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DYNAMIC MODELLING AND CONTROL OF A FLEXIBLE SPACECRAFT WITH FUEL SLOSH

Abstract

Modern spacecraft often contain large quantities of liquid fuel to execute station keeping and attitude maneuvers for space missions. The study of liquid slosh in moving spacecraft has been a problem of considerable interest due to the large amounts of liquid fuel that they use for such manoeuvers. In recent works a hybrid control method based on input shaping technique and feedback linearization for liquid-filled spacecraft maneuvers was proposed to guarantee that the attitude maneuver does not excite the liquid-fuel slosh. In general the combined liquid–structure system is very difficult to model, and the analyses are based on some assumed simplification. A realistic representation of the liquid dynamics inside closed containers can be approximated by an equivalent mechanical system. The technique of equivalent mechanical models can be considered a very useful mathematical tool for solving the complete dynamics problem of a system containing liquid and they are particularly useful when designing a control system or to study the stability margins of the coupled dynamics. The commonly used equivalent mechanical models are the mass–spring models and the pendulum models. The first ones are able to represent the linear lateral sloshing mode whereas the second ones have the advantage that the natural frequency varies with changes in acceleration. Furthermore the pendulum model can represent large slosh motions and are more often used to emulate nonlinear rotary sloshing. As far as the spacecraft modelling is concerned usually they are considered rigid; i.e. no flexible appendages such as solar arrays or antennas are taken into account when dealing with the interaction of the attitude dynamics with the fuel slosh. In the present work the interactions among the fuel slosh, the attitude dynamics and the flexible appendages of a spacecraft are first studied via a classical multi-body approach. In particular the nonlinearly coupled equations of attitude and orbit motion are derived for the partially liquid-filled flexible spacecraft undergoing fuel slosh. Then several attitude control techniques smoothed by the command shaping technique will be implemented and also investigated to study their authorities to compensate the induced oscillations on the fuel-slosh and on the satellite flexible appendages during attitude and station keeping manoeuvers. Numerical simulation results will be presented to demonstrate the effectiveness of the proposed control technique. Finally an experimental set-up of a flexible-free- flyer with a fuel container will be presented and preliminary experimental results will be compared with the numerical ones.