RA-550 Cell Technology: UC RUSAL's New Stage of Technology Development

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Abstract

In 2016, five pilot cells were started up at UC RUSAL's Sayanogorsk Aluminum Smelter. The pilot cells use a completely new busbar design using two-side current feed anode risers, providing for efficient magnetic field compensation in aluminium metal pad and excellent MHD stability without using additional magnetic field compensation. The last seven months have validated the main calculated design parameters of the RA-550 cells and high level performance of main operational parameters, such as current efficiency and power consumption. The pilot cells are meeting or even exceeding the industry's benchmark environmental parameters. Today's key performance indicators confirm that UC RUSAL has developed a competitive, highly-efficient ultra-high-amperage cell technology that can be used both for greenfield and brownfield projects. Plans are to continue testing the RA-550 technology, including amperage increase up to 570 - 600 kA and optimizing energy efficiency over the next two years.

Keywords: Rusal RA-550 cells, two-side current feed anode risers, MHD stability, RA-550 cell key performance indicators, RA-550 environmental parameters.

1. Introduction

For the last 40 years, the main vector of development of the aluminum industry has been related to increasing the pre-baked (PB) cell amperage (Figure 1.)

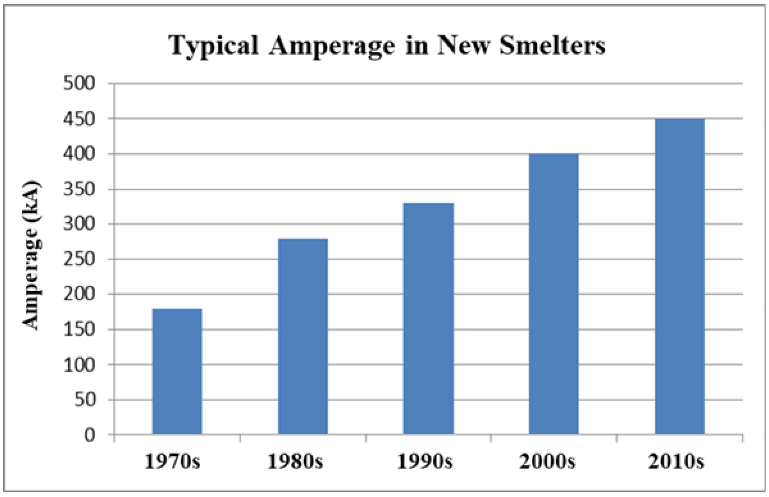

Figure 1. Cell amperage increase over decades.

Evidently, using more powerful cells makes it possible to reduce CAPEX for construction, to improve operational efficiency (or productivity) with retaining, or even improving, the Key Performance Indicators (KPI), which provide for a quicker return on investment and payback of greenfield projects. However, increasing amperage and cell dimensions may lead, at a certain stage, to serious technical limitations; such limitations make further development in this direction quite difficult.

Today, the main limitation, which challenges further cell amperage increase, is the difficulty with magnetic field compensation in the aluminium metal pad (especially the compensation of the vertical component of the magnetic field), which is the necessary condition for MHD stability that, in turn, determines the possibility of achieving the best operational results, such as high current efficiency and low specific energy consumption.

The attempts to create ultra-high-amperage cells operating at higher than 500 kA started back in the 1990s. By the year 2000, there were several operating 500-kA cell prototypes in the world. However, up till now, no operating smelter in the world has presented performance figures for 500-kA technologies that exceed those for 400 – 450 kA technologies, which lately have gained general acceptance for application in greenfield projects.

One of the main factors retarding the implementation of ultra-high-amperage cells, is less efficient magnetic field compensation in the liquid metal pad. As of today, technical and engineering solutions used in the all known 500-kA technologies have shortcomings reducing the economic efficiency and/or energy efficiency of such technologies:

- Additional compensation loop, providing for an acceptable magnetic field configuration in the metal pad but generating additional energy loss in the loop, as well as additional cost for the loop and equipment supplying power to the loop.
- High metal pad, providing for cell MHD stability but deteriorating alumina dissolution conditions and leading to an excessive ledge length on the cathode block, which ultimately reduces energy efficiency and productivity.

Considering the existing experience of operating ultra-high-amperage cells (500 - 600 kA), it is safe to conclude that this amperage level is critical, from the view point of ensuring good magnetic field compensation in the metal pad. This is largely due to the standard approach to developing the busbar design, which includes side-by-side cell arrangement and exclusively one-side current feed through anode risers, which are located along upstream side of the cell. It is obvious that such an asymmetric, one-side arrangement of current-feeding risers predetermines the asymmetry of the magnetic field in metal at the sides of the cell and, in turn, reduces cell MHD stability and which results in uneven metal pad heaving between the upstream and downstream sides of the cell.

2. Project Implementation

In November 2014, a decision was made to launch a project to develop a 500-kA+ technology, which is named ‘RA-550 Cell Technology’, and to construct a pilot area at UC RUSAL’s Sayanogorsk Aluminum Smelter to test such a technology. In December 2014, the new cell concept was defined as follows:

1. A totally new busbar configuration is to be used to ensure a symmetrical configuration of the magnetic field in metal at the sides of the cell, by means of using two-side current feeding.
2. No compensation loop is to be used to implement such a technology.
3. The so-called ‘modular approach’ is to be used to provide for the possibility of developing more powerful cells with 700 - 1000 kA.
4. The cell layout is to be as dense as possible to increase metal output per unit area.
5. The consumption of materials to manufacture each element of the cell is to be reduced (cathode shell, superstructure, lining, anode rod, etc.)
6. The gas exhaust rate is to be reduced and environmental performance is to be improved.

Considering the limitations due to existing potroom width available for the installation of the new cells, the amperage of the new technology was defined to be 520 to 570 kA.

From January to March 2015, the following was carried out:
- Mathematical modeling of all the cell elements;
- Definition of technical solutions for all the cell units and
- Commencement of detailed engineering (completed by August 2015).

In parallel to the commencement of the detailed engineering, a site for the installation of new cells was started to be prepared. For the installation of the new cells, an operating potroom at the Sayanogorsk Aluminum Smelter was selected, where seven 255-kA cells of older design were shut down and dismantled in order to install new RA-550 cells (Figure 2.)

In the meantime, work on the power supply system started. Such work included booster and external busbar installation. In October 2015, work on the busbar started. In December 2015, work on the cathode shell started. Then – in 2016 – work on the lining and superstructures was carried out. By September 2016, the RA-550 Pilot Area, including all the required tending equipment, was ready. The total implementation time of Phase 1 of the Project (5 cells) was 22 months, and it included project team mobilization and RA-550 cell design development.

Figure 2. Site selected for the installation of the RA-550 cells.

Project Phase 2 included modifications of the RA-550 cell design in terms of energy efficiency. Such modifications included changes to the busbar design, providing for a reduction in power consumption by 400 - 450 kWh/t Al, as compared to the basic design. Three modified cells were successfully started up in the third quarter of 2017.

CAPEX for the construction of the RA-550 Pilot Area was less than 2000 USD/t, which is profoundly lower than spent on all similar projects and below the level achieved for aluminum production facilities on an industrial scale.

3. Project Phase 1 - Deliverables

In the period of 25 September 2016 to 14 November 2016, five pilot RA-550 cells were put into operation (Figure 3.)

To analyze data on cell pre-heating (or baking), start-up and early operation of each cell (in order to make, if necessary, corrections for future cells), cells were preheated and started up 1 to 1.5 weeks apart. All the five RA-550 cells were started up in standard mode, without any process deviations; moreover, the design (or calculated) pre-heating and start-up parameters were validated and confirmed. In the meantime, cell cut-in equipment, providing for safe cell cutting-in (without any reduction in the line current), was tested.

Figure 3. RA-550 pilot area.

During the two weeks after the start-up, the voltage at each cell was reduced down to the target; the level of noise (which characterizes cell MHD stability) remained low (at a metal pad of 18 cm before tapping). The above confirms good MHD parameters of the busbar.

Two months after the start-up, when the bath chemical composition stabilized and bottom/side ledge formation was complete, the magnetic field in the metal of the pilot cells was measured. The magnetic field measurement results showed that the RA-550 busbar design created the magnetic field with a distribution that exceeds the design values (Figure 4) and provides excellent MHD stability (Figure 5), including minimum metal-to-bath interface heaving. The vertical magnetic field has the following characteristics:

- Maximum value of the vertical component of the magnetic field in the metal is less than 2.5 millitesla;
- Multiple sign change of the vertical component at each longitudinal side of the cell (7 sign changes on one side and 6 changes on the other one); and
- Reversal of the sign of the vertical component of the magnetic field relative to the longitudinal axis of the cell ('propeller configuration').

Figure 5 shows that the RA-550 busbar design (considering the current level of performance of the pilot cells, which provides for a cell power consumption of approximately 11 900 kWh/t Al) makes it possible to considerably reduce the voltage without raising the cell noise. In a longer run, this potential makes it possible to have a cell net power consumption of less than 11 500 kWh/t Al and a gross power consumption of approximately 12 000 kWh/t Al.

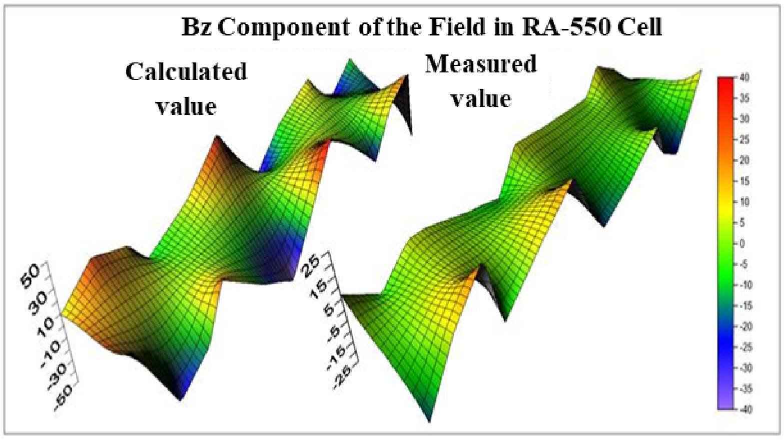

Figure 4. Magnetic field vertical component in metal, both calculated and measured.

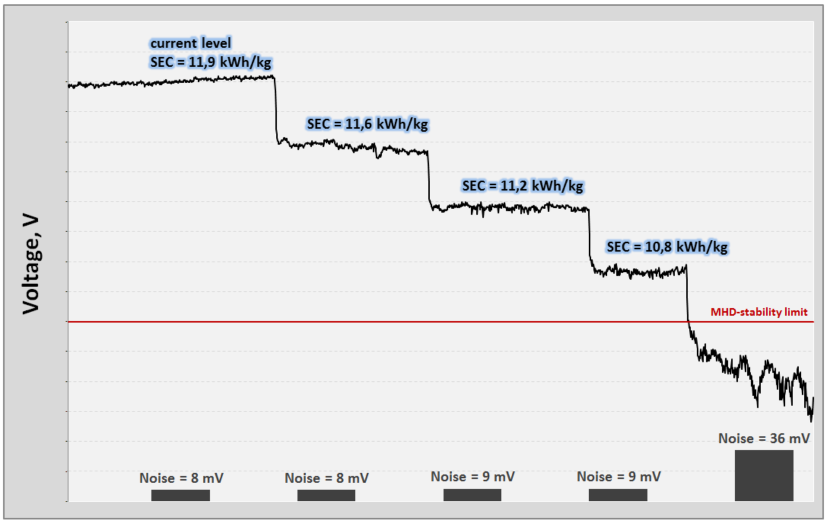

Figure 5. Measurement of the MHD stability limit.

Cathode shell temperature measurements of the pilot cells showed that the new busbar design provided the so-called thermal field symmetry at the longitudinal sides of the cell – in contrast with the classical design with one-side current feeding where higher temperature is observed at the downstream side of the cell.

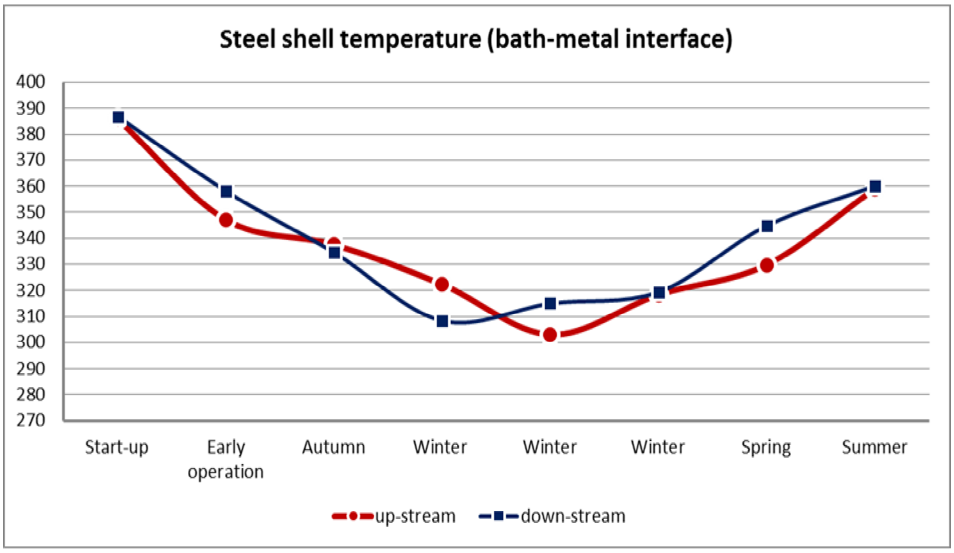

Figure 6. Cathode shell temperature variation through seasons at metal-bath interface level in pilot cells.

4. Basic RA-550 Cell Design Performance

After stabilizing the process condition of the pilot cells and achieving the targets in the process of normal operation, much work was carried out to optimize the pilot cell tending and control methods, including:

- Alumina feeding control,
- Bath composition control,
- Heat balance control,
- Metal tapping control ,
- Optimization of anode change / anode dressing operations.

As a result, the performance of the pilot RA-550 cells considerably improved. Table 1 shows the performance of the basic RA-550 cell design, ‘At the beginning’ compared to ‘As of today’.

Table 1. Pilot RA-550 cell performance.

Parameter	Beginning (December 2016 to February 2017)	As of today (June 2017 to July 2017)
Amperage, kA	520	525
Current Efficiency, %	94.60	95.82
Cell Voltage (Gross), V	4.217	4.136
Total Power Consumption (DC), kWh/t	13 267	12 846
Carbon Consumption (net), kg/t	407	398
Average Noise Level, mV	14.3	9.8
AE frequency, AE/pot-day	0.32	0.015
AE duration, s	52.7	12.6
Total F Emissions, kg/t	0.24	0.21

5. Conclusions

UC RUSAL’s engineers have developed a state-of-the-art, highly-efficient RA-550 technology, which, along with high amperage and high productivity, gives performance indicators conforming to the best industry standards and, in a longer run, exceeds the level achieved as of today.

The innovative solutions included in the busbar, such as two-side current feeding and modular design, eliminate the existing limitations on developing an ultra-high-amperage cell with excellent magnetic field compensation in metal and high operational performance without using a compensation loop.

Over the next two years, UC RUSAL plans to further increase the efficiency of the new RA-550 technology in terms of productivity, energy and environment.