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Dynamic Adaptive Saturated Sliding Mode Control For Deployment of Tethered Satellite System

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Abstract

This paper presents a novel adaptive dynamic sliding mode scheme for the deployment of the tethered satellite system. To overcome the limited inputs of the dynamic model, a new scalable dimensionless transformation and strictly bounded terms are designed, which guarantee the existence of the ratio between limited inputs and command signals. The adaptive saturated sliding mode control scheme is proposed to govern the tether deployment by introducing the adaptive rate into the system gain. The stability analysis indicates that this measure can eliminate the uncertainty caused by the input limitation and guarantee the asymptotically stability of the deployment dynamics. Finally, numerical simulations are presented to verify the effectiveness of the proposed control laws.

Keywords: Tethered satellite system; Sliding mode control; Input limitation; Adaptive control

1. Introduction

The deployment is the key technology of the space tethered satellite system (TSS) [1, 2], which supports various applications for space explorations and scientific researches, such as space debris removals, space elevators, satellite de-orbits and the tethered space robots [3, 4, 5, 6, 7, 8, 9], and involves control theory, communication science and mechanical science [10, 11, 12]. Many international space research institutes have launched orbital, suborbital and ground experiments, such as TSS-1R, SEDS, MAST and YES2, in an effort to verify the feasibility of the proposed theoretical and simulation schemes for the deployment of the TSS [13, 14, 15, 16]. These experimental results intensively help researchers proceed to promote advanced mechanics, kinetic and control studies, to tackle the future challenges of space activities [17, 18, 19, 20, 21, 22].

Recent scientific researches about deployments of the TSS focus on the stabilization of the dynamics, and have provided different kinds of control schemes, including tension, thruster, electrodynamic and Coulomb approaches [23, 24, 25, 26, 27]. Among these stabilization strategies, the hybrid tension and thruster control technique has been a great boost to new developments of the deployment of the TSS. Iki et al. implemented the ground deployment experiment, and utilized the thruster to conduct the deployment of a kilometers-length electrodynamic tether from a special spool-type reel [28]. Aslanov et al. presented a novel model about the spatial motion of a large passive satellite and the tug connected by space tether, and the motion of the overall system was excited by a thruster force acting on the tug [29]. Huang et al. investigated the attitude and deployment dynamics of the tethered space robot from the standpoint of thruster consumption [30]. Jung et al. adopted the thruster scheme to achieve the ideal deployment rate during the deployment of three-body tethered satellites [31]. Liu et al. equipped the subsatellite with the thruster system, consisting of four pairs of thrusters, in order to regulate the attitude and deployment dynamics [32]. Zakrzhevskii divided the deployment process into two stages: in the first stage, the thruster was used to propel the subsatellite to the desired starting point of the next stage, and in the second stage, the tether was adjusted to the stable

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