A Multi-scale Approach to Modelling the Effects of Thermoelectric Magnetohydrodynamics in Laser-based Additive Manufacturing Processes

T. Gan, A. Kao*, C. Tonry and K. Pericleous

Centre of Numerical Modelling and Process Analysis
University of Greenwich,
Old Royal Naval College, Park Row, London
e-mail: a.kao@gre.ac.uk, web page: http://www.cnmpa.gre.ac.uk

ABSTRACT

Melt pools formed in laser additive manufacturing (AM) are subject to large thermal gradients. Large thermal gradients result in the formation of thermoelectric currents due to the Seebeck effect. When in the presence of an external magnetic field, a Lorentz force is formed which drives fluid flow in the melt pool. This phenomenon, known as Thermoelectric Magnetohydrodynamics (TEMHD), can have a significant impact on the melt pool morphology and can alter the microstructural evolution of the solidification process.

The ThermoElectric Solidification Algorithm (TESA) is an in-house, parallel multi-scale model that enabled the modelling of rapid high undercooled solidification in a magnetic field [1] and freckle formation in directional solidification [2]. TESA has since been adapted for the purposes of modelling AM, by capturing the interaction of thermoelectric currents in AM melt pools with a magnetic field on a macroscopic scale. Numerical results show that TEMHD can have a significant effect on the melt pool dynamics and morphology. The system is highly dependent on the orientation and strength of the applied magnetic field, with resulting control in the depth and width of melt pool, as well as potential deflections. By coupling transient macroscopic melt pool calculations to a microscopic Cellular Automata based grain growth model, predictions of the resulting microstructure for several deposited layers have been obtained. Figure 1. shows the melt pool morphology and corresponding microstructure for two magnetic field orientations $\pm\widehat{B_y}$, which are orientated orthogonal to the scan and build directions. The results indicate that the magnetic field can have a transformative effect on the microstructure, potentially alleviating epitaxial growth, a common defect in AM processes.

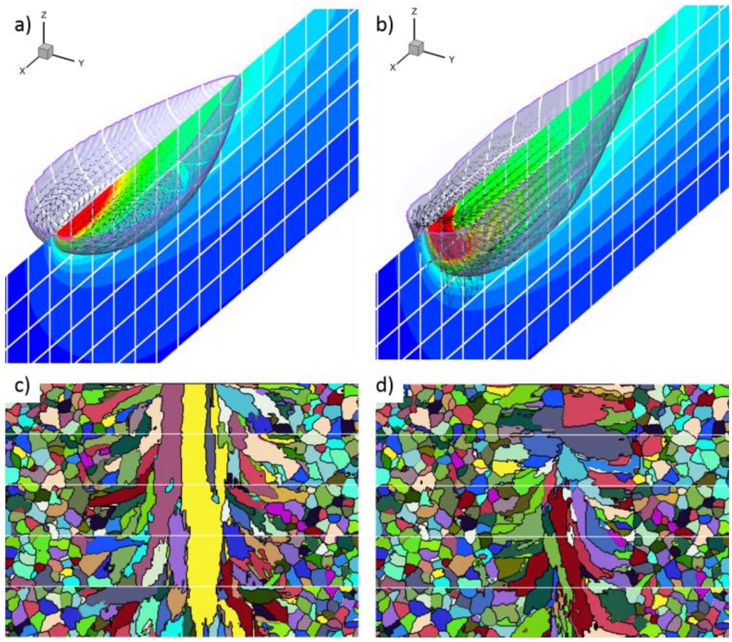

Figure 1. Melt pool morphology and thermal distribution a) $+\widehat{B_y}$ and b) $-\widehat{B_y}$. Cross-section microstructure c) $+\widehat{B_y}$ and d) $-\widehat{B_y}$.

REFERENCES

[1] A. Kao, J. Gao and K. Pericleous, Thermoelectric magnetohydrodynamic effects on the crystal growth rate of undercooled Ni dendrites, Philosophical Transactions of the Royal Society A (2018), Vol 376, Issue 2113.

[2] A. Kao, N. Shevchenko, M. Alexandrakis, I. Krastins, S. Eckert, and K. Pericleous, “Thermal dependence of large-scale freckle defect formation,” Phil. Trans. R. Soc. A, vol. 377, no. 2143, p. 20180206, 2019.