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Review

Overview of wear phenomena in lead processing furnaces

D. Gregurek [a,*], K. Reinharter [a], C. Majcenovic [a], C. Wenzl [b], A. Spanring [b]

[a] *RHI AG, TC Leoben, Magnesitstrasse 2, Leoben A-8700, Austria*
[b] *RHI AG, Wienerbergstrasse 9, Vienna A-1100, Austria*

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Abstract

The main wear parameters influencing the refractory lining life in vessels used in the Pb/Zn industry (e.g., QSL reactor, KIVCET furnace, Ausmelt/Isasmelter™, Kaldo furnace, short rotary furnace) can be subdivided into chemical, thermal and mechanical stresses. In the present work the main wear parameters, such as corrosion by slag attack, high sulfur, soda and iron oxide supply as well as reduction, non-oxidic infiltration and brick damage by hydration, are briefly introduced and discussed. Additionally, the extraordinarily high SiO_2 supply caused by the uncontrolled addition of silica sand results in a massive forsterite formation and in a volume expansion ("forsterite bursting"). Increased operation temperatures in the furnace support also microstructural brick degeneration. All these mentioned wear phenomena lead to a severe degradation of the brick microstructure and consequently to a decreased lining life. Therefore, a detailed understanding of the wear mechanisms through "post mortem studies" is an important prerequisite for the refractory producer.

Keywords: Refractories; Lead metallurgy; Wear phenomena

Contents

* Corresponding author. Tel.: +43 69918705156.
E-mail address: dean.gregurek@rhi-ag.com (D. Gregurek).

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1. Introduction

The profitable primary or secondary pyrometallurgical operation depends on many factors such as furnace type, process conditions, lining design, selection of refractory types, etc. In the non-ferrous metals industry, particularly in lead smelting furnaces, magnesia-chromite bricks are the preferred refractory choice due to their high corrosion resistance. Nevertheless, the refractory lining is exposed to complex and mutual wear caused by chemical, thermal, and mechanical stresses.[1–4] Therefore the exact understanding of the wear phenomena through post mortem studies is an important prerequisite for the refractory producer, since it provides the basis for both customer recommendations and innovative product development. In addition to post mortem studies, laboratory work and experimental testing carried out in the pilot plant of RHI's Technology Center Leoben enable the best possible understanding of the brick wear on the pilot scale.[5,6] Combining all these facts, the adequate choice of refractory is always essential for a successful furnace campaign.

A general overview of wear phenomena in the non-ferrous industry was discussed and introduced in several papers in the past.[7–13] Particularly in the lead industry a lot of work was done regarding refractory corrosion testing in different pilot-scale and industrial furnaces. For instance, Oprea[7] discussed failure mechanisms observed on the magnesia-chromite bricks lined above the slag line of the flash furnace for zinc-lead smelting. In order to explain these findings some laboratory work was done additionally. Prestes et al.[8] analyzed wear phenomena on magnesia-chromite bricks from the lead short rotary furnace. Similar to Oprea, in addition to post mortem studies also some experimental work by crucible corrosion testing was carried out. Monshi et al.[9] investigated wear of the refractory lining out of the top blowing rotary converter (TBRC), whereas Hoed[10] reported on refractory erosion and evidence based on the pilot-scale trials in the DC-arc furnace carried out with refractories and lead blast furnace slag. Wei[11] reviewed available literature concerning corrosion of refractories in the lead-smelting reactors such as KIVCET furnace and TBRC and evaluated in the laboratory the corrosion behavior of various refractory materials against industrial slags. Finally, Scheunis et al.[12] investigated the effect of phase formation during use on chemical corrosion of magnesia-chromite refractories in contact with non-ferrous $PbO–SiO_2$ based slag. Malfliet et al.[13] carried out a critical review work on degradation mechanism and use of the refractory linings in the copper production processes. These findings for copper slags are also interesting and relevant for a better understanding of the refractory wear processes in lead metallurgy, as similar slag systems and refractory qualities are used.

The special features of the different technologies (i.e., bath/flash smelting, stationary/moveable furnaces, different degree of turbulence, batch/continuous process, etc) and slag systems ($FeOx–SiO_2–CaO$/soda) also generate different challenges for the refractory furnace lining.

This paper gives an overview of the main wear mechanisms affecting the refractory lining from the primary and secondary lead processing furnaces, such as KIVCET furnace, Kaldo converter, QSL reactor, Ausmelt/Isasmelter™ (TSL reactor), reverberatory furnace and short rotary furnace (SRF). The knowledge about wear mechanisms is based not only on many years of experience through post mortem studies, but also on additional laboratory work and experimental testing in the pilot plant at RHI's Technology Center Leoben. For a better understanding of the wear phenomena a brief description of the main metallurgical processing routes is given in the following section.

2. Overview of lead production routes

Depending on the nature of the input materials various technologies are available for lead production, generally primary and secondary production route can be distinguished. The primary route uses mainly sulfidic lead concentrates, also with the addition of zinc plant residues or battery scrap, whereas the secondary route processes only materials from secondary sources, especially batteries. Nowadays, secondary production volumes already exceed primary lead production.[14–16]

The traditional primary route is roasting-reduction/smelting (roast-reduction, i.e., sinter plant & blast furnace), however, over the last decades, the direct smelting reduction processes (roast-reaction) have become more important and nowadays are state-of-the-art.[15,16] The process paths can also be seen from Fig. 1. Some of the vessels from primary industry are also used in secondary industry (e.g., SRF, TSL).[14,18]

Generally, the process parameters and technology are chosen according to the input material, i.e. present impurities and required metallurgical work. The conditions range from oxidizing for sulfur removal (roasting) to reducing for smelting and reduction, including slag fuming—sometimes both in one vessel (Fig. 2). The process temperature is generally far higher than the lead liquidus temperature (327 °C), namely around 1000 °C (and even higher for lower PbO levels in the slag), in order to have a liquid and reactive slag that is easy to remove. Additionally, slag chemistry is adjusted in a way to minimize metal overheating. Consequently, the following challenges arise for the refractory[18–20]:

- Slag chemistry: adjusting slag composition within the system $FeOx–SiO_2–CaO$ and/or choice of other slag systems and additives (soda slag) for achieving low liquidus temperature under consideration of other slag properties (e.g., viscosity, lead solubility, lead fuming) causes chemical attack.
- Furnace atmosphere and temperature: especially changing atmosphere (oxidizing/reductive) as well as hot gases lead to increased refractory damage.
- Overheated liquid phases (metal and slag) with resulting very low viscosity cause deep refractory infiltration and chemical attack.

The following overview gives a short introduction into the lead production processes where the slags investigated in this paper originated from. Other production routes like EAF, Outokumpu Flash, SKS (Shuikoushan), KLS (Kosaka Lead Smelting) and the traditional blast furnace route will not be described in the present work[14–16,18,20–24]: A general overview