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A deep insight into carbon conversion during Zhundong coal molten salt gasification

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ABSTRACT

Molten salt gasification is a promising way for collaborative use of solar energy and Zhundong coal, with in situ capture of Cl/S-pollutants as well as alkali metals. The present study provides a deep insight into carbon conversion during molten salt gasification of a typical Zhundong coal in ternary carbonate eutectics (Li_2CO_3-Na_2CO_3-K_2CO_3). The results demonstrated that the molten salt gasification of Zhundong coal underwent a rapid devolatilization of raw coal and then the gasification of char. The interactions between CO_2 and volatiles promoted the cracking of macromolecular compounds, increasing the carbon conversion efficiency during the devolatilization process. The gasification of char was mainly determined by the direct reaction with molten salt, which was slightly affected by the CO_2 concentration in the carrier gas. The results of char characterization evidenced that the condensation/graphitization of char was stimulated in the molten eutectics. Meanwhile, a large amount of O-containing groups, especially carbonyl groups, were formed in the molten salt treated char with carbonates as oxygen supplier. Under the influence of molten salts, some carbonyl groups would be formed inside the char. However, the decomposition of those carbonyl groups was suppressed by the mass transfer resistance of the released CO and/or CO_2. Applying proper feeding mode, such as feeding coal in pulverized form, could enhance the contact of coal, molten salt and CO_2, which remarkably promoted the interactions between molten salts and char containing functional groups.

1. Introduction

In China, coal acts as the most important fossil resource for power generation and plays a significant role in the production of chemicals (such as ammonia) via gasification technology [1]. In order to meet the increasingly stringent environmental protection requirements of China, it has been put on schedule to seek renewable and sustainable access to energy, and more importantly, to promote high-efficient utilization of coal [2]. Molten salt gasification is one means to convert coal into gaseous fuel, supporting power generation as well as chemical industry [3]. Meanwhile, the molten salt is capable of in situ capture of various pollutants, including hydrogen sulfide and hydrogen chloride [4]. On the other hand, molten eutectics have been widely investigated as heat transfer fluids for solar energy storage, which provides a feasible way for the continuous utilization of solar energy on a large scale [5].

In northwestern China, there are abundant resources of both coal and solar energy [6,7]. However, only a small part of solar energy has been exploited [7]. Moreover, the coal produced therein (such as Zhundong coal) generally contains a high concentration of alkali and alkaline earth metals (AAEMs) [8]. Those AAEMs will cause severe slagging, contamination and/or corrosion problems during direct coal combustion or gasification process [9]. The molten salt gasification technology could achieve synergistic and proper utilization of the solar energy and Zhundong coal. Specifically, the solar energy is concentrated in the molten salt, and then promotes the conversion of coal into synthetic gas, avoiding its partial combustion in conventional gasification [10]. More importantly, coal containing AAEMs are dissolved into the salts during the molten salt gasification, reducing the damage to devices.

Generally, fundamental work has been laid by researchers applying Na_2CO_3-K_2CO_3 eutectic salt mixtures in molten salt gasification of coal, municipal solid waste and biomass [3,11,12]. The overall reaction of solid fuel molten salt gasification is an endothermic Boudouard reaction (Eq. (1)), which is supported by the heat stored in molten salt. In addition, the alkali metal carbonates have catalytic effect on the carbon conversion of solid fuels, demonstrated as the following equations (Eqs.

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