Biomass gasification on a new really tar free downdraft gasifier

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Abstract

One of the major obstacles for the application of biomass gasification systems is the high tar content of the producer gas that prevents the use in engines, turbines or fuel cells without further gas cleaning. In this work, features of a novel tar free gasifier are described. Producer gas, containing 2 mg/Nm^3 of tar and dust was obtained. This gas can be used directly to fuel cycle Otto engines to produce electricity and heat. Biomass was converted in producer gas with up to 78% efficiency. Typically from 1.3 kg of woody biomass in dry base, 1 kWh$_e$ and up to 2 kWh$_t$ can be obtained. Operations and maintenance are very simple and can be carried out by non-skilled operators.

Key-Words

Biomass. Gasification. Tar.

Introduction

Biomass is a fuel of increasing interest in power generation since its conversion to energy results in a lower emission of pollutants and it is renewable.

Wood gasification to fuel commercial engines is considered to be one of the most promising techniques for an efficient production of electricity from biomass at a small or medium scale (REED; DAS, 1994; REED;GRABOSKI; LEVIE, 1994). Unfortunately most of gasifiers produce wood gas, incompatible with engine manufacturers specifications (less than 10 mg/Nm^3 tars and chars), so a very expensive and no profitable purification is needed.

In the present paper, features of a novel tar free gasifier are described. The producer gas, containing 2 - 10 mg/Nm^3 of tar and dust, can be used to fuel cycle Otto engines to produce electricity and heat. Operations and maintenance are very simple and can be carried out by non-skilled operators.

The Gas Producer

The gasifier and the gas filtration system are shown in figure 1.

The gas producer unit is constituted of two cylindrical coaxial metallic structures. The section where the actual wood gasifying process occurs is made of a high temperature and chemical corrosion proof steel in order to resist the compounds developing during the process.

The biomass, preferably blocks, is introduced at the top by a hatch equipped with a security loch.

Coming down, the biomass passes through a drying zone, a pyrolysis zone and then gets into the core of the gasifier. Here the fuel meets an air stream, introduced by wall tuyeres opportunely oriented.

In this zone the gasification process is carried out at high temperatures in order to assure the cracking of any possible tarry residue. The gases are drawn off from the bottom and flow upward in the interspaces between the two coaxial structures. The external one is coated by an insulating material, while the internal is provided with additional exchange surfaces to improve the energetic balance of the gasification reaction and to reach the above mentioned temperatures (figure 2).

Figure 1 - Gasifier and gas filtration system

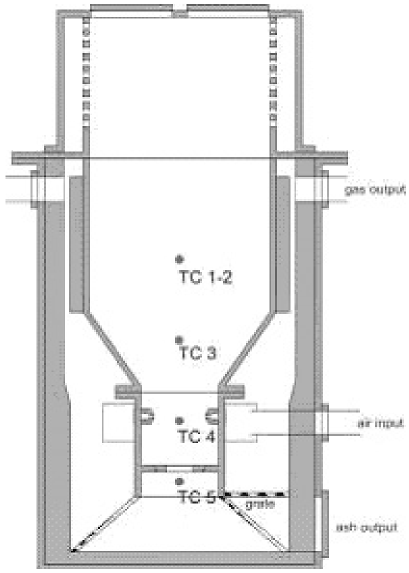

Figure 2 - Scheme of the gasifier

For the achievement of the temperature uniformity trough the whole reaction zone, a necessary condition for the full cracking of tars, cold points should be avoided. This is obtained by tuyeres oriented so as to send an air stream properly directed in the oxidation zone, delimited at the bottom by a transverse choke plate. In such way the ash particles settle on the metallic wall of the reactor. This layer, in a quasi sintered state, protects metal walls from thermal aggression and mechanical stress.

The gas leaves the gas producer at a moderate temperature and is practically tar free. Final cleaning, mainly from dust, is carried out by a very simple and cheap three stages system, made up of a cooling and scrubbing unit, a demister and a final filter.

The cooling unit is a cylindrical tank filled with an inhomogeneous cheap material (expanded clay). The gas is cooled and scrubbed countercurrent by water. The used water is cooled and recycled. A cylindrical tank filled with the same inhomogeneous material constitutes the demister while the final filter is a steel cylinder filled with wood chips or sawdust.

EXPERIMENTAL AND RESULTS

The gasification tests were performed using different biomass. Characteristics are reported in table 1.

Table 1 - Characteristics of biomass

	C	H	N	O	Ash	Moisture
BIOMASS	%wt db	%wt db	%wt db	%wt db	%wt db	%wt
Peach	48.06	5.83	0.55	44.03	1.53	9.8
Olive	46.43	5.63	0.55	44.91	2.48	10.6
Pine	48.18	5.71	0.15	43.89	2.07	9.0

Materials were chopped in pieces of about 2x1x1 cm (figure 3).

The size and shape are very important for the behaviour of biomass in the gasifier as far as the movement, bridging and channelling. Also the thickness of the oxidation zone and the pressure drop depend on these characteristics.

Figure 3 - Biomass fed to the gasifier

Moisture affects the heating value of the gas and the steadiness of the gasification process because it absorbs heat to vaporise. In any case most of the water vaporises in the pyrolysis section of the gasifier and it is condensed and collected at the top of the reactor. Biomasses were successfully gasified with steady operation condition. All tests ran for 3 – 4 hours and were repeated 3 times.

The values of the process parameters and the composition of gases are the result of a medium obtained from readings with frequencies of 30'.

The value of the tars content is the result of an only sampling for every test, with duration of about two hours.

The amount of biomass fed in every test was determined by the difference between the fed fresh biomass and the recovered one into the gasifier at the end of test; so the measure presents some uncertainties.

The process conditions and results are shown in tables 2 and 3.

The gas composition is that typical one that is found in literature. The CO/CO_2 and H_2/CO ratios are constant; the heating value of the gas is a direct consequence of its chemical composition, which depends on the reaction conditions, rather then the heating value of the entering biomass, substantially equal for all those experienced.

The energy efficiency is lower than that of commercial gasifiers; that is the consequence of the small size of experimental model and its proportionally higher heat loss.

The low tar content makes the producer gas suitable to the use in cycle Otto engines. These results have been obtained applying a truly simple and inexpensive washing system.

Table 2 - Process conditions

Biomass		Olive	Peach	Pine
Process time (h)		3.80	2.50	3.10
Temperature (K)	T_1	513	473	503
	T_2	531	491	521
	T_3	880	780	853
	T_4	1,193	1,173	1,143
	T_5	1,123	1,153	1,103
	T_6	425	417	408
Biomass fed (kg)		12.5	7.6	7.75
Flows (Nm^3/h)	Air	5.74	5.3	5.4
	Gas	28.9	18.4	21.3
Draft loss (mm H_2O)		17	22	24

Table 3 - Tests results

Biomass	Olive	Peach	Pine
Inputs			
Gasifier conditions:			
Feed (kg/h)	3.3	3.05	2.5
Gasifier air (20°C, 1 bar) (kg/h)	6.79	6.20	6.45
Outputs			
Dry gas (kg/h)	9.02	8.60	8.17
Water (g/Nm^3)	114.5	96.5	102.3
Char - ash (kg/h)	0.160	0.085	0.128
Tar (mg/Nm^3)	9	2	10
Dry gas analyse			
CO (% vol.)	17.4	17.7	16.0
H_2 (% vol.)	13.2	15.0	12.1
CO_2 (% vol.)	12.4	13.5	11.4
CH_4 (% vol.)	0.8	1.2	0.2
O_2 (% vol.)	1.3	0.9	0.9
N_2 (% vol.)	54.9	51.7	59.4
Dry gas HHV (MJ/Nm^3)	3.55	3.97	3.65
Gas density (kg/Nm^3)	1.183	1.167	1.191
Operating ratios			
O_2 / dry biomass	0.45	0.44	0.44
CO / CO_2	1.40	1.31	1.40
H_2 / CO	0.76	0.85	0.76
Mass balance and energy efficiency			
Mass in / Mass out	1.01	0.98	0.99
Cold gas efficiency	0.61	0.78	0.58

Use of the Producer Gas in Internal Combustion Engine and Electric Generator

As above mentioned the producer gas is directly usable in an internal engine, coupled with an electric alternator (KAUPP; GROSS, 1984).

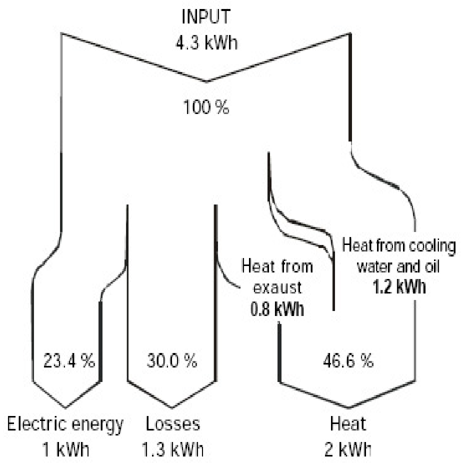

Figure 4 - Rated energy balance (per kWh_e) (JEAG, 2005)

In addition to electricity, thermal energy can be produced recovering heat from cooling water, lubricating oil and exhaust. Up to 2 kW_t per 1kW_e can be obtained (figure 4). Heat can be used to warm as well as to cool using absorption chillier.

A rated balance of the process is depicted in figure 4; assuming a thermal efficiency of 70%, 1.3kg (dry bases) of biomass is needed to produce 1 kWh of electricity.

Conclusions

By the collaboration between University of Sassari and University of Camagüey a novel tar free gasifier based on the Imbert technology, was constructed and tested. A clean low heating value gas was produced with up to 78% efficiency.

The architecture of this downdraft fixed bed permits:

- Maximum flexible matching capability with a wider range of waste wood conditions,
- Lower costs of production by the use of standard components,
- Guaranteed quality and stability in the produced gas according to the engine specifications,
- Reduced management costs.

This gasifier can provide a competitive source of power in particular in developing countries, where fuels handling is difficult, but also in developed countries with abundant biomass resources such as waste wood, sawdust, nutshells etc., in order to produce a costs reduction.

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Gaseificação da biomassa por um novo gaseificador de leito fixo realmente livre de alcatrão

Resumo

Um dos maiores obstáculos para a aplicação dos sistemas de gaseificação da biomassa é o alto conteúdo de alcatrão do gás produtor que impede o uso em motores, turbinas ou células a combustível sem promover a limpeza do gás. Nesse trabalho, características de um recente gaseificador livre de alcatrão são descritas. Gás produtor, contendo 2 mg/Nm^3 de alcatrão e poeira foi obtido. Esse gás pode ser utilizado diretamente para abastecer motores de ciclo Otto para produzir eletricidade e calor. A biomassa foi convertida em gás produtor com até 78 % de eficiência. Tipicamente a partir de 1,3 kg de biomassa da madeira em base seca, pode obter até 1 kWh_e e 2 kWh_t. Operação e manutenção são muito simples e podem ser efetuas por operadores não especializados.

Palavras-Chave

Biomassa. Gaseificação. Alcatrão.

References

JENBACHER ENERGIESYSTEME AG – JEAG. *A-6200*. Jenbach, Austria. Site available at http://www.jenbacher.com. Visited in 28-march-2005.

KAUPP, A.; GOSS, J. R. *Small scale gas producer-engine systems*. Friedr. Vieweg & Sohn, 1984.

REED, T. B.; DAS, A. Handbook of biomass gasifier engine systems. 2. ed. Biomass Energy Foundation Press, 1994.

REED, T. B.; GRABOSKI, M. S.; LEVIE, B. *Fundamentals, development & scale - up of the air-oxygen stratified downdraft gasifier*. Biomass Energy Foundation Press, 1994.