaging values of moisture content, density, and lower heating value, and comparing them with the ones of the other samples it is understandable, that they could not be responsible to convey comparable temperature. In fact, the greater the volume of the pieces of biomass, the slower the feeding rate, see Fig. 7, and consequently the gases residence time raises, enabling a more efficient gasification, as indicated by the decreased concentration in O_2 . According to Billaud et al. (2016), CO_2 formation occurs from the combustion reactions and is directly bound up with the amount of O_2 . In Fig. 5, it can be seen that the increase in CO_2 level is proportional to the decrease in O_2 level. Also, as a consequence of higher temperatures there was an elevation in carbon monoxide concentration, a flammable gas, cf. Yin et al. (2012). It should be mentioned that similar results were obtained by Feng et al. (2011), in studying a catalytic steam gasification of biomass, the only divergence being in the behavior of CO, which decreased because some CO reacted with H_2O . Finally, it should be noted that the lower heating value of the poor gas, being a function of the CO level, made the biomass related to Sample 4, the only one capable to allowing the maximum efficiency of the system to generate electrical power.

5. REFERENCES

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