Frequency Identification of Flexible Hub-Beam System Using Control Data

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This paper studies the parameter identification of a flexible hub-beam system based on the input-output data. Firstly, the first-order approximation coupling (FOAC) model is presented. Then, active position control for the system is studied using optimal tracking control theory. Finally, the observer/Kalman filter identification (OKID) and eigensystem realization algorithm (ERA) method are applied to identify the frequency of the system. In the simulations, the effectiveness of the identification method presented in this paper is verified by comparing the identification results of several different external excitations. Simulation results indicate that the anticipated position of the system may be traced by the proposed controller, and the residual vibration of the beam may be suppressed as well. The frequency of the system can be effectively identified using OKID and ERA. It is feasible and effective to identify the frequency using the control data.

1. INTRODUCTION

Spacecraft is composed of a central body and several flexible attachments. It is a typical rigid-flexible dynamic system with characteristics of dense frequencies and small damping. System assembly on the ground (1G gravity environment) is very difficult in many circumstances because of the flexibility of the structures; it is even more difficult to do vibration experiments on structures due to factors such as air damping, gravity effect, etc. Moreover, in some cases, the experimental apparatus may not be able to meet the experimental requirement of tests on the ground. On the other hand, flexible parameters of spacecraft, especially the natural frequencies of flexible solar array, may have great effect on the control of the spacecraft's attitude, since the flexible parameters will be used in control design. Due to the difference between ground and space environments, vibration behaviour of the solar array in two environments is different, too. So, the flexible parameters obtained by experiments on the ground cannot reflect the actual state of spacecraft in outer space. Therefore, it is necessary to study the on-orbit identification technology for the spacecraft to improve the accuracy in identifying flexible parameters. Since the flexible parameters obtained by the on-orbit identification are based on the real vibration of a spacecraft in outer space, it is more likely that these parameters are of high accuracy, and then control design based on these parameters can ensure high accuracy of attitude control. Furthermore, a system dynamic model may be modified by comparing the on-orbit test with the ground test so as to establish the quantitative relationships among the on-orbit test, the ground test, and the dynamic simulation. This will be helpful for the follow-up development of the spacecraft. The on-orbit identification needs the vibration response of spacecraft under certain excitation, which could be provided by the attitude manoeuvre, which means the realization of on-orbit identification is possible.

On-orbit parameter identification is conducted by directly using the input and output data, with no need of the exact dynamic model of the system. Generally speaking, the parameter identification methods can be divided into frequency domain methods and time domain methods, and the time domain method has better performance than the frequency domain method. Theoretical studies and engineering applications of the on-orbit identification technique have been completed in past research. For example, Haugse, et al.[1] developed an accelerometer measurement system to gather data from an operational, on-orbit, and deployed space vehicle, and Fast Fourier Transform (FFT), Power Spectral Density (PSD) and Eigensystem Realization Algorithm (ERA) are employed for system modal identification. Kim, et al.[2] presented a data processing strategy to generate equivalent free-decay responses from structural response data and used a free-decay time-domain modal identification technique for modal identification of Space Station Freedom. Tokio Kasai, et al.[3] used the extended Kalman filter (EKF) technique to extract the modal parameters of a satellite with flexible solar panels. On the Engineering Test Satellite VI, impulse and random excitation were applied to the central body, and the measurement data were packed and downloaded via S-band digital serial telemetry for the off-line analysis by the ERA method. The identified modal parameters were then used in the synthesis of control law.[4–8]

On the International Space Station (ISS), the shuttle booster ignition pulse was used as an excitation to finish an on-orbit modal parameter identification test five times. The dynamic responses of the Shuttle-ISS mated structure were measured by the Shuttle payload bay video camera photogrammetric system, the Internal Wireless Instrumentation System (IWIS) ac-