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AXIAL LOW BOND NUMBER SLOSHING OF LIQUID HYDROGEN

Abstract

Future launcher concepts use liquid hydrogen (LH2) as propellant and liquid oxygen (LOX) as oxidizer. They may experience long ballistic phases with varying acceleration levels. For propellant management purposes, it is important to understand the response of cryogenic fluids (liquid and vapor) to these disturbances. Furthermore, superheated tank walls influence the moving free surface of the liquid in partially filled tanks. This study investigates the free surface reorientation of liquid hydrogen upon a sudden step reduction of gravity in presence of a superheated wall. The pressure was set around normal pressure leading to a saturation temperature of 20 Kelvin.

The experiment consisted of a glass cylinder partly filled with liquid hydrogen enclosed in a cryostat to insulate it from ambient conditions. Temperatures were recorded at several locations along the cylinder and in the vapor phase. The pressure inside the cylinder was recorded with a pressure transducer and optical access was enabled with an endoscope. Various heating elements were glued to the cylinder for thermal control of the experiment. Thermal stratification in the liquid phase could be neutralized and wall heating elements were used to establish a wall temperature gradient in vertical direction.

Experiments were carried out in the drop tower at the University of Bremen. Experiment time in microgravity lasted 4.7 seconds. Several experiments with varying wall temperature gradients were performed. The reorientation of the free surface could be recorded focusing on wall and center point location. A final equilibrium surface position could not be achieved due to limited experiment time.

A numerical technique was developed to simulate the compressible two-phase flow, the thermal effect including phase change phenomena and fluid-solid heat transfer in enclosed cavities. In the phase-change model coupled with the weakly compressible Volume of Fluid (VOF) formulation under low Mach number conditions, the mass transfer is calculated directly from the heat flux at the liquid-vapor interface. The model has been verified for various phase-change problems, whereas the computed results agree with theoretical solutions. The code is applied to the axial sloshing test problem and shows promising results.