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Author: Mr. Takahiro Sasaki
Osaka Prefecture University, Japan, aero2021@gmail.com

Prof. Takashi Shimomura
Osaka Prefecture University, Japan, shimomura@aero.osakafu-u.ac.jp
Dr. Sayaka Kanata
Osaka Prefecture University, Japan, kanata@aero.osakafu-u.ac.jp

GAIN-SCHEDULED ATTITUDE CONTROL WITH POWER TRACKING AND SINGULARITY AVOIDANCE OF DOUBLE-GIMBAL VARIABLE-SPEED CONTROL MOMENT GYROS

Abstract

Most of satellites have redundant number of actuators to realize attitude control. Four or more reaction wheels (RWs) or various types of redundant control moment gyros (CMGs) allow for 3-axis attitude control of satellites 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 [1] or power tracking [2] control have been made. On the other hand, recently, much attention has 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 3-dimensional large torques. From this advantage, in this paper, we aim to attain both attitude control and power tracking with redundant DGVSCMGs. This is because power consumption of actuators is an important factor for spacecraft such as small satellites which have limitation about available power and energy. A method to use wheels of redundant DGVSCMGs as energy storage devices can be described.

Regarding control law, most of recent studies use Lyapunov function-based controllers to realize 3-axis 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 both guaranteed stability and control performance over a wide range of varying parameters.

Therefore, in this paper, we apply the LPV control theory and introduce a unified LPV model for spacecraft dynamics with redundant DGVSCMGs. Then, we deal with 3-axis attitude control with power tracking via LPV control theory by embedding the parameter dependent part of the input matrix into the steering law while introducing a PDCT (Parameter-Dependent Coordinate Transformation) as well as a virtual state variable. Regarding singularity of DGVSCMGs, we propose a steering law derived from an interesting singularity evaluation function.

Numerical simulations assuming a spacecraft with two parallel DGVSCMGs are conducted, where 3-degree of freedom (3-DOF) of DGVSCMGs are used for attitude control while redundant 3-DOF is used for both power tracking and singularity avoidance. It is shown that the control performance with LPV control theory has been improved, compared with the conventional one.

[1] Sasaki, T. and Shimomura, T., IAC-15-C1. 6. 10, 2015.

[2] Tsiotras, P. and Shen, H., AIAA JGCD, Vol. 24, No. 1, January-February, 2001.