An Optimized Mixing Approach for Improved Anode Quality

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Abstract

In recent years, anode property optimization has mainly been obtained through dry mix, mixing or forming process improvements. Another way to enhance anode properties is to work on raw materials and to study the ability of coal tar pitch to coat and penetrate coke porosities. This paper describes a new approach for paste mixing in two steps to improve anode quality: (i) blending a low viscosity coal tar pitch (CTP) with the grain fraction of the calcined petroleum coke (CPC) recipe to maximize filling of open porosities, (ii) incorporating a high viscosity CTP and the fine fraction of the dry mix into the previously obtained blend. The two sequences are performed at two different temperatures ($T_{step\ 1} < T_{step\ 2}$). The major goal of this two-steps mixing is to maximize the filling of open coke porosities, therefore, to enhance anode quality. The resulting paste is then used to form lab-scaled anodes, which are baked and characterized. Their quality can be quantified by calculating the net carbon consumption, on the basis of a widely acknowledged formula. The results show an improvement of lab-scaled anode quality produced following this sequenced-mixing process, along with a significant decrease of the calculated net carbon consumption.

Keywords: Anode, Calcined petroleum coke, Coal tar pitch.

1. Introduction

The performance of carbon anodes in Hall-Héroult electrolysis remains a major factor in aluminium production efficiency. Over the past decades, industrial innovations have successively improved key production steps from aggregate preparation to mixing and compaction. For example, the introduction of the Rhodax® crusher [1] with its inertial compression mechanism enables selective fragmentation, preserving coarse particles while breaking down porous ones, thus producing a dry aggregate with a high Grain-to-Sand (G/S) ratio. This optimized granular skeleton contributes to better compaction, thermal shock resistance, and anode integrity [2].

Subsequent advances included the implementation of vacuum-assisted vibrocompaction, improving paste densification and structural uniformity. More recently, attention has shifted to the mixing stage with the deployment of the IMC (Intensive Mixing Cascade) [3]. This technology allows fine control over temperature, timing, and pitch addition, making it possible to precisely manage the interaction between pitch and aggregate.

Despite these innovations, conventional mixing protocols still require a single pitch to simultaneously infiltrate coke porosity and coat particle surfaces two functions difficult to optimize under uniform conditions. This often leads to incomplete pore filling and heterogeneous coating. Previous studies, including sessile drop experiments conducted by Bernabé *et al*., have shown that pitch penetration efficiency depends not only on temperature and porosity, but also on the pitch viscosity and chemical affinity with the coke surface [4]. These findings underscore the need for tailored rheological properties and appropriate mixing sequences to optimize pitch distribution and utilization at the grain level. The wettability of coke by pitch is of primary importance for aluminium producers and is the subject of ongoing scientific research [5, 6].

Beyond process efficiency, improving pitch distribution mays also contributes to reducing polycyclic aromatic hydrocarbon (PAH) emissions, with positive implications for environmental impact and occupational health. The use of high-viscosity pitches rich in high molecular weight PAHs and lower in volatile fractions combined with a better balance between impregnation and binder functions, may further help limit the release of volatiles during baking.

To overcome these limitations, this study investigates a sequenced mixing protocol using two coal tar pitch grades with contrasting viscosities. A low-viscosity pitch is first applied to the coarse fraction to promote pitch penetration, followed by a high-viscosity pitch added with fines to enhance surface coating and final cohesion. The approach leverages the thermal flexibility of IMC equipment and aims to decouple the roles of impregnation and coating. This process has been patented [7].

Through laboratory trials, this paper compares conventional and sequenced protocols across multiple pitch contents and distributions. Results are interpreted through key performance indicators density, electrical resistivity, reactivity, and net carbon consumption (NCC) with additional insight into the energy balance during baking.

2. Experimental Works

2.1 Raw Materials

2.1.1 Calcined Petroleum Coke and Butts

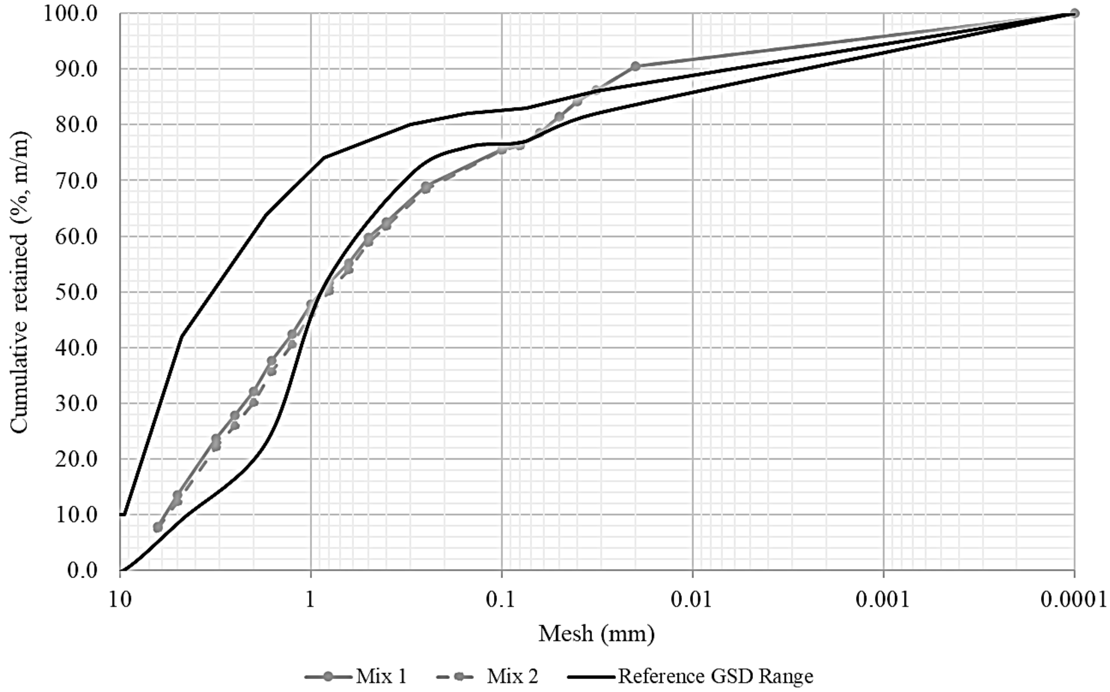

Figure 1. Grain size distribution (GSD) of the CPC aggregate used for laboratory anodes, compared to the SCAP-Rhodax® process reference range (in cumulative retained).

Furthermore, the study underlines the limits of pitch overdosage: increasing pitch content to 18 % consistently led to higher porosity, reactivity, and carbon consumption across all protocols. These results confirm that performance gains hinge not only on pitch quantity but also critically on how and when the pitch is introduced.

The mixing sequence strategy described here is readily compatible with industrial platforms such as the Intensive Mixing Cascade (IMC), offering a scalable path toward more efficient and environmentally robust anode production. Beyond immediate structural and electrical benefits, the approach also has implications for the baking process, where altered volatile profiles must be accounted for in energy balance and furnace operation.

Looking ahead, the use of biosourced fluxing agents, as described in many studies such as modified vegetal pitches or light fractions derived from renewable feedstocks could offer an additional lever for process optimization [14, 15]. These materials, when blended with conventional coal tar pitches, may reduce environmental impact while maintaining or enhancing binder performance. Their application as low-viscosity agents in the first mixing stage appears particularly promising, and merits future investigation in combination with sequenced mixing protocols.

Altogether, this work supports a paradigm shift from single-step pitch dosing to a more controlled, staged approach, unlocking new performance and sustainability avenues in anode manufacturing.

6. Acknowledgements

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