Paper ID: 59770
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (1) (8)

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ADAPTIVE TORQUE EQUILIBRIUM ATTITUDE GUIDANCE FOR RAPID DEORBIT OF SPACE DEBRIS BY AERODYNAMIC DRAG CONSIDERING MODEL UNCERTAINTY

Abstract

The problems posed by orbital debris tend to become more serious in line with the increasing amount of space debris. To solve such crucial problems, this study focuses on small satellites which realizes capture and removal of large debris while considering cost effectiveness. Small satellites offer many advantages due to their rapid development at low cost. Conversely, they also have disadvantages typified by strict limitations on amount of fuel. Thus, this study utilizes orbital disturbances acting on the large body which is the large space debris attached with small satellite in orbital descending phase.

Atmospheric drag is typically considered as a main disturbance force in low Earth orbit, and the dependence of drag forces on a satellite's flow-wise projected area drives the coupling between attitude and orbit states. By tracking the advantage of this coupling effect, aerodynamic disturbance is gained and debris can be rapidly descended. However, large aerodynamic disturbance torque acting on a large debris has a great effect on a small ADR satellite with small-sized wheel actuators such as reaction wheels. Furthermore, the stored angular momentums of satellites per orbit generally become large as the accumulated external torques per orbit increases. The International Space Station suffers from the same difficulty with large stored rates of the angular momentum of spacecraft. A torque equilibrium attitude (TEA) defined by an equilibrium point in attitude dynamics acted by aerodynamic and gravity gradient torques is adopted as one of the attitudes affected by small disturbance torques. Previous research adapted such guidance method to ADR missions revising as an altitude-dependent mean TEA guidance [1] without fully considering modeling uncertainty. However, model uncertainty such as atmospheric density, inertia tensor and mass of noncooperative target debris would be large due to damage of body or unknown amount of fuel remaining.

In this study, adaptive TEA guidance technique is proposed while learning the attitude parameter using combined dynamic inversion and sensor measurement. Then, robust controller is designed to guarantee robustness to disturbances and modeling uncertainties. Finally, effectiveness of the proposed adaptive guidance and robust control are demonstrated through numerical simulations to enhance feasibility of the ADR mission.

[1] Sasaki, T., et al, 70th IAC, US, 2019.