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MITIGATION STRATEGIES FOR ON-ORBIT FLUID SLOSH DEVELOPMENT INDUCED BY REFUELING: SLAT SCREEN SOLUTION

Abstract

The new age of space exploration has brought forth growing implications of space debris connected to satellites, and as such sustainable solutions such as on-orbit satellite refueling is an area of active research. As fuel supply is diminished, satellites are decommissioned despite all other onboard systems functioning. Proposed solutions include a servicing satellite transferring propellant to the empty fuel tank of the satellite being serviced. A significant impediment to such a practice is the development of fluid slosh during this process. As propellant enters the empty fuel tank, fluid motion becomes irregular due to the microgravity environment. This creates dynamic forces which can create instability between the two satellites. As such, it is vital to mitigate the effects of fluid slosh, which can be accomplished by understanding the forces and properties dominant in the formation of this phenomena.

This paper studies dampening of fluid slosh using slat screens during a simulated fuel tank refueling. This was done by filling test chambers with fuel-analogous fluids under microgravity conditions and observing the effect of slat screens on slosh development. Two fluids, each analogous to common spacecraft propellants, were tested in a microgravity environment created by parabolic maneuvers in the National Research Council of Canada's Falcon 20 research aircraft. Water was used as a fluid analogous to hydrazine, a common hypergolic monopropellant, while 3M(TM) FC-72(TM) was used for its properties similar to that of liquid oxygen, a common bipropellant. Over the course of 25 parabolas, fluid was driven into three separate chambers and the resulting slosh was monitored. Two of the three chambers contained different slat screens designed to mitigate sloshing and one chamber with no slat screen served as a control. Sloshing effects were measured through the use of load cells and accelerometers connected to each chamber. These sensors gathered data regarding the acceleration of their respective chambers, which was taken as a proxy for the forces created by the sloshing fluids. Video footage of fluid slosh development within the test chambers continues to be analyzed.

Based on preliminary findings of the hydrazine-analogous fluid, it was found that the perforated slat screen was the most effective in dampening slosh development as liquid entered the chambers. This suggests that similarly designed slat screens could be adopted by industry in the pursuit of on-orbit refueling and the development of more sustainable spacecraft.