

Matte-refractory Interaction; a Review

T. Ramakobya, BM Thethwayo and Antoine F. Mulaba – Bafubiandi

Abstract—In the Platinum Group Metal (PGMs) industries, there are furnaces breakouts due to high operating temperatures. This is mainly due to smelting UG2 concentrates that have high chromite content. Thermodynamically, when the matte temperature is greater than 1500 °C, the probability of matte sulphidising with refractory is very high. Magnesite-chrome brick and alumina-chrome brick are typical in PGM-smelter refractory lining; matte can penetrate and interact with these refractories at operating temperatures. The data published on matte-refractory interaction in PGM smelters is reviewed in this paper. Matte penetration through refractory, refractory dissolution in matte and the composition of the residual matte is discussed.

Keywords— FactSage Modeling, RHI Radex H60 Brick, matte penetration, Chromite Spinel

I. INTRODUCTION

The key part of metallurgical process that recognize Platinum Group Metals (PGM) concentrates refining from that of other base metal sulfide concentrates are displayed. The distinction incorporate extensively higher input chromite and manganese substance that specifically raise the slag liquidus temperature and can possibly expand collections of refractory spinels. In particular, the higher smelting temperature required for PGM melting, and that results to higher matte superheat than matte temperatures of other common refining operations (Eksteen, 2009), thus this tends to damage the furnace refractories.

High matte superheat is a challenge in the furnace operation of PGM melting as the product is being contaminated and furnace breakout rate increases. Refractories must be capable of maintaining good physical, chemical and thermal properties at very high temperatures. The typical refractories are used as lining in PGM smelters, essentially chrome-magnetite and magnesite-chrome and Alumina-Chrome (Lange et al, 2014).

Investigation concerning the understanding of the causes of the refractory materials breaking down in the furnace will be conducted. Penetration of slag, matte, and gases through refractory is observed at typical operating temperatures, dissolutions have also been observed which results to corrosion and erosion of the furnace lining. Temperatures above 1500°C are conducive for sulphidising Cr₃O₄ or Fe/MgCr₂O₄ refractory by matte. In order to consider the furnace operating temperatures, the important parameter is how to control chromium in the system which is achieved by setting up

optimum furnace temperatures (Jacobs, 2006).

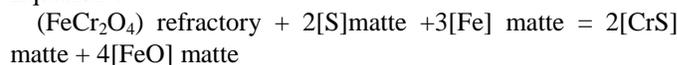
In the furnace, there are three steps that are responsible for the wearing of refractory. Firstly, there should be the matte penetration into the refractory brick. Secondly, the corrosion and erosion occurs where the damaged refractory will report in the tapping channel (Nelson and Hundermark, 2014). The wearing of the refractory in the furnaces is controlled by the way the matte penetrates into the refractory brick and the liquidus temperature of the matte (Nelson *et al.*, 2005).

II. LITERATURE REVIEW

A. SLAG-MATTE INTERACTION

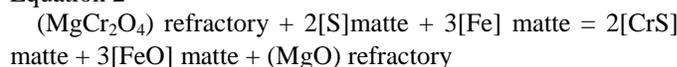
Concerning the type of concentrate treated in the PGMs smelters, when dealing with concentrates containing higher than 1.8% Cr₂O₃ the chromite spinels lacks the ability to dissolve in the slag at the typical slag temperature ranging from 1500 °C – 1550 °C (Lange *et al.*, 2014). This results into the furnace temperatures being increased to dissolve the chromite spinels into a slag. At that high temperatures, the matte have ability to penetrate into the refractory according to factSage calculations conducted by Eksteen (2011).

Equation 1



With $\Delta G^\circ = -8.478 \text{ KJ/mol}$ at $T = 1500 \text{ }^\circ\text{C}$ ($\Delta G^\circ < 0$, when $T > 1450 \text{ }^\circ\text{C}$)

Equation 2



With $\Delta G^\circ = +11.03 \text{ KJ/mol}$ at $T = 1500 \text{ }^\circ\text{C}$ ($\Delta G^\circ < 0$, when $T > 1650 \text{ }^\circ\text{C}$)

Eksteen (2011) used magnesite-chrome brick with the composition of 58% MgO, 19% Cr₃O₄, 6.5% Al₂O₃, 14% Fe₂O₃, 1.4 CaO, and 0.6% SiO₂, and simulated the weight loss when it was exposed to high temperatures together with furnace matte. The resulting graph is in Figure 1. At temperatures above 1500 °C the consumption of the refractory can reach 4 mass percent. This is a substantial loss as it mean the thickness of the refractory can be consumed over time.

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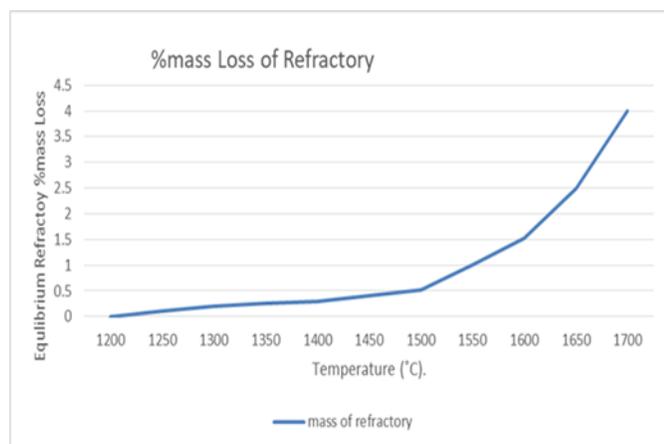


Fig 1: Predicted weight loss due to brick wear of RHI Radex H60 brick by Eksteen (2011)

B. INTERACTION OF MATTE WITH Mg-Cr BRICK

To test the FactSage predictions in equations 1 and 2, Lange et al (2014) conducted some experiments at a laboratory scale. They tested matte interaction with a typical Magnesia-Chrome brick. The brick composition was 57.4% MgO, 21.3% Cr₃O₄, 7.8% Al₂O₃, 11.2% Fe₂O₃, 0.8 CaO, and 1.5% SiO₂. The industrial matte contained 39%Fe, 11% Cu, 15% Ni, 1%SiO₂, and 0.61%Cr. The 1% SiO₂ can be traced from the brick reacting with the matte or slag component dissolution in matte. The temperature was varied from 1300 °C to 1750 °C.

At 1300 °C to 1400 °C, they observed high penetration of matte through the brick. When the temperatures are increased to 1500 °C, some chemical interactions were seen. At 1700 °C to 1750 °C, the penetrated matte had high Cr content than the starting matte forming a new CrS phase and also the evolution of sulphur was observed. It was established that reactions were more complex than the FactSage prediction in Equations 1 and 2 above simulated by Eksteen (2011).

Due to the complexity of the interactions the authors did not determine the mechanism of interaction e.g. formation of a CrS phase, and evolution of sulphur. However, my work sort to determine mechanisms of matte-refractory oxide interaction as it is not known.

C. INTERACTION OF MATTE WITH Al-Cr BRICK

They tested the effectiveness of clay in preventing matte penetration through the refractory brick. The brick tested had 75% Al₂O₃, 20.7% Cr₂O₃, 2.2% P₂O₅, and 1% SiO₂. The industrial matte had 61.9% (Fe, Ni)₉S₈, 13.3% FeS,

6.6% Cu₅FeS₄, 6.8% SiO₂, 6% CaAl₂Si₂O₈, and 3.9% FeCr₂O₄.

From 1350°C as well as to 1500°C matte penetrated through the clay and into the brick. The pre-baked tap-hole clay decreased the penetration of matte through the brick. New phases were observed in the penetrated brick which proved that chemical interaction occurs between the matte and the refractory oxides at elevated temperatures.

D. OXIDE-MATTE INTERACTION

According to Thethwayo *et al.* 2015, Thethwayo 2019, the oxide inclusion in the matte can alter the some properties of the matte during melting. These authors reported that during the

re-melting of industrial matte, an unexpected increase in matte occurred. A typical matte should have ~60% (FeNi)₉S₈, 30% FeS, with the remainder being Cu_xS. Oxides and silicates typically report to the slag but, during smelting some oxides may dissolve in the melt either from the slag phase or from the refractories.

A typical effect of oxides in matte is demonstrated in Figure 2 where the melting stages of an industrial matte pellet are shown. Between 850 °C and 1050 °C the size of the pellet increases by >20 volume %. The residual matte was analyzed with SEM (BSE image in Figure 3). Sulfide and oxide phases were observed on the residual matte. FeCr₂O₄, were among the oxides detected in the matte residue. Based on the composition of the residual matte these authors concluded that the expansion of matte was due to the effect of oxides on matte properties.

However, the mechanism responsible for matte expansion was not determined.

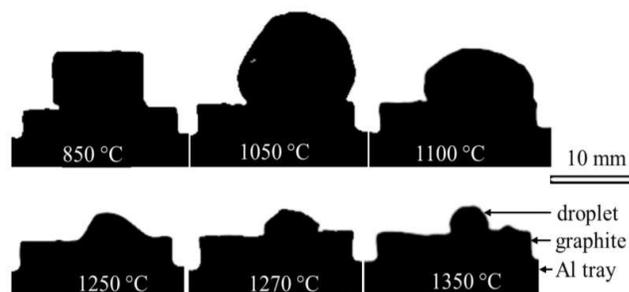


Fig 2: Stages of matte melting with increase in volume during melting stage between 850 °C and 1050 °C

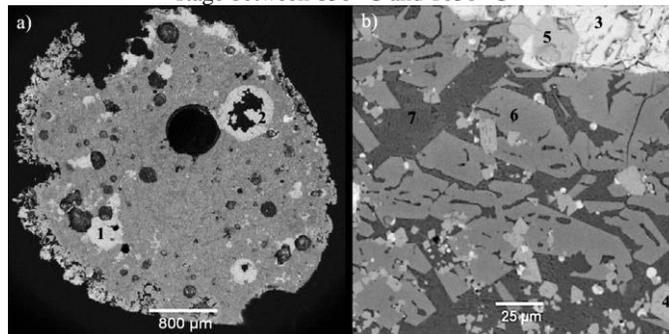


Fig 3: BSE image of matte residue with annotation for identified phases: phases 1, 2 and 3, are sulfides of Fe, Cu and Ni; phase 4 and 5 are the oxides of Fe, Cr and Fe; phases 6 and 7 are the silicates of Al, Ca, Fe, Mg and Mn.

E. Discussion

Worth noting is the composition of the industrial matte reported by mentioned authors; either than the typical sulfides the matte they received had significant amounts of SiO₂, FeCr₂O₄ and silicates. These are detrimental for conversion as described seen in Figure 2 since oxides has significant effects on properties of sulfides.

There were no mechanisms of interaction discussed for the observed new phases. It is evident that at elevated temperatures there chemical interactions between matte and refractory brick oxide

As mentioned that the matte-refractory reactions are complex, it is essential to simplify the interactions by dealing with individual components separately.

III. CONCLUSION

The matte-refractory interaction can be seen when the temperature is above 1750 °C where new phases of different elemental composition evolve. The outcomes that were predicted by FactSage calculations were varying from the practical aspect.

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