TECHNICAL SOLUTIONS TO IMPROVE THE SERVICE LIFE OF THE DOLOMITE LADLE LININGS[1]

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Abstract
It is common knowledge that the refractory lining, set with dolomite bricks, represents nowadays one of the most widespread lining for the steelplant ladles. The reason of this success is mainly due to: its chemical and physical properties that make it highly compatible with the metallurgical practice that uses basic slags; cheapness of use. Often, the dolomite brick characteristics themselves are not enough to highlight all their potential in terms of performance, so, the cooperation and the exchanges of ideas, as well as the experience between user and the refractory supplier becomes very important. Obviously the ladle refractory lining principally depends on the slag as well as on the kind of metallurgical treatment it is subjected, therefore it would make more sense to understand the refractory life as a steel and slag contact time, but practically it is still easier to evaluate the refractory ladle life in terms of number of heats done. Most of the ladle dolomite refractory users know the operating parameters to be adopted in order to get the best yield of their refractory linings, but sometimes, despite the quality and the size of the refractory bricks, it is not easy to reach the aimed campaigns. The present works would like to focus on some practical aspects aiming to improve the dolomite refractory ladle lining life: slag maintenance, ladle operation and newly developed pitch binder system.
Key words: CaO saturated slag; Fast ladle cycle; Low emission binder.

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1 SLAG MAINTENANCE

1.1 Component of the Ladle Slag

The composition of the ladle slag represents the main aspect to understand the chemical attack on the refractory lining (Figure 1).

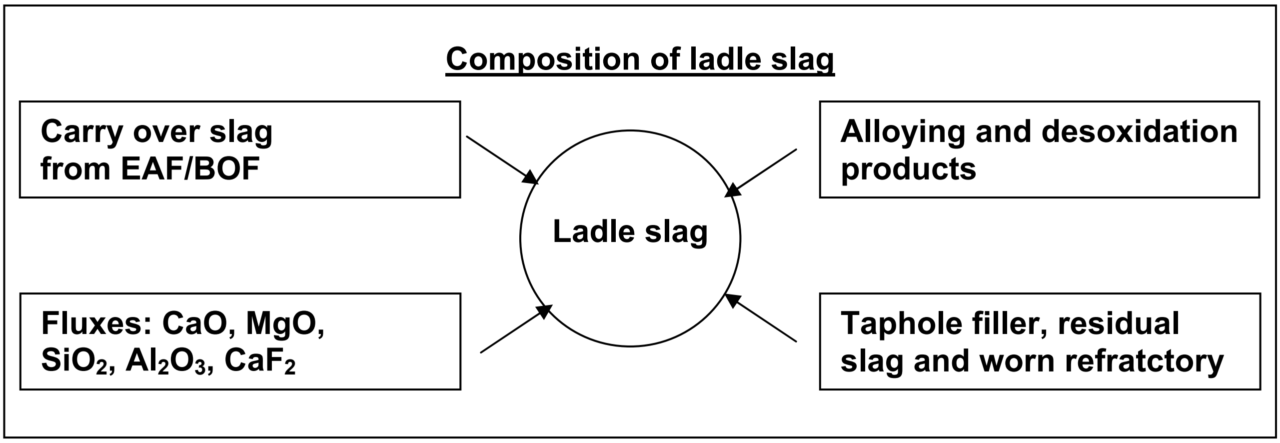

Figure 1. Composition of ladle slag.

Comparision between EAF/BOF slag and Ladle slag

EAF/BOF slag
- System FeO_n, CaO, SiO_2
- CaO/SiO_2 = 3-5
- High FeO content, black colour

Ladle Slag
- System CaO, SiO_2, Al_2O_3
- CaO/SiO_2 depends on the desoxidation (Al or Si killed steel grade)
- $CaO + SiO_2 + Al_2O_3 \geq 85\%$
- Low FeO content, pale colour

1.2 Slag Optimization

Being the dolomite a refractory material made of 60% CaO and 40% MgO, it is essential that the ladle slag can include the same oxide elements in order to balance the other existing elements which could be aggressive against the ladle refractory lining.
It is therefore necessary to saturate the ladle slag on CaO, which means the slag has to contain the maximum amount of CaO chemically combined with the main oxides (SiO_2, Al_2O_3, Fe_2O_3, etc) without any free CaO (Figure 2). An unsatured slag chemically reacts with the basic refractory to satisfy its needs of CaO, while a CaO saturated slag, besides not reacting with the refractory lining, also has the maximum ability to desulphurise the steel and to trap the non metallic inclusions. To better identify the nature of a ladle slag it is recommendable to refer to its saturation index of CaO, instead of only binary basicity index CaO/SiO_2 (Figure 3).

1.3 Properties of a CaO Saturated Slag

- contains the largest CaO amount, without free CaO
- the CaO is completely combined with Al_2O_3 and SiO_2
- the CaO saturation index can substitute the CaO/SiO_2 ratio for the evaluation of the ladle slag
- has the highest desulphurisation potential
- is not aggressive against basic refractories
- remains liquid enough without reducing the ladle volume

Good CaO saturated slags			
– Si killed steel grades –		– Al killed steel grades –	
FeO_n	1%	FeO_n	1%
CaO	59%	CaO	59%
SiO_2	27%	SiO_2	9%
MgO	7%	MgO	6%
MnO	1%	MnO	1%
Al_2O_3	5%	Al_2O_3	24%
CaF_2 addition	< 8%	CaF_2 addition	0%

Figure 2. Good CaO saturated slags.

High SiO_2 containing slags

They are typical of the Si killed steel grades, if FeO_n is very low its fluidity is low too, therefore an addition of a small amount of bauxite, or sometimes a small amount of fluorspar as well can be recommended. They are less aggressive against the Dolomite refractory bricks than the Magnesite refractory ones.

High Al_2O_3 containing slags

They are typical of the Al killed steel grades. Their melting point is low, so they can get a high fluidity at the liquid steel temperature and can infiltrate easily into the refractory lining. The CaO saturation is fundamental to avoid the wear of the Dolomite refractory bricks, at the same time a good saturation index corresponds to the maximum desulphurisation ability of the slag (Figure 4).

The Dolomite refractory bricks contain a 40% of MgO. Both kind of slags can dissolve an amount of MgO $\geq$ 4% ca; an addition of a suitable quantity of MgO is therefore recommended, in order to avoid that the MgO saturation affects the dolomite refractory bricks.

Figure 5 shows a situation where dolomitic lime is not used at all, the MgO found in the slag has been therefore considered as coming from the wear of dolomite lining and has been used as index for the refractory wear.

It is clear that the wear is decreasing by increasing the CaO content in the slag.

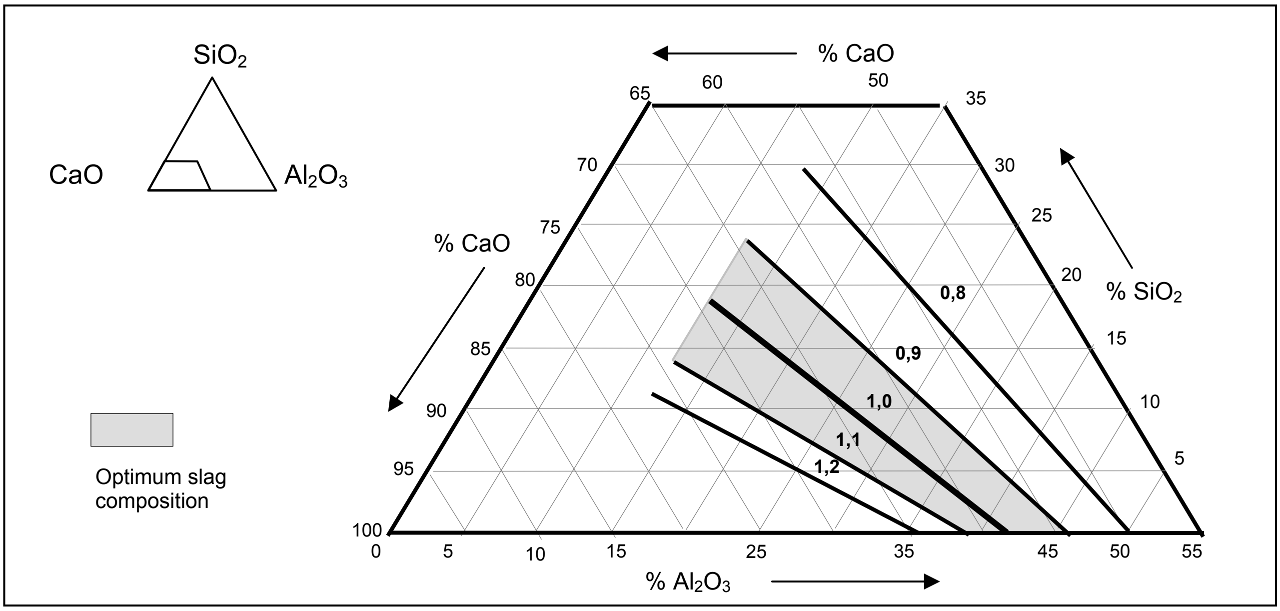

Figure 3. CaO-saturation in the system CaO-SiO_2-Al_2O_3.

An optimum saturation index of 0,9-1,1 means getting a slag with the highest desulphurisation capacity and, at the same time, also having a slag composition which is less aggressive against the Dolomite refractory lining.

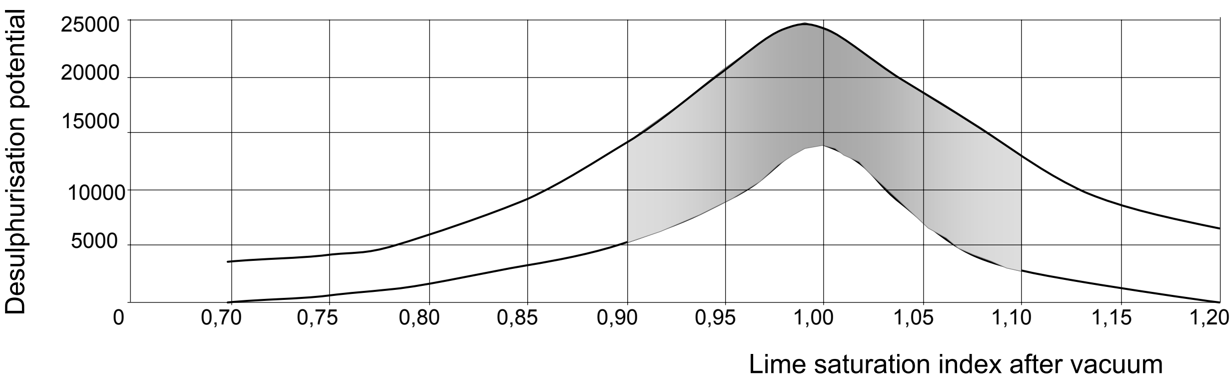

Figure 4. Desulphurisation potential in function of the lime saturation index after vacuum.

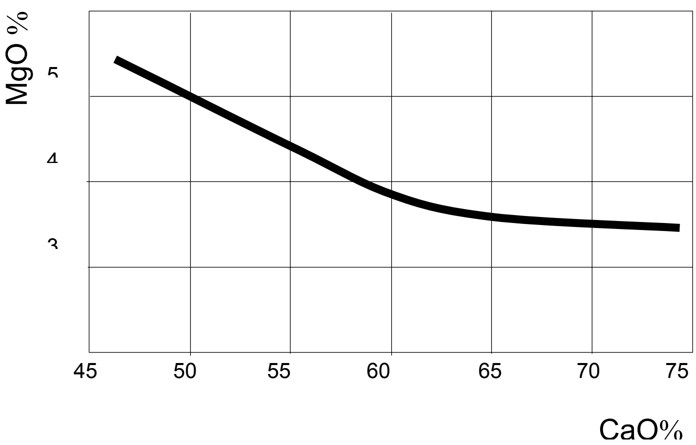

Figure 5. MgO pick-up by slag at various CaO concentration

1.4 Relationship Between Purging and Fluorspar Addition

An interesting aspect concerning the desulphurisation efficiency, linked to service life of a refractory ladle lining, is shown in Figure 6 where it is pointed out that a good desulphurising potential can be obtained either with an addition of fluorspar to the ladle slag or increasing the N_2/Ar gas flow rate blown into the liquid steel through the purging set, without any help of fluorspar. Experience says the result achieved with the second solution is better, as it can also lead to an increased ladle lining service life of about 20%

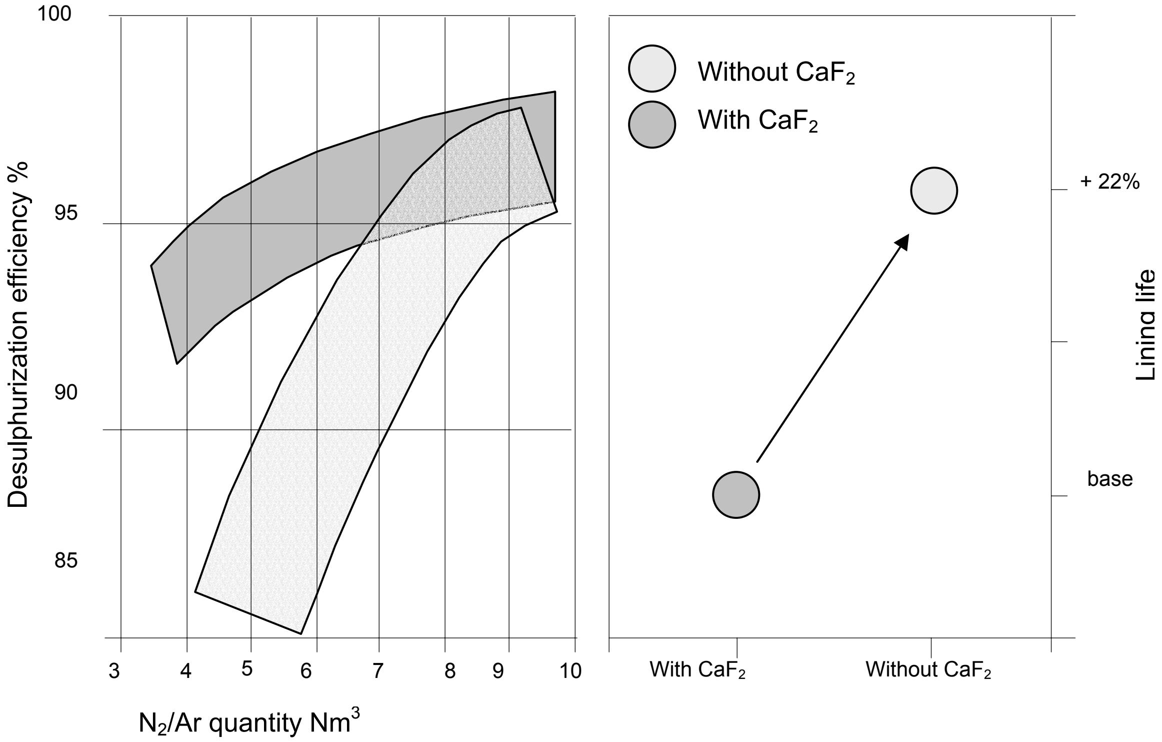

Figure 6. Change of lining life due to N_2/Ar purging quantity with or without CaF_2

2 LADLE OPERATION

- Circulation time,
- Cooling down
- Temperature loss
- Heating device

It is well known that the thermal cycle is important for any kind of ladle refractory lining. The Dolomite ladle lining follows the same rule. Keeping the ladle always at high temperature becomes essential to the ladle lining service life. It means that after a proper preheating, a ladle lined with Dolomite refractory has to cycle as fast as possible, minimizing the dwell of empty time. A long empty time between the heats can lead to a thermal shock on the surface of the bricks. By doubling the daily heats of a ladle it is possible to increase its refractory lining of 10-25% in the barrel and about 100% in the slag line.

Ladle circulation and Performance	
• 10 ladles in hot circulation	• 4- ladles in hot circulation
• 20 heats/day	• 20 heats/day
• 2 heats/day each ladle	• 4-5 heats/day each ladle
Results:	Results:
⇒ MgO.C slag line 25 heats	⇒ MgO.C slag line 50 heats
⇒ Total performance 40-45 heats	⇒ Total performance 50 heats

Too long empty times also mean loss of temperature of refractory lining, practically, energy that has to be recovered by heating the ladle lining again under burner or through a higher temperature of the liquid steel (Figure 7). Both situations can increase the wear of the ladle lining, in the first case by oxidizing the C bond and in the second case by getting a more aggressive slag because of its higher temperature. It is interesting to consider the loss of temperature of a ladle lining with or without lid in function of the empty time (Figure 8) and also how the ladle lining life can increase by installing a burner by the EAF ladle trolley (Figure 9).

Figure 7. Temperature loss in steel depending on different ladle empty times.

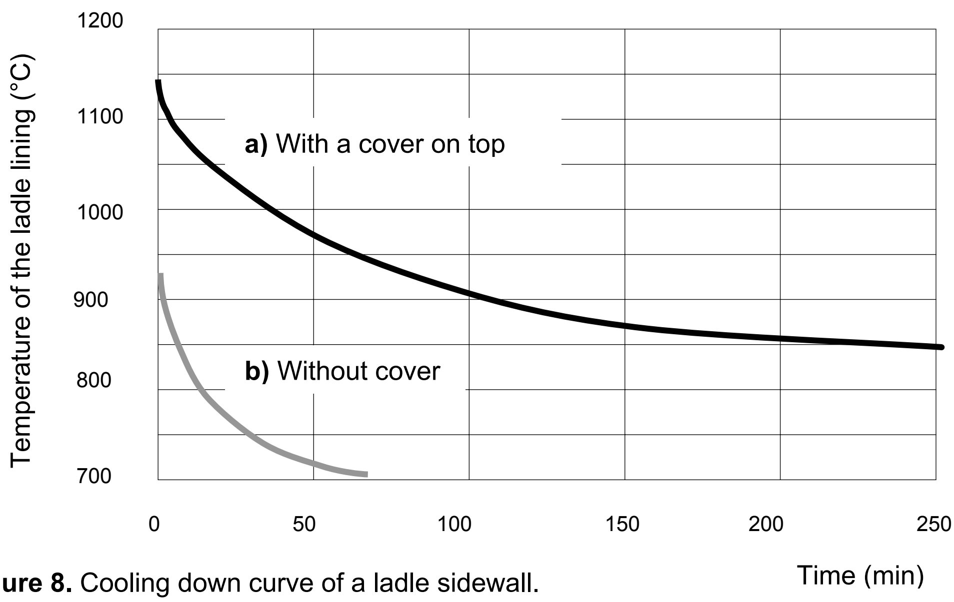

Figure 8. Cooling down curve of a ladle sidewall.

Figure 9. Development of the refractory performance of a Dolomite ladle lining in an EAF Steelplant

3 NEW GENERATION OF CARBON-BONDED DOLOMITE BRICKS

Besides the suggestion on the slag composition as well as the operating cycle, another help to improve the ladle refractory campaign comes directly from the quality of the bricks. Together with an excellent dolomite raw material it is important to produce bricks with the necessary physical and chemical properties, able to line the different zones of the ladle.
Due to their high carbon residue, pitch and phenolich resins are the most suitable binders for dolomite and magnesia bricks. In Europe, pitch-bonded dolomite and magnesia carbon bricks are the most common brick types, as they have proved to be less sensitive to the demanding conditions in European ladles when compared to resin-bonded bricks.
Based on a new developed binder system tested for refractory application, a new generation of carbon-bonded “Low emission” dolomite and magnesia carbon products with an extremely low toxic potential have been developed. Furthermore, the binder system is characterized by a very high carbon yield after carbonization that results in en extremely strong carbon bonding. Further significant advantages of this system are the high oxidation resistance of the highly-ordered structure and the excellent stress-absorbing structure.

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