

## CURRENT STATUS OF RESEARCH AND DEVELOPMENT ON AUTOMATIZATION AND INTELLECTUALITY FOR PLANTS OF ALUMINUM IN CHINA

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### Abstract

Process automatization and intellectuality is becoming an important strategy when traditional electrolytic aluminum of China does its best to catch up with the world advanced level. With mechanization and automatization widely applied in pot controller, multi-function Crane, anode production and assembly and so on, the improvement of process on comprehensive properties and intellectuality also becomes a new development trend for large aluminum electrolysis enterprises in China. In this paper, researches and developments in recent years, which are concerned on automatization and intellect diagnosis of electrolytic aluminum production in China, are discussed from three aspects. One is control optimization in PTM, the other two are on-line monitoring on multi-physical field and diagnosis on cell status, respectively. The great significance of them in the new industrial revolution of aluminum electrolysis field in China is also given.

### Introduction

The quickening economic globalization not only supplies Chinese industry with a bran-new developmental opportunity, but also puts forward a new demand to Chinese industry. Industrial automation and intellectualization has become the signal of the third industrial revolution. As a basic sector of Chinese industry, aluminum electrolysis industry has been developing rapidly and sustainably in "The 11th Five" periods of China and has made great progresses in many respects such as structural adjustment, independent innovation, conserving energy and reducing emissions. It has basically met the needs of the national economic and social development of China. Under the strategic guide of the new approach to industrialization and under the guideline of "Persist in using IT to propel industrialization and using industrialization to stimulate IT application", it is imperative to transform production managing model from mainly with manpower and handwork to mainly with automation and intellectualization. Mechanization of manufacturing and assembling of anode, automatic control of versatile units, intelligence monitoring on process operations of aluminum reduction cell and real-time monitoring system of flue gas cleaning, which are all applied widely.

In recent years, considerable amount of work is carried out in the fields of optimized control of Pot Tending Machine (PTM) automation and intellectualization of production, which includes on-line monitoring of multi-physical fields and cell state diagnosis. All these have already laid a good foundation for further

development on production control of electrolytic aluminum. The status of research and development on PTM, the technique of on-line monitoring on multi-physical fields and diagnosis of cell state in China are summarized as follows.

### 1. Researches and developments on changing and position fixing of anodes by using PTM

PTM is an important unit in modern electrolytic aluminum production. It is mainly used in automatic surface grinding, poles changing, material feeding, liquid aluminum withdrawing, busbar rising and pot overhaul. As a major professional unit automated in operation, PTM undertakes the task of modern scale production. So the researches and upgrades on the automatic system of PTM can improve efficiency and reduce material consumption. Therefore, industrial output value of electrolytic aluminum production will rise.

Chen Zhi-yuan<sup>[1]</sup> applied PLC to material feeding system of crane in 2005. He made automatic material feeding and automatic fault detection of equipments come true.

Han Min<sup>[2]</sup> finished system modification on alignment of material feeding in crane and achieved different interlocked mechanisms of material feeding equipment by coordinative technique as early as 2006. In 2009, she and Zhang Hai-yan<sup>[3, 4]</sup> together solved the problems of frequent malfunction related to electric apparatus in grab crane. In 2010, they cooperated once more in two researches. First, they applied network control system of Rockwell PLC to realize the functions of fault alarming of crane and parameters monitoring. Second, they adopted 1336 series frequency converter to realize speed adjustment during performance of dolly and cart. This technique meets the demands not only in quick anode transporting by crane but also in crane moving at ultralow speed in the operations such as furnace installation, material feeding and cleaning.

Wang Ming-hai<sup>[5]</sup> utilized automatic altitude measuring system of anode rod on versatile units in 2007. The technique can not only promote efficiency of anodes replacing, but it can bring the decrease of flue gas emission and labor intensity.

Qi Sheng-jun<sup>[6]</sup> built Multi-point Interface (MPI) network or Decentralized Periphery (DP) network by collecting S7-300 PLC to the general line of Profibus-DP equipment in 2008. This system consists of an engineer station with CP5611 network card (or CP5511 network card), a frequency converter equipped with PI-SI communication card and an intelligent motor protector. By using this system, the operations needed in a high position previously can now be done in a lower position. Thus, all functions of crane

are achieved and the efficiency of anodes replacing is greatly increased based on the network technique. In the same year, Wang Feng<sup>[7]</sup> combined both PLC and the technique of transducer control, which can realize precise alignment between dolly and cart in 2008. Besides, a set of new multifunction device used for residual block salvaging was designed by Gong Hui-lingin<sup>[8]</sup> in this year. The device can completely salvage all residual blocks fallen into the cell during residual anode lifting just in time. This can also avoid individual injury caused by manual residue cleaning and the potential danger caused by the damage of weather strip plate.

Zhu You-hui<sup>[9]</sup> adopted bus control mode of whole-crane network to realize the functions such as reliable transmission of signals, simple circuit control of electrical machine and anti-jamming capability of magnetic fields in 2009. The whole network is made up of an industrial PC controlled with electronic touch mode, two PLCs, nine DP and a set of remote control system. In this year, Pan Yu-cang<sup>[10]</sup> applied model LCSP-ZG25 intelligent electronic control equipment, which is a monitoring system insulated, to PTM and made a progress in the researches such as real-time monitoring and automatic protecting on insulation structures of PTM.

In 2011, Wang Tao<sup>[11]</sup> innovated and optimized the techniques on limited position control of cleaning-scraper and insulated cover for protecting by installing soot blower along the track of dolly and cart in previous system.

Just because of so many researches and improvements, the comprehensive properties of PTM in electrolytic aluminum of China have been promoted continuously. Nowadays PTM in China has many excellent properties such as automatic precise alignment, intelligent fault diagnosis, stronger anti-jamming capability and better adaptability. Besides, it also achieves lower level of equipments breakage, labor intensity and potential danger in work safety. In a way, the automation and intellectualization of PTM equipments is being shown adequately from all respects in electrolytic aluminum of China.

## 2. Researches and developments on on-line monitoring technique of multi-physical fields

Physical fields of aluminum reduction cell mainly include electric field, thermal field, temperature field, magnetic field, flow field and stress field. The distribution of physical fields directly affects some key techno-economic indicators such as current efficiency, energy consumption and life of aluminum reduction cell. So, continuous on-line monitoring on multi-physical fields of aluminum reduction cell becomes the important method on judging cell state and improving evaluation indicators.

At an earlier time, there were many disadvantages in the process of intermittent manual measurement. They are the problems of unsynchronized measurement time, larger difference between measurement results and actual values, higher labor intensity and discontinuous measurement result. In recent years, researchers have made great contributions in on-line monitoring on temperature, current, magnetic intensity and the shape of ledge profile in the cell.

In the research on the system for on-line monitoring and analysis of anode rod in aluminum reduction cell, Wen Bin<sup>[12]</sup>, Wang Zhen<sup>[13]</sup>, Tie Jun<sup>[14]</sup> and Fan Zhao-jun<sup>[15]</sup> et al. made progresses in the past six years. They designed a kind of modular

hardware architecture and a set of reliable software system used in data acquisition and analysis. Then, the resource data is acquired to judge current distribution and the status of aluminum reduction cell.

In 2006, Zhang Jia-qi<sup>[16]</sup> developed a Delphi7.0 software system, by which three objects can be monitored. They are anode-cathode distance (ACD), three dimensional states of liquid aluminum fluctuation and the distribution of anode rod. He also put forward the idea of operating and managing on homogenizing ACD based on on-line monitoring system of ACD and liquid aluminum fluctuation.

In 2007, Lin Yan<sup>[17]</sup> successfully developed a software system on shape monitoring of ledge profile in the cell by an organic combination of FORTRAN and Visual Basic languages. Industrial tests prove that the software, with friendly interfaces, is easy to be operated and can realize on-line monitoring of freeze profile in the cell. Also it has the advantages of high modularization and independence, and it is easy to be maintained.

Wang Zi-qian<sup>[18]</sup> designed a real-time monitoring system to monitor the fluctuation state of liquid aluminum level in aluminum reduction cell and to estimate the noise of the cell by a computer with C8051 chip as core in 2009. In the system, signals from data acquisition circuit can be processed and fitted, and the data can be memorized automatically. The level fluctuation curve of liquid aluminum can also be displayed by upper level computer. Industrial tests verify that the system not only can intuitively reflect the oscillation of single-source and multi-source in aluminum reduction cell, but also can find the noise caused by anode moving.

In 2011, Meng Ling<sup>[19]</sup> developed a new model on high temperature resistance sensor based on fiber Bragg gratings with Sb-Er-Ge and Sb-Ge rare earth co-doped and constructed a monitoring network of multi-point temperature by the sensors. By this technique, it is possible to realize online temperature monitoring in the conditions of intense magnetic fields, high temperature and dust. Periodic phase mask irradiated by ultraviolet laser solves the key technical issue which is that the fiber grating refractive index modulation diminishes at high temperature.

In a word, compared with the intermittent manual tests, automatic and continuous on-line monitoring systems have the characteristics of stronger anti-jamming capability, the convenience of site installation, the simplicity of operation and lower labor intensity of monitoring. Besides, it can acquire data in real-time by single-channel or multi-channel and store data continuously. Together with the visual convenience of data curves, all the above provide basic information for cell status diagnosing, cell structure design and simulation model building.

## 3. Researches and developments on cell status diagnosis

In the researches on the diagnosis of anode fault and cell status, Liang Han<sup>[20]</sup> developed a selection method applied in the suppression of cell noise. The nature, intensity and the sound source of noise can be judged by model LH-70 anode current measuring instrument. Li Chun-yan<sup>[21]</sup>, Yang Jun<sup>[22]</sup>, Liu Fei-qi<sup>[23]</sup> et al. developed a location detection system of anode effect in Windows 98/XP system by the methods of spectrum analysis, time domain analysis, empirical mode analysis and neural networks. Besides, they also developed an auxiliary system line for the acquisition, analysis and management of anodic signals oscillation. The system can detect and forecast anode effect. Yin Xiao-bao<sup>[24]</sup>

built a diagnosis model with neural network based on the characteristics of energy on anode current signals and realized the diagnosis of the cell status.

### Conclusion

To sum up the above, the researches and developments, which are relative to automatization and intellectuality of PTM, on-line monitoring of multi-physical fields and the diagnosis of cell status, bring a new revolution to aluminum reduction cell in China.

First, a new idea of industrial production added with information technology. It is shown in many aspects from production, monitoring and control to diagnosis, optimization, dispatch, management and decision. The idea provides a guarantee for the improvement of production efficiency, conserving energy, reducing emissions and occupational safety in electrolytic aluminum production.

Second, with the gradual decrease of population extra dividend and the development of automatization and intellectuality in China, especially facing the problem of non-uniformed distribution of the population in China, the production mode of automatization and intellectuality can significantly decrease labor costs and offer new hope for the development of electrolytic aluminum production in West China.

Third, with the implementation of automation in the operations, which include anode manufacturing and assembling, material controlling, malfunction eliminating and flue gas cleaning, the emphasis of researches and developments in electrolytic aluminum production of China will be laid on intellectuality of production.

Fourth, the further development of automatization and intellectuality of electrolytic aluminum production decreased the difference between the technological level of China and the level of advanced countries in the world.

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