MHD and Potshell Mechanical Design of a 740 kA Cell

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Introduction

In the 20th century, the H-H cell size and hence amperage have increased following the following trend.

According to this trend, we should be already building smelters using 500 kA cell technology.

Is the recent slowdown in the increase rate the impact of reaching some kind of physical limitation or simply the consequence of a slowdown in R&D investments?
Introduction

Currently, we can fit Hall-Héroult mathematical models into three broad categories:

- Stress models which are generally associated with cell shell deformation and cathode heaving issues.
- Magneto-hydro-dynamic (MHD) models which are generally associated with the problem of cell stability.
- Thermal-electric models which are generally associated with the problem of cell heat balance.
Thermo-Electric Design of a 740 kA Cell, Is There a Size Limit?

Thermo-Electric Design of a 740 kA Cell Using a Complete Full Cell Quarter Thermo-Electric Model
Thermo-Electric Design of a 740 kA Cell, Is There a Size Limit?

Thermally balanced cell operating respectively at 740, 500 and 300 kA
As far as only the cell heat balance design issue is concerned, there is no limit to the size of cells that can be designed.
MHD Wave Problem Description

As very well explained by Urata in his 2005 TMS paper, in modern high amperage cell, the MHD wave is created by the presence of a longitudinal gradient (Cx) in the vertical component of the magnetic field (Bz).
Not surprisingly, the aim of the Pechiney 1987 busbar layout design is to minimized the longitudinal gradient of the vertical component of the magnetic field.
This is done by having 2 compensation busbars running at each end of the cell, one carrying more current than the other in order to compensate for the impact of the return line while in order to minimize the busbar mass, all the busbars from the upstream side are running under the cell.
MHD-Valdis model of Pechiney Patent

Using MHD-Valdis cell stability code, it is easy to build a model reproducing the Pechiney 1987 patent busbar layout.
As claimed by Pechiney, the compensation busbars are doing a great job reducing the intensity of the Bz magnetic field, but still a 40 gauss over 16.5 meters longitudinal gradient remains even with a return line at 60 meters.
MHD-Valdis model of Pechiney Patent

According to MHD-Valdis, this small Cx is enough to generate a (2,0) (0,1) rotating wave of the type described by Urata

Clearly, this busbar layout design could not be used on cell of more than 500 kA
New 500 kA cell MHD design

No global Bz longitudinal gradient, so no MHD instability wave
New 740 kA cell MHD design

No global Bz longitudinal gradient, so no MHD instability wave
MHD design of a 740 kA cell, Is there a size limit?

The new compensation busbar configuration will equally well work for any reasonable length of potshell and any number of risers, for example a 85.8 meter long, 30 risers, 2380 kA cell could too be magnetically compensated using the same approach. So it is possible to conclude that as far as the MHD cell stability aspect of the cell design is concerned, there is no limit to the size of cells that can be designed.
300 kA Cell Potshell Mechanical Design Model

Relative Vertical Displacement for the Fine Mesh Model
500 kA Cell Mechanical Model Results

Base Case.

With Cooling Fins.

With Forced-Air Cooling.

Temperature distribution for the studied 500 kA cell configurations.
500 kA Cell Mechanical Model Results

Comparison of the relative vertical displacement on the long axis of the 500 kA cell.
740 kA Cell Potshell Mechanical Design Model

Temperature Loading for the Fine Mesh Model
740 kA Cell Potshell Mechanical Model Results

Relative Vertical Displacement for the Fine Mesh Model

DMX = 0.024001
SMN = -0.004463
SMX = 0.022128
-.004463
-.001508
0.001447
0.004401
0.007356
0.01031
0.013265
0.016219
0.019174
0.022128
Comparison of the relative vertical displacement on the long axis.
740 kA Cell Mechanical Model Results

Because of the change of aspect ratio the 26.2 meters long potshell behaves differently and, as a result, the vertical deflection is about the same as the 300 kA cell case instead of being worse than the 500 kA cell case.

It is also important to point out that for all three cases anyway, the vertical deflection remains small because that VAW 300 inspired potshell design is very flexible in the upper section of the potshell sidewalls and deflect more laterally than vertically.
Conclusions

- On the cell heat balance and MHD aspect of the cell design, it is clear that there is no limit to the size of cells that could be designed.

- On the potshell mechanical design aspect, we don’t have the data in hand to be so assertive, but there is no reason to believe that technically, we are facing a size limit.

- On the other hand, if for very high amperage cells, the solution to the potshell vertical deflection problem can only be solved by using expensive forced air convection devices, it is possible that the usage of those devices annihilates the financial incentive to keep designing bigger and bigger cells.