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6-DOF FORMATION KEEPING CONTROL FOR THREE-CRAFT ELECTROMAGNETIC FORMATION CONSIDERING THE EARTH'S MAGNETIC FIELD

Abstract

The inter-satellite electromagnetic force significantly contributes to improving spacecraft relative motion control since it is free of propellant consumption and plume contamination, and ensures potential applications in close formation flying within tens of meters. One of the particular applications is optical interferometry, where the invariant shapes actuated by internal forces play an important role, by which the formation maintains a fixed geometry and behaves as a single rigid body in orbit. Naturally, invariant shapes are convenient for formation keeping control, but the internal force nature as well as the high nonlinearity and coupling of electromagnetic force bring new control challenges for this novel technique, and a 6-DOF formation control problem should be investigated since the relative trajectory and attitude motion are synchronously affected by the electromagnetic actuators. Especially, in the electromagnetic formation flight mission, the torque induced by the Earth's magnetic field interacting with the electromagnetic actuators has great effect to the relative attitude motion and cannot be neglected. This paper mainly focuses on the formation keeping control of three-craft electromagnetic formation, and carries out the analysis on the dynamics characteristics and special control issues in the presence of electromagnetic actuator with the Earth's magnetic field on the basis of the 6-DOF full nonlinear dynamic models. Considering the model uncertainties, external disturbances and sensor noise, a combined control scheme involving feed-forward and feedback control components is proposed for electromagnetic force based formation keeping. The feed-forward component is directly obtained through desired configuration and dynamics under nominal conditions, which is derived based on the relative equilibrium with constant actuation and convenient for the invariant shape application. For a three-craft formation, the superposition and coupling effects of two distinct magnetic dipoles are the key element that potentially complicates the invariant shapes design and nominal magnetic moments control analysis. Otherwise, the feedback component is realized utilizing linear feedback controller based on LQR method and active disturbance rejection control methodology based on extended state observer with some reasonable improvement. Numerical simulation is presented to verify the feasibility and validity of the combined optimal and robust control scheme, which serves as an effective approach for 6-DOF formation keeping control of the three-craft electromagnetic formation, despite the nonlinearity of the dynamics.