EFFECT OF ADDITIVES ON THE PROPERTIES OF Al_2O_3-SiC-C BLAST FURNACE RUNNER MATERIALS

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ABSTRACT

Different additives were applied on Al_2O_3-SiC-C main trough materials (castables) and slag runner materials (ramming mix) of blast furnace for improving workabilities, physical properties and life time. High temperature physical properties and rotary slag test of specimens were examined, and microstructure was observed by SEM. The results pointed out that the mechanical strength was increased and apparent porosity can be reduced up to 7.5 % by added appropriate amount of additive, the corrosion resistance was also well improved, longer life time of main trough materials can be achieved.

INTRODUCTION

Blast furnace main trough system of was consisted of five main parts: main trough, skimmer, iron runner, slag runner and tilting runner. With the progressing of steel industry technology, large-scaled blast furnace with high efficiency and long lifetime were developed, refractory applied on main trough was developed from one type castable into two type castables which suit with metal line and slag line [1].

Main trough was located between taphole and skimmer, the front-end of main trough was wide-shallow shape and progressively change into narrow-deep shape at the rear-end. The slag and molten iron were separated by their gravity difference, slag pass through the upper region of main trough which was so called slag line and lower region was metal line that runs through by molten iron. Castable of these two regions was designed for each operation conditions. Especially on slag line castable, corrosion resistance and oxidation resistance were the two main properties that demanded for this region, castable with high SiC content was widely used due to its low wettability and low reactivity against the molten slag [2].

The molten iron wears and scours the trough more intensively in the large-scaled blast furnace. Different corrosion condition took place between main trough and slag runner, and the composition of refractories for each regions were adjusted for increasing lifetime and reducing the cost, easy construction with high efficiency were also the main target in present.

EXPERIMENTAL

Materials

Raw materials used in this study were brown fused alumina, silicon carbide, carbonaceous powder, alumina cement, clay, sintering additive and four kinds of additives.

Sample preparation

Castables for metal line and slag line of main trough

The composition of castables for metal line and slag line were showed in table 1 and table 2, respectively. A series of composition with different amount of additives were designed and modified from present product M81 and M82. All samples were wet mixed with water by mixer machine (Leader Baker HK-10l), then casted into bar molds (40×40×160 mm^3) by using a vibration table. After casting, the samples were cured for 24 h in mold at room temperature followed by de-molding and drying at 110℃ for 24 h.

Tab. 1: Compositions of metal line castables.

	M81	M1	M2	M3	M4	M5
Al_2O_3 (%)	≧70					
SiC+C (%)	≧20					
Alumina cement (%)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Additive I (%)	—	<0.05	—	—	—	<0.05
Additive II (%)	—	—	<0.05	—	—	<0.05
Sintering additive (%)	—	—	—	<1.0	<2.0	<2.0
Water addition (%)	5.0	5.0	5.0	5.0	5.0	5.0

Tab. 2: Compositions of slag line castables.

Materials	M82	S1	S2	S3	S4	S5
Al_2O_3 (%)	≧55					
SiC+C (%)	≧33					
Alumina cement (%)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Additive I (%)	—	<0.05	—	—	—	<0.05
Additive II (%)	—	—	<0.05	—	—	<0.05
Sintering additive (%)	—	—	—	<1.0	<2.0	<2.0
Water addition (%)	5.0	5.0	5.0	5.0	5.0	5.0

Ramming mix for slag runner

The composition of ramming mix for slag runner was showed in table 3. A series of composition with different amount of additives were modified from present product MTA. The materials were mixed using mixer machine in sequence that coarse particle, additives, fine powder and then water at last, after cured in bag for 24 h at room temperature then the ramming mix were prepared.

The bar specimens were made by ramming the mixes in the bar molds (40×40×160 mm^3) and followed by press forming using 100 ton MTS. After de-molded, the specimens were dried at 110℃ for 24 h.

Tab. 3: Compositions of ramming mix for slag runner.

Materials	MTA	R1	R2	R3	R4	R5
Al_2O_3 (%)	≧60					
SiC+C (%)	≧20.5					
Additive III (%)	—	<1.0	—	<1.0	—	—
Additive IV (%)	—	<1.0	<1.0	<1.0	<1.0	<1.0
Sintering additive (%)	—	—	<2.0	<2.0	<3.0	<1.0
Water contain (%)	4.5~5					

Test methods

Workability of castables

After mixing the castable with appropriate amount of water, flow value was measured according to ASTM C860-91 method.

Workability, bulk density and strength of ramming mix green body

Workability index of ramming mix was evaluated by China Steel Co. testing method CSC-R018-76, bulk density and cold crushing strength of green body were measured according to China Steel Co. testing method CSC-R017-76.

Physical properties

After drying, all the casted specimens were sintered at 1450 ℃ for 3 h, the rammed specimens were preheated at 1000℃ and then sintered at 1450℃ for 3 h. The physical properties that cold modulus of rupture (MOR), cold crushing strength (CCS), bulk density (BD), apparent porosity (AP) and permanent linear change (PLC) were measured. Tests on hot modulus of rupture (HMOR) were conducted at 1400℃ for 3 h, with carbon embedding. BD and AP were measured by Archimedes method. Microstructure analysis was carried out by means of XRD (Rigaku Miniflus II) and SEM (Hitachi S300N).

Slag corronsion resistancet

A rotary slag test was conducted to evaluate the corrosion resistance of slag line castables and ramming mixes. In each cycle, raise the temperature up to 1500℃, then feed the slag mixture (mass ratio of slag/iron is 3) and proceed corrosion for 60 min, drain out the slag and cooling down the specimens by blowing compress air for 10 min. After carry out 10 to 15 cycles, corrosion ratio can be calculated by measuring the cross-section area compared to original area of specimens.

RESULTS AND DISCUSSION

Workability of all samples

The workability of metal line, slag line and slag runner materials were list on table 4. The data shows that all samples possess better workability than previous products (M81, M82, MTA), therefore higher efficiency can be improved when constructing the trough.

Tab. 4: Workability data of metal line and slag line castables, and green body data of ramming mix.

Metal line	M81	M1	M2	M3	M4	M5
Water addition (%)	5.0	5.0	5.0	5.0	5.0	5.0
Flow value (mm)	179	188	191	186	180	185
Slag line	M82	S1	S2	S3	S4	S5
Water addition (%)	5.0	5.0	5.0	5.0	5.0	5.0
Flow value (mm)	175	183	189	186	176	178
Slag runner	MTA	R1	R2	R3	R4	R5
Bulk density (g/cm^3)	2.58	2.65	2.82	2.75	2.74	2.85
CCS (Kg/cm^2)	2.92	3.62	3.46	3.87	3.21	3.50

Physical properties

Metal line and slag line castables

The physical properties of castables after sintered at 1450℃ were showed in figure 1 and 2. Sample M5 and S5 both combined three additives and showing the highest MOR. Only sintering additive was added in sample M3 and S4 showing a noticeable enhance on CCS. Overall, no matter combining or separately make use of additive I, II and sintering additive, mechanical strength were all promoted by compared with M81 and M82. BD, AP and PLC parameters were also in the standard ranges.

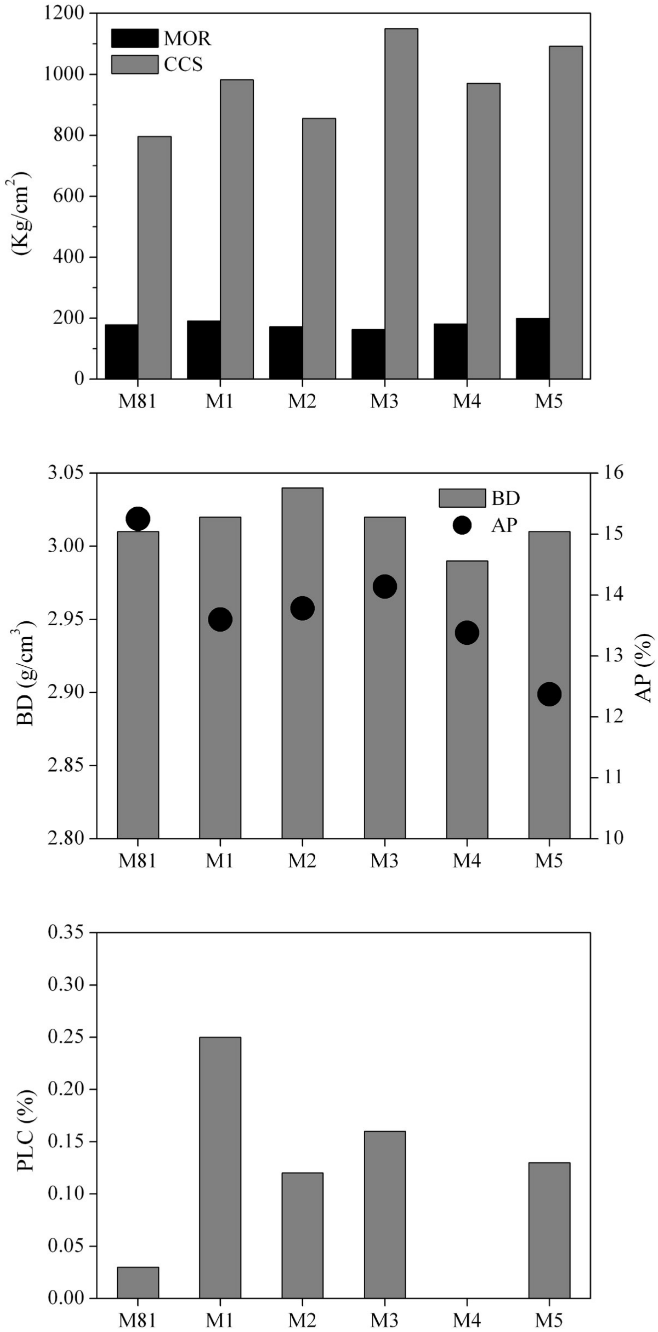
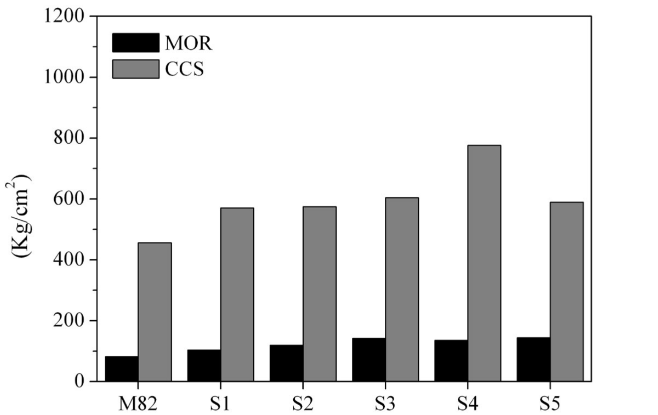


Fig. 1: Physical properties of metal line castables after sintered at 1450℃ for 3 h.



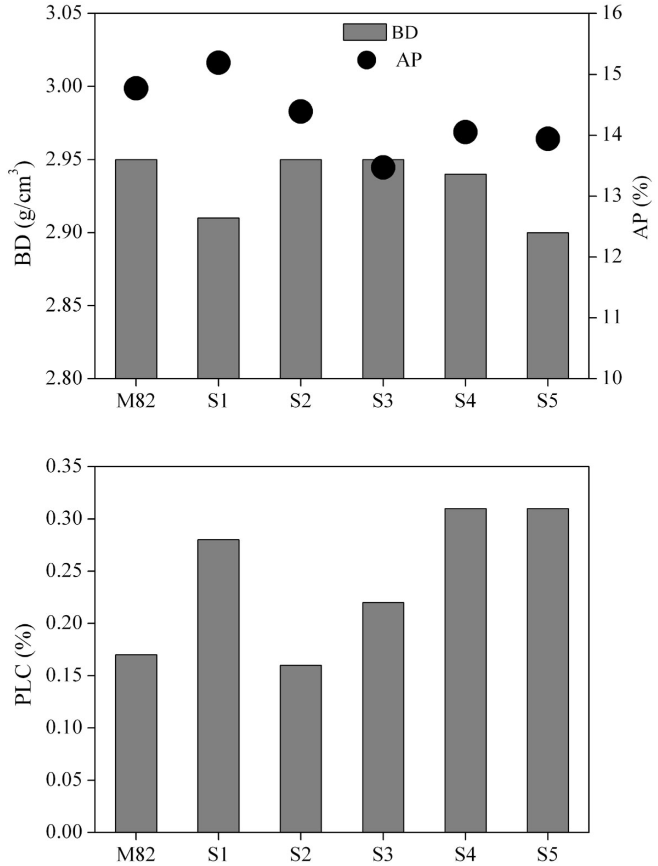


Fig. 2: Physical properties of slag line castables after sintered at 1450℃ for 3 h.

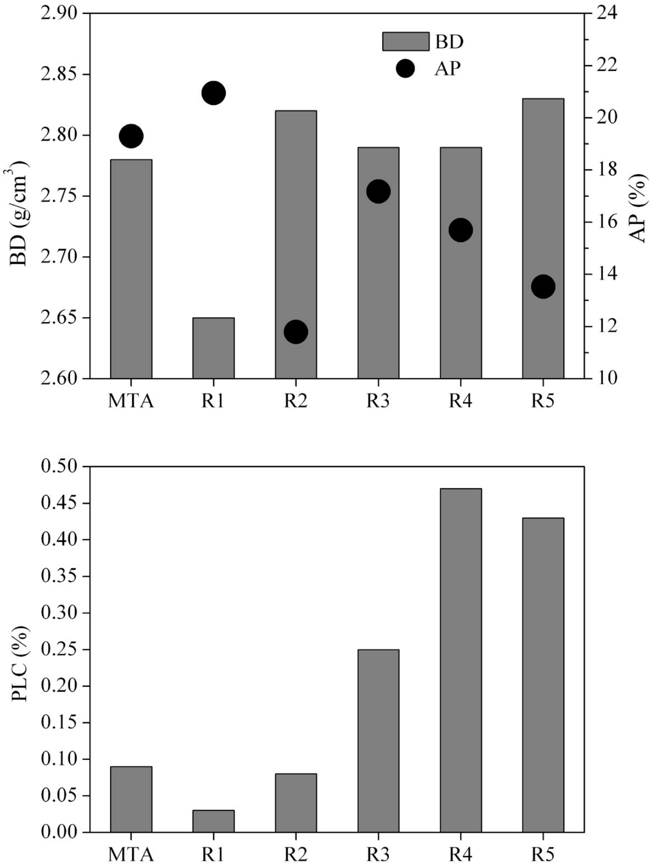
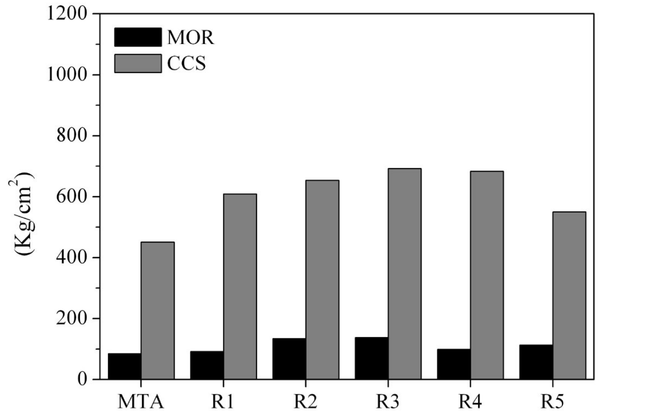


Fig. 3: Physical properties of ramming mixes for slag runner after sintered at 1450℃ for 3 h.

Ramming mixes of slag runner

MOR and CCS of sample R1 to R5 were all enhanced, and BD, AP and PLC parameters were also in the standard ranges. Particularly in sample R2, lowest AP of 11.79 % was achieved by adding appropriate amount of additive IV and sintering additive.



HMOR data of all samples

The HMOR data were showed in table 5, sample M5, S5 and R2 have the highest HMOR in metal line, slag line and ramming mix, respectively.

Tab. 5: HMOR data of metal line, slag line castables and ramming mix of slag runner

Metal line	M81	M1	M2	M3	M4	M5
(Kg/cm^2)	48	77	54	53	69	114
Slag line	M82	S1	S2	S3	S4	S5
(Kg/cm^2)	21	28	37	34	41	56
Slag runner	MTA	R1	R2	R3	R4	R5
(Kg/cm^2)	54	47	71	61	52	55

Slag corrosion resistance

Slag resistance was a major factor that dominated the lifetime of refractories, rotary slag test was conducted to evaluate the corrosion resistance in this study. Table 6 shows the corrosion ratio of salg line and slag runner refractories, sample S5 and R2 showing the best resistance of slag line castable and ramming mix, respectively.

Tab. 6: Slag corrosion data of slag line castables and ramming mixes

Slag line	M82	S2	S3	S4	S5
Corrosion ratio (%)	28.3	23.5	25.9	24.6	21.2
Rating	5	2	4	3	1
Slag runner	MTA	R2	R3	R4	R5
Corrosion ratio (%)	19.7	16.7	18.1	27.0	24.3
Rating	3	1	2	5	4

According to the results of rotary slag test, corrosion ratio was decreased by compared with present products, trough materials with improved lifetime can be expected. Corrosion ratio was related with HMOR and physical properties at high temperature, sample S5 and R2 possessed highest HMOR and MOR in castable and ramming mix, and represented in lowest corrosion ratio.

Microstructure observation

Figure 4 shows the XRD patterns of castable under slag layer after slag corrosion testing, mullite crystalline can be founded.

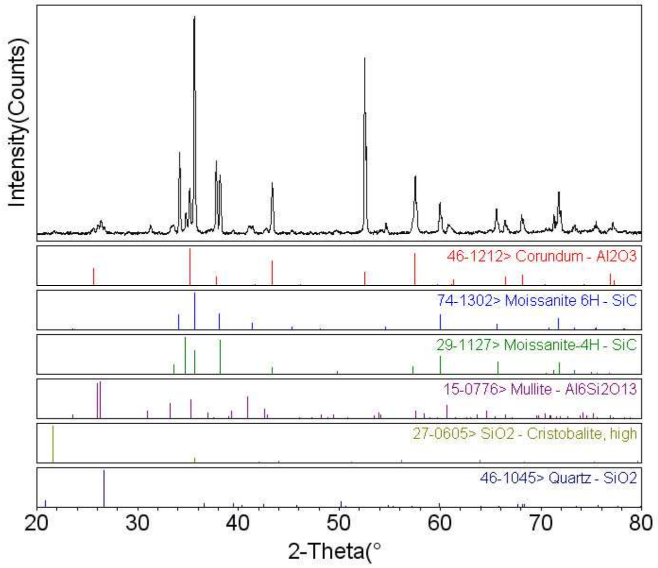


Fig. 4: XRD pattern of castable after slag corrosion test.

Pillar shape mullite crystals can be seen in SEM micrographs (figure 5), the network crystals can conduce to enhance mechanical strength of materials [3].

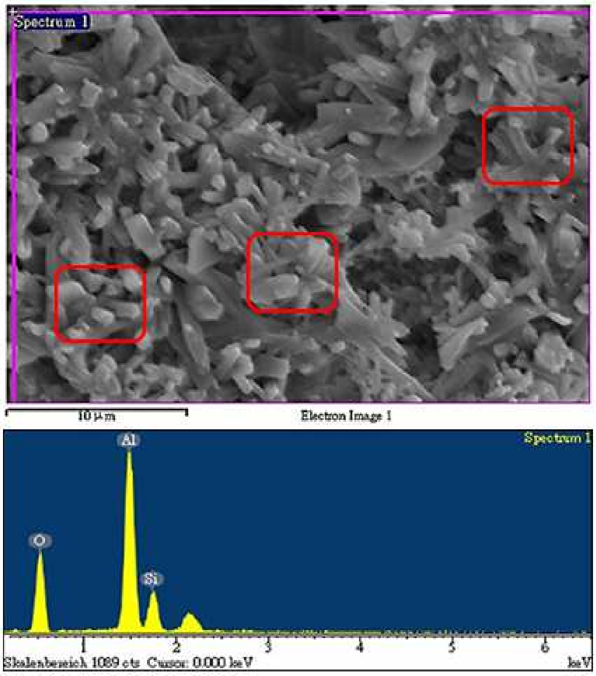


Fig. 5: SEM micrographs of mullite crystals in Al_2O_3-SiC-C castable.

CONCLUSIONS

1. The adding of additives and sintering additives can improve the strength, no matter combining or separately make use of additive and sintering additive
2. Sample M5, S5 and R2 have the highest HMOR in metal line, slag line and ramming mix, respectively.
3. In slag resistance testing, sample S5 and R2 possessed lowest corrosion ratio that showing the best resistance of slag line castable and ramming mix, respectively.
4. The results pointed out that the mechanical strength was increased and apparent porosity can be reduced up to 7.5% by added appropriate amount of additive, longer life time of main trough materials can be achieved.
5. Pillar shape and network mullite crystals can be founded in castable under slag layer, network structure can conduce to enhance mechanical strength.

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