

SHINAGAWA TECHNICAL REPORT

高性能転炉補修用不定形耐火物

High-performance Hot Repair Mixes for BOF

小松原 清 行
Kiyoyuki KOMATSUBARA

佐々木 久 晴
Hisaharu SASAKI

小 山 孝 昭
Takaaki KOYAMA

品川技報

高性能転炉補修用不定形耐火物

High-performance Hot Repair Mixes for BOF

小松原 清 行^{*1}
Kiyoyuki KOMATSUBARA

佐々木 久 晴^{*2}
Hisaharu SASAKI

小 山 孝 昭^{*3}
Takaaki KOYAMA

Abstract

We have developed new high-performance repair mixes for BOF hot repairs. New carbon bonded gunning mixes adhere much better than ordinary gunning mixes even when sprayed onto brick surfaces hotter than 1300°C, which is the typical temperature of a BOF side wall shortly after slag discharging. The curing times of the new hot casting mixes are much shorter than those of ordinary ones, which contributes shortening the repair time. These new repair mixes, gunning and hot casting, are being used successfully in actual applications.

1. 緒言

近年の鉄鋼需要の増加に伴い、多くの製鉄所で生産効率の向上が求められている。製鋼プロセスの中でも特に重要な設備である転炉の補修部位と適用される補修材をTable 1とFig. 1に示す。カーボンボンド吹付け材はリン酸ボンド吹付け材に替わり、スラグラインや出鋼孔周辺に使用されている。焼付け材は装入側壁と出鋼側壁に使用され、焼付け材が使用できないトラニオン側壁は吹

1. Introduction

Many steel making plants require the improved productivity in order to meet increasing demands. There is a strong demand for shortening BOF repair time, because the BOF is one of the most important facilities in the steel making process. Typical hot repair methods for repairing specific locations in a BOF are shown in Table 1 and Fig. 1. Recently, carbon bonded

Table 1 Typical hot repair methods for BOF

Repaired area	Required properties	Material
①Cone	Protection of wall	Phosphate bonded gunning mixes
②Tap hole area	Quick hardening High Durability	Hot casting repair mixes (Water binder system or Carbon binder system)
③Trunion sides	High Durability High adhesive strength	Carbon bonded gunning mixes Phosphate bonded gunning mixes
④Charging side wall	Quick hardening High Durability	Hot casting repair mixes (Carbon binder system)

*¹ 技術研究所 第2研究グループ 主任研究員 Managing Research Engineer, Unshaped Refractories R&D Group, Research Center

*² 技術研究所 第2研究グループ チームリーダー Team Manager, Unshaped Refractories R&D Group, Research Center

*³ 技術研究所 第2研究グループ Unshaped Refractories R&D Group, Research Center

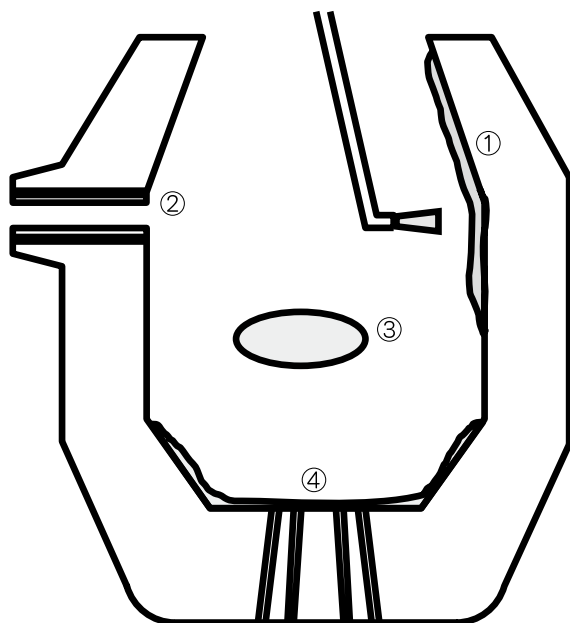


Fig. 1 Schematic image of BOF hot repair.

Table 2 Comparison of carbon bonded and phosphate bonded gunning mixes characteristics

	Carbon bonded	Phosphate bonded
Temperature at gunning	800℃<	<1000℃
Durability	4 ~ 8 heats	2 ~ 4 heats
Remarks	High Durability	General purpose

- High adhesive strength in hot conditions
- Little peeling damage occurs because of low shrinkage value
- Low slag penetration and high corrosion resistance
- Contain no phosphate
- Conventional gunning equipment can be used

付け材が使用される。焼付け材とカーボンボンド吹付け材による補修は共に効率の良い補修方法であるが、生産効率向上のため「補修時間の短縮」というニーズがさらに高まっている。これに対し、当社では硬化時間を大幅に短縮した高性能な超速硬性焼付け材、排滓直後の1300℃を越える高温域でも付着する超高温施工対応型カーボンボンド吹付け材を開発し展開中である。

2. 超高温施工対応型カーボンボンド吹付け材

カーボンボンド吹付け材の特徴をTable 2に示

gunning mixes are applied to repair the side wall such as trunnion sides and the area surrounding the tap hole, while the upper cone is typically repaired with conventional phosphate bonded gunning mixes. Hot casting repair mixes are used to repair the charging or tapping side wall and the bottom. Trunnion side repairs are done by gunning only because a hot casting mix cannot be sprayed over the trunnion side. Even though the use of these repair mixes is effective in extending the BOF lining life, they takes time to apply. Therefore, shortening the repair time is strongly demanded in order to improve BOF operation productivity. We have developed new high-performance repair mixes to satisfy these requirements. New carbon bonded gunning mixes adhere much better than conventional gunning mixes even when they are sprayed over brick surfaces hotter than 1300℃. The curing time of the new hot casting mixes are much shorter than those of conventional ones.

2. New Carbon Bonded Gunning Mixes for High Temperature Repair

General characteristics of carbon bonded gunning mixes are compared to those of phosphate gunning mixes in Table 2. By using a special organic binder, much fewer low melting components form than in phosphate bonded gunning mixes. In addition, carbon restrains over-sintering of the body and the slag penetration. As a result, carbon bonded gunning mixes have less peeling off damages and show high durability. Furthermore, phosphorus contamination of liquid steel is not an issue, unlike phosphate bonded gunning mixes.

A suitable temperature range for gunning ordinary carbon bonded mixes is between 800 and 1200℃.

The adhesion strength of the newly developed

す。カーボンボンド吹付け材は特殊な有機物を結合剤として使用しているため、低融物の生成が少なくカーボンによって過焼結とスラグ浸潤を抑制している。その結果、使用中の剥離脱落が少なく高い耐用性を示す。また磷酸ボンド吹付け材と異なり磷酸塩を含まないため、溶鋼汚染がないことも特徴である。

新たに開発したカーボンボンド吹付け材は、付着助剤(新技術)を活用することにより1000℃付近での接着性だけでなく、1300℃を超える高温域での接着性を大幅に改善している。これにより、排滓直後から補修可能となるため補修時間の短縮につながり、また高温でも補修面と強固に接着するため剥離し難くなり補修回数の低減につながる。

開発した超高温施工対応型カーボンボンド吹付け材の品質表(当社ブランドJTM:ジェットミックスシリーズ)をTable 3に示す。JTM-M-168, JTM-M-207, JTM-M-191の順にカーボン含有量が増加し、耐剥離性が向上、スラグ・溶鋼と濡れにくくなるため高耐用を示す反面、バインダーの増加により燃焼硬化時間が延長傾向となる。JTM-M-207は短時間燃焼硬化性と高耐用性を両立させた製品である。

carbon bonded gunning mixes to the high temperature brick surfaces is substantially improved by using new adhesion aids (new technology). New mixes can adhere to the brick surfaces tightly even over 1300°C. Thanks to this improvement, operators can start gunning repair soon after slag discharging, while the brick surface temperature is still hot. Also, because of the good adhesion, the durability of new gunning mixes is better than ordinary mixes. As a result, not only repairing time but also repair frequency can be reduced.

The typical properties of the newly developed carbon bonded gunning mixes for high temperature repairs are shown in Table 3. As the increase of carbon content, the peeling resistance and the durability improve with the increase in carbon content in the order corresponding to JTM-M-168, JTM-M-207 and JTM-M-191. However, the combustive hardening time tended to be longer due to the increase in the amount of binder corresponding to the amount of carbon. Overall, we think that JTM-M-207 has a good

Table 3 Properties of carbon bonded gunning mixies for high temperature face

Brand name	JTM-M-168	JTM-M-207	JTM-M-191
Chemical composition (mass%)			
MgO	84	78	77
C	7	9	13
Grain size distribution			
Max. size (mm)	3	3	3
> 1.0mm (%)	28	28	28
< 0.075mm (%)	38	38	38
Physical properties (after 1000°C)			
Apparent porosity (%)	30	31	32
Bulk density (-)	2.8	2.8	2.8

Table 4 Performance results of carbon bonded gunning mixes

Repaired area		Trunion sides		
Temperature		1000~1200°C	1300°C	1500°C
Mix consumption		200~1000kg/time		
Durability	Conventional product	2 ~ 5 heats	2 ~ 3 heats	0 heats
	Newly developed mix	5 ~ 10heats	5 ~ 7 heats	1 ~ 2 heats
	Applied product	JTM-M-207	JTM-M-207	JTM-M-191

Table 5 Categorization of hot casting repair mixes

	Non water binder system			Water binder system
	Phenolic resin binder system	Pitch binder system		
		Wet type	Dry type	
Flow ability	◎	◎	◎	◎
Adhesion	△	◎	◎	△
Hardening time	○	○	○	◎
Durability	△	○	○	△～×
Remarks	Hi-cost	Storage×	Total performance	

Good ◎…○…△…× Bad

More popular

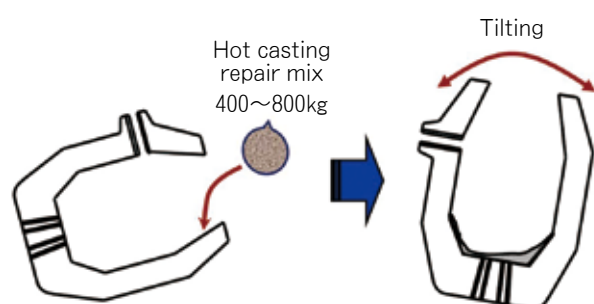


Fig. 2 Schematic procedure of the hot casting mix repair.

また、これらの製品の実炉適用実績をTable 4に示す。実炉において従来のカーボンボンド吹付け材では補修が難しかった1300～1500℃の高温の補修面にも良好に接着することが確認できた。耐用性は従来のカーボンボンド吹付け材に比較して2～2.5倍を示しており転炉の寿命延長、稼働率向上に寄与している。

3. 超速硬性焼き付け材

Table 5に転炉補修用焼付け材の特徴を示す。焼付け材はバインダー系から水系、フェノールレジン系、ピッチ系の3種に大別され、水系およびフェノールレジン系はピッチ系に比較し接着強度がやや劣るため、耐用もピッチ系に劣る傾向にある。ピッチ系には湿潤タイプと粉末タイプとあり材料特性は同等であるが、転炉作業床での保管性すなわち経時変化を起こしにくいことから現在は粉末タイプが主流となっている。焼付け材の補修方法をFig. 2に示す。焼付け材の補修は出鋼、排

balance of short combustive hardening time and high durability.

The actual application results of the new carbon bonded gunning mixes are shown in Table 4. The newly developed products showed good adhesion at various temperatures (1000～1500℃). The high-temperature areas (1300～1500℃) could be repaired with the new mixes, where it was difficult to be repaired by ordinary carbon bonded gunning mixes. Durability of the new products was 2 to 2.5 times better than those of ordinary carbon bonded gunning mixes.

3. Quick Hardening Hot Casting Repair Mixes

Hot casting repair mixes are characterized into three types according to the binder systems, such as water binder, resin binder and pitch binder system. Table 5 shows the characteristics of hot casting repair mixes corresponding to the binder systems. In general, the performance of a water binder or the resin binder system is worse than that of a pitch binder system because adhesion strength is low. There are both dry and wet types of pitch binder systems. The dry pitch system and the wet pitch system have almost the same properties. However, the dry pitch system is more popular because the

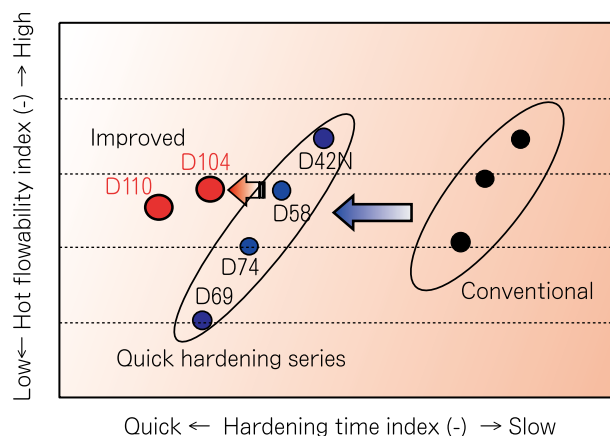


Fig. 3 Flowability and hardening time of improved repair mixes.

滓後に実施され、一般的にスクラップシューターなどで転炉に投入される。投入された焼付け材は燃焼しながら流動し、装入側～炉底～出鋼側のれんが損傷部位を被覆・充填し補修される。そのためすばやく損傷部位へ流動し、すばやく炎が消え硬化するという特性が要求される。開発品と従来品における硬化時間と流動性(熱間展開性)の比較をFig. 3に示す。硬化時間と流動性は焼付け材の重要特性であるが、一般的に硬化時間が短くなるに従い、流動性も低下する傾向にある。開発品はピッチの種類や添加量、助燃剤や粒度構成の検討により短時間硬化と高流動性を実現した。流動性(熱間展開性)が同等の従来品質(FRX-M90-D58)で比較すると開発した超速硬性焼付け材(FRX-M90-D110)はラボでの硬化時間が約30%短縮されている。超速硬性焼付け材の品質表(当社ブランドFRX：フローレックスシリーズ)をTable 6に、実炉使用結果をTable 7に示す。実炉においては作業条件(確保できる補修時間)に応じて最適な製品が選定されているが、開発品は従来品に比較し約30%～約60%の硬化時間短縮が確認されている。高流動性(熱間高展開性)で且つ短時間硬化する超速硬性焼付け材は、各所において転炉稼働率向上に貢献し大好評を得ている。

4. 今後の方向

上述のように超高温施工対応型カーボンボンド

storage time is longer than that of the wet pitch system. The method for hot casting repair is shown in Fig. 2. Hot casting mixes are charged into the vessel with a scrap shooter after slag discharging. The mix in the vessel flows over the target area by tilting the vessel while the pitch melts and burn. Therefore, in order to shorten repair time, the mix needs to flow well and harden quickly. In Fig. 3, hardening time and hot flowability of newly developed mixes are compared to those of ordinary and conventional ones. In general, the flowability tends to be low as the hardening time becomes short. However, as shown in Fig.3, we could create the newly developed products with good balance between short hardening time and high flowability by modifying the kind and quantity of pitch, flammable agents and grain size distribution. The hardening times of the new mixes were approximately 30% shorter than those of the conventional ones with very similar fluidities. The typical properties of the new quick hardening hot casting mixes called are shown in Table 6.

The performance results of the new mixes are shown in Table 7 with a comparison to conventional mixes. The hardening times of the new mixes were about 30% to 60% shorter than those of the conventional ones in actual applications. Application of the new quick hardening hot casting mixes is successfully contributing to the extension of BOF life with high appraisals by customers.

4. Future Direction

As described in above, the efficiency of BOF hot repairs is substantially improved by the use of the new quick hardening hot casting repair mixes and the new carbon bonded gunning mixes for super high-temperature repairs. Meanwhile, the demands for recycling used

Table 6 Typical properties of new quick hardening hot casting repair mixes

Brand name		Newly developed mix		Quick hardening
		FRX-M90-D104	FRX-M90-D110	FRX-M90-D58
Chemical composition (mass%)	MgO	77	75	77
	CaO	0.8	0.7	0.8
	C	7.6	7.2	7.6
Cast at 1000°C				
Apparent porosity (%)		25.5	25.3	25.7
Bulk density (-)		2.46	2.47	2.42
Adhesion strength (MPa)		2.6	2.3	2.5
Hot flowability index (-)		100	98	100
Hardening time index (-)		88	70	100

Table 7 Performance results of new quick hardening hot casting repair mixes

Customer's plant	Plant A	Plant B	Plant C-a	Plant C-b
Repaired part of converter	Charging pad	Bottom	Charging pad Tapping pad	Charging pad Bottom
Repairing temperature	1300°C	1200°C	1400°C	1100°C
Amount used	700kg	900kg	700kg	500kg
Curing time Conventional ↓ Improved (D104) ↓ Improved (D110)	40min ↓ 20min ↓ 10min	45min ↓ 30min ↓ 20min	20min ↓ 10min ↓ 5min	35min ↓ 25min ↓ 15min
Durability	7 ~ 8 heats	5 ~ 6 heats	5 ~ 6 heats	7 ~ 10heats

吹付け材と超速硬性焼付け材を組み合わせることで、転炉の熱間補修の効率は格段に向上する。一方、最近では環境負荷軽減の一つとして耐火物のリサイクルが始まっており、当社でも転炉の使用後MgO-Cれんがを活用した超高温対応型カーボンボンド吹付け材や超速硬性焼付け材を開発し展開している。これらリサイクル製品の使用は今後、着実に拡大していくと考えられる。

refractories are increasing strongly in order to reduce not only refractory cost but also to conserve natural resources. We have already started to utilize used MgO-C bricks in some of these new repair mixes in cooperation with our customers. We believe that the use of these recycled products will steadily expanding.