High Fracture Toughness Type MgO-C Brick for Charging Pad

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Abstract

Recently, the charging pad of the converter often becomes a bottleneck part due to the increase of scrap size and/or ratio. We have developed an improved MgO-C brick for the charging pad by focusing on the improvement of brick toughness, and obtained excellent results in actual furnaces. The development of high toughness type MgO-C brick and its use results in actual application will be described in this report.

1. Introduction

In a converter, the pig iron which is made in the blast furnace and scrap are charged in accordance with a certain weight ratio. A converter converts the hot metal to molten steel by dephosphorization and decarburization treatment at high temperature. The charging pad is the area in which pig iron and steel scrap impact directly. Thus, this area suffers considerable mechanical impact from steel scrap collision. It is well known that the wear rate of the charging pad increases proportionally as the scrap quantity and heavy scrap (over 500 kg) rate increases [1, 2].

Regarding the increase in scrap quantity, the increase in scrap quantity while retaining pig iron quantity can increase molten steel production. Increasing the scrap quantity with a decrease in pig iron (keeping molten steel production) can reduce the CO_2 gas amount that is generated during the pig iron production process in the blast furnace. From these backgrounds, it is thought that the increasing in scrap quantity is beneficial to strong steel demand and environmental programs. In such cases, the increase of scrap size and/or quantity can cause charging pad wear reducing converter durability. For this reason, high durability brick is required for the charging pad.

2. Wear Mechanism of Charging Pad

As mentioned in the preceding section, it is thought that the scrap charging greatly influences charging pad wear. The appearance of charging pad after use in an actual furnace is shown in Fig. 1. The brick surface of the charging pad was rugged compared with the side wall. Peeling and scratched surfaces were also observed on the charging pad. The appearance and cut sections of used charging pad bricks are shown in Fig. 2. The inflection point was seen on the hot face wear line and the crack generation was observed at the hot face in the used bricks. In general, the wear of charging pad is often defined as abrasion. However, judging from the condition of the used bricks, it is thought that the charging pad is worn by the combination of following damages.

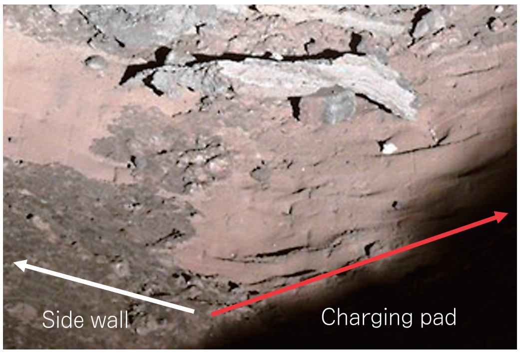

Fig.1 Appearance of charging pad after use.

- Defect damage in which scrap scratches the brick when the scrap impacts on the bricks.
- Abrasion damage caused by the sliding of scrap on the brick surface after impacting.
- Peeling damage due to the extension of cracks generated by the damages mentioned above under cyclic thermal shock conditions.

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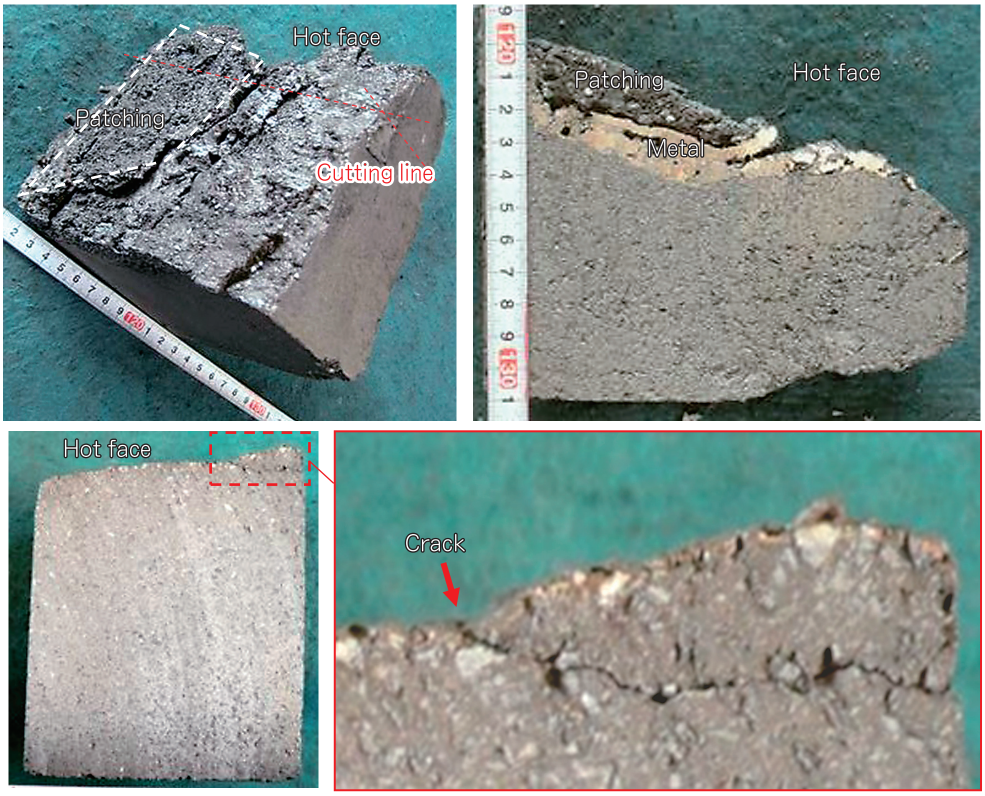

Fig. 2 Appearance and cut sections of used charging pad bricks.

Table 1 Properties of MgO-C bricks

		Material A	Material B	Material C
		Conventional	High strength	High toughness
Chemical composition / mass%	MgO	76	77	79
	F.C.	18	15	14
Typical properties	Apparent porosity / %	2.0	3.0	1.0
	Bulk density / -	2.94	2.99	2.92

Incidentally, it is assumed that abrasion damage caused by the sliding of scrap on the brick surface after impacting is categorized as brittle fracture[3], and called "abrasive wear" in the case of brittle materials. The approximate expression between abrasion volume V and sliding distance L is suggested as Eq. (1).

$$V \propto (W \times L)/(H^{1/2} \times K_{ic}^{1/2}) \quad \cdots\cdots (1)$$

Where, W, H and K_{ic} indicate load, material hardness, and material fracture toughness, respectively.

Based on this expression, it is supposed that the abrasion rate is reduced in accordance with the increase in material fracture toughness.

3. High Toughness Type MgO-C Brick for Charging Pad

We have found that the high toughness material has excellent resistance to crack generation and extension due to scrap impacting through a scrap drop impact test in a past study[4]. Based on this knowledge, we have developed a high toughness type MgO-C brick for the charging pad by optimizing raw material and particle distribution. The typical properties of bricks for the charging pad are shown in Table 1. Material A is a conventional brick for the charging pad, material B is a high strength type created by increasing the amount of metal additive and

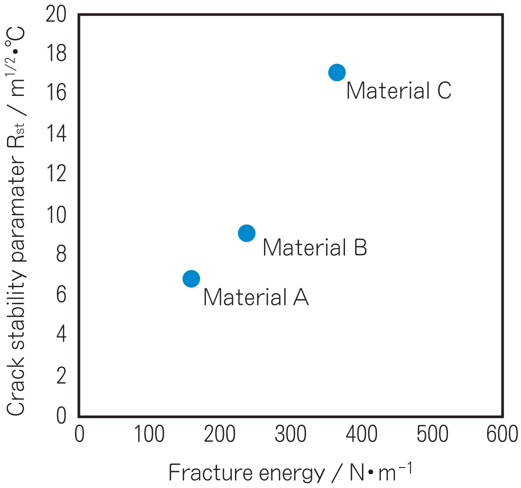

Fig. 3 Relationship between crack stability parameter R_{st} and fracture energy.

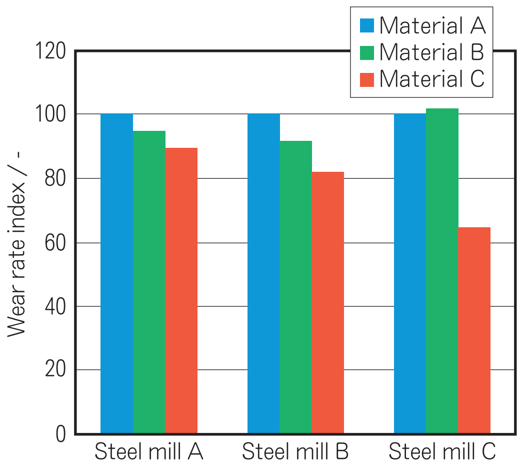

Fig. 5 Comparison of wear rate index of MgO-C bricks used in each steel mill.

material C is the newly developed material to which high toughness technology has been applied.

Regarding to each damage mentioned in Sec. 2, defect damage relates to crack generation and extension when scrap impacts on the bricks and abrasion damage is influenced by material fracture toughness. Since fracture energy is the property which represents the fracture strength and fracture toughness, high fracture energy material is thought to be an effective countermeasure for these damages.

In addition, materials which have a high R_{st} (crack stability parameter) are effective against crack extension and peeling damage. R_{st} is expressed as Eq. (2). Figure 3 shows a comparison of the fracture energy and R_{st} of each material shown in Table 1. A load-displacement curve

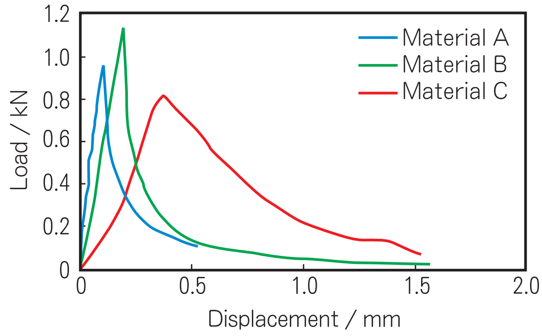

Fig. 4 Load-displacement curve obtained from three-point bending test.

obtained from the three-point bending test is shown in Fig. 4.

$$R_{st} = \{\gamma \times (1-\nu^2) / (E \times \alpha^2)\}^{1/2} \quad \cdots\cdots (2)$$

Where, ν, E, α and γ indicate poisson ratio, modulus of elasticity, thermal expansion coefficient, and fracture energy, respectively.

Developed material C shows high fracture energy and high R_{st} value compared with the materials A and B. Although the fracture load (fracture strength) of material C is lower than materials A and B, it is supposed that material C shows high toughness behavior because the reducing of the load is much more gradual after the fracture point, as can be seen in Fig. 4. Hence, it is thought that the fracture energy of material C is improved by the enhancement of fracture toughness.

4. Use Results in Actual Furnace

A comparison of the wear rate index of each material used for the charging pad in an actual furnace is shown in Fig. 5. The index is compared with the wear rate of material A assumed to be 100. Developed material C shows a lower wear rate index compared with materials A and B in each application. The residual thickness change curve of developed material C used in steel mill C is shown in Fig. 6. The residual thickness of developed material C shows a moderate reduction and the estimated durability calculated by the safety residual thickness is 1.3 times that of conventional material. A comparison of the cut sections of materials B and C used in steel mill B is shown in Fig. 7. The prevention of crack generation and a smooth wear line at the hot face were observed in the cut section of developed material C compared with the conventional high strength material B. From this result, it is thought that high fracture toughness material C was effective against wear in the actual furnace and the wear rate of the brick was improved.

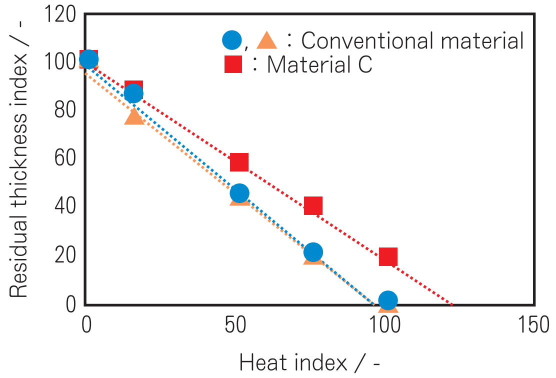

Fig. 6 Residual thickness change of developed material C in steel mill C.

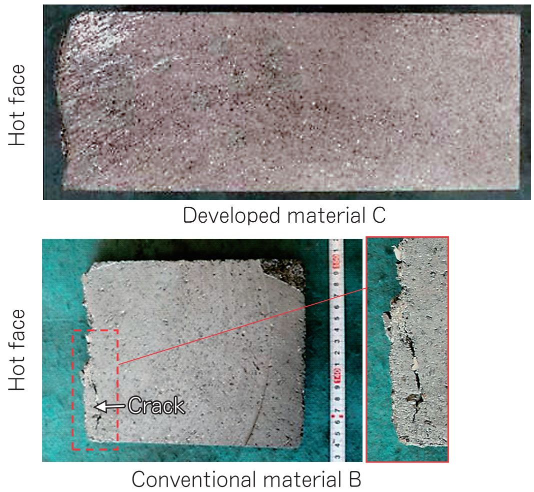

Fig. 7 Comparison of cut section of MgO-C bricks used in steel mill B.

5. Conclusion

It was assumed that the charging pad of the converter is worn by the combination of defect damage, in which scrap scratches the brick when it impacts them, abrasion damage, caused by the sliding of scrap on the brick surface after impacting, and peeling damage, due to the extension of cracks caused by cyclic thermal shock. High toughness material is thought to be effective against such damages. The newly developed material, to which high toughness technology has been applied showed excellent performance in actual furnaces.

References

1) H. Fukuoka, K. Asano, S. Harada, S. Yamamoto, T.Shimao : Taikabutsu, **38** [4] 27-34 (1986).
2) A. Watanabe, O. Okamura, M. Yasuhiro : Taikabutsu, **33** [2] 15-20 (1981).
3) Y. Enomoto : Science of Macchine, **37** [1] 31-36 (1985).
4) R. Fujiyoshi, A. Iida,A. Torigoe, H. Yoshioka : Shinagawa Technical Report, [60] 52-60 (2017).