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STATUS–2000 HOURS OF OPERATION WITH THE VIKING GASIFIER

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ABSTRACT: At the Technical University of Denmark, a biomass gasification CHP test plant named "Viking" has been constructed. The Viking plant is a two-stage gasifier. The plant was commissioned in the summer of 2002 and as of October 2003 more than 2000 hours of operation with wood chips as fuel has been conducted. The plant is a small scale gasifier with a nominal thermal input of 75 kW, plant and engine has been operated continuously and unmanned for five test periods of approximately 450 hours each.
A bag house filter proved to be efficient as gas cleaning system. This cleaning device has proven to be efficient through out several thousands hours of operation. Producer gas properties and contaminations have been investigated closely. No tar or particles were detected in the gas. Minor deposits consisting of salts and carbonates were observed in the hot gas heat exchangers. 25% efficiency from biomass to net electricity was obtained.
Keywords: gasification, combined heat and power generation (CHP), pilot plant

1 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 have been subject for lot research projects [1]. Gasification processes producing only very low amounts of tars will have great potential as tar treatments can be avoided [2].

At the Biomass Gasification Group, MEK, DTU the Two-stage gasification process have been developed during he last 14 years. The main advantages of the two-stage gasification process is, that contrary to most other gasifiers, very small amounts of tar is present in the produced gas. [3], [4], [5], [6].

It was decided to build a small-scale demonstration plant for fully automatic operation for at least 1000 hours at DTU [7]. The small scale (75 kW thermal) was chosen for economical reasons. It was decided to use wood chips as fuel.

The gasifier called "Viking" (see figure 1) is a traditional two-stage gasifier [8] which means that the pyrolysis and char gasification occur in separate reactors (see figure 2).

The main target for the Viking project has been to demonstrate and test long-term CHP operation of a gasifier coupled with a gas engine. The plant was commissioned in the autumn of 2002 and has as of October 2003 been running for more than 2200 hours.

2 PROCESS AND PLANT DESCRIPTION

Figure 1: The Viking Gasifier

2.1 Process

The Viking plant is based on the two-stage gasification principle, where pyrolysis and gasification takes place in two separate reactors (figure 2).

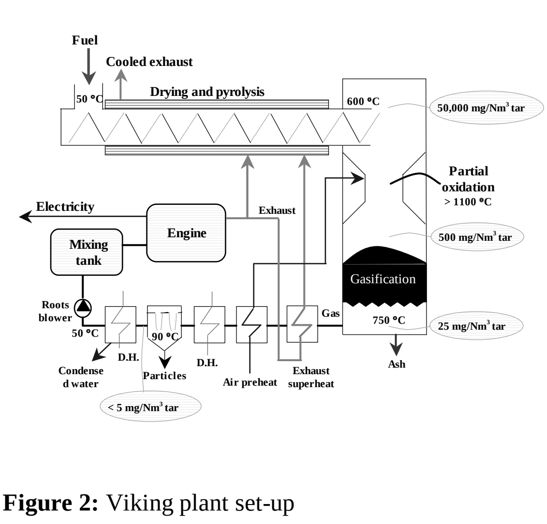

Figure 2: Viking plant set-up

Between the two reactors the 600 °C hot pyrolysis products are partial oxidised by preheated air. This partial oxidation results in a temperature increase to around 1100 °C at which the main part of the tar will decompose.

By passing several heat exchangers, delivering heat for the process and district heating, the produced gas is cooled to 90 °C. At this temperature the soot particles are removed dry in a simple bag house filter.

2.2 Condensate

A further cooling of the gas condenses the steam in the gas. The toxicity of the condensate has been tested and accepted for processing in Danish biological sewage plants. The cooled gas is fuelled to a gas engine coupled to a generator, producing power and district heating.

2.3 Engine

The gas engine is an integrated part of the whole gasification plant, the excess heat from the exhaust gas is utilised for drying and pyrolysis of the biomass in the gasification system, and the engine directly controls the load of the gasifier.

2.4 Tar removal

Between the pyrolysis and the gasification, the pyrolysis products are partially oxidised by air addition. Thus the tar contents in the volatiles are 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 contents are further reduced by a factor of 100.

The resulting tar content in the produced gas is less then 1 mg per Nm^3.

3 OPERATING RESULTS

During the first year the plant was operated for 2200 hours divided into 5 test periods of approximately 450 hours of continues operation each. Between the test periods the plant was disassembled and the system was inspected.

In cooperation with Technical University of Hamburg-Harburg, Germany, the performance of the plant was examined during 400 hours of continues operation in April 2003.

Table I: Key data, 400 hours test, April 2003

Key data	
Thermal input	68 kW
Fuel	Wood chips
Moisture content	35-45 %
Gasifier efficiency	93%
Engine efficiency	32%
Electric efficiency	27%
Overall electric efficiency	25%
Tar level	<1 mg/Nm^3
Dust level	<5 mg/Nm^3

3.1 Gasifier performance during 400 hours

The gasifier was running fully automated, controlled by a PLC, during the 400 hours test in April 2003. During the two weeks test period the process was stable with three close downs according blockages in the feeding system (figure 3).

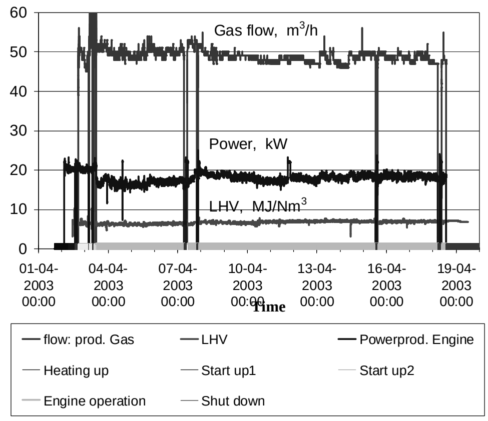

Figure 3: Plant performance during 400 hours experiment, April 2003.

3.2 Carbon loss

Unconverted char is lost from the system during two major sources.

- During the grate as ash particles.
- As dust removed by the bag house filter.

Minor amounts of carbon is lost by deposits in the gas system and by the clean gas delivered to the engine. In total the carbon loss is measured to be 0.1 – 1 % of the biomass consumption.

3.3 Tars

During this period three independent institutes measured the tar content in the raw and cleaned gas. Only one of them was able to measure a minor content of tar in the raw gas (0.1 mg/Nm^3 of naphthalene). The dust content in the gas was negligible as well (< 5 mg/Nm^3).

The gas produced has a very stable composition that makes engine operation easy to handle. The unconverted char in the ash is extremely low.

3.4 Condensate

The condensate from the gas cooler was analysed. It was not possible to detect any harmful compounds: F-, Cl^-, NO_2^-, NO_3^- (detection limit: 1 mg/l) PO_3^-, SO_3^-, SO_4^- (detection limit: 2 mg/l). Neither any tar-compounds (Naphthalene and higher) was detected. The results were compared to results from earlier investigations of condensate from the 100 kW two-stage gasifiers [9] and good agreement with the older experiments was found. High amounts of ammonia, approx. 1 g/l, are seen. This condensate can be led directly to the public sewer system.

3.5 Gas composition

The gas produced has a very stable composition (Table I) that makes engine operation easy to handle (Figure 4).

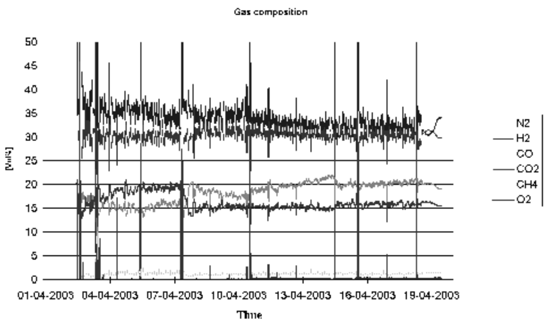

Figure 4: Gas composition during 400-hour experiment, April 2003.

Table II: Results from the 400-hours experiment in April 2003

Gas composition		
N_2	33.3	Vol-%
H_2	30.5	Vol-%
CO	19.6	Vol-%
CO_2	15.4	Vol-%
CH_4	1.2	Vol-%
O_2	0.1	Vol-%
LHV	5.6	MJ/Nm^3
HHV	6.2	MJ/Nm^3
Gas flow(dry)	37.1	Nm^3/h

The dust content in the gas was negligible as well (< 5 mg/Nm^3).

4 INSPECTION AFTER 2000 HOURS OPERATION

4.1 Feeding system.

No alarming corrosion or deposits observed.

4.2 Char gasifier

On the metal shell in the lower part of the reactor ash deposits were found. Surface corrosion was observed on this shell.

Further up in the reactor corrosion on the metal shell was seen as well. Here some iron scales were observed.

In the top the reactor, the ceramic brick lining construction was by visual inspection found mostly unaffected. Further inspection showed minor penetration of alkali in the outer 1-2 mm. In the next long term experiment further investigation with four different ceramics will be carried out.

The air nozzles were partly blocked by deposits of melted ashes.

4.3 Grate

On the grate a lot of big lumps of grey ashes were found. This was obviously not removed during operation, which is understandable as the grate was only activated few times during an experiment.

These lumps could not be removed through the grate, and would soon or later result in operation stop. An experiment was carried out, using additives to the biomass. Using these additives the lumps was avoided and the ash cold be removed during the grate.

4.4 Hot heat exchangers

The hot heat exchangers cool the gas from about 800 °C to about 450°C. Small but significant amounts of hard deposits were sticking to the bottom of the heat exchangers. Analyses of deposits showed that the deposits were ash with low carbon content. The deposits were water-soluble and easy removed by hot water.

4.5 Medium temperature heat exchanger

This heat exchanger cools the gas from about 450 °C to about 90°C. After the first 1200 hours only tiny amounts of deposits were seen. They were powder like and loose.

Later on the powder starts blocking the tubes and an increasing and unacceptable high pressure drop was observed. By installing a system of moveable wires in the tubes the problem was solved.

4.6 Gas system

The gas tubing between the 90 °C gas cooler and the bag house filter were inspected. No-sticking carbon powder was found.

After the bag house filter no visible dust was observed in the gas tubes, the police filter or the roots blower.

4.7 The Engine

The internal parts of the engine has been inspected several times, in order to inspect for the formation of deposits, wear and corrosion but no significant built up has been seen (figure 5).

Figure 5: Top of cylinder after 1400 hours of operation.

5 CONCLUSION

It was demonstrated that the two-stage gasifier could be operated for several thousands hours.

The gasifier was operated automatically day and night.

The operation was successful, and the output as expected.

The bag house filter was an excellent well operating gas cleaning system for this gasifier. No tar or particles was detected in the gas. The condensate produced was clean and acceptable for processing in biological sewage plants.

The engine operated well on the produced gas, and no deposits were seen in the engine afterwards. Small amounts of deposits were observed in the hot heat exchangers.

6 ACKNOWLEDGMENT

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