Modelling and measurements to support technological development of AP60 and APXe cells

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Abstract

With the successful start-up of the new Arvida AP60 smelter in Canada as well as the validation of the APXe cells at Saint Jean de Maurienne in France at a specific energy consumption of 12.2 kWh/kg, Rio Tinto Aluminium has demonstrated its leadership in the development of efficient reduction cells for the benefit of its own projects and its partners and customers. To reach these high productivity and low energy objectives through technological development activities, research and development operation teams rely on modelling and measurements to improve heat balance, electrical and magnetohydrodynamic (MHD) equilibria. Cell design and performance are continuously improved by using the comparison between measurements and models in order to reach new ambitious targets.

Keywords: AP60 cells; APXe cells; cell design and performance; cell modelling; cell measurements.

1. Introduction : AP pot development by modelling and measurements

In the early 1980's, the development of AP technology pots was already supported by numerical simulation. At that time, the pot design was optimized with software developed internally at Laboratoire de Recherche des Fabrications (LRF). Two types of models were used, magnetic field model for pot stability calculation and thermo-electric (TE) models for the busbars design and for the cells thermal balance [1]. Nowadays, several modelling tools are extensively used by for the Rio Tinto dual strategy cell development with AP60 for high energy and APXe for low energy cells [2]. The AP60 will operate at 600 kA and more with specific energy consumption (SEC) of about 13.0 kWh/kg, while the APXe operates at around 500 kA with energy consumption close to 12 kWh/kg (see Figure 1).

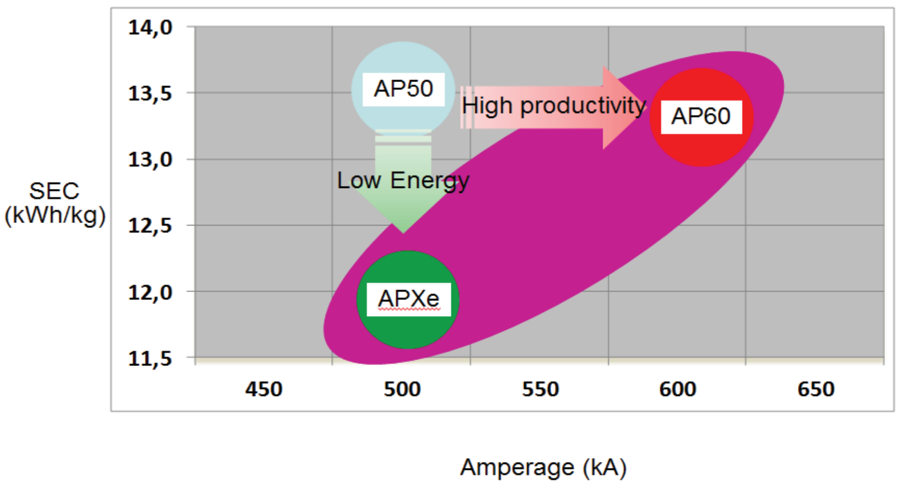

Figure 1. Operating regions of the new AP cell technologies.

2. Modelling tools: TE, MHD and MHD-TE models

The models development in RT takes into account different trade-offs between complexity, running time and accuracy. It involves also a well-balanced equilibrium between the complexity of physical phenomena, and accuracy of measurements and of properties of materials.
Four main models are used for the design and optimization of the AP60 and APXe cells.

- A 3D thermo-electric model representing a single slice. It takes into account the voltage drop, Joule effect, and overvoltages, as well as the heat transfer mechanisms inside and outside the cell. This model predicts accurately both the temperature and the voltage distribution. Being only a single slice, this model is relatively light and fast to run, making it well suited for work on cell design and rapid analysis of different alternatives.
- The busbar thermo-electric model which can predict both, the temperature and the voltage field in the external conductors around the cells. It can be used in normal, bypass or multiple bypass modes.
- A full pot MHD model focused on metal and bath velocity calculation, metal-bath interface deformation and finally pot stability evaluation. The MHD model is also able to calculate alumina distribution [3, 4, 5].
- A coupled MHD-TE model for a complete pot geometry which is used to calculate the temperature field and ledge. This model takes into account the velocity field [6].

3. Modelling and measurements on AP60

At Rio Tinto Arvida Smelter (Jonquière, Canada), in the new AP60 potline, the full validation of the cells and equipment is taking place with already two years of operation [2].

3.1. Magnetic field and metal velocity

In AP60 technology, the busbars configuration was designed to offer the lowest possible vertical magnetic field, the component causing the forces which affect the bath-metal interface. Magnetic fields were also measured on an AP60 cell; the agreement is excellent between the predictions and the measurements (Figure 2).

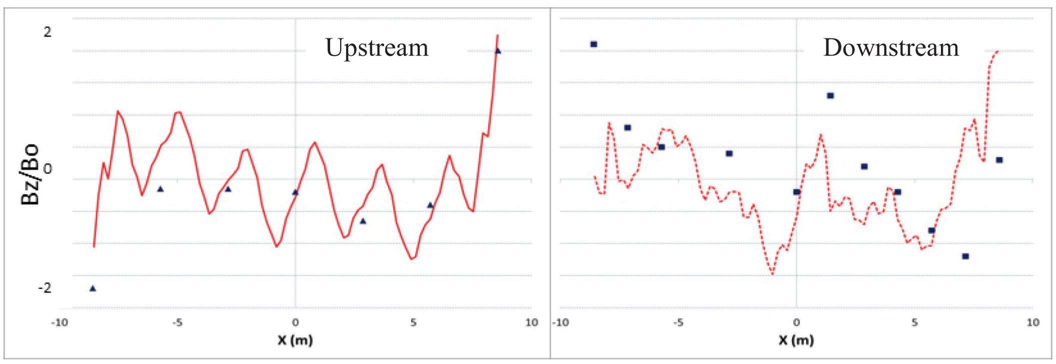

Figure 2. Vertical magnetic field measurements versus model results. (Bo: reference magnetic field).

Metal velocity measurements were also carried out on four AP60 cells. Table 1 shows that the maximum measured velocity is close to the prediction (Figure 3).

Table 1. Metal velocity measurements and prediction for AP60 cells.

4 cells	Max. velocity	Prediction
Measurements	18.2 cm/s	15 cm/s

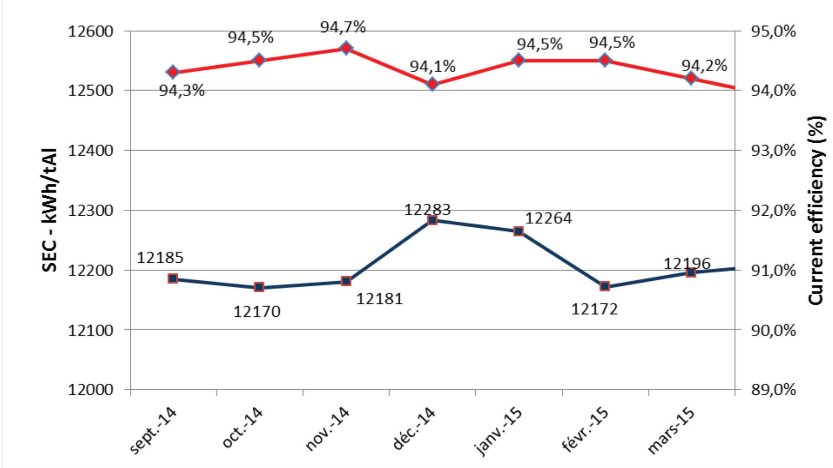

Figure 16. Specific energy consumption and current efficiency on APXe.

5. Conclusions

The development of new AP technology cells, AP60 and APXe, requires continuous improvement of our numerical models in order to solve increasing difficulties with higher amperage and lower ACD, lower bath volume and lower space for building the sidewall ledge. The model development in Rio Tinto is associated with intensive measurements for the validation of the different parts of the model: physics assumptions, numerical solution methods and material properties.

In the last two years, AP60 and APXe have confirmed their expected performance which is a complete validation of our development process, based on modelling and measurements. The next evolution of AP technology - AP64 at 640 kA and APXe at very low energy under 12 kWh/kg Al - will be done with strong support of our modelling tools.

6. References

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