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C2Or4D-05: Cryogenic droplet-spray impact and rewetting dynamics in tank chilldown applications

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In a cryogenic tank chilldown, cryogenic sprays are used to rapidly cool the ullage gas and the tank wall. During chilldown, droplets generated from the spray impinge on the tank wall and exchange heat through boiling regimes such as film boiling, transition boiling, nucleate boiling, and single-phase convection. Since cooling rates differ in each regime, developing computational sub-models requires a detailed description of the droplet impact dynamics. Although the existing literature provides correlations of heat flux in each regime, it lacks detailed time-resolved visualization of cryogenic spray-droplet impact outcome as the solid wall undergoes chilldown. The objective of this investigation is to map cryogenic droplet impact outcomes at different wall temperatures and their dependence on the droplet Weber number. Additionally, this study also examines the differences between the droplet impact and spray impact. In the experimental setup, a full cone spray of liquid nitrogen was impinged on a thin stainless-steel disc instrumented with several thermocouples. The droplet impact dynamics was captured using a high-speed shadowgraph. Results show that the characteristics of droplet impact outcome were governed by rewetting temperature. Above the rewetting temperature, the heat exchange mechanism includes droplet rebound, rebound with droplet breakup, and droplet splash. Below the rewetting temperature, the droplets wet the surface leading to the formation of the thin liquid film. The detailed visualization provides unique insights into the dynamics of a single droplet and spray impact with rewetting temperature as a key factor for computational sub-models

Authors: Mr PATIL, Bhushan (School of Mechanical, Aerospace and Manufacturing engineering, University of Connecticut); SUNG, Chih-Jen (School of Mechanical, Aerospace and Manufacturing engineering, University of Connecticut)

Presenter: Mr PATIL, Bhushan (School of Mechanical, Aerospace and Manufacturing engineering, University of Connecticut)

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