Modelling and Engineering Experience of EGA in Brown Field Modernisation of Aluminium Smelters

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Abstract

EGA has developed extensive experience in the continuous improvement of existing cell designs over the past 30 years. Earlier improvements were empirical and evolutionary, but with the introduction of mathematical modelling more significant and rapid retrofitting of old technologies became feasible. This paper describes EGA's approaches and experience in the development of improved designs for existing cells like D18+ Technology, based on thermo-electrical, mechanical and magnetohydrodynamics (MHD) modelling, as well as the engineering work and challenges which were encountered during the design and implementation stages of these cell technologies. The results of plant modernization will also be shown.

Keywords: Aluminium electrolysis cell modelling; cell design; smelter retrofit engineering; ANSYS.

1. Introduction - D18 Technology History

Dubai Aluminium (DUBAL) – an operating subsidiary of Emirates Global Aluminium (EGA) – commenced operations in 1979 with 360 reduction cells in three potlines using Kaiser P69 technology (later modernised to D18 Technology) with prebaked anodes, two end risers and the cells situated side-by-side. The cells are located in the pit and the potroom has no open basement. An additional potline of 144 cells, utilising D18 Technology, was built in 1990, bringing the total number of cells to 504. More cells were again added in 2008 and 2010, bringing the total number of D18 Technology cells at the DUBAL smelter to 520.

Continuous improvements and development of original technology were carried out on D18 Technology, including conversion to pseudo-point feeding (PPF), additional busbar, modification of the cell lining design, increased anode size and cell control logic. This has allowed the amperage to increase from 150 kA at the beginning to 210 kA today, improved current efficiency and reduction in specific energy consumption and perfluorocarbon (PFC) emissions [1 - 4].

Despite the excellent work of DUBAL's operational and process control teams, all these improvements were mainly empirical and evolutionary. To take the next step in performance improvement, it was necessary to change the design radically, which was not possible without mathematical modelling. A few earlier papers [1 - 4] described the D18+ Technology project from an operational point of view but never focused on the design process itself. Brownfield projects are very often even more complicated than the development of new greenfield high amperage technologies due to many constrains to make modernisation really meaningful and profitable. This paper focuses on the modelling and engineering aspects of the D18+ Technology project.

Although this paper is about modelling, the focus is not on modelling details because modelling methods and model validation have been described in many earlier papers [5 - 7].

2. D18+ Technology Design Approach

2.1. D18+ concept development

D18 Technology cells in DUBAL Potlines 1 and 3 have high energy consumption that limits increases in smelter production by increasing the amperage in the other more modern potlines. A team was formed to investigate the opportunity of upgrading D18 Technology to achieve significant reduction in specific energy consumption, i.e., below 13.0 kWh/kg Al and find solutions to make modernization profitable.

For complete revision of D18 Technology, CD20 and D20 Technologies were looked at as references based on the following:

- CD20 has exactly the same inner shell width as D18 Technology, whereas D20 Technology is wider.
- Both CD20 and D20 Technologies have two more anodes (20 anodes) than D18 Technology (18 anodes), with the same anode width.
- D18 Technology potrooms have the same building width and crane rail width as D20 Technology (in Potline 9).

Based on the above features, it seemed feasible to introduce a cell with the same inner potshell dimensions as CD20 Technology into the Potline 1 and Potline 3 buildings.

An initial estimation of the possible voltage savings was done based on CD20/D20 Technology results and adjusted to D18 Technology amperage. This led to the conclusion that it was feasible to reduce the net voltage of the cell from 4.74 V to 4.14 V (Table 1). Net voltage as used in EGA is the total average cell-to-cell voltage, including all cell-cell external busbars voltage drop, all voltage adders, but excluding the voltage drop of potline busbar linkages (passageways and crossovers).

Table 1. Comparison of voltage breakdown for different technologies - initial estimation.

	D18 PPF	**CD20**	**D18+**
Current, kA	200	241	200
Anode length, mm	1485	1515	1515
# of anodes	18	20	20
Anode current density, A/cm2	0.93	0.98	0.81
Net voltage, V	**4.74**	**4.49**	**4.140**
External (busbar) voltage drop, mV	421	291	242
Cathode voltage drop, mV	326	272	226
Anode voltage drop, mV	508	513	426
Bath + BEMF + bubble drop, V	3.485	3.414	3.247
Specific energy, kWh/kg Al	**15.04**	**14.08**	**13.00**

It was then decided to conduct a detailed investigation into the opportunity of replacing/upgrading D18 Technology cells with D18+ Technology. The main objective for the project was set to achieve the reduction of net energy consumption by at least 2 kWh/kg Al in

As it can be seen from the data, all cells are performing well. June 2016 was a transition month when the amperage was increased from 210 kA to 220 kA. CE is lower that month due to inventory build-up, following amperage increase and freeze melting. In July 2016, the CE returned to a good value.

4. Conclusions

D18+ Technology cell design was developed as a substitute for D18 Technology which had reached its limit in terms of amperage increases. The new design successfully passed industrial trials, significantly exceeding project targets and was approved for full D18 Technology conversion (representing one third of the Jebel Ali smelter cells). Average net specific energy consumption of five D18+ test cells from May 2012 to September 2015 is 12.65 DC kWh/kg Al. The Potline 1 conversion was completed in July 2016 and amperage has already increased to 220 kA. The amperage is planned to be increased further to 230 kA.

The D18+ Technology project has proved that EGA has strong modelling and engineering capabilities to develop technologies for brownfield projects to replace old and aging technologies that have reached their limits. This is another demonstration of EGA's skills in developing highly efficient technologies. Harmonious teamwork and close collaboration between the modelling, engineering, major projects, technical and operations teams allows smooth and fast implementation of the projects.

The experience gained during the D18+ Technology project has helped EGA carry out a new and even more interesting and challenging project: the development of D20+ Technology, focusing on reducing specific energy consumption to replace CD20 Technology and D20 Technology cells which make up the other two thirds of the cells in the Jebel Ali smelter. This time, the conversion is to be done live during the cell change over.

5. References

1. D. Whitfield et al., Development of D18 cell technology at DUBAL, *Light Metals* 2009, 477 – 481.
2. D. Whitfield et al., Update on the development of D18 cell technology at DUBAL, *Light Metals* 2012, 727 – 732.
3. S. Akhmetov et al., D18+: Potline modernisation at DUBAL, *Light Metals* 2013, 561 – 566.
4. D. Whitfield et al., From the least to the most energy efficient DUBAL potline - the P69/D18 developments, *11th Australasian Aluminium Smelting Technology Conference,* 6 – 11 December 2014, Dubai, United Arab Emirates, Paper 11M8.
5. Valdis Bojarevics, Time dependent MHD models for aluminium reduction cells, *Light Metals 2010*, 199-206.
6. G. Arkhipov at al., Simulation of cell thermoelectric field with consideration of electrochemical processes, *Light Metals* 2007, 327-331.
7. Abdalla Zarouni et al., Mathematical model validation of aluminium electrolysis cells at DUBAL, *Light Metals* 2013, 597-602.
8. Abdalla Zarouni et al., Energy and mass balance in DX+ cells during amperage increase, *31st International Conference of ICSOBA, 19th Conference Aluminium Siberia,* Krasnoyarsk, Russia, September 4 – 6, 2013, 494-498.
9. S. Akhmetov et al., Implementation of D18+ Cell Technology in Potline 1 at EGA Jebel Ali. *34th International ICSOBA Conference & Exhibition,* Quebec, Canada, 3 – 6 October, 2016, Paper AL01.