CB01 - Thermo-Mechanical Characterization of Multilayer Clean Ramming Paste Joint

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Abstract

The main carbon components of the Hall-Héroult electrolysis cell are cathodes and anodes. Cathode blocks are arranged so that a gap is left between them to allow their expansion at high temperature. These gaps are filled by ramming paste to prevent infiltration of the liquid metal during cell operation. The ramming paste is a carbonaceous material, which is mainly composed of anthracite and graphite, and a coal tar pitch (CTP) binder. More precisely the binder is obtained by distillation of coal tar, which is a by-product of the cokefaction of coal. CTP contains Polycyclic Aromatic Hydrocarbons (PAH), being potentially carcinogenic. For the health and safety reasons, new generation of ramming pastes, denoted as clean ramming pastes, are developed without the use of coal-tar-pitch.

Properties of ramming paste such as mechanical strength, rammability and density determine if they are acceptable for cell construction. For instance, the density after compaction can greatly influence the baked density and the thermomechanical properties of the ramming paste in the cell. To reveal the relationship between density and other properties such as the compressive strength, volume change and mass loss, an experimental investigation was performed at both industrial and laboratory scales. Different levels of compaction were used to obtain targeted densities. The samples were characterized during and after baking by thermogravimetric analysis and mechanical tests.

Keywords: Hall-Héroult process, clean ramming paste, thermomechanical characterisation.

1. Introduction

The Hall-Héroult cell consists of a metallic shell, refractory lining and a significant proportion of carbonaceous materials, such as graphitized cathodes. The graphitized cathodes constitute the top layer of the bottom of the cell which is directly in contact with molten metal and contains it. The cathode blocks are arranged so that a gap of a certain thickness is intentionally left between them to accommodate cathode expansion during cell operation. The gaps are located between the cathodes themselves and between the cathodes and the inner wall of the electrolysis cell [1]. These gaps must be filled with a carbonaceous material, called the ramming paste. The role of the ramming paste is to prevent the infiltration of liquid metal or cryolite into the cell lining and to absorb the expansion of the cathodes during the heat-up of the electrolysis cell [1].

For many years, the conventional ramming paste, with CTP binder, has been used in cell construction and exhibited suitable mechanical and physical properties [2]. Polycyclic Aromatic Hydrocarbons (PAH) can be found in big proportion in the conventional ramming paste, basically due to the presence of CTP [3]. The PAHs are known to be harmful for health, having also an important noxious impact on the environment [2]. To mitigate these negative effects, Eco-Friendly or Clean ramming pastes have been developed and used in cell construction for a while. [3]. The binder in the Clean ramming pastes is basically biomass-based [2]. Although different types of Clean ramming pastes are available on the market and are being used in industrial scale [3], little information can be found in the literature on their exact chemical composition and production process. Even less information is found in the literature regarding the performance of Clean ramming pastes in electrolysis cell and this aspect is still at an investigation stage [3]. Seemingly, the physical and mechanical behavior of Clean ramming pastes in electrolysis cells and their impact on the lifetime of the cells is not well known. A failure, caused by an improper ramming paste, may cause premature loss of the electrolysis cell, resulting in significant economic loss [1]. Thus, generation of knowledge aiming at better understanding of thermomechanical and physical properties of the Clean ramming paste is of great interest for the industry.

In addition to the chemical composition, the ramming process of the paste can also influence the thermo-mechanical behavior of the ramming paste in the joints between cathode blocks [4]. The long experience of using conventional paste has made it possible to develop techniques and standard methods for quality control of the ramming paste, allowing viable performance of the cells [5]. As the type and the nature of the Clean ramming paste is quite different from those of the conventional ones, further investigations are required to establish best practice to achieve suitable results in the cell with high level of confidence.

The laying of the ramming paste is performed, according to the design of the cell, by depositing multiple layers of paste which are compacted successively [1]. The amount of the paste deposited for each layer depends on the size of the gap to seal. The compaction of each layer is controlled by several parameters which depend on the type of ramming equipment [6]. For instance, for the machines using vibration compaction the parameters such as frequency, applied load or the number of passages could be considered as important parameters to control the process. The compaction is carried out until a desired green density is obtained. The density is usually characterized by coring a sample from the compacted joint or by using non-destructive techniques to assess its hardness. The ultimate objective is to provide adequate mechanical resistance and good adhesion between the paste and gap walls while allowing the paste to accommodate the expansion of the cathode blocks [1]. Indeed, through different compaction sequences, a homogeneous density is also sought.

Due to the relatively new usage of the Clean ramming pastes in the cell construction, it could take years before revealing their long-term performance in the cell. However, laboratory tests combined with the knowledge acquired on the conventional pastes may help setting the right parameters to achieve the best performance. Indeed, these parameters could certainly be adjusted as the field data will be generated in the coming years. In the meantime, the laboratory tests can generate insights for better understanding the behaviour of the Clean ramming pastes, namely their rammability, density gradient and mechanical strength. For instance, the smelters adjust the ramming process to meet the density recommended by the suppliers to meet the QC requirements. In this paper, we present the experimental results encountered with characterization of a commercial Clean ramming paste obtained by industrial compaction process. Density distribution of the compacted sample was revealed and a series of laboratory samples, exhibiting the same density range, were prepared for further characterization.

6. References

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