RUSAL Resource-Saving Technologies

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Abstract

The cost-effective use of resources is a determining factor in reducing the cost of aluminium production. In order to reduce production costs, UC RUSAL develops **no-cost/low-cost** technical solutions as well as **costly and high-cost solutions**. Most of the technical solutions have been tested on prototype pots, many of which have been implemented in RUSAL's potlines.

The company's Energy Conserving Pot Design project uses a strategy focusing on two areas. The first is aimed at improving energy efficiency based on no-cost technical solutions (for example, efficient alumina feeding and voltage control algorithms ensuring a stable reduction process with a low anode-cathode distance, energy-efficient lining designs, etc.), low-cost/costly solutions (for example, elongated anodes with a 4-stud anode rod assembly, steel-copper collector bars, etc.), as well as high-cost technical solutions (for example, energy efficient anode suspension beams, new or retrofitted busbars, etc.). The basic principle of the second area is cost reduction in pot relining through the use of unshaped materials using lignite semi-coke and dry barrier mixes. Unshaped materials can significantly reduce the cost of lining the sub-cathode zone, which enables to recycle at least 80 % of lignite semi-coke.

The above technical solutions are applied for various types of pots in the aluminium smelters in Krasnoyarsk, Sayanogorsk, Bratsk, Novokuznetsk and Irkutsk.

Key words: Cost-effective use of resources, no-cost/low-cost, costly and high-cost technical solutions, unshaped lining materials.

1. Introduction

In the existing pot designs, most of the heat losses fall on the anode cover and the longitudinal side walls (the distribution of the pot heat losses is shown in Figure 1 [1]). This amount of heat losses requires heat recovery based on the pot voltage, which entails increased power consumption and, as a consequence, an increase in aluminium production costs. In this regard, as part of the Energy Conserving Pot Designs project, a design of the cathode has been developed with an increased anode cover depth in order to reduce heat losses from the anode cover, and with an insulated side lining to reduce heat losses from the longitudinal side wall of the pot. Due to the reduction of heat losses, this design results in a more stable reduction process with a lower anode-to-cathode distance, and with lower energy consumption.

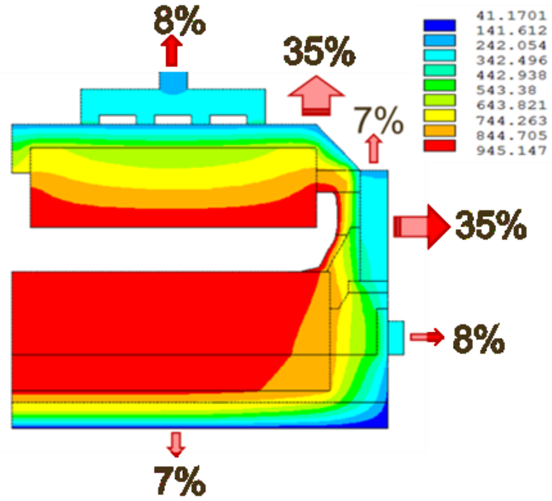

Figure 1. Distribution of heat losses of the pot [1].

To increase the MHD stability through a reduction in the horizontal currents and through a reduction of the cathode voltage drop, a steel-copper collector bar design has been developed and tested in different types of pots. In addition, to ensure a stable reduction process based on continuous monitoring and automatic adjustment of process parameters, the so-called Bath Composition Stabilisation (BCS) algorithm was developed, which reduced variations in the cryolite ratio (CR) and bath temperatures. Also, an algorithm for Automatic Control of the Thermal Balance on the Pot (ACTBP) was developed, which implements the coupled control of a specified voltage and fluoride additives to stabilise the temperature and CR in a specified process range.

Refractory and heat-insulating materials in the form of various-sized bricks are traditionally used as aluminium pot lining. The continuous increase in the cost of energy resources leads to an annual increase in prices for lining materials. In addition, the use of lining materials in the form of bricks is extremely labour intensive since it involves brick laying - an operation whose automation is extremely complicated. The presence of joints between the bricks leads to an increased risk of metal and bath penetrating the cathode shell, and thereby increases the consumption of fluorides. The volume of aluminium production scrap at industrial landfills amounts to tens of millions of tonnes. Of these, about 30 % of the waste comes from spent refractory and thermal insulation materials (spent potlining, or SPL), the recycling of which is a complex process. Up to 40 % of this waste is represented by fluorides, which, along with compounds such as cyanides, which are formed during the reduction of aluminium, are the main cause of the environmental problems in the aluminium industry [2].

One of the possible ways of solving the above-mentioned problems is by using RUSAL's new resource-saving technology that reuses unshaped materials for lining the cathode assembly of pots. A distinctive feature of the technology is the use of a virgin, unshaped lining material (ULM) based on lignite semi-coke [3, 4, 5] and specialised equipment for its installation and compaction.

This article presents the main test results of certain energy-efficient technical solutions that make it possible to reduce power consumption and ensure a stable reduction process without significant capital expenditures. In addition, this article presents the main results of the application of the new unshaped material for lining the cathode assembly and describes the main aspects of the equipment for loading, laying and compacting ULMs.

2. Increased MHD Stability and Cathode Voltage Reduction

Technical solutions were tested on OA-120 pots with an amperage of 140 kA at the Krasnoyarsk aluminium smelter. It saved electricity by reducing the cathode voltage drop in the bottom and decreasing heat losses. The steel-copper cathode collector bars, the design of the cathode assembly with a deeper insulation and the insulated side lining were all implemented and tested. In addition, also the height of the carbon anodes was increased. The implementation of these technical solutions resulted in a shorter start-up period by reaching an operating voltage of 3.960 V only 30 days after start-up. Figure 2 shows a diagram of voltage reduction during the start-up period of energy-efficient pots using the OA-120 technology.

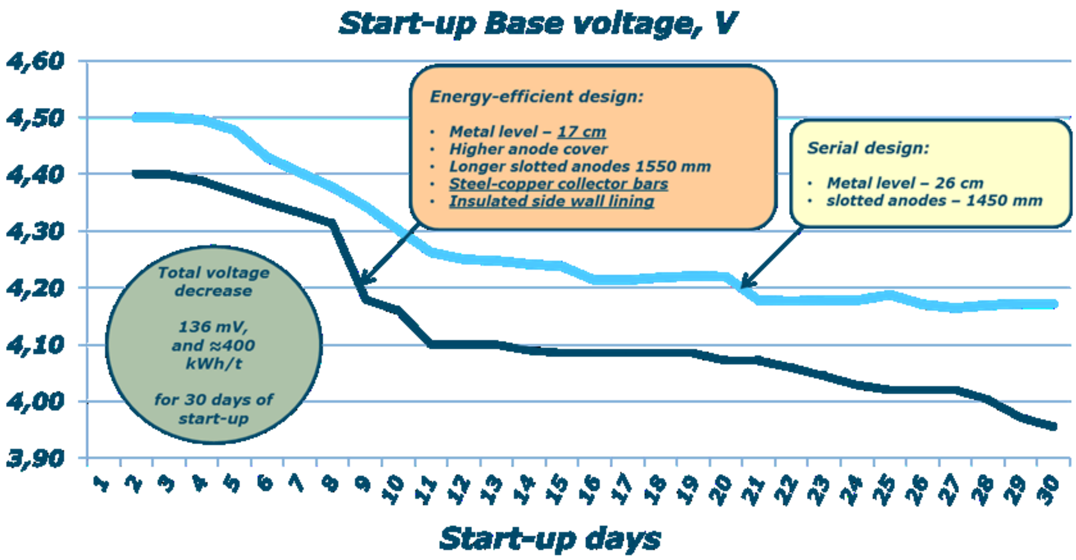

Figure 2. Diagram of voltage reduction during the start-up period.

During the period of field tests in energy-efficient pots with current efficiency of 95.6 %, a reduction in electricity consumption by more than 900 kWh/t Al (13 127 kWh/t Al) was achieved when compared with standard pots (14 042 kWh/t Al). Due to the use of steel-copper cathode rods, the cathode voltage drop was reduced by 60 mV with respect to the standard pot design.

In addition, these technical solutions were applied in a number of pots at the Irkutsk Aluminium Smelter using the OA-300 technology with an amperage of 330 kA where, thanks to the use of steel-copper collector bars, the cathode voltage drop was reduced by 60 mV as well and the associated power consumption was reduced by more than 550 kWh/t Al (12 824 kWh/t Al) with respect to standard pots (13 406 kWh/t Al). The current efficiency for the OA-300 energy-efficient pots was 95.4 % at a target voltage of 3.788 V.

3. Reduction Process Control Automation

The heat and mass balance of the aluminium pot is controlled by actions of an automation system: adding AlF_3 through the automatic fluoride feeding system, adding Al_2O_3 through the automated alumina point feeding system and changing the target voltage. A change in the height and composition of the anode cover, a change in the height of the anode beam, and a change in the height of the melts can be considered episodic "manual" control actions.

For successful control and stable operation of the pot in a specified range of process parameters, control actions in different control loops should be interconnected. Particular attention should be paid to the connection of voltage additions and AlF_3 additions, since the effect of these additions on the heat balance is interconnected through a) melting the side ledge, b) through the bath solidification temperature, c) through the current efficiency and d) through the bath conductivity. Based on these assertions, an algorithm was developed that implements coupled control of a specified voltage and additions of fluorides (the BCS module) to stabilise the bath temperature and CR in a specified process window. Figure 3 shows a diagram of the specified voltage and CR coupled control algorithm—the algorithm of the Automatic Control of the Thermal Balance on the Pot (ACTBP).

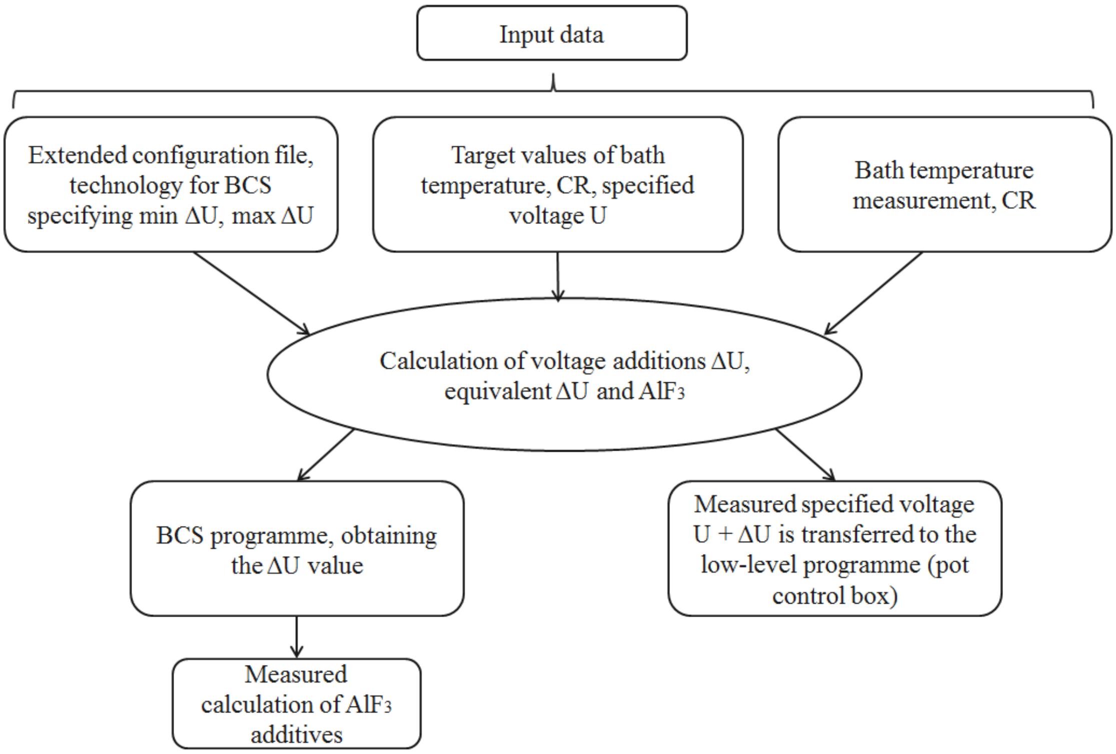

Figure 3. Coupled ACTBP algorithm operation flow diagram.

Currently, the BCS module has been implemented in the pot controllers in all pots of the Sayanogorsk Aluminium Smelter (C-175, C-190, and C-255 technology in the 3-series, and C-255 in the 4-series). The implementation of the BCS module resulted in a significant reduction of the variations in the bath temperature and CR, which led to a more stable reduction process. It also resulted in a reduction of voltage additions, as well as to reduce the consumption of AlF_3. In addition, the ACTBP programme is being tested on the OA-120 and OA-300 pots. During these tests, a decrease in the standard deviation of the reduction process parameters was observed, which stabilised the thermal balance on the pot due to minimal change in the pot cavity profile.

4. Unshaped Materials for Pot Cathode Lining

The semi-coke of brown coal (lignite semi-coke) produced according to the TERMOKOKS-KS technology [6] is used as the main unshaped lining material (ULM) and one of the main characteristics is that it can be reused after it has been recovered from delining a pot. For cathodes with ULM, the process of laying chamotte and heat-insulating bricks is replaced by the process of loading and laying lignite semi-coke of and dry barrier mixes (DBM). However, this process does require the use of special equipment for loading and laying the ULM (Figure 4). This equipment is integral part of the technology.

Figure 4. General arrangement of equipment for loading and laying ULM.

The use of this equipment minimises dust formation and ensures a good distribution of lignite semi-coke and DBM. After laying all the layers, the ULM is compacted using a vibration compactor. The principle of operation of the compactor is given in Figure 5.

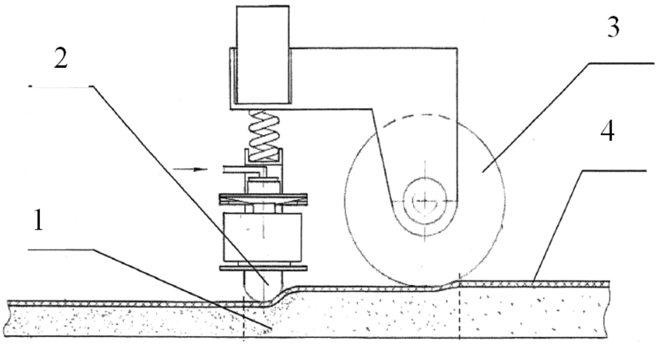

Figure 5. Principle of operation of the compactor:
1 – ULM; 2 – vibratory unit; 3 – roller; 4 – resilient cover.

A distinctive feature of the compacting equipment [7] is that the ULM is compacted to a high degree within a limited space. The material cannot be pushed out from the side of the vibratory unit, since it is "locked" by the finally compacted material; and from the side of the roller, it is "locked" by the preliminary compacted material. From above, it is "locked" by an elastic cover. This provides for the maximum possible degree of compaction (the porosity reaches only 17 – 19 %), minimum dust emissions and stable properties of the barrier layers. In the compaction process, a layer of aluminosilicate DBM on top forms a seamless aluminosilicate of high density and low porosity.

Analysis of a group of pilot pots with ULM showed that using the lining equipment reduced labour costs for lining the sub-cathode zone from 44 to 19 man-hours when compared to conventional cathodes. Due to a higher productivity, the pot downtime (re-lining time) reduced by 6 hours. The cost of lining the sub-cathode zone using ULM decreased from 3 656 USD/pot to 998 USD/pot (about 73 %). The evaluation of the recycling potential of lignite semi-coke based on the autopsy of the C-255 pilot pot showed that at least 80 % of lignite semi-coke remained visually intact (Figures 6, 7). These are very good results.

Currently, the ULM sub-cathode zone is implemented in the cathode assemblies of the pots at the Sayanogorsk and Krasnoyarsk aluminium smelters. Tests are under way to replicate ULMs in other UC RUSAL smelters.

Figure 6. General arrangement of the cathode cross section with ULM.

Figure 7. Cross section with lignite semi-coke in the free state.

5. Conclusions

In Energy Conserving Pot Design project UC RUSAL has developed low energy consumption pots, that reduced specific energy consumption by 550 to 900 kWh/t Al. This was achieved with the use of steel-copper cathode collector bars, which reduced the cathode voltage drop by 60 mV and with new pot control system, which reduced cryolite ratio and bath temperature variations and stabilised thermal and MHD equilibrium of the pots.

The new resource-saving technology for lining the sub-cathode zone of the pots with un-shaped lignite semi-coke-based lining materials reduces the lining cost by 73 % and can be in major part recycled.

6. References

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