The Production of a Fuel Gas with High Content of Hydrogen through Biomass Gasification

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An installation of biomass gasification in fixed bed and downstream circulation was realized to obtain a fuel gas with high content of hydrogen. A particularity of this gasifier is considered to blow in the gasification agent in the middle of the gasifier hight, the reduction zone is situated beneath the oxidation zone. In this way the biomass humidity and all the products of dry distillation are cracked passing through the oxidation zone. The obtained gases pass through the reduction zone where take place the basis reactions of the gasification. The gas produced in this way does not contain volatile substances, only a small quantity of water and solid particles easy to be released. As raw material were used agricultural wastes (pellets of sunflower waste). As gasification agents were used steam and air. To have a higher content of hydrogen in the obtained gasifier gas was introduced in the gasification reactor an air rich in oxygen. For a certain content of oxygen in the air used as gasification agent is recorded the composition of the gasifier gas and is followed the hydrogen content. The realized experiments have as purpose repeated tests, in such number to obtain concluding data for the efficiency in obtaining a gasifier gas rich in hydrogen, for a long period of time. There are also presented the results from the experiments (3-5 experiments for each composition of the gasification agent).

Keywords: biomass gasification, hydrogen, renewable technologies

The gasification is the partial oxidation of the organic mass of a material in the aim of its transformation into fuel gases.

The process consists in passing over a solid fuel of a gasification agent that may be air rich in oxygen or steam. The gasification process is composed by sub processes that take place in the gasifier:

- drying - the raw material has a humidity of 5-35%. At a temperature over 100°C, the water is released and is transformed in steam. During the drying process the solid fuel do not suffer any transformation.

- pyrolysis - take place at a temperature of 200-230°C and consist in thermal transformation of the solid fuel. The pyrolysis gas contains tars, polycyclic aromatic hydrocarbons, methane, steam and carbon dioxide. The solid waste contains ash and coke.

- oxidation - the coke resulted from pyrolysis reacts with a controlled quantity of gasification agents like air and steam. The coke is decomposed in gases as carbon monoxide, carbon dioxide and hydrogen. These reactions take place at 700-1100°C.

- reduction - in this process takes place chemical reactions in absence of air at high temperature (800-1100°C). The gases resulted are carbon monoxide, hydrogen, carbon dioxide, methane. The solid waste is represented by ash.

A biomass gasifier converts solid fuel such as wood waste and agro-residues into a gaseous fuel through a thermo-chemical process and the resultant gas can be used for heat and power generation applications. The overall thermal efficiency of this process is more than 75%. The combustible gas mixture, known as "producer gas", typically contains carbon monoxide (20 - 22%), hydrogen (12 - 15%), nitrogen (50 - 54%), carbon dioxide (9 - 11%) and methane (2 - 3%). The produced gas has relatively low calorific value, ranging from 1000 to 1100 kcal/Nm^3 (5500 MJ/Nm^3).

Table 1
THE REACTIONS THAT TAKE PLACE AT GASIFICATION AND THE THERMAL EFFECT OF THESE REACTIONS

No.	Reaction	The reaction enthalpy, ΔH_{298}, (kJ/mol)
1.	$C + O_2 \Leftrightarrow CO_2$	-394,9
2.	$2C + O_2 \Leftrightarrow 2CO$	-219,1
3.	$C + H_2O \Leftrightarrow CO + H_2$	+132,8
4.	$C + 2H_2O \Leftrightarrow CO_2 + 2H_2$	+89,7
5.	$C + CO_2 \Leftrightarrow 2CO$	+175,8
6.	$C + 2H_2 \Leftrightarrow CH_4$	-87,4
7.	$2CO + O_2 \Leftrightarrow 2CO_2$	-570,7
8.	$CO + H_2O \Leftrightarrow CO_2 + H_2$	-43,0
9.	$CO + 3H_2 \Leftrightarrow CH_4 + H_2O$	-208,7
10.	$2CO + 2H_2 \Leftrightarrow CH_4 + CO_2$	-247,2
11.	$2H_2 + O_2 \Leftrightarrow 2H_2O$	-484,6
12.	$CH_4 + 2O_2 \Leftrightarrow CO_2 + 2H_2$	-803,5

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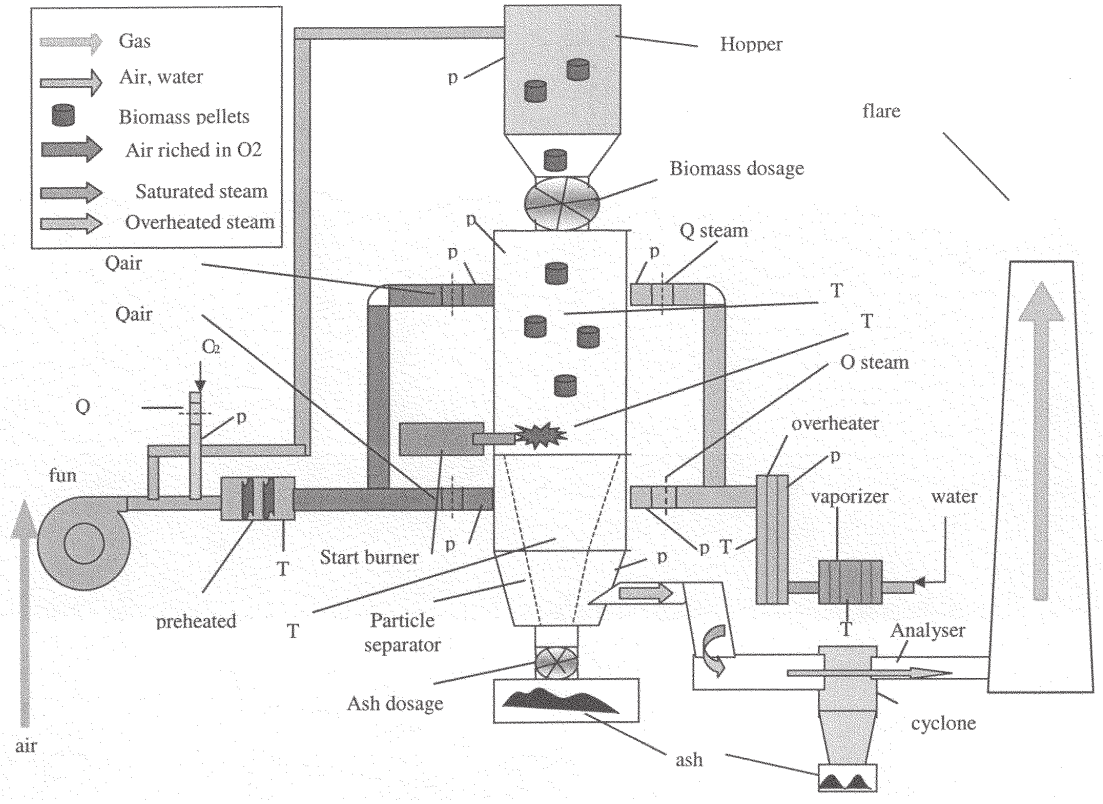

Fig 1. Experimental installation of biomass gasification

Experimental part

The gasification plant has the following components: biomass dosage and feeding system; gasification reactor operational; oxygen/steam distributor; gas-solid separator; ash evacuation system; steam feeder; oxygen feeder; thermal insulation; start burner; TESTO gas analyser; data acquisition system.

In figure 1 is presented the technological diagram of the biomass gasification experimental installation.

For the performing of the gasification tests the pellets of sunflower waste are is used as biomass. In table 2 is characterized this type of biomass.

The gasification tests were performed in the following conditions:

- feed stock: agricultural biomass pellets with diameter of 10 - 20 mm;

-biomass medium capacity: 25 kg/h;

-gasification agent: steam and air enriched in oxygen. Tests were performed with air gasification agent and air enriched in oxygen, 30 and 50% oxygen.

-overheated steam capacity: 3 kg/h;

- air capacity respectively air enriched in oxygen: 33 Nm^3/h;

- preheated air maximum temperature: 350°C;

- gasification temperature: 800 - 900°C;

-working pressure: atmospheric

The gasifier gas was drawn and analyzed every 30 min along one experiment.

Results and discussions

The experiments aimed to establish the functioning conditions of the gasification reactor and to determine the influence of the gasification agent composition on the quality of the produced gas. The increase of the oxygen content in the gasification agent leads to the increase of the compounds content that gives heating value to the produced raw gas: $CO + H_2 + CH_4$.

Table 2
THE TECHNICAL AND ELEMENTARY ANALYSIS OF THE PELLETS USED IN THE GASIFICATION EXPERIMENTS

No.	Constituent	Symbol	Unit	Value
1	Moisture	Wi	% gr.	16,86
2	Ash	Ai	% gr.	1,95
3	Carbon	Ci	% gr.	41,80
4	Hydrogen	Hi	% gr.	4,70
5	Nitrogen	Ni	% gr.	0,83
6	Oxygen	Oi	% gr.	33,86
7	Sulphur	Si	% gr.	urme
8	Higher heating value	Qis	kcal/kg	3752
			kJ/kg	33,29
9	Cellulose	-	%	15,76
10	Hemicelluloses	-	%	14,04
11	Lignin	-	%	15,61
12	Total pentosans	-	%	0,81
13	Resins	-	%	1,68
14	Proteins	-	%	16,86

Table 3
EXPERIMENT RESULTS FOR THE DIFFERENT GASIFICATION AGENT COMPOSITION

biomass	Gasification agent composition	No.	CO_2	CO	CH_4	H_2	N_2	O_2	Gas density (kg/m^3)	Heating value (Kcal/m^3)	Productivity (Kg gas/kg pellets)	Productivity (m^3 gas/kg pellets)
Sunflower waste pellets	Air + 30% O_2	1	18,20	26,00	2,10	32,50	20,50	0,70	0,993	1641	1,673	1,685
		2	17,80	25,60	2,20	32,90	20,7	0,8	0,985	1650	1,685	1,711
		3	18,20	26,10	2,0	31,80	21,3	0,6	1,002	1612	1,687	1,690
		4	18,50	26,40	2,0	31,50	21,0	0,60	1,007	1614	1,677	1,665
		5	18,30	25,90	2,3	33,10	19,6	0,8	0,986	1669	1,655	1,679
	Air + 50% O_2	1	18,90	29,20	2,40	38,50	10,40	0,60	0,926	1897	1,431	1,545
		2	19,20	29,80	1,90	39,20	9,4	0,5	0,923	1887	1,415	1,533
		3	18,90	29,30	2,50	38,40	10,3	0,6	0,927	1905	1,427	1,539
		4	19,10	28,20	2,70	37,90	11,4	0,7	0,933	1863	1,456	1,561
		5	18,40	29,50	2,50	38,50	10,5	0,6	0,922	1913	1,548	1,428

Conclusions

The tests performed at laboratory plant for agricultural biomass gasification, have proved the feasibility of the adopted technical solutions referring to the used equipment and materials.

In order to increase the content of hydrogen in the produced gas, it is necessary to use as gasification agent the air enriched in oxygen or the oxygen itself. Also, the content of nitrogen that is an inert gas is decreased.

The results regarding the raw gasifier gas content in useful components, hydrogen and carbon monoxide, are reproducible and comparable.

The synthesis gas ($CO+H_2$) has a better value in the produced gas, so the heating value is higher than the cases in which the content of O_2 is smaller.

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