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SLOSHING BEHAVIOR OF LIQUID NITROGEN IN A LARGE SCALE CRYOGENIC TANK DEMONSTRATOR

Abstract

The knowledge about the behavior of the propellant in tank systems is of crucial importance for the design of spacecraft. The sloshing of liquid propellants is of direct importance for the flight stability since the sloshing forces must be controlled by the guidance navigation system. For the prediction of the sloshing behavior in addition the sloshing frequency and the damping behavior has to be known. In case of cryogenic liquids additional thermodynamic effects has to be considered which can have an effect on the tank pressure. To investigate the sloshing phenomena, as well as to generate an experimental data base for tool validation, sloshing test with liquid nitrogen has been performed with a Cryogenic Tank Demonstrator provided by ArianeGroup.

The aim of this study is to determine the damping behavior and the natural frequency of liquid nitrogen in the Cryogenic Tank Demonstrator for various fill level and excitations. The tank demonstrator is mounted on a hexapod system and is equipped with a fill level sensor, an acceleration sensor and a force measurement system. During the tests, first the liquid is forced to a defined sinusoidal motion. After stop of excitation the sloshing forces and liquid motions are recorded and evaluated.

The results show a strong influence of the damping behavior on the sloshing angle. The damping varies during decaying movement and decreases with decreasing sloshing angle. The large tank radii, in conjunction with the low viscosities of the cryogenic liquids, lead to a significant increase in the Galilei number. In addition, turbulent effects are promoted in large tank systems due to the higher fluid velocities paired with low viscosity in case of sloshing. The influence of the sloshing angle on the damping behavior is presented and discussed. The experimental results are compared with state of the art correlations from the literature.