Experimental study of the segregation of burden distribution during the Charging Process of Bell-less Top Blast Furnace with Two Parallel Hoppers

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Abstract. To study the segregation of burden distribution during the hopper discharging process of bell-less top system with two parallel hoppers, a 1:1 model of the bell less top system with two parallel hoppers of 5500 m³ blast furnace was established, and the influence of rotating chute structure, and central throat diameter on the falling point radius was also studied. From the experimental results, it can be concluded that the distribution of the inner and outer falling point radius of burden in the circumferential direction of throat is not uniform, and the segregation of the falling point radius of burden can effectively reduce by using the rectangular rotating chute. The outer falling point radius of burden is almost same when the central throat tube diameter is 650 mm and 730 mm, and the inner falling point radius of burden when the central throat tube diameter is 650 mm is smaller than that when the central throat tube diameter is 730 mm.

1. Introduction
To increasing the production of pig iron, blast furnace is developing towards large-scale. With the large-scale development of blast furnace, the working uniformity of blast furnace circumference becomes more and more important. During the charging process of blast furnace, the charging matrix becomes more complex with the large-scale of blast furnace. Moreover, with the large-scale of blast furnace, it is more difficult for hot gas to enter the center of blast furnace.

Uniform operation of blast furnace means uniform distribution of gas flow, while uniform distribution of gas flow requires uniform distribution of burden. Therefore, the uniform distribution of burden has great significance on the production of large blast furnace. During the hopper charging and discharging process of the blast furnace, it has four types of segregation [1, 2]. So far, the research approaches of segregation phenomena mainly include mathematical model, physical experiment, and DEM simulation. Mitra analyzed the phenomena of mixed layer and proposed a mixing index to evaluating the mixed layer extent [3, 4]. Zhang et al analyzed the size segregation of particles during the hopper discharging process of blast furnace, and the results showed that the burden flow mode was “mass flow” in the upper part, whereas the burden flow mode was “funnel flow” in the lower part of the hopper [5]. Yu et al investigated the effect of particle shape on size segregation during the hopper discharging process, and it indicated that the particle shape has little effect on the results [6-8]. Mio et al also analyzed the particle size segregation during the charging process [9], and it showed that large particles discharge last, because they are near the side wall of hopper.
Due to the high cost of hopper charging and discharging experiment, few researchers have studied the burden distribution rule through 1:1 model experiment. In this study, a 1:1 scale model of an actual 5500 m³ blast furnace with two parallel hoppers was established, and the effect of rotating chute structure and central throat tube diameter on the burden distribution was also studied, respectively. Through this experiment, it can provide the guidance for the design of the rotating chute and central throat tube, reduce the segregation of burden distribution during the hopper charging and discharging process, and promote the stable and smooth production of the blast furnace.

2. Experimental setup
A 1:1 model of 5500 m³ blast furnace with two parallel hoppers is established, which mainly includes large inclined angle of main feeding belt, hopper, Y-shaped tube, central throat tube, rotating chute and the throat, as shown in Fig. 1. It should be pointed out that due to the limitation of the experimental site, the inclination angle of the feeding belt used in the experiment is much larger than that used in the actual blast furnace production.

In order to study the influence of chute structure on burden distribution, semicircular chute and rectangular chute are used in the experiment, as shown in Fig. 2. In addition, in order to analyze the influence of the central throat tube diameter on the burden distribution, 730 mm and 650 mm of central throat tube were also used in the experiment.

In order to quantitatively evaluate the segregation degree of the falling point, it is necessary to measure the radius of the falling point at different circumferential azimuth angle. When measuring the radius of the falling point of the burden, the sing ring charging mode is adopted, and a tracer rod is installed at the 0.3 m stock level to measure the radius of burden falling point in 12 directions along the circumferential direction of the throat, as shown in Fig. 3. When measuring the radius of burden falling point, the measurement is based on the center of the furnace throat.
3. Results and discussion

Figure 4 and Figure 5 show the burden falling point radius when the tilting angle of the rotating chute is 35 degrees, 37 degrees and 39 degrees using semicircular and rectangular rotating chute, respectively. It can be seen that the inner and outer falling point radius of burden are basically uniform in the circumferential direction of throat when using the rectangular rotating chute. However, the inner and outer burden falling point radius are larger at 210 ~ 360 ° of throat, and that are smaller in other range of throat when the semicircular chute is used. Moreover, the burden flow width using the semicircular rotating chute is smaller than that using the rectangular rotating chute. In addition, it can be obtained that the inner and outer falling point of burden using the rectangular rotating chute is smaller than that using the semicircular rotating chute.

Figure 4. The burden falling point radius distribution when using the semicircular rotating chute.

Figure 3. The schematic diagram of tracer rod setup in the throat.
Figure 5. The burden falling point radius distribution when using the rectangular rotating chute.

Figure 6 and Figure 7 show the burden falling point radius when the tilting angle of chute is 35 degrees, 37 degrees and 39 degrees using 650 mm central throat tube and 730 mm central throat tube, respectively. It can be obtained that the outer burden falling point radius almost same whether the central throat tube diameter is 650 mm or 730 mm. The inner falling point radius of burden when using the 650 mm central throat tube is smaller than that when the central throat tube diameter is 730 mm. Therefore, the burden flow width using the 650 mm central throat tube is larger than that using the 730 mm central throat tube.

Figure 6. The burden falling point radius distribution when the central throat tube diameter is 650 mm.

Figure 7. The burden falling point radius distribution when the central throat tube diameter is 730 mm.
4. Conclusions

A 1:1 scale model of an actual 5500 m$^3$ blast furnace with two parallel hoppers was established in this study, and the effect of rotating chute structure and central throat tube diameter on the burden distribution was also studied, respectively. Some conclusions were obtained as follow:

1. The inner and outer falling point radius of burden are basically uniform in the circumferential direction of throat when using the rectangular rotating chute. However, the inner and outer burden falling point radius are larger at 210 ~ 360 ° of throat, and that are smaller in other range of throat when the semi-circular chute is used. Moreover, the burden flow width using the semi-circular rotating chute is smaller than that using the rectangular rotating chute. In addition, the inner and outer burden falling point radius using the rectangular rotating chute is smaller than that using the semi-circular rotating chute.

2. The outer burden falling point radius almost same whether the central throat tube diameter is 650 mm or 730 mm. The inner burden falling point radius when using the 650 mm central throat tube is smaller than that when using the 730 mm central throat tube. Therefore, the burden flow width using the 650 mm central throat tube is larger than that using the 730 mm central throat tube.

Through this experiment, it can provide the guidance for the design of the rotating chute and central throat tube, reduce the segregation of burden distribution during the hopper discharging process, and promote the stable and smooth production of the blast furnace.

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