Drying and breaking behavior of hot air heavy medium fluidized bed

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Abstract. The drying and crushing behavior of air heavy medium fluidized bed was studied, and the effects of surface moisture, drying temperature, drying time, air volume and other factors on the content of crushed pulverized coal and dropped pulverized coal were investigated. A mathematical correlation of crushed pulverized coal content and a mathematical correlation of dropped pulverized coal content were established. The results show that the mathematical correlation of crushed pulverized coal content and the mathematical correlation of dropped pulverized coal content can well simulate the drying and crushing behavior of fluidized bed. The increase of surface moisture, drying temperature, drying time, air volume and other operating parameters of coal will lead to the increase of crushed pulverized coal content and the decrease of dropped pulverized coal content. In the stage of fluidized bed drying, coal does not produce much pulverized coal. The pulverized coal less than 1mm produced by falling coal is much larger than the pulverized coal produced by crushing in the fluidized bed, and the larger the operating parameters are, the more obvious the influence on the pulverized coal content is.

1. Introduction
About 2/3 of China's coal resources are distributed in drought-stricken areas such as the northwest, and it is difficult to improve coal quality by wet coal preparation technology. Dry coal preparation has the advantages of no water use, low investment and operating costs (about 1/2 of the same-type wet-process coal preparation plant), and no pollution after dust removal. It has great development potential and broad application prospects[1-3]. The dry coal preparation of air heavy medium fluidized bed is an efficient dry sorting technology. It introduces gas-solid two-phase fluidization technology into the coal preparation field. The precision and stability of sorting are much higher than that of wind coal preparation and compound dry separation[4-6]. In this paper, the drying and fracture behavior of coal in a hot air heavy medium fluidized bed was investigated by studying the air heavy medium fluidized bed drying and sorting integrated device.

2. Experimental device and method
The experimental device is a drying and sorting integrated model device of air heavy medium fluidized bed, which is composed of an air supply system, an electric heating system, a separation system and a temperature detection system. The structure diagram is shown in Figure 1.
The design of the experiment was carried out by Design-Expert software. The experimental results were analyzed and discussed. The effects of drying temperature, surface moisture, drying time and air volume on the drying and crushing behavior of the fluidized bed were investigated. The mathematical model related to the drying and crushing behavior of fluidized bed was established. The experimental design and results are shown in Table 1. The specific operation of the experiment is as follows: select a 50~25mm drying coal sample with a certain quality and conduct manual humidification, then immediately put it into the fluidized bed and carry out the experiment under the set conditions. The percentage of the quality of 25~0.3mm coal sample to the mass of >0.3mm coal is defined as the percentage of crushing, and the percentage of the mass of 1~0.3mm coal sample to the mass of >0.3mm coal is defined as the content of crushed pulverized coal; In order to investigate the falling crushing rule of coal after drying in a fluidized bed, the drop crushing test was carried out. The percentage of the mass of 1~0.3mm coal sample to the mass of >0.3mm coal is defined as the dropped pulverized coal content. The experimental results are based on the percentage of crushing, the content of crushed pulverized coal and the content of dropped pulverized coal. Experimental parameters: drying temperature is 30℃, 40℃, 50℃, coal surface moisture is 1%, 2%, 3%, drying time is 1min, 3min, 5min, air volume is 8m³/h, 10m³/h, 12m³/h.

Table 1. Design and results of fragmentation behavior in process of drying and separating of coal.

| Number of groups | Drying temperature(℃) | Coal surface Moisture(%) | drying time (min) | Air volume (m³/h) | Broken ratio (%) | crushed pulverized coal content(%) | dropped pulverized coal content(%) |
|------------------|------------------------|--------------------------|-------------------|------------------|-----------------|-----------------------------------|-----------------------------------|
| 1                | 40                     | 1                        | 3                 | 11               | 0.120           | 0.032                             | 0.110                             |
| 2                | 50                     | 2                        | 5                 | 10               | 0.250           | 0.045                             | 0.310                             |
| 3                | 50                     | 3                        | 3                 | 10               | 0.165           | 0.050                             | 0.310                             |
| 4                | 40                     | 1                        | 1                 | 10               | 0.045           | 0.005                             | 0.040                             |
| 5                | 40                     | 2                        | 3                 | 10               | 0.090           | 0.025                             | 0.090                             |
| 6                | 40                     | 2                        | 3                 | 10               | 0.097           | 0.021                             | 0.100                             |
| 7                | 40                     | 2                        | 3                 | 10               | 0.085           | 0.025                             | 0.090                             |
| 8                | 40                     | 1                        | 5                 | 10               | 0.090           | 0.021                             | 0.160                             |
| 9                | 40                     | 3                        | 1                 | 10               | 0.080           | 0.022                             | 0.150                             |
| 10               | 40                     | 2                        | 1                 | 11               | 0.045           | 0.013                             | 0.050                             |
| 11               | 40                     | 3                        | 3                 | 11               | 0.200           | 0.039                             | 0.240                             |
| 12               | 50                     | 2                        | 1                 | 10               | 0.125           | 0.018                             | 0.170                             |
| 13               | 40                     | 2                        | 1                 | 9                | 0.070           | 0.005                             | 0.030                             |
| 14               | 50                     | 2                        | 3                 | 9                | 0.095           | 0.020                             | 0.050                             |
| 15               | 50                     | 2                        | 3                 | 11               | 0.245           | 0.042                             | 0.170                             |
| 16               | 40                     | 2                        | 3                 | 10               | 0.090           | 0.025                             | 0.100                             |
3. Study on the content of crushed pulverized coal

3.1. Establishment of mathematical correlation of crushed pulverized coal content

According to the experimental data of crushed pulverized coal content, the experiment of crushing pulverized coal content was simulated by quadratic correction model. Through the simulation, the mathematical correlation between the crushed pulverized coal content and various operating parameters is obtained:

\[
\text{The crushed pulverized coal content} (\%) = -0.397 - 1.523 \times 10^{-3}A - 6.867 \times 10^{-3}B + 0.011D + 0.076D + 2.925 \times 10^{-5}A^2 + 3.425 \times 10^{-3}B^2 - 9.875 \times 10^{-4}C^2 - 3.450 \times 10^{-3}D^2
\]

Based on the mathematical correlation of the crushed pulverized coal content, the prediction results and the experimental results are compared and analyzed. The comparison between the experimental values and the predicted values is shown in Figure 2. It can be seen that the experimental values and the predicted values are highly consistent.

3.2. The effect of drying temperature and drying time on the content of crushed pulverized coal

Figure 3 shows the effect of drying temperature and drying time on the content of crushed pulverized coal. It can be seen from Figure 3 that the content of crushed pulverized coal increases with the increase of drying temperature and drying time. It can be seen that the tendency of the crushed pulverized coal content to change with drying temperature and drying time is similar to the percentage of crushing, because the more the coal is broken in the fluidized bed, the greater the probability of producing pulverized coal. It can also be seen from Figure 3 that the crushed pulverized coal content is still small even when the drying time and the drying temperature are both high.
3.3. The effect of surface moisture and air volume on the content of crushed pulverized coal

Figure 4 shows the effect of surface moisture on the content of crushed pulverized coal, and Figure 5 shows the effect of air volume on the content of crushed pulverized coal. It can be seen from Figure 4 that with the increase of surface water content of coal, the content of crushed pulverized coal increases; when the surface moisture of coal is 3%, the content of crushed pulverized coal is the largest. This is because the increase of surface moisture of coal will increase the diffusion and evaporation of water, destroy the internal structure of coal, thereby increasing the total amount of coal crushing, and the content of pulverized coal in the fluidized bed will also increase; As can be seen from Figure 5, with the increase of air volume, the content of crushed pulverized coal increases; this is because the increase of air volume will make the gas-solid contact more fully, the heat and mass transfer effect more strongly, and the collision between coals will be increased, so that the total amount of coal crushing increases, the pulverized coal generated by crushing will also increase; in addition, even if the operating parameters are high, the crushed pulverized coal content is still small, which means that the coal does not produce more pulverized coal in the fluidized bed drying stage.

4. Study on the dropped pulverized coal content

4.1. Establishment of mathematical correlation of dropped pulverized coal content

According to the experimental data of the dropped pulverized coal content, the dropped pulverized coal content experiment was simulated by the quadratic correction model. Through the simulation, the mathematical correlation between the dropped pulverized coal content and various operating parameters is obtained:

\[
\text{The dropped pulverized coal content (\%) = } -2.849 - 0.016A - 0.154B - 0.058C + 0.613D + 2.696 \times 10^{-4}A^2 + 0.044B^2 + 0.012C^2 - 0.029D^2 + 0.013BC
\]

Based on the mathematical correlation of the dropped pulverized coal content, the prediction results and the experimental results were compared and analyzed. The comparison between the experimental values and the predicted values is shown in Figure 6. It can be seen that the experimental values and the predicted values have a high degree of agreement.
4.2. The effect of drying temperature and air volume on the content of dropped pulverized coal

The drop strength is closely related to the dropped pulverized coal content. The smaller the drop strength, the more likely it is to produce pulverized coal after falling. Figure 7 shows the effect of drying temperature and air volume on the dropped pulverized coal content. As shown in Figure 7, the dropped pulverized coal content increases with increasing drying temperature and air volume.

4.3. The effect of surface moisture and drying time on the content of dropped pulverized coal

Figure 8 shows the effect of surface water and drying time on the dropped pulverized coal content. As shown in Figure 8, as the surface water of the coal increases, the dropped pulverized coal content increases; as the drying time increases, the dropped pulverized coal content increases. It can also be seen from the figure that the amount of pulverized coal less than 1mm generated by falling is much larger than that generated by crushing in the fluidized bed, and the larger the operating parameters are, the more obvious the influence on the pulverized coal content is.

5. Conclusion

(1) The drying and fracture behavior of air heavy medium fluidized bed was studied. The mathematical correlation of broken percentage, the mathematical correlation of crushed pulverized coal content and the mathematical correlation of dropped pulverized coal content were established:

The crushed pulverized coal content(%) = $-0.397 - 1.523 \times 10^{-3}A - 6.867 \times 10^{-3}B + 0.011C + 0.076D + 2.925 \times 10^{-5}A^2 + 3.425 \times 10^{-3}B^2 - 9.875 \times 10^{-4}C^2 - 3.450 \times 10^{-3}D^2$

The dropped pulverized coal content(%) = $-2.849 - 0.016A - 0.154B - 0.058C + 0.613D + 2.696 \times 10^{-4}A^2 + 0.044B^2 + 0.012C^2 - 0.029D^2 + 0.013BC$

(2) The effects of factors such as surface moisture, drying temperature, drying time and air volume on the content of crushed pulverized coal and dropped pulverized coal were investigated. The increase of operating parameters such as coal surface moisture, drying temperature, drying time and air volume will lead to the increase of crushed pulverized coal content and the decrease of dropped pulverized coal content.

(3) Coal does not produce more pulverized coal at the drying stage of fluidized bed. The amount of pulverized coal less than 1mm generated by falling is much larger than that generated by crushing in the fluidized bed, and the larger the operating parameters are, the more obvious the influence on the pulverized coal content is.

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