Identification and Ranking of Indicators on The Quality of The Casting Silica Sand by Using A Multi-criteria Decision Making Technique

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ABSTRACT
Silica sand is one of the most important materials in casting and Iranian casters use it technically though some other casters believe that it is not so valuable and beneficial. Silica advantages such as high resistance and abundance and its low price encourage many casters utilizing it in different ways. Generally speaking the process of casting should be controlled completely because every ignorance in this field can lead to some events such as sand burning. Therefore, sand is a very crucial and determinative factor in the quality of casting final product. By developing the technology of sand molds during recent years and invention of new binder, our knowledge about chemical and physical features of casting sands has been developed. In this survey we tried to investigate the main effective and qualitative factors on quality of casting molds from the mines as the first phase to the phase of delivering the final product to the casters. The results of this survey can be used by all of casters and silica sand producers in Iran and all over the world.

INTRODUCTION

Silica is an essential and important material in casting industry even though the casters have not paid enough attention to it. Silica is the most plentiful element in the earth surface can be found as oxide and one of its usages is for making molds in casting industry [1]. The quartz which can be found as sand in the mines includes some hard natural materials mixed together. However, if we separate pure sand from other things we will have silica oxide or SiO2 or quartz. Silica oxide is good at temperature transmission and has high resistance and can be shaped easily in casting industry [2]. By developing the technology of sand molds and inventing new generations of binders it is necessary to know more about chemical and physical features of casting sands [3]. These sands are abundant and cheap and therefore some casters prefer to use it a lot. It can be claimed that molding is the main pillar of casting and has determinative impact on the final product quality.

A huge amount of silica sand is used for making the molds in casting and steel making industry. In these industries the sands are molded and mixed with melting material and are shaped as the molds. Generally casting sands should have some features especially easy molding [4]. Molding by sands is a very useful and suitable method has been used by casters for a long time. There are different kinds of sands can be used in casting that include: green sand, dry sand, core sand, cement, bonded sand, shell, molding sand and flaskless molding sand. Totally the molding sands should be easy to be shaped and molded by which some healthy components could be produced [5].

According to above discussion and high importance of silica sands in casting industry our main goal in this survey is identification and ranking of indicators on the quality of the casting silica sand by using a multi-criteria decision making technique. For doing this we used some validity and mathematical methods and followed below stages:
A: Data analysis according to questionnaires data
B: The questionnaires were distributed between experts, managers and counselors of silica sand company.
C: The data derived from questionnaires have been analyzed and concluded.
D: Analyzing the data some suggestions for improving the quality of silica sand used in casting industry has been presented.
MATERIALS AND METHODS

In this survey the process of identification and ranking the effective indicators on quality of silica sand used in casting has been investigated and for these some multi-criteria decision making methods were used. We divided these indicators into four groups include:

A: Chemical indicators
B: Physical indicators
C: Processing and producing indicators
D: Mineral indicators

It should be noticed that chemical indicators include purity percentage and chemical analyzes of elements and zinter point. Physical indicators include permeability, thermal conductivity, expansion, humidity percent, size spread, GFN and specific surface area. Processing and producing indicators include separation, washing, grinding, floating, recycling and drying. Mineral indicators include organic acids, kaolin feldspar, quartz, dolomite and calcite.

Research process:

The main issue of this survey is Identification and ranking of indicators on the quality of the casting silica sand by using a multi-criteria decision making technique. For answering to the questions related to this issue some open and closed questionnaires have been prepared and distributed and some library studies and interviews have been done. The data were collected and analyzed by special software and finally some suggestions have been provided. Additionally all effective indicators and sub indicators on silica sand quality have been compared technically.

Main indicators:

Fig. 1: Quality indicators of casting silica sand.
A: Chemical indicators’ value (weight) was 0/323 and they have the most effective role on the quality of silica sand.
B: Physical indicators’ value (weight) was 0/319 and they are second effective indicators on the quality of silica sand.
C: Processing and producing indicators with weight of 0/211 were in the third grade.
D: Mineral indicators with weight of 0/145 were in the fourth ranking.

RESULTS AND DISCUSSIONS

Physical indicators comparison:

Table 1: Effective physical indicators.

<table>
<thead>
<tr>
<th>Physical Indicators</th>
<th>Physical resistance</th>
<th>Specific surface area</th>
<th>Humidity percent</th>
<th>Sorting coefficient couple</th>
<th>Round corner</th>
<th>Permeability</th>
<th>GFN</th>
<th>Slab</th>
<th>Thermal Conduct</th>
<th>Expansion</th>
</tr>
</thead>
</table>

After consideration and testing these indicators, we suggested below ranking for them: Physical resistance with the weight (value) of 0/127 was in the first grade, GFN with weight of 0/125 was in second grade, permeability with the weight of 0/122 was in the third, Round corner with the weight of 0/120 was in the fourth, Specific surface area with the weight of 0/106 was in the fifth, Thermal conduct with the weight of 0/096 was in the sixth, expansion with the weight of 0/086 was in the seventh, Humidity percent with the weight of 0/074 was in the ninth and Sorting coefficient couple with the weight of 0/055 was tenth.
• Chemical indicators comparison
• Chemical purity
• Zinter point
• Clay percentage
• Acid Demand Value (ADV)

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After consideration and testing these indicators, we suggested below ranking for them: Chemical purity with the weight of 0/384 was the most important and effective indicator, Zinter point in casting silica sand with the weight of 0/374 was the second, Clay percentage with the weight of 0/165 was the third and Acid Demand Value (ADV) with the weight of 0/087 was the fourth important indicator.

Table 2: Chemical analyzes of effective chemical indicators on quality of silica sand.

<table>
<thead>
<tr>
<th>Effective chemical indicators</th>
<th>SiO2</th>
<th>TiO2</th>
<th>K2O,CaO and Na2O</th>
<th>SO</th>
<th>MgO</th>
<th>Al2O3</th>
<th>Fe2O2</th>
<th>LoI</th>
</tr>
</thead>
</table>

Our calculation suggested below results: SiO2 with the weight of 0/211 has the most effective indicator, Fe2O2 with the weight of 0/191 was the second, Al2O3 with the weight of 0/163 was the third, MgO with the weight of 0/133 was the fourth, TiO2 with the weight of 0/100 was the fifth, Na2O with the weight of 0/089 was the sixth, LoI with the weight of 0/065 was the seventh and SO with the weight of 0/048 was the eighth effective indicator in the quality of casting silica sand.

Effective mineral indicators on quality of silica sand:
• Organic acids
• Feldspar
• Kaolin
• Quartz
Dolomite
Calcite

Our calculations suggest below results: Quartz indicator with the weight of 0/265 has the most effect on quality of silica sand, Feldspar Indicator with the weight of 0/225 was in the second rank, Kaolin with the weight of 0/219 was the third effective factor, Dolomite with the weight of 0/177 was the fourth, Calcite with the weight of 0/093 was the fifth and organic acids with the weight of 0/21 has the sixth grade in this field.

Effective processing and producing indicators on quality of silica sand:

These indicators include disintegration, washing, attrition, grinding, seeding, and floating or magnet separator, recycling and drying. Our calculations suggest below results: Disintegration with the weight of 0/177 was the most effective indicator, washing with the weight of 0/174 was the second attrition, with the weight of 0/143 was the third, seeding with the weight of 0/126 was the fourth, grinding with the weight of 0/109 was the fifth, floating with the weight of 0/098 was the sixth, recycling with the weight of 0/092 was the seventh and drying with the weight of 0/082 was the eighth effective processing and producing indicator on quality of silica sand quality.

<table>
<thead>
<tr>
<th>Final weight</th>
<th>Normal Weight</th>
<th>Sub Indicator</th>
<th>Weight</th>
<th>Main Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.12096</td>
<td>0.384</td>
<td>Chemical purity</td>
<td>0.315</td>
<td>Chemical Indicators</td>
</tr>
<tr>
<td>0.11781</td>
<td>0.374</td>
<td>Zinter point</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.051975</td>
<td>0.165</td>
<td>clay percentage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.02457</td>
<td>0.078</td>
<td>ADV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.021594</td>
<td>0.117</td>
<td>disintegration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.021228</td>
<td>0.174</td>
<td>washing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.017446</td>
<td>0.143</td>
<td>attrition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.015372</td>
<td>0.126</td>
<td>grinding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.00132</td>
<td>0.0109</td>
<td>seeding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.010858</td>
<td>0.098</td>
<td>Floating and magnet separation</td>
<td>0.122</td>
<td>Processing and Producing Indicators</td>
</tr>
<tr>
<td>0.011224</td>
<td>0.092</td>
<td>Recycling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.010004</td>
<td>0.082</td>
<td>Recycling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.194941</td>
<td>0.249</td>
<td>Organic acids</td>
<td>0.89</td>
<td>Effective Mineral Indicators</td>
</tr>
<tr>
<td>0.20025</td>
<td>0.235</td>
<td>Feldspar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01869</td>
<td>0.021</td>
<td>Kaolin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.23585</td>
<td>0.265</td>
<td>Quartz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1573</td>
<td>0.177</td>
<td>Dolomite</td>
<td></td>
<td>Physical Indicators</td>
</tr>
<tr>
<td>0.08277</td>
<td>0.093</td>
<td>Calcite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.02336</td>
<td>0.127</td>
<td>resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.02244</td>
<td>0.122</td>
<td>permeability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.02208</td>
<td>0.120</td>
<td>Round corner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.11224</td>
<td>0.610</td>
<td>SSA</td>
<td>0.184</td>
<td></td>
</tr>
<tr>
<td>0.17664</td>
<td>0.096</td>
<td>Heating resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.015824</td>
<td>0.086</td>
<td>expansion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.015436</td>
<td>0.084</td>
<td>slab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.013616</td>
<td>0.074</td>
<td>humidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01012</td>
<td>0.055</td>
<td>Sorting coefficient-couple</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion:

According to our researches, the most important and effective indicators on quality of silica sand include:
* Chemical indicators
* Physical indicators
* Processing and production indicators
* Mineral indicators

By developing the casting industry, the quality of silica sand has found increasing importance. Most of companies have complete control on all variables except casting silica sand and therefore lack of sufficient information about this vital factor can make a lot of wastes and decrease the quality and purity of sand and lead to more sand burning. There are some materials attached to the sand such as Mgo, Al2o3, TiO2, Cao, Na2oso, Fe2o3, and etc which have obvious impact on quality of components. Some extra components like iron, potassium, sodium and calcium can decrease the melting point of silica sand and its temperature from 1700°C to 1200°C. These elements prevent decreasing of silica sand PH. For removing this problem, some clay binders can be used, of course mixing the sand and binder should be done systematically and carefully. If the pollution in the sand could not be removed by water, acid washing should be examined and repeated for three or four times in order to help separation of clay and salt from sand.
It is suggested that attrition should be done before final washing. This process help removing of extra elements from silica sand. We have tested this trend repeatedly and summarized the results in table 5. It should be noticed that these tests have been done in Dorr Oliver co laboratory. We found that silica expansion is rather than other casting sands such as Cromit because it can expand quickly and change from condition of $\alpha$ to condition of $\beta$. These events often takes place in 570°C and can be problematic during casting process and make some crashes in components. There are some attachments to sand such as clay which are harmful in casting and resist against gas crossing and decrease the influencability of sand. For compensating this casters add artificial clay to the sand. It should be considered that this added sand should be limited otherwise has negative impact on sand solidity.

The casters must pay more attention to SSA (Specific Surface Area) and know that low levels of SSA means that we need less glue for forming and this can decrease the costs of casting process. Physical indicators such as GFN are very important factors in casting process that determine the quality of silica sand. Therefore the sand processing companies focus on this variable a lot. However, this variable cannot provide complete information about the quality of sand and we cannot just depend upon it as a determining factor. Additionally, neglecting about some important factors such as SSA can lead to more glue consumption and increasing costs.

The casting sand resistance can be examined by cutting, elastic and bending tests. Generally speaking, even though there is special test for each resistance capacity, in most of the cases, cutting and elastic tests are used and give casters more general and clear picture. The results of these tests help casters to predict the casting sand reaction in real world situation. It should be considered that some extra elements in mine such as feld spots and organic acids that influence the quality of casting sand negatively. In addition to these factors, the percentage of quartz is an essential and key factor for guarantying the high quality of casting sand.

REFERENCES

[5] Dawson.m 18-Silica Sand_Foundry requirements Cast metal services pty.ltd