Simulation of Macrosegregation in Low-Frequency Electromagnetic Casting by a Meshless Method

Vanja Hatić[1], Boštjan Mavrič[1,2] and Božidar Šarler[1,2*]

[1] Institute of Metals and Technology
Lepi pot 11, 1000 Ljubljana, Slovenia
Web page: https://www.imt.si

[2] Faculty of Mechanical Engineering, University of Ljubljana
Aškerčeva 6, 1000 Ljubljana, Slovenia
Web page: https://www.fs.uni-lj.si/
[*] Corresponding author: bozidar.sarler@fs.uni-lj.si

ABSTRACT

The novel use of a meshless numerical approach for simulation of macrosegregation in the low-frequency electromagnetic casting is presented along with the analysis of the simulation results. The casting model includes a coupled set of mass, momentum, energy, and species conservation equations. Lorentz force is computed with the induction equation and used in the solidification model. The coupled physical model is solved in cylindrical coordinate system and can be used to model aluminium alloy billet production. Explicit scheme is used for the temporal discretization, while the meshless diffuse approximate method is used for the spatial discretization. The method is localized with subdomains containing 14 local nodes. The Gaussian weight is used in the weighted least squares minimization. Furthermore, the Gaussian is shifted upstream, when an upwind effect is required in order to increase the convection stability. Direct chill casting under the influence of electromagnetic field (EMF) is simulated for various electric amplitudes and currents. The material properties of Al-5.25wt%Cu are used. The casting parameters and material properties are constant in all presented simulations, while EMF is turned off in some cases in order to study its effect on solidification. The results show that EMF has a large effect on the melt-flow and solidification. Oscillatory, instead of a steady-state, solution is obtained in case of certain geometries in EMF casting. The effect of EMF is hard to predict without the use of numerical simulations, due to strong coupled effects of casting geometry, casting parameters, and EMF parameters. This shows the need for numerical modelling of this strongly coupled problem for its better understanding.

REFERENCES

[1] J. Ni, C. Beckermann, "A volume-averaged two-phase model for transport phenomena during solidification" *Metallurgical Transactions B*, Vol. **22**, pp. 349-361 (1991).

[2] L. Heyvaert, M. Bedel, M. Založnik, H. Combeau, "Modeling of the Coupling of Microstructure and Macrosegregation in a Direct Chill Cast Al-Cu Billet" *Metallurgical and Materials Transactions A*, Vol. **48**, pp. 4713-4734 (2017).

[3] V. Hatić, B. Mavrič, N. Košnik, B. Šarler, "Simulation Of Direct Chill Casting Under The Influence Of A Low-Frequency Electromagnetic Field" *Applied Mathematical Modelling*, Vol. **54**, pp. 170-188 (2018).

[4] B. Šarler, R. Vertnik, J. Perko, "Application of diffuse approximate method in convective-diffusive solidification problems" *Computers, Materials & Continua*, Vol. **2**, pp. 77-83 (2005).

[5] B. Nayroles, G. Touzot, P. Villon, "Generalizing the finite element method: Diffuse approximation and diffuse elements" *Computational Mechanics*, Vol. **10**, pp. 307-318 (1992).

[6] H. Sadat, C. Prax, "Application of the diffuse approximation for solving fluid flow and heat transfer problems" *International Journal of Heat and Mass Transfer*, Vol. **39**, pp. 214-218 (1996).