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ROBUST TETHER DEPLOYMENT CONTROL FOR ELECTRODYNAMIC TETHER DEORBIT SYSTEM

Abstract

The electrodynamic tether deorbit system (ETDS) provides an effective way to passively remove last stages of launch vehicles. The deployed electrodynamic tether flying in the geomagnetic field is able to generate the electrodynamic drag, which greatly increases the orbital decay rate of the deorbit system. Compared with propulsion-based way, it can avoid extra propellant for deorbit and thus reduce the total weight and product cost of the launch vehicle. For this method, stabilized tether deployment is one of key technologies. During tether deployment, the in-plane libration, out-of-plane librations, and the tether vibration should be effectively attenuated by designing appropriate control strategy. However, different from traditional control strategies for tethered satellite systems, the control effect for tether deployment of ETDS is only depend on the generated current flowing in the tether and the tensional force along the tether, while thrusters on the spacecraft or other control actuators are hard to be taken into consideration due to cost reduction. This leads that the dynamics of ETDS performs not only highly nonlinear but also under-actuated, which restricts the direct application of common control methods to a great extent. The present technical research is mainly focused on this stabilization control problem of the tether deployment of the electrodynamic tether deorbit system. To this end, based on the rigid rod model, the system dynamics is firstly formulated to describe the in-plane libration, out-of-plane libration, and the tether vibration of ETDS. Then, to handle the under-actuated issue, a novel stage transformation is proposed, which guarantees the transformed system to possess cascaded property. In a natural manner, this characteristic makes the backtepping technology a preferable approach to deal with the control problem. Thus, a filtered-backtepping based robust tether deployment control scheme is then developed, where a first-order filter is introduced to overcome the "term explosion" and facilitate the computation. The rigorous closed-loop stability is analyzed and given in the Lyapunov framework. Besides the theoretical analysis, a numerical simulation is also given to show the effectiveness and the robustness of the proposed control scheme.