In-Situ Study on Thermal Behaviors of Coal Particles Based on Entrained-flow CWS Gasification

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Highlights

- The in-situ study of high-temperature particles in entrained-flow gasifier is realized.
- The axial evolution of particle group below the burner plane of the gasifier is revealed.
- The life-cycle conversion of a single coal particle is discussed in detail.
- The volatile oxidation behavior and flame ignition and propagation are analyzed.

1. Introduction

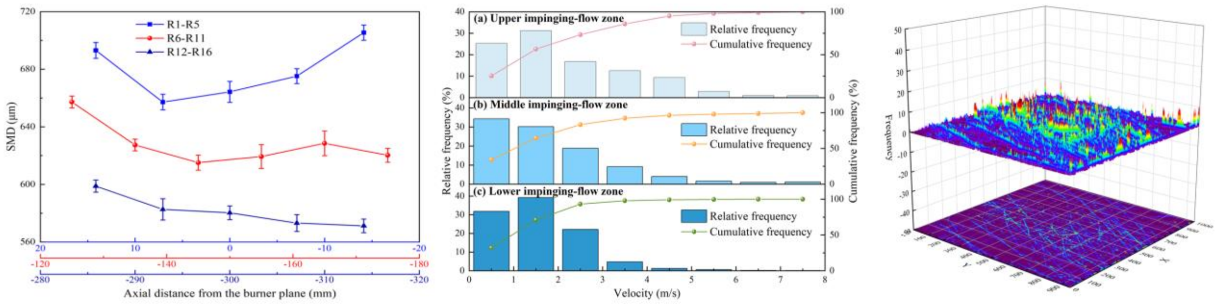
The opposed multi-burner (OMB) entrained-flow coal-water slurry (CWS) gasification technology strengthens the homogeneous mixing and multi-phase transfer process by introducing impinging flow technology [1]. During the gasification process, the flow rate of particles generated from CWS atomization in the gasifier is high, and the residence time is short [2]. The thermal behaviors of the particles have significant effects on the heat transfer and reaction in the gasifier. As the particles move down along the axial direction, the gasification reactions proceed more severely [3], whereas the space-time-resolved evolution of the particle group and single particles below the burner plane is still far from being understood. Benefited from improvement of the temperature tolerance and stain resistance of the imaging systems, the detailed characteristics of the axial particle group evolution and single particle conversion in the hot environment in the gasifier is investigated.

2. Methods

Experiments are carried out based on bench-scale OMB CWS entrained-flow gasification experimental platform. The composition of the experimental platform, especially the structure of the gasifier, as well as the experimental procedure, can be found in [4]. The radial system composed of a PCO Dimax S4 high-speed camera, a high-temperature endoscope and a 0/45 ° lens is used to collect the image sequences of coal particles in the upper impinging-flow zone, middle impinging-flow zone and lower impinging-flow zone [4]. A calibration system has been built outside the gasifier (the same as the parameters set during the experiment) [5] to obtain the scale factor. The image post-processing algorithms [6] are adopted to extract the information of the particles.

3. Results and discussion

3.1. Axial evolution of particle group



(a) SMD (b) Velocity distribution (c) Spatial distribution

Figure 1. Axial evolution of particle size distribution (a), velocity distribution (b), and spatial distribution (c).

Figure 1 shows the axial evolution of particle size, velocity field and spatial distribution. The results show that the Sauter mean diameter (SMD) is distributed in the range of 560–720 μm in all statistical regions, and the particle concentration is distributed in the range of 20,000–360,000. Both of the SMD and the particle concentration get smaller in the zones farther away from the burner plane. The proportion of particles ranging in the velocity interval of 0–4 m/s increases with the axial downward movement of the particle group in the three impinging-flow zones, which are 85.76 %, 92.33 % and 97.88 %, respectively. The average velocity of particle group decreases, which are 2.17 m/s, 1.83 m/s, 1.58 m/s, respectively. The spatial distribution frequency decreases.

3.2. Time-resolved conversion of a single particle

The conversion of a single particle can be divided into four typical stages, which are heat up and pyrolysis, volatile oxidation, volatile/char oxidation and char oxidation, respectively. In the upper impinging-flow zone, less than 30 % of the particles are in volatile oxidation stage, while about 50 % of the particles are in char oxidation stage. With the axial downward movement of the particle group, the proportion of particles in char oxidation stage decreases, while the proportion of particles in volatile oxidation stage shows an opposite trend.

3.3. Volatile oxidation and flame propagation

With the development of oxidation, the probability density function (PDF) of volatile flame intensity changes from single-peak distribution to multi-peak distribution, indicating that the volatile oxidation is a dynamic process. The change of the flow field and temperature distribution around the particle results in the uneven amount of pyrolysed volatile. A macroscopic description (**Figure 2**) of ignition and propagation of particle volatile flame is proposed to explain the oxidation behavior of particle volatile in the entrained-flow gasifier.

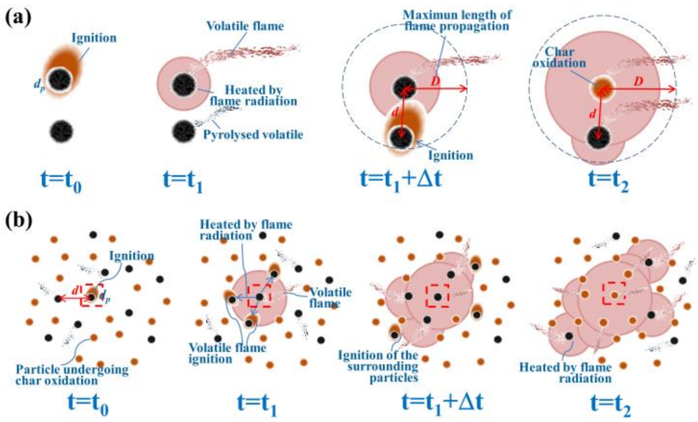


Figure 2. Macroscopic description of volatile flame ignition and propagation, (a) single particles and (b) particle group..

4. Conclusions

An in-situ study of the axial evolution of particle group below the burner plane and conversion of a single coal particle is carried out in a visualized impinging entrained-flow gasifier. The results indicate that with the axial downward movement of the particle group, the SMD, particle concentration and spatial distribution frequency show an overall decreasing trend. The conversion of a single coal particle can be divided into heat up and pyrolysis, volatile oxidation, volatile/char oxidation and char oxidation. The propagation of volatile flame between singles particles can be extended to the propagation of volatile flame within particle groups.

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Keywords
Entrained-flow gasifier, Particle group evolution, Single coal particle conversion, Volatile flame propagation