Influence of feedline configuration and its thermal mass distribution on cryogenic childown performance

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by

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Abstract

Feedlines carrying cryogenic fluids need to be pre-chilled 'apriori' to avoid two phase flow at the start of actual operation. This is very critical, especially in applications where only limited time and fluid quantity are available for chilling, as in the case of cryogenic rocket engines. The system and parameters need to be tuned to optimise the chilldown performance without any compromise on the mission requirements. This makes the chilldown process optimisation a very important component at the engine design phase itself. The chilldown process is highly sensitive to parameters like mass flux of cryogen, type of feedline insulation and heat in-leak, orientation of the feedline and its thermal mass distribution, thermophysical property of feedline material and its surface parameters like presence of coating, surface finish etc.. In the present work, influence of these parameters is experimentally studied employing stainless steel test sections insulated with poly-isocynurate foam with liquid Nitrogen as the simulant fluid. Experiments are performed using test sections of two different diameters. Measurements are made with the test section held horizontal and at different upward and downward orientations. Wall heat flux at different stations along the length of the test section is estimated by inverse heat transfer technique using the measured temperature data and its pattern of variation studied. Visualisation studies are performed to understand the flow structure prevailing in the test section during experiments with varying orientations and the trend in wall temperature profile is correlated with flow structure observed. Influence of thermal mass distribution of the feedline is investigated with additional thermal mass located near to the inlet as well as exit of the test section. Effect of thermophysical property, presence of metallic and nonmetallic coatings, and surface finish on chilldown performance are also evaluated experimentally. The experiments are followed up with numerical studies for varying orientations of test section to predict the wall temperature profile and results are compared with the experimental data.

The present study shows that chilldown performance is significantly improved with upward orientation as compared to horizontal or downward orientation and the reason for the same is corroborated with the observations from visualisation studies. Studies done to understand the effect of feedline thermal mass distribution show that additional thermal mass placed near to inlet gives better performance as compared to its placement near the exit. Studies on influence of thermal conductivity and coatings have given valuable inputs on measures to be adopted to optimise the chilldown performance. Findings of the present study would certainly help to explain the physics, improve the understanding on the effect of sensitive parameters on the chilldown performance of cryogenic feedlines and would certainly enable the designers to configure feed systems with improved chilldown performance.