

Newest MHD-Valdis cell stability studies

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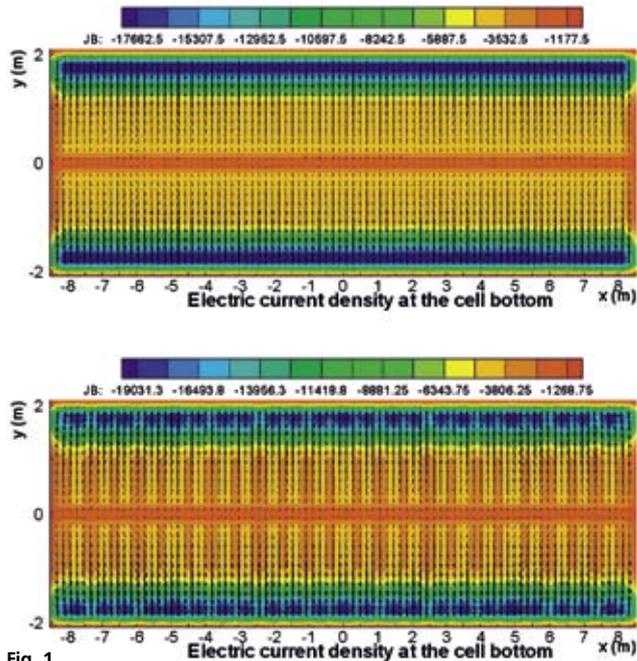


Fig. 1

This year at the TMS 2014, the authors will show how the cathode surface geometry influences the metal pad current density and the cell stability. This study [1] analyses cell stability using a MHD-Valdis code version which does not take into account the impact of the cathode surface geometry on the cathode surface current density. Also this year at the TMS, the second author will present a new version of the MHD-Valdis code that does take cathode surface geometry into account [2]. The first cell stability study presented here is a repetition of the study presented in [1] on the impact of transversal ridges on the cell stability using that new code version.

In 2005, the first author presented the cell heat balance study of a virtual 740 kA cell [3]. One year later, the authors presented the cell stability study of that same 740 kA cell [4]. That cell used an innovative magnetic compensation scheme that ensured its MHD stability. The authors claimed at the time that they cannot foresee any thermo-electric, thermo-mechanic or MHD related issue that would limit the size of a cell. Since that time, many 400+ kA full size smelters have been built in China, Russia and UAE, and the AP60 demonstration smelter has started its operation in Canada.

Since a 740 kA cell no longer seems far-fetched, the second cell stability study pre-

sented here is the one of a virtual 1500 kA cell. This is to reiterate the point that as far as MHD cell stability is concerned, there is no foreseeable limit to the size on an aluminium electrolysis cell.

Study of the impact of transversal ridges on cell stability

A cathode surface with transversal ridges is a design now very popular in China [5]. It has proved to much reduce specific energy consumption, as presented in [6]. This energy economy results from greatly reducing the ACD, which suggests that cells with transversal ridges are more stable than cells with a flat cathode surface. Yet the cell analysis studies presented in [7] and [1] do not confirm that interpretation of the observed facts.

The study presented in [7] neglected the impact of the cathode surface geometry on the cathode surface current density. The study presented in [1] did account for that effect, but not very accurately, as it had to

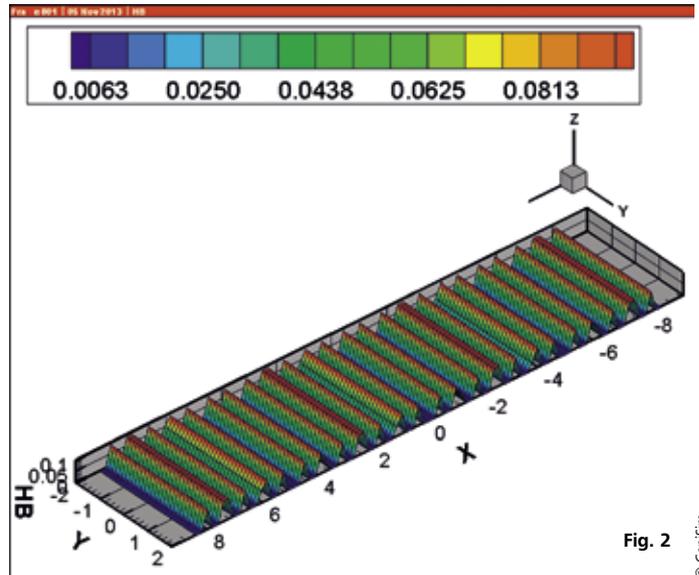


Fig. 2

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impose the effect of the cathode surface geometry on the cathode surface current density. The new cell stability study presented here uses the most recent version of the MHD-Valdis code. This takes fully into account all the impact of the transversal ridges on the MHD behaviour of the cell [2].

Fig. 1 presents the metal pad current density solutions comparing the case of a flat cathode surface (top) with that of the cathode surface with transversal ridges (bottom). The geometry of the cathode surface ridges is presented in Fig. 2. It can be seen that the mesh is not quite fine enough to perfectly capture

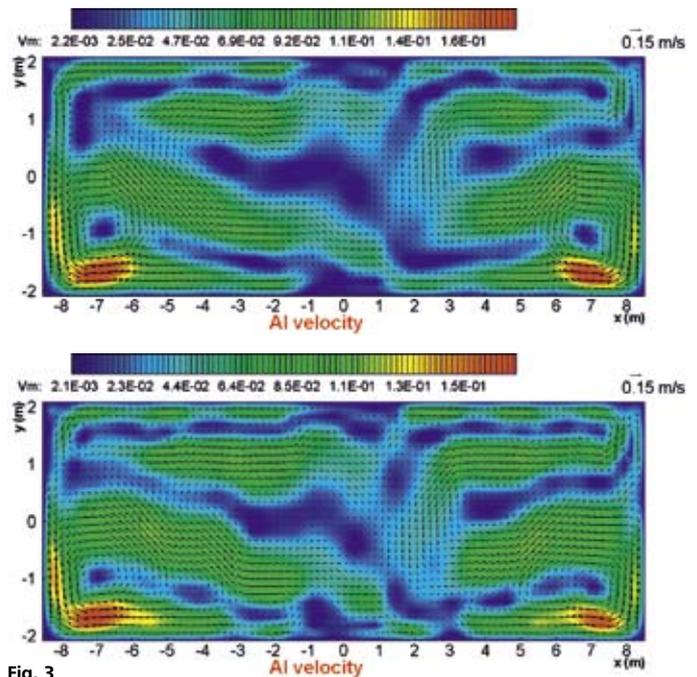


Fig. 3

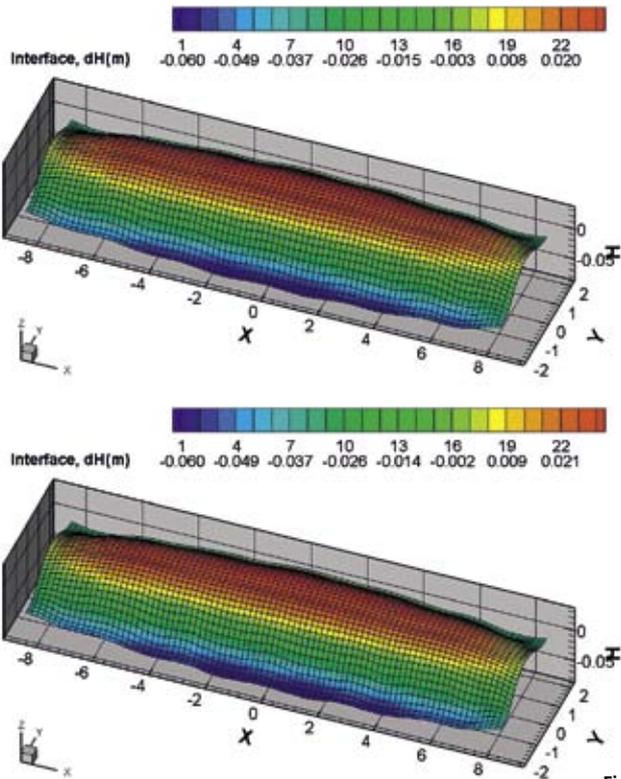


Fig. 4

the geometry of the ridges or the extra longitudinal currents (JX) they generate (see [1] for more details).

Fig. 3 compares the steady-state metal pad flow field solutions. The presence of the ridges slows down the metal flow, but not significantly. Fig. 4 compares the steady-state bath-metal interface deformation solutions. Again, the presence of the ridges is only barely affecting the shape of the interface deformation.

The previously presented results demonstrated that the presence of the transversal ridges only marginally affects the steady-state solution, adding some flow resistance to the cathode surface. This in turn slows down the metal recirculation flow, which is good for cell stability, but it also introduces some longitudinal horizontal current, which is bad for cell stability.

Only the full non-linear transient cell stability analysis can tell us what is the impact of those transversal ridges on the cell stability, and the only practical tool to carry-up such a non-linear transient cell stability analysis is MHD-Valdis. Fig. 5 presents the comparison of the transient cell stability analysis results. The results indicate that the addition of transversal ridges, while keeping the same metal pad height hence reducing the mass of metal, slightly decreases the cell stability. So this new cell stability study confirms the results of the previous ones, that adding transversal ridges has only a marginal effect of the cell stability, and that that marginal effect can be detrimental

if the mass of metal is not kept the same. See [1] for an alternative explanation as for where the observed gain of cell stability is coming from.

Study of the cell stability of a 1,500 kA aluminium electrolysis cell

The 1,500 kA cell of this study is twice the size of the 740 kA in [3, 4], which itself was 50% bigger than the 500 kA cell retrofitted into a 600 kA cell in [8]. That 50 metres long cell has 72 cathodes blocks, 144 anodes and 18 risers. Each riser feeds the current coming from four cathodes blocks to eight anodes.

In principle, the 740 kA cell could be retrofitted into a 890 kA cell; so 1,500 kA is well within reach of a cell having twice that size. Fig. 6 presents the BZ component of the magnetic field obtained by passing 1,500 kA into a 50 metres long cell fed through 18 risers and using a very efficient magnetic compensa-

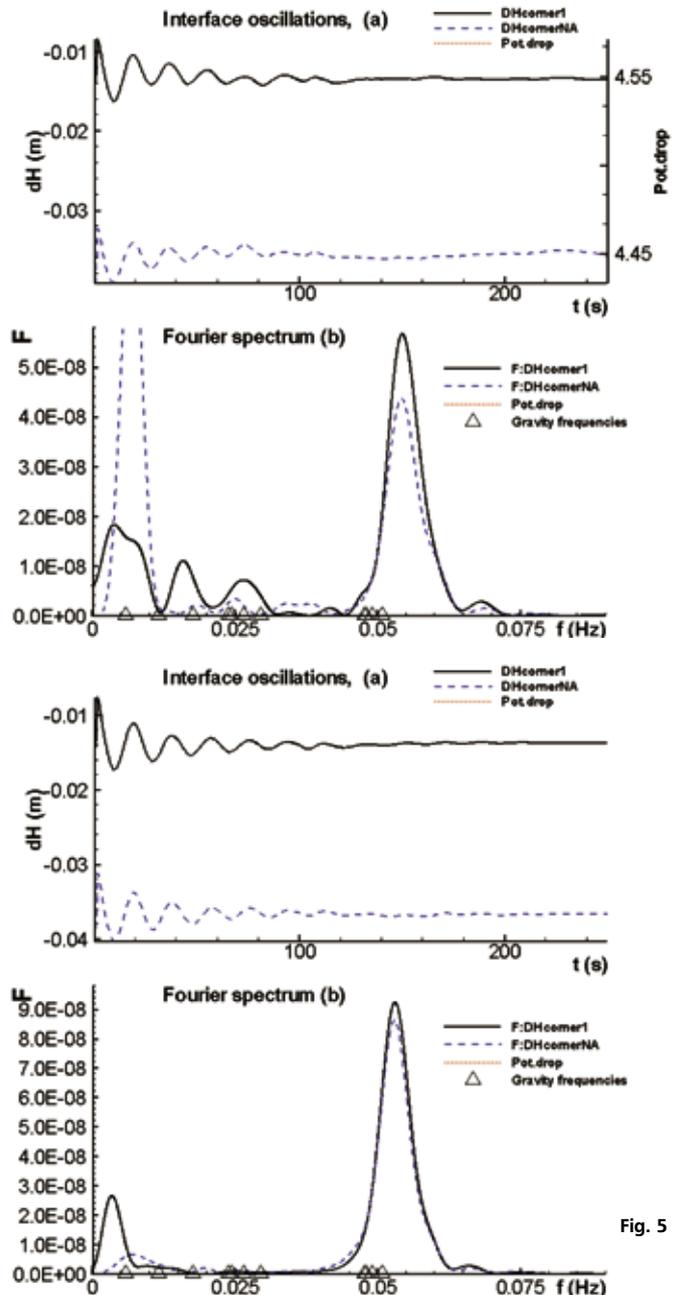


Fig. 5

tion scheme. Since the magnetic compensation scheme is 100% scalable, it works equally well on any cell size, as this 1,500 kA cell example demonstrates.

Fig. 7 presents the resulting metal pad flow field solution, while Fig. 8 presents the steady-state bath-metal interface deformation. Notice the upstream/downstream symmetry of

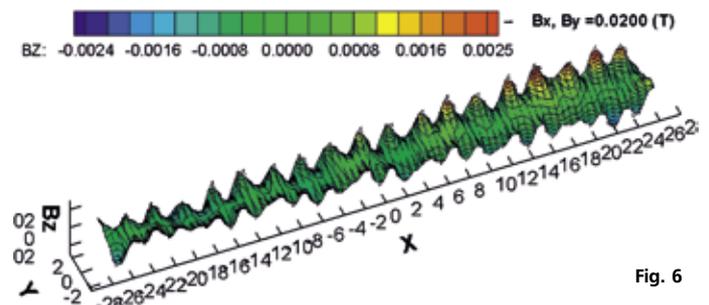


Fig. 6

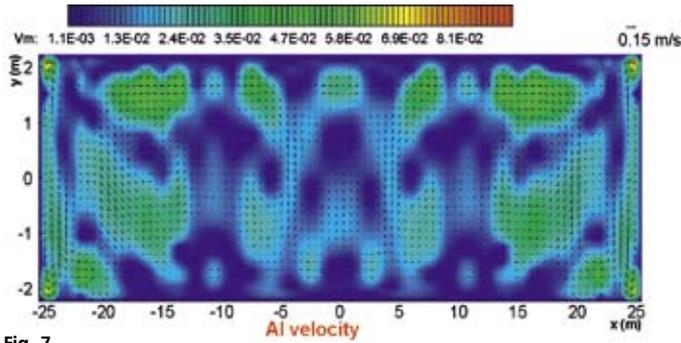


Fig. 7

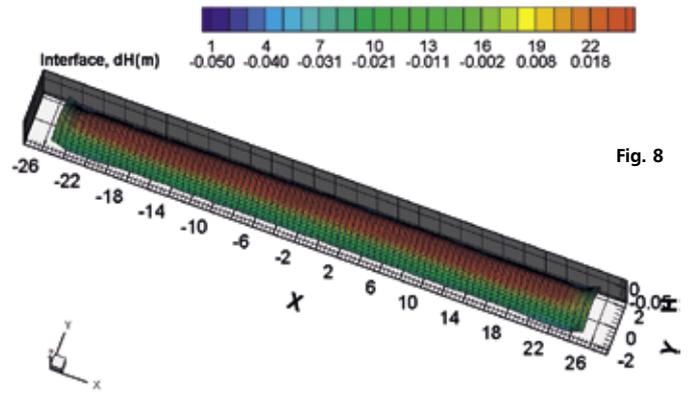


Fig. 8

the bath-metal interface deformation, which also results from the magnetic compensation scheme used.

The transient cell stability analysis predicts that this 1,500 kA cell, having essentially no existing BZ gradient in the long (X) direction of the cell, will be extremely stable, as Fig. 8 shows. Any organisation interested in patenting the busbar compensation scheme used in that study in partnership with GeniSim Inc. can contact the first author.

Conclusions

The authors hope that these demonstration studies highlight the value of using mature state-of-the-art mathematical models like MHD-Valdis to carry out such MHD cell stabil-

ity studies. MHD-Valdis, used by the majority of the groups actively developing high amperage cell technology today, is available to the whole aluminium industry through GeniSim Inc.

References

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Authors

Dr. Marc Dupuis is a consultant specialised in the applications of mathematical modelling for the aluminium industry since 1994, the year when he founded his own consulting company GeniSim Inc (www.genisim.com). Before that, he graduated with a Ph.D. in chemical engineering from Laval University in Quebec City in 1984, and then worked ten years as a research engineer for Alcan International. His main research interests are the development of mathematical models of the Hall-Héroult cell dealing with the thermo-electric, thermo-mechanic, electro-magnetic and hydrodynamic aspects of the problem. He was also involved in the design of experimental high amperage cells and in the retrofit of many existing cell technologies.

Dr. Valdis Bojarevics is Reader in magnetohydrodynamics at the University of Greenwich (UK). He specialises in the numerical modelling of various electrometallurgical applications involving complex interactions of the fluid flow, thermal and electrical fields, melting front and free surface dynamics. He has been involved in numerous industrial consulting projects.

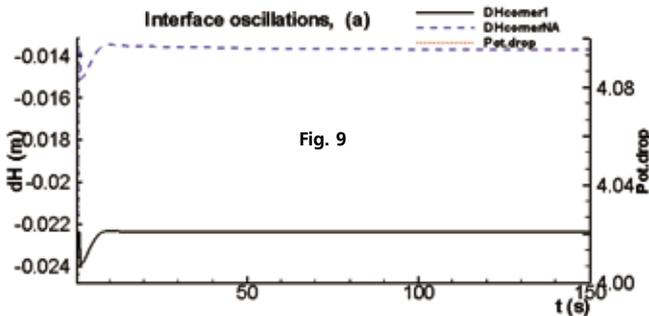


Fig. 9