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Calcined Magnesite Utilization for Secondary Metallurgy Operations via Metallurgical Aspect

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Steelmaking is a prior industry to shape all production sector in the world. In steelmaking process, slag composition plays a major role in steel quality. Due to high amount of material usage, there should be a balance between basic oxides and refractory oxides in the slag composition. At the end blow of converter, when liquid metal is transferred to ladle, which is called tapping, some alloying elements and slag-forming materials are added. In terms of slag saturation for basic oxides, some calcined magnesite material should be used for an ideal metallurgical slag composition. At tapping operations, Aluminium is used as a deoxidizer to eliminate dissolved oxygen in molten steel pool and some alloying elements are added before the secondary metallurgy processes. On the other hand, in order to protect the MgO-based ladle refractories, calcined magnesite is added and lime is introduced to achieve a certain slag saturation. In this case, total amount of calcined magnesite usage is crucial point for both refractory material and optimum slag composition. In this study, adjusting the calcined magnesite material at tapping process has been investigated in both thermodynamic and practical aspect.

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1. Introduction

Initially, end of the blowing at Basic Oxygen Furnace (BOF) there are some additions such as lime, calcined magnesite and other slag maker components. Principally, these basic oxides are protecting the converter lining and providing to make converter life longer. Also in secondary metallurgy process, life of the refractory material is crucial for sustainable production. While adding ferroalloys at tapping, some slag modifier elements are taking into account for steel's slag saturation [1]. Slag plays an important role in steelmaking and its thermodynamic effect to elemental balance promotes the steel quality and steel cleanliness directly. The final situation of each ladle after the operation has being checked and inspected by production engineers. Because of the endless production management, the refractory equipment handling and maintenance are the key parameters for sustainable production in Ladle Furnace (LF) process. In this scientific work calcined magnesite (MgO) usage has been renovated and investigated during the tap time.

Molten slags are created with compex silicate, aluminate, some ions and metal oxides such as FeO, CaO and MgO. With the addition of metal oxides to the molten slag structure, a number of fractures and rearrangements occur in the bonds of the silicate-based slag structure. To balance the basic oxides and acidic oxides in the slag, some thermodynamic equations should be considered.

2. Experimental

In plant studies, different ratios of MgO additions were examined. The heat size of the trials were 200 tons per ladle. During tapping, some carry-over slag was transferred due to process design. Carry-over slag, which comes from BOF, remains high amount of iron-oxide. The formation of FeO brings about some

problems such as low sulphur removal capacity, high-oxidized iron content and formation of non-metallic inclusions in secondary metallurgy process [2]. The tapping additions are compared in Table 1.

Table 1. Comparison of Tapping Additions

Tapping Additions (kg)	General	Trial
Ferro Manganese	900	900
Calcium Fluorite	100	100
Lime	1100	1100
Aluminium	300	300
Calcined Magnesite	250	150

In plant trials, calcined magnesite are added in tapping by correlating carbon rate in liquid steel. The amount of MgO in slag, is directly relevant with basicity. Therefore, the content of MgO provides to minimize refractory erosion. Oxygen and carbon reactions occur by the following equations that are given below.

$$C + ½\ O_2 = CO \quad (2.1)$$

$$C + (FeO) = CO + Fe \quad (2.2)$$

While the reactions are occurring, bubbles of CO are expanding and covering the slag. On the other hand, saturation of CaO and MgO create some solid components, which behave as bubble nucleation areas, producing a wider numbers of tiny bubbles in the ladle.

In plant studies, the calcined magnesite addition correlated with all ferroalloy and flux additives. Due to this assumption at LF process, the material balance table has been occurred in Table 2. Also all the trials have been implemented at flat rolled steel qualities which killed with Aluminium.

Table 2. Calcined magnesite addition at tapping operation

Total Material Addition	All Types of Ferromanganese, Ferrosilicon, Ferro Silicomanganese	Calcined Magnesite (kg)
Material (kg/heat)	> 3000	50
	1500-3000	100
	< 1500	150

3. Results

The slag saturation for MgO demand has been calculated with mathematical model. In Table 2, it is shown that CaO demand is less than regular practice.

Table 3. Mathematical model of slag optimization

Input Composition			Input Data		Slag Optimization Model		
MgO	%	1,5	Temperature (°C)	1600	MgO	%	7,87
CaO	%	48	Metal weight (ton)	202	CaO	%	56,69
FeO	%	1	Slag weight (kg)	1700	Al_2O_3	%	22,86
Al_2O_3	%	20	Initial sulfur (%wt)	0,01	SiO2	%	9,14
SiO_2	%	8	Oxygen content (ppm)	20	***Program Option***	***Dual Saturation***	
MnO	%	2	Oxygen activity	0,001	***CaO demand***	***kg***	***33,9***
					MgO demand	***kg***	***113,8***

In order to evaluate results, FactSage 7.2 thermodynamic software was used. FToxid, FactPS and FSstel databases have been applied to calculate thermodynamic impact on steelmaking slags. In Figure 1, the alteration of MgO compound in the slag has shown. It is clearly seen that, after 50-100 kg addition of calcined magnesite, ratio of MgO content does not change dramatically.

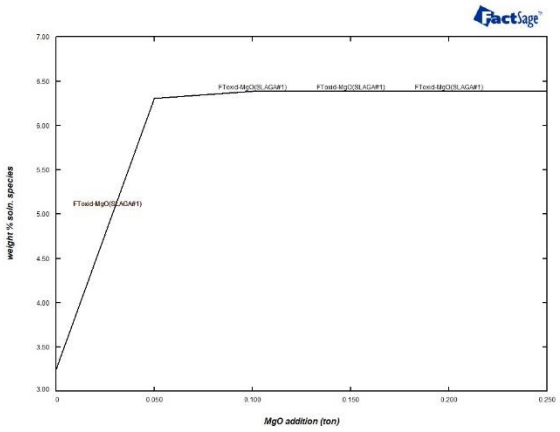

Figure 1: *Change of MgO content in steel slag*

Due to determine a slag composition, input materials are considered as Table 3 below. The slag temperature is determined 1600°C. Total metal weight was assigned 202 tons of liquid steel. End-blow oxygen content measured as 700 ppm.

Table 3. Input materials at taping for Aluminium-killed steel grade

Material	kg
Middle carbon FeMn	250
Calcium-aluminate slag maker	100
Lime	1150
Aluminium	425
Carry-over slag	1500

To clarify MgO saturation in slag, the correlation between CaO and MgO has been studied. In Figure 2, it is shown that while CaO decreases, MgO compound increases in the total amount of LF slag because of the total saturation.

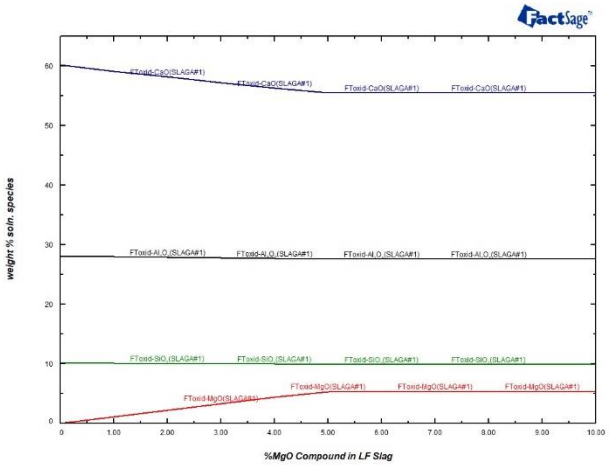

Figure 2: *A slag model related with MgO content in LF slag, which occurred in FactSage software*

In Figure 3, it is clarified that relation with exaggerated FeO content plays a significant role at MgO content. On the other hand, this graphic provides us to understand the connection between Al_2O_3 acidic oxide. In other literature studies some metallurgical relevance between FeO content and MgO dual saturation [3].

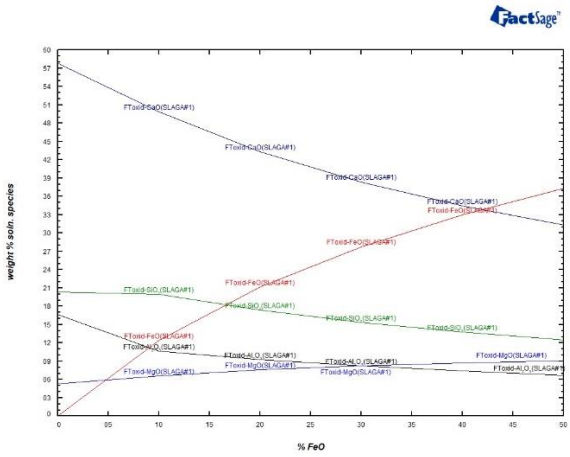

Figure 3: *Exaggerated FeO content affects the whole content in slag in terms of thermodynamic balance between basic and acidic oxides*

Conclusion

In this scientific research, mathematical and thermodynamic studies were carried out on slag saturation. It is theoretically studied which levels of MgO should be in the ideally metallurgical slag. In addition, the consumption coefficient of calcined magnesite in Isdemir plant was determined per heat and it was examined whether the same double saturation region could be captured with less material usage. The consumption rates of calcined magnesite, which are given in the same amounts to each grade as standard in aluminum killed steel grades, have been revised according to the material rate given in the ladle furnace. According to this, it is reported that 50 kg calcined magnesite will be effective for given over 3000 kg materials in ladle furnace. For steel grades where less material is used in the ladle furnace, this ratio is reduced to 150 kg. Thus, total savings are achieved in approximately 60% rate per heat.

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