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FULLY-COUPLED DYNAMICAL JITTER MODELING OF A RIGID SPACECRAFT WITH IMBALANCED DOUBLE-GIMBAL VARIABLE-SPEED CONTROL MOMENT GYROS

Abstract

Recently, much attention has been paid to a double-gimbal variable-speed control moment gyro (DGVSCMG) [1] as a new type of an attitude actuator of a spacecraft. A DGVSCMG has two gimbals attached to one variable speed wheel and can generate large three dimensional torques if the RW motor torque is sized accordingly. Implementing DGVSCMGs for attitude control can reduce the number of actuators and the total weight of actuators, which leads to reduced mass and volume within the spacecraft. On the other hand, a key source of pointing jitters are due to wheel or gimbals mass imbalance about the wheel spin axis or gimbal rotation axes in a DGVSCMG. Although these effects are often characterized through experimentation in order to validate requirements, it is of interest to include jitter in a computer simulation of the spacecraft in the early stages of spacecraft development. An estimation of jitter amplitude may be found by modeling wheel or gimbals imbalance torques as an external disturbance on the spacecraft. A physically realistic dynamic model may be obtained by defining mass imbalances in terms of a wheel or gimbals center of mass locations and inertia tensor. The fully-coupled dynamic model allows for momentum and energy validation of the system. This is often critical when modeling additional complex dynamical behavior such as flexible dynamics and fuel slosh. Furthermore, it is necessary to use the fully-coupled model in instances where the relative mass properties of the spacecraft with respect to the DGVSCMGs cause the simplified jitter model to be inaccurate. This paper presents a fully-coupled dynamical jitter model of a rigid spacecraft equipped with N DGVSCMGs. This model is a generalized description of a fully-coupled dynamical jitter model for a spacecraft with momentum exchange devices (MEDs) since the equation of motion (EOM) of DGVSCMGs includes the EOM of all MEDs such as reaction wheels or single-gimbal CMGs.

[1] D. Stevenson and H. Schaub: Nonlinear Control Analysis of a Double-Gimbal Variable-Speed Control Moment Gyroscope, AIAA JGCD, Vol. 35, No. 3, May-June 2012, pp. 787-793.