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SPRAY ANGLE EVOLUTION OF FLASH BOILING LIQUID NITROGEN SPRAYS DURING THE START-UP OF HIGH-ALTITUDE LIQUID ROCKET ENGINES

Abstract

Technology development for propulsion systems of upper stages and reaction control thrusters is driven by green propellants to substitute hydrazine. At high-altitude conditions prior to ignition these liquid propellants are injected into the combustor at near-vacuum. Due to the sudden pressure drop the liquid is in a superheated thermodynamic state, resulting in an eruptive evaporation and fast expansion, a process called flash boiling. To know the composition related to phase and atomization is important for both to determine the probability of a successful ignition and to avoid destructive pressure peaks.

Hence, a cryogenic test bench with a temperature controlled injection system was built at DLR for an experimental investigation of cryogenic flash boiling sprays. The injection system allows variable cryogenic injection temperatures, which are kept constant during the whole injection process and homogenous in the whole test fluid feed line. The jets are injected into a vacuum chamber to provide high-altitude conditions.

In a first test campaign the characteristics and morphology of flash boiling liquid nitrogen (LN2) jets are investigated in terms of their spray patterns depending on the injection conditions like injection temperature, injection pressure and back pressure. The resulting sprays are visualized by high-speed shadowgraphy and show opening angles of up to 180 with remaining liquid cores close to the injector exit. By post-processing the shadowgraphy images, the spray angles of the investigated LN2 sprays were determined depending on the injection conditions.

These spray angles show a clear evolution for changing degrees of superheat. With the experimental data of flash boiling LN2, a spray angle model from literature derived for storable fluids was modified for the use of cryogenic fluids. The knowing about those spray features is helpful and necessary for the development of numerical models about superheated cryogenic fluids. The test campaigns with LN2 are a detailed preparation for the investigation of flash boiling of actual rocket propellants at this test bench like LOX or LCH4.