PRE-SHAPED REFRACTORY CASTABLE FOR REHEATING FURNACE BURNER BLOCKS

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ABSTRACT

Pre-shaped refractory burner blocks play an important role in reheating furnaces operation and melt shops production since they are responsible for heating the billets/plates so that they reach the temperature required for lamination. This paper presents the main characteristics and properties of a *new refractory castable* developed for pre-shaped burner blocks, which significantly improved the performance of reheating furnaces burner blocks. Tests carried out in 3 different melt shops have shown that the new refractory castable was able to extend the service life of the refractory burner blocks from 1 year (*standard product*) to more than 3 years (*new castable*), showing perfect conditions to continue operating for a longer period.

INTRODUCTION

Reheating furnace is the equipment that mostly dictates the speed of production of a melt shop, since a furnace that frequently stops for maintenance forces an interruption of the plant production and, in the case of an integrated mill, can also entail an output reduction in the blast furnace. Within this important equipment in the steel production flow, the refractory burner blocks play an important role in the furnace operation since they are responsible for heating the billets/plates so that they reach the temperature required for lamination [1-3]. Besides compromising the reheating furnace operational safety, worn or damaged refractory burner blocks can cause uneven heating of the steel products, consequently requiring longer residence time causing the loss of productivity and possibly the overheating of some billets/plates that can lead them to melt. On the other hand, poorly heated billets/plates can breakdown during lamination process, causing an emergency stop and the loss of production in addition to materials losses, labor waste and lost profits until the operation is resumed. The performance of Magnesita's reheating furnace burner blocks (*standard product*) used to last for 1 year, when spalling and/or cracks were observed in the pre-shaped refractory[4-6] blocks which necessarily required a furnace stoppage for their replacement. This paper presents the main characteristics and properties of a *new refractory castable* developed for pre-shaped burner blocks, including raw materials and particle size distribution[7] adjustments, physico-chemical properties, hot modulus of rupture, thermal expansion behavior and thermal shock resistance, which leaded to a significant improve of the reheating furnaces burner blocks´ performance.

MATERIALS AND METHODS

A high alumina cement bonded refractory castable (LCC) was the reference basis (standard product) for this development. Two high alumina aggregates were evaluated as raw material base for the refractory castables: Aggregate type 1 and aggregate type 2. 50Kg of each refractory composition was homogenized in a "V" mixer for 10 min. Then, 10Kg of dry material was sampled to determine the particle size distribution. The remaining 40Kg were then wet-mixed in a planetary mixer for 5 min and the water content and vibra-flow measured (vibrating table, 100Hz for 10 seconds). Prismatic specimens of 160x40x40mm were casted (air cured for 24h), then dried at 110°C/24h and fired at 1200°C/5h for characterization: *Chemical analysis* (X-ray fluorescence spectrometry, ISO 12677:2014, PHILIPS MagiX PRO), *bulk density and apparent porosity* (ABNT NBR 11221:2010), *cold crushing strength* (ABNT NBR 11222:2010), *hot modulus of rupture* (ABNT NBR 9642:2012) *and thermal shock resistance* (ABNT NBR 13202:2015). The specimens used to evaluate the thermal-shock resistance were pre-fired at 1400°C/5h and the elastic modulus was measured after 5 thermal shock cycles (1400°C/30min + cooling plate). Dilatometry was determined by heating twice (5°C/min) cylinders (∅ = 11mm; length = 25mm) up to 1400°C in a dilatometer NETZSCH DIL 402 PC (ABNT NBR 6637:2013). Optical microscopy of the refractory castables' microstructure was carried out in a ZEISS AXIO Imager.A1m.

RESULTS AND DISCUSSION

The particle size distribution (PSD) of the new castable was modified in order to improve thermo-mechanical properties. Tab.1 presents the differences in the PSD of the refractory castables: *standard product* and *new castable*. The changes revealed an increase in the amount of coarse aggregates and a decrease of the medium and fine particles.

Tab.1: Refractory castables´ particle size.

# Sieves		*Standard product*	*New castable*
Coarse	8,00/2,00mm	19	35
Medium	2,00mm/300μm	46	34
Fines	< 300μm	35	31

Besides adjusting PSD, the type of the refractory aggregate used in the new castable was changed. Tab.2 presents the differences of the main compounds of both refractory castables. The Al_2O_3 content of the new castable was decreased and the amount of SiO_2 increased. Additionally, the CaO and Fe_2O_3 contents were reduced to adjust refractory castable sinterability. Fig. 1 shows the microstructure of the different refractory aggregates used in the standard product and the new castable.

Tab.2: Refractory castables´ chemical composition.

Main compounds (wt.%)	*Standard product*	*New castable*
Al_2O_3	75,7	60,8
SiO_2	17,4	36,7
CaO	1,6	0,9
Fe_2O_3	1,3	0,6
Others	4,0	1,0

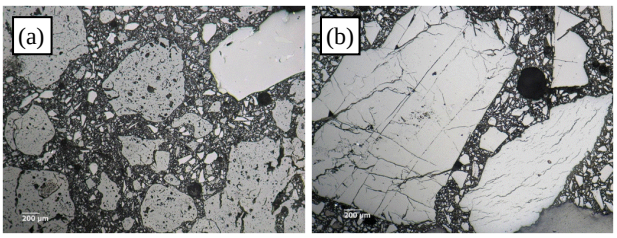

Fig. 1: Refractory castables' microstructure: (a) aggregate type 1 (*Standard product*), (b) aggregate type 2 (*new castable)*.

Tab.3 presents the main properties of the refractory castables. The results revealed an increase of the water content necessary for the new castable to develop similar flowability under

vibration when compared to the standard product. After drying at 110°C/24h and firing 1200°C/5h, the new castable presents higher apparent porosity (AP) and lower cold crushing strength (CCS). After firing, both the refractory castables experience an increase in the apparent porosity. Nevertheless, similar bulk density was observed. The CCS also increased after firing, but while the new castable raised ~50% its mechanical strength the standard product raised ~150%. PLC measurements show lower shrinkage after firing for the new castable. These results suggested that this material exhibits poorer sinterability which could enhance the performance of pre-shaped burner blocks at reheating furnace operating temperatures by reducing its susceptibility to spalling and crack formation. The hot modulus of rupture (HMOR) revealed that both the refractory castables experience a decrease in the mechanical strength by increasing the test temperature. Nevertheless, the new castable show a smaller reduction of HMOR values when compared to the standard product and still exhibit superior mechanical strength at temperatures of 1200°C and 1400°C.

Tab.3: Refractory castables´ main properties.

Main properties		*Standard*	*New castable*
Water (wt.%)		5,1	5,6
Vibra-flow (mm)		184	179
110°C/24h	BD (g/cm3)	2,73 ± 0,04	2,63 ± 0,03
	AP (%)	12,7 ± 0,5	13,9 ± 0,4
	CCS (%)	35 ± 6	29 ± 7
1200°C/5h	BD (g/cm3)	2,60 ± 0,02	2,61 ± 0,02
	AP (%)	14,2 ± 0,4	16,3 ± 0,8
	CCS (%)	87 ± 8	45 ± 3
	PLC (%)	-0,5 ± 0,3	-0,1 ± 0,1
HMOR 1000°C/3h (MPa)		10,3 ± 0,9	5,2 ± 0,5
HMOR 1200°C/3h (MPa)		2,1 ± 0,8	3,9 ± 0,7
HMOR 1400°C/3h (MPa)		1,5 ± 0,6	3,8 ± 0,4

The thermal expansion behavior of the refractory castables was evaluated by dilatometry. The results show that the new castable presents lower expansion after 2 heats up to 1400°C (Fig.2), which indicated a superior dimensional stability at high operating temperatures.

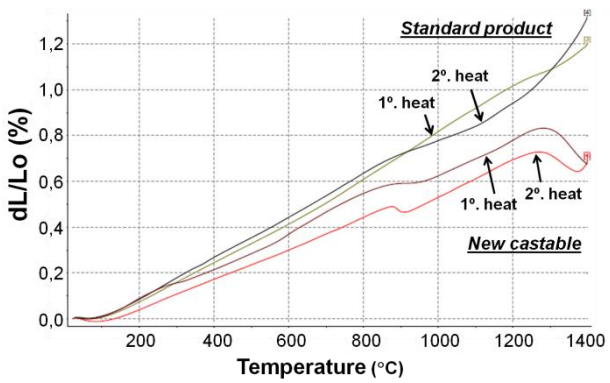

Fig.2: Dilatometry of the different refractory castables.

The specimens used to evaluate the thermal-shock resistance were pre-fired at 1400°C/5h. This previous thermal treatment revealed that new castable presents almost 3 times lower Elastic Modulus (*E*) when compared to the standard product (Fig.3). Although both refractory castables experience a significant drop in the *E* after the first thermal-shock cycle (TSC), no significant reduce was observed for the new castable in the following TSCs while the standard product *E* values kept decreasing. These results suggested that the new castable could exhibit better thermo-mechanical properties by showing a superior resistance to cracks' propagation.

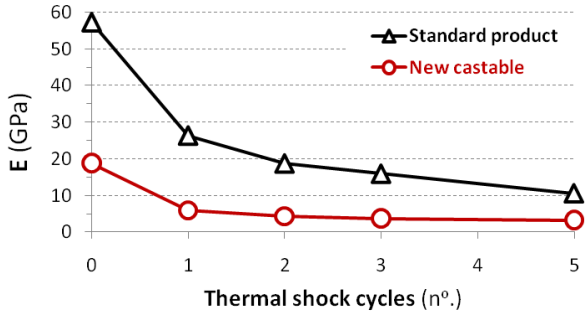

Fig.3: Thermal shock resistance.

The performance of Magnesita's reheating furnace burner blocks (*standard product*) used to last for 1 year, when spalling and/or cracks were observed in the pre-shaped refractory castable blocks which necessarily required a furnace stoppage for their replacement (Fig.4).

Fig.4: Visual aspect of a severely damaged refractory burner block on the Reheating Furnace´s roof after 1 year operating.

Therefore, based on the characteristics and properties exhibited by the new castable developed, new pre-shaped refractory burner blocks were produced and tested in different reheating furnaces in South America to evaluate their performance. Fig. 5 shows the visual aspect of the roof burner blocks in a reheating furnace soaking zone after 3 years operating. The evaluation carried out by periodic inspections shows no evidences of spalling or surface deterioration in the refractory burner blocks indicating that they can continue operating for a longer period.

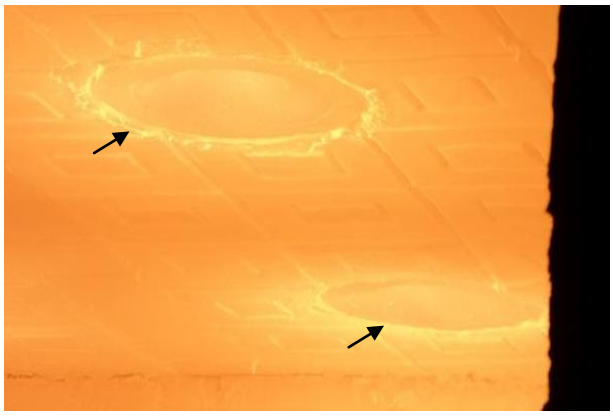

Fig.5: Visual aspect of the new refractory burner blocks on the Reheating Furnace´s roof after 3 years operating.

CONCLUSIONS

The development of a new refractory castable to extend the performance of reheating furnace pre-shaped burner blocks requires multiple adjusts in castable's formulation. The characterization presented in this paper revealed that particle size distribution, physico-chemical properties, hot modulus of rupture, thermal expansion behavior and thermal-shock resistance were optimized and/or improved leading to the development of a promising new product. Tests carried out in 3 different melt shops have shown that the new refractory castable was able to endure severe and unstable reheating furnace operating conditions extending the service life of the refractory burner blocks from 1 year to more than 3 years, showing perfect conditions to continue operating for a longer period.

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