Experiments and numerical simulation of sawdust gasification in an air cyclone gasifier

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HIGHLIGHTS

- High-temperature gasification with less oxygen is studied in a cyclone gasifier.
- Biomass fast pyrolysis model is built.
- Particle size, tar combustion and gas temperature effect the yields of CO and CO2.

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ABSTRACT

In this paper the gasification of sawdust in an air cyclone gasifier was investigated to produce a high-quality fuel gas with less tar. The effect of air to fuel ratio on the gasification characteristics was studied. The results indicate that as the air to fuel ratio varying from 0.23 to 0.35, the lower heating value of the produced gas is 4.5–5.7 MJ/Nm³, the carbon conversion is 77.0–94.2%, the cold gas efficiency of the gasification system is 53.6–63.0%, while the tar content is 4.4–8.4 g/Nm³. A detailed CFD model of a cyclone gasifier has been developed, based on the Fluent package. Models of sawdust pyrolysis and combustion of volatiles and char have been added to the standard model. The model provides information on the gas temperature in the gasifier and the composition of the outlet gas.

1. Introduction

Biomass is a major potential resource for energy production. Gasification of biomass is a promising technology that provides a competitive means for producing chemicals and energy from renewable energy resources. A lot of research has been made on biomass gasification. Cyclone gasifier is a type of entrained-flow bed used as both a gas cleaner and a gasifier. Gabra et al. [1] investigated the cyclone gasification in order to keep the gasification temperature at a lower level where the volatilisation of corrosive elements such as sodium and potassium will not occur. The sodium and potassium can then be separated with the char residue. Guo et al. [2] investigated air–steam cyclone gasification of biomass micron fuel (0.083–0.198 mm) in order to increase H₂ content. As well known, gas–solid mixing in the cyclone separator is strongly. The main objective of this study is to achieve high-temperature gasification with less oxygen based on the strongly gas–solid mixing in order to decrease tar content of the produced gas. The paper presents experiments of sawdust gasification in a cyclone gasifier, and the effect of air to fuel ratio on the cyclone gasification of sawdust was studied.

Numerical simulation is an effective means to design, scale and optimize gasifiers. Investigations of modelling biomass gasification have been carried out by many different researchers [3–8]. Biomass is a characterized by a higher content of volatile matter, and biomass pyrolysis is the first step of biomass gasification. Various pyrolysis reactions have been used in the simulation of biomass gasification. Zhou et al. [4] developed a one-dimensional unsteady heterogeneous mathematical model for straw combustion in a fixed bed. The volatiles composition mass fraction used in the model was obtained from TG-FTIR analysis of biomass pyrolysis. Umeki et al. [5] addressed the performance analysis of an updraft gasifier using a numerical model. In the model, coefficients of the pyrolysis reaction were taken from fixed pyrolysis reactor. Sharma [6] developed a mathematical model EQB for a downdraft biomass gasifier and the pyrolysis process was modelled at slow heating rate as a function of temperature and residence time. Fletcher et al. [7] simulated the flow and reaction in an entrained flow biomass gasifier based on the CFX package, which addressed combustion modelling via the addition of a simple model for devolatilization. Oevermann et al. [8] assumed a heat-neutral pyrolysis