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CONTROL OF BENDING/TORSIONAL VIBRATION OF TAPE TETHER USING SMART FILM SENSORS/ACTUATORS

Abstract

Tethered satellite systems (TSSs) facilitate satellite orbit transfer, formation systems, transportation, subsatellite attitude control, and other tasks. Electrodynamic tethered (EDT) systems, which use the Lorentz force derived from the interaction between an electric current on the tether and Earth's magnetic field, are expected as space debris removal systems. However, the practical application of TSSs remains difficult, because of the highly complex nonlinear dynamics of the tether. Space tethers are expected to be deployed over 1 km and the tension varies with the length. Thus, the vibration of the tether cannot be treated as a string vibration. If a tether begins to vibrate in space, the damping would be minimal owing to the almost zero drag force. The vibration of the tether may disturb the attitude of the mother satellite, the subsatellite, and a climber travelling on it. Many previous studies on tethers assumed string tethers and focused on only bending and pendulum vibrations. However, tape tethers are more durable than string tethers when exposed to space debris, and effective EDT systems require a large area for the collection of electrons on the tether surface from the plasma environment in space. In addition, torsional vibration cannot be ignored in tape tethers considering their width. Indeed, NASA observed the torsion of a tether during a mission of the Gemini 11 Agena Target Vehicle in 1966. Furthermore, during the T-Rex mission, a tape tether twisted after it was deployed from a slowly rotating rocket. It is difficult to apply point-type sensors and actuators to tape tethers because of the length of the tether, movement of a climber, and use of a deployment mechanism such as a reel. To overcome these difficulties, we propose the use of smart film sensors and actuators for controlling the vibration of a tape tether. Although several studies have been conducted on the deployment of a tape tether, to the best of our knowledge, none have used smart film sensors and actuators to sense and control the vibration of the tether. In this paper, the experimental results are presented which confirm that the bending and torsional vibration of a tape tether can be separately measured and damped out by smart film sensors/actuators pasted on appropriate surfaces of the tether.