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LONG TERM DYNAMICS AND CONTROL OF A BARE ELECTRODYNAMIC TETHERS UNDER MULTI-ENVIRONMENT PERTURBATIONS

Abstract

This paper studies the long term libration dynamics and control of deorbiting nano-satellites by short and bare electrodynamic tethers (EDT). The EDT has great potential in space engineering application and its most appealing one is in the space debris prevention and mitigation. Over the past decades the area of EDT dynamics are well studied and a lot of orbital and suborbital missions have been proposed and own. It is well understood that the EDT libration is unstable if the electrodynamic force is not properly controlled. Although vast literature exists in the EDT area, there still remain some problems unsolved, such as bare tether current generation and deorbit efficiency of the EDT technology in the orbits with high inclination. Besides, most prior studies on tether libration dynamics and control focus on a long tether with large current, they adopt a tilted or non-tilted geomagnetic field model and ignore the perturbations except electrodynamic force. The ignored high-order variation of Earth's magnetic field and environmental perturbations have long term effects on the EDT dynamics, thus cannot be ignored in a bare and short EDT research. In the present work, we analyzed the long-term orbital and librational dynamics of a bare EDT in the process of nano-satellite self-deorbit on orbits with high inclination angles. Multiple time-varying space environmental perturbations including atmospheric drag, the Earth's oblateness effect, irregularity of Earth's magnetic field, ambient plasma density subjected to the variation of geomagnetic and solar conditions, solar radiation pressure, and lunisolar gravitational attractions are considered together with electrodynamic force. In order to avoid the tether tumbling, a simple control law is designed and applied to the deorbit process. A single index is derived from the libration energy, based on which an on-off switching ensuring the negative work done by the electrodynamic force is used to regulate the current. Only the out-of-plane libration angle is required and the libration amplitude is reduced through nonlinear modal coupling between the in- and out-of-plane librations. The dynamic response of the EDT system to the proposed current regulation is simulated, while the results demonstrate that the EDT libration angles can be effectively stabilized through this single-input-single-output control strategy.