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Numerical Investigation of the Breath Figure Spot Characteristics in a Jet Impingement Condensation Process

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Condensation passive containment cooling systems in combination with small modular reactors are pivotal for removing excessive heat from reactors during steam release accident scenarios. However, the presence of non-condensable gases (NCG) significantly reduces the heat transfer, causing safety concerns. This is mainly caused by the accumulation of NCG during condensation. A better understanding of the physics of the accumulation of NCG owing to condensation leads to the design of efficient heat removal and better coolant recovery mechanisms. Additionally, the accumulation of NCG (mainly hydrogen and oxygen) in the main evaporator of a nuclear reactor containment may cause explosion safety concerns. In a recent study, jet impingement condensation (JIC) was reported as an excellent method for achieving high condensation rates owing to the improved thinning of the diffusion boundary layer associated with the accumulation of NCG near the liquid-vapor interface. The high convective heat and mass transfer coefficients associated with impinging jets have been successfully utilized in several industrial applications, such as drying processes, electronic cooling, and cooling of turbine blades, to name a few. Designing an optimal JIC system requires understanding its physics at varying parameters, such as jet size, jet-to-surface distance, jet speed, jet-to-surface temperature/concentration difference, and environmental temperature/concentration. In this study, we present a numerical model to investigate the influence of these parameters on the initial stages of the condensation process. We look mainly at the existence of Breath Figure spots, which are defined as the effective areas at which condensation occurs. The numerical model was validated against experimental and semi-analytical work on a single round jet issued from a tube at a prescribed temperature, NCG concentration, and flow rate. Our model provides an effective numerical tool for better understanding the physics of efficient condensation in the presence of NCG.

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