Magnesia Chrome Brick with Superior Erosion Resistance for Secondary Refining Facilities

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Abstract

Since one of the typical refractory damage patterns observed in secondary refining facilities is erosion, sufficient erosion resistance is consequently required for magnesia chrome bricks commonly used in secondary refining facilities. Taking into account actual operational circumstances, erosion resistance especially under thermally deteriorated condition A is thought to be more important. A semi-rebonded magnesia chrome brick of which the erosion resistance was improved to have sufficient durability to thermal fluctuations in actual secondary refining operation by means of enhancing the brick's binding structure is introduced in this report.

1. Introduction

Due to its superb erosion resistance, magnesia chrome brick composed mainly of MgO and Cr_2O_3 is broadly applied for refining furnaces in the steelmaking process. Magnesia chrome bricks relined in secondary refining facilities are usually ultrahigh temperature fired bricks, which, in association with the kinds of raw materials used, are classified into direct bonded type, rebonded type and semi-rebonded type[1].

It is said that damage to refractories relined in secondary refining facilities is influenced by circulation and/or stirring of molten steel. The refractory damage pattern is caused by a combination of chemical corrosion from the molten slag mixed up in the circulated or agitated molten metal, and by mechanical abrasion, which is referred to as erosion. Erosion is thought to be major damage factor of refractories relined in secondary refining facilities.

An RH vacuum degassing unit, in operation at one of the secondary refining facilities, is schematically illustrated in Fig. 1. The internal temperature of its vessel exceeds 1700 ℃ in association with ferro alloy addition for adjusting steel compositions or securing molten metal temperature and/or by oxygen gas blowing. During standby time after treatment, the furnace internal temperature is lowered to 800 ℃. That is, refractories relined in the RH vacuum degassing unit vessel are exposed to marked thermal fluctuation, namely, repetition of heating up and cooling down. Taking into account the preceding reports on alteration of physical properties of magnesia chrome brick induced by lowered mechanical strength at elevated temperatures associated with brick structure deterioration caused by repeated heating and cooling[3, 4], it is inferred that erosion resistance under thermally deteriorated condition is important.

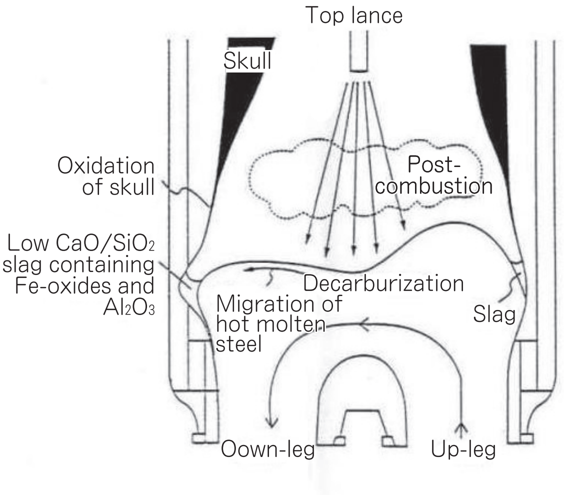

Fig.1 Schematic illustration of RH degassing operation[2].

Semi-rebonded magnesia chrome brick of which the erosion damage in actual operation is markedly reduced by improved thermal deterioration resistance is introduced in this report.

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Table 1 Typical properties of magnesia chrome brick A and B

		A	B
Chemical composition / mass%	MgO	61.2	63.8
	Cr_2O_3	23.9	24.1
	SiO_2	1.1	0.8
	Fe_2O_3	8.7	6.0
Apparent porosity / %		12.7	13.5
Bulk density / $g \cdot cm^{-3}$		3.37	3.31
Cold crushing strength / MPa		80	45

2. Characteristics of Improved Magnesia Chrome Brick

Table 1 shows the major chemical and physical properties of improved semi-rebonded magnesia chrome brick A, along with magnesia chrome brick B, which was selected for comparison. The hot modulus of rupture (HMOR) of two types of magnesia chrome brick was measured at 1400 ℃ before and after cyclic heating, in other words, the thermal deterioration treatment is shown by index in Fig. 2. Thermal deterioration treatment was conducted with 10 times' repetition of heating at 1400 ℃ for 10 minutes and cooling down to 600 ℃ for 10 minutes in an electric furnace with lifting up and down function of its specimen floor.

As shown in Table 1, a relatively large amount of accessory components, such as SiO_2 or Fe_2O_3, are contained in magnesia chrome brick A. Since accessory components contained in the brick function to promote liquid phase sintering during firing process[5], the binding structure in brick A has been enhanced with optimum amount of accessory components. While, due to its smaller amount of accessory components, magnesia chrome brick B with a similar level of Cr_2O_3 content is characterized by having better corrosion, which is resistance associated with lowered chemical reactivity. However, the binding structure in brick B is not as enhanced as that in brick A.

The difference in the binding structure of the two types of magnesia chrome bricks is reflected in the HMOR as well as thermal deterioration resistance. As shown in Fig. 2, magnesia chrome brick A with more enhanced binding structure exhibits higher HMOR than brick B. Since the binding structure in brick is fragmentarily deteriorated by thermal fluctuation[3], both bricks exhibited lowered HMOR after cyclic heating. However, better thermal resistance due to the well enhanced binding structure of magnesia chrome brick A is represented by its 40 % HMOR reduction rate, much better than the roughly 48 % HMOR reduction rate of brick B[3,4].

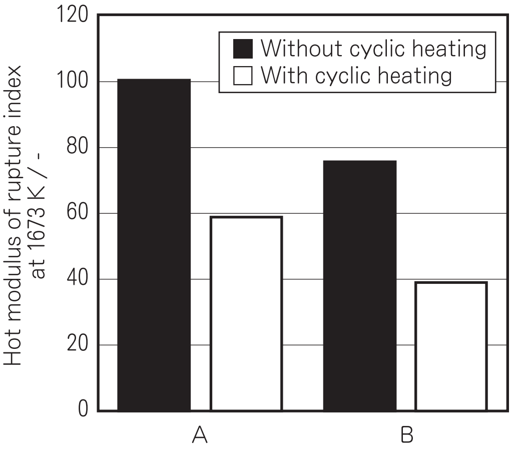

Fig. 2 HMOR of magnesia chrome brick specimens with and without cyclic heating.

3. Evaluation for Erosion Resistance

The erosion test was conducted on magnesia chrome brick specimens using rotary drum erosion test device with arc heating function. The erosion test specimens were relined in a stepwise pattern in which, as shown in Fig. 3, the specimens alternately protruded from base level so that molten slag flow becomes more dynamic[6]. It was thought that, since the test specimens were relined in a stepwise pattern would be erosively damaged by a combination of chemical corrosion and mechanical abrasion, the erosion damage of magnesia chrome bricks in actual operation could be well reproduced by this test method. The erosion test was carried out at 1700 ℃ for 6.5 hours with exchanging of synthetic slag every 0.5 hours for the initial 1.5 hours and every 1 hour after that. The chemical

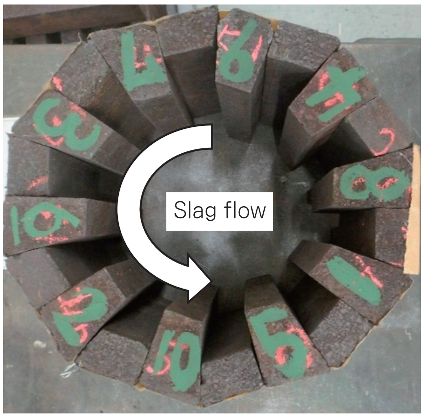

Fig. 3 Photograph of erosion test specimens relined in stepwise pattern.

composition of the synthetic slag used for the erosion test are shown in Table 2. The erosion test was conducted on magnesia chrome brick specimens with cyclic heating as well as on virgin magnesia chrome brick specimens separately.

Table 2 Chemical compositions of synthetic slag

	CaO	SiO_2	Al_2O_3	FeO
mass%	30	30	20	20

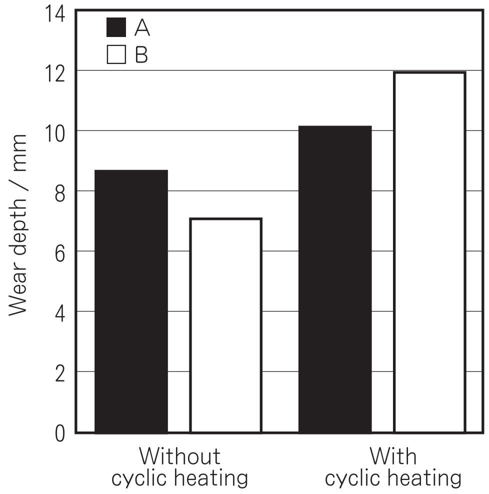

Fig. 4 Wear depth of magnesia chrome brick specimens after erosion test.

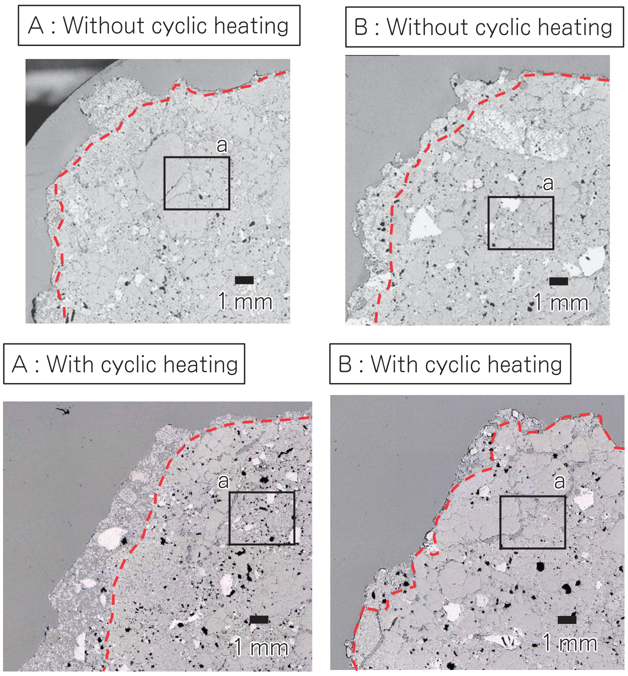

Fig.5 Micrographs of hot faces of magnesia chrome brick specimens after erosion test.

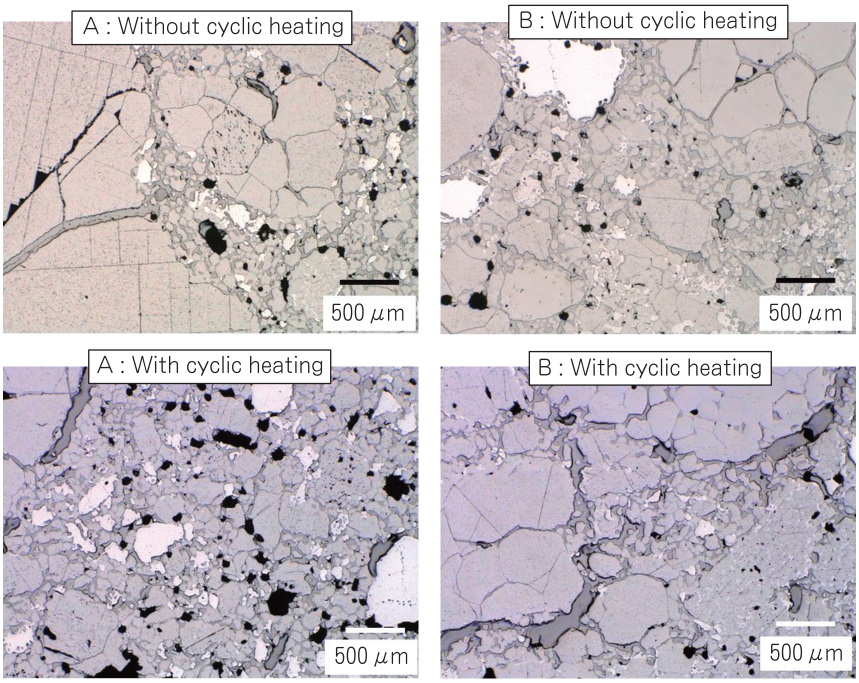

Fig. 6 Magnified images of framed area indicated with "a".

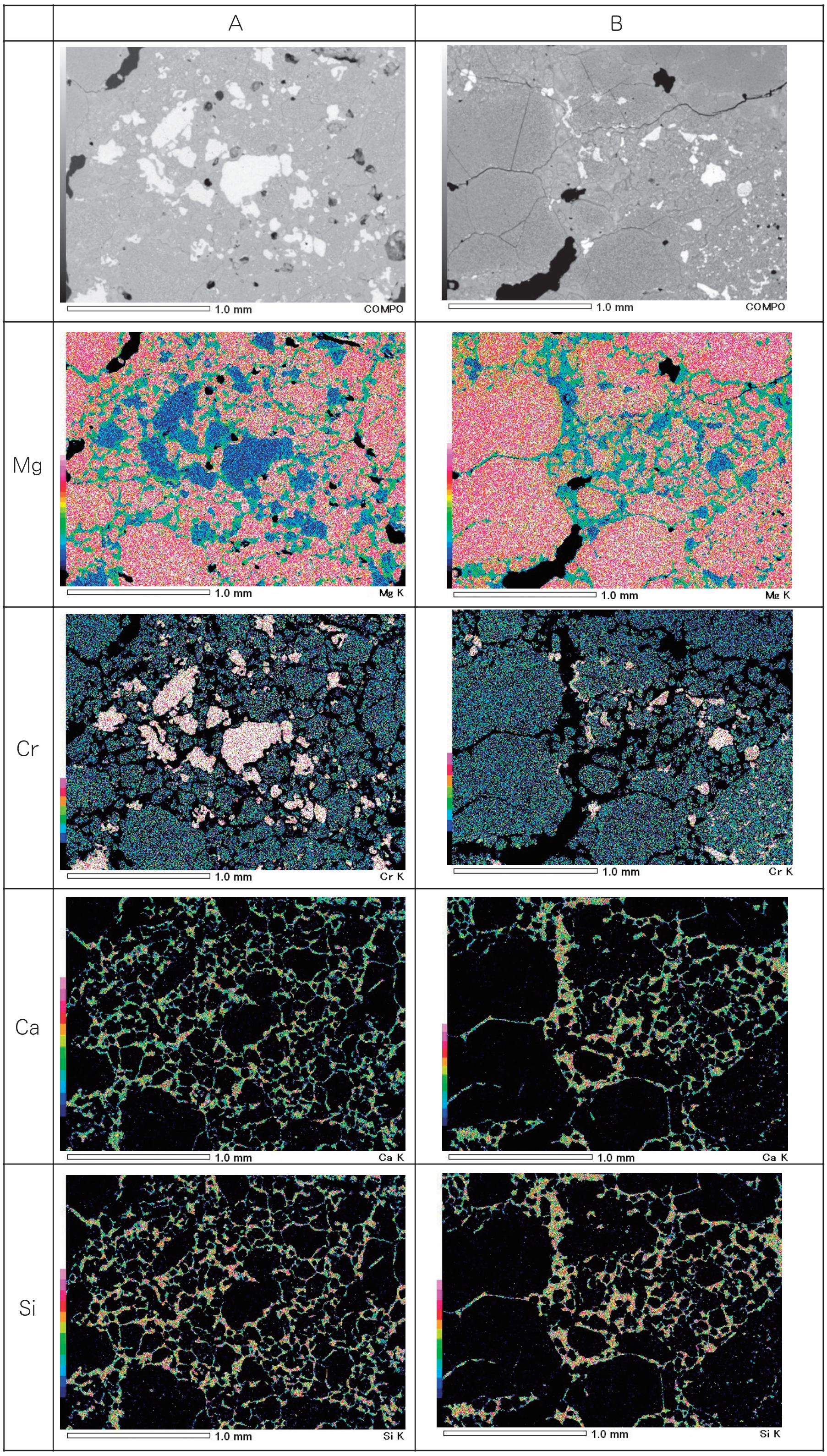

Fig. 7　Element distribution mapping in matrix of erosion test specimen with cyclic heating.

The erosion test results are shown in Fig. 4 with the wear depth which was calculated with the specimen dimensions measured before and after the erosion test. In the erosion test on virgin magnesia chrome brick specimens, magnesia chrome brick A exhibited bigger wear depth by 18 %, indicating of its inferior erosion resistance to that of magnesia chrome brick B. In erosion test on magnesia chrome brick specimens after thermal deterioration treatment, however, magnesia chrome brick A exhibits smaller wear depth by 16 % indicating superior erosion resistance under actual operational conditions.

Focusing on their microstructures near their hot faces, micrographs of the test specimens after the erosion test are shown in Fig. 5, in which hot face of each specimen is indicated with a dotted line so as to compensate for the indistinctive image of the interface between the specimen body and adhering slag. Magnified images of the framed area indicated with “a” and element distribution mappings in the corresponding region are shown in Fig. 6 and Fig. 7, respectively. It can be observed in the micrograph of the magnesia chrome brick B specimen put through thermal deterioration treatment that several coarse particles protrude from hot face associated with foregoing damage in the matrix region. In addition, the magnesia chrome brick B specimen put through cyclic heating exhibits more loosened matrix structure in its magnified image than the virgin magnesia chrome brick B specimen and, as observable in Fig. 7, slag components such as CaO or SiO_2 have infiltrated the loosened matrix structure. It is inferred that foregoing erosive damage in the matrix region was induced by physical abrasion and relatively large amount of slag infiltration in the loosened matrix structure. Even though a certain degree of deterioration, such as cavity formation around coarse particles, can be observed in magnesia chrome brick A with superior thermal deterioration resistance, its matrix structure damage is not so marked. This is considered to be associated with less amount of infiltrated slag because of less loosened matrix as observable in brick A with or without cyclic heating.

In short, it can be concluded that, since erosion damage is influenced by deterioration of brick structure caused by cyclic heating, application of magnesia chrome brick A with better thermal deterioration resistance is effective for reduction of erosion damage of refractories relined in operational facilities.

4. Results of Application in Actual Operation

Magnesia chrome brick A and B, both of which were relined in the lower vessel wall of an RH vacuum degassing unit, were compared for the relation between oxygen gas consumption. Wear rate of the relined brick is shown in Fig. 8. Over almost the whole range of oxygen gas consumption, the wear rate of magnesia chrome brick A is smaller than that of brick B by roughly 20 %. Micrographs of the microstructure near the hot face of magnesia chrome brick A and B retrieved after campaign life are shown in Fig. 9, in which the actual hot face is similarly indicated with a dotted line. Coarse particles

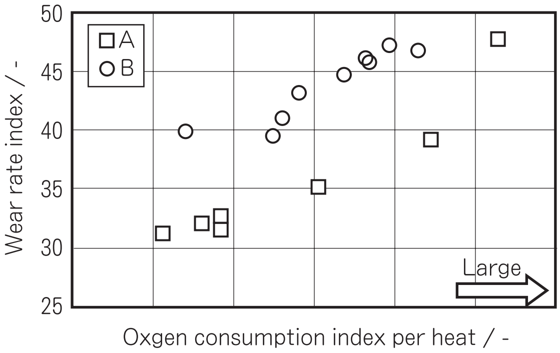

Fig.8 Comparison of wear rates of magnesia chrome bricks A and B relined in lower vessel of RH degasser.

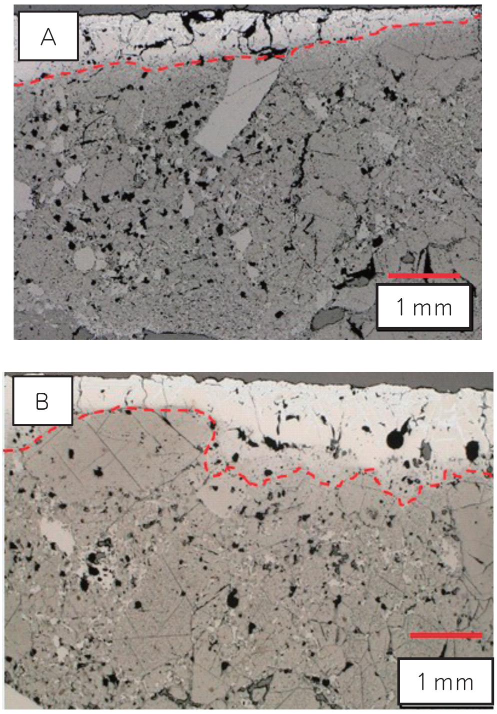

Fig.9 Micrographs of hot face of magnesia chrome bricks used in lower vessel of RH degasser.

protruding from deteriorated matrix region are observable in magnesia chrome brick B. Magnesia chrome brick A exhibits a relatively straight hot face associated with suppressed foregoing damage in the matrix region. It is safe to conclude that, since the micrograph observation results for the magnesia chrome bricks retrieved from an actual operation facility are quite similar to those of magnesia chrome brick specimens treated with cyclic heating after the erosion test, erosive damage of magnesia chrome brick A, with better thermal deterioration resistance, was reduced in actual operation, resulting in improved wear rate.

5. Conclusions

Magnesia chrome brick A which was improved with the intention of reducing erosion damage in secondary refining facilities by suppressing binding structure deterioration caused by cyclic heating achieves sufficient performance in actual operation. Application of magnesia chrome brick A results in an improved wear rate in RH vacuum degassing units by roughly 20 %, indicating effectiveness of thermal deterioration resistance for improvement in erosion resistance.

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