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EXPERIMENTAL AND NUMERICAL INVESTIGATION OF LIQUID SLOSH DYNAMICS ON GROUND AND MICROGRAVITY PLATFORMS

Abstract

The slosh dynamics in cryogenic fuel tanks under microgravity is a problem that severely affects the reliability of spacecraft launching. To date, computational fluid dynamics (CFD) models which examine low-gravity slosh, as well as the dynamics of fluid-structure coupling during slosh events, have not been benchmarked against experimental data. Experimental measurements of slosh are made using a variety of platforms, including ground-based testing and parabolic flights. It is proposed that the 3-D rigid body acceleration of the tank relative to an inertial frame, along with the initial liquid distribution and tank geometry, uniquely determines a slosh event. A slosh event is completely described by the rigid body acceleration of the tank, and a set of orthogonal images. The proposed hypothesis is validated by CFD models. Both the tank's predicted acceleration and images of the liquid profile are used to assess the ability of the proposed approach to correctly predict a slosh event. To bridge the gap of acquiring low-gravity, liquid slosh data a Slosh platform is designed with the intent of performing experiments on the International Space Station (ISS). The proposed experimental platform consists of a tank partially filled with water, inertial measurement units to measure the dynamics of the system, as well as cameras to image the fluid distribution in the tank. The SPHERES Slosh Experiment (SSE) utilizes the existing ISS SPHERES apparatus, which will be used to maneuver the tank through a variety of trajectories. To mimic the motions of actual upper-stage rocket maneuvers, a scaling analysis based on relevant non-dimensional parameters is performed and applied to the design and operation of the SSE onboard the ISS. A rigid body analysis and a computational analysis are performed to optimize the experiment and motion profiles. The SSE is scheduled to fly to the ISS in September of 2013