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Slosh Investigations on a Spacecraft Propellant Tank for Control Stability Studies

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Abstract : Spacecrafts generally employ liquid propulsion for their attitude and orbital maneuvers or raising it from geo-transfer orbit to geosynchronous orbit. Liquid propulsion systems use either mono-propellant or bi-propellants for generating thrust. These propellants are generally stored in either spherical tanks or cylindrical tanks with spherical end domes. The propellant tanks are provided with a propellant acquisition system/propellant management device along with vanes and their conical mounting structure to ensure propellant availability in the outlet for thrust generation even under a low/zero-gravity environment. Slosh is the free surface oscillations in partially filled containers under external disturbances. In a spacecraft, these can be due to control forces and due to varying acceleration. Knowledge of slosh and its effect due to internals is essential for understanding its stability through control stability studies. It is mathematically represented by a pendulum-mass model. It requires parameters such as slosh frequency, damping, sloshes mass and its location, etc. This paper enumerates various numerical and experimental methods used for evaluating the slosh parameters required for representing slosh. Numerical methods like finite element methods based on linear velocity potential theory and computational fluid dynamics based on Reynolds Averaged Navier Stokes equations are used for the detailed evaluation of slosh behavior in one of the spacecraft propellant tanks used in an Indian space mission. Experimental studies carried out on a scaled-down model are also discussed. Slosh parameters evaluated by different methods matched very well and finalized their dispersion bands based on experimental studies. It is observed that the presence of internals such as propellant management devices, including conical support structure, alters slosh parameters. These internals also offers one order higher damping compared to viscous/ smooth wall damping. It is an advantage factor for the stability of slosh. These slosh parameters are given for establishing slosh margins through control stability studies and finalize the spacecraft control system design.

Keywords : control stability, propellant tanks, slosh, spacecraft, slosh spacecraft
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