Flocculation and sedimentation characteristic of coal slurry in coal preparation plant

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Abstract. Flocculation sedimentation test was carried out on the coal slurry of the selected coal preparation plant. A mathematical correlation model of initial settling velocity, upper clarification turbidity and sediment volume with various influencing factors was established. The results show that: the initial settling velocity increases first and then decreases with the increase of flocculant concentration; when the flocculant concentration is 10g/m^3, the initial settling velocity is the largest; the initial settling velocity increases with the increase of the mass ratio of coagulant and flocculant. The upper clarification turbidity decreases first and then increases with the increase of the flocculant concentration; when the flocculant concentration is 10g/m^3, the supernatant has the lowest turbidity; the upper clarification turbidity decreases with the increase of the mass ratio of coagulant and flocculant. The volume of sediment increases with the increase of flocculant concentration, and increases with the increase of mass ratio of coagulant and flocculant.

1. Introduction
In recent years, with the significant increase in the degree of mechanization of coal mining, the proportion of fine coal content in raw coal has been increasing, the concentration and treatment volume of the coal slurry also increases, especially for coal slurry with high gray and fine mud which was hard to settle, it is very difficult to process [1-2]. The coal slurry treatment system is the important link of most complex, most invested, most costly and most difficult to manage in coal preparation plant, it would restrict the economic and social benefits of the coal preparation plant. The treatment effect directly affects the indicators of water washing reuse and closed loop, it also has a great influence on other aspects of the coal preparation plant, such as sorting efficiency, product quality index, and technical indicators of various process links [3-4]. Therefore, the research of high-efficiency treatment technology of coal slurry has always been a research hotspot at home and abroad [5-10]. Flocculation sedimentation test of the selected coal slurry, and the research of the appropriate amount of agent and the ratio of flocculant to coagulant, can formulate a reasonable pharmaceutical system for the coal preparation plant, and provide a basis for the design and optimization of the coal slurry.

2. Test design and method
The design was completed using Design-Expert, and the test results were analyzed and discussed, the effects of flocculants concentration and mass ratio of coagulant and flocculant on initial settling velocity, upper clarification turbidity and sediment volume were investigated. A mathematical correlation model of initial settling velocity, upper clarification turbidity and sediment volume with
various influencing factors was established. The flocculant concentration and mass ratio of coagulant and flocculant are represented by A and B respectively (the test uses polyacrylamide as flocculant and polyaluminum chloride as coagulant), the test design and results are shown in Table 1. Selection of test parameters: the flocculant concentration is 4 g/m³, 6 g/m³, 8 g/m³, 10 g/m³, 12 g/m³. The mass ratio of coagulant to flocculant is 0, 3, 6, 9, 12.

| Number of groups | Flocculant concentration (g/m³) | Coagulant and flocculant mass ratio | Initial settling velocity (cm/min) | Upper clarification turbidity (NTU) | Sediment volume (ml) |
|------------------|---------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|---------------------|
| 1                | 6                               | 3                                 | 57.6                              | 54.7                              | 117                 |
| 2                | 6                               | 6                                 | 85.2                              | 54.9                              | 125                 |
| 3                | 10                              | 6                                 | 115                               | 18.4                              | 126                 |
| 4                | 4                               | 0                                 | 15.43                             | 88.9                              | 120                 |
| 5                | 10                              | 3                                 | 116.4                             | 19                                | 122                 |
| 6                | 8                               | 6                                 | 96                                | 25.9                              | 124                 |
| 7                | 8                               | 9                                 | 88.8                              | 24.9                              | 129                 |
| 8                | 10                              | 9                                 | 114                               | 14                                | 132                 |
| 9                | 8                               | 3                                 | 100.8                             | 26                                | 121                 |
| 10               | 12                              | 6                                 | 126                               | 13.4                              | 129                 |
| 11               | 12                              | 12                                | 102                               | 15                                | 135                 |
| 12               | 8                               | 0                                 | 91.2                              | 22                                | 115                 |
| 13               | 12                              | 0                                 | 87.6                              | 12.5                              | 120                 |
| 14               | 4                               | 12                                | 17.28                             | 63.3                              | 125                 |
| 15               | 4                               | 6                                 | 13.89                             | 91.6                              | 123                 |
| 16               | 6                               | 9                                 | 61.2                              | 34.2                              | 127                 |
| 17               | 8                               | 12                                | 114                               | 24.8                              | 126                 |

3. Initial settlement velocity of coal slurry

3.1. Establishment of mathematical correlation of initial settlement velocity

Based on the initial settling velocity test data, the quadratic model was used to simulate and analyze the test results, the mathematical correlation between the initial settling velocity and the two factors A and B was obtained:

Initial settlement velocity (cm/min) = -141.85 + 47.33A + 2.27B - 2.29A² - 0.20B² + 0.11AB

Based on the mathematical correlation of initial settling velocity, the comparison between the prediction result and the test result was carried out, as shown in Figure 1, it can be seen that the experimental value and the predicted value are in good agreement.
3.2. Effect of flocculant concentration and mass ratio of coagulant and flocculant on initial settling velocity

The effect of flocculant concentration and mass ratio of coagulant and flocculant on initial settling velocity as shown in Figure 2. It can be seen from Figure 2 that when the mass ratio of coagulant and flocculant is constant, the initial settling velocity first increases and then decreases as the flocculant concentration increases; when the flocculant concentration is 10g/m³, the initial settling velocity is the largest. It can also be seen in Figure 2 that when the flocculant concentration is constant, the initial sedimentation velocity gradually increases with the increase of the mass ratio of coagulant and flocculant, but the variation range is small.

![Figure 2](image)

Figure 2. Effect of flocculant concentration and mass ratio of coagulant and flocculant on initial settling velocity.

4. Upper clarification turbidity of coal slurry

4.1. Establishment of mathematical correlation of upper clarification turbidity

Based on the upper clarification turbidity test data, the quadratic model was used to simulate and analyze the test results, the mathematical correlation between the upper clarification turbidity and the two factors A and B was obtained:

\[
\text{Upper clarification turbidity (NTU)} = 202.812 - 34.02A - 1.19B + 1.49A^2 - 0.17B^2 + 0.31AB
\]

Based on the mathematical correlation of upper clarification turbidity, the comparison between the prediction result and the test result was carried out, as shown in Figure 3, it can be seen that the experimental value and the predicted value are in good agreement.

![Figure 3](image)

Figure 3. Comparison of experimental value and predicted value of upper clarification turbidity.
4.2. Effect of flocculant concentration and mass ratio of coagulant and flocculant on upper clarification turbidity

The effect of flocculant concentration and mass ratio of coagulant and flocculant on upper clarification turbidity as shown in Figure 4. It can be seen from Figure 4 that when the mass ratio of coagulant and flocculant is constant, as the concentration of the flocculant increases, the upper clarification turbidity decreases first and then increases, when the flocculant concentration is 10g/m³, the upper clarification turbidity is the lowest. It can also be seen from Figure 4 that when the concentration of the flocculant is constant, the upper clarification turbidity continuously decreases as the mass ratio of coagulant and flocculant increases.

![Figure 4. Effect of flocculant concentration and mass ratio of coagulant and flocculant on upper clarification turbidity.](image)

5. Sediment volume of coal slurry

5.1. Establishment of mathematical correlation of sediment volume of coal slurry

Based on the sediment volume test data, the quadratic model was used to simulate and analyze the test results, the mathematical correlation between the sediment volume and the two factors A and B was obtained:

\[
\text{Sediment volume (ml)} = 125.48 - 2.54A + 1.09B + 0.17A^2 - 0.07B^2 + 0.10AB
\]

Based on the mathematical correlation of sediment volume, the comparison between the prediction result and the test result was carried out, as shown in Figure 5, it can be seen that the experimental value and the predicted value are in good agreement.

![Figure 5. Comparison of experimental value and predicted value of sediment volume.](image)
5.2. Effect of flocculant concentration and mass ratio of coagulant and flocculant on sediment volume

The effect of flocculant concentration and mass ratio of coagulant and flocculant on sediment volume as shown in Figure 6. It can be seen from Figure 6 that when the mass ratio of coagulant and flocculant is constant, the sediment volume gradually increases as the concentration of the flocculant increases. It can also be seen from Figure 6 that when the concentration of the flocculant is constant, the sediment volume increases with the increase of the mass ratio of coagulant and flocculant.

![Figure 6. Effect of flocculant concentration and mass ratio of coagulant and flocculant on sediment volume.](image)

6. Conclusion

(1) The initial settling velocity increases first and then decreases with the increase of flocculant concentration; when the flocculant concentration is 10g/m^3, the initial settling velocity is the largest; the initial settling velocity increases with the increase of the mass ratio of coagulant and flocculant. The upper clarification turbidity decreases first and then increases with the increase of the flocculant concentration; when the flocculant concentration is 10g/m^3, the supernatant has the lowest turbidity; the upper clarification turbidity decreases with the increase of the mass ratio of coagulant and flocculant. The volume of sediment increases with the increase of flocculant concentration, and increases with the increase of mass ratio of coagulant and flocculant.

(2) A mathematical correlation model of initial settling velocity, upper clarification turbidity and sediment volume with various influencing factors was established: 
- Initial settling velocity(cm/min) = -141.85+47.33A+2.27B-2.29A^2-0.20B^2+0.11AB;
- Upper clarification turbidity(NTU) =202.812-34.02A-1.19B+1.49A^2-0.17B^2+0.31AB;
- Sediment volume(ml) =125.48-2.54A+1.09B+0.17A^2-0.07B^2+0.10AB.

(3) The flocculant concentration has a great influence on the flocculation and sedimentation of the coal slurry; in the selected ratio range, the larger the mass ratio of coagulant and flocculant, the faster the sedimentation speed of coal slurry, and the smaller the upper clarification turbidity.

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