GASIFICATION OF CORN STOVER

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Biomass gasification has been seen to be especially relevant conversion technologies for dispersed power/energy production, particularly in small and medium capacities. In the present study, it has been developed a model for the gasification process in down draft gasifiers, which can be applied for a corn stover with different relative humidity contents. The model has been used especially to design an experimental gasifier for chopped corn stover, regime control and for indirect estimation of the biomass average humidity. The model is also a very useful tool in learning about gasification processes.

Keyword: gasification, cornstover, humidity, concentration, LCV

1. Introduction

Biomass is considered the renewable energy source with the highest potential to contribute to the energy needs of modern society for both the developed, and developing economies world-wide. Energy from biomass based on annual cultivation energy crops: corn, swichgrass, can significantly contribute to the accomplishment of the Kyoto Protocol objectives in reducing the greenhouse gas emissions and coping with climate change issues.

Further on, we are offering a comparative study of the energy renewable resources that emphasize the advantages and disadvantages of using energy crops.

Table 1

Some of the Features of Different Renewable Energy Sources

	Wind	**Solar**	**Dedicated Energy Crop**	**Landfill Gas**
The Environment				
Is this a renewable energy source?	Yes	Yes	Yes	No
Does this produce a new source of oxygen?	No	No	Yes	No
Does this source use/absorb carbon dioxide?	No	No	Yes	No
Dependability				
Is this a 24 hour year round source of electricity?	No	No	Yes	No

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	Wind	**Solar**	**Dedicated Energy Crop**	**Landfill Gas**
Cost				
Is electricity from this source cost competitive?	Yes	No	Yes	Yes
Aesthetics				
Is this source of electricity pleasing to the eye?	No	Yes	Yes	No
Wildlife Friendly				
Is this source dangerous to birds?	Yes	No	No	No
Does this source promote wildlife habitat?	No	No	Yes	No
Does this source offer food and shelter to wildlife?	No	No	Yes	No
Soil Conservation				
Does this source promote soil conservation?	No	No	Yes	No
Does this source prevent soil erosion?	No	No	Yes	No
Can this process help reduce water runoff?	No	No	Yes	No
Can this process prevent excess nutrient runoff?	No	No	Yes	No
Jobs				
Does this source create new jobs in the area?	Limited	limited	Yes	Limited
Does this source create farm jobs?	No	No	Yes	No
Does this source promote rural economic development?	No	No	Yes	No
Other Uses				
Can this source be used to make ethanol?	No	No	Yes	No
Can this source be used to make paper?	No	No	Yes	No
Can this source be used to dispose of wastewater?	No	No	Yes	No
Can this source be used to dispose of sludge?	No	No	Yes	No

Corn, intensively cultivated, as energy source has proven itself as economically profitable. With an average crop of 10 tons per hectare of grain corn, one can obtain a Collected Biomass Energy of 160 GJ/ha for shelled corn and another 140 Gj/ha for corn stover. For production it requires about 20-25 GJ/ha to grow. It results a ratio output energy /input energy of 6.4/1 for the shelled corn and of 12/1 for the whole biomass obtained from the crop – shelled corn+corn stover. The complete utilization of the corn stover for the energy generation proves the energy corn crop to be very competitive, especially on the small capacities market, adjacent to the production area, that do not necessitate high transport expenditures.

Biomass – corn stover can be converted to energy via thermal, biological and physical processes. While a number of conversion technologies are available for various biomass materials, biomass gasification has been seen as especially relevant for dispersed power/energy production, particularly in small and medium capacities. Gasification is the conversion of solid carbonaceous fuel into combustible gas by partial combustion. The mixture of gas thus produced is called producer gas.

In view of a more efficient conversion of biomass energy in thermal and electrical energy, the optimization of gasification processes and gasifiers is necessary. For this purpose, the prediction of the gas generator performances for various biomass composition and humidity, most important factors in gasification processes, with a global model for biomass gasification in downdraft stratified gasifier, it is required [1,3,4,6,8,10,11,13].

2. Modelling the corn stover biomass gasification process

In this study the authors have developed a general model of the biomass gasification process in a downdraft gasifier and stratified down-draft gasifier that has the following exit characteristics: the gas structure (component concentrations %), energy conversion efficiency η_{conv}, low calorific value of producer gas LCV (MJ/Nm^3), reduction zone temperature T_r (K), relative gas flow F_{sg} (Nm^3/kg. biomass), relative air flow F_{air} (Nm^3 air/Nm^3 gas), using a typical chemical formula of carbonaceus biomass, based on a single carbon atom CH_xO_y, with the relative humidity u_{bm} and ash content k_{as} [1, 3, 4, 10, 11].

Within the model, the team has chosen as an independent variable Fair (Nm^3air/Nm^3gas). Because the model is conceived to be used also for the automatical control of a gasifier, Fair is the real fulfilment measure in the regulation circuit of the gasification regime that can be measured precisely enough in real exploitation circumstances.

The most frequent chemical formula resulted in the modelling and simulation processes of the corn stover biomass gasification was $CH_{1.25}O_{0.61}$ [5, 14, 15]. In fact, the corn stover component concentration varies depending on: sort, crop field, meteorological conditions, rainfall level and irrigation level. Thus, it was established that the corn stover composition has huge variations:Glucan: 35...59%; Xylan 20...25%; Lignin 11...19%;Ash 2.5...15% [15]. These variations are reflected in the chemical formula CH_xO_y type, utilized in the gasification process model. The simulation program was structured in such manner to allow an easy modification of the chemical formula taking into account the utilized biomass.

The model of the biomass gasification process resembles to the models presented in [1, 3, 10, 13] using a model of global gasification reaction, material balances for carbon, hydrogen and oxygen and heat balance for gasification process assured to be adiabatic.

The formula of the general heat balance needs the value of the biomass formation heat H_{fBM} (MJ/kmol). To calculate this value, one can use the heat balance formula for stoichiometric combustion process of biomass formula type

CH_xO_y [3]. For more precision biomass formation heat for corn stover was computed with three different models [10], with probability corrections, resulting for the average a value of H_{fCS} = -12.267 MJ/kmol, number that fits into the experimentally established domain [8].

The simulation program was constructed in the simulation environment for dynamic systems MEDSIMFP10, conceived and developed in free licence programming language FreePascal 2.1.4 at the Biotechnical Systems Department within the University "Politehnica" of Bucharest.

3. Model simulation results

Figure 1 presents the corn stover biomass gasification process simulation results, depending on the relative air flow F_{air}, for the variation of reduction temperature T_r, low calorific value LCV and yield of energy conversion η_{conv} for relative biomass humidity u_{bm} 10…30 % and relative air flow F_{air}.

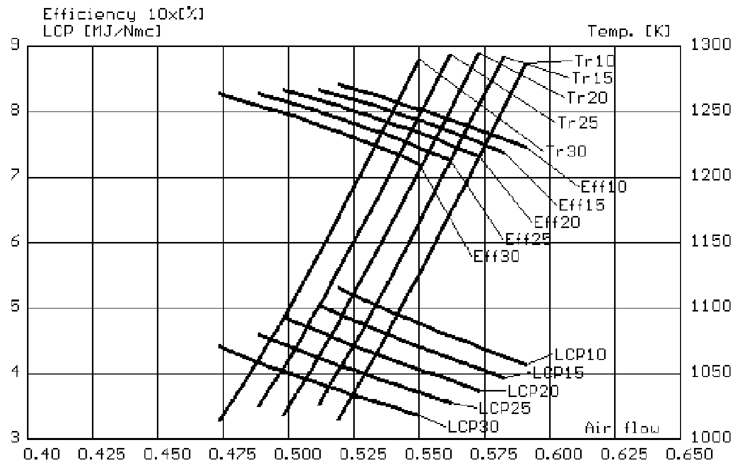

Figure 1. Gasification processes for different average corn stover relative humidity

It was found that from the corn stover gasification with an average humidity of 15% at a reduction temperature Tr = 850ºC, to avoid the high content of alkali ash vitrifying, results a gas with a low calorific value LCV = 4.7 MJ/Nm^3 comparable with the experimental data [ ], and with the ones from the wood gasification with 20% humidity. The gasification process is stable and efficient in a narrow field of the air flow, close to the value F_{air} = 0.525 Nm^3/kg, that requires the implementation of an automatical control to maintain the stability and the energy optimization. In the stability area of the gasification process it was found a high conversion efficiency situated around a value of 80%.

Figure 2 presents the corn stover biomass gasification process simulation results, with an average biomass humidity u_{bm} = 15 % taking into account the relative air flow F_{air}. Graphs are presented for the variation of component dry gas concentration: H_2, CO, CO_2 and CH_4, LCV, energy conversion efficiency η_{conv} and the specific gas flow F_{sg} (Nm^3gas/kg.biomass).

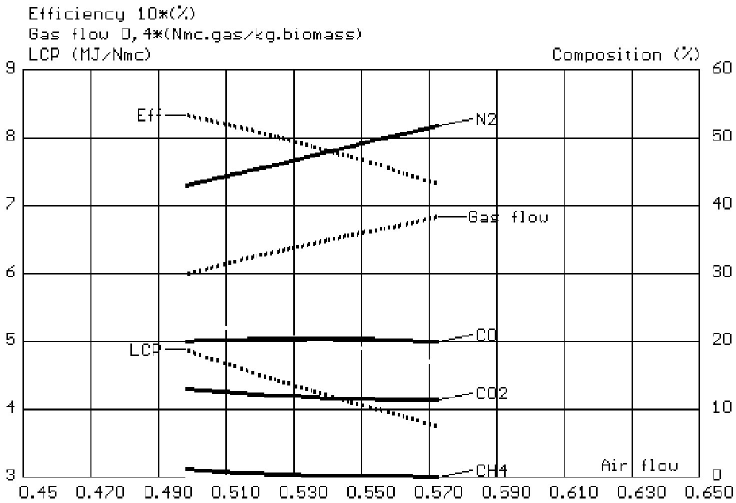

Figure 2. Gasification processes for corn stover humidity u_{bm} = 15%

4. Conclusions

It has been developed a global model for the gasification process in down draft gasifiers, of corn stover biomass materials with different relative humidity contents, model and simulation program verified with specific experimental data.

The developed static model for biomass gasification can be used also for corn stover biomass with a varied composition depending upon the sort, crop field, meteorological circumstances, and rainfall and irrigation levels.

The model was conceived to obtain a compact simulation program, with a very short running period, to be utilizable in the predictive and optimal automatical management in just in time of a gasifier.

The developed model structure allows its use in just in time identification procedures of the real characteristics of the gasified biomass, data that are necessary for the predictive and optimal exploitation of the gasifier.

With the simulation programme, optimal operation regimes have been established for:

- Thermal energy generation;
- Mechanical and electric energy generation;
- Co-generation of electrical and thermal energy.

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