“Five Cycle Control”(FCC) technology for Aluminium Reduction Cells in China

Yi Xiaobing
CHALIECO GAMI Guiyang Guizhou, China 550081

Keywords: Electrolysis aluminium production, MPPIC and FCC technology

The advanced multivariate process parameters intelligence control (MPPIC) technology[1], developed by CHALIECO GAMI, had been used in many large domestic and abroad green-field built or modernized smelters. In this paper, the new concepts and development contents with MPPIC technology named “Five Cycle Control”(FCC) technology will be discussed. The successful application of this new technology, resulting in significantly higher current efficiency and reduced energy consumption in several pilot and section’s cells of two large domestic smelters, will also be discussed. The original MPPIC technology is currently being upgraded toward FCC technology.

Introduction

Based on several cell control technologies research and application achievements in recent years, especially original “MPPIC technology” developed by GAMI, with reference to and learning a lots of successful experiences from the theoretical research and practices of the cell intelligent control systems at China and abroad and taking the in-depth research of cell control technology software and hardware as the core subject, this technology is a set of more high-efficient, energy-saving and emission-reducing control technology system for aluminium reduction cells, namely “Five Cycle Control” (FCC)technology developed by CHALOEICO GAMI. As to further achieve the obvious economic and social benefits based on the existing conditions for Chinese primary aluminium industry, through the practice and continuous improvement on the large CWPB pilot cells, which of it had been demonstrated in several large CWPB potlines now.

Over the past decade, the original “MPPIC technology” and device with independent intellectual property rights developed by GAMI has reached the international advanced level and achieved great reputation in China and abroad (the special software for the system is the internationally original), which is widely applied in China and abroad with excellent product quality and technical service. However, with the rapid development of world primary aluminium industry, especially the Chinese primary aluminium industry during this decade, it injects the fresh energy to the world primary aluminium industry, but also raises the more and more intensive competition of the area to the higher point, and facing the world economic recession and more intensive energy shortage in China, some aluminium smelters in China have approached loss. Therefore, how to reduce further the production cost becomes the one of the key tasks for each aluminium smelter to face and deal with. At present, the average
power cost of Chinese primary aluminium industry exceeds total cost by 44%, and is about 16% higher than the rest of the world average level[2], so how to reduce the energy consumption of unit product by varied measures becomes the priority for the aluminium smelters in China.

The “Five Cycle Control”(FCC) technology is the latest generation of intelligent control technology for cells researched and developed based on the above basis and situations to ensure each large CWPB reduction cell achieving best technical and economic index with high efficiency and low energy consumption under the stable production conditions of least personnel interruption, which is not only the development direction of intelligent cell control system for primary aluminium industry but also the research and development trend of energy saving and emission reduction for aluminium reduction.

**The concept of “Five Cycle Control”(FCC) technology**

The FCC technology is the expansion and deepening of the original MPPIC technology, which not only improves the original MPPIC for single cell but also brings the monitoring and control for material and energy circulation in primary aluminium production process flow to the system, as well as the hardware of corresponding control systems is upgraded.

Besides being related with some parameters such as designed current intensity, anode current density, work voltage depending on the voltage balance, etc; the “static balance” of cells is also impacted by other factors like the materials selection and installation during the construction period and the process control level in preliminary stage of baking, etc. Especially for various complicated bath systems of cells in Chinese aluminium smelters, the best “static balance” of cells can only be realized by well controlling the “dynamic balance” parameters (including alumina concentration, AlF3 excess and voltage balance); in particular, high current efficiency requires the ideal “cell cavity shape”, and the “static balance” is the basis of ideal “cavity shape” via the basic condition for good cell integral performance. “Superheat” is a bridge between the “static balance” and the “dynamic balance”, and the most important parameter for regulating such 2 balances.

![Figure 1](image1)

Figure 1 shows the relationship between the “Five Cycles” for aluminium reduction process. How to treat such mutual relationship is the key to reach the excellence in high efficiency, energy saving and emission reduction. As shown in figure 1, “superheat” as bridge is the key in “Five Cycle”.

The bath has a liquidus temperature (or melting-point temperature) which is the function of its compositions and impacted greatly by the concentrations of AlF3 and alumina [3]. The sum of such temperature and the superheat is called as the bath temperature. The bath melting-point temperature is impacted greatly by both cell material balance and energy balance. The energy balance is to impact and change the superheat by forming and melting the side ledge profile of molten cryolite, and impact the total molten cryolite amount in bath so as to change the concentrations of AlF3 and alumina.

The superheat is mainly the reaction result of cell energy balance, but they are impacted mutually by the impact of material balance on energy balance. It shall be indicated especially
here that the cell energy balance is impacted by current efficiency, bath and metal level and liquidus temperature.

Figure 1: Relationship among “Five cycles”

Upgrade of Control Model

The main characteristic of the original MPPIC technology is to make analysis and deduction on the measuring data of cell and the data generated during cell control, realizing the identification of “superheat” and on-line control of AlF3 excess at “dynamic balance” in the first time for Chinese cell control technology, with its original control model as the following Figure 2. Such control model can be applied in the basic computer network control platform as the following Figure 3.

Figure 2 Control model of MPPIC technology

However, the most important feature of the FCC technology is to build up one completely new ”cell status analysis system” model after adding some hardware measuring devices such as “precise tapping device”, “high-precision anode stroke measure device” and “intermittent-type automatic measure device for cell temperature”, and improve the “comprehensive
assessments” function in the control model of the original MPPIC technology as per each newly-added computer feedback, thus realize the more accurate “alumina concentration control” and “AlF3 feeding control”. Moreover, this technology also covers the whole set of process control on “fume treatment plant (FTP)” and “alumina circulating conveyance system” affecting directly the “energy balance” and “material balance” during reduction process flow, which not only reduces greatly the unit DC consumption but also the comprehensive AC consumption of unit aluminium and the total fluoride emissions in the system, so as to achieve the sustainable high-efficiency, energy-saving and emission-reduction. The control model of upgraded FCC technology is as the following Figure 4.

![Figure 3 Basic computer network control platform](image)

**Figure 3 Basic computer network control platform**

![Figure 4 Control model of upgraded FCC technology](image)

**Figure 4 Control model of upgraded FCC technology**

The control model of upgraded FCC technology can be applied in the Computer Network Control Platform designed for plant as the following Figure 5.
Key points of the research and development

1) Cell conditions analysis system
   • Intelligent tapping device
     o Improving the tapping accuracy for better control of the “energy balance”;
     o Coordinating with the high-accuracy anode stroke measure device to achieve the cell cavity identification;
   • High-accuracy measure anode stroke device;
     o High-accuracy double-pulse generator (resolution of 0.125mm as figure 6 above), instead of the original pulse generator and rotary counter;
     o Working with the intelligent tapping device to achieve the cell cavity identification.

2) Temperature measure system
   • On-line intermittent bath temperature measure system;
   • Coordinating and connecting with the cell conditions analysis system;

3) Control software development for “dynamic balance”[4]
   • Multi-mode AlF3 feeding control;
   • Double-tracking alumina feeding control;
   • Cloudy superheat identification;
   • Voltage balance control;
   • Cloudy tapping amount deduction;
   • Cell conditions analysis;
4) Aluminum reduction double-recycle optimization
   - Establishment on the energy recycle for single cell and the system;
   - Adding some equipment and materials for the system improvement, with the corresponding adjustment and modification for electrical control system required;
   - The corresponding improvement on the interior of dust filter and fume pipes[5];
   - Research on the relationship between materials recycle and alumina fluidity;
   - The regulation of reduction production operation system.

![Figure 6 - High-accuracy double-pulse generator](image)

![Figure 7 Topologic figure of cell conditions analysis system](image)
**Contents and purpose of research and development**

1) The contents of Technology Research and Development and Application

   The contents of the complete set of “Five Cycle Control” (FCC) technology upgraded based on the research and development and upgrade of original MPPIC technology are as follows:
   - Research and development and application of cell “FCC” software;
   - Research and development and application of aluminum reduction management-control integration system;
   - Research and application of the 8th generation of new-type “cell controller” (GAMI-VIII);
   - Research and development and application of aluminum reduction fume energy recycling;
   - Research and development and application of aluminum reduction material recycling optimization;
   - Research and development and application of cell multi-parameter precise detection technology;
   - Research and application of identification technology for cell cavity dynamic change;

2) Technology research and application team

   Utilizing the technology combination advantage of the participant companies, and in the principle of “coordination, management reinforcement, research reinforcement and high efficiency and high quality”, a competent technical project research and application team is organized as required to ensure successful implementation of project and achieving the expected effect.

![Figure 8 The organization structure of technology research and application team](image)

3) Technical and economic index of demonstration cell line

   This research aims at achieving the following technical and economic index at the world
advanced level after developing all the above technology contents.

- Current efficiency: 94-95%
- Comprehensive AC consumption: ≤13000Kwh/t-Al
- Gross anode consumption: ≤495kg/t-Al
- Anode effect coefficient: 0.05±0.03 times/cell/day
- Unit AlF3 consumption: 16±2kg/t-Al
- Fluorides emission concentration at stack: 1.5±0.5mg/m³

The whole research contents about FCC technology are planned to be completed within 2-3 years.

**Current achievements on research and development**

At present, the research and development of the FCC technology has been applied respectively and gradually in 160KA, 200KA, 240KA, 300KA and 420KA potlines of 2 Chinese aluminium smelters according to the plan, obtaining the stage achievements, in which the average current efficiency of the best potline applied early with this technology reaches 94.5%, and the comprehensive AC consumption is below 13200Kwh/t-Al. The Figure 9 is the multi-dimensional data electronic account results comparison of cell 715# on the 300KA line before and after using the FCC technology.

![Figure 9 The multi-dimensional data electronic account results comparison of cell 715# on the 300KA line](image)

**Acknowledgements**

With the assistance and support from CHALIECO GAMI and the cooperated aluminium smelters for the research and development of the New FCC technology, Thanks to everybody in the scientific research, production and management staff who participating in the project.

**Reference**


**Biography of Presenter**

Yi Xiaobing  
CHALIECO GAMI Co. Ltd.  
Deputy Engineer & Professor

Mr. Yi has been involved in the design and research works for primary aluminium industry about 30 years after graduating from the Centre South of University of China, and took part in the engineering and construction works for several large aluminium smelter projects as chief designer in the domestic and foreign countries. He is an specialist in the area of smelter process technology also, and has been involved with technology exchange with more than 10 countries. He has published 20 papers in journals and international conferences.

易小兵 ——  
中铝国际 贵阳铝镁设计研究  
院有限公司主管副总工程师  
教授级高级工程师

易小兵先生自中南大学毕业至今，在铝工业从事设计和研究工作已经30余年，曾作为项目总设计师先后成功参加了数个国内外大型铝电解工程的设计和施工建设。他还是一个铝电解工艺技术专家。到现在为止，他去过十几个国家进行技术交流并发表在国内外期刊杂志和国际会议上发表了20余篇文章。