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Experimental study of the particle deposition characteristics in an entrained flow gasifier

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HIGHLIGHTS

- Particle deposition characteristics are studied based on a hot model gasifier.
- Advanced visualization techniques are applied in this study.
- Particle deposition characteristics are classified into four different types.
- Statistical results of deposition characteristics are obtained for the first time.

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ABSTRACT

With the development and operation of the bench-scale opposed multi-burner gasification system and the application of advanced visualization techniques, the particle deposition characteristics in a gasifier has been studied. The particle deposition characteristics are mainly divided into four different types: particles impact and adhere, particles impact and rebound, particles detach after adherence, and particles impact and break up. The high-temperature and low-temperature particle deposition characteristics are discussed separately. The probability of low-temperature particle impact and adhere (39.50%) is approximately the same as that of impact and rebound (45.50%), and the proportion of adhered particles detach from refractory wall is 12.50%. The probability of high-temperature impact and adhere is 75.70%, which is much higher than that of impact and rebound (21.10%), whereas only 0.80% of high-temperature particles detach after adherence. The proportion of particle break up is almost the same for both high- and low-temperature particles, with a percentage of ~2.50%.

1. Introduction

Coal gasification plays an important role in clean coal technologies to convert coal to chemical products or energy. Entrained-flow gasification is operated at a temperature of 1550–2000 K, where chemical reactions proceed so rapidly that the velocity of the reaction process is controlled by diffusion process (Higman and Burgt, 2008). East China University of Science and Technology (ECUST) has developed the opposed multi-burner (OMB) gasification technology based on the principle of impinging flow strengthening mixing and has successfully demonstrated the technology in industry (Yu et al., 2011). With widespread and successful application, this technology has greatly promoted the development of the coal chemical industry in China (Gasification Technologies Council, 2015). Currently, ECUST's OMB gasification technology is one of the leading technologies in the world gasification market (Gasification Technologies Council, 2015).

As the key equipment of the gasification process, the gasifier is operated at high temperature and high pressure. Massive particles are generated in a gasifier during coal water slurry (CWS) gasification. Most gasification reactions occur on particles, and their characteristics can be considered as important criteria for the evaluation of the gasification process. The operational conditions of the gasifier are highly related to the particle surface temperature, including its spatial location, particle morphology, and particle deposition characteristics. Thus, the investigation of particle deposition in a hot model gasifier

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with advanced visualization technologies is one of the key research areas in the study of the gasification process.

Due to the complicated environment in a gasifier generated by combustion and gasification, the investigations on particle deposition in a gasifier are mainly based on simulation, while the experimental investigations are relatively rarer. The prediction methods of particle deposition are mainly divided into the empirical distinguishing model and the mechanism model. Researchers have proposed several slag models, including ash and slag formation (Yan et al., 2001; Lee and Davis, 2000), particle movement in space (Greenfield and Quarini, 1998; Fan and Ahmadi, 2000), particle impinging and sticking on a wall (Wood, 1981; Guha, 1997), and particle deposition and growth (Richards et al., 1993; Erickson et al., 1995). Because the traditional approach to the prediction of deposition behavior is usually unreliable, Wang and Harb (1997) integrated an ash deposition model with detailed analysis of the particle deposition process, which includes a description of the deposit growth that approximates both the physical properties and the chemistry of the deposit as a function of operating conditions.

Considering the impinging and sticking process of particle deposition, Walsh et al. (1990) proposed a model that combines ash melting temperatures with slag viscosities to predict the probabilities of particles sticking on the wall. Zhao et al. (1996a, 1996b)established a theoretical model based on the Lagrangian formulation in order to study the process of the impingement of a liquid droplet upon a substrate, and the effects in terms of substrate material, droplet size, physical properties and impinging speed were discussed separately, each of which was verified by experiments. By adopting an Eulerian approach, the particle impinging dynamics and the thermal phenomena were modeled by Le Bot et al. (2005), this model was used to simulate the flow field and temperature distribution in the impingement process. The volume of fluid (VOF) function can also be used to simulate the impinging process (Liu et al., 1993; Fujimoto et al., 2007). Furthermore, Pasandideh-Fard et al. (2002) improved the three-dimensional model of Bussmann et al. (1999) by introducing heat transfer and phase transition to the model; this improved model showed good agreement with the experimental results. Based on a gasification system, Ni et al. (2011) developed a submodel for predicting slag deposition by defining the excess rebound energy required to establish the rebound criterion.

The above-mentioned models have greatly contributed to understanding the particle deposition process. To establish a reliable deposition theory, essential experiments are performed by researchers. The drop tube furnace (DTF) is widely used in particle deposition

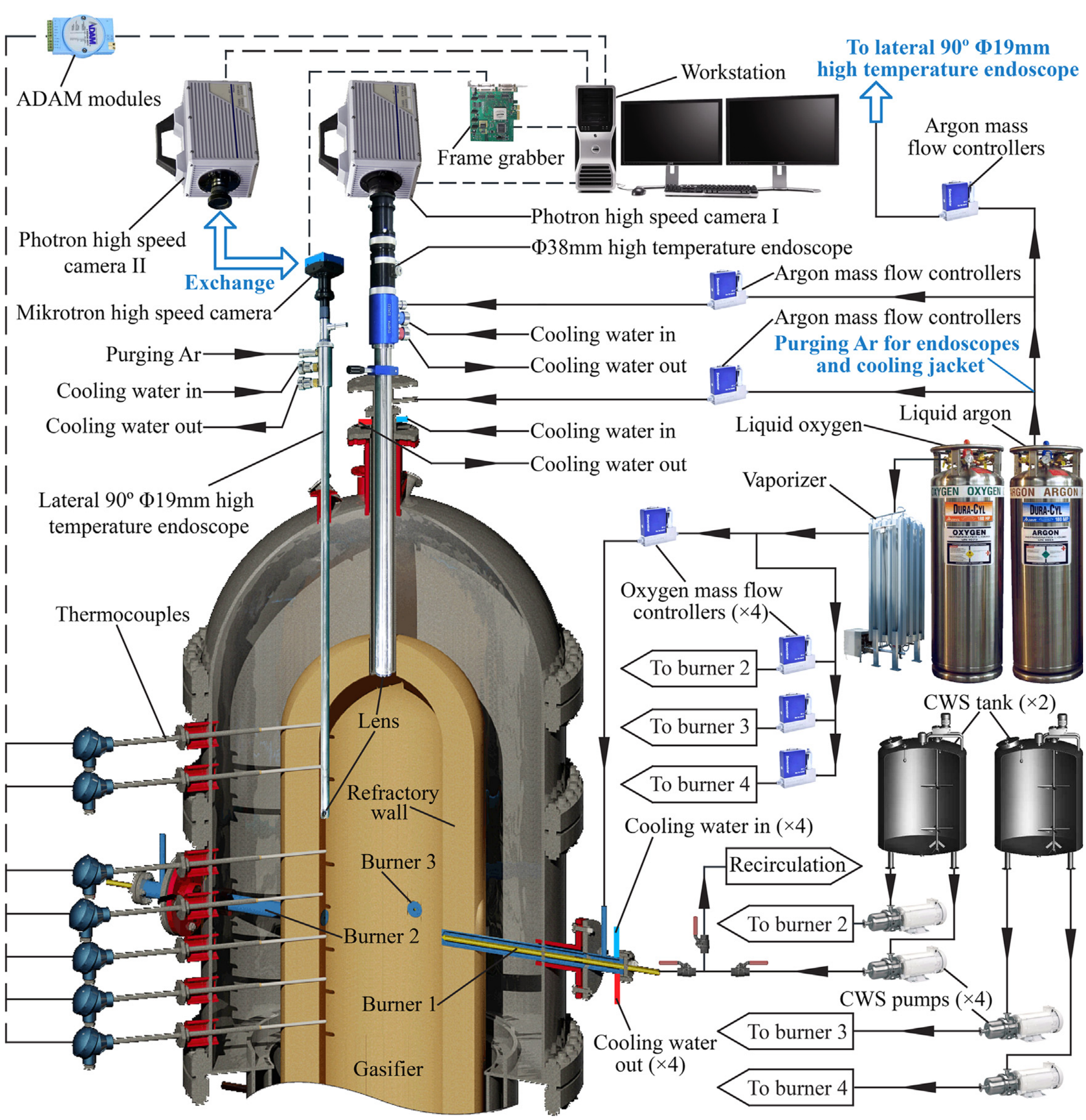

Fig. 1. Schematic diagram of the OMB gasification platform.