Hydrodynamic Model of Capillary Puddle Vibrations in Planar-Flow Melt Spinning

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Planar-flow melt spinning (PFMS) is a single-stage technique for rapid manufacturing of thin metal ribbon. Liquid metal is forced through a nozzle into a narrow gap between the nozzle and a rotating metal wheel or substrate, where it forms a puddle constrained by surface tension. A solidification front grows from the substrate as it translates, leading to a thin ribbon (~100μm) which is continuously pulled from the puddle. Heat transfer, solidification, fluid flow and contacting mechanics are involved.

The stability of the liquid metal puddle is the focus of this analysis. High-speed video imaging reveals a high frequency vibration of the puddle (~1000 Hz), which is found to scale as a balance between capillary and inertial forces. We develop a hydrodynamic model of the puddle oscillations to account for the onset of the vibration and the observed oscillation frequencies. A cross-stream wave defect, occurring at the same frequency, is observed in the cast ribbon. The defect consists of local thickness reductions in the ribbon at regularly spaced wavelengths. The mechanism by which the puddle oscillations transfer to the cross-stream wave defect in the ribbon will be discussed.

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