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QUICK DESIGN TOOL FOR STRATIFICATION PROCESSES IN CRYOGENIC FUEL TANKS WITH FOCUS ON SANDWICH COMMON BULKHEADS

Abstract

Thermal stratification in cryogenic fuel tanks is a recurring topic due to the recent decisions on new developments of next generation launch vehicles. The complexity of mechanisms involved and the inaccessibility to measurements under realistic conditions make it hard to gain fundamental understanding and consequently to make accurate predictions. While external aerothermodynamics and heat conduction through solid walls are fairly well understood, motion of cryogenic multi-phase fluids is subject to many different problems. Driven by energy entry from various sources, fluid motion leads to temperature stratification, evaporation and pressure buildup. In the context of space transportation vehicles this topic is crucial to mission planning, weight- and cost- efficiency. Since energy entry and evaporation are associated with loss of valuable fuel, it is of high interest to keep it at a minimum. Modern computational fluid dynamics (CFD) tools require considerable effort and fair amounts of computational power and time in order to model the problem. For preliminary design it is important to obtain accurate results in a short time and be able to test a variety of parameters. Thus the development of a computer-based model that predicts global system properties like pressure, temperature stratification and mass fluxes with little resources is desired. This paper will describe an enhanced Matlab-based model that has proven to perform well in the mentioned aspects. The axisymmetric approach bases on temperature and velocity boundary layers induced by natural convection. An ordinary differential equation solver calculates mass- and temperature- development in boundary layer and bulk cells, as well as tank walls, from which all other physical values are being deduced. Pressurization with Helium gas and different wall/insulation configurations can be taken into account. The model is capable of representing all relevant phases of flight, from pre-takeoff venting on the ramp to coasting on a transfer orbit. This method has been validated with measurements of two demonstrator tanks and further improved to provide sandwich common bulkhead functionality.