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The effect of natural and forced melt convection on dendritic solidification in Ga-In alloys

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Abstract

The directional solidification of Ga–25wt%In alloys within a Hele-Shaw cell was visualized by means of X-ray radioscopy. The experimental investigations are especially focused on the impact of melt convection on the dendritic growth. Natural convection occurs during a bottom up solidification because lighter solute is rejected at the solid-liquid interface leading to an unstable density stratification. Forced convection was produced by a rotating wheel with two parallel disks containing at their inner sides a set of permanent NdFeB magnets with alternating polarization. The direction of forced melt flow is almost horizontal at the solidification front whereas local flow velocities in the range between 0.1 and 1.0 mm/s were achieved by controlling the rotation speed of the magnetic wheel. Melt flow induces various effects on the grain morphology primarily caused by the convective transport of solute. Our observations show a facilitation of the growth of primary trunks or lateral branches, suppression of side branching, dendrite remelting and fragmentation. The manifestation of all phenomena depends on the dendrite orientation, local direction and intensity of the flow. The forced flow eliminates the solutal plumes and damps the local fluctuations of solute concentration. It provokes a preferential growth of the secondary arms at the upstream side of the primary dendrite arms, whereas the high solute concentration at the downstream side of the dendrites can inhibit the formation of secondary branches completely. Moreover, the flow changes the inclination angle of the dendrites and the angle between primary trunks and secondary arms.