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SOME ASPECTS ABOUT THE REFRACTORY LINING WEAR IN FURNACES

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ABSTRACT

For melting cast iron, carbon steel, copper and copper alloys the quartzite is still one of the most used lining material and the most cost effective as well. The silica lining has to be replaced frequently due to the wear. In this paper there are present some aspects about the refractory lining wear in furnaces.

KEYWORDS: silica, quartzite, lining wear, furnace

1. General aspects

As is known to those skilled in the art, the handling of high temperature liquids, such as molten steel, requires special materials and techniques. The melting temperature of steel approaches 1600 °C, a level above that which most containment materials can withstand. Moreover, molten steel usually includes slag that can be fluid and corrosive which adds to the complexity and difficulty of efficient handling.

Ladles for handling such high temperature liquids typically have been constructed of steel outer shells lined with refractory brick that can withstand the extremely harsh conditions to which they are exposed. However, such brick wear and from time to time must be repaired or replaced. In addition, when high temperature liquids are poured into such ladles the impact forces (as, for example by a tap stream of molten steel) tend to markedly increase erosion in the lower sidewall and bottom regions of the ladle.

The silica lining normally used has to take the full burden of the chemical and mechanical wear that is imposed upon it during the melting. Chemical reactions will occur during the melting. The slag formed has several sources and the predominant source differs from furnace to furnace as will the slag composition.

The normal wear of a silica lining is the reaction of carbon with the silica $2C + SiO_2 \rightarrow Si + 2CO$. An increased reaction will take place when the carbon content goes up and silicon goes down. Increased temperature will speed up not only this reaction, but all chemical reactions between slag, oxides and lining material.

Typical refractory material life for the furnaces (i. e. total replacement as opposed to weekly repair of the pouring lip) lies between 320 and 490 runs [1]. The material could exceed 500 runs without problems as long as the pouring temperature does not exceed 1520 ^{o}C.

The so called "normal" slag has a very wide chemical composition as it is a result of several sources. This may come from [2]:

- scrap with rust which gives FeO;
- scrap with impurities such as sand and soil from scrap yard which gives SiO_2, Al_2O_3 etc.:
- slag binder not deslagged properly out of the furnace SiO_2, Al_2O_3, CaO, MgO, K_2O, Na_2O;
- alloying elements that are oxidized (MnO is the most severe);
- returns with adhering mould sand (sand, bentonite, sodium silicate etc.), SiO_2, Al_2O_3, Na_2O;
- cupola slag CaO;
- returns of ductile iron, Mg silicates.

The chemical composition of a slag can vary considerably but mostly fall inside the limits shown in table 1 [2].

Table 1. *The chemical composition of a slag*

Component	Variation limits
SiO_2	50 – 80 %
Al_2O_3	5 – 20 %
FeO	0 – 20 %
MnO	0 – 15 %
MgO	0 – 15 %
CaO	0 – 10 %
Alkali	0 – 5 %

The slag reacts with the lining material until it is saturated. If the temperature is increased a saturated slag formed at low temperature can dissolve more lining material. If an aggressive slag or oxide continuously is formed during the melting operation the slag attack will be unlimited.

The liquidus temperature of the slag should be as low as possible to diminish radiation heat losses but must also result in acceptable viscosities. Furthermore, low liqiudus temperatures will cause less refractory lining wear.

The variation of the slag infiltration in the refractory as a function of time and temperature is demonstrated, indicating that with an increase in holding time and temperature, slag infiltration increases substantially with a simultaneous decrease in the remaining refractory wall thickness.

The presence of residual moisture reduces the surface tension of the liquid metal, thereby augmenting its power of penetration into the refractory material. This results in a penetration depth of approximately 60 %, which already occurs during / after sintering. Too much residual moisture in the refractory material leads to significant metal penetration during the first days of operation.

The lining wear is directly influenced by the inside furnace space temperature. It is well-known the fact that the temperature is not evenly distributed on the entire lining thickness. The temperature decreases from the inside to outside of the lining, fact which make as well as the lining wear follow the same value effect.

The lining – melt metal separation surface is practical the most wear yielding zone of the entire lining weight. Being the zone in which both the maximum temperature of the lining and the medium aggressiveness from the furnace inside is at high level, this is practical the most affected zone. Following the wear distribution way on the refractory wall thickness it is apparent that the lining outside weight remains in good state even after a long usage standing.

2. Experimental data

The reaction with the melt metal and the slag is the most common reason for the inside furnace lining wear. The lining wear is promoting in time to the opposite side of the furnace lining getting on after a time to destroy them.

The wear distribution way analysis on the wall thickness was made using a Silica Mix melting crucible from a coreless induction furnace employed to iron melting process approximately 4 months. The furnace inside temperature was 1450 ^{o}C. After the melting crucible replacement, by this was taken samples which were analyzed. The analysis was made at the lining – melt metal surface (fig. 1); at 10 mm inside from this surface (fig. 2); at 30 mm inside from this surface (fig. 3); at a half of refractory wall thickness (fig 4) and at the outside lining surface (fig. 5).

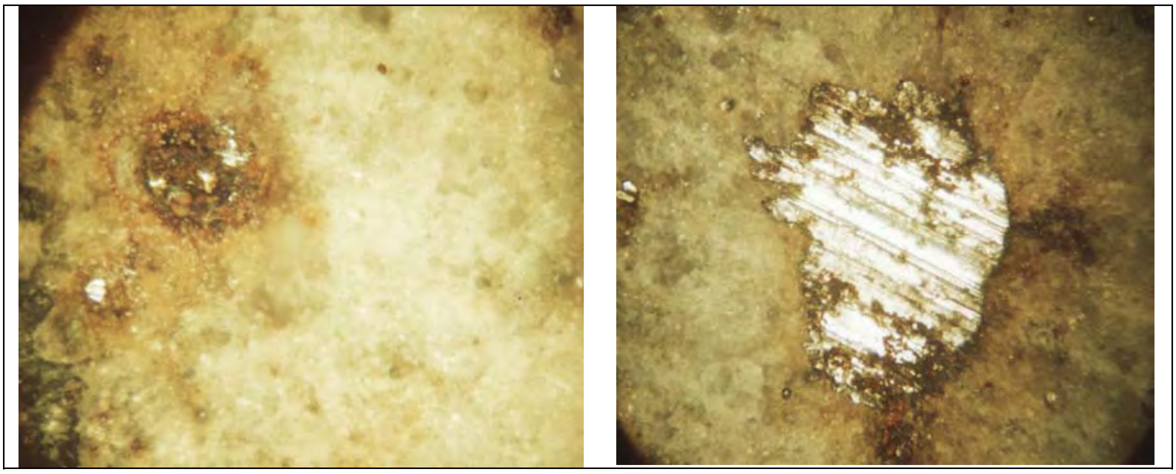

***Fig. 1**. Lining – melt metal interface (t = 1450 ^{o}C; time = approx. 4 months)*

It is to notice the fact that the lining structure is almost destroyed at the internal surface (they are many metallic and slag inclusions) and become more and more uniform and homogeneous toward exterior. The fact that the lining wear is more increased at high temperatures is to understand concerning the pictures in fig. 6 and fig. 7.

There are presented samples from a melting crucible used at iron melting process (fig. 6) and samples from a melting crucible used at aluminum alloy melting process (fig. 7) (though it is to remark that in fig. 6 it is presented a Silica Mix furnace lining, while in fig. 7 it is presented an Orsova quartzite furnace lining).

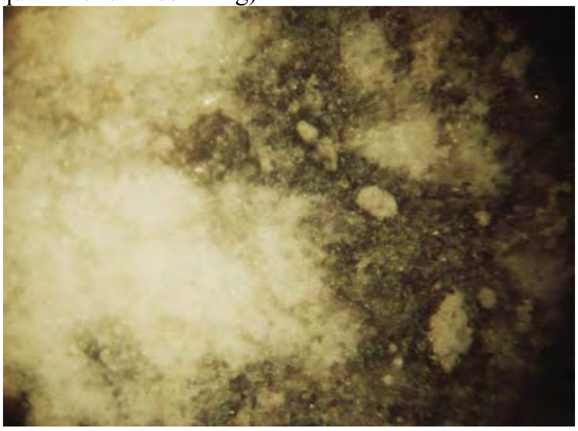

***Fig. 2**. δ = 10 mm from the lining – melt metal interface*
(t < 1450 °C; time = approx. 4 months)

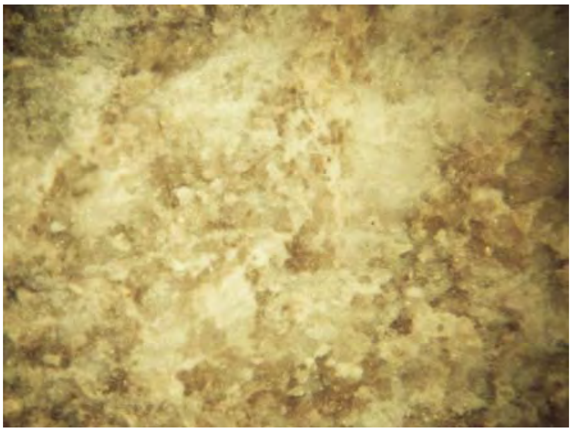

***Fig. 3**. δ = 30 mm from the lining – melt metal interface*
(t < 1200 °C; time = approx. 4 months)

***Fig. 4**. δ = 1 / 2 of refractory wall thickness*
(t ≈ 700 °C; time = approx. 4 months)

The coreless induction furnace is presently the most used type of melting furnaces in the foundry industry. By careful handling of the slag together with a correct choice of lining material the increase of the lining life can be considerable.

***Fig. 5**. The exterior of the refractory wall*
(t ≈ 100 °C; time = approx. 4 months)

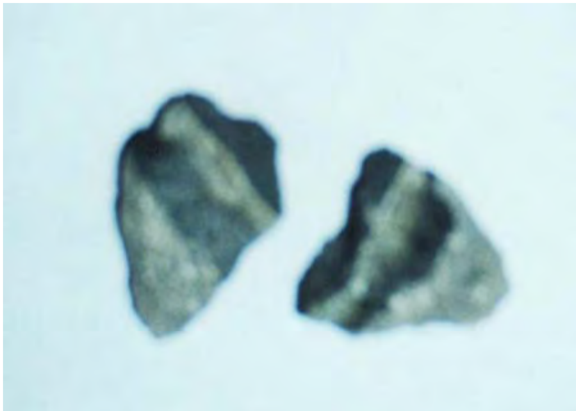

***Fig. 6.** Macrostructure – Silica Mix lining*
Crucible used to iron melting

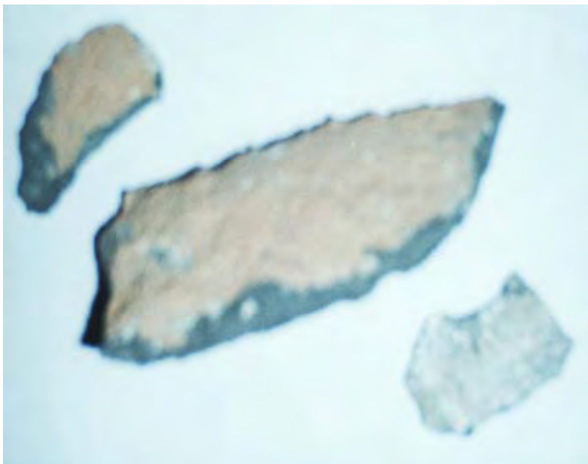

***Fig. 7.** Macrostructure – Orsova quartzite lining*
Crucible used to ATSi5Cu1 melting

3. Conclusions

Contrary to the case of the crucible furnace, in numerous metallurgical units, locally advanced but solidified metal penetration in the refractory material represents no risk. Even if metal fins extend through the refractory towards the vessel wall (steel shell) these are not dangerous as long as, on account of the cooling conditions, they are solidified or have a low temperature. Only when such or other wear phenomena lead to local overheating do these represent a potential hazard [3].

The premature failure of the refractory lining can result in the need for unplanned shutdowns to enable repairs to be made. Due to the need to cool, empty, repair and restart the furnace these "mini-shuts" can last for up to one week, with the resulting loss of production and disruption to normal operations. The unplanned nature of such shuts may result in them not being performed in the most efficient, cost effective or safe manner possible.

References

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[3] Manfred Hopf, *Monitoring of lining wear in crucible and channel induction furnaces*, Casting Plant + Technology International 2 / 2002, p 24 - 31