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Control Performance Simulation and Analysis for Microgravity Vibration Isolation System Onboard Chinese Space Station

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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 disturbance from TH and provide high-level microgravity for science experiment payload. 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, and ESU suspends within FU and without physical connection. 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 used to generate force and moment to control FU's motion. Measurement module on 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, the linearized 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 mm□±2° 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-T-H showed that control performance was from 0 to -20 dB for vibration frequency from 0.01 to 0.1 Hz, and vibration was attenuated 40 dB per ten octave above 0.1Hz. The simulation results of T-E-H showed that vibration was attenuated 20 dB per ten octave at the beginning of 0.01Hz.

Keywords : microgravity science experiment rack, microgravity vibration isolation system, PID control, vibration isolation performance
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