ABSTRACT

Title of Dissertation: EXPERIMENTAL INVESTIGATION
OF AIR ENTRAINMENT BY
DISTURBED PLUNGING JETS

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The ubiquity of bubble creation, or air entrainment, by plunging jets in the modern world cannot be overstated. They appear in environmental flows such as breaking waves, in waste treatment and aquaculture, in metal casting, and even in the home. Of particular interest to modern industry is the role that air entrainment plays in affecting the quality of cast metal parts. Air entrainment during the pouring of a casting can cause pockets of air to be entrapped within the melt, weakening parts and impacting their mechanical properties. The ubiquity and importance of air entrainment has made it the object of study for many years, yet certain crucial physics remain poorly understood. In particular, little systematic attention has been paid to the role that disturbances, or roughness, upon a plunging jet play in entraining air.

This dissertation describes experiments conducted using an apparatus that generates controlled, repeatable disturbances upon a plunging water jet. The conditions are such that in the absence of disturbances, no air is entrained, enabling the direct association of known disturbance

parameters with air entrainment physics. Multiple air entrainment mechanisms were documented, including one mediated by the action of Faraday gravity-capillary waves induced by harmonic jet forcing.

Inception conditions for the appearance of Faraday waves in the plunging jet and the subsequent onset of entrainment were documented, as were their morphology and spatial symmetry. The volumetric air entrainment rate was measured for three different entrainment mechanisms across a variety of forcing and jet flow conditions, using both direct measurement (by way of physically capturing bubbles) as well as indirectly via image analysis. Scaling arguments derived from physical reasoning and prior work are provided alongside empirical correlations for all the documented entrainment mechanisms.

It was found that the submerged jet flow plays a significant role in creating bubbles, and this was investigated further by way of time-resolved particle image velocimetry measurements and the calculation of instantaneous pressure fields from those data. The fusion of multiple data sources including bubble profile measurement, velocity, and pressure field data reveal a multi-step process of air entrainment that is initiated and controlled by jet disturbances, and the physical components that underlie the process are discussed.