Cell Design Modifications to Reduce Specific Energy Consumption

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Abstract

The Hall-Héroult aluminium reduction is an energy-intensive process with Specific Energy Consumption (SEC) ranged in 12–15 kWh/kg Al, with around 50 % of energy efficiency. Thus, reducing energy consumption through investment in advanced technologies and practices can enhance manufacturing competitiveness and collaborate to reduce the aluminium industry carbon footprint.

Along the years, Aluar implemented a continuous research and development program that led to several upgrades of the original cell designs. Since 2018, the introduction of copper inserts in collector bars to reduce cathode resistance in Lines C and D, the consequent redesign of the lining to maintain thermal balance, and the installation of shell cooling fins have resulted in the reduction of 0.5 kWh/kg Al. This paper highlights the improvement process and the road map to convert 384 cells to a more energy efficient design, which is currently under way.

Keywords: Hall-Héroult reduction cells, Collector bar copper inserts, Cell autopsy, Cell design.

1. Introduction

Mainly due to energy costs and global decarbonisation goals, the industry is continuously improving its energy efficiency, looking for innovative alternatives to produce aluminium. In the last decades, many smelters have modified their cells in order to reduce the specific energy consumption (SEC) of the Hall-Héroult process, achieving a state-of-art design close to 12 kWh/kg Al [1-2].

Aluar started its operations in 1974 installing two Montecatini P155 end-to-end side-worked prebake (SWPB) lines, with 200 cells each, running at 150 kA. After diverse upgrades implemented in the last 50 years, Lines A and B are operating close to 200 kA [3]. As a first expansion stage, Line C was started in 1999 with 144 side-by-side AP Technology™ AP18 cells running at 180 kA, which have been gradually transformed to AP Technology™ AP22 since 2006 in order to increase the line current up to 220 kA. In 2007, a second expansion phase put Line D into operation with 240 AP22 cells. At present, Aluar has an installed capacity of 456 000 tonnes per year, and an average energy consumption of 13.7 kWh/kg Al.

The worldwide use of copper in collector bars motivated the development of Aluar's most recent projects to reduce SEC, based on in-house cell redesigns. This paper focuses on the major changes implemented in Lines C and D, and on the main project milestones that lead to the on-going transformation process. Since the so-called "al23" design could run at up to 235 kA, it could enable future amperage increase potential.

2. Cell Design

The al23 is the first comprehensive change done to standard cells, and the applied modifications aim to improve both energy efficiency and magnetic compensation. The initial phase of the project started in 2016, and the characteristics are the result of extensive research and modelling work, tests, measurement campaigns, prototypes, detailed engineering, collaboration projects, decision-making, risk analysis, validation, and comparison of different alternatives; looking for an optimal cost-benefit ratio that increases profits and minimises implementation period.

Two years later, 7 al23 cells were successfully started in Line D. These first prototypes are still running, with more than 2200 days in normal operation and no registered failures. Black paint details on the super-structure helped floor operators to distinguish the new design inside the room (Figure 1). Once the validation stage was completed, a second trial of 12 cells started in Line C in 2020.

Figure 1. First al23 cell started in September 2018.

The al23 cells registered a reduction of 0.5 kWh/kg Al in the specific energy consumption, stable cathode resistance below 0.9 µΩ, and ~150 mV voltage reduction compared to standard design cells.

The main modifications are copper inserts in collector bars, longer cathode blocks and cooling shell fins. Therefore, since copper has a higher electrical and thermal conductivity, it was necessary to adjust the lining to compensate the extra heat extracted through collector bars. The latter is necessary to maintain the thermal balance and, more importantly, to keep isotherms at the desired location, avoiding cold cathode blocks. In addition, the use of longer cathodes in the same shell requires a side lining resize, resulting in a larger volume of liquid bath and/or enough room for bigger anodes, enabling future amperage increases.

2.1 Copper Cored Collector Bars (CCCB)

The potential benefits of using copper in collector bars can be resumed as follows, promoting in this way lower energy requirements and/or a line current increase:

6. Conclusions

The al23 project started in 2016 with the objective to develop, model, build and operate a new cell design in Lines C and D that improves its energy efficiency. The main modifications are the use of CCCB and longer cathode blocks to reduce the horizontal current density distribution and improve MHD stability, the use of cooling fins in the shell to avoid the use of a forced convection network and minimize heat losses, and the redesign of the lining to compensate the extra heat extracted through the collector bars.

The al23 has demonstrated good performance and achieved expected results since the start-up. The gross specific energy consumption is reduced in 0.5 kWh/kg Al and it will help to reduce the total energy requirements of the smelter after full conversion. On the other hand, the new design has amperage increase potential.

Last, but not least, Aluar has gained considerable knowledge about cell design and operation parameters that could bring to future revisions in order to keep on continuous improvements.

7. Acknowledgments

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8. References

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