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Intrinsic reactivity of biomass-derived char under steam gasification conditions-potential of wood ash as catalyst

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HIGHLIGHTS

- Steam gasification of biomass char was studied in a thermo-gravimetric analyzer.
- Biomass gasification can be catalytically enhanced by its own ash.
- Char can be completely gasified within 12 min at 700 °C.
- Ash loading and distribution are important for obtaining high gasification rates.
- CO and H_2 in the gasifier can inhibit char gasification by a factor 2.

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ABSTRACT

The influence of ash on the steam gasification rate of pine wood derived char particles in the temperature range 600–800 °C is investigated. Ash derived from pine wood or specific ash components were added to the pine-wood (before pyrolysis) or to the produced char (after pyrolysis) via physical mixing or impregnation. The addition method and the amount and type of ash/ash component have been studied and the obtained gasification rates are compared. Impregnation of ash/ash components by ~10 wt% or more (in the original pine wood) always resulted in a significant increase in the (initial) gasification rate. At 700 °C, e.g., impregnating 9.5 wt% KOH in pine wood resulted in complete char conversion within 12 min, corresponding to an increase in (initial) gasification rate by a factor 30 compared to char without impregnation. SEM images of the chars showed that impregnating the wood with concentrations up to 14 wt% resulted in unevenly distributed ash (components) in the particles. Based on this, the hypothesis is that besides the overall amount of ash also its distribution among and inside the char particles is important for enhancement of the reaction rate. A biomass gasification concept in which the steam gasification reaction of char is catalyzed by concentrating the ashes in the biomass is feasible.

1. Introduction

Biomass gasification has drawn a lot of attention over the past decades as a process for power generation, for gaseous and liquid fuels production, as well as for chemicals [1]. The most important heterogeneous gasification reactions taking place during the gasification process which involve solid carbon are: the water–gas reaction (1), the Boudouard reaction (2) and the heterogeneous methanation reaction (3).

$$C + H_2O \leftrightarrow CO + H_2 \quad (1)$$

$$C + CO_2 \leftrightarrow 2CO \quad (2)$$

$$C + 2H_2 \leftrightarrow CH_4 \quad (3)$$

In this paper, these reactions are studied and in particular the effect of ash additives on the reaction (gasification) rates. The work presented in this paper is part of a larger research program dealing with methane production from biomass via thermal gasification [2,3]. In this concept, alkali(ne earth) metals contained in the biomass are intended to catalyze pyrolysis, gasification, methanation and tar cracking/reforming.

Char steam gasification has been a research topic for many years, especially in the coal gasification research of the 1980s. A lot of work is available on the steam gasification of coal char with various mixed or impregnated alkali metals such as: K_2CO_3 [4–18], KOH [5,6,14,18], KCl [6,9,14,18], $KHCO_3$ [18], KNO_3 [15,18], K_3PO_4 [15], Na_2CO_3 [7,9,14], NaOH [11,14], NaCl [6,9,14]. Calcium has also been studied for coal char steam gasification as a cheap alternative to alkali metals: CaO [9,17], $Ca(OH)_2$ [13], $CaCl_2$ [9], as well as iron

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