Application and Research of Wet-gunning Based on Colloidal silica for Main trough of Blast Furnace

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Abstract

In this study, the wet-gunning compositions were defined and based on Al_2O_3-SiC-C, the binding system was used colloidal silica (CS) to substitute calcium aluminate cement (CAC).The tests were carried out trough workability, physical properties, binding strength, adhesion testing by gunning machine, accelerators, rotary slag testing. The initial result shows it passed the testing and applied of China Steel Co. and the CS of performance is also better than CAC binding system. In our future study, we are going to concentrate with the improvement of hot repaired at the wet-gunning refractories.

1. Introduction

The recent development of blast furnace manufacturing process forwards to minimize frequently refractories repairing and reduce the time of installation. The purpose of this manufacturing process is that reducing the consumption of refractories and increased the life time of main through. In order to achieve this target, the development of maintain technique can effectively reducing the consumption and expanded the life time of refractories before blast furnace operators repair to cast the main trough. Wet-Gunning maintains technique is currently adopted by China-Steel Plant; the characteristic of materials closed to castable and have great erosion resistance with liquid pig iron.

The wet gunning methods have two characteristic of material. The one is have high plastic and binding performance, it can be used to attain adhesion of maintain without add accelerator in the nozzle. On the other hand, wet gunning has two properties: thixotropy and free-flowability. While the material was used to repair the work area, the state of the material from gel to solid because it reacts with accelerator..

2. Experimental Procedure

2.1 Sample preparation[)]

The comparison of wet gunning material TS1 (cement) and CS1 (non-cement) in this experiment. Cement and non-cement wet-gunning material were produced by brown fused alumina, silicon carbide, calcined alumina and carbon additives, but the binder of cement is calcium aluminate cement; Non-cement wet-gunning material is colloidal silica. These samples were prepared to rectangle (40mm × 40mm × 160mm) and trapezoid (height 65mm, 60mm and 160 mm are the length of the parallel sides) according to JIS R2553. After drying 24h at ambient temperature, these samples were dried 24h at 110℃. Addtionally, wet-gunning material was shooted on the work area for testing adhesion ability and erosion ratio.

2.2 Materials Tested

Conical module(up diameter: 70mm, down diameter: 100mm, height: 50mm) was fill up wet-gunning material, then withdraw the conical module and measure the material diffusion distance according to JIS R2521.

Sample (40mm × 40mm × 160 mm) was sintered in atmosphere and reducing atmosphere respectively at 1450℃× 3h before measuring apparent porosity, bulk density, Modulus of rupture and cold crushing strength according to JIS R2553.

The slag resistance of sample was tested by rotation slag resistance. The condition of rotation slag resistance, temperature at 1550℃× 6 cycles (30min/cycle, then air blow 10min/cycle) , rotation speed 3rpm, slag/iron ratio 1/1. After testing by rotation slag resistance, samples were cut in half for analysis.

After rupturing by test machine, the sample was casted with TS1 and CS1 respectively, then dried 110℃× 24h. The dried sample was sintered in atmosphere and reducing atmosphere respectively at 1450℃× 3h before testing M.O.R.

Cement and non-cement wet-gunning material were produced by brown fused alumina, silicon carbide, calcined alumina and carbon additives, but the binder of cement is calcium aluminate cement; Non-cement wet-gunning material is colloidal silica (**Table 1**). Gunning testing with accelerator S and accelerator SA respectively by wet-gunning machine (type: RP-10, Allentown)

Table 1 Chemical composition of castables

	Al_2O_3	SiC+C	Cement
TS1	75	20	3
CS1	75	20	0
M81	75	20	1

3. Results and discussion

According to results (**Table 2**), the workability of CS1 as same as TS1,M81 and the setting time of CS1 longer than TS1, M81. we can obtain that CS1 more advantage than others because of longer setting time that avoid wet-gunning material causing an obstruction in the pipe.

Table 2 Workability of castables at room temperature

Sample	water/ colloidal silica (%)	Self-flow (mm)	Flow (mm)	Setting time (min)
TS1	7/-	115	170	360
CS1	-/8	110	185	>4320
M81	5/-	106	180	200

According to the result that CS1 can be substituted for TS1. Hence, the replacement of physical properties reduces the potential risks between current and previous products (**Table 3**).

Table 3 Physical properties of castables (1450℃ 3hrs)

Sample	Porosity (%)	Bulk density (g/cm^3)	M.O.R (MPa)	C.C.S (MPa)
TS1	16	2.89	18	87
CS1	16	2.89	16.5	93
M81	15	3.04	15.5	74.6

The average erosion rate of off-operating brick (**Fig. 1**), we compared with same gunning materials; the slag resistance ability of Al_2O_3-SiC-C binding system is obviously higher than the slag resistance ability of ceramic binding system. However, both of them are lower than casting material. In fact, the bonding strength in 1400℃of Al_2O_3-SiC-C binding system is obviously higher than the bonding strength in 1400℃of ceramic binding system. Therefore, the refractories have great physical resistance when it is used in high temperature environment.

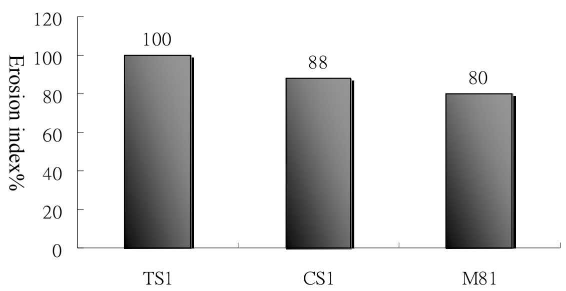

Fig. 1 Erosion index of rotation slag experiment (1500℃)

The slag resistance of CS1 higher than TS1,but lower than M81(**Fig. 1**). The main reasons are listed in Table 4 that are the grain distribution and main material, brown fused alumina. The characteristics of fused alumina are low porous, high strength and complete physical structure that make the excellent performance on its physical and chemical resistances. After the matrix completely combine with main material, the performance of erosion resistance positive correlate with the grain size of corundum and it can also reduce the matrix to be physically eroded by molten iron.

Table 4 Particle distribution of castables

	>6mm	1mm-6mm	<1mm
TS1	0	44	56
CS1	0	45	55
M81	1.5	51	47.5

The combined bonding strength of old and new refractories (**Table 5**). The record shows the combined bonding strength doesn't relate with old matrix, the strength performance comes from the contribution of new material (Casting). The main elements of silica gel are the particles of water and nanometer SiO_2. After added the nanometer particles in the mixed gunning material, it can increase the combined area between old and new materials. It can also create the solid diffusivity to achieve better sintering reaction. Therefore, when the silica gel becomes the combining system of new material, the bending strength is higher than ceramic to be the combining system of new material.

Table 5 Comparision of bonding strength by different matrix

Bonding strength (MPa)		Casting	
		SPNG-TS1 (Cement)	SWG-CS1 (Colloidal silica)
Matrix	TS1 (Cement)	4.5	10
	CS1 (Colloidal silica)	6.2	9.4

According to the current information from CSC, the thickness of each side in blast furnace main trough is 450 mm to 500 mm to evaluate the repaired performance of CS1. The attached result of gunning machine as Fig. 2; the max thickness of gunning is 850mm, it's 1.5 times thicker than the max thickness of main trough. The hardening mode of silica gel is the SiO_2 particles in silica gel that have hydroxyl functional groups. After hydroxyl functional groups are catalyzed by hardener, the hydroxyl functional groups process the reaction of condensation and synaeresis. This reaction also corresponds with the attached and shrinking phenomena of physical. Therefore, it causes the attached characteristic of gunning.

Fig. 2 Adhesion of gunning material (CS1)

The attached processes of gunning machine tested different accelerators, simultaneously (as **Fig. 3**). The better harden time in gunning operation is around 40 ~ 50 seconds. The testing results show the consumption of accelerator SA is the 50% consumption of accelerator S. In addition, the accelerators of traditional gunning material usually include the elements of sodium and potassium that will reduce the refractoriness performance of materials. As a result, the new accelerator doesn't mix the elements of sodium and potassium so it can reduce the poor performance from low-grade melting eutectic mixture.

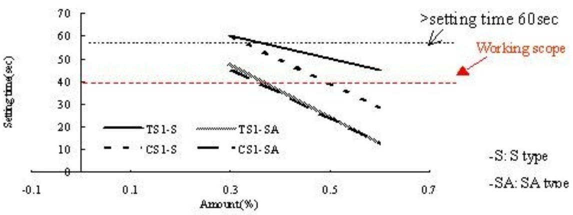

Fig. 3 Adhesion of gunning material (CS1)

The max erosion rate of non-ceramic gunning after off-operated by cool and hot repaired operation in the #3 Blast Furnace of CSC. Base on the same cool repaired operation mode the max erosion rate of CS1 is 0.33cm/ 1000 MT and TS1 is 0.42 cm/ 1000 MT; the improvement of erosion resistance is around 22%. Comparably, the hot repaired operation mode the max erosion rate is 1.17 cm/ 1000 MT. However, the standard of CSC is 0.83 cm/ 1000 MT. The difference between cool and hot repaired operation might relate to the drying of water content. The current construction mode is after gunned the repaired material CSC adopts high temperature to dry the construction area around 3 ~ 4 hours and immediate taking molten iron. Therefore, the existed percentage of water content may highly correlate and influence with the potential performance of repaired material.

4. Conclusions

After a serial physical and chemical analysis for the wet gunning material of blast furnace main trough, the initial evaluation shows as following points;

(1) The difference of constructible and physical in normal temperature between CS1 and TS1 are a few. That can also reduce the risk of replacement between new and old materials.

(2) The slag resistance, combinable and the test of attached of CS1 are better than TS1. The only change is the combining system to achieve the total performance of refractories.

(3) The operating result of CSC and Dragon Steel shows the erosion resistance of CS1 is 22% higher than TS1 under same cool operating condition. The only unclear situation is the erosion resistance under hot operating condition because it doesn't setup a certain target. The difference might come from the complete of water content remove. It will be the topic of our future research.

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