Optimizing Stub-to-Carbon Contact for Higher Amperage in Aluminium Smelting – A Computational Study

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Abstract

With the rising demand for aluminum, many manufacturers are expanding their production capacity through greenfield and brownfield expansions, as well as by increasing amperage in existing potlines. Among these, amperage increase has emerged as the most popular option due to its ability to deliver higher productivity gains with relatively lower investment. Modern pots are designed to operate at specific amperage levels. To achieve higher amperage while maintaining thermal balance and similar direct current energy input, key design modifications are necessary. Published literature identifies cathode lining and anode design adjustments as critical changes required for such upgrades. In this study, we developed an FEA-based computational model to predict the stub-to-carbon contact voltage drop. The model was validated through plant measurements. This paper further presents a parametric study evaluating the impact of amperage increase on stub-to-carbon contact drop. Additionally, various stub hole design modifications were simulated to identify solutions for reducing voltage drop without compromising the mechanical strength of the stub-to-carbon connection.

Keywords: Aluminium Smelting, Amperage increase, Stub to Carbon Drop, Stub hole design

1. Introduction

Mahan Aluminium has an AP 36 potline designed for 360 kA. In the recent past, smelter have raised the amperage to 376 kA to meet the increased demand for aluminum. This increase in amperage has led to a rise in anode current density from 0.893 A/cm^2 to 0.917 A/cm^2. To fully leverage the potential of amperage ramp-up, the smelter is planning to further increase it to 400 kA. Raising amperage also impact the voltage drop across the potline. The pot process control logic operates based on a set pot voltage value. An increase in ohmic drop, caused by a higher voltage drop in the anode assembly, is ideally offset by reducing the interpolar distance or the distance between the anode and cathode. However, decreasing the interpolar distance makes the pot more susceptible to MHD (magnetohydrodynamics) instabilities. In order to keep the interpolar distance constant, it is necessary to adjust the pot's set voltage value. This adjustment results in higher specific DC (Direct Current) energy consumption. Design modifications in the anode assembly and cathode lining offer an opportunity to decrease the ohmic drop across the pot and run the smelter with lower specific energy, even at higher amperage. Previous studies have reported such efforts in amperage increase campaigns [1]. In this paper, prime focus is on anode assembly design. Anode assembly voltage drop is divided into various components such as rod drop, bimetallic or transition joint drop, yoke drop, stub to carbon drop and anode block drop. Stub to carbon contact drop in anode assembly accounts for ~30 % of total anode voltage drop. The magnitude of electrical resistance across the contact surface between the anode block and the cast-iron thimble depends on the surface roughness and the effective contact pressure generated on the contact surface. The intensity/magnitude of the contact pressure depends on the initial air gap between the cast iron and the stub hole, as well as the thermal expansion of the cast iron thimble and stub during the process in the pot. In addition to the pouring temperature of the liquid cast iron and the preheating temperature of the carbon block and pin, the geometry of the stub hole and the thickness of the cast iron also play important roles in determining the value of the initial air gap. Optimization of the stub-to-carbon contact has been a topic of interest for the aluminum smelting community for a long time. Many experimental and computational studies have been conducted in the past to improve the stub hole design and pin design to reduce the drop of the stub to carbon contact [2–4].

In this paper, a FEA (Finite Element Analysis)-based computational model is developed to examine the impact of stub hole design modifications on the thermal, electrical, and mechanical behavior of the anode assembly. This model is utilized to conduct simulations and analysis to optimize the stub hole design and transition joint to reduce the ohmic drop across the anode assembly.

2. Computational Model Development

This section describes the anode assembly geometry, meshing details, boundary conditions and analysis procedure used in the model.

2.1 Geometry

Each anode assembly consists of one anode rod, one hexapod, a transition joint, six cast iron thimbles, and two carbon anode blocks. The distance between two anode blocks is 10 mm. To reduce simulation time, only half of the anode assembly is modelled.

3D geometry used in the model is shown in Figure 1. It includes (i) half anode assembly comprising half anode rod, half transition joint, half hexapod, pins, three cast iron thimbles, and one anode block. According to operational practice, stub to carbon drop measurements is conducted after 5–6 days of installation of the anode block. Historically measured data forms the basis for analyzing the impact of operating conditions on the anode assembly voltage drop. Therefore, the anode block height at half-life is considered in the geometry.

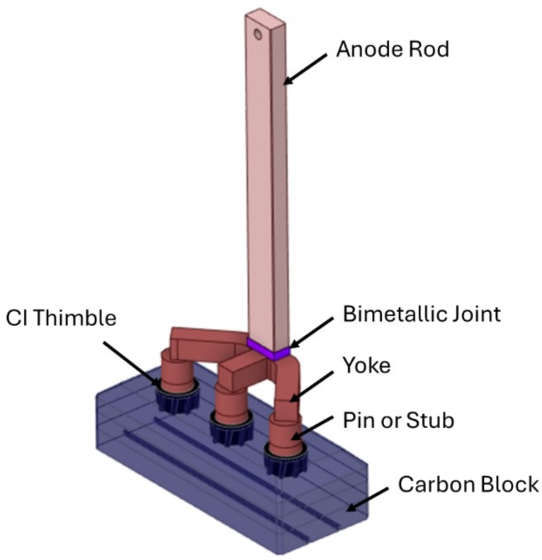

Figure 1. Anode assembly geometry considered as modeling domain.

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