Refractory ceramics for the aluminium foundries: novel perspectives for greater process and product sustainability

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Keywords: aluminium, ceramic, refractory, sustainability, chemistry, chemical analysis

The mastery of metallurgy represented a transformative leap for mankind, enabling the production from the first revolutionary tools and weapons to today's hi-tech materials. Global aluminium production is reported to be second only to that of iron, with the smelting of 70.593 MT of Al in 2023 alone[1]. Endless recyclability, reduced production costs, and eco-compatibility, combined with metal's extreme versatility, make aluminium foundries sustainability-conscious and cutting-edge to the extent that future projections anticipate an 80% increase in demand by 2050[2]. Castable refractory ceramics play a crucial role in the aluminium production process, thus special features such as high-temperature, thermal shock, chemical and mechanical resistances as well as formability, durability and insulating properties are required.

In this work, BN-doped ternary SiO_2-Al_2O_3-CaO ceramics were manufactured and fully characterised. The well-known SiO_2-Al_2O_3-CaO system is able to meet many demands[3]. Nevertheless, a deep insight into the mechanisms at the base of their performance in the specific application is highly necessary. Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) analyses confirmed the theoretical values of the major elements, while Scanning Electron Microscopy (SEM) provided morphological and structural information showing the heterogeneity of the ceramic product which consisted of a calcium aluminosilicate matrix in which fragments of silica and BN were dispersed. Moreover, SEM technique revealed that sintering caused a decrease in macroporosity with a concomitant increase in microporosity. X-Ray Diffraction (XRD) showed that the microstructure of the ceramic was a result of both amorphous and crystalline phases. Interestingly, the microstructures before and after the heat treatment appeared very similar despite a slight increase in the crystalline/amorphous ratio and the loss of two water-related phases, *i.e.*, aluminium hydroxide (*nordstrandite*) and calcium aluminium hydroxide hydrate. This phenomenon has already been observed and ascribed to water loss with consequent modifications in the crystalline lattice[4]. In addition to the physicochemical characterization, thermal analyses and mechanical testing were started with the aim to disclose specific correlation between product characteristics and its performance.

Finally, a MatLab-based calculation tool was developed to estimate the heat losses occurring during the transportation of molten Al from the holding furnace to the casting station. This met the need for improved product sustainability combined with the possibility of creating uniqueness, whose purpose is to lead to products and processes customization.

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