

SHINAGAWA TECHNICAL REPORT

ポーラスプラグ用多孔質れんがの開発

Development of Porous Brick for Porous Plug

尾 形 和 信
Kazunobu OGATA

籠 貴 大
Takahiro KAGO

品川技報

ポーラスプラグ用多孔質れんがの開発

Development of Porous Brick for Porous Plug

尾 形 和 信^{*1}
Kazunobu OGATA

籠 貴 大^{*2}
Takahiro KAGO

要 旨

気孔の微細化により耐食性を向上させた多孔質れんがHSP209を開発した。HSP209は従来材質と比べ約30%高い耐食性を示した。実機使用においても損耗速度が約30%改善し、耐用の向上が認められた。

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. 緒言

LF法などの二次精錬では、溶鋼温度の調整、成分の均一化、介在物の除去を目的に取鍋の炉底に設置したガス吹きプラグからアルゴンなどの不活性ガスを吹き込み、溶鋼や精錬材の攪拌を行っている¹⁾。取鍋底吹き用のガス吹きプラグには、ポーラスプラグおよびスリットプラグが使用される。ポーラスプラグはガス流量の制御が容易で、バブリングの信頼性が高いことを特長とするが、スリットプラグと比べ耐食性が劣り、酸素洗浄時の損傷が大きい点が短所となる¹⁾。

本報告では、ガス吹きプラグの基本性能を維持したまま耐用を向上させた新材質について紹介する。

2. ポーラスプラグの損傷と高耐用化

Fig.1にポーラスプラグの模式図を示す。ポー

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, etc¹⁾. 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 resistance¹⁾.

*1 西日本工場 赤穂製造部 Ako Plant, West Japan Works

*2 西日本工場 赤穂製造部 主任部員 Staff Manager, Ako Plant, West Japan Works

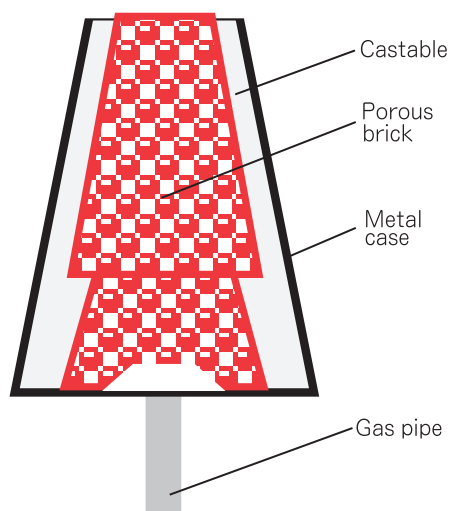


Fig. 1 Schematic illustration of porous plug.

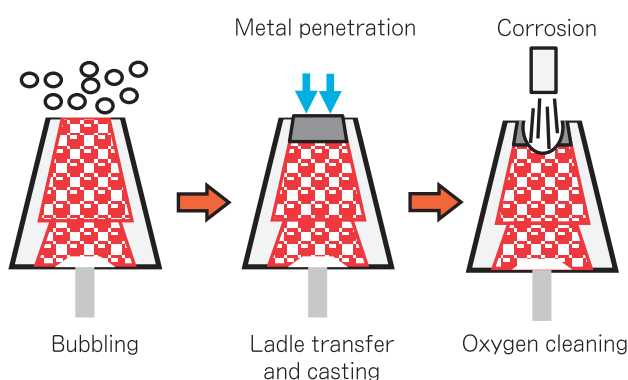


Fig. 3 Wear mechanism of porous plug by oxygen cleaning.

ラスプラグは、気孔を介して通気させる多孔質れんがを中心に構成した機能性耐火物である。Fig.2に多孔質れんがの組織写真を示す。多孔質れんがは、主骨材としてアルミナ球状粒を用いて空隙をつくり、通気を確保している²⁾。

Fig.3に酸素洗浄時のポーラスプラグの損傷模式図を示す。取鍋の運搬中や鑄造時はガス吹きを停止するため、溶鋼が静圧によって多孔質れんが内へ浸透する。鑄造後に取鍋が冷却されるとプラグ稼働部で溶鋼が凝固し、通気性が低下する。通気回復のため酸素洗浄で凝固層を除去するが、このとき健全な多孔質れんがも溶損し、酸素洗浄がポーラスプラグの主要な損傷要因となっている。そのためポーラスプラグの高耐用化には、多孔質れんがの耐食性を向上する必要がある。

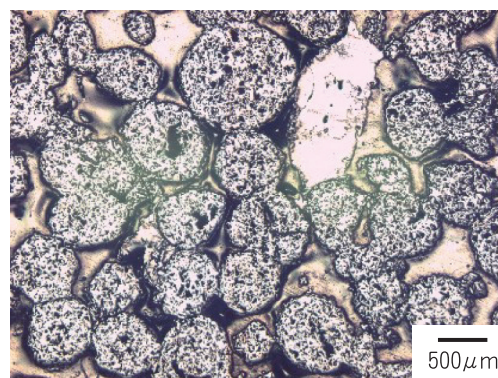


Fig. 2 Microstructure of porous brick.

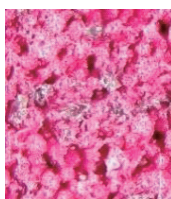
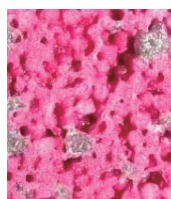
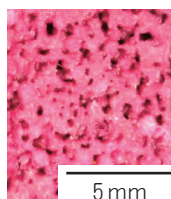
In this report, we introduce a newly developed product with improved durability while maintaining the basic properties of gas purging plugs.

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 permeability²⁾.

The porous plug wear mechanism during oxygen 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

Table 1 Typical properties of porous bricks

Code		ALP-A14	ALP-A21	HSP20	HSP203	HSP209
Cross section						
Chemical composition / mass%	Al ₂ O ₃	79	80	89	86	86
	SiO ₂	19	15	7	7	6
	ZrO ₂		3		3	3
	Cr ₂ O 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

3. 新材質HSP209

3. 1 従来材質とHSP209の特徴

耐火れんがにおいては、一般的に組織の緻密化が耐食性の向上に有効である。しかし、多孔質れんがは通気性が低下するとガス吹き処理能力が低下するため、緻密化による耐食性の向上は困難であった。

これまでは、焼結助剤の活用によりアルミナ球状粒の結合を強化して耐食性の向上を図ってきた。また同時に、球状粒のサイズを一定に揃えることや中間粒を削減することにより、空隙を制御して通気性を確保してきた。Table 1に多孔質れんがの標準品質を示す。

新材質HSP209は、当社ラインナップの中で最も耐食性に優れるHSP203をベースに開発を行った。HSP209は、連続的な粒度構成とすることで気孔の微細化を行い、耐食性を向上させた多孔質れんがである。また粘土を減量し、マトリックス部の充填率の低減と焼結を抑制することで気孔を確保して通気性の低下抑制を図った。

3. 2 HSP209の評価

新材質HSP209の改善効果を評価するため、従来材質HSP203との比較試験を行った。

耐食性はランス溶損試験で評価した³⁾。Fig.4にランス溶損試験の模式図を示す。燃焼線の入った

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

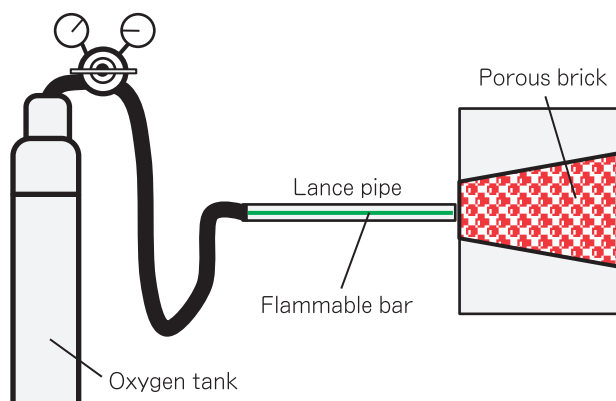
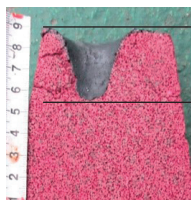


Fig. 4 Schematic illustration of oxygen-lance blowing test.

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

Code	HSP209	HSP203
Cross section		
Wear depth	30 mm	41 mm

ランスパイプへ酸素を吹き込んで先端部で点火し、炎を多孔質レンガの表面に接射して溶損深さを測定した。酸素は0.5MPaの圧力で吹き込み、接射時間は30秒とした。多孔質レンガは、実際の製品と同じ円錐台の形状を用いた。Table 2に試験後試料の切断面写真と溶損深さを示す。HSP209の溶損深さはHSP203と比べ27%低減した。また切断面に確認された亀裂の程度は同等であった。

通気性はJIS R 2115に記載の方法で測定した流量を比べて評価した。試験は試料に0.1MPaの圧力で窒素を流し、流量を測定した。HSP209の流量はHSP203と比べ13%低下した。通気率低下によるガス吹き能力への影響を確認するため、実際の製品と同じ構成で流量を測定した。HSP209はHSP203と比べ流量は約10%低下したが、ガス吹き能力への影響は軽微であるため、実使用において問題無いものと判断した。

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.

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 test³⁾. 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

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

4. HSP209の実機使用結果

開発したHSP209をA製鉄所にて実機使用した。二次精錬でのガス吹き処理は問題なく行われた。Table 3にHSP209と従来材質HSP203の使用後製品の切断面写真と使用結果を示す。HSP209は、溶損による損傷を低減でき、HSP203を使用した場合と比べ損耗速度が約30%改善した。

5. まとめ

気孔の微細化により耐食性を向上させた多孔質れんがHSP209を開発した。HSP209は従来材質と比べ約30%高い耐食性を示した。実機使用においても損耗速度が約30%改善し、耐用の向上が認められた。

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.

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

- 1) The Technical Association of Refractories, Japan (TARJ) : Taikabutsu Techou (Kaitei 12 han), TARJ (2015) pp.262-265.
- 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).