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SPACECRAFT ATTITUDE AND TOTAL POWER OPTIMAL CONTROL WITH REDUNDANT DOUBLE-GIMBAL VARIABLE-SPEED CONTROL MOMENT GYROS

Abstract

Most of satellites have redundant number of actuators to realize attitude control. Having four or more reaction wheels (RWs) or various type control moment gyros (CMGs) allows satellites to realize to complete attitude control if a certain actuator has a mechanical failure.

However, in most cases, to realize 3-axis attitude control, this extra redundancy of the actuator assembly is not used efficiently. To utilize this redundancy, some researches such as power optimal or power tracking control have been made. On the other hand, these days, much attention have been paid on a Double-Gimbal Variable-Speed CMG (DGVSCMG) as a new type of CMG. A DGVSCMG has two gimbal axes and a variable speed wheel and it can generate three dimensional and large torques. From this advantage, in this paper, we aim to attain an attitude and total power optimal control with redundant DGVSCMGs. This is because power consumption of actuators is an important factor for a spacecraft such as small satellites which have limitation about available power and energy.

Regarding control law, most of recent studies use Lyapunov function-based controllers to realize complete attitude control. With these controllers, overall stability of attitude control is always guaranteed, however control performance is hard to evaluate. Then the LPV (Linear Parameter-Varying) control has advantages such that it provides guaranteed stability and control performance over a wide range of varying parameters [1].

Regarding power optimal control, we deal with total power optimal control with considering power regeneration. While dynamo, power regeneration is realized by spinning up lower wheel spin rates and spinning down higher wheel spin rates.

Therefore, in this paper, we apply the LPV control theory and introduce the generalized LPV model of spacecraft dynamics (including the generalized dynamics of a spacecraft with redundant DGVSCMGs). Then, we deal with complete attitude control with considering power optimal control via LPV control theory by using approximation of final error quaternion values. Through numerical simulations, we demonstrate improvement of power consumption of actuators while or while not considering power regeneration as well as control performance of attitude control.

[1] Sasaki, T. and Shimomura, T., Generalized Dynamics of A Spacecraft with Plural MEDs and Attitude Control with DGVSCMGs via LPV Control Theory, AIAA SciTech (2015).