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FAULT ESTIMATION AND FAULT-TOLERANT CONTROL FOR CONTROL MOMENT GYRO ACTUATED HIGH AGILITY SPACECRAFT

Abstract

Control moment gyroscopes (CMGs) are widely used in the attitude determination and control of high agility spacecraft owing to its torque amplification property. However, unexpected fault or failure of the CMG can cause severe performance degradation or even mission failure. To improve the robustness of spacecraft attitude control, this paper investigates the modelling, fault identification and fault-tolerant control problem as applied to CMG actuated spacecraft. Firstly, the CMG is modelled as a cascade combination of an electrical motor and variable speed drive (EM-VSD) system. Each control freedom corresponds to an EM-VSD loop. For instance, a single gimbal CMG contains a gimbal control loop and wheel speed control loop. In the gimbal control loop, the EM-VSD system is used to generate the gimbal angular velocity, which produces the gyroscopic output control torque. In the wheel speed control loop, the EM-VSD system governs the constant wheel speed, resulting in a constant angular momentum that is the source of the CMG's torque amplification. Potential faults lie in the mechanical part of the EM, sensors, actuators, VSD and electrical part of these components. Hence, the fault can be modelled as an effectiveness loss fault and additive bias fault, which correspond to multiplicative fault and additive fault mathematically. Secondly, an auxiliary state is introduced to transform the multiplicative fault and additive fault into a unique equivalent effectiveness factor. Then an observer is constructed to estimate the time-varying equivalent effectiveness of the CMG. We prove the convergence of these estimators in this work. Finally, a fault tolerant control strategy that combines the estimates of the effectiveness observer is developed to accommodate the CMG faults. The stability of this approach is proven via the Lyapunov method. To verify the effectiveness of the proposed identification method and fault-tolerant strategy, we conducted numerical simulations on a rigid spacecraft maneuver. Simulation results show that spacecraft reorientation can be achieved under the various fault scenarios with a high level of responsiveness.