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THREE-DIMENSIONAL ATTITUDE CONTROL OF SPACECRAFT BY THREE THRUSTERS

Abstract

This study discusses thruster configurations of spacecraft considering critical condition that most of control devices are breakdown, and introduces control strategies for the angular velocities and attitude angles in three dimension with three thrusters.

In deep space missions, the malfunction possibility of control devices increases according to longer mission time. Thus, the attitude control by using remained fewer thrusters is discussed in this study, because attitude control is crucial to continue the mission. Usually, three-dimensional attitude is controlled by independent torques around three principal axes. However, by utilizing nonholonomic dynamics for attitude motion, it is possible with fewer number of thrusters. There are numerous researches for attitude control utilizing nonholonomic constraints, but most of them make the following assumptions, 1) clockwise and counterclockwise directional torques can be generated around two principal axes of a satellite, and 2) identically zero torque is induced around the third axis. However, satisfying these two assumptions is not realistic when only three thrusters remain, considering the misalignment of thruster or mass center change due to fuel consumption. Thus, this study makes the assumption 2) relax to more realistic one; the torque around the third axis is not restrict to identically zero under the assumption 1), since it depends on the control for other two axes.

Under this condition, 'preferable' three-thruster configurations are discussed for a cube-shaped satellite with eight thrusters placed on each vertex; in this study, configuration is called 'preferable' when it has high possibility to satisfy the necessary conditions for nonholonomic attitude control even when the satellite's mass center changes. Then, based on the obtained preferable thruster configurations, the directions and grouping of thrusters are reexamined; they are usually decided from empirical knowledge in other missions. From a viewpoint of redundancy, these eight thrusters are usually divided into two groups considering pipe-configuration and valves between a fuel tank and thrusters. The directions and grouping proposed in this study find that one thruster-group (4-thruster) can generate independent control torques around three axes, and that three thruster configurations happened by additional malfunction of a thruster in the remained group has high probability to satisfy the nonholonomic attitude control condition. Finally, new control strategies for angular velocities and attitude angles in three-thruster configurations are introduced by utilizing Polhode motion, and their validities are shown in numerical simulations.