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A FINITE-TIME DEPLOYMENT CONTROL OF SPACE MULTI-TETHERED SATELLITE FORMATION SYSTEM

Abstract

Tethered formation system has been widely studied due to its extensive applications in aerospace engineering, such as Earth observation, orbital location, and deep space exploration. For different missions, different tethered formations have been addressed, such as the triangle formation, double-pyramid, hub-spoke formation, etc. As a classic formation of space observation, a triangle tethered formation system has been considered as a practicable structure due to its easy expandability and spatial orientation stability in spinning case. Although the triangle formation has been studied a lot, there are still some problems. Most of the paper are based on a rigid and inelastic tether model, which has greatly reduced the difficulty of the controller design. The longitudinal oscillation due to the elasticity of tether, along with the lateral oscillation of space tether caused by the Coriolis force, make the control problem complex. The main requirements of the formation's deployment are speediness, and consistency. In consequence, the system can quickly achieve the stable spinning condition (will be discussed in the manuscript) and maintain in a desired formation. But normally, convergence time of triangle tethered formation is around half orbit. In this paper, a triangle tethered formation system is modeled, and an exact stable condition for the system's maintaining is carefully analyzed, which is given as the desired trajectories; then a new control scheme is designed for its spinning deployment and stable maintaining. As an effective deployment control scheme, it is composed of a second order sliding mode control with a nonsingular sliding manifold, which can achieve the desired stable spinning quickly and symmetrically, and suppress the tethers' oscillation as well. Because the transition process from the initial state to the desired state is not stable, the desired spinning rate should be achieved as soon as possible. Based on the theoretical proof, the addressed sliding variable from an arbitrary initial condition can converge to the manifold in finite time, and then sliding to the equilibrium in finite time as well. The simulation results show that compared with classic second sliding mode control, the proposed scheme can speed up the convergence of the states and sliding variables. The spinning rate can be converged within 0.2 orbits, and the formation during the whole process of deployment is nicely symmetrical.