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Cold experiments on ligament formation for blast furnace slag granulation

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ABSTRACT

Rotary cup atomization for molten slag granulation is an attractive alternative to water quenching. However, the mechanism of disintegration of molten slag must be assessed. In the present study, a glycerol/water mixture was substituted for molten slag, and the mechanism of ligament formation in a rotary cup was investigated using photos taken by a high-speed camera. The effects of the angular speed and inner depth of the rotary cup on ligament disintegration was investigated.

The results showed that one state of disintegration may transform into another state as the angular speed of the rotary cup increases at a given liquid flow rate. During ligament formation, the number of ligaments increased with an increase in the angular speed of the rotary cup, and a decrease in the diameter of ligament and liquid drop was observed. Moreover, the initial point of disintegration of the ligament moved to the lip of the rotary cup as the angular speed increased. An equation describing the relationship between the diameter of the liquid drop and various factors was used to predict the diameter of the liquid drop. A rotary cup with an inner depth of 30 mm was the best choice for granulation. The results of the present study will be useful for designing devices used in molten slag granulation.

1. Introduction

Currently, blast furnace slag, which is emitted at temperatures ranging from 1450 to 1650 °C, is treated by water quenching, and the heat of the slag is not recovered, despite the large heat content of molten slag. Moreover, large amounts of energy are consumed during water quenching, and harmful waste is discharged into the environment. Dry granulation for molten slag has recently received a considerable amount of attention due to environmental and energy considerations. In dry granulation, molten slag granulates into particles, and the waste energy of slag can be recovered to produce steam or heated air in moving or fluidized beds. Thus, the waste heat recovery rate of the system is determined by the diameter of slag particles. Pickering et al. [1], Featherstone et al. [2], Purwanto et al. [3] and Mizuochi et al. [4] used a rotary cup as an atomizer for molten slag granulation, and Yoshinaga et al. [5], Xie et al. [6] and Purwanto et al. [7] used a rotary disk as an atomizer. Mizuochi et al. conducted cold experiments on rotary vaned-disks and wheels for slag granulation to determine the optimal atomizer [8]. However, the mechanism of disintegration of molten slag must be further investigated.

Rotary cups and disks have been widely used for gas–liquid contact processes in chemical, agricultural and food-related industries [9–11]. Hinze and Milborn identified three different types of disintegration, including direct drop formation, ligament formation and sheet formation, which may occur around and beyond the lip of the rotary cup, the central axis of which is horizontal [12]. For a given liquid, rotary cup and angular speed, the transition from one state to another likely occurs due to an increase in the liquid flow rate. Various factors affecting the dimensions of the liquid sheet from the rotary cup have been investigated, including the cup dimensions, speed, liquid flow rate and viscosity. However, ligament formation was chosen as the most appropriate process for the present study [13–15]. Ligament formation can offer sprays with narrower ranges of drop sizes than those produced by sheet formation and can provide higher liquid flow rates than those obtained via direct drop formation.

In the present study, for a given liquid, liquid flow rate and rotary cup size, the transition from one state to another was assumed to occur due to an increase in the angular speed. The mechanism of disintegration of ligament formation was investigated by obtaining photos with a high-speed camera. The effects of the angular speed and inner depth of the rotary cup on the disintegration of ligaments were determined.

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