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ROBUST CONTROL OF SATELLITE WITH FUEL SLOSH INSTABILITIES

Abstract

Sloshing is defined as the periodic motion of the free surface of a liquid in a partially filled tank or container. In launch vehicles or spacecrafts, sloshing can be induced by tank motions resulting from guidance and control system commands or from changes in vehicle acceleration. Fuel slosh creates low-frequency disturbances which interact with the spacecraft's dynamics. In telecom satellites, propellant needed to reach geosynchronous orbit and perform further trajectory adjustment can represent near half of the initial total mass. Thus, fuel slosh oscillations have to be safely managed by the attitude control system, especially during Orbit Raising Mode where the propellant is excited by the apogee engine and the reaction control thrusters. Slosh control is currently studied by Thales Alenia Space (Cannes) to improve controller design methodology. The problem is to control the attitude of a satellite while performing the apogee boost required to reach geosynchronous orbit. This satellite has two propellant tanks which natural slosh frequencies are located close to the controller's cut-off frequency. One of the tricky aspects of this design is that the two sloshing modes has opposite pole/zero succession, creating one left and one right rotating cycles on the Nichol's chart of the open loop. Thus, accurate phase control is required to ensure stability. The other tricky point of the dynamics comes from the solar arrays' bending modes. To avoid structural damage, we want the bending modes resonances to stay below 0dB, which is usually done by using a roll-off filter. However the first bending mode has a natural frequency located only half a decade higher from the second sloshing mode, thus making the design of the controller quite complicated. Therefore, the required controller has to operate phase control on the slosh modes, gain control on the solar arrays' modes, while satisfying additional time constraints. What is more, it must be robust to uncertainties and parametric variations such as the propellant tanks' filling ratio without using gain interpolation or gain-scheduling techniques. This study aims at using H method to allow a simpler, faster, and more robust design of controller.