ANNALS OF FACULTY ENGINEERING HUNEDOARA
- INTERNATIONAL JOURNAL OF ENGINEERING
Tome IX (Year 2011). Fascicule 2. (ISSN 1584 - 2665)

[1]Maria NICOLAE, [2]Irina VÎLCIU, [3]Emanuela-Daniela STOICA

RESEARCH ON THE MECHANISM OF DAMAGE LINE BRICKS IN THE SLAG LF

[1,3] POLITEHNICA UNIVERSITY BUCHAREST, ROMANIA
[2] ECOLOGICAL UNIVERSITY OF BUCHAREST, ROMANIA

ABSTRACT: This paper proposed to analyze, based on fundamental known, the slag influence generated on LF process on the ladle refractory. In this purpose were studied the refractory destruction mechanisms used on LF, the slag quality, quality refractory and the slag influence on refractory especially because of the interactions between them, definitely elements for steel quality and also for the refractory endurance.
KEYWORDS: refractory, interaction slag-refractory

❖ INTRODUCTION

The main wear mechanisms of the refractory ladle slag line are chemical corrosion and mechanical erosion due to stirring of the steel bath.Chemical potential difference between the refractory and the slag under high temperature conditions is driving force for chemical wear mechanism.Destruction process depends on many variables: temperature, refractory composition, slag thickness, slag composition and stirring degree.

The objective of this paper is to analysis of the interaction between LF bricks steel ladle in contact with slag. In this purpose were determined the slag characteristics on the hot face brick, the slag and the refractory interaction carried out by optical and electronic microscopy (SEM) and X-ray diffraction.

❖ THE STUDY

The study was carried out on scrapped brick from LF installation from Calarasi, the brick is part of the steel ladle refractory lining slag level. Determined proprieties for the studied brick are in the following table 1.

The slag deposited thickness on the refractory brick varies between 3-6 mm (fig.1).

Tabel 1. Properties of bricks used at slag level

Apparent density (g/cm^3)	2,95
Apparent porosity (%)	4,8
Apparent density after heating at 1150 ^{0}C	2,87
Apparent porosity after heating at 1150 ^{0}C	11,2
Mechanical strength (MPa)	30

The bricks appearance is shown in Figure 1 and in figure 2 is presented the bricks appearance after removal of an important part of slag layer deposited.

Fig.1. Deposited slag on brick after its used in LF

Fig.2.Interface between slag layer and brick

Tabel.2. LF slag chemical composition deposited on hot face brick

CaO	MgO	Al_2O_3	SiO_2	SO_3	Fe_2O_3	CoO	TiO_2	MnO	Cr_2O_3	P_2O_5
30,14	29,54	10,43	2,95	1,31	0,16	0,33	0,12	0,08	0,05	0,05
Ca	Mg	Al	Si	S	Fe	Co	Ti	Mn	Cr	
25,64	15,45	5,14	1,36	0,59	1,06	0,34	0,01	0,08	0,05	

Tabelul 3.LF slag chemical composition

CaO	Al_2O_3	SiO_2	MgO	FeO	MnO	Cr_2O_3	P_2O_5	TiO_2	S	K_2O	Na_2O
56,47	30,92	6,47	3,73	0,62	0,11	0	0,02	0,34	1,2	0,02	0,07
57,03	32,03	4,92	3,83	0,52	0,08	0	0,01	0,26	1,2	0,02	0,06
58,28	31,13	4,44	4,08	0,39	0,06	0	0,02	0,38	1,2	0,01	0,06

The removed slag was analyzed chemical and structural The results are in table 3. Slag layer shows pores and two different layers (Fig. 3). These layers contain phases and micro structural aspects of different chemical compositions.

- First layer has 2.2 mm thickness and it is composed from dendrites crystals of magnesium oxide, iron oxide, iron and calcium aluminates and calcium crystals silico-aluminates. All these are immersed in a matrix of calcium aluminates.
- The second layer has 3 mm thickness and it is is composed of magnesium crystals damaged by iron and manganese alumino-silicates crystals with different contents of calcium, iron and titanium, calcium aluminates - magnesium - iron and calcium silicate crystals.

Fig.3. Two of slag layers

INTERACTION SLAG AND BRICK GRAIN

At the interface between slag and brick MgO grains were found torn from brick and immersed in slag. Distribution of elements in this area is shown in Figure 4. Corrosion can be observed due to the interaction between the iron grains oxide and magnesium oxide. Slag penetrates the silicate sinters grains network and melt intragranular silicates. This interaction speeds the lower temperature phase formed and facilitates separation from crystal.

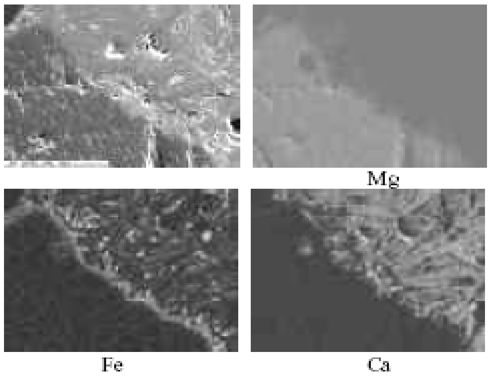

Fig.4. Indirectly Corrosion of MgO grains

Slag- brick martix

Micro structural analysis reveals the decarburization process of the brick matrix in contact with slag (Fig. 5).Interface slag-brick is shown in Figure 6. In the brick matrix there are formed spinal crystals. Also, crystals were identified calcium silicate in the brick matrix.

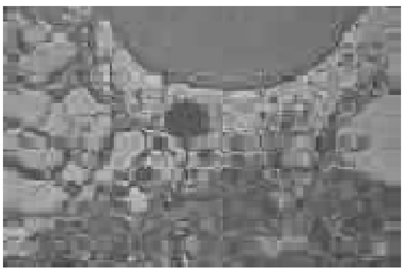

Fig. 5. Decarburization slag matrix and interface

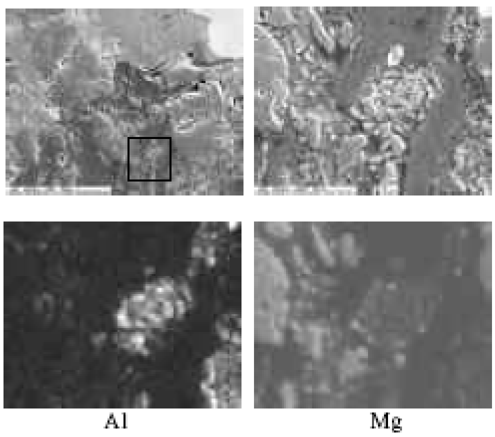

Fig. 6. Distribution of elements in hot brick surface

ANALISES, DISCUTIONS, APPROCHES AND INTERPRETATIONS

The first slag layer is composed on calcium aluminates matrix with melting temperature at 1400^0C and different crystals:

- calcium alumina and iron alumina, with softening temperature at 1336^{0}C (equilibrium phase diagram for the system Al_2O_3 - CaO - FeO);
- Calcium and aluminum silicates with softening temperature of 1380 0C (equilibrium phase diagram for the system Al_2O_3 - CaO - SiO_2 Fig. 7);
- MgO dendrites.

The chemical composition of the first slag layer is shown in Figure 6. This chart show that the slag is completely liquid at 1600^{0}C, and therefore, it is not saturated endanger. First layer of liquid slag is not saturated with MgO and at 1600 0C.

The second layer is composed from adhered slag stickled to the brick, this layer contains a higher level than the first layer of iron oxide slag. He probably comes mainly from the pot slag before the LF treatment. Also, the second slag layer has a lower content of calcium oxide than the first layer of slag. The second layer of slag is composed of calcium aluminates matrix and different types of crystals:

- calcium, titanium, and iron silicates and aluminum with different contents of these elements with melting point at 1400-1500^{0}C;
- calcium silicates and aluminum with melting temperature at 1450^{0}C (fig. 7 diagram of phase equilibrium in the system Al_2O_3 - CaO - SiO_2);
- different contents alumina of calcium, magnesium and iron;
- MgO crystals attacked with iron oxide first and then the manganese oxide and calcium oxide.

This mechanism is the result of iron elements, manganese and calcium existing in the slag that runs the fastest in the refractory material to form the corresponding reaction products.

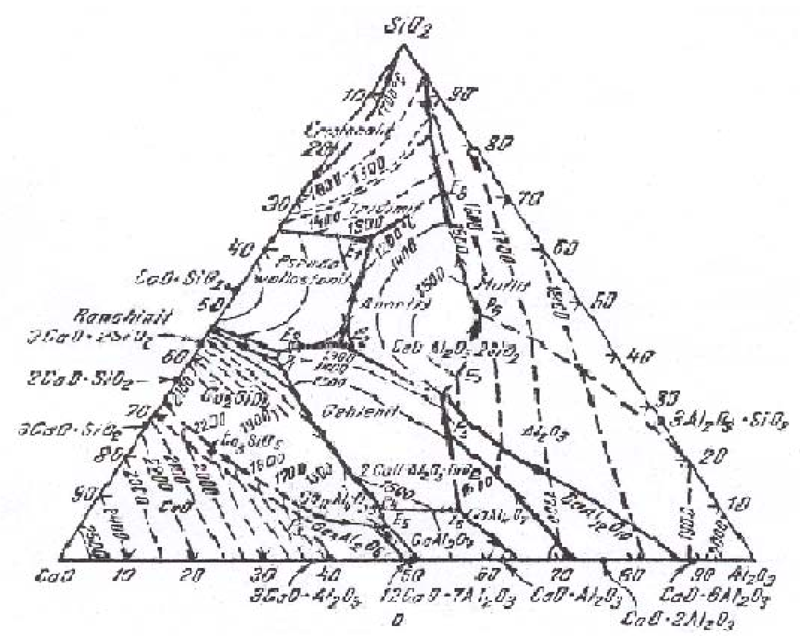

Fig. 7. Phase equilibrium diagram of the system Al_2O_3–CaO-SiO_2

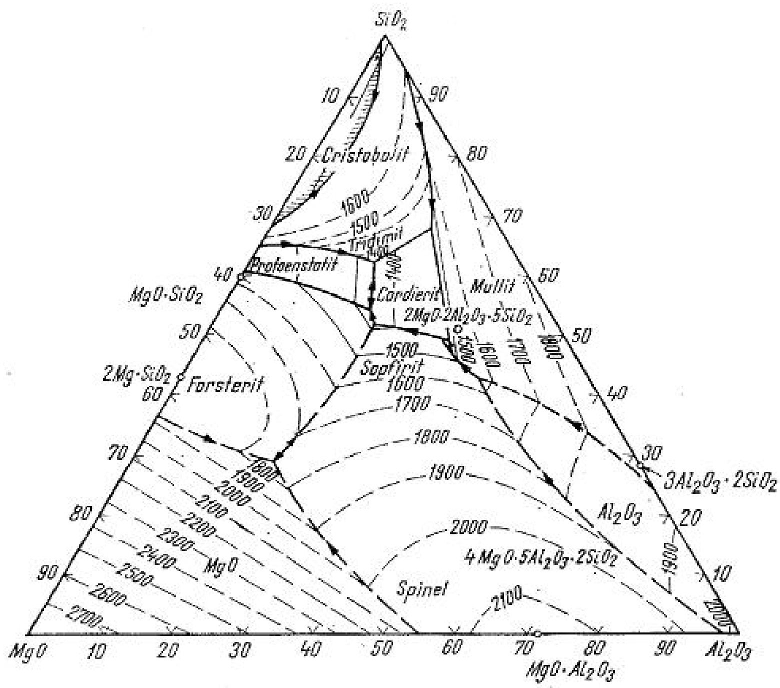

Fig. 8. Phase equilibrium diagram of the system MgO-SiO_2 - Al_2O_3

The chemical composition of the second layer is shown in Figure 8. This slag is saturated with magnesium oxide at 1600 ^{0}C.

CONCLUSION

The study of brick out off used was carried out through optical and electronic microscopy (SEM) and EDS analysis, allowed identification of slag- brick adherence characteristics, refractory wear mechanism and the mircostructural changes inside the brick.

The slag on the brick hot face is composed of two different layers.. Aceste straturi conțin aspecte microstructurale distincte şi faze cu compoziții chimice diferite. Both layers are aggresive to the refractory material lining.

- The first slag layer is not saturated with magnesium oxide and it is completely liquid at the process temperature. It is well known that this conditions are the main cause of corrosions and bricklayer destructions;
- The second slag layer is saturated with MgO but contains a high level of iron content. This oxide in growth the slag fluidity-broke the silicate network from the brick and allow the matrix decarburization, thus :

$$FeO + C = Fe + CO$$

Graphite oxidation growths bricks porosity, allowing slag penetration in the system, fallowing periclase grains dispersion in slag. Review mechanisms identified are: graphite oxidation, slag penetration into matrix and around MgO grains and finally MgO grains dissolution into slag. More over, iron spread in MgO grain and allows MgO slag molder. This new phase decrease the MgO grains refractory and also delay speed destroy of refractory material. This mechanism leads indirect MgO grain dissolution.

REFERENCES

[1.] A. Nicolae s.a. - Materiale ceramice refractare pentru instalaţii termotehnologice, Ed. Fair Parteners, Bucureşti, 1999.
[2.] P. Bartha et.al. – Heavy ceramic shaped materials, process for the production thereof and the thereof, United States Patent , nr. 4,775,648 oct.4.1988.
[3.] G. Yuasa, et.al. - Refining Practice and Application of the Ladle Furnace (LF) Process în Japan, Transactions of the Iron and Steel Institute of Japan, vol, 24, no.5(1984), pp 412-418.
[4.] P.G. Jonsson, L. Jonsson, D. Siched – Viscozities of LF slag and their impact on ladle refining, ISIJ International, 1997, vol.37, no.5, pp 484-491.
[5.] Z. Adolf, i. Husar, P. Suchanekz - Investigation of the influence of the melt slag regime in a ladle furnace on the cleeanliness of the steel, Materiali in tehnologije / Materials and technology 41 (2007) 4, 185–188
[6.] L.Mihok, K. Seilerova, M. Frohlichova - Influence of Steel Cleanliness by Ladle Furnace Processes, Materials Science, vol. 11, no. 4. 2005,pp 320-323.
[7.] P..S. Fredriksson - Thermodynamic studies of FeO-containing slags and their impact on ladle refining process. VII International Conference on Molten Slags Fluxes and Salts, The South African Institute of Mining and Metallurgy, 2004, pp 285-292.
[8.] K.C. Mills, E.D. Hondros, L.Yushu - Interfacial phenomena in high temperature processes, Journal of materials Science 40, 2005, pp 2403-2409.
[9.] Silvia Camelli, Marcelo Labadie-Analysis of the wear mechanism of MgO-C slag line bricks for seel ladles,49. Internationales Feuerfest-Kolloquium 2006, pp 30-34.

ANNALS OF FACULTY ENGINEERING HUNEDOARA
– INTERNATIONAL JOURNAL OF ENGINEERING