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A numerical study of metal pad rolling instability in a simplified Hall-Héroult cell

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Liquid metal instabilities in the aluminium production using the Hall-Héroult process are a known problem. During the production process, currents up to 800kA and voltages up to 5V are reached. The induced magnetic field from the current carrying busbars, especially the vertical component, creates in combination with the horizontal component of the current a high Lorentz force. This force induces liquid metal instability known as Metal Pad Rolling (MPR). Experimental investigations of MPR are rare, since cryolite dissolves most materials in short time, which make measurements inside the Hall-Héroult cell complicated. For this reason numerical simulations are needed to examine the flow- and the electromagnetic field, such that the stability conditions for Hall-Héroult cell can be predicted.

This work focuses on the development of a multi-phase/region solver to predict MPR instabilities. The solver is implemented in the open source framework OpenFOAM®. Volume of fluid method with phase-fraction based reconstruction approach is used to solve the multi-phase system. The magnetic field is implemented using the magnetic potential approach. The four step projection method [1] is employed to obtain a conservative formulation for the current density. A parameter study investigating the MPR in a simplified Hall-Héroult cell is carried out for a wide range of magnetic fields and current densities. One result of this study is that recalculating the magnetic field does not influence the maximum amplitude of the moving interface. For the current densities of $5\,kAm^{-2}$ and $6\,kAm^{-2}$, an increase in the external magnetic field initially destabilizes the Hall-Héroult cell, followed by restabilization. Further increase in the external magnetic field results in stronger instabilities based on simulations. Presumably, it is the first known occasion this specific behavior is observed in a numerical simulation. The frequencies of the MPR instability obtained from the simulation corresponds with the analytically determined frequency. Furthermore, a sensitivity study has been conducted to understand the influence of the solver specific parameters.

REFERENCES

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