SUMMARY OF Ph.D. DISSERTATION

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Title

Abstract

Modern space vehicles often consists complex, large and light extensible membrane structures which have a mechanism to maintain the membrane tension. However, the deformation–heating coupling may generate vibrations of increasing amplitude that have caused spacecraft to experience such large motions that they were unable to complete their intended missions.

For the assurance of reliability, so called "fault tolerant" design is usually employed for the Spacecraft Attitude Orbit and Control Subsystem (AOCS). More specifically, FDIR (Fault Detection, Isolation and Reconstruction) techniques have been applied to many satellites with successful mission operations. On the other hand, the healthiness of extensible membrane structure is monitored by ground off-line evaluation using telemetry data of sensors attached to the structure. However, there is possibility that the anomaly of extensible membrane structure can result in total loss of spacecraft because of time delay of technical decision.

From above technical points of view, new mathematical model and analytical method to evaluate spacecraft attitude stability are proposed focusing on stick-slip phenomenon excited unstable vibration of extensible membrane structure. For the fault tolerant design of extensible membrane structure, the design method of new FDIR that predicts anomaly and maintains healthiness of membrane structures on-board is proposed. In the primary chapter, background on this study and transition of other research are outlined. In addition, the necessity of the positioning of this study and purpose of this research are clearly shown.

In chapter 2, new mathematical model to evaluate spacecraft dynamics including stick-slip phenomenon is proposed. This model assumes that the spacecraft is composed of a main rigid body and flexible appendages, consisting of a number of rigid plates connected by torsional hinges. The key parameters of the hinges have been determined by applying the equations of the vibrational motion of a uniform cantilever beam with tangible physical parameters.

In chapter 3, the formulation of thermal distortion of flexible solar array and stick-slip phenomenon of Tension Control Mechanism (TCM) are presented Using these model and mathematical spacecraft model proposed in chapter 2, spacecraft dynamics including stick-slip phenomenon of ADEOS(ADvanced Earth Observing satellite) and ADEOS-II (ADvanced Earth Observing Satellite) is simulated. As a result of comparison the simulation results with flight data, mathematical model used here is evaluated.

In chapter 4, approaches to decrease the vibration of spacecraft caused by stick-slip phenomenon of TCM is proposed. From hardware technical point of view, the design method to improve the non-linearity friction characteristics of TCM is proposed based on the ground tests and flight data analysis. From software technical point of view, the method to optimize AOCS gain with linear dynamics model with movement of equilibrium point is proposed.

In the chapter 5, the design method of new FDIR that predicts anomalies of membrane structures and prevents fatal losses of spacecraft is proposed. In case of that the accelerometer data of membrane structure and the gyro data of spacecraft are exceed threshold value, the AOCS control mode is changed automatically on orbit and decrease the coupling oscillation between AOCS and membrane structure and stress of membrane structure.

In chapter 6, the results derived from each chapter are summarized and the conclusion of this dissertation is described.