Development of Porous Brick for Porous Plug

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Abstract

We developed porous brick HSP209 with improved corrosion resistance by pore size refinement. According to the laboratory evaluation, HSP209 showed corrosion resistance approximately 30 % higher than a conventional product. As a result, the wear rate was reduced approximately 30 % in actual use, and durability improvement was confirmed.

1. Introduction

In some kinds of secondary refining processes such as ladle furnaces, molten steel and refining agents are stirred by blowing inert gas such as argon through the gas purging plugs installed on the bottom of the ladle. The stirring is carried out in order to adjust the molten steel temperature, homogenize components and remove inclusions, etc[1]. A porous plug and a slit plug are used as the gas purging plugs for ladle bottom blowing. Porous plugs are excellent in bubbling reliability due to precise regulatability of gas flow; on the other hand, the disadvantage is that damage by oxygen-lance blowing to remove clotted layers, which is so-called oxygen cleaning, should be greater than the slit plug because of inferior corrosion resistance[1].

In this report, we introduce a newly developed product with improved durability while maintaining the basic properties of gas purging plugs.

2. Wear Profile and Durability Improvement of Porous Plug

Fig. 1 shows a schematic illustration of a porous plug. Porous plug is a functional refractory mainly composed of gas permeable porous brick. Fig. 2 shows the microstructure of a porous brick. Porous bricks are mainly made of alumina spherical aggregates to form voids in order to impart permeability[2].

The porous plug wear mechanism during oxygen

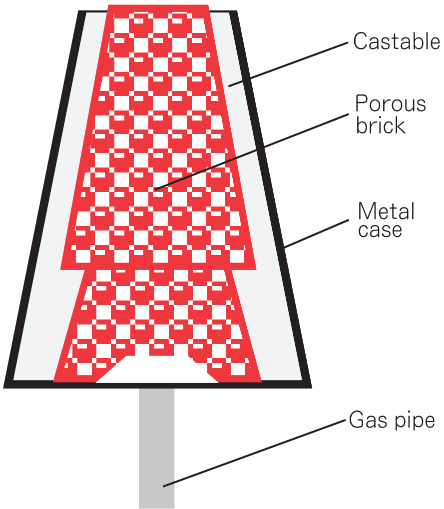

Fig. 1 Schematic illustration of porous plug.

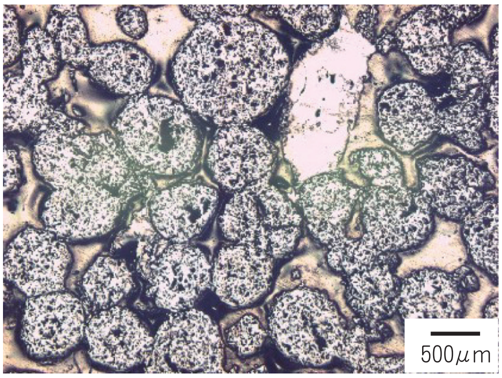

Fig. 2 Microstructure of porous brick.

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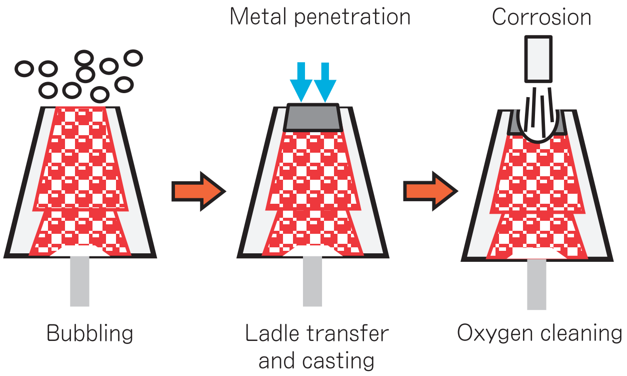


Fig. 3 Wear mechanism of porous plug by oxygen cleaning.

cleaning is illustrated in Fig. 3. Because gas blowing is stopped during ladle transporting or casting, molten steel penetrates into the porous brick due to the ferro-static pressure. When the ladle gets cold after casting, molten steel solidifies on the hot face of the plug and the gas blowing ability decreases. In order to recover the original gas flow rate, the clotted layer needs to be removed by oxygen cleaning, but in this process, the non-penetrated part is also corroded with the oxygen cleaning. Therefore, the oxygen cleaning would be a main cause of porous plug wearing. Therefore, in order to develop the durability of the porous plug, it is necessary to improve the corrosion resistance of porous bricks.

3. Newly Developed Product HSP209

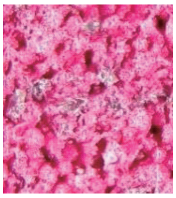
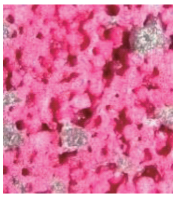
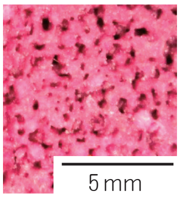
3. 1 Conventional product and properties of HSP209

For refractory bricks, densification of texture is generally effective for improving corrosion resistance. However, when the gas permeability of a porous brick decreases, the gas stirring performance decreases. For this reason, densification is not a suitable measure for improving the corrosion resistance of porous brick.

In previous works, the corrosion resistance of the porous plug has been improved by strengthening the bonding between the spherical alumina particles by utilizing sintering aids. In addition, to ensure permeability, the void structure was controlled by adopting single-sized or gap-sized spherical aggregates. Table 1 shows the typical properties of porous bricks.

The new product, HSP209 was developed based on HSP203. HSP203 shows the highest corrosion resistance among the existing lineup. HSP209 is a porous brick with improved corrosion resistance attained through pore size refinement by adopting continuous particle size distribution. In addition, in order to secure pores and maintain permeability, the packing degree of matrix and sintering were reduced by decreasing the amount of clay.

Table 1 Typical properties of porous bricks

Code		ALP-A14	ALP-A21	HSP20	HSP203	HSP209
Cross section						
Chemical composition / mass%	Al_2O_3	79	80	89	86	86
	SiO_2	19	15	7	7	6
	ZrO_2		3		3	3
	Cr_2O_3	1	1	2	2	4
Apparent porosity / %		26.3	27.4	24.0	23.4	22.5
Bulk density /g·cm^{-3}		2.47	2.56	2.80	2.83	2.89
Cold crushing strength / MPa		36	48	54	86	89

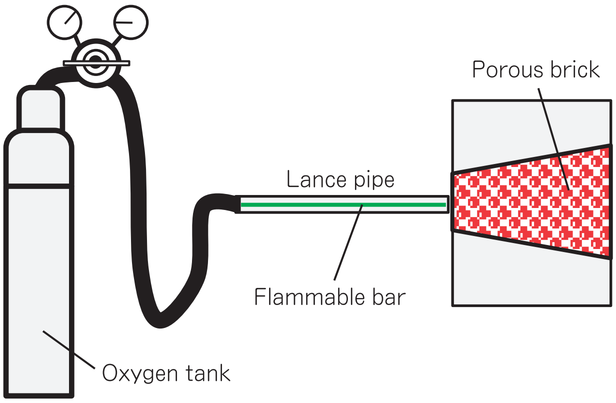
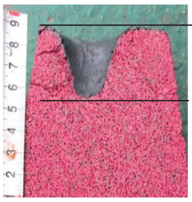


Fig. 4 Schematic illustration of oxygen-lance blowing test.

Table 2 Cross section of samples after oxygen-lance blowing test

Code	HSP209	HSP203
Cross section		
Wear depth	30 mm	41 mm

3. 2 Evaluation of HSP209

We evaluated the improvement of newly developed HSP209 by a comparison test with conventional HSP203.

Corrosion resistance was evaluated by oxygen-lance blowing test[3]. Fig. 4 shows a schematic illustration of the test. The test was conducted as follows; oxygen was blown into the lance pipe and flammable bar. The flammable bar was ignited on the tip, and the generated flame was blown on the surface of the sample brick from a position almost contact by the brick. After those processes were completed, the wear depth was measured. Oxygen was blown at 0.5 MPa pressure for 30 seconds. The sample porous bricks were formed in truncated cone shapes, which were the same as the actual products. Table 2 shows cross sections and the wear depths of the samples after the test. The wear depth of HSP209 was reduced by 27 % compared with the result of HSP203. The cracks confirmed on the cut surface of each sample were nearly the same.

Gas permeability was evaluated by comparing the flow rate measured the method described in JIS R 2115. In the test, the gas flow rate was measured with applying nitrogen gas at 0.1 MPa pressure to the sample. The gas flow rate with HSP209 was 13 % lower than that with HSP203. In order to confirm the influence of the decrease in permeability on the gas stirring performance, the flow rate was measured with the actual plug configuration. As a result, the measured flow rate with HSP209 was reduced by approximately 10 % compared with the value with HSP203. While, this reduction degree is considered to be so small that the influence on gas stirring performance should not be significant. Therefore, it was concluded that it is applicable to actual use.

4. Result of Actual Use of the Developed Product HSP209

The developed product HSP209 was used in an actual ladle at steelworks A. Gas stirring in the secondary refining process was done without any problem. Table 3 shows the cross sections and result data of the new product HSP209 and the conventional one HSP203 after use. As for HSP209, the corrosion was reduced and the wear rate decreased by approximately 30 % in comparison with HSP203.

Table 3 Cross section of improved and conventional plug after use

Code	HSP209	HSP203
Cross section		
Wear rate	5.8 mm/charge	8.1 mm/charge

5. Summary

We developed porous brick HSP209 with improved corrosion resistance by pore size refinement. As a result of laboratory experiment, HSP209 showed corrosion resistance approximately 30 % higher than the conventional product. Accordingly, the wear rate was reduced by approximately 30 % in actual use. Thus, durability improvement was confirmed.

References

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2) A. Tsuchinari and O. Shimobayashi : Taikabutsu, **41** [1] 41–42 (1989).
3) E. Ishihara and T. Saeki: Shinagawa Technical Report, [54] 87–96 (2011).