Dry reusing and wet reclaiming of used sodium silicate sand

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Abstract: Based on the characteristics of used sodium silicate sand and the different use requirements for recycled sand, "dry reusing and wet reclaiming of used sodium silicate sand" is considered as the most suitable technique for the used sand. When the recycled sand is used as support sand, the used sand is only reused by dry process including breaking, screening, dust-removal, etc., and it is not necessary that the used sand is reclaimed with strongly rubbing and scraping method, but when the recycled sand is used as facing sand (or single sand), the used sand must be reclaimed by wet method for higher removal rate of the residual binders. The characteristics and the properties of the dry reused sand are compared with the wet reclaimed sand after combining the different use requirements of support sand and facing sand (or single sand), and above the most adaptive scheme has also been validated.

Keywords: used sodium silicate sand; dry reusing; wet reclaiming

1. Introduction

Foundry workers and researchers around the world recognize the difficulty of reclaiming or reusing used sodium silicate sand. Among the possible reclaiming or reusing methods, there is no agreed single process that is the most rational, low cost and high quality [1-2]. It is generally accepted that dry reclaimed process is simple but the quality of dry reclaimed sand is poor, and that wet reclaimed process is complex but the quality of wet reclaimed sand is good. The authors believe that the combined process of dry reclaiming and wet reclaiming should be the most suitable methods. This paper summarizes the test results of this new process in the past several years.

2. Reusing and reclaiming foundry used sand

The dry reusing process of foundry used sand generally includes breaking, demagnetizing, screening, dust removal, cooling, and the process can be circled many times. The wet reclaiming process of foundry used sand mainly includes stripping off the residual binder on the used sand particles after breaking, demagnetizing, and dust removal. The quality of wet reclaimed sand is close to that of new sand, so the new sand can be replaced by wet reclaimed sand in many cases. The main difference between the dry reused sand and the wet reclaimed sand is their quality. The quality of dry reused sand is inferior to the new sand and facing sand (or single sand) when mixed with a large amount of new sand. Since the quality of wet reclaimed sand may be close to new sand in physical and chemical performance, it can be used as facing sand (or single sand) completely instead of new sand [1].

Due to the differences between dry reusing sand and wet reclaiming sand in quality and use requirements, their processes and recycling equipments are very different. In general, the dry reusing process is considered as the first step of the reclaiming process, and the emphasis of dry reusing process is on breaking, demagnetization, and dust removal. The aim of wet reclaiming process is to rub off the residual binders stuck to the used sand particles surface, and to make the quality of the sand near the new sand, after the above disposal process. So it can be considered that the reclaiming process actually includes two steps: the first step is reusing, and the second is striping off the residual binders.

3. The characteristics of used sodium silicate sand

A lot of practices and researches have revealed the following characteristics of used sodium silicate sand [2-4]:

- The residual binder films on the used sodium silicate...
sand particles can not be burnt out or decomposed at casting temperatures, but rather become a layer of sodium silicate gel which has lower melting point and strong binding force with sand particles surface. These characteristics explain the low de-skinning rate of dry reclaimed used sand.

- Due to the residual sodium silicate gel and salt on the sand surface, used sand particles possess a stronger absorbability to water in the atmosphere and dry reclaimed sand become more difficult for recycling, and the de-skinning rate of used sand particles increases when heated before being reclaimed.

- Most of the residues including sodium silicates, esters and resulting salts on the used sand particles are soluble in the water, so most of the residues can be easily washed away by the wet reclaiming process, and the de-skinning rate of wet reclaimed sand is very high, the quality of the wet reclaimed sand is very close to that of new sand.

- The residues on the used sand particles, including higher modulus water-glass, esters, salts and others, have great effect on the mold sand properties (such as bonding strength and workable time), so the main aim of the reclaiming process is to dispose as much residues as possible.

4. The comparisons of several common reclaiming methods of the used sodium silicate sand

Despite the agreement among foundrymen that reusing and reclaiming the used sodium silicate sand is a difficult task, they disagree on which is best reclaiming process based on cost, quality, equipment investment, and so on. The practices and researches for years show that there are three main methods to recondition the used sand: dry reclaiming process, wet reclaiming process and chemical reclaiming process. Each process has its unique advantages and disadvantages; therefore, users or companies would choose one according to their specific requirements.

4.1 The localization and predominance of dry reclaimed sodium silicate sand

There are many kinds of dry reclamation methods, including mechanical reclamation, airflow reclamation, vibration reclamation, and so on, but in essence they have a common reclaiming principle of "collision and friction". When "collision and friction" causes a higher strength than the yield strength or the joint strength of the residual binder film with sand grain surface, the residual films on the used sand particles are destroyed and rubbed off, and after winnowing the dry reclaimed sand can be obtained. In this process, the cleaner the reclaimed sand, the better the reclaimed sand quality, if the used sand is collided and scrubbed more fiercely and more frequently. However, the abrasion of equipments will be added consumedly under the condition of excessive collision and friction, also the sand grains can be cracked as well. It is thus not good that the reclaiming strength and time are excessively increased.

According to the characteristics of the used sand as mentioned above, researches have revealed the disadvantage of dry reclaiming the used sand: it possesses low de-skinning rate (the de-skinning rate of common dry reclaiming process is 5%~20%, and the rate is to 20%~35% when the used sand is preheated before dry reclaiming process); it would get inferior reclaimed sand quality (low re-bonding strength, short workable time, only used as backing sand or filling sand, low fire-resistant temperature after repeated uses); it can increase the re-bonding strength and prolong the workable time of reclaimed sand when the used sand is preheated to 320 °C before reclaiming process, but the collapsibility of the reclaimed sand will become poorer when the reclaimed sand is used as facing sand (or single sand) in cycles.

So, the dry reclaiming sand can only be used as support sand. The system of the dry reclaiming process mainly includes the following equipments: breaking equipment, demagnetizing equipment, heating equipment, dry reclaiming machine, winnower and others.

The main predominance of dry reclaiming used sodium silicate sand, comparing to wet reclaiming, is simpler equipment and system, lower cost and investment, and less secondary pollution.

4.2 The advantage and disadvantage of wet reclaiming used sodium silicate sand

As mentioned, the residual binders on the surface of used sodium silicate sand are mostly soluble, so when water is mixed with the used sand, the residues will be dissolved. The wet reclaiming process possesses following advantages:

- High de-skinning residual rate (over 90%) and high reusing rate of the used sand (over 90%).
- High reclaimed sand quality: the properties of reclaimed sand such as re-bonding strength, workable time, fire-resistant temperature are very close to those of the...
new sand.

- The wet reclaimed sand can be replaced using as facing sand (or single sand), and only about 10%~20% new sand is added when the reclaimed sand is recycled.

Comparatively, this process requires more complicated equipments comparing to the dry reclaiming process because the polluted water must be disposed to reuse or let off harmlessly.

The wet reclaiming system mainly includes following equipments: breaking equipment, demagnetizing equipment, wet reclaiming machine, dehydrating equipment, drying equipment, sewage disposing equipment and others.

### 4.3 Chemical reclaiming used sodium silicate sand

Chemical reclaiming is that some chemical reagents or solvents are added and mixed to the used sand, so the residual binder films and other harmful materials can be rubbed off by chemical reactions, and the quality of this reclaimed sand can be renewed to their raw sand. The chemical reagents, which commonly are NH\(_4\)Cl, HCl, H\(_2\)SO\(_4\) and other acidic reagents, would neutralize the residual Na\(_2\)O. The chemical reclaimed sand has similar quality to the new sand, but the chemical reclaiming need high cost and capital investment, so it seldom was put into practice.

Prof. Chunxi ZHU \(^7\), who worked extensively on modified water-glass binders and reclamation of the used sodium silicate sand for many years, believes that the residual Na\(_2\)O in the used sand can be divided into three parts: (1) about 5%~10% residual Na\(_2\)O exists in the molten glassy state, and this part has no effect on the workable time of the reclaimed sand; (2) about 30%~35% is in Na\(_2\)CO\(_3\), NaHCO\(_3\) or CH\(_3\)COONa, and this part will deteriorate the workable time and the fire-resistant temperature of the reclaimed sand; (3) about 60%~65% exists in dehydrated water-glass state with higher modulus. Prof. ZHU\(^7\) proposed that the high modulus of the dehydrated water-glass might be descended and the dehydrated water-glass could also be dissolved to restore its partial bonding ability by adding some NaOH solution to the used sand, and this process was termed as "chemical reclaiming". But the essence of this process should be a "chemical modification" on the used sand (or the reclaimed sand), because the process must combine with dry reclaiming in practice, otherwise the accumulation of the residual Na\(_2\)O in the sand would be ascended greatly upon cycling.

One issue with the "chemical reclaiming" process proposed by Prof. ZHU is the difficulty in distinguishing the usable residual Na\(_2\)O from the unusable residual Na\(_2\)O in the used sodium silicate sand in practical industry production. Furthermore, the unusable residual Na\(_2\)O will be accumulated more expeditiously when the sand is recycled. Other issues should also be tested and proved, such as the amount of NaOH solution and water dissolved into the residual water glass with higher modulus and how the high modulus can be descended in a short time.

According to Prof. ZHU\(^7\), a part of used water-glass in the used sand hardened by ester will possess re-bondability, and the workable time of re-bonding sand will be prolonged, when a proper solution of NaOH (the concentration is about 8.5%), water and appropriate ester is added to the used sand. To confirm this finding, the following tests were carried out in this study, and the test results are shown in Table 1 (the tested used sand is the used sodium silicate sand hardened by ester), and the results indicated that the effect of residual water-glass in the used sand on the re-bondability is very limited.

The lower re-bonding strength and shorter workable time of the dry reclaimed sodium silicate sand found in

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Test scheme</th>
<th>Re-bonding strength [Mpa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3% Water, 0.2% MDT type fast hardening ester</td>
<td>0.0192 0.0345 0.0612 0.0467 0.000</td>
</tr>
<tr>
<td>2</td>
<td>3% (8.5%NaOH solution), 0.2% MDT type fast hardening ester</td>
<td>0.0294 0.0473 0.0556 0.0529 0.0598</td>
</tr>
<tr>
<td>3</td>
<td>3% (17%NaOH solution), 0.2% MDT type fast hardening ester</td>
<td>0.0382 0.0562 0.0639 0.0603 0.0667</td>
</tr>
<tr>
<td>4</td>
<td>3% (8.5%NaOH solution), 0.1% MDT type fast hardening ester</td>
<td>0.0424 0.0584 0.0639 0.0737 0.0798</td>
</tr>
<tr>
<td>5</td>
<td>3% (8.5%NaOH solution), 0.05% MDT type fast hardening ester</td>
<td>0.0406 0.0584 0.0631 0.0739 0.0751</td>
</tr>
</tbody>
</table>

Remark: the test conditions above were (1) Testing temperature: 13~14 °C; (2) Testing humidity: 88%; (3) In the test scheme, the quantity of water, NaOH solution and ester is respectively percentage of the used sand.

this study may be related to the residual water-glass, ester and salts, as well as the complicated phenomenon of surface chemistry and catalyst chemistry. That is a problem that needs further study.

5. The property comparisons of some reclaimed sodium silicate sand

To illustrate the different properties of the dry reclaimed sand and wet reclaimed sand, the following comparative tests have been performed:

5.1 Preparation of sand sample

The new sand is Dalin standard sand (0.300 mm/0.150 mm, ASTM E11-70, ASF) in China, and the ingredients for the mould sand are the following: the new sand (1,000 g), water-glass (m = 2.8, °Be = 42, 40 g), ester (1# ester, 4 g). The clump of the used sand is broken into particles and was transacted respectively by the dry reclaiming process and wet reclaiming process. The tests were carried out at Huazhong University of Science and Technology (HUST). Table 2 shows the residual Na$_2$O and the de-skinning rate of the used sand.

5.2 The effect of water-glass modulus on the re-bonding strength of reclaimed sand

Fig. 1, Fig. 2, and Table 3 show the results of the comparative re-bonding strength of the dry reclaimed sand, the wet reclaimed sand and the new sand. Two water-glass binders with different modulus (m = 2.8, °Be = 42; m = 2.1, °Be = 50) were used in the tests. The water-glass added was 4 percent of the sand, and the ester (1#) was 0.4 percent of the sand, and the testing temperature was 25~27 °C, the testing humidity was 91%.

It can be seen from Fig. 1, Fig. 2 and Table 3 that the re-bonding strength and workable time of the dry reclaimed sand is significantly inferior to the wet reclaimed sand and the new sand, and the modulus of the water-glass has a profound effect on the re-bonding strength and workable time. So it is a valid method to enhance the strength and workable time of the sand by descending the water-glass modulus for re-binding.
5.3 The effect of ester content on the hardening strength of dry reclaimed sand

The ester content will affect the re-bonding strength and workable time because there is an amount of residual ester in the used sand and dry reclaimed sand. Fig.3 and Table 4 show the test results of ester content effect on the dry reclaimed sand. It can be seen that reducing the ester content can enhance the re-bonding strength and workable time of the sand. The test conditions were that 4% water-glass \( (m = 2.8, °Be=42) \) and 0.4% ester \((1^\#)\) were added, testing temperature was 21~23°C and testing humidity was 89%.

5.4 The effect of preheating temperature on the workable time of dry reclaimed sand

If the used sand is heated to a temperature before breaking and dry reclaiming, the quality of the dry reclaimed sand is directly related to the preheating temperature. The test results listed in Table 5 show that the re-bonding strength increased with temperature, and the workable time was greatly prolonged after a preheating at 320 °C. The test conditions were that 4% water-glass \((m = 2.5, °Be=46)\) and 0.4% ester \((1^\#)\) were added, testing temperature was 13~14 °C and testing humidity was 87%.

5.5 The collapsibility of mould sand worsens when the dry reclaimed sand as single sand for cycling

If the used sand is reclaimed by dry process after preheating at 320°C, and the dry reclaimed sand is used as single sand added at about 20% new sand each cycle, the collapsibility of mould sand would worsen with each additional cycle due to the increased residual strength. The results are showed in Fig.4. The test conditions were that 4% water-glass \((m = 2.5, °Be=46)\) and 0.4% ester \((1^\#)\) were added, testing temperature is 13~14 °C and testing humidity is 87%.

### Table 4 The effect of ester content on the dry reclaimed sand

<table>
<thead>
<tr>
<th>Content of ester (%)</th>
<th>0.4</th>
<th>0.3</th>
<th>0.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workable times [min]</td>
<td>~5</td>
<td>5~10</td>
<td>~10</td>
</tr>
</tbody>
</table>

### Table 5 The effect of different preheating temperature on properties of the dry reclaimed sand

<table>
<thead>
<tr>
<th>Category of the sand sample</th>
<th>Re-bonding strength [Mpa]</th>
<th>Workable time [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2h</td>
<td>4h</td>
</tr>
<tr>
<td>Dry reclaimed sand sample after 120 °C preheating</td>
<td>0.25</td>
<td>0.36</td>
</tr>
<tr>
<td>Dry reclaimed sand sample after 220 °C preheating</td>
<td>0.40</td>
<td>0.46</td>
</tr>
<tr>
<td>Dry reclaimed sand sample after 320 °C preheating</td>
<td>0.45</td>
<td>0.75</td>
</tr>
<tr>
<td>New sand</td>
<td>0.38</td>
<td>0.94</td>
</tr>
</tbody>
</table>

### Table 6 The effect of different preheating temperature on properties of the dry reclaimed sand

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</tr>
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<td>0.94</td>
</tr>
</tbody>
</table>

6. Summary

(1) Because the dry reclaiming process has a low de-skimming rate and dry reclaimed sand possesses low re-binding strength and short workable time, the dry reclaimed sand is used usually only as support sand. Even some characteristics (such as re-bonding strength and workable time) of the dry reclaimed sand made after the
used sand preheated to 320 °C can reach the need used as single sand or facing sand, the authors still consider that the dry reclaimed sand is not suitable for the single sand or facing sand owing to the collapsibility of mould sand would worsen as the number of reuse cycles increases.

(2) The de-skinning rate requirement and the fire-resistant temperature are not high when the dry reclaimed sand is used as support sand, so it is not necessary to collide and scrub more fiercely to reach high de-skinning rate, and more attention should be paid to the enough re-binding strength and workable time. As formentioned, the effect of dry reclaiming process lies on the strength of the collision and friction in the process (that is, the better the effect of the dry reclaiming process, the higher the strength of the collision and friction), however, the sand particles were also broken under too high collision and friction strength, thus the dry reclaiming process with high collision and friction strength is not always the best process for sand reclaiming.

(3) After dry reusing process (including breaking, demagnetizing, screening, dust removal, cooling, and other steps), the de-skinning rate can be improved by 10% ~30%, and combining with the use of low modulus water-glass binder, the dry reused sand can meet the requirement as backing sand. So it is economical and rational to use dry reused sand as support sand.

(4) If the reclaimed sand is used as facing sand or single sand, it is necessary to use the wet reclaiming process to reach the high de-skinning rate (over 90%), and the quality of wet reclaimed sand is very similar to new sand.

(5) Based on above tests and analyses, there are three practicable methods to reclaim or reuse the used sodium silicate sand according to the different requirements:

- With a de-skinning rate of 10%~30%, dry reusing process can be used for support sand. In this way, about 25%~35% new sand is added at each cycle, and about 20% of the used sand will be discarded.

- With a de-skinning rate of 85%~95%, wet reclaiming process can be used for facing sand (or single sand). In this way, about 5%~15% new sand is added at each cycle, and the sewage must be recycled for reuse or be disposed harmlessly, and all the used sand can be recycled.

- The most suitable process is "dry reusing and wet reclaiming". That is to combine the advantages of the dry reusing process and the wet reclaiming process: the method is used for support sand, and the discarded sand (about 20%) should be reclaimed by the wet reclaiming process. Because the wet reclaimed sand can replace new sand to be used as single sand or facing sand, no used sand is disposed. This process is the most economical way because of the low cost and high quality of the recycled sand.

References


