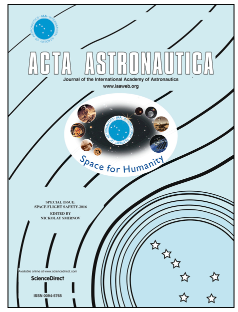
Accepted Manuscript



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Yuanyuan Li, Zilu Wang, Cong Wang, Wenhu Huang

PII: S0094-5765(17)30896-2

DOI: 10.1016/j.actaastro.2017.10.008

Reference: AA 6497

To appear in: *Acta Astronautica*

Received Date: 30 June 2017

Revised Date: 20 September 2017

Accepted Date: 4 October 2017

Please cite this article as: Y. Li, Z. Wang, C. Wang, W. Huang, Planar rigid-flexible coupling spacecraft modeling and control considering solar array deployment and joint clearance, *Acta Astronautica* (2017), doi: 10.1016/j.actaastro.2017.10.008.

Planar Rigid-flexible coupling spacecraft modeling and control considering solar array deployment and joint clearance

Yuanyuan Li[a], Zilu Wang[b], Cong Wang[a*] and Wenhu Huang[a]

[a]School of Astronautics, Harbin Institute of Technology, Harbin, P.R. China

[b]School of Aerospace Engineering, Tsinghua University, Beijing, P.R. China

*Corresponding author email address: alanwang@hit.edu.cn

ABSTRACT

Based on Nodal Coordinate Formulation (NCF) and Absolute Nodal Coordinate Formulation (ANCF), this paper establishes rigid-flexible coupling dynamic model of the spacecraft with large deployable solar arrays and multiple clearance joints to analyze and control the satellite attitude under deployment disturbance. Considering torque spring, close cable loop (CCL) configuration and latch mechanisms, a typical spacecraft composed of a rigid main-body described by NCF and two flexible panels described by ANCF is used as a demonstration case. Nonlinear contact force model and modified Coulomb friction model are selected to establish normal contact force and tangential friction model, respectively. Generalized elastic force are derived and all generalized forces are defined in the NCF-ANCF frame. The Newmark- β method is used to solve system equations of motion. The availability and superiority of the proposed model is verified through comparing with numerical co-simulations of Patran and ADAMS software. The numerical results reveal the effects of panel flexibility, joint clearance and their coupling on satellite attitude. The effects of clearance number, clearance size and clearance stiffness on satellite attitude are investigated. Furthermore, a proportional-differential (PD) attitude controller of spacecraft is designed to discuss the effect of attitude control on the dynamic responses of the whole system.

Keywords: NCF-ANCF, Solar arrays, Clearance joint, Attitude control

1 Introduction

Solar arrays, as vital spacecraft appendage, provides necessary power for the whole system. The success of deployment of solar array is the first task for a spacecraft in space and the failure would be a disaster for a space mission. Moreover, the deployment of large flexible solar arrays disturbs the spacecraft flight and has un-neglected effect on satellite attitude in orbit. Thus, to model the deployable solar array system and to study the effects on satellite attitude have deserved attentions from many researchers, which are the foundations of mechanism design, precision analysis and control system design.

Paolo et al. [1] analyzed the attitude behavior of the spacecraft with one flexible panel under the sloshing motion described through a spherical pendulum model. Liu et al. [2] proposed a rigid-flexible-thermal coupling dynamic model for satellite multibody system. Alipour et al. [3] derived a precise compact dynamic model for an active stabilized spacecraft system with flexible members and then developed attitude control algorithm. Birhanu et al. [4] used ADAMS and ANSYS computer programs to simulate and model solar panel deployment and locking process, and the results demonstrated the effects on attitude of satellite. Li et al. [5] presented a modeling method for rigid solar array system considering joint