航空学报
ACTA AERONAUTICA ET ASTRONAUTICA SINICA
ISSN 1000-6893
CN 11-1929/V

航空学报 » 2013, Vol. 35 » Issue (11) :2635-2644 DOI: 10.7527/S1000-6893.2013.0254

空间绳系机器人逼近过程的位姿一体化控制

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Integrated Pose Control of Tethered Space Robot in Approaching Process

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摘要

逼近过程的协调控制一直是空间绳系机器人系统研究的重点，为了弥补传统方法在控制精度和工质消耗等方面的不足，首先，基于Hamilton原理建立了一种考虑系绳分布质量和作用在系绳上分布力的新型位姿耦合动力学模型;然后，使用hp自适应伪谱算法求解了逼近过程中最省工质的轨迹和与之对应的理想输入;最后，通过PD控制器对系统真实状态进行调节使其跟踪上规划的理想轨迹，从而实现了对空间绳系机器人系统位置和姿态的闭环一体化控制。仿真结果表明：在存在0.1 m初始长度偏差和5°初始角度偏差的情况下，设计的控制系统能够实现对空间绳系机器人逼近过程的有效控制;与传统模型相比，新型位姿耦合模型能够显著提高系统的控制精度;与位姿分离控制方式相比，一体化控制方式不仅能够避免产生过大的姿态扰动力矩，而且能够大幅减少系统的工质消耗。

关键词： 空间绳系 位姿一体化控制 最优控制 Hamilton原理 hp自适应伪谱算法 PD控制器

Abstract:

The coordinated control of a tethered space robot in its approaching process has always been a focus of research. In order to compensate for the deficiency of traditional methods in precision and fuel consumption, a new pose coupling dynamic model is built in this paper which takes into consideration the distributed mass of the tether and the distributed force acting on the tether based on the Hamilton principle. Secondly, a hp-adaptive pseudospectral method is utilized to obtain the minimum-fuel trajectory and the corresponding ideal input. Finally, a PD controller is employed to ensure that the practical state can track the designed trajectory. Thus, an integrated closed-loop pose control of the tethered space robot is achieved. The simulation results show that in the case of existing 0.1 m initial length deviation and 5° initial angular deviation, the closed-loop controller designed in this paper can realize the effective control of the system state. Furthermore, compared with the massless rod model, the proposed pose coupling model can significantly improve the control precision of the system. Compared with the separate control of position and attitude, the integrated control can not only avoid large attitude disturbance torque, but also reduce fuel consumption considerably.

Keywords: space tethers integrated pose control optimal control Hamilton principle hp-adaptive pseudospectral method PD controller

Received 2013-01-22; published 2013-05-29

Fund:

国家自然科学基金（11272256，61005062）;航天飞行动力学技术重点实验室开放基金（2012afdl022）

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引用本文:

胡仄虹, 黄攀峰, 孟中杰, 马骏. 空间绳系机器人逼近过程的位姿一体化控制[J]. 航空学报, 2013, 35(11): 2635-2644.DOI: 10.7527/S1000-6893.2013.0254

HU Zehong, HUANG Panfeng, MENG Zhongjie, MA Jun. Integrated Pose Control of Tethered Space Robot in Approaching Process[J]. Acta Aeronautica et Astronautica Sinica, 2013, 35(11): 2635-2644.DOI: 10.7527/S1000-6893.2013.0254