Development of New Immersion Part Materials for Ladle Shrouds

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Abstract

Improving thermal shock resistance and suppressing quality deterioration during use are countermeasures for preventing cracking failure at the immersion area of the ladle shroud. We have developed materials with high thermal shock resistance by optimizing the graphite grain size distribution. In this report, we introduce a new ladle shroud immersion part material and its actual results.

1. Introduction

A ladle shroud in continuous-casting is a refractory used for introducing molten steel from a ladle into a tundish (TD), and prevents re-oxidation of the molten steel by preventing the molten steel from coming into contact with the outside air. The damage forms of the ladle shroud include lower part breakage, fracture, and longitudinal cracks. Figure 1 shows damage form of the ladle shroud at Steelworks A. Lower part breakage and longitudinal cracks are dominant, and it is important to avoid such damage to the immersed part. Figure 2 shows the timing of the occurrence of the damage to the immersed part in Steelworks B. Since the damage tends to occur in the latter half of casting when heating and cooling are repeated, material capable of maintaining high thermal shock resistance is considered to be effective, even for use with multiple TD changes.

We have developed new materials G37S3 and G31S10, which have excellent thermal shock resistance, by optimizing the grain size distribution of the graphite material in order to suppress deterioration of thermal shock resistance and property changes during use.

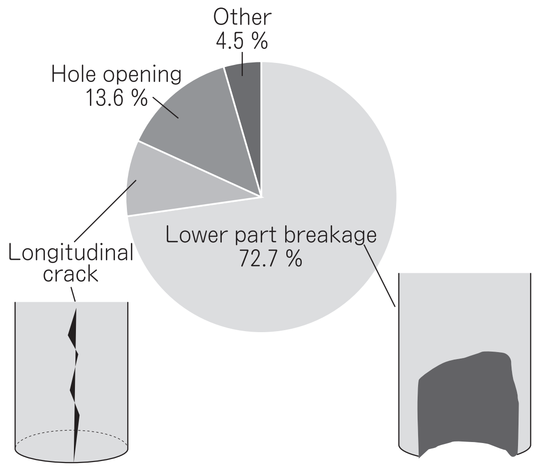

Fig. 1 Types of damage occurring at immersed section of ladle shroud at Steelworks A.

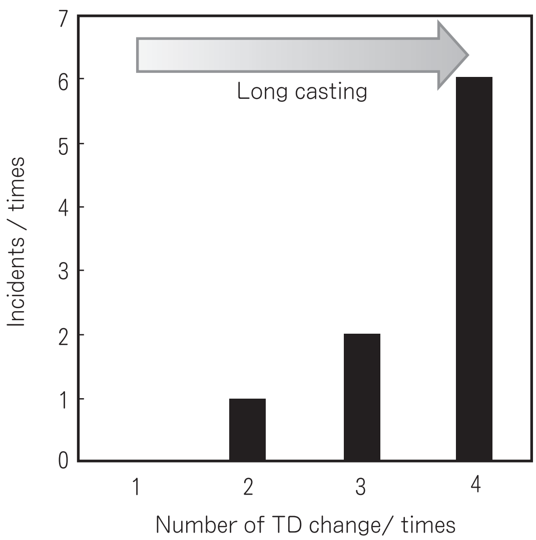

Fig. 2 Timing of damage occurring at immersed section of ladle shroud at Steelworks B.

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Table 1 Properties of newly developed products

		Base	1	2	3
Chemical composition / %	Al_2O_3	62	62	62	68
	C+SiC	37	37	37	31
	C material size (median)	coarse	medium	fine	fine
Apparent porosity / %		13.3	16.4	17.1	15.9
Bulk density		2.54	2.51	2.42	2.49
Modulus of rupture / MPa		11.1	10.8	10.7	13.5
Coefficient of thermal expansion at 1000 ℃ / K^{-1}		0.42	0.38	0.35	0.37
Thermal shock resistance index R※		100	113	149	157
Corrosion resistance index		100	98	94	101
Oxidation resistance index		100	98	94	89

※R=S/(Eα) S : Modulus of rupture / MPa, E : Modulus of elasticity / GPa,
α : Coefficient of thermal expansion / K^{-1}

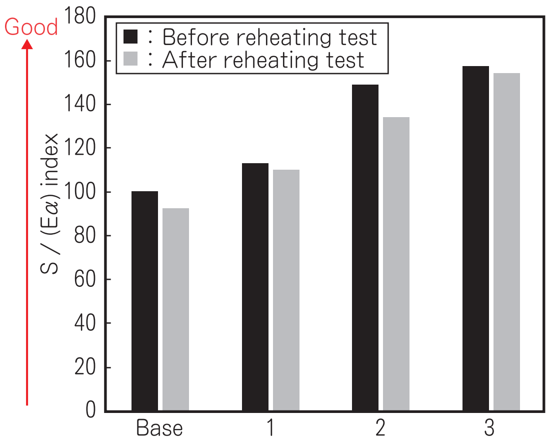

Fig. 3 Change in S/(Eα) index with repeated heating.

2. Characteristics of the New Immersion Part Materials for Ladle Shroud

The newly developed immersion material has optimized graphite particle size distribution based on conventional high carbon non-silica AG material. Table 1 shows the qualities of some prototype products.

Figure 3 shows the thermal shock resistance index change with repeated heating. The reheat test was conducted at 1550 ℃ for 3 hours in a N_2 atmosphere. The erosion test was carried out at 1550 ℃ for 1 hour by immersion method1). The erosion material was TD-flux (SiO_2 : Al_2O_3 : CaO = 20 : 20 : 60) with lithium carbonate, which was added in order to adjust viscosity. The corrosion resistance index of the base material after the erosion test was calculated as 100. The oxidation test was conducted using a rotary hearth electric furnace at 1400 ℃ for 1 hour. The oxidation resistance index was calculated by setting the average oxide layer thickness of the base material after the oxidation test to 100.

The new material exhibited higher thermal shock resistance than the base material both in the prototype fired product and after repeated heatings. In addition, No. 2 and No. 3, which were finer in graphite than No. 1, exhibited higher thermal shock resistance. As a result of the erosion test and the oxidation test, No. 1 and No. 2, which had the same total graphite content, had higher porosity than the base material, and tended to have slightly inferior corrosion resistance and oxidation resistance, but the differences were slight. On the other hand, No. 3, in which the quantity of total graphites was reduced, had the same corrosion resistance as that of the base material. Based on the results after use in actual machines, it was concluded that it was necessary to determine whether the slight deterioration in corrosion resistance and oxidation resistance is critical or not.

Figure 4 shows the microstructure of the developed material. Compared with the base material, the structure of the new material was such that the graphite raw material were distributed evenly among the alumina particles.

Table 2 shows the typical properties of G37S3 and G31S10.

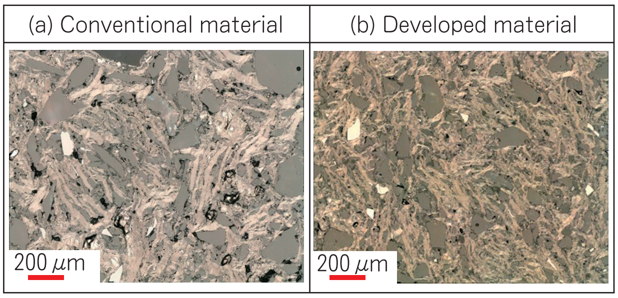

Fig. 4　Micrographs of each material. (a)Conventional and (b)Developed

Table 2　Typical properties of newly developed products

		G37S3	G31S10
Chemical composition / %	Al_2O_3	62	68
	C+SiC	37	31
Apparent porosity / %		16.5	16.0
Bulk specific gravity		2.50	2.50
Modulus of rupture / MPa		11.0	13.5

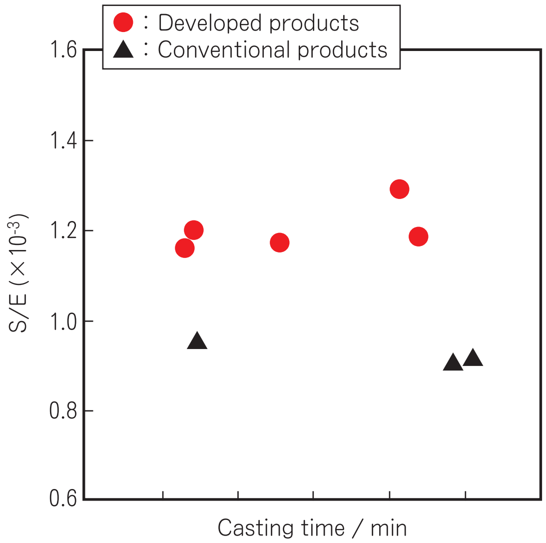

Fig. 5　Results of S/E of used ladle shrouds at Steelworks B.

3.　Actual Application Results

In the continuous casting machine of the Steelworks B, the ladle shroud in which a new material was applied to the immersion part was used. The S/E (S: Modulus of rupture, E: Modulus of elasticity) of the immersed part after use at Steelworks B is shown in Fig. 5.

No abnormality was observed in the quality of any of the products after use, and the S/E tended to be higher than that of the products after use of the conventional materials in the past.

The new material, having the optimized graphite grain size distribution, has high thermal shock resistance at the manufacturing stage, and is useful as an immersion part material of a ladle shroud in which repeated heating is performed. The developed material can be expected to function stably in various plants.

Reference

1）H. Niitsuma, K. Moriwaki and W. Lin : Shinagawa Technical Report, [57] 49-60 (2014).