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Technologic optimization for separation of scarce coal sludge

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Abstract

Qianjiaying coke coal slime is extremely difficult to float. Conventional flotation process leads to a massive waste of high quality coal. In this paper, raw coal slime and rough separation concentrate are grinded to improve separation effect. Coal slime grinded directly through rough-cleaning process can get concentrate rate of 52.87% and concentrate ash of 11.27%. In the rough concentrate grinding process, concentrate ash drops to 10.74%, when the concentrate accumulation rate reaches up to 55.53%. Compared with the coal slime direct floatation, the concentrate rate was enhanced by 4.66%, and the ash was decreased by 1.02%. Besides, in the regrinding of middlings flotation, the concentrate rate reaches as high as 68.35% and ash rate is only 11.51%, the production efficiency is greatly improved.

Keywords: difficult-to-float coal slime; grinding; flotation process; condition optimization

1. Introduction

Generally, gas coal is easy to separate in China, whose sulfur content and inherent ash are quite low. On the contrary, the fat coal and the coking are at large difficult-to-float, and their inherent ash and sulfur content are quite high. The high-sulfur fat coal accounts for 47.95% in fat coal, while the high-sulfur coking coal takes merely 1/3 of the coking coal. The coking coal separation plants usually generate three products, namely concentrate, middlings and gangue. For coking coal and fat coal, the goal is to enhance the combustible recovery ratio of concentrate as far as possible, in which case the concentrate ash may achieve 12.5%. However, as the market demanding for ash content of coking coal becomes lower and lower, the coal separation plants have to reduce the recovery ratio of concentrate and increase the ratio of middlings. With the middlings ash being reduced and the calorific value being increased, massive scarce coking coals are taking as the fuel, which causes large losses. On the other side, the average ash content of concentrate for metallurgical industry in China is still higher than that in the developed countries, which seriously restrict metallurgical industry development. Therefore, taking into account for the property of scarcity coal and combined with new coal separation crafts, some new coal separation methods are exploited to improve the recovery rate of concentrate and to reduce the amount of concentrate ash and sulfur content, which are very important to the development of metallurgical industry in China [1].

Fu Xiaoheng and Shan xiaoyun [1] adopted flocculating method to separate deeply dissociated coal, and has achieved comparatively satisfactory separation results. The main goal of this paper is also to solve difficult-to-float coal slime separation problem by further dissociating coal slime and thus enhances the coal separation effect. The

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solution mainly involves three aspects. First, coal slime is directly grinded, and then follows flotation. Second, the degree of dissociation for rough concentrate is enhanced and the concentrate ash is reduced. Third, low ash concentrate is extracted first, and then rough tailings is classified and the fine fraction is discarded while the coarse fraction of rough tailings is taken as middlings and the grinding-flotation process further carried on.

2. Experimental

2.1. Equipments and materials

The paper selects the flotation process feed of Qianjiaying Coal separation plant in Tangshan as the experimental sample. The reagents are conventional flotation reagents. Petroleum oil is taken as collector, and 2-Octanol is used as foaming agent, and the concentration with 5% of sodium hexametaphosphate is adopted as regulator. The main equipments are a flotation cell XFD-1.5L and a grinding mill XMQ-240×90.

2.2. Experimental process

Qianjiaying coal slime from different working area belongs to coking coal and fat coal respectively. As the continuous increase of mining mechanization extent and the deterioration of geological condition of coal resources, conventional flotation technique cannot offer guarantee for achieving both low concentrate ash and high concentrate production rate, which results in massive loss of high quality coal. The paper exploits four kinds of separation technological conditions, and discovers optimum conditions for this coal slime separation process.

1) Take groups of 120 g mixed coal slime sample and carry on the flotation process. The experimental process is shown in Fig. 1(a).

2) Take groups of 500 g mixed coal slime sample and carry on the grinding process, with 500 g coal slime sample and 500 mL water are added into the grinding mill each time. After the grinding process, the pulp is dehydrated by vacuum filter and dried by thermoelectric thermostat drying box. Then the mixed grinding coal is taken for coal slime floatation. The concrete flowsheet is shown in Fig. 1(b).

3) Carry on rough concentration grinding process. The rough concentrate is extracted as high as possible from coal slime by means of reagent controlling strategy, and then carries on grinding process on the rough concentrate. The grinding way of rough concentrate is the same as that of coal slime. 500 g rough concentrate sample and 500 mL water are added to the grinding mill. The detailed flowsheet is specified in Fig. 1(c).

4) Extract low ash concentrate first through reagent controlling measure, and then rough tailings is classified and thus the fine fraction is discarded. Take the coarse fraction of rough tailings as middlings and carry on grinding-flotation process. The grinding way of middlings is the same as that of the original coal sludge. The specific flowsheet is shown in Fig. 1(d).

Fig. 1. Experimental process

Table 1. Result of flotation process A
3. Results and discussion

3.1. Coal slime direct flotation process

The results of direct flotation with petroleum oil and 2-Octanol are shown in Table 1. Concentrate combustible recovery (Ec) value is 58.70% while the concentrate ash is 11.76% and rate 50.87%. The results are not very ideal. Moreover the tailings ash is only 35.70%. This separation process causes large loss. Commeasurable float test is carried on for coal slime according to the standard GB4757-84 [2], where combustible recovery (Ec) is taken as the evaluating criteria, by which the coal slime floatability can be grouped into five hierarchies, respectively the easiest-to-float, the easier-to-float, the moderate-to-float, the difficult-to-float and the very difficult-to-float. Compared with such ranks of coal floatability, this coal slime should be attributed to difficult to float.

3.2. Grinding-floatation process

Take petroleum oil as collector and 2-Octanol as foaming agent and sodium hexametaphosphate as regulator. Various separation conditions are exploited, with the grinding condition concentration 50% and grinding time 10 min. The corresponding result of grinding fineness is -0.074 mm where material accounts for 86.85%. The floatation tests diagram is shown in Fig. 1(b). Compared with the density of coal slime and grinded coal slime (in Fig. 2), the product with density less than 1.5 g/L has increased substantially, which is the key point for recovery. Therefore, theoretically, grinding-floatation process is able to improve the flotation efficiency.

The comparison for the results of process A and process B is shown in Fig. 3: with the same reagent controlling, the concentrate rate of grinding-floatation process has increased 6.94% (up to 57.81%), but the concentrate ash also increases from 11.76% to 12.32%, i.e., the efficiency of floatation has not improved. Since fine grinding increases dissociated minerals, the concentrate rate also increases under the condition of the same reagent controlling measure. On the other hand, as a result of grinding, the particle size of gangue reduces too and the increase of surface area leads to increased sliming. However, the concentrate is seriously polluted by the fine high-ash slime in flotation process.
Fig. 4. Influence of depressant dosage in fine grinding process

Since the grinding direct flotation process is very difficult to raise separation efficiency, the regulator is used to enhance the degree of dissociation to enhance flotation process effect. Test results are shown in Fig. 4. Under the same dosage of petroleum oil and 2-Octanol as process A, the optimum separation effect is achieved by 1000 g/t sodium hexametaphosphate and concentrate ash close to directly floatation concentrate, where the concentrate rate is enhanced 0.49%. Keep increasing the dosage of sodium hexametaphosphate, the concentrate rate will reduce, but the change of concentrate ash is slight. Because the stable complex compound is generated by the reaction of sodium hexametaphosphate and Ca$^{2+}$, Fe$^{3+}$, Mg$^{2+}$ in the surface of gangue, the gangue is inhibited to floatation. The adsorption of sodium hexametaphosphate in mineral surface can also increase superficial electro-negativity of gangue when the dosage is kept on adding, which also dissociates the slime and excludes the influence of slime on the flotation process. Therefore, the role of continued increase of sodium hexametaphosphate improves slime dissociate, but the increase of sodium hexametaphosphate dosage is futile in further reducing the concentrate ash. Experimental results prove that raw coal grinding-floatation process cannot achieve satisfactory separation effect.

3.3. Rough concentration grinding flotation process

To resolve the limitations in grinding-floatation process, rough concentration grinding-flotation process is designed in this paper, as shown in Fig. 1(c). In this process, rough concentrate is extracted as high as possible from coal slime by controlling the dosage of reagents, and then grinding process of rough concentrate is further carried on. The rough tailing which obtains mainly gangue minerals is discarded. Without those tailings, the concentrate pollution is reduced in the separation process. Finally the clean concentrate and middlings are obtained through a cleaning separation. The analytical of experimental results are shown in Table 2 and Fig. 5.

Table 2. Results of process C

<table>
<thead>
<tr>
<th>Number</th>
<th>Concentrate (%)</th>
<th>Middlings (%)</th>
<th>Rough concentrate ash (%)</th>
<th>Accumulated concentrate rate (%)</th>
<th>Ec (%)</th>
<th>Dosage (g/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r_A$</td>
<td>$r_A$</td>
<td>$r_A$</td>
<td>$r_A$</td>
<td>$r_A$</td>
<td>$r_A$</td>
</tr>
<tr>
<td>◐</td>
<td>68.95</td>
<td>10.67</td>
<td>31.05</td>
<td>27.36</td>
<td>15.85</td>
<td>53.95</td>
</tr>
<tr>
<td>◐</td>
<td>78.87</td>
<td>11.26</td>
<td>21.13</td>
<td>29.96</td>
<td>15.21</td>
<td>61.72</td>
</tr>
<tr>
<td>◐</td>
<td>81.72</td>
<td>11.53</td>
<td>18.28</td>
<td>31.81</td>
<td>15.23</td>
<td>63.95</td>
</tr>
<tr>
<td>◐</td>
<td>75.88</td>
<td>11.02</td>
<td>24.12</td>
<td>28.88</td>
<td>15.33</td>
<td>59.38</td>
</tr>
<tr>
<td>◐</td>
<td>70.96</td>
<td>10.74</td>
<td>26.04</td>
<td>29.25</td>
<td>15.71</td>
<td>55.53</td>
</tr>
<tr>
<td>◐</td>
<td>66.02</td>
<td>10.37</td>
<td>33.98</td>
<td>25.60</td>
<td>15.54</td>
<td>51.66</td>
</tr>
</tbody>
</table>

Fig. 5. Influence of dosage of depressant in rough concentration grinding flotation process

The concentrate rate and ash also gradually increases along with the dosage of collector and foaming agent increased in the first three groups in Table 2. At a fixed dosage of collector and the foaming agent, the concentration rate drops gradually, and at the same time, the concentrate ash also drops along with the dosage of regulator
increased in the latter three groups (see Fig. 5). The data shown in Fig. 5 are that of the grinding-flotation circuit and not of entire process. Compared with direct flotation process, consumable recoveries have varying degree of enhancements. The concentrate ash is controlled between different separating conditions according to the user’s requirements in actual production.

3.4. Grinding middlings flotation process

The optimum results of process D are shown from Table 3 to Table 6 in the following. Compared with the direct flotation concentrate ash, concentrate ash of process D is almost the same, but its rate has increased greatly. The results of density analysis of middlings are shown in Fig. 6. The product rate with density less than 1.5 g/L is 54.82% and ash is 11.00% in middlings, and middle density and high density production rate are quite low. When low ash concentration is produced, the dosage of collector and foaming agent is relatively few. The mechanical strength is low of bubble-wall surface, and the froth is not stably and is easy to varnish. Therefore the particles are easy to fall off [3]. Moreover particles are set as sphere $V = \frac{\pi}{6} d^3$. The volume is $8.18 \times 10^{-3} \text{mm}^3$ with the average size 0.25 mm for coarse particles, and the volume is $2.12 \times 10^{-4} \text{mm}^3$ with the average size 0.074 mm for fine particles. Coarse particles volume is 38 times larger than that of fine particles. Therefore, to float off coarse particles, the flotage needs to be at least 38 times larger than that of fine particles [4]. When the dosage of medicament is low, part of low ash coarse particles is not able to float, and the middle density and the intergrowth of coal and gangue also do not float. The grinding of middlings can solve this problem and the consumable recovery is raised greatly.

At present the problem is that the added grinding craft results in a series of increased craft cost. Real economic benefits of this process should be on further experimental study.

Table 3. Results of roughing (the dosage of petroleum oil and 2-Octanol are respectively 200 g/t and 100 g/t)

<table>
<thead>
<tr>
<th>Concentrate (%)</th>
<th>Tailings (%)</th>
<th>Ash of feed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>$Ad$</td>
<td>$r$</td>
</tr>
<tr>
<td>54.48</td>
<td>11.76</td>
<td>45.52</td>
</tr>
</tbody>
</table>

Table 4. Results of classification (roughing tailings is screened by 0.05 mm sieve)

<table>
<thead>
<tr>
<th>&gt;0.05 mm</th>
<th>&lt;0.05 mm</th>
<th>Ash of feed (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$ (%)</td>
<td>$Ad$ (%)</td>
<td>$r$ (%)</td>
</tr>
<tr>
<td>66.00</td>
<td>30.65</td>
<td>34.00</td>
</tr>
</tbody>
</table>

Table 5. Results of scavenging (the dosage of petroleum oil and 2-Octanol are respectively 200 g/t and 100 g/t)

<table>
<thead>
<tr>
<th>Concentrate</th>
<th>Tailings</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$ (%)</td>
<td>$Ad$ (%)</td>
</tr>
<tr>
<td>46.16</td>
<td>10.86</td>
</tr>
</tbody>
</table>

Table 6. Synthesized results of process D (concentrate of roughing and scavenging taken as product of concentrate and <0.05 mm product of classification and scavenging tailings are mixed as tailings)

<table>
<thead>
<tr>
<th>Concentrate</th>
<th>Tailings</th>
<th>Ash of feed (%)</th>
<th>Ec (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$ (%)</td>
<td>$Ad$ (%)</td>
<td>$r$ (%)</td>
<td>$Ad$ (%)</td>
</tr>
<tr>
<td>68.35</td>
<td>11.58</td>
<td>31.65</td>
<td>50.31</td>
</tr>
</tbody>
</table>
4. Conclusions

1) Coal slime of Qianjiaying coal separation plant is extremely difficult to float. The results of directly flotation are not ideal.

2) Grinding flotation process can reduce the ash content of concentrate. Grinded coal slime using rough-cleaning process can obtain concentrate rate of 52.87% and concentrate ash of 11.27%. The scope of concentrate rate ash drops not very sharply, and does not achieve the goal of enhancement of separation efficiency.

3) Rougher concentrate grinding flotation process is suitable for the Qianjiaying coal slime separation. In this process, when the concentrate accumulation rate is 55.53%, the concentrate ash may drop to 10.74% (< 11.00%). Compared with direct-floatation process, the production rate of rougher concentrate grinding flotation process was enhanced by 4.66% and the ash was decreased by 1.02%. This craft achieves good separation indicator.

4) Grinding middlings flotation process result shows that concentrate rate can reach to 68.35%, while ash content is only 11.51%, and the production efficiency is further considerably improved.

Acknowledgements

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References


