

HOT REPAIRING MGO-C SELF-FLOW CASTABLE FOR BOF CONVERTER WITH ZERO FUME EMISSION

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ABSTRACT

A novel self-flow MgO-C castable was conceived to be delivered to the customer as a R2U (ready-to-use) product and to be compatible to MgO-C bricks. Some challenges were overcome such as, the development of a new organic liquid with low viscosity, a specific grain size distribution to avoid segregation during storing and transportation, a fast curing time after installation, a new sort of dispersant for non-aqueous medium and a very easy installation by self-flowing. Hot repair can be performed at any temperature of BOF bricks and applied as simple as by throwing a super sac or a bag directly to the damage area. Trials were conducted at steel shops and the performance was similar when compared with resin bonded basic material, but with zero fume and non-pollutant emission. After installation BOF converter is ready to resume operation in 30-45 minutes.

1 INTRODUCTION

Basic oxygen furnace is the most popular process selection for oxygen steelmaking and with worldwide production in the range of the 60%. MgO-C brick is the major refractory product for BOF converters and slag line of steel ladles. Throughout campaign hot repairing is usually carried out to extend these vessels working time. Most of the hot repairing materials are based on wet gunning products, using water as liquid. Thermal shock and hydration are observed in MgO-C bricks and the gunning material properties present a large scatter. This paper reports the development of a novel hot repairing material with no water addition and no fume emissions.

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grain size distribution to avoid segregation during storing and transportation, a fast-curing time after installation, a new sort of dispersant for non-aqueous medium and a very easy installation by self-flowing. Hot repair can be performed at any temperature of BOF bricks and applied as simple as by throwing a super sac or a bag directly to the damage area. Trials were conducted at steel shops and the performance was similar when compared with resin bonded basic material, but with zero fume and non-pollutant emission. After installation BOF converter is ready to resume operation in 30-45 minutes.

2 MgO-C CASTABLE DEVELOPMENT

Basic dry gunning mixes have been conventionally used for hot repairing of BOF and ladle slag line since 1970s^{1,2}, when phosphates bonded materials were mainly applied. The increasing in demand of lower carbon steel brought severe operating conditions to BOF converters, and as consequence, the MgO bricks and repairing mixes had to be redesigned. Conventional dry gunning mixes usually need water as a liquid to wet the material. Specially for BOF repairing, water is not suitable due to thermal shock damage in MgO-C bricks. Usually, the water amount for gunning is not easy to control and the final properties present a large scatter.

A novel conception for a hot repairing mix was based on a MgO-C bricks in order to develop a MgO-C castable. Nevertheless, hydraulic binders have serious limitation to be used with basic aggregates (such as MgO sources) and the metallic additives with water. Graphite also presents oxidation and poor wettability in water systems. Therefore, phenolic resin was selected as the main binder for several reasons³⁻⁵:

- Low polluting organic binder
- Full compatibility with antioxidant additives
- Compatibility with carbon and oxide wettability
- Generation of carbon bonds after soaking
- Easy incorporation of carbon to the mix
- Easy handling and pouring into the mix

MgO-C self-flow castable was developed to replace conventional dry gunning mixes and to be delivered as a R2U (ready-to-use) product. This product has been offered as a hot repair solution since 2006 with great success in different BOF's sizes and types⁶. Although phenolic resin has a low fume emission compared to any other carbon binder, increase in the environment restriction from some customers was the driven force to find a new

solution for this self-flow mix. The improvement of this novel product and field trials will be discussed in this paper.

The improvement of the hot repairing product was idealized to keep fulfilling some requirements as:

- Compatibility with MgO-C bricks
- Multi-functional installation: self-flowing or pumping
- R2U (ready-to-use) castable delivery to customer with all liquid incorporated to the mix in order to have properties that are more homogeneous and predictable.

Main challenge to this new hot repair mix was the development of a new binder that associates a non-fume organic liquid with an inorganic one. The new binder system enables carbon and oxides sources wettability. Product is still based on DBM as main aggregate in all particle size ranges, although fused magnesia could also be employed if application requires. To cover all range of Andreasen grain size distribution model, submicron MgO and carbon particles are used. Metallic additives for higher hot modulus of rupture were also incorporated and kept on this new product. Fine powders required a very special dispersant for non-aqueous medium because the new binder system is also partially organic. All phenolic resin was eliminated in the mix. Electro steric dispersants are effective on both magnesia and carbon surfaces and helped to decrease the content of the liquid closed to 25wt%. The minimum self-flowing index attained for the castable was 70%.

High fluidity is necessary for product installation, but it can promote segregation during transportation or storing. Grain size distribution and matrix viscosity were designed to prevent this problem. Storing time is also affected by particle agglomeration and castable stability was achieved using appropriated dispersion system. MgO-C castable kept its original properties after 90 days.

3 EXPERIMENTAL PROCEDURE

3.1 Chemical and Physical Properties

All comparative evaluation was performed from mixes produced in plant, casted iron moulds in R&D and cured at 200°C/6h under a 10°C/min heating rate. For the physical and thermo-mechanical characterization steps, samples were cut into different sizes

(according to the selected test) using a diamond saw. Samples were evaluated after cure and after coking at 1400°C/5h (electric oven, 10°C/min heating rate).

Bulk density and apparent porosity were measured according to ASTM C20. Cold crushing strength was carried out in universal mechanical testing equipment (EMIC, Model PC200C, Brazil) according to ASTM C133. For HMOR evaluation no previous thermal treatment was carried out and tests were performed using internal testing equipment (RHI Magnesita, Brazil). Samples were wrapped in nickel foil to prevent oxidation. Elastic modulus was evaluated by sonic resonance method (James Instrument, Model V Meter, USA) according to ASTM C885. Permanent volumetric expansion (PVE) was measured according to ASTM C134 after firing the samples in electric furnace.

Corrosion test was performed with octagonal prismatic samples in an induction furnace at 1700°C/3h. Samples were previously coked at 1000°C/5h to eliminate any volatile to prevent explosion and were immersed in molten steel and synthetic slag. Each 30min the slag was refreshed to prevent saturation. Table 1 shows the chemical, physical and mechanical properties of the MgO-C R2U castables with resin and new multiple binder system

Table 1. Chemical physical and mechanical properties of the MgO-C R2U castables with resin and new multiple binder system.

| | Resin Binder | Multiple Binder System |
|------------------------------------|---------------------|-------------------------------|
| MgO (%) | 89.3 | 89.3 |
| Al ₂ O ₃ (%) | 2.2 | 2.2 |
| C (%) | 6.5 | 2.7 |
| Others (%) | 8.5 | 8.5 |
| After 200 °C | | |
| Density (g/cm ³) | 2.47 | 2.50 |
| Porosity (%) | 17.3 | 18.1 |
| CCS (MPa) | 28 | 31 |
| HMOR (MPa) | 4 | 3 |
| Slag corrosion ⁽¹⁾ (%) | 33 | 34 |
| After coked 1400 °C | | |
| Density (g/cm ³) | 2.52 | 2.55 |
| Porosity (%) | 25.4 | 20.4 |
| CCS (MPa) | 24 | 27 |
| HMOR (MPa) | 4 | 3 |

(1) induction furnace – 1700 °C x 3h, steel + 40% FeO slag

Main difference in the chemical analysis is the carbon content. Composition was kept the same but totally eliminating the resin as binder. MgO-C castable with new multiple binder

system shows higher density due the carbon content decreasing but attained similar porosity after curing. Mechanical and hot properties were similar for both materials. Corrosion resistance was also very similar besides of lower carbon content showing that powder carbon is more effective than the glassy one from the resin. Nevertheless, results after coked at 1400 °C indicating better sinterability to the new binder with improved density and porosity results. HMOR was kept at same level as this property is the result of carbide formation due of the interaction of metallic powders and the carbon in the composition.

Figure 1 shows the flow table test used to for quality control before installation. Acceptable flow is in the range between 70-90%.



Figure 1: Self-flow test for quality control of MgO-C castable.

Hot self-flow test was performed to evaluate fume emission before customer trials. Sample of 300g is placed on ceramic plate heated by thermal elements at 800°C. Flame color and flow are observed during the test. Figure 2 presents the evaluation of the MgO-C R2U castables with resin (a) and new multiple binder system (b).

Due to the higher molecular weight chain of the resin the flame is much brighter and yellow than the new binder system. Also, resin is more flammable and fume generation is related to the capacity of carbon-carbon bonds formation that is not presented in the multiple binder developed.



(a)



(b)

Figure 2: Evaluation of the MgO-C R2U castables with resin (a) and new multiple binder system (b).

4 STEEL SHOP TRIALS

MgO-C castable was installed by self-flowing in a 320t BOF converter just throwing the supersack using the scrap crane. Hot repair mix was delivered in supersacks from 500 to 1200kg, following customer demand.

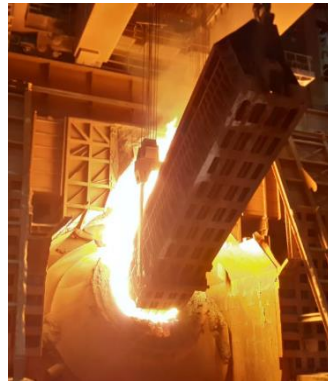
Figure 3 shows the sequence of the hot repairing in a converter tap pad using 2t of MgO-C castable with the multiple binder system. Material was charged by the scrap crane into the impact pad. Then the converter was rotated up to the point that the material flows through out tap pad. The whole operation was completed in less than 40s. BOF was kept in this position for material setting. After 40min vessel can resume normal operation.

Mix flowability was the same as the resin bonded material but no fume was reported during all the trials performed at this customer. Figure 4 registers the critical time for the application when fume can be detected. As visualised in the lab during the hot flow test no emission was present with the new binder system but easily observed for the resin bonded hot repair mix. After several promising trials, this technology has been transferred to other customers for maturing.

MgO-C castable R2U has also been used for impact pad and bottom hot repairing. Campaign at similar brick wearing condition was at same level as the previous resin bonded material. Setting time was also similar.



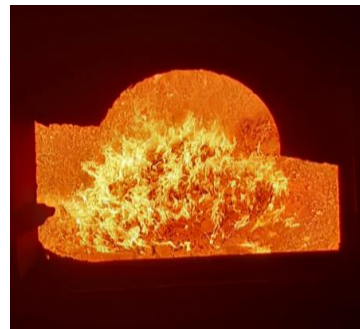
(a)



(b)



(c)



(d)

Figure 3: BOF hot repairing mix schedule: (a) scrap crane used to load MgO-C castable, (b) MgO-C castable is applied into impact pad, (c) material flows to tap pad, (d) material is set and BOF is ready to return.



(a)



(b)

Figure 4: (a) No fume emission installation of the new multiple binder system and (b) fume emission with resin bonded BOF hot repairing mix

5 SUMMARY AND CONCLUSIONS

Novel multiple binder system for MgO-C castable has been developed and used for hot repairing of BOF. This material has shown to be compatible to MgO-C bricks and steel making process basic slags but with no fume emissions as reported with resin bonded mix. Trials conducted on steel shops are validating this clean technology.

This hot repair mix was designed to keep the self-flowing installation and it is delivered as R2U (ready-to-use) castable with no segregation to attending the demand to be environmentally friendly.

This novel material technology is been also transferred to other developments such as hot repairing of ladles, well and plug blocks for steel ladles.

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