Thermochemical Gasification of Agricultural Residues for Energetic Use

Uzuneanu Krisztina, Ion V.Ion

Thermochemical Gasification of Agricultural Residues for Energetic Use: *In this paper we present the possible energetic use of agricultural residues. The best method consists in the previous gasification of agricultural residues and then the supplying with syngas of a technological steam boiler. We will obtain two certain advantages: the decrease of energetic costs for the producing oil process and the decrease of the environmental impact proper to those processes.*

Key words: *Agricultural residues, Thermochemical gasification, Gasification reactor, Syngas.*

INTRODUCTION

Agro and food industries and wood industry generate large amount of lingo-cellulose waste, with a good energetic potential. Those amounts of wastes are included in the meaning of biomass. The base process for those industries are energy consumers, and the energy costs is found in the final products costs. The decrease of production costs represents the first argument for the energetic use of biomass even in the process where biomass is produced.

The second argument is based on environmental protection. It is obvious that biomass resulted from different industries and energetic unused, must stored and neutralized, so that its environmental impact to be minimum. This aspect raises great problems that lead to the biomass combustion for energetic use. More, the energetic use of biomass is included in the frame methods for the decrease of Green House Effect for the whole world, by reducing the CO_2 emissions from the fossil fuels. This relies on the fact that quantity of CO_2 produced by the biomass combustion is the equivalent necessary for the plants regeneration. We talk about the so-called short cycle of carbon, the produced energy from biomass being considerate as renewable energy.

AGRICULTURAL RESIDUES GASIFICATION

Agricultural residues, as a source of renewable energy which has sustainable and mitigating global warming characteristics is getting greater attention. The thermochemical gasification is one of the effective methods for obtaining energy from biomass [1].

Gasification of solid biomass converts it to gas often referred to as producer gas or syngas which is mainly composed of CO, CO_2, CH_4, H_2 and N_2 (if the gasification agent is air). The useful gas or combustible gas components are CO, CH_4 and H_2 [2]. Stoichiometric combustion occurs when all the carbon in the fuel is converted to CO_2 and there is no excess O_2 left over. The basis of gasification is to supply less oxidant than would be required for stoichiometric combustion of a solid fuel. The energy value of the useful gas is typically 75% of the chemical heating value of the original solid fuel. The syngas temperature will be substantially higher than the original solid fuel due to the gasification process [3].

The energetic use of biomass supposes its combustion, so that the produced heat is used to generate hot water, technological steam or energetic steam. The simplest method to use the biomass is to burn it directly into the steam boiler burner. This method raises great problems, because of the high temperature in the furnace (approximately 1400^0 C) determines the melt of fly ash, this can contain alkalis with low melting point. In contact with the cold surfaces, the melted ash drops solidifies and form an insulator layer on the heat exchanging surfaces. Practical at 2-3 weeks the boiler has to be stopped and cleaned of these sediments.

The method of biomass used by previous gasification eliminates these problems [1], [4].

Gasification is a thermal-chemical process which converts solid biomass feedstock into a mixture of combustible gases, called syngas, and the ash is separated and eliminated from the energetic cycle. The clean syngas supplies the boiler burners for energetic biomass recovery.

Gasification takes place into a closed chamber called gasification reactor, at a pressure close to the atmospheric one.

Basely the gasification supposes the biomass introduction into reactor with an air ratio lower than the stoichiometric one. The heat necessary for the gasification is generated by partial combustion of biomass.

Generally speaking, in any gasification reactor can be identified the following four zones, that contribute to the biomass convert into synthetic gas (syngas) (Fig.1).

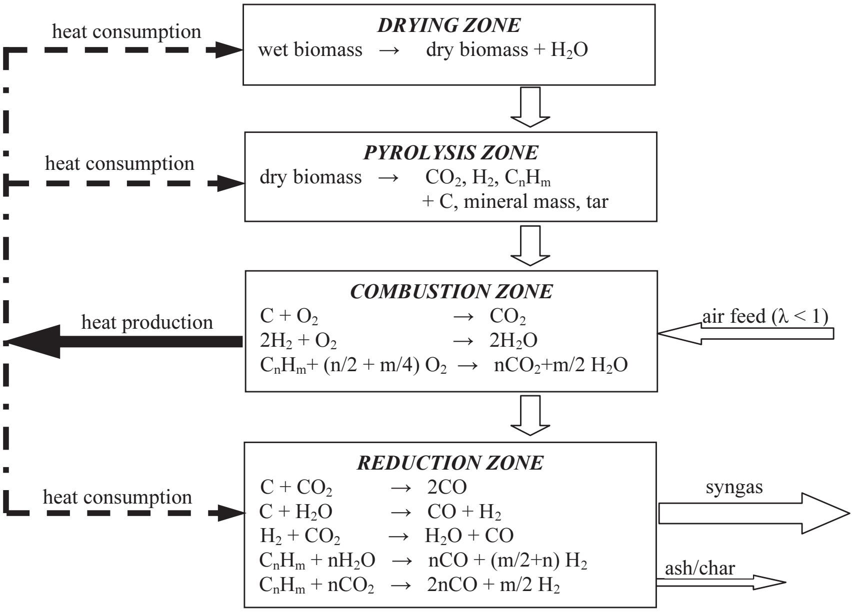

Fig.1. Biomass gasification zones

1. Drying zone – wet biomass is heated, water being removed and converted into steam. Biomass consists of moisture ranging from 5 to 35%. During the drying the chemical composition of biomass is not changing.
2. Pyrolysis zone – dry biomass is thermal decomposed in the absence of oxygen. Pyrolysis involves the separation of the solid products with high containing of carbon, mineral mass and tar, from the gaseous products containing CO_2, H_2 and light hydrocarbons type C_nH_m, these proportion being influenced by chemical composition of biomass. We must mention that no matter how gasifier is built, there will be always a high temperature zone and oxygen absence, where pyrolysis takes place.
3. Combustion zone – the oxidation reactions of C, H and C_nH_m take place with result of CO_2, H_2O.

$$C + O_2 \rightarrow CO_2 \quad (1)$$

$$2H_2 + O_2 \rightarrow 2H_2O \quad (2)$$

$$C_nH_m + (n/2 + m/4)\, O_2 \rightarrow nCO_2 + m/2\, H_2O \quad (3)$$

This zone of combustion represents the zone where the heat is produced in the reactor, heat necessary to the syngas generation.

4. Reduction zone – is the zone where a part of CO_2, H_2O, C_nH_m, in the absence of O_2 converts into CO and H_2.

$$C + CO_2 \rightarrow 2CO \quad (4)$$
$$C + H_2O \rightarrow CO + H_2$$
$$H_2 + CO_2 \rightarrow H_2O + CO$$
$$C_nH_m + nH_2O \rightarrow nCO + (m/2+n)\ H_2 \quad (5)$$
$$C_nH_m + nCO_2 \rightarrow 2nCO + m/2\ H_2 \quad (6)$$

In this zone a number of chemical reaction takes place. These reactions need over 700 ^{0}C temperature.

The resulted syngas has the following composition:

CO → 17…28 %
CO_2 → 8…12 %
CH_4 → 1.5…5 %
C_2H_4 → 1…2 %
H_2 → 11…17%
H_2O → 8…15%
N_2 → 45 … 55 %
NH_3 → 0.1 … 0.3 %

This composition is variable with the air ratio and the composition and moisture of biomass. Syngas can have the low caloric value of 4.0…6.0 MJ/m^3_N.

Splitting of the gasifier into the 4-th zones is theoretically. The biomass particles are involved in the process described successively or simultaneous, function of material flow organization into reactor and function of the physical and chemical characteristic of biomass.

Actually, the gasification efficiency depends on the optimum circulation organization inside the reactor, so that all the biomass particles pass the presented zones.

Very important is the air ratio in reactor. Although gasification means incomplete combustion of biomass due to sub-unit air ratio, this ratio cannot be decreased too much. First, it is necessary a minimum quantity of air so that the process in the combustion zone could take place and could deliver sufficient heat to maintain the temperature over the minimum limit (>700^0 C).

Secondly, if the air ratio is too high, the products percents for incomplete combustion decrease, the low caloric power of the syngas and the gasification efficiency decrease too. The optimum air ratio is experimentaly established and it is specific to the reactor type and to the characteristics of the used biomass.

The energetic analysis on such an installation must establish the condition to control the air ratio so that the efficiency of biomass energetic use to be maximum. This means insignificant quantities of carbon eliminated with the ash and a good insulation of the installation compounds.

In the future is necessary to study some problems that will lead to increase the energetic efficiency of gasification and the improvement of environmental problems [5], [6]:

- recycling of fluidized bed improvement so that unburnt carbon from ash to be totally eliminated.
- decreasing of temperature in the gasification reactor, introducing some catalysers capable to sustain reduction processes at lower temperature
- preheating of the air before reactor in order to increase gasification efficiency.

EXPERIMENTAL PROCEDURE

The biomass materials used in this experiment were briquettes made from agricultural residues. The agent gasification used was air. All experiments were carried out at ambient temperature and at a pressure of 1 bar.

Table 1. Fuel properties

Fuel sample	Reed briquettes	Sawdust briquettes	Sawdust 50%+ corn stalk 50% briquettes	Sawdust 50%+ wheat straw 50% briquettes
Ultimate analysis (% of dry fuel with ash)				
C	52.4	53.3	49.41	50.63
H	5.91	6.28	5.90	6.12
N	0.65	1.91	0.43	0.53
O	33.55	35.75	40.73	38.08
A	7.85	2.77	3.54	4.64
Proximate analysis (% of wet fuel)				
Fixed Carbon	29	24.85	22.60	20.30
Volatile matter	56.70	66.55	67.40	70.10
Ash	7.30	2.60	3.30	4.40
Moisture	7	6	6.70	5.20

The gasification process consists of drying, pyrolysis or devolatilization, combustion or oxidation and gasification or reduction [7]. These processes are largely dependent on the parent biomass composition, moisture content, local stoichiometry, reactivity of agricultural residues and the gasifier design [2].

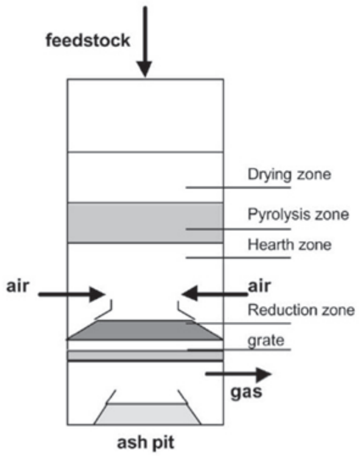

Fig.1. The downdraft fixed bed gasifier [2]

The choice of gasifier type depends on the type of fuel to be gasified and end use of the gas produced. In a downdraft fixed bed gasifier, the biomass is fed in from the top, the gasifying agent is introduced at the sides above the grate and the producer gas is withdrawn under the grate Fixed bed reactors are relatively simpler, reliable, amenable to gasify different kinds of feedstock, other lower particulate concentration in product gases, and can achieve higher efficiencies than other reactors [8].

CONCLUSIONS AND FUTURE WORK

The method of biomass gasification inside a gasifier with circulating fluidized bed ensures an energetic efficiency of 92…96%. For example, on the technological processes of oil producing, the energetic recovery of husks by gasification ensures an economy of natural gases up to 60%, with relative low costs of investment and exploitation.

We also remark that using the biomass by gasification reduces the environmental impact both by their elimination and by decrease of emissions in atmosphere comparative with direct combustion method. The NO_x emissions will also decrease because in the gasifier and in the steam boiler furnace the temperatures are maintained at lower values than using natural gases for technological steam producing.

In the future is necessary to study some problems that will lead to increase of the energetic efficiency of gasification and the improvement of environmental problems.

REFERENCES

[1] Baratieri, M., Baggio, P., Fiori, L., Grigiante, M., Biomass as an energy source: Thermodynamic constraints on the performance of the conversion process, *Bioresource Technology*, Vol. 99, 2008, pp. 7063–7073.

[2] Belgiorno, V., De Feo, G., Della Rocca, C, Napoli, R.M.A., Energy from gasification of solid wastes, *Waste Management,* Vol. 23, 2003, pp. 1-15.

[3] Boerrigter, H., van der Drift, A., Biosyngas. Energy research Centre of the Netherlands (ECN), Petten, The Netherlands, report C--04-112, December 2004, 29 pp.

[4] Knoef**,** H.A.M., Gasification of Biomass & Waste – Practical Experience**,** In: Procedings of International Slovak Biomass Forum, February 3 rd -4 th, 2003, pg. 41, Bratislava.

[5] Milne, T.A., Evans, R.J., Abatzoglou, N., Biomass Gasifier “Tars”: Their Nature, Formation, and Conversion. Report of National Renewable Energy Laboratory (NREL), November 2010, Colorado USA.

[6] Plis, P., Wilk. R.K., Theoretical and experimental investigation of biomass gassification process in a fixed bed gasifier, *Energy*, Vol. 36, 2011, pp. 3838-3845.

[7] Wang, Y., Yoshikawa, K., Namioka, T., Hashimoto, Y., Performance optimization of two-staged gasification system for woody biomass, *Fuel Processing Technology*, Vol. 88, 2007, pp. 243–250.

[8] Wolters, C., Kanaar, M. and Kiel, J. Co-gasification of biomass in the 250 Mwe IGCC plant “Willem-Alexander Centrale”, Biomass Gasification workshop, Second World Conference and Technology Exhibition, Biomass for Energy, Industry and Climate Protection, May 10-14, Rome Italy, 2004.

About the authors:

Assoc. Prof. Krisztina Uzuneanu, PhD, Assoc. Prof. Ion V. Ion, PhD, Department of Thermal Systems and Environmental Engineering, *“Dunărea de Jos”* University of Galaţi, Phone: *+40 336 130208, E-mail: kuzuneanu@ugal.ro, iion@ugal.ro*

This paper has been reviewed.