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Numerical simulation of directional solidification of a nickel-based superalloy with applied electric current

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ABSTRACT

To investigate the mechanism of crystal growth under applied electric current, a special cellular automaton-finite difference (CA-FD) model of dendrite growth is developed. The evolution of dendrite microstructure is dominated by the CA rules, which involve the effects of supercooling, interfacial curvature, and crystal anisotropy. Meanwhile, the distribution of electric current and its several kinds of physical effects generated near the solid–liquid interface, including Joule heat, electromigration, and electromagnetic flow, are solved by the FD calculation. By using the model, the directional solidification of a model nickel-based superalloy with electric current is simulated. The different influences of the various physical effects on the crystal growth are examined. The result of simulation indicates that Joule heat brought by electric current delays the dendrite growth and influences the dendrite arm spacing. Excessive Joule heat caused by too large electric current will completely terminate the dendrite growth. Besides, duo to the effect of Joule heat, the dendrites can partly self-adjust their growth rates to achieve macroscopic flat S/L interface during directional growth. The electromagnetic flow induced by the electric current may accelerate the dendrite growth when the current density is large enough.

KEYWORDS: crystal growth, directional solidification, electric current, numerical simulation