Paper ID: 10048
oral
student

ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control - Part 1 (7)

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CONTROLLABILITY RESEARCH OF AN UNDERACTUATED SPACECRAFT WITH THRUSTER UNDER DISTURBANCE

Abstract

During the past two decades, underactuated spacecraft attitude control problem has become a new hot research area. One of the key issues of this area is the controllability problem. In the aspect of underactuated spacecraft control using thruster, existing researches mainly focus on the controllability of inertia attitudes of spacecraft with two-dimension control torques while considering little about perturbation. For the purpose of designing a control law for a more universal system, this article analyses the attitude controllability of an underactuated spacecraft affected by periodical oscillation disturbance torques in orbit frame. The research object is a rigid spacecraft with thrusters which can only provide one-dimension torques.

The spacecraft attitude control essentially becomes a nonlinearity problem due to underactuation. According to nonlinear control theory, when the drift vector field of a system is positively Poisson stable or weakly positively Poisson stable (WPPS), the sufficient and necessary condition of the global controllability is Lie algebra rank condition (LARC). Therefore, this article firstly builds a dynamical models for the underactuated spacecraft with respect to orbit coordinate, then uses (w, z) parameters to describe spacecraft attitude motions. After considering periodical oscillation disturbance torque, the article uses Liouville theorem to confirm that the flow generated by the drift vector of the underactuated attitude control system is volume-preserving, and all of state variables are bounded. Furthermore, according to Poincaré's recurrence theorem, we draw conclusions that this drift field is weakly positively Poisson stable (WPPS). Finally, we obtain the system controllable condition on the basis of Lie algebra rank condition (LARC), and then prove that the condition is sufficient and necessary.

Moreover, a kind of Lyapunov controller based on the controllable condition mentioned above is designed, and system stabilization is proved using Lyapunov stability theorem and LaSalle invariance theorem. Simulation is carried out and results illustrate the global asymptotic stability of the proposed controller.