Comparative Analysis of KPIs and MHD Stability Between Pots with Graphitized and Graphitic Cathodes

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Abstract

Graphitized cathode blocks play an important role in energy savings, efficiency improvement and environmental friendliness for the aluminium smelting process. As a result of this, graphitized cathode blocks have been widely applied in western aluminium smelters. This paper explored an application of graphitized cathodes in Guangxi Hualei New Materials. After comparative analysis of pot KPIs, the average current efficiency of two graphitized cathode pots was found to be 1.46 % higher than in the graphitic cathode pots, and the DC power consumption was about 200 kWh/t Al lower as well. Squeezing tests were further carried out to detect the threshold of magnetohydrodynamic (MHD) stability. At the same pot voltage and other conditions, the average anode-cathode distance (ACD) of graphitized cathode pots was about 1.22 mm higher than the graphitic cathode pots. It was also found that the graphitized cathodes played a beneficial role in homogenizing ACD distribution and strengthening its ability of anti-interference deformation compared with graphitic cathode pots.

Keywords: Aluminium pots, Graphitized cathode, Graphitic cathode, MHD stability.

1. Introduction

The carbon cathode assembly constitutes one of the principal components in aluminium reduction pots. Serving as the crucial element in maintaining electrical and thermal balance, the cathode block has to possess excellent thermal and electrical characteristics. Simultaneously, as the first barrier against molten salt [1], the ability to resist corrosion and sodium penetration at high temperatures should be outstanding as well.

Regarding the selection of cathode materials, western and Chinese aluminium industries pursued different technical ways. Western giants (e.g., Alcoa, EGA, Hydro, RUSAL, etc.) started the research and applications of graphitized cathode blocks very early. The main reason could be attributed to its excellent electrical conductivity, thermal conductivity and sodium penetration resistance. Western pots were characterized by their high current density and high current efficiency [2]. In contrast, due to the economic and labour advantages, Chinese aluminium companies preferred graphitic cathodes for a very long time. Now the cutting-edge technologies in Chinese aluminium producers have reached the world-leading standards in DC energy consumption. However, there still is a clear gap in current density and current efficiency compared to western aluminium smelters.

In recent years, domestic design and research institutes and smelters began to pay more attention to the advantages of graphitized cathodes. Some industrial explorations have been carried out in smelters. Tao et. al [3] conducted a study based on an aluminium smelter to analyse the process parameters between graphitized cathode pots and graphitic cathode pots. Statistical analyses revealed that the cathode voltage drop (CVD) of graphitized cathode pots was maintained between 240 mV and 260 mV over a very long period, while that of graphitic cells increased to 340 mV. The annual data showed that a 1.49 % higher current efficiency was obtained in graphitized cathode pots. A similar industrial trial was done by Song et. Al. [4] in Yingkou Zhongwang Aluminum. By comparing 40 graphitized cathode pots with another group of graphitic cathode pots, it was found that the pots with graphitized cathodes showed a reduction of 45.5 mV in CVD, an improvement of about 1 % in current efficiency, and a reduction of 150 kWh/t Al in DC power consumption.

Until 2020, the graphitized cathode blocks had not been widely adopted in China's aluminium electrolysis industry. An exploration of two graphitized cathode pots was started-up in Guangxi Hualei New Materials (Hualei) in 2020. This paper compares the pot KPIs between the test pots and original graphitic cathode pots. The squeezing tests were further carried out to analyse thresholds of MHD stability. The findings may provide some experience and reference for domestic and overseas smelters.

2. Comparative Analysis of Pot KPIs

Two pots (No.1202 and No.1722) were equipped with graphitized cathode carbon blocks, while two other pots (No.1328 and No.1514) were installed with graphitic cathode blocks. Table 1 presents the comparison of physical and chemical properties between the two types of cathodes. The four test cells shared similar thermal balance and lining structure designs. The startup time of all pots was within 20 days. The management procedures, production conditions and raw material were standardized across all test pots and reference pots.

Table 1. Comparison of physicochemical properties between graphitized and graphitic cathodes.

Physicochemical properties	Apparent density (g/cm^3)	True Density (g/cm^3)	Crushing strength (MPa)	Room-temperature resistivity (μΩ·m)	Ashes (%)	Supplier
Graphitized carbon blocks	1.71	2.16	23	8	0.14	Enterprise A
Graphitic carbon blocks	1.69	2.07	32	22	0.78	Enterprise B

The comparison data began to be collected after 6 months from pot startup. Table 2 is a summary of the consecutive data gathered from six months of normal operation of these pots. It was found that the pot voltages were nearly identical with a tiny difference of 5 mV. Process parameters such as aluminium level, bath level, and bath temperature were similar in the group. However, the average current efficiency of the graphitized cathode pots was 1.46 % higher than that of the

The two graphitized cathode pots were operated at an average ACD of 40.20 mm, whereas the two graphitic cathode pots showed an average ACD of 38.98 mm. There was a 1.22 mm difference in ACD between the two cell types. Regarding the electrolyte composition used in the test pots, the 1.22 mm ACD corresponded to a voltage drop of approximately 41 mV [9] in the bath layer. Comparative analysis of ACD standard deviations further revealed that the graphitized cathode pots showed a better uniformity of ACD distribution compared to that of graphitic cathode pots.

Graphitized cathode blocks have higher electrical conductivity compared to that of graphitic cathode blocks (YS/T 623-2012 and YS/T 699-2009). The graphitized cathode pots have an advantage in CVD, which gives a better pot KPIs. The above study further revealed an important part beyond the inherent physical voltage reduction: the graphitized cathodes played a beneficial role in homogenizing ACD distribution.

When the pot voltage was reduced from 3.88 V to 3.80 V, the standard deviation of ACD showed no increase in the two graphitized cathode pots. It even showed a slightly downward trend, indicating that the interface distribution of metal-bath remained stable. In contrast, the two graphitic cathode pots showed about 22 % increase in standard deviation under the same operation conditions. It illustrated the deteriorating trend of the interface pattern. This comparative analysis showed that the ability of anti-disturbances was slightly strengthening for graphitized cathode pots compared to graphitic cathode pots.

5. Conclusions

This paper analyzed the industrial data to compare pot KPIs and MHD stability between graphitized and graphitic cathode pots. Some key conclusions are summarized as follows:

(1) Six-month data comparison revealed that the graphitized cathode pots achieved a 1.46 % higher in current efficiency and about 200 kWh/t Al lower in DC power consumption compared to graphitic cathode pots under similar operating conditions.

(2) The tests to detect the threshold of MHD stability showed that some localized anode current fluctuations emerged at 3.70 V in graphitized cathode pots, whereas similar instabilities arose at a higher voltage of 3.75 V in graphitic cathode pots.

(3) Equivalent ACD calculations showed that the graphitized cathode pots maintained an average ACD of 40.20 mm, which was 1.22 mm higher than graphitic cathode pots (38.98 mm). The standard deviation of ACD in graphitic cathode pots was about 33 % higher as well. The graphitized cathodes played a beneficial role in homogenizing ACD distribution.

(4) When the pot voltage was reduced from 3.88 V to 3.80 V, the standard deviation of ACD showed no increase in the two graphitized cathode pots. The two graphitic cathode pots showed about 22 % increase in standard deviation. The graphitized cathodes played a beneficial role in strengthening its ability of anti-interference compared with graphitic cathode pots.

(5) Based on these findings, Hualei plans to conduct an expanded trial to confirm the advantage of graphitized cathode blocks.

6. References

1. X.D. Yang and M. Liu, Innovative ideas on heat balance design of large energy-saving aluminum reduction pot, *Light Metals*, Vol.12, (2017), 21-25. (In Chinese)
2. Shenyang Aluminium & Magnesium Engineering & Research Institute. Science and technology development report of Chief Engineer of Chinalco (aluminum reduction), 2019. (In Chinese)
3. S.H. Tao, The technological parameters statistics and comprehensive analysis of graphite and graphitized cathode aluminum electrolysis pot, *Light Metals*, Vol.12, (2018), 16-20. (In Chinese)

4. S.H. Song and D. Xu, Application comparison of graphitized cathode carbon block and 50% graphite cathode carbon block in 500 kA prebaked aluminum reduction pots, *Light Metals*, Vol.9, (2019), 31-35. (In Chinese)
5. Y.F. Lu, B. Bai and X. Cao, Application of graphitized carbon cathode block in 400kA energy-saveing type aluminum reduction cell, *Energy Saving of Nonferrous Metallurgy*, Vol.3, (2017), 31-34. (In Chinese)
6. B.G. Chen, Y.F. Liu and X.A. Liao, The application of graphite cathodes in aluminium reduction cell, *Light Metals*, Vol.9, (2012), 45-47. (In Chinese)
7. Wei Liu, Dongfang Zhou and Zhibin Zhao, Progress in application of energy-saving measures in aluminum reduction cells, *JOM*, Vol. 71, (2019), 2420-2429.
8. F.Q. Wang, Z.W. Wang, Q.S. Zhang, Z.B. Zhao, S.H. Tao, W. Liu and X.D. Yang, Computation and validation of ACD for aluminum reduction cell, *Light Metals*, Vol.2, (2020), 23-25. (In Chinese)
9. N.X. Feng, *Aluminum electrolysis*, 1st ed. (Beijing: Chemical Industry Press., 2006).