Utilization of Agriculture Waste as Energy Resource: Rice Husks Gasification

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Abstract: - Agriculture wastes can potentially be used as energy supply on the continuous seeks for renewable energy resources. Such a subject is highly aligned with the idea of merging the current energy policy for a more sustainable one, substituting the fossil base fuels used nowadays. Since agriculture wastes are increasing due to the increase of food production in several countries, the application of such wastes as renewable energy resources can be used in together with gasification technology for syngas production, which can then be applied for power generation. Since rice husks are a surplus in many producing countries, such energy resource could be used for electricity production using combined cycles with gasification plants. This paper presents an investigation using rice husks applied as fuel in a fluidized bubbling bed for syngas generation. Numerical simulations were performed using the software CSFMB (Comprehensive Simulator of Fluidized and Moving Bed Equipment) showing that such waste can generate a good quality gas with high carbon conversion. Simulations predicted the production of a syngas with high heating value as well stable operation for the gasifier itself.

Key-Words: - Biomass, gasification, simulation, fluidized bubbling bed, rice husks, syngas.

1 Introduction

Gasification technology has been developed over the last decades as an additional option for fuel production, as well as chemical substances, at a competitive price when compared with crude-oil based products. Even though such a technology has been extensively investigated and some high-power plants are operating around the world, many unknown variables are yet to be evaluated especially when related to operational conditions. The use of renewable resources, such as agriculture wastes, has become an interesting and important area to be developed. In this case, such wastes can be used as fuel in biomass gasification units for syngas generation, which can then be used for energy (electricity) production. As many countries around the world present high production of rice, the rice husks could then be considered as a potential energy resource, which could become an important part of the country's energy matrix. Even though great developments were performed for coal gasification [1,2] the use of biomasses has gained interest because it represents an important energy resource for being renewable. In this last case, the use of waste biomasses can and should be applied for thermal and fuel gas production as an alternative source of available power to be integrated in many countries' energy matrix. Such use could also mitigate the problem of discharging agriculture wastes and residues to the environment without the proper treatment. Thus, agriculture wastes used in gasification units could generate syngas for electricity production upon using the so-called BIG-GT (Biomass Integrated Gasification-Gas Turbine) [3-9] combined with Rankine Cycle (also called BIG-GT-CC). In this case, the overall cycle's efficiency is higher than in standard equipments using boilers where the waste is simply burned in a furnace for steam generation. Also, gasification units are known to be associated with low CO_2 emissions when compared to combustors.

Investigations regarding gasification units using biomass for gas production that could be applied for electricity generation using a BIG-GT-CC [10], as promising results are a potential and must be carefully considered. Depending on the range of power that the gasification unit should operate a given gasification technology could be applied but is not limited to the technology itself. Simple gasification units such as the ones using moving bed technology could be applied to operate at output powers as high as 2 MWt, which is also suitable for bubbling fluidized bed equipments. Following this

route, gasification units operating on a given output power using bubbling fluidized bed can also find units working with circulating beds. The choice of technology that should be applied is dependent on the designers' experience, as well as the available budget and domain of the knowledge.

Since gasification has been extensively investigated mainly for coal, the use of biomass has found a wide range of applications in order to have a new option for power production. As biomasses usually present lower heating values when compared to coal, the design of the gasification unit must be carefully evaluated so the system can present high efficiencies and availabilities. For this investigation, a mathematical model called CSFMB (Comprehensive Simulator for Fluidized and Moving Bed) was used, which has been extensively validated over the last years [11,12] with remarkable correlation between real and calculated data. Rice husks were considered as fuel for the gasification unit, as this agriculture waste can be found in several countries around the world.

2 Gasification Characteristics

Previous investigation towards the use of rice husk as an energy source for gasification has been done, showing promising results [13]. Since this type of biomass is extensively found in countries in Asia and South America, it becomes a potential and rather important source of renewable energy that shall be considered.

For this specific investigation, a small scale fluidized bubbling bed is considered for the sake of evaluation on the potentiality of using such biomass as an energy resource. From already published investigations, the necessary properties for the rice husk biomass can be summarized on Tables 1 and 2.

Table 1: Proximate analysis for rice husk (mass percentage – wet basis).

Moisture =   9.0800 %
Volatile =   60.3700 %
Fixed carbon =   12.3700 %
Ash =   18.1800 %
High heating value (dry basis) = 15.9 MJ/kg

It must be carefully evaluated the application of rice husks due to its low apparent density, as segregation may occur, which can result on a low efficiency of the gasification process. In this case, the addition of an inert material becomes necessary in order to guarantee a better fluidization and high mixing

values in the bed, towards the achievement of high carbon conversions and better syngas quality.

Table 2. Ultimate analysis for the rice husk (mass percentage – dry basis).

C   = 37.6000 %
H   = 5.4200 %
N   = 0.3800 %
O   = 36.5600 %
S   = 0.0300 %
SiO2 = 20.0100 %

For this specific case, the apparent density of the rice husk is estimated to be around 311.2 kg/m^3 which require the use of an inert in the bed during the operation of the gasifier. Such information shall be considered when operating the gasifier but for the present analysis, only the biomass was considered for the simulations.

3 Gasifier Geometry

The geometric characteristics and the operation parameters for the gasifier are presented by Tables 3 and 4, respectively. Since this is a small scale gasifier, one should be careful when performing the scale up in order to achieve higher output power. It should be noticed that this gasifier operates at atmospheric pressure and uses air as gasification agent. Insulating material has been considered during this investigation, containing a thickness of 5 cm with mean thermal conductivity of 0.26 W/mK.

Table 3. Main geometric characteristics of the gasifier.

Parameter	
Bed diameter (m) / depth (m)	0.255 / 0.225
Reactor diameter (m)/ height (m)	1.775 / 1.745
Number of orifices for gas injection	394
Diameter of orifices for gas injection (m)	7 x 10^{-3}
Position of main gas withdraw (m)	2.0

Table 4. Flow rates and operational conditions.

Parameter	
Carbonaceous feeding rate (kg/s)	0.434 x 10^{-2}
Gas feeding rate (kg/s)	0.502 x 10^{-2}
Temperature of carbonaceous feeding (K)	293.0
Temperature of gas feeding (K)	600.0
Cold efficiency (%)	68.28
Combustion Enthalpy of Cold Gas (MJ/kg)	5.42

For the conceptual design of the gasification unit, the CSFMB software was used as it represents the most reliable tool to simulate fluidized bed equipments available on the market. Several validations have been performed in the past [10,11], which are the baseline for the application of this software on the future designs of gasification units. The version 24.5 has been used with outstanding correlation regarding real equipments.

Exhaustive simulations were performed in order to achieve a unit with high cold efficiency at the output range established by the design requirements, along with optimized injection system in the bed with flutes.

4 Results and Discussion

Following the parameters established for the operation of the gasifier using rice husk, cold efficiency above 50% was achieved as presented on Table 4, even though the injected air was at atmospheric condition.

From the simulation results, mixing index of 100% could be achieved. However, as mentioned before, for such low apparent density, segregation can be an issue for this type of biomass. As low moisture is present in the biomass, along with all the other important properties of the rice husk, carbon conversion above 94% could be achieved, which gives to this biomass an outstanding condition for syngas generation, as presented by Table 5.

Table 5. Gas composition – dry basis.

	MASS PERCENTAGE	MOLAR PERCENTAGE
Ar	0.8720	0.6057
H2	0.3984	5.4842
H2O	0.0000	0.0000
H2S	0.0113	0.0092
NH3	0.1739	0.2833
NO	0.0004	0.0004
NO2	0.0546	0.0330
N2	51.4443	50.9595
N2O	0.0000	0.0000
O2	0.0000	0.0000
SO2	0.0085	0.0037
CO	21.9913	21.7864
CO2	19.5895	12.3515
HCN	0.0004	0.0004
CH4	4.5889	7.9372
C2H4	0.0007	0.0007
C2H6	0.0000	0.0000
C3H6	0.0000	0.0000
C3H8	0.8658	0.5448
C6H6	0.0001	0.0000
Tar	0.0000	0.0000
H-Tar	0.0000	0.0000

The resulting syngas presents high concentration of CH_4 (4.59%), H_2 (0.39%) and CO (21.99%), which represents gives a high quality for this gas. Along with the combustion enthalpy of the cold gas, it means that the generated syngas can be used for electric power production when used as fuel for motogenerator systems.

Figure 1 presents the temperature profiles in the bed, where it shows that the levels achieved are adequate for using standard furnace material (refractory bricks and insulation), which could lead to low cost equipment. Figure 2 presents the superficial velocities calculated during the simulation, showing that at any position in the gasifier, the velocities were above the minimum fluidization required to achieve good conditions for gasification. Such a parameter contributes to obtain high mixing values and, as a result, high gasification efficiencies generating a high quality syngas.
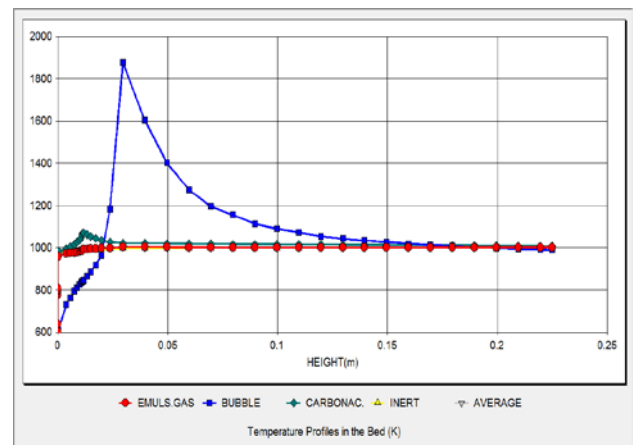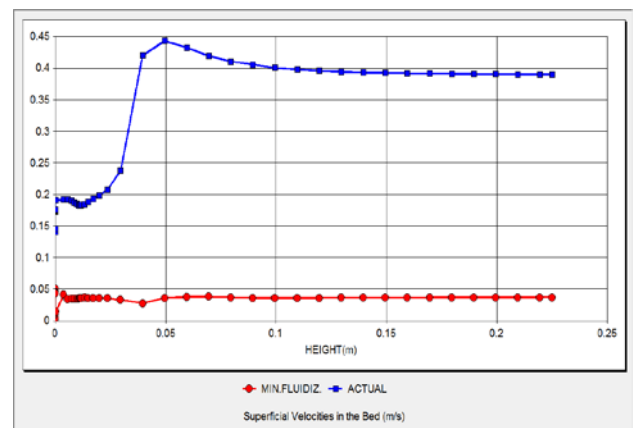

Figure 1. Bed temperatures.

Figure 2. Superficial velocities.

Figure 3 presents the temperature profiles in the freeboard. Apparently, high thermal interaction is

taking place between the gasifier and the environment, as the gas stream is losing heat as it goes up in the freeboard, which contributes to the decrease of its temperature. Such an effect is not considered to be bad as the syngas shall not have to go through a heat exchanger to be cooled down prior to be filtered in order to remove any particle that might damage the motogenerator.
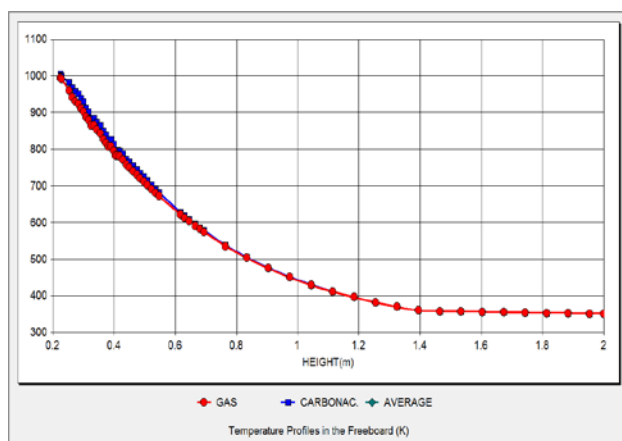

Figure 3. Temperature profiles in the Freeboard.

5 Conclusions

The obtained results show that the use of this type of biomass is promising, which could be used to generate decentralized electricity especially. As a agriculture waste, the producer can use it to generate the syngas and then generate electricity to supply what is needed for the equipments in the property, which can directly impact on the level of work and processing for the agriculture tasks. Therefore, the use of rice husks can potentially improve the work results and gain for small producers. Such results and potentials could then be used to promote new policies for small producers as well as new approaches for non-distributed electricity.

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