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Wood Gasification Behaviour in an Entrained Flow Reactor

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Abstract

Wood gasification has been studied in a laboratory scale atmospheric pressure entrained flow reactor. Effects of operating conditions on the solid and gas products were investigated. The wood was completely converted at all investigated operating conditions but the syngas still contained some soot. Higher temperature, steam addition, relatively higher excess air ratio, longer residence time and increasing feeder air flow can effectively decrease the soot yield, while the inlet oxygen level seems not to influence the soot yield significantly.

1 Introduction

Among the renewable energy sources, biomass has a high potential [1][2]. Gasification is one of the key technologies for utilization of biomass [3]. Of several gasification methods entrained-flow gasification has the advantage to produce a gas with low tar content and possibility to run at high pressure [4].

In this work, wood gasification was investigated under entrained-flow reactor conditions with respect to gas composition and soot yield as a function of operating conditions, such as reactor temperature, steam/carbon ratio, excess air ratio, inlet oxygen level, residence time and feeder air flow.

2 Experimental

A laboratory scale atmospheric pressure entrained-flow reactor was used for wood gasification experiments. It has an inner diameter of 0.08 meter and a length of 2 meter. The reactor is externally heated by seven independent electric heating elements, which can be heated to a maximum temperature of 1500°C. A reasonably uniform temperature in the reactor can be realized. Fuel and feeder air are fed through a central water-cooled tube while the remaining gas (named main gas) is preheated to the reactor temperature and fed in a co-axial tube around the fuel feeder tube. Besides the reactor, the complete facility includes equipment for fuel particle feeding, gas supply, solid particle sampling, gas sampling and analysis, liquid sampling, and flue gas treatment.

3 Results and Discussion

A reasonable carbon mass balance closure was achieved for all conditions (carbon out/carbon in ≥95%).

Effect of reactor temperature: The researched reactor temperature range is 1200-1400°C at fixed other parameters (steam/carbon ratio=0.5, excess air ratio=0.3, inlet oxygen level=21%, residence time=3.0s and feeder air flow=10Nl/min). The product distribution is shown in Figure 1. The yields of H_2 and CO increase while CO_2 yield decreases with increasing temperature because char and soot gasification is endothermic. The increased H_2 and CO_2 formation is also caused by the conversion of tar and larger hydrocarbons into lighter gaseous products. The yield of C_xH_y (hydrocarbon up to C_3 species) decreases because it is converted to soot and light gases at higher temperature. From 1200°C to 1400°C, the soot yield decreases because at higher temperature soot has higher gasification reactivity.

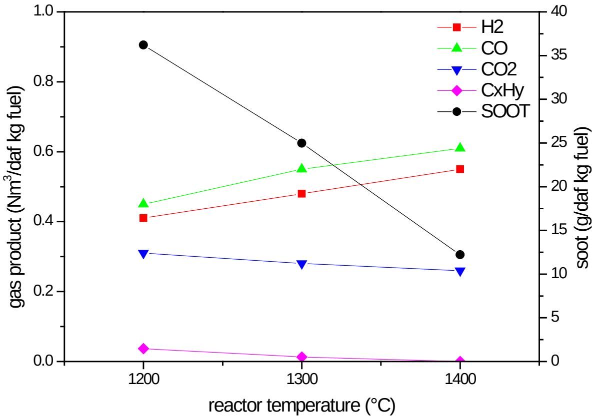

Figure 1 The effect of reactor temperature

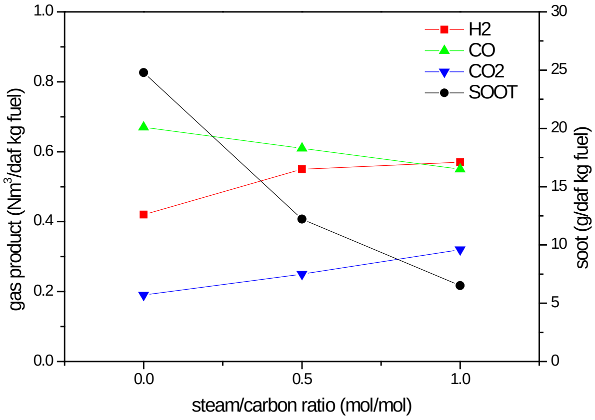

Figure 2 The effect of steam/carbon ratio

Effect of steam/carbon ratio: The researched range of steam/carbon ratio is 0-1 at fixed other parameters (reactor temperature=1400°C, excess air ratio=0.3, inlet oxygen level=21%, residence time=3.0s and feeder air flow=10Nl/min). The product distribution is shown in Figure 2. As the steam/carbon molar ratio increases, the H_2 and CO_2 yields increase, accompanied with a decrease of the CO yield, because the steam addition tends to promote the water gas shift reaction. The yield of soot decreases clearly with increasing steam/carbon molar ratio due to steam gasification of the soot.

Effect of excess air ratio: The researched range of excess air ratio is 0.25-0.35 at fixed other parameters (reactor temperature=1400°C, steam/carbon ratio=0.5, inlet oxygen level=21%, residence time=3.0s and feeder air flow=10Nl/min). The product distribution is shown in Figure 3. The H_2 and CO yields decrease with increasing excess air ratio, whereas the CO_2 yield increases due to oxidation of soot and CO. It is observed that the amount of soot decreases with increasing excess air coefficient because a larger part of the soot or its precursor is combusted.

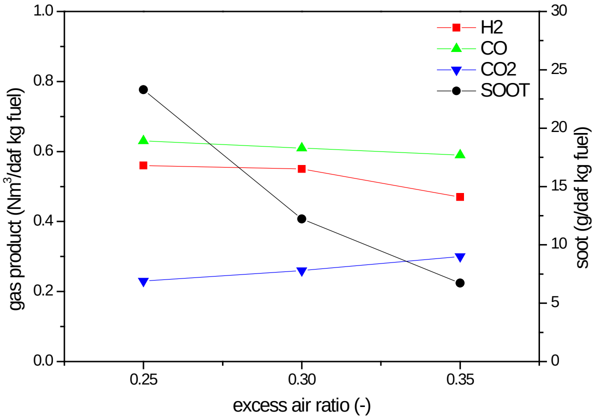

Figure 3 The effect of excess air ratio

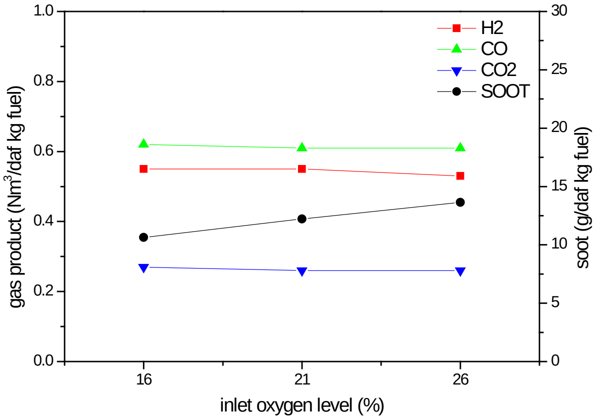

Figure 4 The effect of inlet oxygen level

Effect of inlet oxygen level: The researched range of inlet oxygen level is 16-26% at fixed other parameters (reactor temperature=1400°C, steam/carbon ratio=0.5, excess air ratio=0.3, residence time=3.0s and feeder air flow=10Nl/min). The product distribution is shown in Figure 4. It seems no big influence on the product yields except the soot yield increase a little with the increasing inlet O_2 level.

Effect of residence time: The researched range of residence time is 2.4-3.6s at fixed other parameters (reactor temperature=1400°C, steam/carbon ratio=0.5, excess air ratio=0.3, inlet oxygen level=21% and feeder air flow=10Nl/min). The product distribution is shown in Figure 5. With increasing the residence time, the yields of gas product almost keep constant, while the soot yield decreases slightly because more soot can be gasified in a longer reaction time.

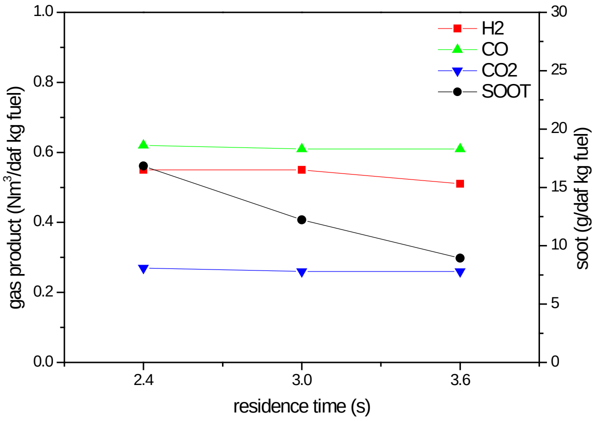

Figure 5 The effect of residence time

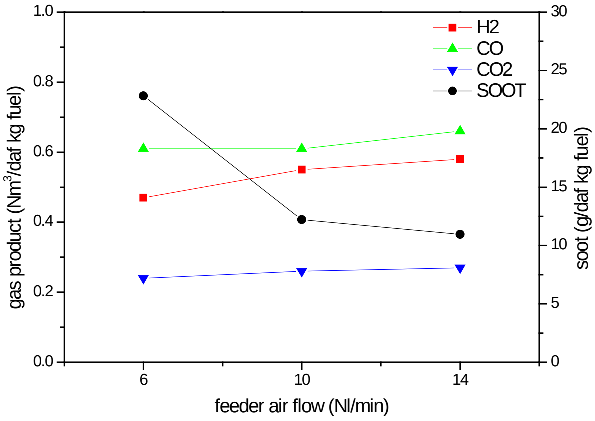

Figure 6 The effect of feeder air flow

Effect of feeder air flow: The researched feeder air flow range is 6-14Nl/min at fixed other parameters (reactor temperature=1400°C, steam/carbon ratio=0.5, excess air ratio=0.3, inlet oxygen level=21% and residence time=3.0s).The product distribution is shown in Figure 6. The gas product yields increase but the soot yield decreases because increasing the feeder air flow can improve the mixing condition. Probably improved mixing leads to tar converted to gas instead of cracking to soot.

References

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