DEVELOPMENT OF LOW FUMES EMISSION REPAIR MATERIAL AT BASIC OXYGEN FURNACE APPLICATION

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ABSTRACT

The increase on steel market pressure for more sustainable production in accordance to global trend for reducing CO_2 emissions on products and processes oriented Shinagawa Refractories (SRC) / Saint-Gobain (SG) prioritizations to develop products focused on the same guidelines. In a Basic Oxygen Furnace (BOF), the corrosion caused by high FeO content slag and high oxidation are the most critical conditions for maintenance of refractory lining integrity. As a consequence of all technologies and innovations taken by SRC/SG, the durability of refractory products applied at BOF lining is improved and it is possible to reduce the quantity of repair material throughout the campaign which leads CO_2 emissions reduction. The present work will show the significant results associated with low fumes emission repair material developed for BOF applications.

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INTRODUCTION

The evolution of technology in industrial processes increase the pressure on steelmaking market with a more diverse demand for higher products quality aligned with a growth on restricted sustainability measures. Refractories products has a meaningful role on steel industry due to its effect on manufacturing costs and product quality as they are applied on harsh plant operating environments to endure high temperatures and wear conditions. Refractories' quality is becoming much higher than before in an extensive range of processes of hot metal refining, such as decarburization, desulfurization, dephosphorization and desiliconization leading on an increase of secondary refining of molten steel ratio [1].

Refractories technology has been developed with the objective of increase furnaces life extension reaching the needs for higher productivity, lower costs and raw materials consumption decrease with a consequently CO_2 emission reduction. For Basic Oxygen Furnaces (BOF) market this means the converter and refractory-technologies optimization is focusing on increase their life-times together as a combined system. The technology has also advanced to improve the diagnosis technique of internal furnace conditions and to effectively repair the damaged lining [1].

Usually steel can be considered as a permanent material which can be recycled continuing times without the degradation of its properties. It is well acknowledged that steel production demands for high amount of energy and it is responsible for 11% of overall global carbon emissions [2]. In the 21st century, climate change is the greatest issue for steel producers and as it was agreed at the aims of Paris Agreement [3] the steel industry is committed to continuous decrease of greenhouse gas emissions in a short time to achieve a climate neutral world by 2050 from its operations and the use of its products.

Even MgO-C bricks are widely used in BOF due to their desirable resistance to chemical corrosion and mechanical stresses, hot repair is required to improve the total life time of the converter lining as previously mentioned. Traditionally, the application for hot repair BOF and ladle slag line have been filled with basic dry gunning mixes since the 1970s, when mostly phosphate-bonded materials were utilized. A continuously growth on lower-carbon steel demand has caused severe operating conditions to converters as previously mentioned on this paper. As a consequence, MgO bricks and repairing mixes needed to be redesigned [4,5].

Generally, charging area can be repaired by hot repair mix and mainly at the tapping area which requires refractory bricks with high mechanical shock and erosion resistances in opposition to molten metal and steel scrap charging. In these scenarios hot repair mix is commonly applied because of their higher hot strength when compared to spray material. In addition, the curing time also effects on the steel making process and if the hot repair mix does not go through enough curing time, it can easily fall off during the operation and shorten the life time [6].

During the application of hot repair mix into the hot converter it is required a time to burn up the volatile matters with an origin on carbon content of some raw materials present on the formulation. The burning of these volatiles can cause some fumes emissions which reduction is the main propose of this paper. The development of the hot repairing mix reported in this paper is based on MgO-C brick formulations maintaining the required properties of its compatibility with MgO-C bricks and allowing self-flowing application. But most important focusing on lowering suspended particles and gases emissions.

DEVELOPMENT

Basic self-flow mix for hot repairing was formulated using high grade calcined magnesia of different grain sizes in order to contribute not only for material densification but also to allow necessary high fluidity for product installation due to an optimized grain sized distribution and matrix viscosity control. Additives were incorporated mainly to increase hot modulus of rupture (HMOR).

Table 1 presents chemical and physical properties established after baking at 200°C and after heat treatment at 1,400°C on reducing atmosphere in order to simulate their evolution during BOF operation.

Table 1 – Physical chemical properties of basic self-flow mix for hot repair

Properties	**Basic self-flow mix**
Composition (%)	
MgO	88.5
Carbon	7.0
Others	4.5
	After baking at 200°C
Apparent density (g/cm^3)	2.43
Apparent porosity (%)	19.3
Cold crushing strength (MPa)	15.1
Module of rupture (MPa)	4.4
	After heating at 1,400°C
Apparent density (g/cm^3)	2.39
Apparent porosity (%)	26.6
Cold crushing strength (MPa)	11.1
Module of rupture (MPa)	2.0
HMOR (MPa)*	9.42

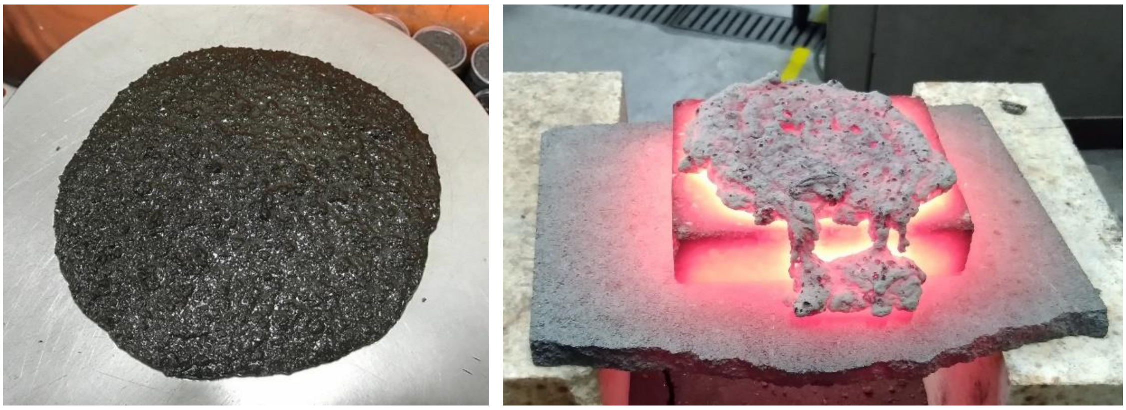
*Hot modulus of rupture test performed under reducing atmosphere at 1,400°C.

RESULTS AND DISCUSSION

As previously presented on Table 1, the basic mix shows good properties of density and porosity with expected results after curing and heat treatment which are consistent with other basic hot repair mixes developments [5,6]. The hot repair mix also shows great mechanical properties on both temperatures and the most important a high hot module of rupture which can indicate a good field performance of enduring mechanical impact of liquid metal on BOF converters.

During BOF operations for steel refining, after converter tapping, the temperature inside it is between 1,200°C and 1,400°C and when the curing of hot repair mix is concluded the temperature lowed close to 1,000°C. Because of that conditions, thermal fluidity of the repair mix was fixed at 1,000°C [6].

Figure 1 present the aspect of the mix after self-flow test and demonstrate the good thermal fluidity after a test at 1,000°C which indicates a good workability of this hot repair mix to be applied at converters covering well the refractory work area.



(a) (b)

Figure 1 – (a) Self-flow test for self-flow repair mix; (b) Thermal flow at 1,000°C.

Below at Table 2 presents the results of hot repair mix fluidity after self-flow and self-flow after 15 beats tests.

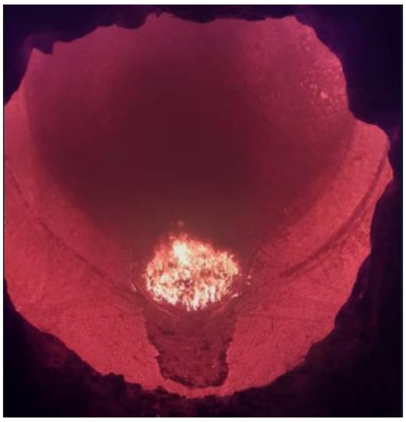
Table 2 – Fluidity properties of basic hot repair mix.

Self-flow (mm)	173
Self-flow after 15 beats (mm)	190

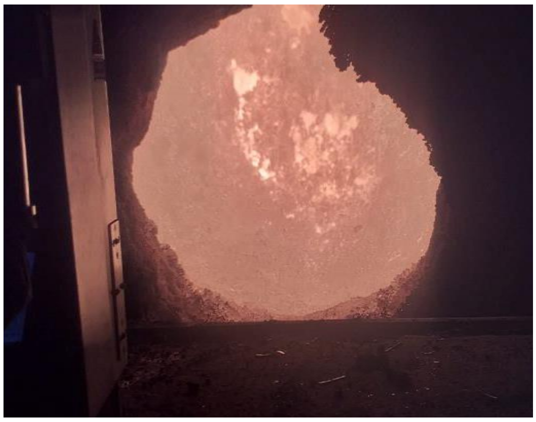
Basic hot repair mix was installed using self-flowing methodology in a 315-ton capacity BOF converter of a steel producer which represented almost 35% of total crude steel production of Brazil at 2021[7]. Hot repair mix was delivered in 0,5 ton big bags and the one-month test used a total of 6 ton of the material. Figure 2 presents the steps sequence of hot repair mix application in converter at impact bottom region.

(a)

(b)



(c)



(d)

Figure 2 – (a) Load of hot repair mix big bag; (b) Low fumes emission; (c) Application on interested region; (d) Sintering process after complete thermal fluidity of the mix.

Hot repair mix was installed with the help of crane's arm to put 0.5-ton big bag inside the converter and the total of 6 tons were used at one-month trial when the work lining repair was required. Considering the perception of production works and evidenced by the Figure 2(b) there was no great emission and the mass of the mix was in the objectified region.

CONCLUSION

High hot mechanical strength and thermal fluidity properties of the developed mix measured by laboratory trials were validated by the great performance at field trial which is a good indication of productivity improvement steel making due to extension life of converter.

Besides the good workability and sintering of the hot repair mix it was possible to notice a reduction in particulate emissions by production workers' perception achieving the main purpose of developing this mix.

Shinagawa Refractories / Saint-Gobain efforts to reduce not only the fumes but also carbon footprint and CO_2 emissions of hot repair mix will be continued in the future.

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