Grau, Marten and Tetzlaff, Frank

Thermo chemical gasification of biomass

The intensified usage of biomass for generating energy and raw materials for chemical industry is discussed now. Hereby the processes of thermo chemical conversion play a key role. In this contribution important criteria for process management and facility control are shown and explained through an experiment description.

Keywords
Gasification, pyrolysis, biomass

Abstract
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The decomposition of carbon-containing raw materials using the thermo chemical gasification of materials like coal or crude oil has been largely researched and is ready for industrial large-scale applications. However, for agriculture, the utilization of self-produced primary and secondary raw materials for energy generation is important. Reasons for that are the German Renewable Energy Law and the possibility of an additional income for farmers. The most used charge material in gasification plants is wood. The usage of other secondary raw materials for gasification like solid manure or digestates from fermentation plants is in experimental state. Because of the large spectrum of usable biomass, an adaptation of the gasification technology to the special needs of these materials is strongly needed [1].

Process and quality parameters

For the operation of a thermo chemical gasification facility and the decomposition of carbon-containing raw materials two parameters are considered to provide qualitative and quantitative assessments of the process efficiency: first the cold gas efficiency and secondly the carbon converting rate. These parameters give a rough estimation of the efficiency of the thermo chemical conversion. But they do not provide any information about the gas composition or the gas quality. Gasification processes with a high content of methane for instance often come along with a high cold gas efficiency. On the other hand, the carbon conversion rate is a quantitative parameter for the utilization of the charge material. Modern fluidized bed gasifiers are working more efficient than 97 % [2].

The removal of solid particles from the generated gas is obligatory. Different technologies like cyclones, hot gas filtering, electrical and fabric filters and wet gas cleaning systems are available. The content of solid particles in the raw gas depends among other things on the gasification process itself: counter flow, parallel flow, entrained flow and fluidized bed. The particle concentration in the raw gas reaches from 0.1 g/Nm³ (parallel flow) up to 100 g/Nm³ (fluidized bed) [3].

Description of the used equipment

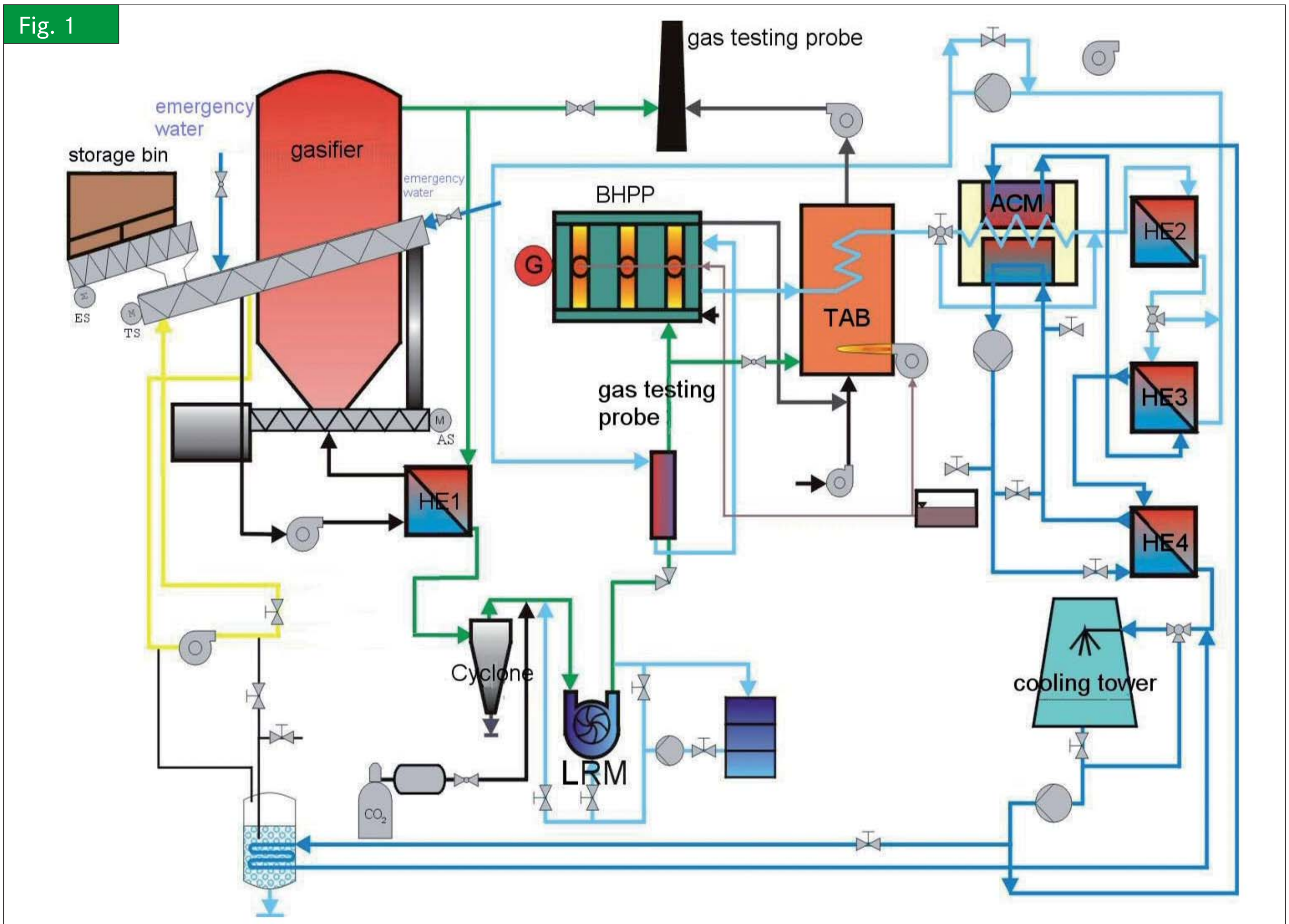
The tests were carried out at the biomass utilization facility at the Martin-Luther-University Halle-Wittenberg (Germany). This test facility is mainly suitable for the use of wood chips. The rated input power of the gasification reactor is about 200 kW. This value describes the amount of chemical bounded energy per time unit, which can be generated through a loss-free and complete conversion of wood. The ratio between input energy and output energy in the produced gas is represented by the cold gas efficiency. If other raw materials are used, the maximum of the input power can vary because of the fixed dimensions of the reaction spaces and the limited maximum power of the gas conditioning units and the gas flow devices. Overall, this reactor configuration can be used to gasify a lot of different free-flowing biomass materials.

The facility is divided into three functional parts:

- generation of the product gas,
- gas conditioning and
- usage of the produced gas and heat utilization (**figure 1**).

The decomposition of wood through thermo chemical reactions takes place at an atmospheric gasifier with a stationary fluidized bed. The main reaction zones for the pyrolysis of the wood and the following gasification of the pyrolysis products are separated from each other. By using continuously variable speeds of the screw conveyors the reaction times of the biomass in the reaction zones are adjustable. This functionality allows an adaption of the gas generating process according to alternating fuel characteristics. The gas is cleaned in two steps: first dry at a centrifugal separator and subsequently wet at a gas scrubbing unit. The last- mentioned device also cools down the gas. The conditioned gas can be used directly in a block heat and power plant for power generation, or in a heat generator. In addition to normal heat utilization, the heat can also be used in an absorption chiller for chilling tasks. This facility is a practical configuration that is typically employed at farms in agriculture.

Fig. 1



Storage bin	Vorratsbehälter	TAB (Thermal after burning)	Thermische Nachverbrennung
Gasifier	Vergaser	ACM (Absorption cooling machine)	Absorptionskälteanlage
HE (Heat exchanger)	Wärmeüberträger	BHPP (Block heat and power plant)	Blockheizkraftwerk
Cyclone	Zyklon	Cooling tower	Kühlturm
LRM (Liquid Ring Machine)	Flüssigkeitsringmaschine	Emergency water	Notwasser
Gas testing probe	Messgasentnahme		

Facility scheme BENA 200

Trial description

For the trial, wood chips of the classification G30 were used. The dimension of the raw material pieces has a large influence on the conversion speed. The described reactor is designed for materials with a mean feed size of 5 to 30 mm. The throughput during the trial was adjusted to 38 kg/h (absolute dry). With a lower heating value of about 5.1 kWh/kg, this equals an input power of 194 kW. The wood moisture was measured with 28 %. The construction of the gasifier permits the use of moist material. The wood chips are dried within the reactor before they reach the pyrolysis zone. The vapor and the pyrolysis gases are conveyed into the fluidizing bed. The whole process was set up to achieve a high cold gas efficiency and a maximization of carbon conversion.

Results

Figure 2 shows the product gas composition over the trial time. The generated gas is a poor gas with a mean heating value of 5.4 MJ/Nm³ (steady state). The gas flow was about 95 Nm³/h. The heating value is in normal range for air driven gasifiers. The low heating value is due to the high content of nitrogen in the gas. Higher values will be attained by using pure oxygen or vapor as process gas.

Table 1

Particle loads [mg/Nm³]

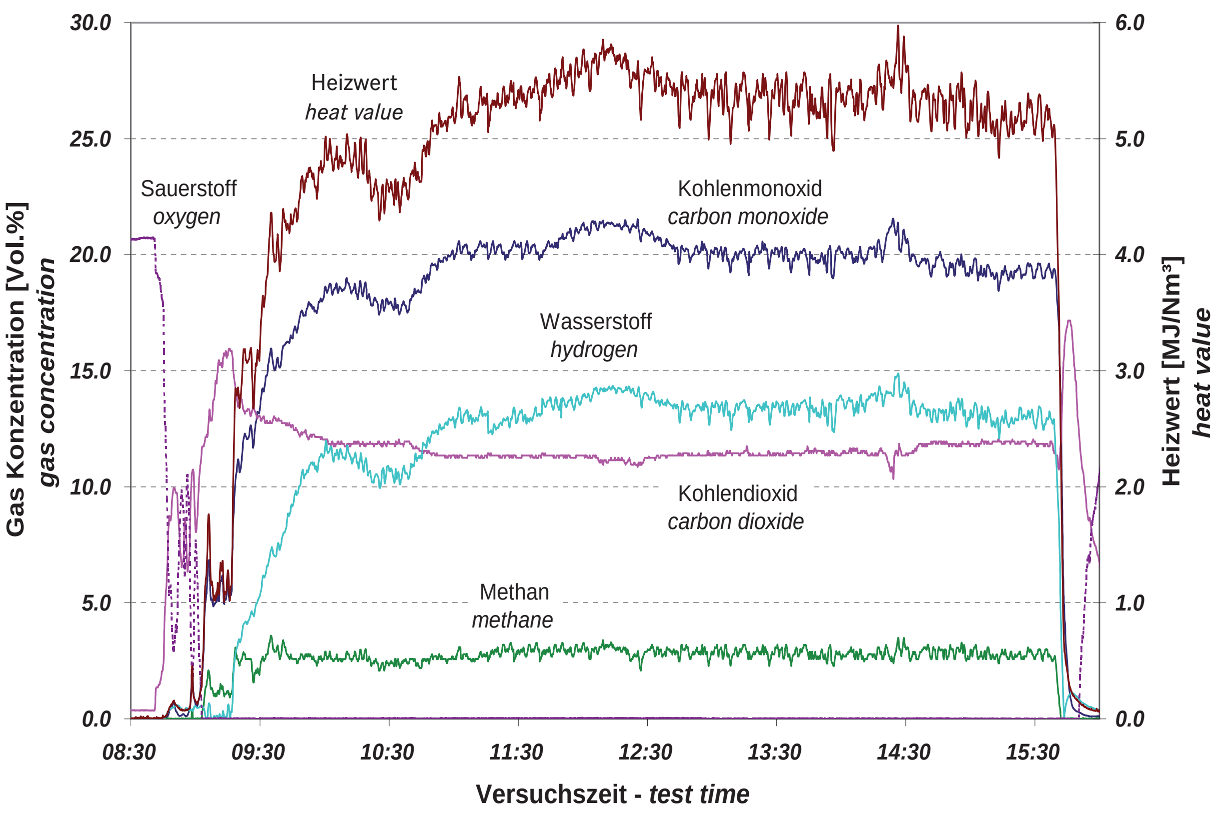
Vergaserausgang *Gasifier outlet*	Zyklonausgang *Cyclone outlet*	Ausgang Gaswäsche *Gas scrubber outlet*
3700	1150	46

Table 1 shows the measured total contents of dust before and after the gas cleaning stages. The generated gas leaves the fluidized bed gasifier with a low content of particles of about 3.7 g/Nm³. This value was also nearly reached in other trials. At the following cyclone, most of the larger particles were separated. The separation rate was 2.55 g/Nm³.

The following gas scrubbing unit is filled with fatty methyl ester (FME). Beside the removal of particles, also condensable parts from the gas will be separated at this point. The leftover particle content in the cleaned gas was about 46 mg/Nm³.

In addition to the dust removal at the gas cleaning units, annealed ash is transported out of the fluidizing bed. Overall, 52 % of all ashes respectively particles were separated at the cyclone.

Fig. 2



Product gas composition

The usage of the cleaned gas for gas turbines or fuel cells is not recommended because of the rest particle content. Additional gas cleaning would be necessary here.

The cold gas efficiency averaged to about 73 %. The biomass was converted into the product gas with a carbon conversion rate of about 98 %.

An improvement of the cold gas efficiency is possible by achieving a higher heat flux from the product gas to the process air. But the flow resistance of the additional heat exchanger would cause a higher energy input at the gas conveying unit than the conserved heat at the reactor. That is why the reduced efficiency is acceptable.

Conclusions

The thermo chemical gasification of biomass from agriculture in small plants with a good efficiency and high fuel utilization is possible. A decentralized application at farms can be realized [4]. However, before a wide practical use, long-term trials at the testing facility are necessary to proof high function availability. At last, the usage of other raw materials than wood has to be tested.

Literature

Books are signed with ●

[1] Schüssler, I. et al: Schwachstellenanalyse an BHKW-Vergaseranlagen. Abschlussbericht, TU Dresden, 2009

[2] ● Higman, C. and van der Burgt, M.: Gasification. 2nd Edition. Elsevier Inc., 2008

[3] ● Kaltschmitt, M. und H. Hartmann: Energie aus Biomasse. Springer Verlag, Berlin, 2001

[4] Grau, M.: Thermo Chemical Processes for Biomass Conversion. Proceeding of BECOTEPS Workshop 2 "Opportunities for new business concepts with the combined non-food biomass chains under the KBBE umbrella", Brussels, October 7-8, 2009

Authors

Marten Grau is scientist at the Institute of Agricultural and Nutritional Sciences (IANS) of the University of Halle-Wittenberg (Germany), Julius-Kuehn-Str. 23, 06112 Halle (Saale),
E-mail: marten.grau@landw.uni-halle.de

Frank Tetzlaff is scientist at the Centre of Research and Consulting of Agricultural Engineering Systems (FBZ AS) Halle, Julius-Kuehn-Str. 23, 06112 Halle (Saale)

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