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Review

Degradation mechanisms and use of refractory linings in copper production processes: A critical review

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Abstract

The use and degradation of refractory linings in copper furnaces are discussed, thereby describing the main steps taken at the research, development and industrial level to minimize refractory wear. Which combination of chemical, thermal and mechanical degradation mechanisms is dominant depends on many factors such as the furnace type, the lining design, including the selection of the refractory type, and the process conditions. Magnesia-chrome bricks are widely used to line copper furnaces, despite the potential risk for the formation of hexavalent Cr under specific conditions, typically in the presence of alkali or alkaline earth oxides. To understand and predict refractory degradation, both post-mortem investigations and lab scale tests are considered to be helpful tools, thereby supported by phase diagram investigations and thermodynamic and kinetic calculations. This review concludes with refractory selection and use on the industrial level, including the waste and recycling management of spent refractories.

Keywords: Refractory; Copper furnaces; Degradation

Contents

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1. Introduction

Copper is a versatile metal with a variety of industrial and residential applications, such as in electronic products, construction, industrial machinery, transportation and as alloying element in brass and bronze.[1] The pyrometallurgical processing of copper from ores or recycled scrap, may comprise either batch, semi-continuous, or fully continuous processes, thereby involving smelting, converting and/or refining furnaces. The reliable and profitable operation of these furnaces strongly depends on the integrity of the vessel, which is often subjected to turbulent and aggressive process conditions. In 1923, Pyne[2] wrote "The requirements of refractories in the copper industry may be classed as follows: Resistance to temperatures; Resistance to chemical action; Ability to withstand sudden temperature changes; Minimum absorption of slag and metal; Absence of manufacturing defects".

In the current practice the ability of the refractory lining to withstand the combined action of the thermal, chemical and mechanical loads, remains the primary factor to evaluate the refractory. It is however not the only driving force for the refractory companies to develop new bricks and procedures. Although the most appropriate material to line the furnaces of the copper industry so far is considered to be the magnesia-chrome type due to its high resistance against slags with different basicities, the possible formation of Cr^{6+}, above all when working with calcium ferrite slags in converting processes or sodium carbonate/hydroxide slags in refining processes,[3] has increased the interest in magnesia and alumina bricks as alternatives. To the best of our knowledge, the use of the latter brick types is still mainly in the research and development phase, and their future evolution will depend amongst others on how the use of Cr containing bricks in the steel industry will evolve.

Finally, with respect to the recent evolutions in the copper production, two trends that will affect further brick development should be mentioned. Firstly, the input material of the primary copper production is changing as concentrates with low levels of impurity elements are becoming more scarce. These increased level of impurity elements can change the refractory degradation behavior, either directly or through a change in operation conditions. Secondly, secondary copper production is gaining importance, thereby introducing new flowsheets, operating conditions and input material compared to the primary production processes.

Fig. 1 shows the authors' vision on the interaction between research and development and industry in their endeavor to