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ACTIVE DISTURBANCE REJECTION CONTROL FOR SPACECRAFT RELATIVE MOTION IN LIBRATION POINT ORBITS SUBJECT TO ACTUATOR SATURATION AND TIME-DELAYS

Abstract

The aerospace industry has undergone rapid advancements, leading to an increase in the complexity and diversity of on-orbit tasks. Considering the special spatial geometry and abundant dynamic characteristics of the libration point orbits (LPOs), a number of space exploration missions, including, but not limited to, rendezvous and docking and formation flying, have been implemented in LPOs. These on-orbit tasks require a high level of precision and technical expertise. To be more specific, effective attitude and orbit control is the fundamental requirement in the field of space technology.

Recent years have witnessed a constant research interest in the study of the spacecraft attitude and orbit control. Some research results have been achieved to overcome the disturbances under some ideal conditions, however, the time-delays, actuator saturation and other objective problems are unavoidable in practical engineering. In this article, a novel active disturbance rejection control scheme is proposed for the spacecraft relative motion system with actuator saturation and fixed time-delays in LPOs.

Firstly, the dimensionless relative coupled dynamical model is designed based on dual quaternion for improving the computation efficiency and accuracy. Then, an improved extended state observer (ESO) is developed to estimate the unmeasurable system states and the so-called disturbance induced by parameter uncertainties and external disturbances. It is also worth pointing out that, in the newly proposed ESO, an output predictor is devised for the time-delays problem, which could predict the time-delays signal by employing the state estimation information. In addition, the anti-windup is employed to mitigate the potential actuator saturation issue during the spacecraft's position and attitude adjustment process. Subsequently, a composite control strategy integrating the anti-windup compensator and the estimates provided by the improved ESO is devised to guarantee the stability of the studied spacecraft relative motion system.

Finally, the effectiveness of the presented methodology is verified for the spacecraft rendezvous and docking and formation flying, where the time-delays and actuator saturation are considered according to practical engineering. Simulation results show that the states of relative position and attitude are asymptotic stability, and the settling time which defined as the time required for the response curve to reach within $\pm 5\%$ of the steady-state is about 8s. Furthermore, the proposed control strategy is also suitable for other space exploration missions with time-delays or data loss phenomenon.