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Deposition of a Circular Liquid Jet on a Moving Wall

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Abstract

A free surface liquid jet impinging on a moving wall is relevant to many industrial applications including surface coating, cooling and cleaning. Depending on the flow variables, the impingement can be steady (deposition in the form of a thin film or capillary thread) or unsteady (splash or spreading into hydraulic jumps). This study focuses on the steady regime where a Newtonian liquid jet impinges on a moving wall and then spreads into a U-shaped lamella. We particularly focus on the parameter space of jet Reynolds number (Re_j) from 50 to 1200 and wall-to-jet velocity ratio (U_w/V_j) from 0.6 to 6. Boundary layer theory is utilized to analyze the spreading characteristics of the lamella. The non-dimensional lamella heel length, L_h/d (d is the jet diameter), and lamella width L_w/d, are solely functions of Re_j and U_w/V_j. Our theory predicts that L_h/d and L_w/d scale with $Re_j^{1/3}$. With further insight provided by numerical simulations, we found that (L_h/d, L_w/d) roughly scales with $(U_w/V_j)^{1/2}$. These scaling relationships are verified against experiments.

Simulations also confirm that the lamella can be divided into four regions: (i) the stagnation region near impingement, where a strong pressure gradient dominates the flow and turns the jet radially, (ii) the potential expansion region, where the flow outside of the bottom boundary layer is unaffected by the viscous stresses and maintains a nearly constant radial speed equal to V_j, (iii) the full boundary layer region, where the whole lamella has been consumed by boundary layer and viscous stresses are appreciable up to the free surface, and (iv) the far downstream region, where the entire lamella is simply convected along at the wall velocity

The theory can be used to guide industrial applications where a desired coating condition can be achieved by selecting the flow parameters based on the proposed theory.