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Morphological evolution of single char particle with low ash fusion temperature during the whole gasification process

Ming Liu[1,2], Zhongjie Shen[1,2], Qinfeng Liang[1,2,3], Jianliang Xu[1,2], Haifeng Liu[1,2,*]

1 Key Laboratory of Coal Gasification and Energy Chemical Engineering of Ministry of Education, East China University of Science and Technology, P. O. Box 272, Shanghai 200237, PR. China;
2 Shanghai Engineering Research Center of Coal Gasification, East China University of Science and Technology, P. O. Box 272, Shanghai 200237, PR. China;
3 State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences

Highlights

- Surface characteristics of coal char during gasification process was analyzed.
- Ash on char surface was loosen structure below deformation temperature.
- Ash agglomerated to molten slag with compact structure above fusion temperature.
- The slag thickness was related to the dramatic decrease of particle shrinkage.

1. Introduction

Entrained flow gasifier operates at the high temperature and high pressure condition. The temperature inside the gasifier is above the ash fusion temperature, and the reactivity of carbon particle is sensitive to the reaction temperature. The high reactivity of brown coal char mainly because of the porous structure and the catalytic effect of ash forming is in significant at or above 1200 ℃ [1]. Besides, the molten ash inhibits the diffusion of gasifying agent above the fusion temperature. The effects of mineral in coal and its fusion on gasification reactivity of coal was investigated by Ding et al. [2]. It was found that ash content, ash fusion temperature and gasification temperature are accountable for the char-slag transition process [3]. Gasification reactivity of raw coal char is higher than that of de-ash char at the conversion of 0-0.9, while the gasification reactivity of raw char decreased when the conversion was above 0.9. This indicated that the gasification products were barriers to the reaction. The char structure development during gasification was studied by Komarova, et al. [4]. The micropore of coal char develop to mesopore during the reaction. The reactivity of coal char depends more on the surface area and pore volume compared with graphite crystallites [5]. It was found that the mineral in coal ash obviously catalyze the gasification of char below the deformation temperature. While above the fusion temperature, the aggregation of minerals blocks the meso- and micropores in char, which reduces the initial gasification rate [6]. The fusion of coal ash on the particle surface may gather to form a slag layer and covered the reaction surface, which hinder the contact of carbon and reactant gas. Therefore, the evolution of morphology of coal char and the ash fusion on the char particle surface were of importance to the gasification.

2. Methods

In this study, two representative coal samples (Xiaolongtan lignite coal and Shenfu bituminous coal) were chosen to prepared for coal chars. To study the morphological evolution of char particles, the whole gasification process was recorded by high temperature stage microscope system (HTSM) [7]. The experimental system consists of a TS1500 high temperature stage (Linkam, U.K.), DM4500P LED microscope and a camera (Leica, Germany), gas supply system, recirculated cooling water system and a computer. Char particles were spread on the sapphire slip (99.9% purity of Al_2O_3) in a ceramic crucible. The ceramic crucible and char samples were heated to 100 ℃ by a copper heating element and held for a minute in Ar atmosphere to preheat the apparatus. The temperature then rose to 1300 ℃ at the rate o The projecting plane of char particles during reaction process was further measured and analyzed by ImageJ software f 100 ℃ /min and was held for 10 min at 1300 ℃ to stabilize the temperature of char particles. The reaction began with switching the gas flow from Ar (99% purity) to CO_2 (99% purity) at the flow rate of 0.3 L/min. Meanwhile the microscope camera system began to record the complete gasification process at 1300 ℃.

3. Results and discussion

In this study, morphological evolution of single char particle with low ash fusion temperature was investigated using in-situ high temperature stage microscope (HTSM). The shrinkage of char particles above the deformation temperature (1300 ℃) was higher than that below the deformation temperature (1000 ℃). Besides, there was a critical shrinkage above the deformation temperature during the gasification process, and the value of it was about 0.7-0.8. The morphological evolution of coal char is significantly affected by the reaction products, especially for coal with high ash content. Below the ash fusion temperature, the coal ash after gasification reaction formed a solid layer with porous structure. Above the ash fusion temperature, the coal ash was melted at high temperature and transformed into molten slag, which covered the char particle (see in Figure 1), which evidently hindered the diffusion of gasifying agent. The EDS analysis indicated that the critical point in the shrinkage curve was related to the molten slag on char surface. The evolution of the average thickness of slag layer on char surface was calculated to analyze the gasification characteristics. It was found that the critical thickness of slag layer was about 3-12 μm and coal chars with different ash contents showed a good coincidence.

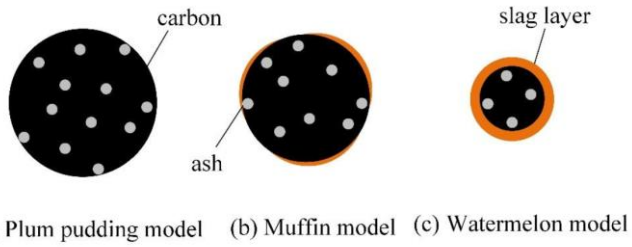

Figure 1. Schematic of the characteristics of coal char at different reaction stages above thedeformation temperature.

4. Conclusions

The shrinkage of char particles above the deformation temperature (1300 ℃) was higher than that below the deformation temperature (1000 ℃). A critical point in the shrinkage curve of the gasification process above the deformation temperature, and the critical shrinkage of XLT char was about 0.7-0.8. The ash in coal char was a disperse distribution and the dispersed molten slag gradually aggregated to molten slag layer during the reaction process above the deformation temperature, which evidently hindered the diffusion of gasifying agent. The critical point in the shrinkage curve was related to the molten slag layer on char surface. The evolution of the average thickness of slag layer on char surface was calculated to analyze the gasification of coal char. The shrinkage of coal char dramatically decreased when the thickness of slag layer on char surface reached to the critical point. Furthermore, it was found that the critical thickness of slag layer was about 3-12 μm and coal chars with different ash contents showed a good coincidence.

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Keywords
Coal, char, gasification, molten slag layer.