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DEVELOPMENT OF EXPERIMENTALLY DERIVED ENGINEERING MODELS FOR THE SIMULATION OF THERMAL STRATIFICATION AND SLOSH-INDUCED PRESSURE DROP IN CRYOGENIC PROPELLANT TANKS

Abstract

A well designed propellant management system in rocket stages is of crucial importance for successful launcher design. Typically about 90Minimization of the required fluid masses requires accurate estimations of propellant heating, thermal stratification and of the enhancement of condensation/evaporation across the liquid vapour interface due to propellant sloshing. Especially in case of missions with long ballistic flight phases where cryogenic propellants are used, as is the case for the ESC-B upper stage currently under development, this is true.

To obtain a better understanding of the effects mentioned above, experiments are carried out at Centre of Applied Space Technology and Microgravity (ZARM) in Bremen, Germany. The experiments involve a closed dewar filled with liquid nitrogen. Due to heat leaks from the surroundings the liquid nitrogen is heated causing thermal stratification in the liquid. Due to evaporation, pressure in the dewar increases. Once a certain pressure is reached the dewar is excited causing the liquid to slosh. The sloshing causes a sharp pressure drop in the system. Detailed investigations of the experiments are done by numerical simulation with the commercially available code FLOW 3D. Using the numerical results engineering models are derived to predict the stratification and thermodynamic effects caused by sloshing without the need of 3D CFD solvers. These models can be used for analysis of full scale upper stage configurations, allowing for more accurate determination of required pressurization gas mass and thermal residuals. This eventually leads to more efficient upper stage designs.

This paper will describe the experimental procedure and discuss the experimental results. The engineering models will be explained in detail and will be compared with experimental and CFD results.