Separation characteristic of hot air heavy medium fluidized bed

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Abstract. The air-density fluidized bed drying and sorting integration experiment system was used to conduct the separation experiment on wet coal. The effects of surface water of coal, drying temperature, drying time, air volume and other factors on separation precision and separation density were investigated. A mathematical correlation model of separation precision and separation density with various influencing factors was established. Studies have shown that the drying temperature and surface water of coal have a significant influence on the separation precision; the increase of drying temperature can improve the separation effect and increase the separation density, the increase of surface water of coal leads to the decrease of separation precision and the decrease of separation density. The increase of drying time contributes to the removal of surface water of coal, which makes the separation precision increase and the separation density increase; As the air volume increases, the separation precision first increases and then decreases, and the separation density decreases first and then increases slightly.

1. Introduction
Coal is one of the main raw materials sources of the industry. It is known as “industrial grain”. The dominant position of coal in China's energy production and consumption structure is unlikely to change significantly in a short period of time. Coal preparation is an internationally recognized first choice for efficient and clean coal utilization. Coal preparation technology is divided into wet coal preparation and dry coal preparation. Air heavy medium fluidized bed belongs to dry heavy medium sorting [1-2], in theory, it is the best method for dry re-election, which can effectively sort 50~6mm coal, and can increase the separation precision of gas-solid fluidized bed coal preparation by introducing vibration energy and magnetic field [3-4], therefore, it has always been the key research direction in the field of dry coal preparation [5-6]. Domestic and foreign scholars have done a lot of research work on heat and mass transfer characteristics, material drying model research, coal drying characteristics. In this paper, the effects of operating parameters such as surface water of coal, drying temperature, drying time and air volume on the separation characteristics of hot fluidized bed were investigated by studying the air heavy medium fluidized bed drying and sorting integration device.

2. Experimental device and method
The experimental device is an air heavy medium fluidized bed drying and sorting integrated model device, which is composed of a supply air system, an electric heating system, a sorting system and a temperature detecting system. The structure diagram is shown in Figure 1.
The design was completed using Design-Expert, and the experimental results were analyzed and discussed. The effects of surface water of coal, drying temperature, drying time, air volume and other factors on separation precision and separation density were investigated. A mathematical correlation model of separation precision and separation density with various influencing factors was established. Among them, the four factors of drying temperature, coal surface moisture, drying time and air volume are represented by A, B, C and D respectively. The experimental design and results are shown in Table 1. The separation precision is based on the $E_P$ value as the evaluation index, and the smaller the $E_P$ value, the higher the separation precision. Selection of experimental parameters: drying temperature is 30℃, 40℃, 50℃, surface water of coal is 1%, 2%, 3%, drying time is 1min, 3min, 5min, air volume is 8m$^3$/h, 10m$^3$/h, 12m$^3$/h.

Table 1. Design and results of separation experiments of bituminous coal sample.

| Serial number | drying temperature (℃) | surface water of coal (%) | drying time (min) | air volume (m$^3$/h) | $E_P$ (g/cm$^3$) | separation density (g/cm$^3$) |
|---------------|------------------------|--------------------------|------------------|---------------------|----------------|-----------------------------|
| 1             | 40                     | 2                        | 3                | 10                  | 0.050          | 1.675                       |
| 2             | 30                     | 3                        | 3                | 10                  | 0.060          | 1.660                       |
| 3             | 50                     | 2                        | 3                | 12                  | 0.045          | 1.710                       |
| 4             | 50                     | 2                        | 1                | 10                  | 0.045          | 1.685                       |
| 5             | 40                     | 1                        | 3                | 12                  | 0.045          | 1.730                       |
| 6             | 40                     | 2                        | 5                | 8                   | 0.110          | 1.740                       |
| 7             | 50                     | 2                        | 5                | 10                  | 0.025          | 1.700                       |
| 8             | 40                     | 3                        | 5                | 10                  | 0.055          | 1.670                       |
| 9             | 40                     | 3                        | 3                | 12                  | 0.065          | 1.720                       |
| 10            | 40                     | 2                        | 3                | 10                  | 0.055          | 1.680                       |
| 11            | 40                     | 1                        | 1                | 10                  | 0.040          | 1.685                       |
| 12            | 40                     | 1                        | 3                | 8                   | 0.100          | 1.745                       |
| 13            | 50                     | 2                        | 3                | 8                   | 0.065          | 1.750                       |
| 14            | 40                     | 2                        | 1                | 8                   | 0.120          | 1.730                       |
| 15            | 30                     | 2                        | 3                | 8                   | 0.130          | 1.725                       |
| 16            | 30                     | 2                        | 5                | 10                  | 0.055          | 1.675                       |
| 17            | 40                     | 2                        | 3                | 10                  | 0.055          | 1.680                       |
| 18            | 40                     | 2                        | 5                | 12                  | 0.050          | 1.725                       |
| 19            | 40                     | 3                        | 1                | 10                  | 0.065          | 1.660                       |
3. Separation precision

3.1. Establishment of mathematical correlation of separation precision

Based on the separation precision test data, the quadratic correction model was used to simulate and analyze the test results, the mathematical correlation between the separation precision and the four factors was obtained:

\[ E_p = 1.031 + 3.693 \times 10^{-3}A + 0.013B - 3.542 \times 10^{-3}C - 0.195D - 6.491 \times 10^{-5}A^2 + 9.158 \times 10^{-3}D^2 \]

Based on the mathematical correlation of separation precision, the comparison between the prediction result and the test result was carried out, as shown in Figure 2, it can be seen that the experimental value and the predicted value are in good agreement.

![Figure 2](image1.png)

Figure 2. The comparison between experimental and predicted values of \( E_P \).

![Figure 3](image2.png)

Figure 3. The effect of drying temperature and surface water of coal on \( E_P \).

3.2. Effect of drying temperature and surface water of coal on separation precision

Figure 3 shows the effect of drying temperature and surface water of coal on the separation precision when the drying time is 5 min and the air volume is 10 m\(^3\)/h. It can be seen from Figure 3 that when the surface water of coal is constant, the \( E_P \) value decreases with the increase of drying temperature, and the separation precision increases. When the drying temperature is 50 °C, the \( E_P \) value is the smallest and the separation precision is the highest.

3.3. Effect of drying time and air volume on separation precision

Figure 4 shows the effect of drying time on the separation precision when the surface water of coal is 2% and the air volume is 10 m\(^3\)/h. It can be seen from Figure 4 that when the drying temperature is constant, as the drying time increases, the separation precision increases, and when the drying time is 5 min, the \( E_P \) value is the smallest and the separation precision is the highest.

It can be seen from Figure 5 that, at the same drying temperature, with the increase of air volume, the separation precision first increases and then decreases. When the air volume is 10 m\(^3\)/h, the \( E_P \) value is...
the smallest and the separation precision is the highest; as shown in Figure 5, the air volume is 8 m$^3$/h, the bed fluidization is not sufficient and relatively viscous, the separation precision is low; when the air volume is increased to 10 m$^3$/h, the bed activity is enhanced, and a fluidized bed with uniform density and stability can be formed, and the separation precision is the highest; when the air volume is 12 m$^3$/h, the movement mismatch effect of the bed is obvious, the stability is deteriorated, and the separation effect is deteriorated.

Figure 4. The effect of drying time on $E_P$.

Figure 5. The effect of air volume on $E_P$.

4. Separation density

4.1. Establishment of mathematical correlation of separation precision

Based on the separation density test data, the quadratic correction model was used to simulate and analyze the test results, the mathematical correlation between the separation density and the four factors was obtained:

Separation density $= 2.759 + 5.958 \times 10^{-3}A - 7.500 \times 10^{-3}B + 3.333 \times 10^{-3}C - 0.238D + 0.013D^2 - 5.000 \times 10^{-4}AD$

Based on the mathematical correlation of separation density, the comparison between the prediction result and the test result was carried out, as shown in Figure 6, it can be seen that the experimental value and the predicted value are in good agreement.

Figure 6. The comparison between experimental and predicted values of separation density.

4.2. Effect of drying temperature and surface water of coal on separation density

Figure 7 shows the effect of drying temperature and surface water of coal on the separation density when the drying time is 3 min and the air volume is 10 m$^3$/h. It can be seen from Figure 7 that under the same surface water of coal, as the drying temperature increases, the separation density increases, and when the drying temperature is 50 °C, the separation density is the largest. It can also be seen from Figure 7 that at the same drying temperature, the separation density decreases as the surface water of coal increases, and the separation density is the smallest when the surface water of coal is 3%.
4.3. Effect of drying time and air volume on separation density

Figure 8 shows the effect of drying time on the separation density when the surface water of coal is 2% and the air volume is 10 m³/h. It can be seen from Figure 8 that under the same air volume, the separation density increases as the drying time increases, and the separation density is the largest when the drying time is 5 min. Figure 9 shows the effect of air volume on separation density when the surface moisture of coal is 2% and the drying time is 3 min. It can be seen from Figure 9 that as the air volume increases, the separation density decreases first and then increases. When the air volume is 10 m³/h, the separation density is the smallest.

5. Conclusion

(1) The air-density fluidized bed drying and sorting integration experiment system was used to conduct the separation experiment on wet coal. The effects of surface water of coal, drying temperature, drying time, air volume and other factors on separation precision and separation density were investigated:

\[ E_p = 1.031 + 3.693 \times 10^{-3}A + 0.013B - 3.542 \times 10^{-3}C - 0.195D - 6.491 \times 10^{-5}A^2 + 9.158 \times 10^{-3}D^2 \]

\[ \text{Separation density} = 2.759 + 5.958 \times 10^{-3}A - 7.500 \times 10^{-3}B + 3.333 \times 10^{-3}C - 0.238D + 0.013D^2 - 5.000 \times 10^{-4}AD \]

(2) The effects of surface water of coal and drying temperature on separation precision and separation density were investigated. The drying temperature and surface water of coal have a significant influence on the separation precision; the increase of drying temperature can improve the separation effect and increase the separation density; the increase of surface water of coal leads to the decrease of separation precision and the decrease of separation density.

(3) The effects of drying time and air volume on separation precision and separation density were investigated. The increase of drying time contributes to the removal of surface water of coal, which makes the separation precision increase and the separation density increase; As the air volume increases, the separation precision first increases and then decreases, and the separation density
decreases first and then increases slightly.

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