

SHINAGAWA TECHNICAL REPORT

取鍋用高性能アルミナ-マグネシア質
キャストブル

High Performance Alumina-Magnesia Castable
for Steel Ladle

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品川技報

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要 旨

低水分化を図った高性能アルミナ-マグネシア質流し込み材を開発した。開発品の特徴と実機使用結果について報告する。

Abstract

We have developed high performance alumina-magnesia castable for the steel ladle. Features of the developed material and actual furnace application results are described in this report.

1. 緒言

現在、溶鋼取鍋用内張り材にはアルミナ-マグネシア材質が広く用いられている。アルミナ-マグネシア材質は、アルミナ原料とマグネシア原料を組み合わせた材質であり^{1)~3)}、加熱時に両者が反応して以下の(1)式に従い2次スピネルを生成する。



この均一なスピネル相により、高耐食性、高耐スラグ浸潤性の特性を有している。

実炉での損傷形態は、亀裂・剥離が主体である。亀裂・剥離の発生は耐火物中へのスラグの浸潤が要因の一つと考えられ、高耐用化にはスラグ浸潤抑制が不可欠なテーマである。

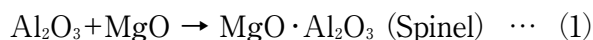
アルミナ-マグネシア材質のスラグ浸潤抑制の手法として、①マグネシア量の最適化、②低融点生成物の減量、③低水分緻密化が考えられる。

これまで、アルミナ-マグネシア質キャストブルにおいて、マグネシア添加量と耐スラグ性の関

1. Introduction

At present, alumina-magnesia castable is mainly used for steel ladles. Alumina-magnesia castable is comprised of alumina and magnesia raw materials.

During heating, secondary spinel is formed by the reaction of alumina and magnesia according to (1) in alumina-magnesia castables.



Because of the forming of homogeneous spinel phase, alumina-magnesia castable has high corrosion resistance and high slag penetration resistance.

The main damage morphology of alumina-magnesia castable in actual service is cracking and peeling.

With the increase of slag penetration, cracking and peeling occur. Therefore, inhibition of slag penetration is essential for long service life.

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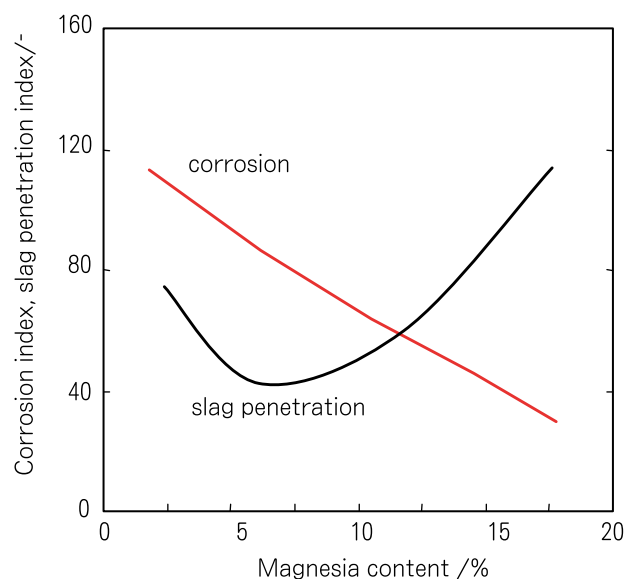


Fig. 1 Result of slag test.

係について数多くの検討がなされている。耐食性はマグネシア添加量に比例して向上し、一方で、耐スラグ浸潤性はマグネシア添加量がある一定量を超えると大きく低下することがわかっている (Fig. 1)。したがって、マグネシア量の最適化が重要な役割を果たしていたといえる。

最近では、低融点物を生成するCaO成分に着目した検討も行われており、ノンセメント系アルミナ-マグネシア材料も注目されつつある。

今回、高耐用化を目的に高性能分散剤を適用することで低水分化を図った取鍋内張り用高性能アルミナ-マグネシア質流し込み材を開発した。開発品の特徴と実機使用結果について報告する。

2. 開発品の特徴

2.1 流動性

所定量の水量で混練し、V5フロー値（5秒間の振動フロー）を測定した。V5フロー値は実機施工を想定し200mmを目安にして添加水量を調整した。

Fig. 2に、V5フロー値を示す。従来材に比べて1.0%以上の減水効果が認められ、実機施工において添加水量4.0%以下の低水分施工が可能な流動性を実現した。

There are three approaches for restraining slag penetration of alumina-magnesia castable : ①the optimization of magnesia content, ②the restraining of low-melting-point material, and ③the densification by reducing the amount of water addition.

There are many studies about the relation between the amount of magnesia and corrosion resistance of alumina-magnesia castable. On the other hand, slag penetration resistance became drastically worse with over a certain amount of magnesia content (Fig. 1). Therefore, it can be said that the optimization of magnesia content performs a crucial function.

Recently, some reports focus on the CaO component that reacts to product low-melting-point material, and non-cement alumina-magnesia castable is attracting attention.

We have developed high performance alumina-magnesia castable for the steel ladle that has achieved reducing the amount of water addition by using high performance dispersant for long service life. In this report, characteristics of the developed material and actual results are presented.

2. Characteristics of the Developed Material

2.1 Flowability

The amount of water addition was set so that the flowability would be constant (V5 flowability = 200).

Fig. 2 shows the V5 flowability of the developed material and conventional material. The water addition of the developed material was decreased by more than 1.0% compared with the conventional material making it is possible to cast below 4.0% water addition at the actual furnace.

2.2 Properties

40×40×160mm samples were prepared with each mix. After drying at 110°C-24h, the

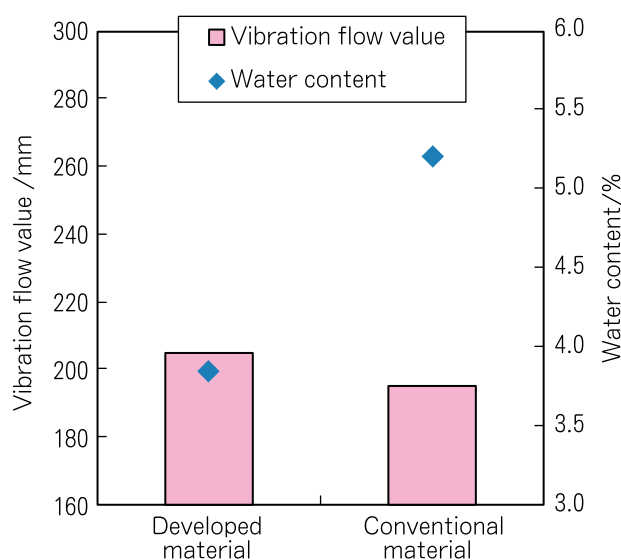


Fig. 2 Flow characteristics of the material (vibration flow value).

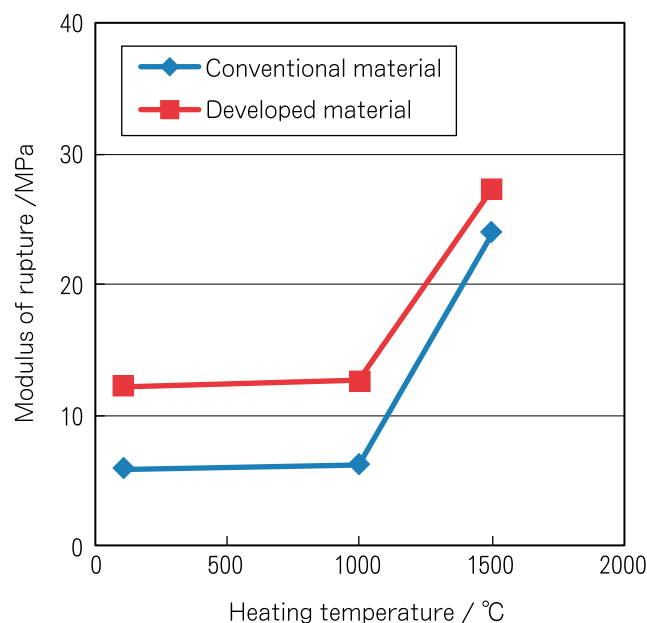


Fig. 3 Modulus of rupture.

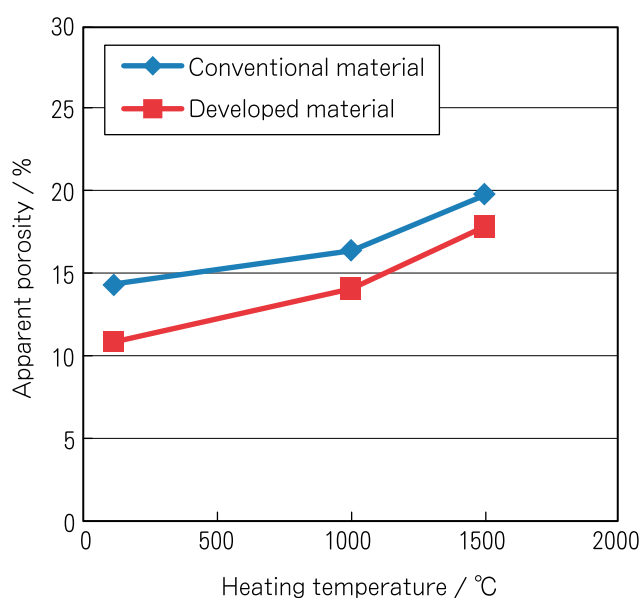


Fig. 4 Apparent porosity.

2. 2 品質特性

各サンプルを所定量の水量で混練し、 $40 \times 40 \times 160$ mmの金型に鋳込み、成形した試料を 110°C -24h乾燥後、 1000°C および 1500°C で3h加熱後の条件で、一般品質を測定した。

(曲げ強度と圧縮強度はJIS R 2553に準じ、見掛け気孔率と嵩比重はJIS R 2205に準じて行った)

samples were heated at 1000°C -3h or 1500°C -3h. After that, the characteristic value of the samples was measured.

(The standard for the measurement of modulus of rupture and cold crushing strength is JIS R 2553. The standard for the measurement of apparent porosity and bulk density is JIS R 2205.)

The modulus of rupture (MOR) and apparent porosity of the samples after heating at several temperatures are compared in Figs. 3 and 4. By decreasing the water addition, after heating below 1000°C the MOR was increased. The ratio of strength between samples heated at 1500°C and samples heated at 1000°C decreased by about 40%. The results promise higher resistance against crack propagation than the conventional material.

According to the difference of the apparent porosity, the developed material had a denser texture than the conventional material.

2. 3 Corrosion resistance and slag penetration resistance

The rotary drum test was carried out to

Table 1 Properties of castables

		Developed material	Conventional material
Chemical composition /mass%	Al ₂ O ₃ MgO CaO	92 5 1	92 5 1
Permanent liner change /%	110°C×24h 1000°C×3h 1500°C×3h	0.00 0.05 +1.94	-0.03 -0.03 +1.21
Modulus of rupture (Crush strength)	110°C×24h 1000°C×3h 1500°C×3h	12.2(49.7) 12.6(64.4) 27.3(72.2)	5.9(30.8) 6.2(52.4) 24.0(65.1)
Apparent porosity / % (Bulk density)	110°C×24h 1000°C×3h 1500°C×3h	10.9(3.27) 14.1(3.25) 17.9(3.10)	14.3(3.21) 16.4(3.19) 19.8(3.00)
Water content /%		3.5~4.5	5.0~6.0

Fig. 3に、曲げ強度、Fig. 4に、気孔率を示す。低水分化を実現したことで、低温域から中間温度域（1000℃）での強度アップが認められる。1500℃と1000℃焼成後の強度比が約40%低減しており、実機での剥離抑制が期待できる。また、気孔率も全温度域での低下（緻密化）が認められた（Table 1）。

2. 3 耐食性・耐浸潤性

各サンプルの耐食性、耐スラグ浸潤性を調査するため、回転ドラム侵食試験を行った。熱源はアーク加熱を用い、試験温度は1650℃-4hで行った。スラグは転炉スラグ（C/S=3, FeO=25%）を用いた。

Fig. 5に、耐食性試験後試料切断面を示す。従

evaluate the slag corrosion and penetration resistance of each sample.

The details of the testing conditions are as follows;

Heating method: electric arc

Testing temperature and time: 1650℃×4h

Slag: Converter slag (basicity=1.7, FeO=25%)

Fig. 5 shows the result of the corrosion test. The corrosion and slag penetration resistance of the developed material was 20% superior to conventional one by the effect of densification.

2. 4 Explosive spalling test

The dimensions of the test specimens were 80φ×80mm and 40×40×160mm. The curing conditions were 5℃-24h. After curing, the M.O.R of the 40×40×160mm samples was measured. The explosive spalling test was done with the 80φ×80mm samples. After curing, the 80φ×80mm samples were placed in a pre-heated electric furnace to confirm whether the samples would cause explosive spalling or not.

The explosive spalling test results are shown in Table 2. The developed material is high strength and with the equivalent resistance to explosion as compared to conventional material.

	Cross section of sample	Corrosion depth (penetration depth)
Developed material		10.1mm (5.3mm)
Conventional material		12.4mm (6.7mm)

Fig. 5 Result of slag test (1650℃-4h, C/S=3.3).

Table 2 Result of explosive spalling test

Sample	Developed material	Conventional material
M.O.R. after curing /MPa	4.1	2.3
Results of explosive spalling test	× (900°C) ○ (800°C)	× (900°C) ○ (800°C)

○ : no explosion, × : explosion

来材に比べ、開発品は低水分・緻密化の効果により、耐食性、耐浸潤性で約20%の改善効果が得られた。

2. 4 耐爆裂性

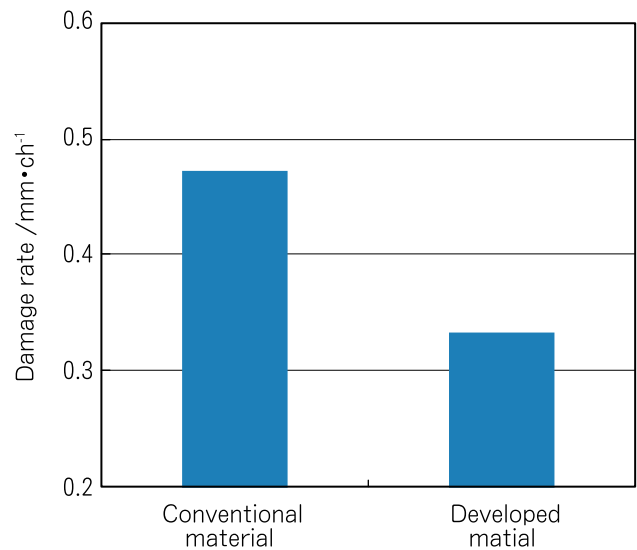
80φ×80mmの円筒状の型枠および40×40×160mmの金型に鋳込み、養生条件は5℃-24hに設定した。養生強度は40×40×160mm形状サンプルにて測定し、爆裂テストは80φ×80mmサンプルにて行った。爆裂試験は、電気炉内へ養生後の80φ×80mmサンプルを投入し、爆裂の有無を確認した。

Table 2に、耐爆裂性試験の結果を示す。開発品は高い養生強度を示し、従来材と同等の耐爆裂性を確保していた。

3. 実機使用結果

Fig. 6に、実機使用での損耗速度を示す。A製鉄所溶鋼鍋ML材に使用した際の損耗速度では、約30%の耐用性向上効果が得られた。

Fig. 7に、使用後の回収サンプル切断面を示す。従来品と比較して、スラグ浸潤厚みが20mmと薄

**Fig. 6 Damage rate.**

3. Performance Information for Actual Ladle

We applied the dense type alumina-magnesia castable to an actual ladle lining. The comparative results for the wear rate between conventional material and developed material are shown in Fig. 6. The results showed 30% improvement in the wear rate of the developed material compared to the conventional material.

Cross section photographs of the developed material and conventional material after use are shown in Fig. 7. The slag penetration layer of the developed material was thinner than that of



Developed material (364ch)



Conventional material (290ch)

Fig. 7 Cross section of used castable samples.

く、施工体内部に亀裂、地金侵入は認められず、良好な組織を有していた。

4. まとめ

溶鋼取鍋内張り用高性能アルミナ-マグネシア質キャストブルを開発した。高性能分散剤の適用により大幅な低水分化を実現し、中間温度域での強度アップ、耐食性、耐浸潤性の向上効果が得られた。実機においてもスラグ浸潤厚みが薄く、損耗速度の低減効果が確認できた。

the conventional material. As well, there was no cracking or steel penetration in the castable.

4. Conclusion

We have developed a high performance alumina-magnesia castable for the steel ladle. We have achieved a reduction in the amount of water addition to the castable by using a high performance dispersant. As a result, the strength at mid temperature, corrosion resistance and slag penetration resistance of the castable were improved. Significant improvement in slag penetration resistance and wear rate was confirmed in an application to an actual furnace.

References

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