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APPLICATIONS OF NEW STRUCTURE REDUCTION CELL TECHNOLOGY IN CHALCO'S SMELTERS

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Abstract

A new generation of key energy saving technology for aluminum reduction has been implemented by Chalco. A new structure aluminum reduction cell technology has been successfully developed by Chalco and is now widely applied in several of Chalco's smelters. This new structure includes key technologies such as the new specially designed cathode installation, a heat preservation lining and a low voltage operation control system. The molten metal fluctuation that is driven by the great magnetic field is greatly restrained in the cells, based on reducing the anode to cathode distance (ACD) without any loss of current efficiency. This realizes a lower energy consumption and less GHG emissions. The industrial tests and applications of this technology have been carried out successfully in the various scale aluminum reduction cells in Chalco's smelters and about 12000 kWh of DC consumption per ton of aluminum and 3.70-3.75 V of cell voltage have been achieved.

Introduction

The large amperage prebaked reduction cell technology has been wide applied and optimized since 280kA prebaked cell technology was successfully developed in China in 1996. The design technology with magnetic field simulation, modern computer control systems, high graphite cathodes, new lining materials and high quality anodes are used in Chinese aluminum industry so that the DC consumption is reduced to 13-13.5 kWh per kg of aluminum.

Nevertheless, a great energy saving pressure is put on Chinese smelters due to the higher and higher energy prices. In addition, there are enhanced requirements for energy saving and emissions reduction from Chinese government and environmental protection agencies. The energy cost in the most Chinese smelters occupies more than 40% of total production cost. To develop the new generation reduction technology aimed mainly on great energy saving and sustainable development becomes urgent and more important.

The study on energy consumption reduction in the smelting process has been carried out by many aluminum companies.

Comalco Research Centre and CSIRO, Australia make a great effort on the drained cell technology and the great progresses in such aspects as cathode TiB_2 coating technology, cathode structure with slope surface and low ACD operation etc.

Northeastern University in China developed the technology to change cross section shape of the cathodes for low cell voltage in recent years. This technology is based on blocking walls in the molten metal in the cells by changing cross section shape of the cathodes to retard the metal flow so that ACD can be reduced. But the cracking and breaking are possibly occurred for the abnormal shape cathodes due to the impact and erosion by molten metal flow and high stress inside the cathodes.

Shenyang Aluminum and Magnesium Engineering Institute developed the technology to put the barrier blocks on the cell cathodes to block the molten metal electro-magnetic flow for lower ACD. But selection of the block materials are still very difficult for they have to undertake the serious smelting operation conditions without great corrosion and erosion and to be stable enough with suitable density and shape.

Chalco has put a great importance on the new structure reduction cell technology and set up a series of R&D projects around the technology development. About 10 years have been spent on laboratory tests, 4kA cell simulation experiments, 160kA new structure cell tests and on large scale industrial applications. A great achievement has been made by the new structure reduction cells that the DC consumption is reduced by about 1000 kWh per ton aluminum while the cell operation is kept very stable for sustainable results.

Development of the new cell structure

The theoretical considerations for energy saving in reduction cells were made during R&D of the new structure cells.

The energy efficiency mainly depends on DC in the aluminum reduction process, while the direct current consumption can be calculated by the following formula:

$$DC = 1000V/(\eta \times 0.3356)$$

With DC--direct current consumption, kWh;
V--cell voltage, V;
η--current efficiency, %.

It can be seen from formula (1) that cell voltage reduction should be major approach to reduce energy consumption and improve energy efficiency. And the most efficient way to reduce DC is ACD reduction. The cell voltage will be reduced by more than 300mV by only 10mm reduction of ACD and DC will reduced by about 7% if no current efficiency loss happens. It is concluded

that ACD reduction can be the great potential and important approach for energy saving in aluminum reduction.
Nevertheless, the reduction of ACD and cell voltage is restricted by the molten metal electro-magnetic flow in the common cells. About 4.5-5.5 cm of ACD has to be kept for reducing aluminum secondary reaction loss caused by fluctuation of bath--metal interface and metal diffusion to anode area. The general cell voltage distribution is shown in Figure 1.

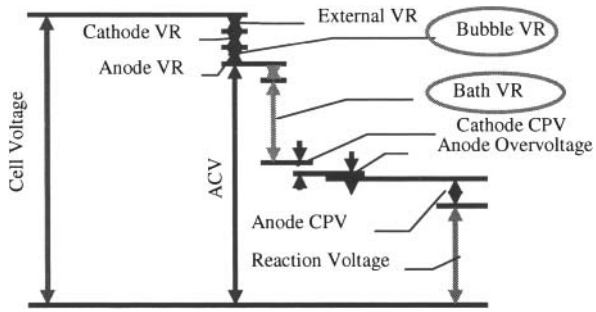

Fig 1 Voltage Distribution in Reduction Cell

With: ACV—Voltage Between Anode and Cathode;
VR—Voltage Reduction;
CPV—Content Difference Polarization Voltage

It can be found in Figure 1 that the voltage reduction in the bath is up to 1.5-1.6V and occupies almost 35-40% of total cell voltage under 4.5-5.5 cm of ACD.

Most of this part of energy input will change into useless heat and the heat emitted. The reduction potential for the bath voltage might be 400-500mV at least according to the study results. Therefore the focus is on finding some way to reduce ACD and bath voltage reduction without any efficiency loss.

The current efficiency mainly depends on the aluminum secondary reaction happened in the anode areas and caused by the reaction between the aluminum dissolved in bath and CO_2 or even anodes. So reduction of aluminum content in the bath and its diffusion under a lower ACD is by us regarded the best solution for low cell voltage without efficiency loss.

For the present Hall-Héroult aluminum reduction technology it is only through changing the design concept and the key technological route that the aluminum content in the bath and its diffusion can be reduced.

The horizontally installed cathode and side wall lining structures of the cells are changed so that the fluctuation of molten metal caused by the magnetic field is greatly reduced and the CO_2 is removed quickly from anodes areas.

This is the technical basis for the development and design of the new structures in the cells. In order to get the better operation results it is necessary to develop suitable operation technology to fit to the new structure cell.

The cell voltage reduction should correspond to the heat loss reduction to keep heat balance in the cells. As Figure 2 shows the reasonable way is reduction of heat emission from the cells.

The most feasible approach to reduce heat losses is to use heat preservation materials for the areas of the side walls and enhance the coverage over bath, which is the heat preservation lining structure design concept of the new structure cell technology.

It will become difficult to keep uniformity and homogeneousness of ACD for the different anodes and aluminum content in the different areas in the cells under low ACD and less fluidity. The technical challenge can be solved by optimizing both cell structure and operation conditions.

The application of TiB_2-C composite wetted cathodes developed by Chalco is a great benefit to the operation of the new structure cells due to high wettability, high resistance to sodium corrosion and high mechanical strength.

The wettability of TiB_2 composite cathode and common cathode is compared in Figure 3.

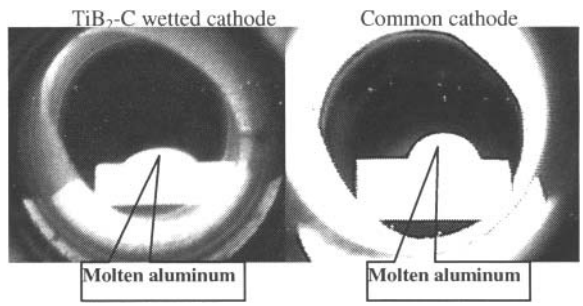

Fig.3 Wettability Comparison of Cathodes under Vacuum

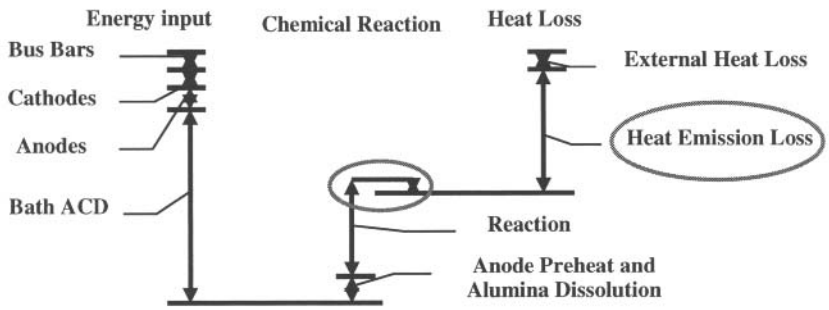

Fig.2 Energy Balance in Reduction Cell

The operation technologies of new structure cells

The baking and starting up methodologies for the new structure cells have been developed. The cathode structure permits to apply the simple, reliable and low cost coke resistance heating practice for the cell baking with the advantages of homogeneous baking, and therefore the benefit to longer cell life. During the development procedure lots of technical problems were solved for reducing the surface oxidation and thermal stress impacts.

A quick voltage reduction methodology after cell start up has been developed as well. The cell temperatures and bath chemistry should be adjusted synchronously with the cell voltage reduction so as to keep the cell operation stable and regular ledge formation on the side walls. The energy saving can be achieved during the first period after start up by the quick reduction of cell voltage.

A new cell control system has been developed for the new structure cells that is adapted to the new requirements for low cell voltage and low ACD. One of the advantages of the new structure cells is to permit higher alumina concentrations in the bath without too much sludge formation on the cathodes, which will provides better conditions for reducing AE and PFC's emission. This is proven by the industrial application.

Main results of the industrial applications in Chalco's smelters

The new structure cell technology is applied in almost all the Chalco's smelters. The industrial tests were carried out in the various types of cells, such as 160kA, 200kA, 240kA, 280kA and 300kA cells.

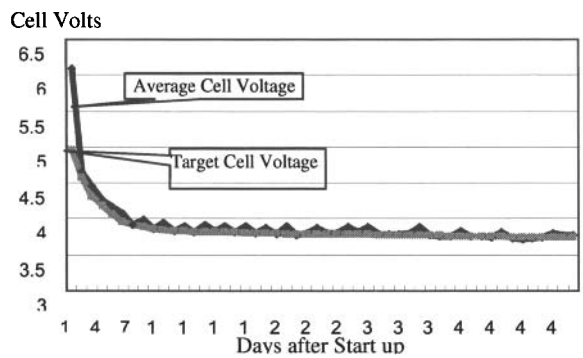

Fig. 4 Cell Voltage Change of 280kA Cells after Start up

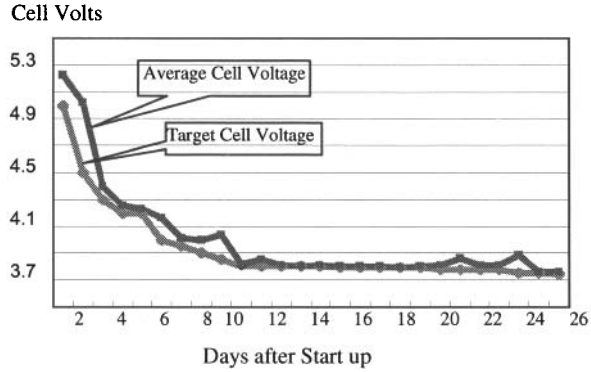

Fig.5 Cell Voltage Change of 200kA Cells after Start up

It is concluded from Fig. 4 and Fig. 5 that the cell voltages of all the new structure cells, whether 280kA or 200kA cells, will be reduced quickly after their start up and to the target cell voltage of about 3.7-3.75 volts in two months. All the new structure cells have been operated stably and controlled constantly at the target cell voltage.

It is confirmed by the tests and applications that the new structure cell technology developed by Chalco has the better applicability, operation stability.

The working cell voltages of the smelters using the new structure cell technology are usually reduced to 3.7-3.75 V without obvious efficiency loss.

The electricity consumption for the new structure cells in a long term operations is accounted and compared with the average consumption of the Chinese smelters in the past years from 2006 to 2009 as shown in Fig. 6.

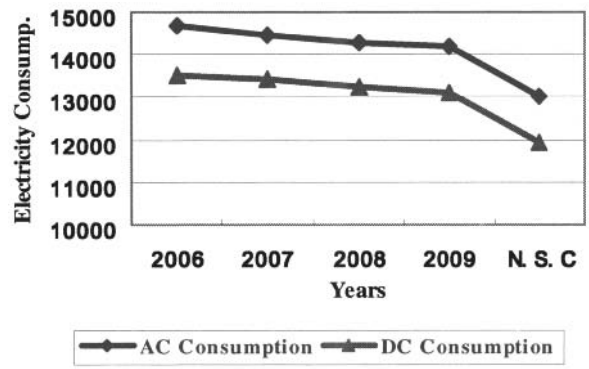

Fig. 6 AC and DC Electricity Consumption Comparison
N.S.C--- for New structure cells in 2010
Others--Average for Chinese smelters in the past years

It can be found in Fig.6 that the AC and DC energy consumption is reduced to about 13000 and 12,000 kWh per ton of aluminum respectively for the new structure cells, which is at least 1000 kWh/ton less than the common technologies.

The input energy into the cells is reduced by about 7% and the heat balance is kept by heat emission loss reduction. The overall energy utilization efficiency is improved by 6.34%.

Furthermore the anode effect coefficient of new structure cells can be reduced to less than 0.05 owing to their higher alumina content in the bath without sludge on the cell bottom.

New structure cell technology has been expended over the Chalco's smelters since its great technological and economical advantages. More than 300 cells of 160kA, 200kA, 240kA, 280kA and 300kA have been set up and put into successful operation in Chalco's Lanzhou Branch, Liancheng Branch, Qinghai Branch and Jiaozuo Wanfang Smelter etc. in 2009-2010.

Nevertheless, the cell temperature and alumina content fluctuations easily take place due to the smaller heat capacity of the new structure cells. This results in that all the operation parameters should be more accurately controlled and the various

operations, especially the aluminum tapping and anode changing, have to be more careful and prepared.

The cell structure, operation parameters and control system of the new structure cell technology has to be optimized continuously in the future applications to further reduce energy consumption, improve efficiency and aim to realize zero anode effects.

Conclusion

[1] The new structure aluminum reduction cell technology has been developed and widely applied by Chalco through the study and tests for nearly 10 years.

[2] The key technical solutions for the low cell voltage without efficiency loss are the following:
   a. horizontal installed wetted cathodes;
   b. new structure of cathodes;
   c. heat preservation lining;
   d. special baking and start up technologies;
   e. new control system and operation technology.

[3] The great technical and economical achievements have been made for the new structure cell technology. The DC power consumption is reduced by more than 1000 kWh per ton to 12000 kWh/ton of aluminum, and the energy utilization efficiency is increased by about 7%. In addition, PFC's and CO_2 emissions are alsogreatly reduced.

[4] Coninuous improvement of the new structure reduction cell technology will further optimize energy consumption, improve efficiency and minimization of anode effects.

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