Development and Application of Crushing-shaped Silica Sand with High Silica Content and Roundness from Quartzite Crushing and Shaping

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Abstract: Sand casting accounts for about 80% of the world's casting production, and more than 50 million tons of silica sand are consumed each year, the vast majority of which are high-quality natural silica sand. Limited by resources, many foundries have to purchase silica sand from natural silica sand plants thousands of miles away, resulting in not only a higher logistics cost than the cost of silica sand itself, but also a great increase of carbon emissions. In this study, a new crushing and shaping technology was used to develop a shaped silica sand with high silicon content and roundness. The silica content of shaped sand is above 98.5%, and the roundness is higher than 0.89. Moreover the sand broken rate is low, and the refractoriness is high. Tests in various processes and foundries show that shaped silica sand can replace completely high-quality natural sand.

KeyWords: quartzite, shaped silica sand, high roundness, high quality silica sand, carbon reduction

1 Introduction

Quartzite is a mineral widely existing in nature, its silica content is greater than 99%. Some foundries use silica sand from quartzite crushing in steel casting, but due to poor grain shape, it can only be used for CO_2 hardening water glass process along with problems of high amount water glass addition, poor collapsibility, and low regeneration rate. Therefore, the development of silica sand with high silica content and round grain shape can help solving the resource constraint, reducing logistics costs and carbon emissions in steel casting.

2 Production process of shaped silica sand

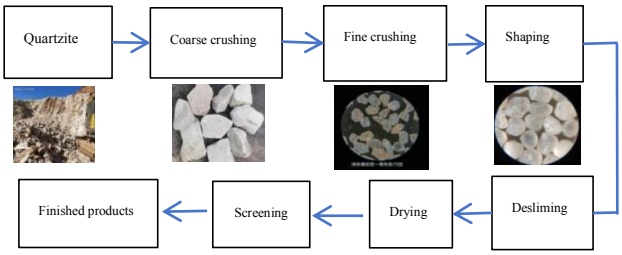


Fig.1 High silica content and roundness shaped silica sand production process

This process is determined after screening and optimisation of various shaping equipments and processes.

3 Comparison of physical and chemical properties

Table 1 Physical and chemical properties of sand

Silica sand	Roundness *	Specific surface area (cm²/g)	Clay content	AFV	refractoriness (℃)	LOI	SiO_2 content
Fujian sand	0.878	89.63	0.41%	4.81	1710	0.19%	>98 %
Hainan sand	0.885	82.20	0.33%	1.42	1720	0.11%	>99 %
Crushed sand	0.854	93.25	0.56%	15.64	1730	0.18%	>99 %
Shaped sand	0.902	75.58	0.30%	4.79	1730	0.15%	>99 %

The data in Table 1 shows that the silica content, roundness and specific surface area of shaped silica sand are better than high-quality natural silica sand and crushed silica sand, which is conducive to reducing core binder addition and improving quality of castings.

4 Broken Rate

The formation of micro-cracks on the surface of

shaped sand during the crushing and shaping process can significantly influence sand breakage during casting and sand regeneration, affecting both particle size distribution and reusability. To investigate this, we conducted a series of tests and experiments.

4.1 Broken rate test

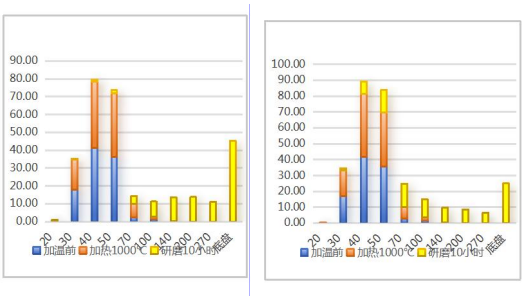
The broken rates of cast iron natural silica sand, Hainan natural sand and shaped silica sand were respectively tested, and the results are shown as below in Table 2.

Table 2 Test results of breakage rate

Silica sand	Broken rate （%）	Test pressure
Cast ion natural silica sand	2.74%	35MPa
Hainan natural sand	2.84%	35MPa
Shaped silica sand	0.89%	35MPa

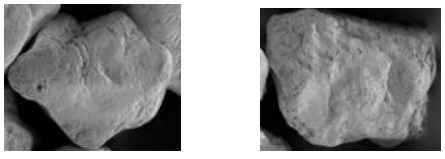
4.2 Simulated crushing test of simulated casting and sand regeneration process

We heated natural silica sand and shaped silica sand with same particle size to 1000℃, and then naturally cooled to room temperature, grinding under the same conditions for 10 hours. The changes of particle size and surface morphology of the two kinds of sand before and after grinding were compared. Results are shown in Figure 2 and 3.

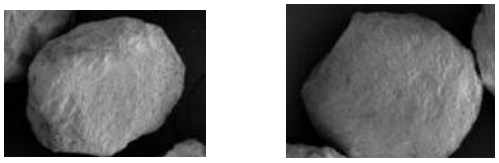


(a) cast steel natural silica sand (b)shaped silica sand

Fig 2. Simulated crushing tests result



Natrual silica sand before grinding Natrual silica sand after grinding



Shaped silica sand before grinding shaped silica sand after grinding

Fig.3 SEM photos of sand images

All the tests and results show that there are no micro-cracks on the surface of shaped silica sand, and its crushing resistance is better than that of natural silica sand.

5 Process properties tests

Sand （sameAFS）	24h pulling strength（MPa）			
	Furan process①	Alkaline phenolic process②	Easter hardening water glass③	RCS④
Fujian Sand		0.70		4.11
Hainan Sand	0.96			
Shaped sand	1.45	0.83	2.55 （compressive）	5.48
Crushed sand			1.08 （compresive）	

①resin addition1.0%，hardener addition 45%（of resin）
②resin addition1.63%，hardener addition 20%（of resin）
③water glass addition 2.7%，ester addition 18%（of water glass）
④resin addition 2.5%，hexa addition15%（of resin）

The strength test results of several molding and core-making processes show that the strength of shaped silica sand is better than that of natural silica sand under the same amount of binder.

6 Conclusion

The new high roundness and high silicon content shaped silica sand can be used for a variety of core molding processes, it has high SiO_2 content（>99%），roundness（>0.90）and better reusability, especially the binder consumption can be reduced, and can completely replace the high-quality natural silica sand in steel casting.