SPACE SYSTEMS SYMPOSIUM (D1)
Innovative and Visionary Space Systems (1)

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MULTI-DOF DYNAMIC SIMULATION AND EXPERIMENT OF ELECTROMAGNETIC RENDEZVOUS AND SOFT DOCKING OPERATION WITH REAL-TIME FEEDBACK CONTROL

Abstract

The contactless inter-satellite electromagnetic force, with its feature of no propellant consumption, no plume contamination and low impact, is a unique approach to satellite-satellite formation flight, rendezvous and docking. Thus, electromagnetic actuators have potential applications in on-orbit distributed optical interferometry, based on separation, and rendezvous and docking of multiple microsatellites, whose main concern is minimizing the contamination to optical mirrors.

However, the high non-linearity and coupling of electromagnetic force/torque leads to new control challenges for precise and soft docking. A multi-DOF dynamic problem should be investigated, since the relative trajectory and attitude motion are synchronously affected by the electromagnetic actuators.

Up to now, most control strategies employed were designed with limited priori knowledge learned from static electromagnetic calculations, and the feedback control loops use far-field dipole model, which is not appropriate for close proximity and docking operation.

In this paper, we have used Finite Element Method for near-field and middle-field electromagnetic dynamic simulations, which provide more accurate force and torque at every step of the approaching and docking operation, and could be used in the robust control. To verify the simulation results, we have built a platform with the Kistler sensor to measure the electromagnetic force and torque between two docking models. For a docking process with relative distance smaller than 100mm, our simulation results show a good agreement with experimental results. For larger distance, the scale of electromagnetic force drops exponentially, leading to complexity of accurate force simulation and measurement. As a compromise, for docking distance between 100mm and 400mm, we have considered both the finite element method and far-field model, which helps to improve the simulation accuracy.

With our methods, parameter optimization of docking mechanism could be done with virtual simulations, which saves resources and provides a reference to researchers regarding space-related electromagnetic mechanism design. Our goal is to use computer simulations to model the dynamics of electromagnetic

problems to a certain extent, and to help researchers to deal with electromagnetism related near-distance control problems. Our future work is to include the Earth's magnetic field and Earth gravity J2 disturbance in the modeling.