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LIQUID-FILLED SPACECRAFT FINITE-TIME ATTITUDE MANEUVER CONTROL WITH ANGULAR AND VELOCITY CONSTRAINT

Abstract

With the development of the aerospace industry, the mass of liquid fuel carried by spacecraft is also increasing to conduct more complex space exploration missions such as on-orbit refueling and space debris removal. Moreover, there is an increasing liquid fuel consumption when the spacecraft completes attitude and orbit maneuver, significantly increasing the nonlinearity and uncertainty of spacecraft dynamics and bringing significant challenges to spacecraft attitude maneuver control. Considering that during attitude maneuver, the control torque is easy to stimulate the liquid slosh, which will affect the attitude control performance and even lead to system instability. So it is necessary to constrain the angular velocity during the attitude maneuver. This paper considers the large-angle attitude maneuver control of a liquid-filled spacecraft system. Because of the consumption of liquid fuel, the mass property of the system is unknown and slowly time-varying. So a novel finite-time attitude maneuver control law based on barrier Lyapunov function (BLF) and backstepping method in the presence of unknown, time-varying system dynamics and angular velocity constraint aims to avoid violent liquid slosh is proposed. Firstly, the sloshing liquid in a partially filled tank carried by spacecraft is equivalent to a sloshing slug — a sphere of uniform density with a variable radius, and the rigid-liquid coupling dynamic equations with unknown parameters of the spacecraft are deduced by using the law of conservation of moment of momentum. Secondly, a finite-time prescribed performance function (FTPPF) is proposed to guarantee the convergence of spacecraft attitude error to zero within the setting time, with the help of FTPPF and the angular velocity constraint, a time-varying BLF and a logarithmic BLF are proposed correspondingly. Furthermore, a backstepping control law is designed for the spacecraft attitude maneuver based on augmented Lyapunov functions. Meanwhile, an adaptive law is designed to estimate the unknown and slowly time-varying parameters in the spacecraft system. Finally, numerical simulation results are provided to show the effectiveness of the proposed control and estimation algorithms.