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Microgravity Sciences Onboard the International Space Station and Beyond - Part 1 (6)

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CONTROL PERFORMANCE SIMULATION AND ANALYSIS FOR MICROGRAVITY VIBRATION ISOLATION SYSTEM IN CHINESE SPACE STATION

Abstract

Microgravity Science Experiment Rack (MSER) will be onboard TianHe (TH) spacecraft planned to be launched in 2018. TH is one module of Chinese Space Station. Microgravity Vibration Isolation System (MVIS), which is MSER's core part, is used to isolate the disturbance from TH and provide high-level microgravity for science experiment payloads. MVIS is two-stage vibration isolation system, consisting of Follow Unit (FU) and Experiment Support Unit (ESU). FU is linked to MSER by umbilical cables. ESU suspends within FU and has no physical connection with it. The FU's position and attitude relative to TH is measured by binocular vision measuring system, and the acceleration and angular velocity is measured by accelerometers and gyroscopes. Air-jet thrusters are utilized to generate force and moment to control FU's motion. Measurement module for ESU contains a set of Position-Sense-Detectors (PSD) sensing the ESU's position and attitude relative to FU, accelerometers and gyroscopes sensing ESU's acceleration and angular velocity. Electro-magnetic actuators are used to control ESU's motion. Firstly, linearize equations of FU's motion relative to TH and ESU's motion relative to FU are derived, laying the foundation for control system design and simulation analysis. Subsequently, two control schemes are proposed. One control scheme is that ESU tracks FU and FU tracks TH, shorten as E-F-T. The other one is that FU tracks ESU and ESU tracks TH, shorten as F-E-T. In addition, motion spaces are constrained within 15 mm2 between FU and ESU, and within 300 mm between FU and TH or between ESU and TH. A Proportional-Integrate-Differentiate (PID) controller is designed to control FU's position and attitude. ESU's controller includes an acceleration feedback loop and a relative position feedback loop. A Proportional-Integrate (PI) controller is designed in the acceleration feedback loop to reduce the ESU's acceleration level, and a PID controller in the relative position feedback loop is used to avoid collision. Finally, simulations of E-F-T and F-E-T are performed considering variety uncertainties, disturbances and motion space constrains. The simulation results of E-F-T showed that control performance was from 0 to -20 dB for vibration from 0.01 to 0.1 Hz, and vibration was attenuated 40 dB per ten octave above 0.1Hz. The simulation results of F-E-T showed that vibration was attenuated 20 dB per ten octave at the beginning of 0.01 Hz.