Stub to Carbon Design Improvement

Dolfy Antonio Sinaga[1], M. Ragagora Widagdo[1], Manda Mahyudin[2], Edi Mugiono [3] and Edwin El Ammar[3]

1. Process Engineer
2. Superintendent
3. Senior Vice President

PT Indonesia Asahan Aluminium (INALUM), Kuala Tanjung, North Sumatra, Indonesia

Corresponding author: dolfy_sinaga@inalum.id

Abstract

High voltage drop results in excess energy consumption which is not used to produce Aluminium metal. One of the areas where voltage drop occurs in aluminium electrolysis is in stub to carbon (STC) connection. The voltage drop between stub and anode is an essential part of the overall voltage drop in anode section and has an impact on the electrolytic process. INALUM has developed STC design improvement to reduce voltage drop in this area. We showed that reducing stub hole depth, flatten base, reducing stub hole diameter and reducing number/width of flutes are strongly impactful to STC voltage drop and cast-iron consumption. According to application test result in reduction cell, application of STC with design 6 flutes, flatten base and modification casting collar, INALUM could successfully save STC voltage drop of 17.70 mV (from 293.2 to–275.5) and it could reduce 33.6 % cast iron consumption.

Keywords: Stub to carbon, Voltage drop, Contact pressure, Air gap, Cast iron.

1. Introduction

In order to reduce alumina to be aluminium in electrolysis process at reduction cell, it consumes huge energy around 14,000 kWh/ton Al and some technologies, energy consumption has even 12,000 kWh/ton Advancement in energy-saving measures. Voltage drop is used as the main index to evaluate the performance of reduction cell. High voltage drop consumes excess energy which does not need to produce Aluminium metal. One of voltage drop produced in aluminium electrolysis is in area stub to carbon (STC) connection. The voltage drop between stub and anode is an essential part of the overall voltage drop in anode section and has an impact on the electrolytic process. Anodic voltage drop is attributed to steel/cast iron/carbon interface as per Jeddi et al. [1]. Referring to this condition, it is imperative to ascertain the most optimal and precise design for stub to carbon area to minimize voltage drop.

The anodic voltage drop is one of the components of the overall pot voltage or cell voltage. The cell voltage refers to the total voltage present in the electrolytic cell which divided into several entry to anode voltage (anodic voltage drop), bath voltage, cathode voltage and collector bars to exit voltage. The anodic voltage drop generally contributes approximately 6 % of the total pot voltage, with the bath voltage being the primary determinant. Nevertheless, it remains essential to optimize the anode voltage drop, particularly in the stub to carbon region, as it plays a significant role in the overall performance of the system. High electrical contact resistance in stub to carbon area is predominantly caused by contact pressure, specifically cast iron to carbon interface in the prebaked anode which certainly a cause of waste energy consumption in aluminium electrolysis.

2. Contact Pressure

The contact surface between the cast iron thimble and anode carbon is a major contributor to variations of electrical contact resistance. These variations depend on not only the roughness of the contact surface but also the effective contact pressure generated on the contact surface. The contact pressure is a function of the initial air gap that forms during thermal contraction of the cast iron and steel stub during casting process, as well as the subsequent thermal expansion generated during use within the reduction cell [2].

Figure 1. shows the contact pressure for cast iron thimble surface. The peak contact pressure is located at lower portion of the stub hole walls, close to the stub hole base, even though the contact zone is slightly changed for each stub hole wall. The regions with no contact pressure, deep blue, represent high electrical resistance. It can be seen that there is almost no contract pressure on the entire collar area, particularly for the mid stub holes [3]. Contact pressure must be greater than 1 MPa to achieve adequate electrical contact. Figure 1 also shows that virtually no contact exists at the top of the thimble.

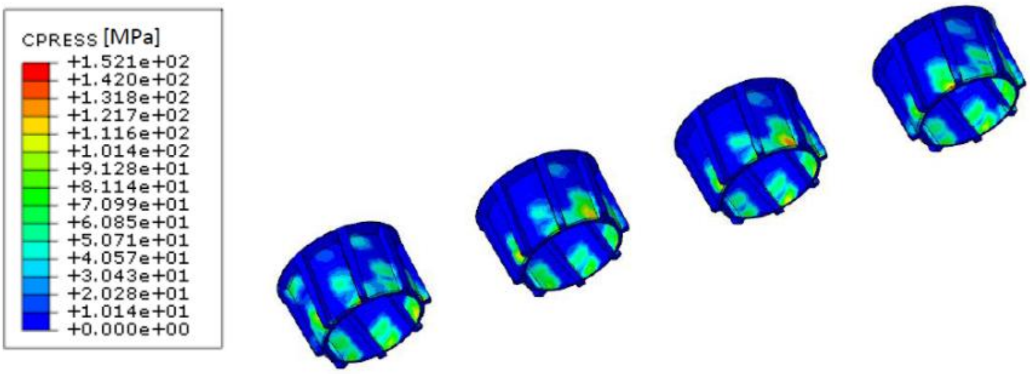

Figure 1. Contact pressure distribution on stub hole wall [4].

Hugues Fortin et al. [5] also present on figure 2 the normal contact pressure between cast iron and carbon in the center stub hole. The contact pressure is strong (red) on lower cylindrical side of the cast iron thimble.

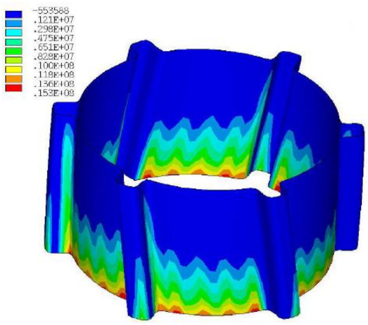

Figure 2. Normal contact pressure on the middle stub hole [5].

3. Contact Resistance and Contact Pressure Relationship

The high contact resistance at the STC originates from solidification shrinkage of the cast iron connection which creates an initial gap between the iron thimble and carbon stub hole wall with a low contact pressure [6]. Cast iron thimble has a lower thickness at the tip of the stub than in the upper part of stub hole. The shrinkage of cast iron in the upper, thick-wall part is usually

10. Reference

1. E. Jeddi, et, al., Experimental and Numerical Investigation of Voltage in Anode Assemblies. *Light Metals* 2013, 1347-1352.
2. K. Ding, et al., Prediction of Voltage Loss on Electrical Connection for Aluminium Smelter Reduction Cells. *Proceedings of the Institution of Mechanical Engineers Part C. Journal Mechanical Engineering Science*, 2011, Melbourne; https://doi.org/10.1177/0954406211417369 .
3. K. Ding, D. Molenaar and A. Kapoor, FE Modelling of Voltage Loss During Stub Tip Deterioration in Anode Assemblies. *Presented at the 10th Australiasian Aluminium Smelting Technology Conference,* Paper 4c4*,* 2011.
4. K. Ding, D. Molenaar and A. Kapoor. Prediction of Voltage Loss on Electrical Connections for Aluminium Smelter Reduction Cells. *Proceedings of the Institution of Mechanical Engineers Part C, Journal of Mechanical Engineering Science*. 2011, 981-994
5. H. Fortin, et al., FEM Analysis of Voltage Drop in The Anode Connector Assembly. *Light Metals* 2009, 1055-1060.
6. D. Molenaar, K. Ding and A. Kapoor. Development of Industrial Benchmark Finite Element Analysis Model to Study Energy Efficient Electrical Connections for Primary Aluminium Smelters. *Light Metals* 2011, 985-990.
7. S. Wilkening and Jules Cote. Problems of The Stub – Anode Connection. *Light Metals* 2007, 534-542.
8. M. Reverdy and Vinko Potocnik. A Historical Review of Aluminium Reduction Cell Start-Up and Early Operation. *Light Metals* 2022, 991-997.
9. W. Berends, S. Haley and M. Gagnon. Low Resistance Anode Assembly Using Steel Stubhole Conductors Across the Cast Iron to Carbon Interface. *Light Metals* 2016, 965-969.
10. M.A. Aly, M.M. Ali and A.A. Atlam. A Study of Anodic Voltage Drop in Aluminium Reduction Cell by Finite Element Analysis. *International Journal of Engineering Research and Application.* 2016.
11. Thermal Pressure. https://en.wikipedia.org/wiki/Thermal_pressure. (Accessed on 5th June 2023).