Mass Distribution in the Falling Stream of Burden Materials

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(Received on March 10, 2008; accepted on June 4, 2008)

The burden material in a blast furnace is essentially a collection of particles having wide range of size and shape. It is discharged from the hopper and distributed on the stock level. The mass distribution of the falling stream determines the shape of the stock profile. The stock profile dictates the radial variation of ore/coke ratio, size segregation, gas distribution and burden descent, which in turn influence the formation and shape of the cohesive zone. Knowledge of the stock profile is therefore essential for understanding these phenomena. The complex nature of the flow has made a first-principle prediction of the mass distribution in the falling stream extremely difficult. Kondoh et al. have reported mass fraction distribution in the falling stream at different elevation but the complete description as a function of chute angle is not reported. The present work attempts to predict the mass fraction distribution in the falling stream for three burden materials, viz. iron ore, coke and sinter.

1. Experimentation

The experiments were conducted using actual bell less top charging equipment of the furnace in a trial rig. Figure 1 shows a schematic diagram of the experimental setup. The rig was comprised of the complete material charging system including receiving hopper, common hopper, upper seal valve, lower seal valve, flow control gate and rotation chute. A brick-walled cylindrical tank of 5 m diameter and 1.5 m height was built for simulating the furnace throat. A small section of the falling stream was kept open for removal of the charged materials. Proper electrical and mechanical arrangements were made for the rotational motion of the distributing chute. Tilting angle of the chute was changed manually and the chute was set to rotate at a constant speed. To feed the material in the receiving hopper, a special charging hopper of volume 1.43 m³ was fabricated with a discharge gate at the bottom.

For the purpose of collecting the materials from the falling particle stream, a semi-cylindrical pipe was inserted along the throat diameter at 1.6 m below the chute tip (design stock level). The pipe was divided into 25 compartments of 20 cm width each. In the experiment, rotating chute distributed the material along the peripheral direction and completed full rings. When the falling stream crossed the inserted pipe, material was collected in the different compartments, as shown in Fig. 2. For each full ring rotation of the chute, material was collected in two different locations, one on either side of the throat centre-line. Materials from individual compartments were weighed and mass fraction distribution was calculated.

2. Results and Discussion

The striking position of the falling stream of sinter for different chute inclination angle is shown in Fig. 3. The stream moves toward furnace wall with the increase in chute angle. In the figure, the filled points are the striking positions of the outer stream and the void points are the striking points of the inner stream. The stream width, defined as the distance between the inner and outer stream, remains almost constant for all chute angles. The mass distributions in the falling stream for sinter at 41° chute angle and iron ore at 34° chute angle are shown in Fig. 4. The left side and right side mass fractions are shown for both iron ore and sinter. The fractional values at a particular position are very similar for left and right side. This implies that the distribution of material along the peripheral direction is symmetrical about the central axis of the furnace.

The location where most mass fraction flows can be defined as the main stream of the trajectory. Figure 4 shows...
the main stream for sinter and ore were at about 0.72 and 0.56 of the radius and the mass fraction were 29% and 24% of the total mass collected. Since the dimension of the compartment of each collecting section was 20 cm, the main stream would be measured with ±10 cm accuracy. The distribution is symmetry about the maximum and the shape is like bell. Similarly, for other chute angles the mass fraction distributions have the same shape. Since the flow is of multi-particles and during the flow lots of collision and other disturbances take place, the behavior is thought to be stochastic. So it is felt that normal distribution may represent the mass fractionation distribution. We have used the following normal distribution equation to represent the mass distribution in the falling stream:

\[ y = \frac{1}{\sqrt{2\pi} \sigma} e^{-(r-\mu)^2/2\sigma^2} \] .................(1)

where \(ydr\) is the mass fraction collected in the interval \(r\) and \(r+dr\) during experiment. \(\mu\) (mean) is the location of the main stream and \(\sigma\) (standard deviation) is associated with the width of the material stream. For normal distribution, mean±2×standard deviation covers 95% area under the curve. So \(\pm2\times\)standard deviation) is considered as the spread of the material stream. The spread of coke, sinter and ore streams were found to be 0.35, 0.4 and 0.48 of the radius, respectively. Figure 5 shows the calculated location of main stream for a normal distribution of mass, using the experimentally measured stream width. Similar type of mass fraction distribution was obtained by Okuno et al.\(^{21}\)

They represent the mass distribution by the following equations

\[ \eta = \frac{\cos \zeta + 1}{2}, \quad \zeta = \frac{\pi(r-r_p)}{D/2} \] .................(2)

where \((-\pi \leq \zeta \leq \pi)\). \(\zeta\) represents non-dimensional height of the mass fraction taking the maximum as 1, \(D\) (m) is the width of the stream, \(r_p\) (m) is the distance of the main stream from the furnace centre and \(r\) (m) is the distance from the furnace centre. Figure 6 compares the measured values with results obtained using Okuno’s model and normal distribution, for ore at 30° and 39° chute angles. Every discrete point represents the arithmetic sum of the mass fractions collected on left-hand and right-hand positions, for a particular radius. The continuous line and the broken line represent the best-fit mass fractions obtained using nor-
mal distribution and Okuno’s model, respectively, for chute angles of 30° and 39°. The normal distribution curve was obtained considering 0.54R and 0.66R to be the location of main streams for 30° and 39° chute inclination angles, respectively (as shown in Fig. 5). Calculations using Okuno’s model yielded as 0.54R and 0.67R, respectively, as the location of the main stream.

3. Conclusion
The spread of the falling stream is not same for coke, ore and sinter but are comparable. Mass fraction distribution follows normal distribution for all the three materials. The location of the main stream of material varies linearly with the chute angle.

Acknowledgements
The authors gratefully acknowledge the Management of Tata Steel for granting permission to publish the work. Authors would also like to thank Prof. Ashok Kumar Lahiri of Indian Institute of Science for many fruitful discussions and timely cooperation.

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