Improvement Lifetime of Trough Cover by Using Al_2O_3-SiC-C Castables

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Abstract

Trough cover is applied in stopping from molten iron spray and protecting workers. Refractories used on trough cover must possess good corrosion resistance and thermal shock resistance at 1500-1800℃ service condition. The lifetime of high-alumina castables is about 20 days in main trough of China Steel Co. In this study, Al_2O_3-SiC-C castables were proposed by replacing high-alumina castables. It showed that the modulus of rupture (MOR) is 47 kg/cm^2 after subjected to 6 cycles of thermal shock tasting (1000℃, water quenched) and the lifetime can be prolonged to 37 days.

1. Introduction

The application of trough cover is to avoid the spatter of molten iron from tapping hole. The inner lining rafractories casting on the steel shell of trough cover should provide the characteristics of anti-corrosion and thermal shock resistance. For instance, the trough cover performance of China Steel Corporation's #4 Blast Furnace showing approximately 20 day of lifetime and 43,620 MT molten iron of production capacity by using high alumina materials as refractories.

Castables in the Al_2O_3-SiC-C system have been developed and studied by many workers.[1-3] Silicon carbide is commonly used to increase the thermal conductivity and decrease the thermal expansion coefficient of high-alumina castables so as to enhance the thermal shock resistance. Carbon (graphite or pitch) has a similar effect on thermal properties and inhibits metal and slag corrosion because of its non-wetting nature. In this study, Al_2O_3-SiC-C castable refractories were proposed for substitution, and the main target is to improve the lifetime of trough cover.

2. Experimental

Three formulas B, C and D were proposed according to original sample A (**Table 1**). The chemical composition of all samples were inspected by wavelength dispersive X-ray fluorescence (WDXRF) and listed on **Table 2**.

Each sample was produced by wet mixing with water addition, casting under vibration into bars of 40mm×40mm×160mm, dried at 110℃ for 24h and then sintered at 1450℃ for 3h.

Physical properties in terms of bulk density (BD), apparent porosity (AP), vibration flow value, modulus of rupture (MOR), cold crushing strength (CCS), hot modulus of rupture (HMOR) (1450℃) and permanent linear change (PLC) of sintered specimens were tested in accordance with related regular standards. Static slag crucible method was used to evaluate the corrosion resistance. Thermal shock testing was conducted at 1000℃ and then water quenched for 6 cycles. Microstructures were analyzed by scanning electron microscopy (SEM).

Table 1 Composition of samples

Sample	A	B	C	D
8-5 mm			12.5	12.5
5-3 mm	10	10	15	15
3-1 mm	25.0	22.5	22.5	22.5
1-0 mm	30	30	16	16
fine powder	24.8	27.3	26.8	28.8
cement	10	10	7.5	5
additive I	0.1	0.1	0.1	0.1
additive II	0	0	0.1	0.2
total	99.9	99.9	101.0	100.1

Table 2 Chemical composition of samples

Sample	A	B	C	D
Al_2O_3(%)	63.3	52.4	60.6	61.2
SiO_2(%)	30.8	32.5	20.4	21.2
SiC(%)	0	9.4	15.3	15.1
CaO	3.6	3.7	2.5	1.8
others	2.3	2.0	1.2	0.7

3. Results and discussion

The fine powder addition of sample B was slight higher than sample A, hence helps to improved bulk density and decreased porosity (**Fig. 1**). It also revealed on higher MOR of sample B (**Fig. 2**). However, the increased fine powder addition replacing coarse grain will reduced the CCS. Therefore, in further formula C and D not only increased the fine powder but also raised the coarse grain proportion to evaluate the variations of CCS and MOR.

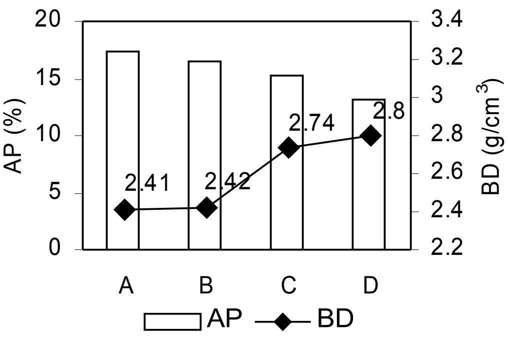

Fig. 1 Bulk density and apparent porosity of sintered samples.

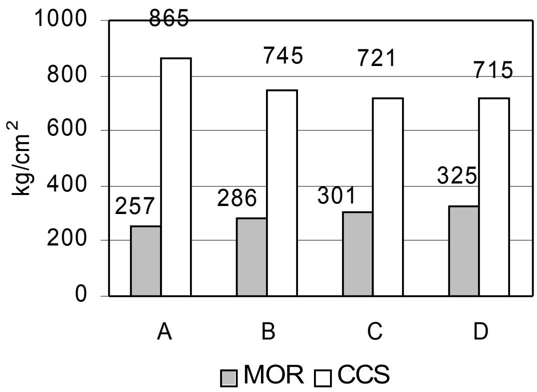

Fig. 2 CCS and MOR data of sintered samples.

The sample B showing glutinous characteristic when construction and the flow ability did not increased after rising fine powder content. Since the PLC showed high shrinkage of sample A and B (**Fig. 3**)**,** and leaks appeared for both samples after drying, so the formula A and B can't be used on trough cover.

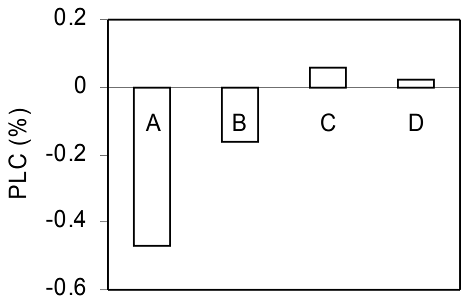

Fig. 3 Permanent linear change (PLC) of samples.

SiC (9.4%) was imported into sample B and result in better corrosion resistance than sample A. It is confirmed that the addition of SiC can improve the performance of anti-corrosion (**Fig. 4**). In hence, base on the testing results of sample A and B, the formula C and D were adjusted and modified.

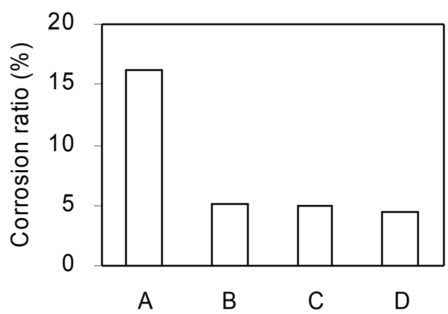

Fig. 4 The corrosion ratio evaluated by static slag crucible method (1450℃).

Course grain 8-5 mm was introduced and the percentage of fine powder was modified in sample C and D. The result shows that the porosity of sample C and D down to less than 15% and the bulk density increased above 2.7 g/cm^2 (**Fig. 1**). The SEM analysis also showed the sintered bodies of samples C and D are denser and less pore than sample A and B (**Fig. 5**). As the result, the modification of total grain size really improved the density of sample structure.

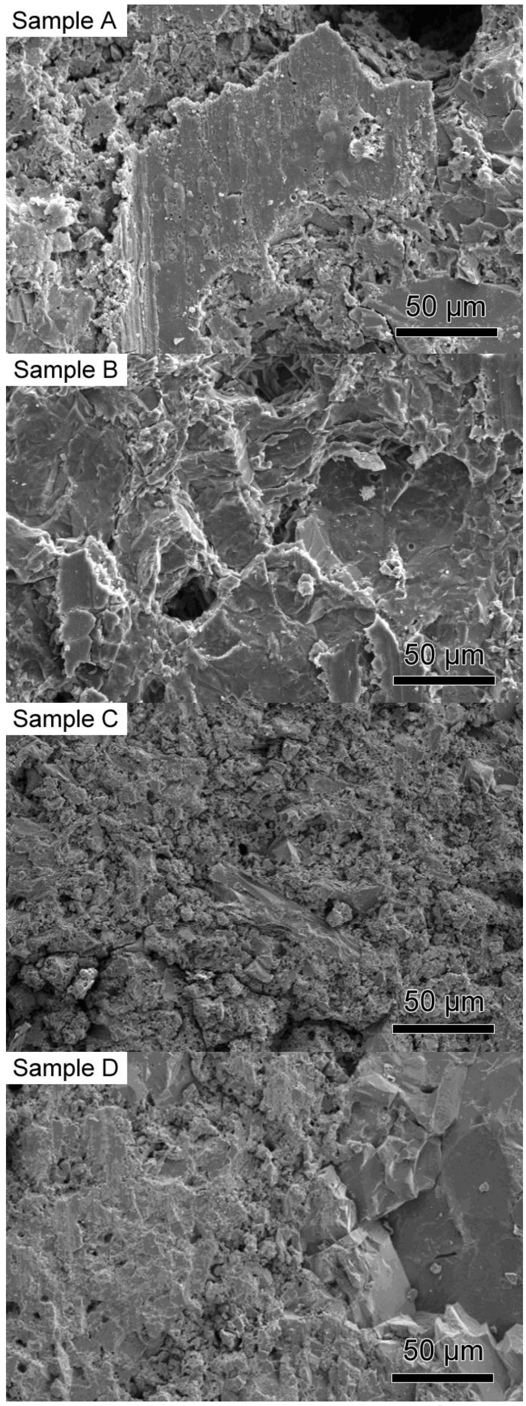

Fig. 5 SEM micrographs of 1450℃ sintered bodies.

In addition, after reducing the percentage of cement and adjusting the additives, the water addition also decreased in the sample C, but the flow ability of is too high and unfavorable for construction operation. Nevertheless, the water addition of sample D is lowest (**Fig. 6**) and the flow ability is appropriate for construction. This result also agree with some researches in high-alumina castable systems, the water demand in high-alumina castables is decreased remarkably by reducing the cement content. Therefore, the low or ultra-low cement castables exhibit better physical properties than the traditional medium-cement castables.[4,5)]

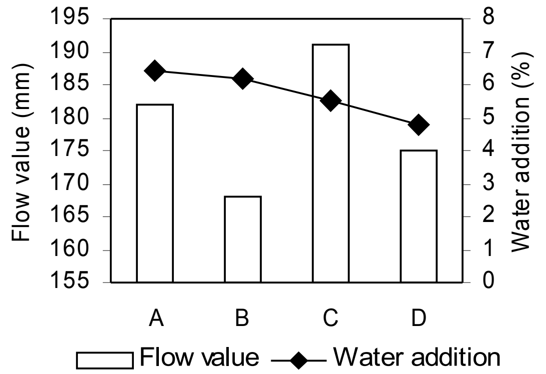

Fig. 6 Water addition and flow value of castables.

The CCS test showed the sample A has highest strength. Even though the CCS reduced om adjusted formula C and D, but the MOR increased (**Fig. 2**). The reason is that the samples C and D are not only adjusted the grain size, but also added Additive II to raise the MOR bending strength. The HMOR test also showed that the strength of sample C and D increased, and highest strength can achieved ~200 kg/cm^2 in sample D (**Fig. 7).**

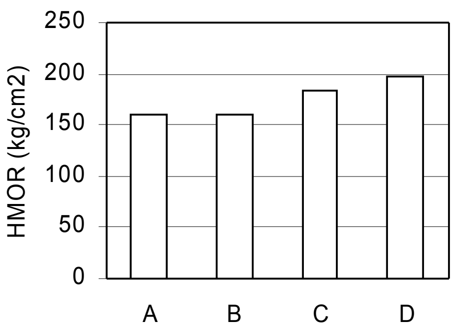

Fig. 7 HMOR data of specimens at 1450℃.

Moreover, the static slag crucible test shows that sample D has excellent molten iron resistance, the corrosion ratio of is 4.5% and is much lower than the 16.2% of sample A. Each sample has measured MOR after through the thermal shock testing which ramped to 1000℃ then water quenched for 6 cycles. The strength of sample D can achieve 47 kg/cm^2 and is higher than sample A and B (**Fig. 8**). The PLC of sample D at 1450℃ is only 0.02% (**Fig. 3**), so it is difficult for material D to result in spall and leak when drying after casting or under high temperature operation.

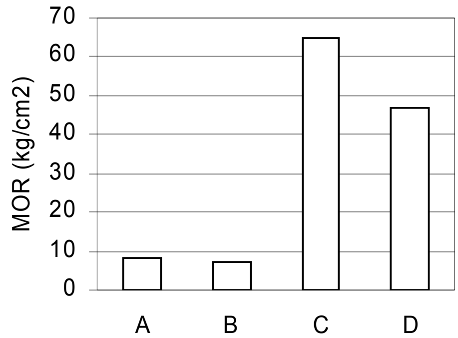

Fig. 8 MOR data after thermal shock testing (1000°C, water quenched, 6 cycles).

All of tested results show the density and high temperature performance of sample D is better than others. The water addition of material and the flow ability of casting are appropriate for apply construction. As the result, China Steel Corporation chose the material of sample D to be the trough cover lining refractories in the #3 and #4 main trough of #4 blast furnace.

The water addition was decrease progressively applied under casting operations. Castable with 7.5-8% water addition was used at the initial stage (the roof of trough cover), then followed with 6.5% water addition castable, and 5.5-6% water addition at final (**Fig. 9**). In this way, the flow ability was controlled so as to get good workability and easy to apply. It can also make sure the completeness and material adhesion after from removal. After trough cover casting accomplished, around 2 days aging time is needed before baking and drying.

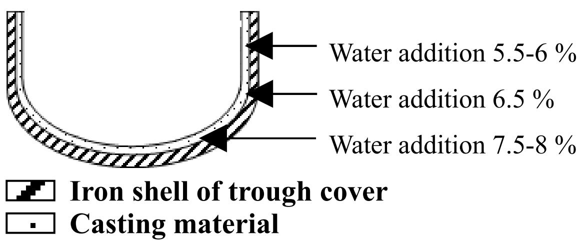

Fig. 9 Working condition of castables on trough cover.

The operating performance of material D is that the total production of molten iron is 101,275MT (20,494MT in #4 main trough and 80,781MT in #3 main trough of #4 blast furnace). The total operated day is 37 days. By comparing with trough cover with high alumina materials that total production of molten iron is 43,620 MT and the total operated day is 20 days, the material D can attain 2.3 times of molten iron production and obviously improve the lifetime of trough cover.

4. Conclusions

(1) The addition of SiC can improve the anti-corrosion ability of material, but the adjustment of grain size and the addition of additive II are needed to increase the density of material.

(2) The applied water addition differs from the casting region and the adhesion, but the operating performance would not be varied by different water addition. It significantly shows the convenience of adjustable flow ability under construction.

(3) The reduction of cement used in refractories can also decrease the formation of low-grade melting eutectic mixture and enhance the performance of materials.

(4) The used of Al_2O_3-SiC-C castable materials not only increases the lifetime of trough cover but also reduce the frequency of material reinstalling and the cost of labor.

(5) The testing result shows that the physical properties of sample C are similar to sample D; even the thermal shock resistance is much better than sample D, but the flow ability of sample C is too high that unfavorable for construction. Moreover, leaks may appear on the surface of sample C castable after baking; therefore, the formula C was eliminated.

(6) The formula D has passed the practical operation of China Steel Corporation; the total production of molten iron increase to 2.3 times, it also really achieved the target of increasing lifetime of trough cover.

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