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# THE IMPACT OF THE SLOSHING MOTION COMBINED WITH FLEXIBILITY OF SPACECRAFT COMPONENTS IN THE DESIGN OF ATTITUDE AND ORBIT CONTROL SUBSYSTEMS

**Abstract**

The sloshing effects in the space vehicle dynamics have been subject of studies since the early days of the space conquest. Before 1966, the problems of fuel sloshing and its suppression/control during thrusting or for large axial acceleration conditions were fairly well analyzed/understood. However, the corresponding knowledge of fluid behavior during periods of low accelerations was rather meager and restricted to specific applications. In 1966 to 1970 NASA conducted researches to study the lateral sloshing of liquids in non symmetric tanks under zero-g circumstances. The studies involved very complex mathematical modeling and dynamics analysis accounting for the shape of the fluid container as well as the devices to make the fluid motion frequency widely separate from those of control subsystems. The sloshing problem solution for spacecraft under zero-g gravity still persists and recent accidents associating sloshing with the mission failures have been reported in the space news. To avoid catastrophic sloshing in spacecraft, the attitude and orbit control subsystem frequencies, the vehicle elastic structure frequencies, and the fluid-slosh frequencies must be fairly widely separated and unfortunately this is not always the case. For example, space vehicle under rotating motion such as spinning and unavoidable wobbling and precession cause the liquid to oscillate, and thus generate dynamic forces, which can destabilize the spacecraft. Recently the sloshing problem received special attention in the control subsystem of the automated transfer vehicles, the ATVs, an expendable spacecraft to transfer cargo to and from the International Space Station (ISS). The analysis carried out took into the perturbation caused by the sloshing and solar panels that should be avoided by the design of sloshing damping devices or controlled by the control subsystem. Also the effect of sloshing on the solar panel vibration and vice-versa as well as from both, sloshing and solar panel on the control subsystem was considered in the analysis. Solutions are much more towards mechanism and procedures to avoid the control structure (including the liquid tanks) interaction than trying to actively, control the sloshing and vibrational/rotational dynamics. The subject of this paper is to discuss the problems of sloshing modeling and computer simulations including the effect of flexible component vibrations and the associated interaction with the control actions to keep the spacecraft behavior according to the mission specifications.