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ADVANCED SENSOR TECHNOLOGIES FOR CRYOGENIC LIQUID PROPELLANT FLOW PHENOMENA

Abstract

Sensors for various fluid physical quantities play a vital role in the management of cryogenic liquid propellants (hydrogen, oxygen, methane), used worldwide in heavy-lift launchers such as the European Ariane rockets. In addition, measurement devices are particularly central in all basic scientific fluid experimentation, investigating for instance liquid sloshing, free liquid surface movement, boiling or bubble formation. The results of these experiments in microgravity and on ground enable the efficient design of present-day cryogenic launcher (upper) stages and – as possible future applications – of long-term orbital propellant storage facilities, in-orbit refuelling stations and interplanetary cryogenic propulsion. These utilisations call for sensor technology to efficiently perform propellant mass gauging and to determine fill-levels, temperature fields, phase change quantities and bubble formation in a non-intrusive fashion. Being non-intrusive, a sensor may not impact flow behaviour and any parasitic heating of the cryogenic liquid is to be minimised or avoided completely. Ideally this leads to an improved insight into propellant behaviour and enables a meaningful comparison of experimental results/flight data to CFD (Computational Fluid Dynamics) simulations performed in parallel.

An overview of various candidate cryogenic sensor technologies currently investigated by the authors is provided. Tomographic techniques based on sound waves and electrostatic fields are discussed with respect to their applicability in cryogenic liquids, potential applications areas, engineering challenges and corresponding validation tests. Fibre-optic technologies for visual observations and large scale, high resolution distributed temperature measurements are presented with first results of their validation in cryogenic liquids. New and improved insights into cryogenic liquid propellant behaviour are possible, as

is shown based on experimental applications.