Stability of 500 kA Cells with Graphitized Cathodes and Copper-Insert Collector Bars During Early Operation

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Abstract

This paper analyses the issues of high noise, significant voltage deviations, and unstable performance observed during early operation of a 500 kA fully graphitized cathode aluminium reduction cell with copper-insert collector bars in a smelter. It further elaborates on the innovative control measures implemented and their corresponding effectiveness. These measures have significantly improved cell stability, reduced energy consumption, and ensured efficient and stable operation of the cells. Furthermore, the innovation and feasibility of using these control methods have been explored.

Keywords: Fully graphitized cathode, Copper-insert cathode collector bar, Aluminium reduction cell, Early operation of cells, Cell stability.

1. Introduction

In the production of electrolytic aluminium, the stable operation of the cells directly impacts production efficiency, energy consumption, and product quality. The early operation period (the post-start-up adjustment phase of about three months) is a critical transition stage for forming a regular ledge. The extent to which technical and economic indicators are met at this stage will have a significant impact on the service life of the cell and the subsequent stability of normal production operations.

Operational data from a smelter revealed significant anomalies during the first month of 500 kA fully graphitized cathode cells with copper-insert collector bars: (1) voltage oscillation noise reaching 50–60 mV, (2) voltage deviations exceeding 150 mV, and (3) degradation of cell stability. These issues led to higher power consumption, intensified thermal shocks to the potshell bottom/sidewalls, and compromised ledge integrity, adversely impacting subsequent performance. Although fully graphitized cathode cells with ordinary steel collector bars also face similar issues, the copper-insert collector bar structure exacerbates the problem due to its higher electrical conductivity and heat dissipation properties. This inherent incompatibility with conventional abnormal phase management strategies urgently demands the establishment of refined and differentiated control solutions. This study is of significant practical value for achieving safe, stable, and efficient operation of the cells.

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2. Fully Graphitized Cathode with Copper-Insert Collector Bars

The fully graphitized cathode with copper insert collector bars for aluminium reduction cells is an innovative technology that significantly enhances cell performance by combining the high electrical and thermal conductivity of fully graphitized cathodes with the composite structural advantages of copper-insert collector bars. The fully graphitized cathode has superior electrical and thermal conductivity, effectively reducing cathode resistance and decreasing energy loss, thereby improving current efficiency. Meanwhile, its uniform thermal conductivity helps stabilize the cell thermal equilibrium, mitigating risks of localized overheating and enhancing operational stability. The copper-insert collector bars employ a copper-steel composite structure, where the high conductivity of copper further reduces cathode resistance to improve current transmission efficiency, and the steel matrix provides sufficient mechanical strength to ensure structural stability of the cell cathode. This design reduces energy consumption while enhancing the durability of cells. The fully graphitized cathode incorporating copper-insert collector bars in the cells integrates the benefits of enhanced energy efficiency, prolonged cell lifespan, and improved production efficiency, thereby providing a novel technological approach for optimizing the aluminium electrolysis process.

3. Factors Affecting Stability During Early Operation

3.1 Management During the Cell Preheat

During the cell preheat, uneven preheat temperatures can lead to temperature variations within the cell ledge after startup, which is a critical factor affecting cell stability. Non-uniform temperature distribution may cause inconsistent expansion of the lining materials, which may induce internal stress and compromise the structural integrity and operational stability of the cell. It is noteworthy that the fully graphitized cathode with copper-insert collector bars, due to its superior electrical conductivity, is more sensitive to the uniformity of coke particle paving and the building of conductive networks during preheat. If not handled properly, its inherently higher current density may exacerbate risks of localized overheating or insufficient heating, requiring stricter preheat uniformity control compared to conventional steel collector bar cathodes.

3.2 Poor Management During the Initial Startup Phase

Improper initial voltage, bath height, and material replenishment procedures result in insufficient preheat of the cathode lining. Inadequate cathode lining preheat adversely affects its electrical conductivity and structural strength, leading to operational anomalies such as voltage fluctuations and uneven current distribution, thereby compromising the cell stability.

3.3 Deficiencies in Operational Quality Control

A large amount of carbon dust not being promptly removed after startup leads to carbon-contaminated bath, increased bath voltage drop, and compressed anode-to-cathode distance (ACD). The presence of carbon dust increases bath resistance, reduces current efficiency, adversely affects uniform current distribution, and exacerbates cell instability.

3.4 Ledge Formation Failure and Related Issues

The newly installed cells lack well-formed ledge, resulting in high horizontal current density, elevated noise, and poor stability. After anode replacement, irregular current distribution and anode current deviation further exacerbate the instability of the cell. The ledge plays a critical role in stable cell operation by protecting the lining, reducing heat loss, and stabilizing current distribution. Inadequate ledge formation disrupts the thermal equilibrium and current distribution, adversely affecting the stability of the cell. The high conductivity of copper-insert collector bars of fully graphitized cathodes may lead to more uneven horizontal current density distribution before complete ledge formation, potentially causing more pronounced magnetic field fluctuations and cell stability issues (such as voltage oscillation) during the startup phase compared to conventional steel collector bar cathodes.

Table 4. Voltage operation statistics of two cells after improvement.

Cell No.	Cell age/days	5	15	30
607	Set voltage/V	4.273	4.070	3.933
	Operating voltage/V	4.422	4.140	3.947
	Voltage deviation/mV	149	70	14
228	Set voltage/V	4.274	4.067	3.920
	Operating voltage/V	4.389	4.132	3.954
	Voltage deviation/mV	115	65	34

According to the enhanced statistical data, following the implementation of the improvement measures, the cell operating voltage decreased significantly compared to the pre-improvement values. Particularly after the cell age reached 10 days, both the working voltage and voltage deviation fell within the acceptable range, showing a reduction of over 100 mV from the initial values. These results indicate a favourable improvement effect.

5.3 Improvement of Ledge Regularity and Stability

The stability of the new cell has been significantly improved, ensuring the formation of a well-structured ledge and laying a solid foundation for efficient long-term operation. A stable ledge structure facilitates uniform current distribution and effective heat transfer, thereby enhancing production efficiency and product quality in the cell. Through refined management tailored to the characteristics of fully graphitized cathode cells with copper-insert collector bars, their stability during the early period is notably superior to that of conventionally managed cells of the same type, as well as that of fully graphitized cathode cells with ordinary steel collector bars during same periods. This creates favourable conditions for the rapid formation of a regular and robust ledge in the new-design cells and serves as the key foundation for their subsequent efficient and long-life operation.

6. Conclusion

A smelter implemented a series of innovative management and control measures to address issues during the early operation period of 500 kA fully graphitized cathode cells with copper-insert collector bars. The effectiveness of these measures, particularly innovative voltage regulation, enhanced carbon dust removal, and optimized graphite-coke particle ratio during preheat, has been thoroughly validated through comparative analysis of data from traditional cells in the same smelter as well as pre-improvement data from the new cells. This approach provides a proven solution for the early period management of large-scale fully graphitized cathode cells with copper-insert collector bars, while also offering valuable insights for optimizing other cell types. In future electrolytic aluminium production, these innovative practices can serve as a reference for other enterprises, contributing to technological advancement and sustainable development in the industry.

7. References

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