HYDROGEN RICH GAS FROM BIOMASS STEAM GASIFICATION

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ABSTRACT: The FICFB (**F**ast **I**nternally **C**irculating **F**luidized **B**ed) gasification process is an innovative process to produce a high grade synthesis gas from solid fuels. The design of the gasifier and the use of steam as gasification agent gives this process a small heat loss and a nearly nitrogen free product gas with a high calorific value of 13 MJ/Nm^3 dry gas. This process has been studied over five years and a lot of experiments were carried out in the 100kW$_{th}$ pilot plant. By using a natural catalyst as bed material and gasification temperatures above 750°C the tar content was reduced below 3g/Nm³. In former work the product gas was cleaned and cooled down to 30°C without problems. In this paper the work carried out within the scope of EC-project "Hydrogen rich gas from biomass steam gasification" JOR3-CT97-0196 is presented.

1 INTRODUCTION

The objective of this project is the development of a fluidized bed gasification process for the production of a hydrogen rich gas from biomass. The gasification process is based on an Fast Internally Circulating Fluidized Bed (FICFB) configuration [1,2,3,4]. In order to achieve the necessary high hydrogen yield, steam-fuel ratios between 0,5 and 1 were used. Also suitable catalysts (Ni-catalysts or natural catalysts) will be included in the bed inventory. The project demonstrates one powerful application of the product gas, producing electric energy in a fuel cell, which will be integrated in the process.

Partners:

- Technical University of Vienna (TUV)
- AE Energietechnik (AE)
- Universite Lois Pasteur, Strasbourg (ECPMS)
- Universität de l'Aquila (UNIVAQ)
- Ansaldo CLC (CLC)
- University College London (UCL)
- ENEA, Italy (ENEA)

2 DESCRIPTION OF THE PILOT PLANT

2.1 Basic design of the pilot plant

The pilot plant consists the gasifier, the fuel feeding system, the steam and air supply, the product and flue gas treatment system and a gas treatments system for the fuel cell.

The feeding system includes a bunker, a sluice, and a screw system, which transports the biomass directly into the fluidised bed in the gasification zone. Feeding the biomass into the bed has the advantage of a better contact of the catalytic bed material with the biomass. Because of the pressure in the fluidised bed a sluice system is necessary to avoid a leakage to the bunker.

The gasification reactor consists of two zones, a gasfication and a combustion zone (see figure 1). The circulating bed material serves as heat carrier from the combustion to the gasification zone.

Steam is used as gasification agent which is produced by an industrial steam generator unit and is overheated up to 500°C. There is also the possibility to mix the steam with recycled product gas to vary the steam-fuel ratio. Air used as fluidization gas in the combustion zone is supplied by a compressor and heated up to 300°C.

The flue gas treatment consists of a cooler, a filter, a fan and at last a chimney. The product gas treatment

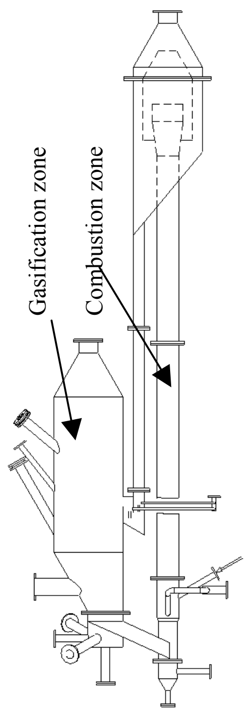

Figure 1: FICFB-Gasifier

consists primarily of a heat exchanger, a filter, a fan and a flare, where the main part of the gas is burned. An amount up to 200 Nm³/h can be mixed with the steam and recycled to the gasification zone as mentioned above. A small amount (about 25 Nm³/h) is led to the fuel cell.
Before feeding the gas into the fuel cell a gas treatment is necessary. First the rest of particulates and tars is removed by a dust filter, then the H_2S and NH_3 is removed by two steps of scrubbers. The rest of H_2S is removed by a zinc oxide catalyst. To increase the amount of hydrogen a two step shift reactor converts CO with steam to H_2 and CO_2. After this treatment the gas is ready to be used in the fuel cell.

2.2 Work content

The work described in this paper consists of two main parts. The first one is fundamental research in a laboratory unit. There the influence of temperature, steam-fuel ratio and other parameters were investigated. The second part are tests of the catalyst in the $100kW_{th}$ FICFB-gasifier at TUV. All these fundamental research will help to optimise the operation of the $500kW_{th}$ pilot plant at ENEA. The start up of the pilot plant is planned in June 2000. In the pilot plant there will be parameter tests (5-10 hours) to investigate the influence of various parameters on the performance of the gasifier (see table 1) and long term tests (some days) to study the overall performance of the integrated system will follow.

Table 1: the following parameters will be investigated

Parameter	Range
Feedstock	Wood chips, annual crops, perennial energy crops (at least 3 feedstocks)
Water content of feedstock	15-40 %
Steam/biomass ratio	0,5-1,2
Gasification temperature	700-850 °C
Load	60 - 100 %
Bed material	Quarz sand natural catalytic substance Ni-catalyst mixed with natural catalyst

3 RESULTS OF THE EXPERIMENTAL TESTS

3.1 Results of the Laboratory unit at UNIVAQ

The work performed at UNIVAQ aimed at the experimental verification of the effectiveness of catalysts for tar destruction and methane reforming in the biomass steam gasification process [5]. This objective has been accomplished by means of laboratory tests carried out with a bench scale facility which allowed to check the performance of different catalyst batches at the effective operating conditions encountered in biomass gasification.
The activities have been directed at the acquisition of the knowledge and experience needed to operate the pilot plant, where the catalyst will be placed directly in the gasifier. Therefore, they have been focussed to check the capability of the catalyst to stand the particle attrition problems typical for fluidised bed inventories without substantial loss of activity. Moreover, the influence of changes in the operating conditions on the yield and quality of the fuel gas product has been also investigated.
In diagram 1 the influence of the steam-biomass ratio on the dry gas yield and the tar content is show.

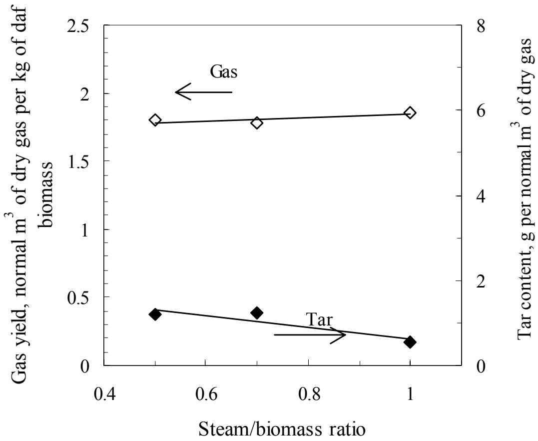

Diagram 1: influence of steam-biomass ratio

In diagram 2 the dependency of the dry gas composition on the gasification temperature is shown.

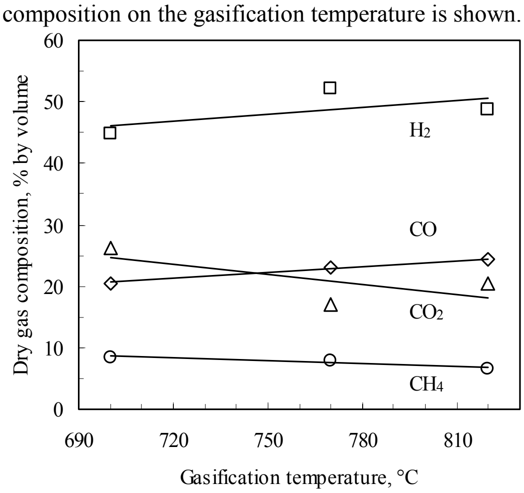

Diagram 2: influence of temperature

3.2 Results of the $100kW_{th}$ FICFB gasifier at TUV

The aim of these experiments was to test the catalyst in the FICFB-gasifier. This gasifier has a similar design as the pilot plant, only the size is different. Gas composition, tar, steam and dust content of the product gas was measured. Table 2 shows the parameters, which were used for the experiments.

Table 2: parameters for the gasification tests at TUV

fuel	25 kg/h
steam fuel ratio	0.5
temperature	770-830°C
bed material	43% catalyst

In the following diagrams the results of these experiments is shown. In diagram 3 the gas composition over time is shown. From this diagram can be seen, that the catalyst shows no deactivation over the testing period of 50 hours. In diagram 4 the gas composition, which results by the catalytic bed material, is compared to former results with natural catalyst as bed material. It can be seen, that the hydrogen content is about 8vol% higher than at the experiments with natural catalyst as bed material. Methane is about 3-4vol% lower as at the experiments without a catalyst.

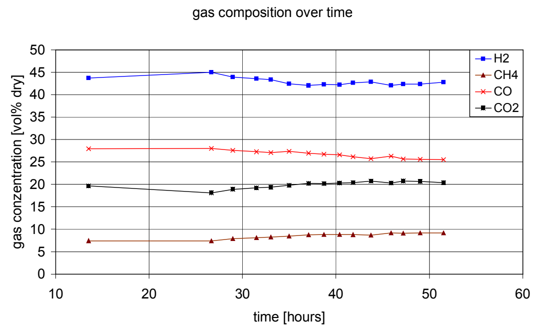

Diagram 3: gas composition over time

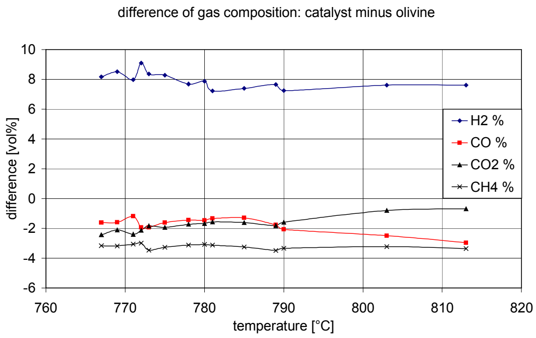

Diagram 4: comparison of catalyst and natural catalyst

3.3 General results

Table 3 gives a summary of the performance of the new catalyst:

Table 3: performance of catalyst

plant	Laboratory unit	100kW gasifier	
Bed material	catalyst	natural catalyst	43% catalyst
Steam/Fuel [kg/kg]	1	0,5	0,5
Temperature [°C]	820	800	800
H2 [%]	50	38	46
CO [%]	24	31	28
CO2 [%]	21	21	19
CH4 [%]	5	10	7
Tar [g/Nm^3]	0,4	2,0	0,3
Attrition [%/h]	0,6	0,3	0,3

4 CONCLUSION

The experiments at the laboratory scale gasifier at UNIVAQ and at the 100kW$_{th}$ gasifier at TUV showed, that it is possible to produce a gas with the qualities shown in table 4.

Table 4: quality of product gas

content of nitrogen	<5%
hydrogen content	40-60%
calorific values	above 11MJ/Nm³
tar content	<600mg/Nm³

The attrition of the catalyst is about 0.3 m% per hour. This is the same attrition as measured in former experiments with natural catalyst as bed material. The tests at the laboratory unit showed also, that the gas quality is almost independent of the water content of the biomass. These results will be verified at the 500kW pilot plant, when the pilot plant will be in operation.

In this project a system for production of a hydrogen rich gas from biomass by steam gasification is demonstrated. In further work the gas treatment system will be optimised, that a fuel cell unit can be integrated into the system, without poisoning the fuel cell.

Acknowledgement. This work has been carried out under the Project no. JOR3-CT97-0196 of the EC.

5 REFERENCES

[1] Hofbauer, H.; Stoiber, H.; Veronik, G.; (1995).*"Gasification of Organic Material in a Novel Fluidization Bed System"*, Proc. Of the 1st SCEJ Sympoion on Fludization, Tokyo, pp. 291-299

[2] Fleck, T.; Hofbauer, H.; Rauch, R.; Veronik, G.; (1996). *"The FICFB Gasification Process"*, Proc. Of the IEA Bioenergy Meeting Banff, Canada May 1996

[3] Zschetzsche, A.; Hofbauer.; Schmidt, A.; (1994). *"Biomass Gasification in an Internally Circulating Fluidized Bed"*. Proc.of the 8th European Conference on Biomass for Agriculture and Industry, Vol. 3, pp. 1771-1777

[4] Fercher, E.; Hofbauer, H.; Fleck, T.; Rauch, R.; Veronik, G.;*"Two Years Experience with the FICFB-Gasification Process"* 10th European Conference and Technology Exhibition, Würzburg (Jun e 1998)

[5] Rapagna, S.; Provendier, H.; Petit, C.; Kiennemann, A.; Foscolo, P.U.; (2000). *"Development of Catalysts Suitable for Hydrogen or Syn-Gas Production from Biomass Gasification"*. 1st World Conference and Exhibition on Biomass for Energy and Industry, Sevilla, Spain, June 2000