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Author: Dr. lei yang
China Academy of Space Technology (CAST), China, yanglei@cast.cn

Dr. Hua Huang
China Academy of Space Technology (CAST), China, huang.hua@163.com

RESEARCH ON COUPLED DYNAMICS OF LARGE AMPLITUDE LIQUID SLOSHING WITH SPACECRAFT BASED ON 3D CONSTRAINT SURFACE MODEL

Abstract

With the increasing amount of liquid on board spacecraft, liquid sloshing and its influence on the spacecraft attitude dynamics and control is becoming increasingly important. During fast attitude maneuver, docking or landing , the acceleration of the spacecraft can induce large amplitude liquid sloshing. Liquid sloshing may have a significant effect on the spacecraft motion. Hence, analysis of liquid sloshing dynamics of spacecraft has been a problem of considerable interest. For small amplitude liquid sloshing analysis, the traditional approach is to model the sloshing liquid by an equivalent pendulum model or an equivalent mass-spring model. While for large amplitude liquid sloshing , the methods based on computational fluid dynamics (CFD) is usually used. However, the CFD methods usually require mass time, and they are very difficult to model the coupled dynamics between liquid sloshing and spacecraft movement. A 3-dimensional constraint surface mechanical model, which can predict the forces and moments of large amplitude liquid sloshing in containers of spacecraft, was developed. The model portrays the liquid as a point mass moving on a constraint surface, which is the locus of location of liquid center of mass when rotating the container slowly. In order to increase the precision of the model, the point mass was allowed to move into the constraint surface. The Newton-Euler method was used to derive the coupled dynamic equations between liquid sloshing and spacecraft attitude motion. The model was validated against a CFD software and experimental data. The calculation speed of present model is about 300 times that of CFD software (Fluent). The numerical results were in good agreement with the on orbit experimental results of Sloshsat FLEVO launched in 2005.