186b Capillary Puddle Vibrations Linked to Defects 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 (~100 microns) 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). This vibration is found to be independent of the substrate-speed and scales with the nozzle to substrate spacing. 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 frequency of the menisci vibrations are found to scale as a balance between capillary and inertial forces, much like the classical problem of a freely oscillating spherical droplet [1]. We extend the analysis to model the normal modes of oscillation of an inviscid liquid confined between two parallel plates, similar to that of [2]. A stability analysis gives the oscillation modes and frequencies as the contact angle between the liquid and the wall is varied. The mechanism by which the puddle oscillations transfer to the cross-stream wave defect in the ribbon will be discussed.

(1) H.Lamb. Hydrodynamics. Cambridge University Press, Cambridge, 6th Edition, 1932.

(2) A.D. Myshkis, V.G. Babskii, N.D. Kopachevskii, L.A. Slobozhanin, A.D. Tyuptsov. Low-Gravity Fluid Mechanics. Springer-Verlag, 1987.