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REFORM OF GAS FROM BIOMASS PYROLYSIS USING THERMAL PLASMA

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Abstract. *Due to the limited supply of fossil fuels and conventional energy consumption increasing in coming decades, alternative sources are being explored to generate sustainable, clean and renewable energy. Pyrolysis of biomass is one of the alternatives, however, the main challenge is the quality of the gas generated because it contains fractions of heavy hydrocarbons and particulate matter. The chemical and physical properties of tar are considered the key points to understanding its thermal decomposition. Works demonstrated that temperature above 1273 K is enough to destroy the compounds of tar and particulate matter. The aim of this work was to minimize the tar and particulate matter present in the pyrolysis gas. For this, it was built a venturi with a thermal plasma inserted in the throat. The pyrolysis gas flows through the venturi, and by the high plasma temperature, was reformed. The mass of tar and particulate matter was measured according to the document CEN/BT/TF-143 elaborated by the European Commission and the European Free Trade Association. As a result, it was found that the mass flow rate of tar and particulate matter collected according to that document in conventional pyrolysis was* $(4.71 \pm 0.30)10^{-3}\ g.s^{-1}$ *whereas for reforming using thermal plasma it was* $(2.85 \pm 0.65)10^{-3}\ g.s^{-1}$*. Therefore, the concentration of tar and particulate matter in the reform of pyrolysis gas using thermal plasma was* $39.5\ \%$ *lower than in the conventional pyrolysis.*

Keywords: *tar, thermal plasma, reform, pyrolysis.*

1. INTRODUCTION

The reform of gas from biomass pyrolysis using plasma torch is of great importance today. Due to limited offer of conventional fossil fuels and energy consumption sharply in coming decades, alternative sources are being explored to generate sustainable, clean and renewable energy (Meng *et al.*, 2011). Thus, works show the possibility of heat and electricity generation from biomass pyrolysis or gasification (Rutberg *et al.*, 2011; Shie *et al.*, 2011). These processes are studied internationally and they involve waste treatment (Rutberg, 2003) and reform of contaminating gases (Oda, 2003). However, the main difficulty of these technologies is the quality of the produced gas because it contains fractions of heavy hydrocarbons and particulate matter (Nair, *et al.*, 2003).

The use of conventional technology have not been very effective for tar removal in pyrolysis gas due aerosols, which are particles formed by the condensation of tar, less than $1\ \mu m$ of diameter. Because the viscosity of the tar, such particles adhere to the walls of equipment (for example, filter clogging or pipe), decreasing the efficiency of tar removal (Kumar, Jones and Hanna, 2009). Accordingly, the use of conventional equipment for the removal of particles has achieved limited success when referring to the tar removal (Bizzo, 2010).

Given the scenario presented, instead of tar and particulate matter removal, an alternative of cleaning treatment of the pyrolysis gas is destroy these pollutants transforming them into gas, thus resulting in the pyrolysis gas reformation by means of thermal plasma.

The chemical and physical properties of the tar are considered the fundamentals for understanding the thermal decomposition (Chunshan and Suzuki, 2009). Studies have shown that temperatures above $1273\ K$, with reasonable residence time, are longer than necessary to destroy the tar compounds in the pyrolysis gas (Milne and Abatzoglou, 1998).

The plasma torch is a versatile tool that can achieve high temperature in its vicinity, in the range of 5.000 to $50.000\ K$, and has practical applications such as thin film deposition, welding, auto-industrial furnaces, production of metal powders, chemical analysis elements, plasma gasification, among others. (Godoy, 1997).

The aim of this work is to minimize the tar and particulate matter present in the pyrolysis gas using a commercial thermal plasma. For this, we present the design of a venturi system and a collection system of tar and particulate matter.

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2. METHODOLOGY

2.1 Biomass characterization

The biomass used for pyrolysis was a blend between Peroba and Garapeira sawdust obtained at the company Campsul - Wood and Aluminum, located on road Zeferino Vaz, 1752, 115 km, Barão Geraldo district, Campinas, SP. With this biomass, the following analyzes were performed: particle size, proximate analysis, elemental analysis and heating value.

The particle size analysis was performed according to ASTM E828-81.

The proximate analysis was performed to identify the moisture content (ASTM E871-82), volatile matter (ASTM E872-82), ash (E872-82) and fixed carbon, which is determined by dry basis difference.

The elemental analysis (CHN) was obtained using the Perkin Elmer CHN-2400 on a dry basis, with deviation less than or equal to $0.2\ \%$, performed in the Analytical Chemistry Institute of the University of São Paulo.

The heating value was obtained according to ASTM E711-87.

2.2 Collection system of tar and particulate matter

The purpose of installing the collection system of tar and particulate matter is to quantify the amount of tar and particulate matter present in the pyrolysis gas. The method used was adapted from the document CEN/BT/TF-143.

The system operation is given at isokinetic way, ie the velocity of gas collection must have the same gas velocity that exist in the pyrolysis reactor outlet pipe. The pyrolysis gas is collected by a probe nozzle installed in the outlet pipe of the reactor and conducted by an insulated pipe for the collection system (impingers). At this point, condensation occurs inside the impingers which temperature are under the $5\,^{\circ}\mathrm{C}$. This entire system is sucked by a vacuum pump that, after the impingers, is pumped to a flow meter and the gas meter that records data. Finally, the gas is collected into bags suitable for analysis or disposal. The samples are analyzed by the difference between initial and final gravimetric of the whole system: hoses, Ts connections, filters and impingers.

It is necessary that the vacuum pump system provides flow velocity identical to that existing at the outlet of the pyrolysis reactor and, thereby, does not interfere with the flow. For that to be achieved, a manometer was inserted to record the local pressure at the exit of the reactor and another in the gauge line of the isokinetic system. Considering the temperatures at the sample tube and the nozzle equal and the pressure of both equal, the speed of the two flows are equal. To equalize the pressure in the probe with the sample tube, it used an adjustment of a main valve located in the bypass line of a vacuum pump.

Figure 1 presents the collection system of tar and particulate matter as described in the document CEN/BT/TF-143.

2.3 Plama torch

The plasma torch used was Hypertherm T80M commercial model and is represented in Fig. 2. Its arc is started by means of an ignition switch at the rear of the power supply. The working gas used was nitrogen contained in a drum type T of $9.0\ m^3$. The plasma torch was used in mode confined arc, non-transferred with DC current using nitrogen as working gas. It is necessary also a high pressure regulator capable of supplying gas from the power source to a rate of $0.032\ m^3.g^{-1}$ with a pressure of $4.0\ bar$.

The consumables used were from Hypertherm brand, produced with plastic and copper. These supplies were selected for the gouging operation mode, so that the arc is uniformly open, and are diagrammed in Fig. 3.

The Tab. 3 shows the models of consumables utilized.

Table 1. Consumables

Item	Model
Protection nozzle	HT220798
Retention nozzle	HT220854
Nozzle	HT220797
Electrode	HT220845
Gas distributor	PMX 6585-HT220857

2.4 Plasma reforming system

The plasma reforming system is composed with a plasma torch and a Venturi tube that was installed in the outlet pipe of the pyrolysis reactor. Figure 4 shows the venturi dimensions. Figure 5 presents a picture of the Venturi tube in which it is possible to notice the flanges for installation in pipe, neck tube and bracket into which is inserted the plasma torch. Figure 6 shows the electric arc plasma torch into the throat of the Venturi tube.

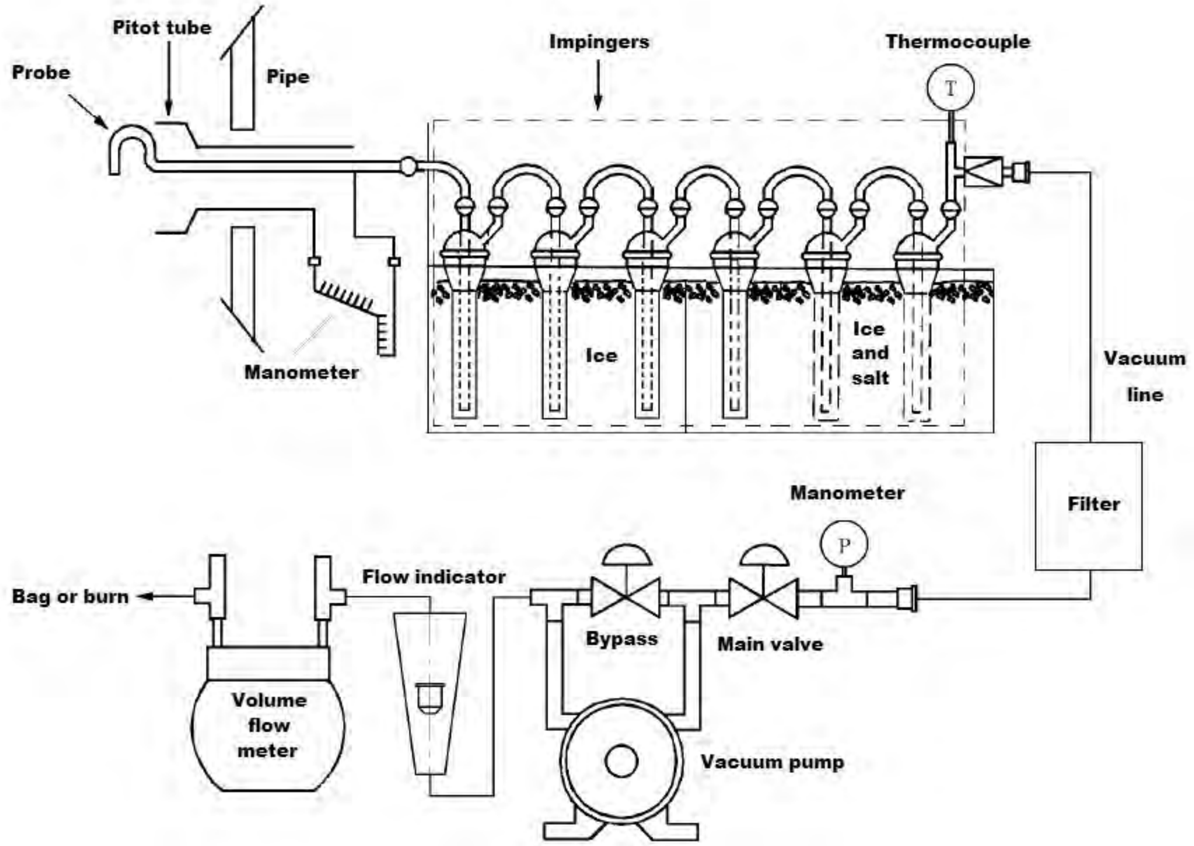

Figure 1. Tar and particulate matter train

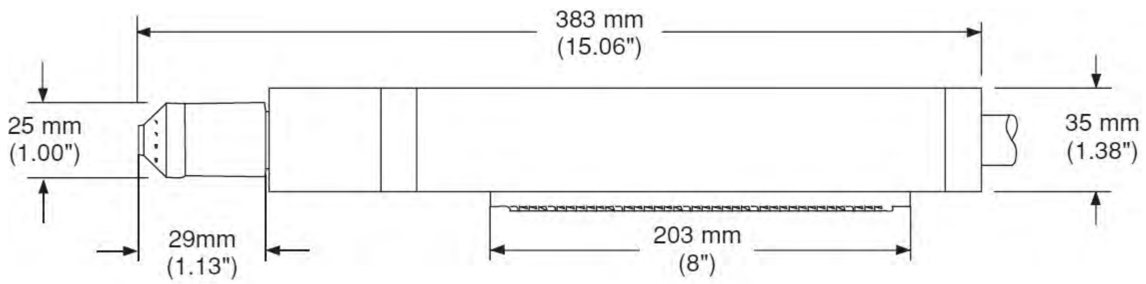

Figure 2. T80M plasma torch dimensions

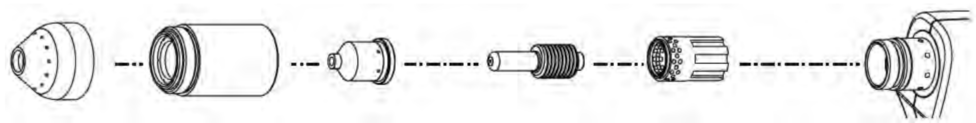

Figure 3. Scheme of installation of consumables for gouging. From left to right: nozzle protection, retention nozzle, nozzle, electrode, gas distributor and nozzle coupling torch

3. RESULTS

The average diameter obtained in the size analysis was $474 \pm 32\ \mu m$ for biomass. The Tab. 2 shows the proximate analysis whereas Tab. 3 presents the elemental analysis. The lower heating value was $16.14 \pm 0.13\ MJ.Nm^{-3}$.

Table 2. Proximate analysis

Moisture ($w.b.$ %)	Fixed carbon ($d.b.$ %)	Volatile matter ($d.b.$ %)	Ash ($d.b.$ %)
11.85 ± 0.23	9.00 ± 0.58	84.05 ± 0.44	6.95 ± 0.90

Figure 7 shows a picture at the time that the pyrolysis gas is within some impingers. Table 4 presents the gravimetric

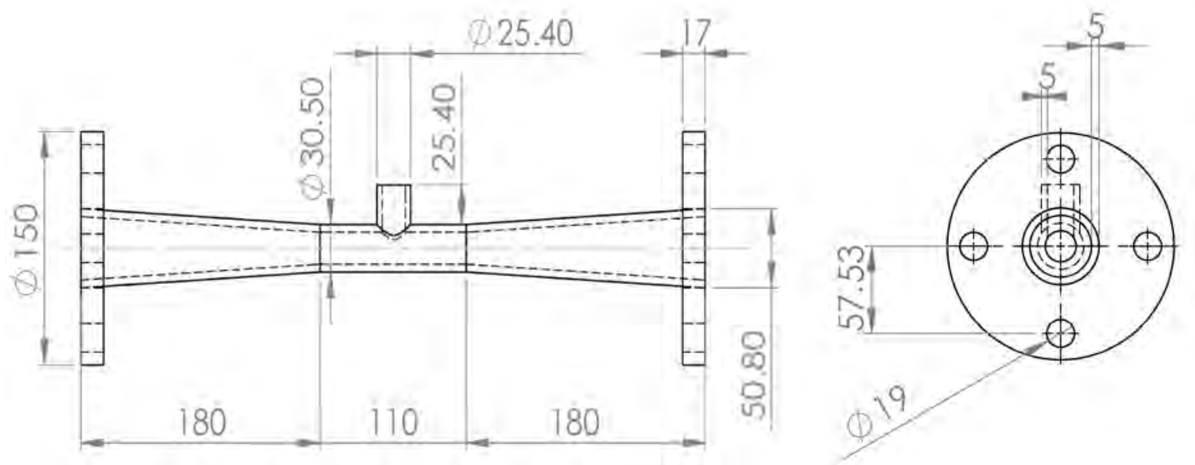

Figure 4. Venturi views and dimensions

Figure 5. Venturi tube

Figure 6. Electric arc working inside the Venturi

tar and particulate conventional pyrolysis and pyrolysis with reforming plasma data.

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Table 3. Ultimate analysis

Element	Value (%)
Carbon	46.9 ± 0.2
Hydrogen	6.0 ± 0.2
Nytrogen	0.3 ± 0.2
Oxygen^i	46.8 ± 0.2

$^{(i)}$ Oxygen by difference considering ashes from proximate analysis

Figure 7. Pyrolysis gas inside the impingers

Table 4. Collection rate of conventional pyrolysis and pyrolysis using thermal plasma

Conventional pyrolysis ($g.s^{-1}$)	Pyrolysis using thermal plasma ($g.s^{-1}$)
$(4.71 \pm 0.30)10^{-3}$	$(2.85 \pm 0.65)10^{-3}$

4. CONCLUSION

The pyrolysis gas reformation system was designed and composed with a Venturi tube and a plasma torch Hypertherm T80M model.

The tar and particulate matter in pyrolysis gas was high. This may be explained by the high content of volatile matter and some operating characteristics of the reactor as, for example, temperature. The tar and particulate matter gravimetric rate present in the pyrolysis gas was analyzed according the document CEN/BT/TF-143. Note that, when held up reform of pyrolysis gas through the plasma torch, the tar and particulate matter were 39.5 % lower when compared the tar and particulate obtained in conventional pyrolysis.

The analysis, design and values obtained in this work show that there is a possibility of working with reform of gas from biomass pyrolysis using thermal plasma.

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6. RESPONSIBILITY NOTICE

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