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On-orbit modal parameter measurement and identification method for large flexible structures of space stations

空间站大型挠性结构模态参数在轨测量及辨识方法

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Foreword

This document conforms to GB/T 1.1-2020 "Standardization Work Guidelines Part

1.Structure and Drafting Rules of Standardization Documents". Drafting is scheduled. Please note that some content in this document may involve patents. The issuing organization of this document assumes no responsibility for identifying patents. This document is under the jurisdiction of the National Technical Committee on Standardization of Manned Spaceflight (SAC/TC 570). This document was drafted by: Beijing Institute of Control Engineering, Beijing Spacecraft Overall Design Department, and Shanghai Aerospace Systems Engineering Institute. Beijing Institute of Space Technology Information The main drafters of this document are. Lang Yan, Zhang Guoqi, Zhang Jinjiang, Li Gongjun, Guo Chaoli, Lei Yongjun, Shi Jixin, Li Jingtao, Zang Xu, and Song Xiaoguang. Wang Xu. On-orbit measurement of modal parameters of large flexible structures on space station and identification methods

1.Scope This document specifies the purpose, typical modal parameters, and observation methods for conducting on-orbit modal parameter measurements and identification of large flexible structures on the space station. Measurement, on-orbit measurement system, timing and process of measurement and identification, implementation preparation, on-orbit measurement, modal parameter identification and processing, and identification results. Effectiveness evaluation. This document applies to the on-orbit measurement and identification of modal parameters for large flexible structures such as solar panels on the space station. Other large flexible structures... This is used as a reference for on-orbit

measurement and identification experiments of spacecraft.

4.On-orbit measurement and identification objectives By stimulating the intrinsic modal motion of a specific large flexible structure on the space station, the on-orbit modal parameters of the tested large flexible structure are measured and obtained. The model of the tested flexible structure is corrected by the data, providing a basis for optimizing the design of the control system.

5 Typical modal parameters and observations

In-orbit identified modal parameters generally include natural frequencies, modal damping, and mode shapes. These three modal parameters are mainly derived from data collected over a period of time. The data is obtained from the continuous vibration motion curves of a large flexible structure under test, excited by external forces/torques. Displacement, acceleration, and angular velocity are the three physical parameters. The quantity can be used to characterize the vibration and motion characteristics of flexible structures. This is achieved by collecting displacement, acceleration, or... at a single measuring point on the large flexible structure under test. Continuous-time curves of any physical quantity, such as angular velocity, can be used to identify natural frequencies and modal damping; by collecting data from the tested large flexible structure, the same... The continuous-time curves of displacement or acceleration at multiple measuring points within a certain time period can be used to identify the mode shape.

6 On-orbit Measurement System

6.1 Composition The on-orbit measurement system consists of sensors and information processing units deployed on the space station. The sensors are used to acquire data from the large flexible structures under test. The vibration characteristic data at the measurement points on the structure includes three types. displacement sensors, acceleration sensors, and angular velocity sensors. The information processing unit uses... It can receive, store locally, and transmit vibration characteristic data from sensors in orbit.

6.2 Sensors

6.2.1 Performance Requirements The sensor performance requirements are as follows:

a) The frequency response range covers the frequency range of the flexible structure under test. For the space station's solar panels, the sensor's frequency response... The range should cover

0 Hz to

b) The sampling frequency should generally be 5 to 10 times the upper limit of the vibration frequency to be measured of the flexible structure under test, preferably 10 times.

c) The signal-to-noise ratio of the measurement data should meet the accuracy requirements for modal parameter identification of the space station, and should preferably be greater than 10.

d) The sensor installed on the flexible structure being tested should be small in size and light in weight.

e) Measurement error over the entire temperature range in orbit. 1) The displacement sensor is better than 2 mm; 2) The accelerometer is better than 2x10^-3 m/s^2; 3) The angular velocity sensor is better than 1x10-3 °/s.

6.2.2 Layout Requirements Simulations were conducted to predict the dynamics of the large flexible structure under test on the space station, and the simulation results were used to guide the selection and placement of sensors. The sensor placement requirements are as follows:

a) The excitation response measurement data at the sensor measurement point should have a high signal-to-noise ratio, preferably greater than 10.

b) The number of sensor measurement points should be sufficient to meet the requirements for mode shape identification; generally, an optical camera is selected. The optical camera should be able to... Effective observation of the area/point to be measured in the flexible structure.

c) Meet the space station's installation constraints for measurement sensors.

6.3 Information Processing Unit The information processing unit has the following requirements.

a) Processor. Clock speed not less than 50 MHz, 64-bit clock/counter, continuous timing capability greater than 30 days, meeting high-speed data acquisition requirements; Requirements for storage, transmission, and clock synchronization.

b) Data storage. This includes the amount of data per frame from the measurement sensor, sampling frequency, acquisition duration of a single test, and data transmission after multiple tests. Related to parameters such as cycle time. The space station's on-orbit measurement and identification mission requires an effective storage capacity of no less than 58 GB, optical... The camera storage area should be no less than 56 GB, and the accelerometer storage area should be no less than 2 GB.

7 Timing and Procedures for On-Orbit Measurement and Identification

7.1 Implementation Timing In the event of any of the following conditions, on-orbit measurement and identification of modal parameters of large flexible structures should be carried out on the space station.

a) Significant changes have occurred to the space station's solar panels. for example, impacts from debris have caused substantial changes in their structural properties, or new structural elements have been installed. Solar wings made of structural materials.

b) Other large flexible structures that may affect control performance have been added to the space station complex.

c) Situations where the overall assessment of the space station project deems it necessary to conduct on-orbit identification.

7.2 Implementation Process By actively or passively exciting the flexible structure of the space station in orbit, modal vibrations are induced in the identified flexible structure, and the vibrations are then analyzed. Dynamic measurement sensors collect vibration data, which is then transmitted to the ground via the measurement and control subsystem. Ground equipment receives the data and, based on... The modal parameters were identified using the modal identification method based on the measurement data. The implementation process of the on-orbit measurement and identification test of modal parameters of large flexible structures on the space station is shown in Figure 1.

8 On-orbit preparation

8.1 Flight Attitude Requirements The flight attitude under active excitation should meet the engineering constraints of subsystems such as energy, thermal control, telemetry and communication, structure, and control, as well as vibration. Constraints on the effective use of dynamic measurement sensors. Under the premise of prioritizing the controllability of the space station's attitude, the attitude angle and attitude angular velocity... The degree error meets the requirements of the identification task and the safety requirements of attitude control. There are no specific requirements for flight attitude under passive excitation.

8.2 Incentive Requirements

8.2.1 Incentive Position Requirements Under active excitation, the excitation location should be selected to excite the main modes of the flexible structure and to ensure engineering feasibility.

8.2.2 Incentive Method Requirements Prioritize the use of attitude control and orbit control thrusters, control torque gyroscopes, and flexible structure drive mechanisms from the space station to control the measured flexibility. The structure implements active stimulation. When active stimulation is inconvenient, the space station's orbital control, attitude control, and docking maneuvers can be utilized. Passive incentives are implemented through actions such as striking.

8.2.3 Requirements for Active Excitation Signals The requirements for active excitation signals are as follows: