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Published in:

Proceedings of 1. World Conference and Exhibition on Biomass for Energy and Industry

Publication date:

2000

Document Version

Early version, also known as pre-print

[Link back to DTU Orbit](#)

Citation (APA):

Brandt, P., & Henriksen, U. B. (2000). Decomposition of tar in gas from updraft gasifier by thermal cracking. In *Proceedings of 1. World Conference and Exhibition on Biomass for Energy and Industry*

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DECOMPOSITION OF TAR IN GAS FROM UPDRAFT GASIFIER BY THERMAL CRACKING.

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ABSTRACT: Continuing earlier work with tar reduction by partial oxidation of pyrolysis gas [1] thermal cracking has been evaluated as a gas cleaning process. The work has been focusing on cleaning gas from updraft gasifiers, and the long term purpose is to develop a tar cleaning unit based on thermal cracking.

An experimental set-up has been built, in which a flow of contaminated gas can be heated up to 1290°C in a reactor made of pure Al₂O₃. Four measurements were made. Three with gas from a pyrolysis unit simulating updraft gasifier, and one with gas from an updraft gasifier. Cracking temperatures was 1200, 1250 and 1290°C, and the residence time at this temperature was 0.5 second.

The measurements show that at the selected residence time of 0.5 second, the gas flow in a thermal tar cracking unit has to be heated to at least 1250°C to achieve sufficient tar cleaning. At 1290°C, a tar content as low as 15 mg/Nm³ was obtained on gas from an updraft gasifier. The lower heating value of the cleaned gas was 6.0 MJ/Nm³, and the energy content of the non condensable gasses was 19% higher than before cracking.

1. INTRODUCTION

Continuing previous work with partial oxidation of pyrolysis gas [1], thermal cracking has been evaluated as a gas cleaning process. The work has been focusing on cleaning gas from updraft gasifiers, and the long-term purpose is to develop a tar cleaning unit based on thermal cracking.

The primary purpose of the work was to find the temperature needed for sufficient cracking of tar in the gas from an updraft gasifier at a fixed residence time (0,5 second). The secondary purpose was to determine the composition of the gas after cracking.

The residence time was selected on the basis of practical process considerations keeping in mind that data from the literature show that a higher residence time makes it possible to lower the temperature and still obtain a sufficient tar reduction [2].

2. EXPERIMENTAL

An experimental set-up has been built, in which a flow of contaminated gas can be heated up to a maximum temperature of 1290°C. The reactor in which the gas flows was made of pure Al₂O₃ to ensure no catalytic reactions on the surface. Actions were taken to ensure good heat transfer from reactor wall to the gas. The reactor was placed in an oven with two heating zones with separate temperature regulation. Figure 1.

Temperatures in the reactor were measured at 8 points in the centre of the reactor. The temperature profile along the centre of the reactor is shown in Figure 2.

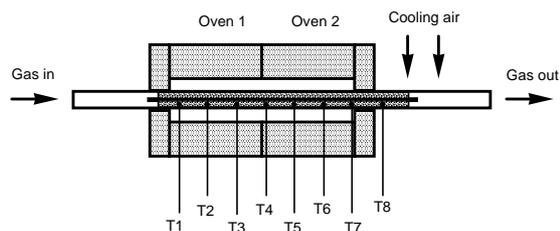


Figure 1. Reactor used in the experimental set-up.

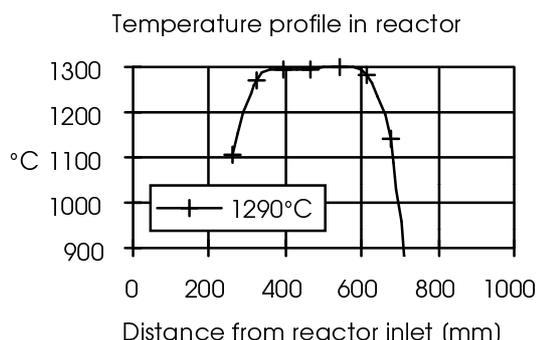


Figure 2. Temperature profile in reactor centre at 1290°C.

The tar content in the gas after cracking was measured by cooling the gas down to 15°C in a water-cooled condenser followed by a combined cottonwool and PUF aerosol filter. The water phase was collected in the condensate flask. Figure 3. After sampling the water phase was removed and the equipment was rinsed with acetone. The tar contaminated acetone was subsequently filtered for solids and analysed by GC/MS for light tars. Light tars were

defined as organic contaminants with retention times from phenol to pyrene (roughly 94u to 202u) using a non-polar 25-m fused silica column. The light hydrocarbons such as benzene, toluene and xylenes were not considered as tar compounds. The water phase was analysed for 27 PAH components and NVOC (non-volatile organic carbon)

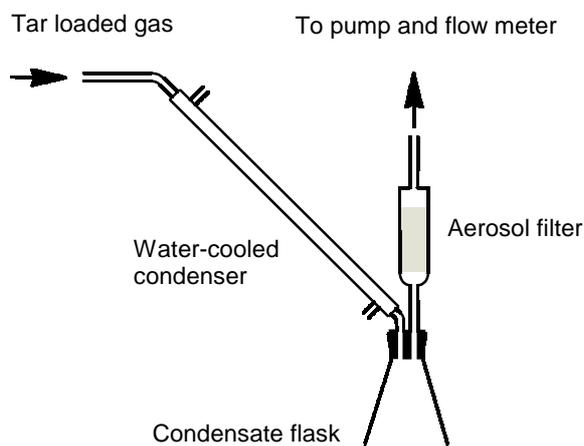


Figure 3. Tar sampling equipment

Between the cracking reactor and the tar measuring equipment, a combined quartz and glass wool filter, heated to 120°C, was placed in order to measure soot and particulates in the gas. After sampling, the filter was dismantled, and a sample of the soot was taken for subsequent determination of volatile by TGA-analysis.

Test runs were made, cracking tars in a pyrolysis unit simulating updraft gasifier tars and cracking tars in gas from an updraft gasifier. Feed stock for the pyrolysis unit was straw, and feed stock for the updraft gasifier was wood chips.

Table I. Tar and soot in gas after cracking.

Temperature in reactor [°C]	1200	1250	1290	1290
Gas producer	Pyrolysis	Pyrolysis	Pyrolysis	Updraft
Light tar in condenser determined with GC/MS [mg / kg dry feed stock]	670	21	1	7
Light tar in aerosol filter determined with GC/MS [mg / kg dry feed stock]	250	n.d.	5	10
Light tar in soot determined with GC/MS [mg / kg dry feed stock.]	n.d.	n.d.	n.d.	15
Soot in gas [g / kg dry feed stock]	4.8	6.6	6.3	3.6
Soot. Volatile after drying. TGA [%]	3	1	4	2
PAH in condensate. Sum of 27 components [mg / kg dry feed stock.]	19	0.021	0.033	0.070
NVOC in condensate [mg C / kg dry feed stock]	260	290	41	20

Note n.d.: not detected

3. RESULTS AND DISCUSSION

Four measurements were made. Three with the pyrolysis unit at 1200, 1250 and 1290°C and one with the updraft gasifier at 1290°C. The residence time for the gas at maximum temperature was 0.4 to 0.5 second. The contents of tar and soot in the gas are shown in Table I. The total content of light tar can be calculated as the sum of the light tar in the condenser, aerosol filter and in the soot. All three values are only present at the updraft measurement. The other measurements have been evaluated on the basis of the values that are present. According to Beenackers and Manuatis [3], the preferable tar content in gas for engine application are below 50 mg/Nm³. With a gas production of 2.6 Nm³/kg dry feed stock, this value is equal to 130 mg/kg dry feed stock. Comparing this value with the results in table I shows that cracking at 1200°C resulted in a to high tar content exceeding 1000 mg/kg dry feed stock. 1250°C was at the limit for sufficient tar reduction, and 1290°C gave the lowest value as expected.

The results from cracking tar from an updraft gasifier at 1290°C showed a slightly higher tar content than the pyrolysis unit experiment at same temperature. The total tar content in the cracked gas from the updraft gasifier can be calculated to be 32 mg/kg dry feed stock. This value is equal to 12 mg/Nm³, and 15 mg/Nm³ including an estimated heavy tar fraction.

The high cracking temperature results in a production of soot. SEM-analyses (scanning electron microscope) of the soot show agglomerated particles with a size of 0,1 µm. Soot in the gas was measured to be 3.6 g/kg dry feed stock at the updraft measurements.

Table II. Gas composition before and after cracking. Updraft gasifier

	Unprocessed gas	After cracking at 1290°C
H ₂ [Vol. %]	12.2	26.3
CO [Vol. %]	24.6	22.2
CH ₄ [Vol. %]	4.9	0.9
CO ₂ [Vol. %]	9.6	11.0
O ₂ [Vol. %]	0.0	0.0
N ₂ [Vol. %]	48.7	39.6
Lower heating value [MJ/Nm ³]	6.2	6.0

The gas compositions before and after cracking at the updraft measurement are shown in Table II. After cracking, the content of hydrogen was increased, and the content of methane and nitrogen was decreased.

The gas composition was consistent with the composition according to the water gas shift reaction at 1200°C. Assuming that the volume flow of nitrogen was constant before and after cracking, the gas volume after cracking was 23% higher and the energy content of the non-condensable gasses was 19% higher.

4. CONCLUSION

Four measurements were made with thermal cracking of tar loaded gas at 1200, 1250 and 1290°C. The results show that at the selected residence time of 0.5 second, the gas flow in a thermal tar cracking unit has to be heated to at least 1250°C to achieve sufficient tar cleaning. At 1290°C, a tar content as low as 32 mg/kg dry feed stock was obtained on gas from an updraft gasifier. This value is equal to 12 mg/Nm³, and 15 mg/Nm³ including an estimated heavy tar fraction. After cracking, the gas was nearly in equilibrium according to the water gas shift reaction. Soot in the gas was measured to be 3.6 g/kg dry feed stock. The lower heating value of the cleaned gas from the updraft gasifier was 6.0 MJ/Nm³, and the energy content of the non condensable gasses was 19% higher than before cracking.

ACKNOWLEDGEMENTS

This work was financed by the Danish Energy Agency.

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