Optimal Attitude Control for Spacecraft Using two Variable-Speed Control Moment Gyros

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In this paper, a rest-to-rest spacecraft maneuver by using two variable-speed control moment gyros (VSCMG) as shown in Fig. 1 is considered.
Time trajectories of angular momentums and gimbal angles are derived by two methods in the viewpoint of maneuver time minimization under some physical constraints. One is an analytical method by using the variational calculus. From the analytical solution, time trajectories of angular momentums and gimbal angles are expressed by polynomial functions and the dynamic characteristics of the attitude maneuver are easily understood. However, there is an attitude error in the analytical solution due to its approximation. This attitude error is eliminated by another method, a numerical method. The numerical method uses the combination of a bisection method and the Newton's method. The attitude error is eliminated by the Newton's method using the analytical solution as initial values, while the maneuver time is minimized by the bisection method. Figure 2 shows the comparison between the analytical solution and the numerical one, where the final attitude error is eliminated in the numerical solution.
The analytical and numerical calculations are executed in all the directions of the attitude maneuver, and the maneuver time in each direction is plotted as the length from the origin as shown in Figs. 3 and 4. As shown in these figures, the analytic solutions and numerical ones are almost the same in maneuver time and the surface of the maneuver time is asymmetric with respect to x-axis and xz-plane. The reason of this asymmetry is based on the weak torque of the wheels as compared with the CMGs, which can be explained quantitatively by the dynamic characteristics of the analytical solution.

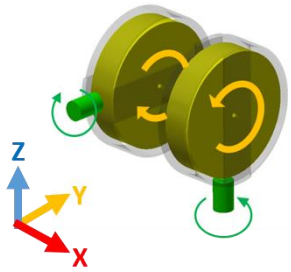

Fig. 1. Arrangement of VSCMGs

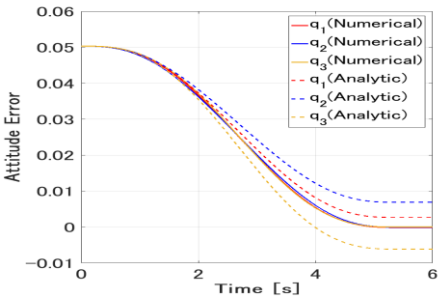

Fig. 2. Time trajectories of Attitude error (vector part of error Euler parameters)

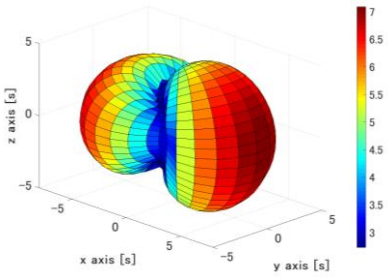

Fig. 3. Surface of maneuvering time (analytical method).

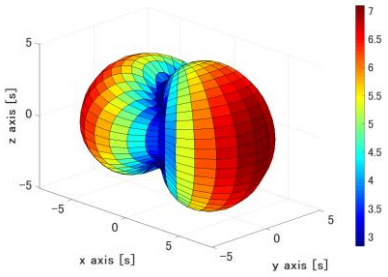

Fig. 4. Surface of maneuvering time (numerical method).

References

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