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Construction and operation of a small scale two-stage gasifier(Viking gasifier)

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ABSTRACT: The Two-Stage Gasifier was operated for more than 1000 h. This paper will focus on the first tests (465 h). During these tests the gasifier was operated automatically unattended day and night, and only small adjustments of the feeding rate were necessary once or twice per day. The operation was successful, and the output as expected. The engine operated well on the produced gas, and no deposits were observed in the engine afterwards. The bag house filter was an excellent and well operating gas cleaning system. Small amounts of deposits consisting of salts and carbonates were observed in the hot gas heat exchanger. Analysis showed that the metal part of the reactor, where the char bed is located, was not corroded. The top of the reactor had to be reconstructed in some other material.

KEYWORDS: Gasifier,tar, pyrolysis, operation

I. INTRODUCTION

Development of processes for thermal gasification of biomass has been going on for many years. One of the main problems has been the presence of tars in the produced gas. Tars damage internal combustion engines, gas turbines and other machinery. Therefore gas cleaning and reduction of the produced tar has been the subject of many research projects [1]. Gasification processes producing only very low amounts of tars will have great potential as tar treatments can be avoided [2]. The main advantages of the two-stage gasification process is, that contrary to most other gasifiers, tars are only present in very small amounts in the produced gas [3,4]. Test runs of up to a few days duration of different manually operate two-stage pilot plants have been carried out. After this, a small-scale demonstration plant for fully automatic operation for at least 500 hours. The small scale (100 kW thermal) was chosen for economical reasons. It was decided to use wood chips as fuel. The gasifier called 'Viking' is a traditional two-stage gasifier which means that the pyrolysis and char gasification takes place in separate reactors (see Fig.1). Between the pyrolysis and the gasification, the pyrolysis products are partially oxidised by means of air addition. Thus the tar content in the volatiles is reduced by a factor of 100 and thermal energy for the endothermic char gasification is produced. When the partially oxidised pyrolysis products pass through the char bed in the char gasification reactor, the tar content is further reduced by a factor of 100. The resulting tar content in the produced gas is less than 15 mg per Nm3 [5].

II. THE PLANT

The plant consists of a number of main components, which will be described briefly in the following

A. FEEDING SYSTEM

A container with a conveyer in the bottom feed the wood chips to a screw conveyer. A lock hopper system (two valves separated by a screw conveyer) secures that no gas escapes the system. After this the wood chips are fed into a box where a screw conveyer feed the fuel to the pyrolysis unit. The rotational speed of this screw controls the feeding rate. A little nitrogen was supplied to the box to avoid tar condensation in the feeding system [7].

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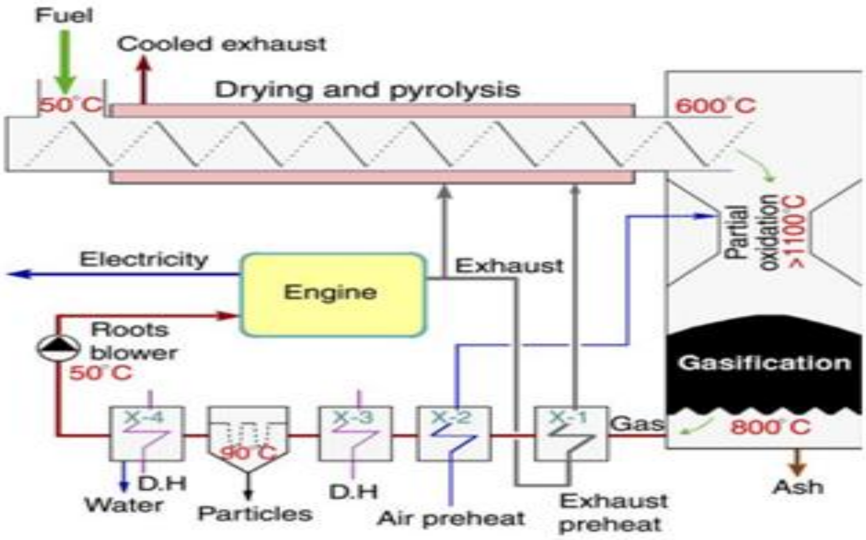

Fig.1. Viking gasifier [5]

B. PYROLYSIS UNIT

The exhaust gas from the connected gas engine is used for external heating of the pyrolysis reactor. A screw conveyer transports the biomass through the pyrolysis reactor. In the first part of the pyrolysis reactor, the biomass is dried. In the second part, the pyrolysis takes place. Pyrolysis demands higher temperatures than drying, and to satisfy this, the exhaust gas is split into two streams (see Fig.1). One stream is heated further by heat exchanging with the hot producer gas, and the other is led directly to the pyrolysis unit where it joint the other stream.

C. CHAR GASIFIER

The gasification reactor is build with a metal shell. In the top (at the partial oxidation), where the temperatures are at the highest (up to 1270.8C) and only gas is present, a ceramic composite construction based on ceramic fibres coated with aluminium oxides is used.In the char bed metal (253 MA) is in direct contact with the char. It provides a gas tight reactor wall keeping the gas from bypassing the char bed, as this will result in increased tar amounts in the produced gas [6]. Geometrically the reactor is constructed as concentric cylinders. In the bottom, the cylinder meets a square grate.

D. GRATE

The grate is a moving grate, see Fig. 2. When the grate is moved, ash and char pass through causing the pressure drop over the char bed to decrease. Grate movement is triggered when the pressure drop across the char bed in the char gasifier exceeds a threshold (e.g. 300 mm WG). The ash is removed by two screw conveyers.

E. GAS SYSTEM

The gas is heat exchanged with a part stream of the exhaust gas. Then the gas is heat exchanged to preheat the air for the gasifier. Then it is cooled down to just above the water dew point (about 90.8C) and cleaned in a bag house filter. After the bag house filter a paper cartridge filter acts as a police filter. After this the gas is cooled further down to about 50 8C and condensate is removed. To ensure that droplets produced during the condensation is removed, the gas then passes through another paper cartridge filter (similar the police filter) which acts as demister. The gas flow is driven by a roots blower, which is a volumetric machine. The blower is built from conventional steel.

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F. BAG HOUSE FILTER

The filter material in the bag house filter is ordinary polyethylene bags, which is back-flushed by nitrogen. When the pressure drop exceeds 75 mm WG the back flush is initiated, reducing the pressure drop to about 25 mm WG,

G. ENGINE

The produced gas is feed to an engine. The engine is a natural aspirated three cylinder DEUTZ spark ignition gas engine operating at full load. The engine is connected to producer gas and natural gas. Natural gas is used during start up. It is possible to operate the engine on producer gas, natural gas or any mixture of the two. The produced electricity is supplied to the electric grid. The produced heat from cooling the producer gas cooling the exhaust gas and the cooling of the engine are supplied to a heat system in order to simulate a district heating system. The return temperature from the heating system is kept constant.

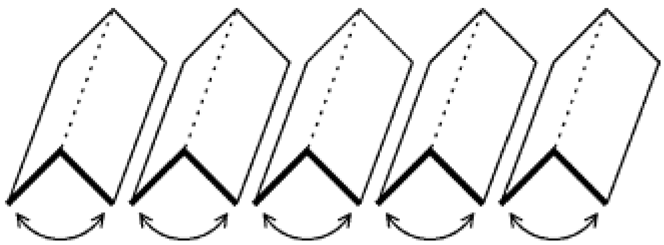

Fig.2. Grate.

H. CONTROL

The gasifier is controlled by a PLC. The overall control strategy used in this study was to produce a constant gas flow to the engine. In order to obtain this, the roots blower was operated at constant speed. The air addition was adjusted to give atmospheric pressure at the biomass fuel inlet of the pyrolysis unit. The system is equipped with automatic security systems, and can operate unattended.

III. OPERATION

The gasifier had been started a few times before the 400 h test. Each time different problems occurred, and were solved. During the summer of 2013 the gasifier was in operation for 75 h with wood chips to the gasifier and of these 50 h with producer gas to the engine. The temperature of the return water in the heating system was constantly 40 C.The only essential parameter, which was not adjusted automatically, was the fuel-feeding rate. Thiswas adjusted manually once or twice per day as the process was quite stable. The fuel was woodchips from beech.

IV. RESULTS

The efficiency of the system was about 25% from wood to net electricity. During this test there were some shut downs for different reasons. For long periods no problem occurred. The longest continuous running period was 190 h. In Fig. 3, the gas flow during the full test is shown. The gas composition was quite constant in spite of oscillations with a frequency equal to the rotation frequency of the screw conveyer in the pyrolysis unit. The reason is that char falls down in batches.

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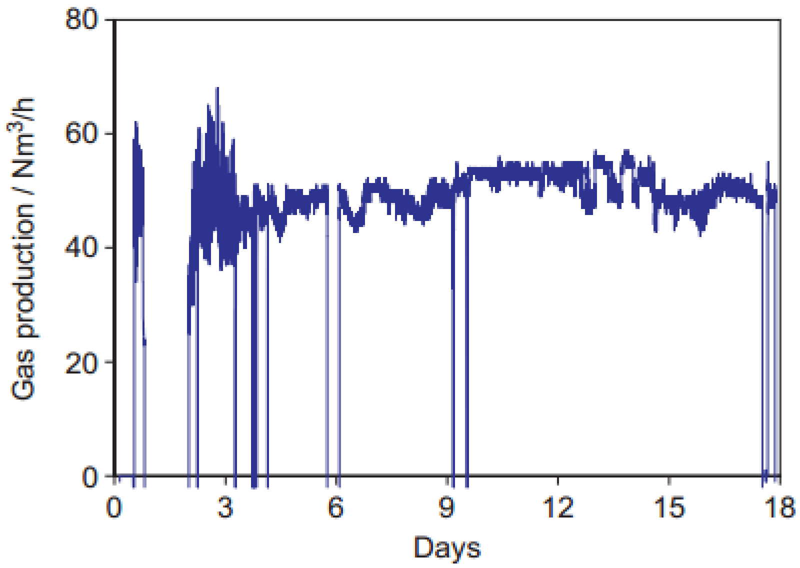

Fig.3. Gas flow development during the test period.

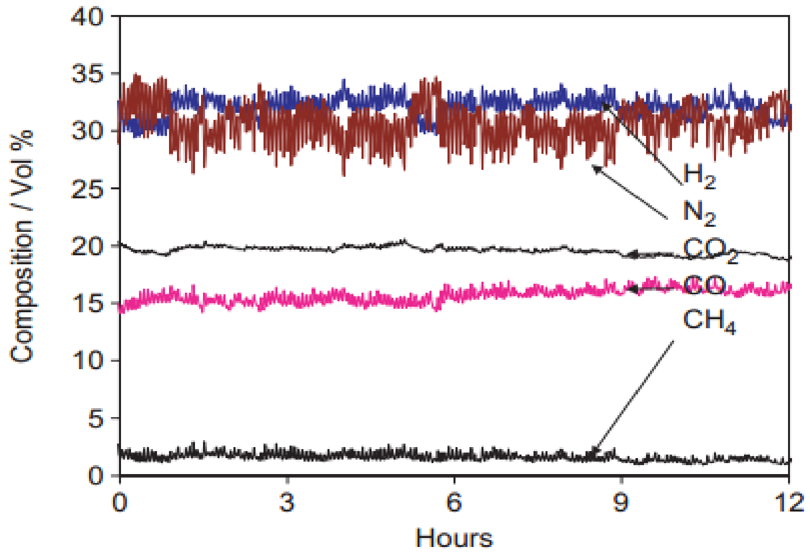

Fig. 4. Gas composition.

These are heated up to gasification temperature and gas is rapidly released and this influences the gas composition. In Fig. 4, an example of the gas composition development is shown for a 12-h period. The specific heating values for a 12-h period are shown in Fig. 5. The temperature at the char outlet of the pyrolysis unit is around 600 C. The maximum operatingtemperature in the top of the gasifier is 1100–1200 8C, while the grate and in the gas outlet the temperature is 725–800C. An example of the temperature development in the gasifier is shown in Fig. 6. The pressure drop development across the char bed is shown in Fig. 7. It is seen that the pressure drop is oscillating. This happens without activating the grate. It was concluded that the pressure drop across the char bed could stabilize without active removal of char and ashes from the bottom of the bed.

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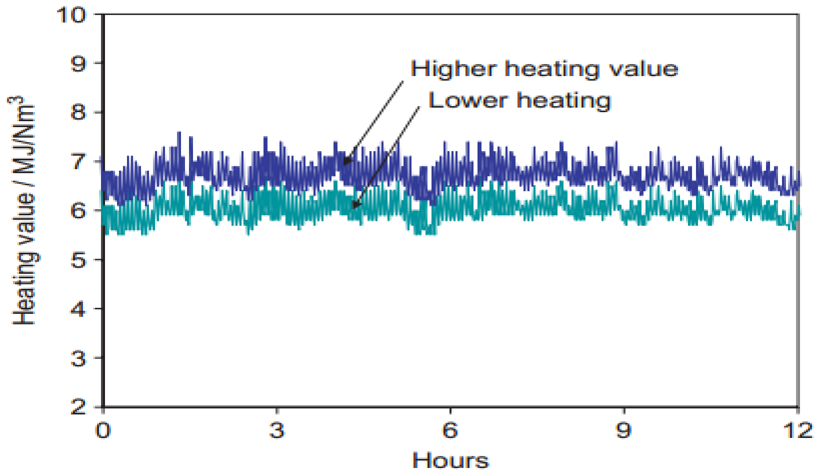

Fig. 5.Specific heating values in the produced gas.

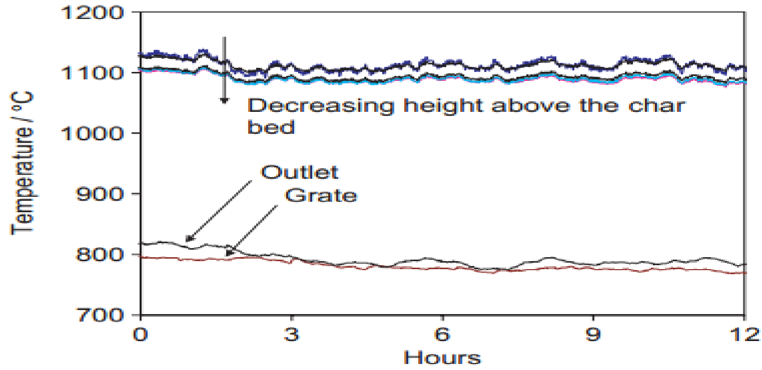

Fig. 6. Temperatures in the gasifier.

A. BAG HOUSE FILTER

The operation of the bag house filter was successful. The speed of the gas through the filter material was about 0.2 cm/s. Back flushing occurred about once a day and the result of one flush can be seen in Fig. 7. After 400 h no permanent increase in pressure drop was seen. The pressure drop across the police filter was constant (about 5 mm WG) during the whole test. This indicates a good cleaning efficiency of the bag house filter.

B. ENGINE

The engine was operated for 410 h on producer gas. The engine was started up fuelled by natural gas, and switched over to producer gas. The power was reduced compared to natural gas operation by a factor of 0.8 and the power output was about 15–20 kW electric. The efficiency from gas to mechanical power was about 28%. The oxygen content in the exhaust gas from the engine varied from 0.5 to 6%. During the test occasional problems with the ignition system was observed. Sometimes one of the cylinders did not ignite for several rotations.

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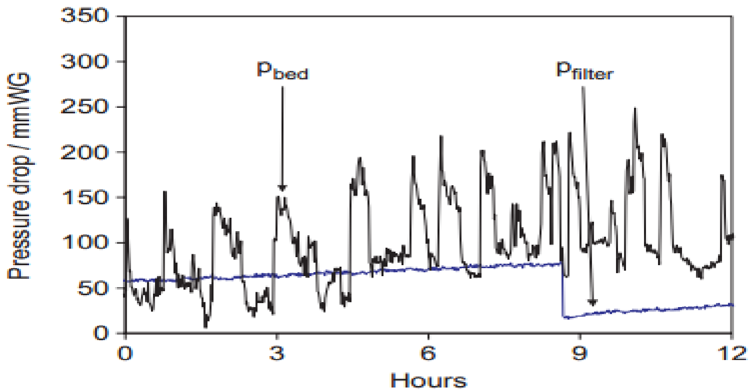

Fig.7. Pressure drop across the char bed and across the bag house filter.

C. PYROLYSIS REACTOR

The biomass and char transportation, through the pyrolysis reactor is carried out by a screw-conveyer, and thus, for every rotation a portion of char will fall into the gasifier. This lead to an oscillating gas flow and gas-composition as the temperature here is several hundred degrees higher than the pyrolysis temperature. For water content in the fuel up to 45% wet basis the capacity of the pyrolysis reactor was sufficient.

D. GRATE

During this test the grate was only moved once or twice. In all other situations, the pressure drop did not exceed the upper limit (300 mm WG). The char lost with the ashes were about 0.5% of the supplied dry fuel, which is a very low fraction for this type of gasifier.

F. FEEDING SYSTEM

The feeding system worked well during the test with only one stop. A big piece of wood was blocking. The gas sealing from the gasifier to the surroundings was acceptable.

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