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DEVELOPMENT OF A CONTROL MOMENT GYRO CONTROLLER FOR SPACECRAFTS

Abstract

Single Gimbal Control Moment Gyro (SGCMG) is an attitude control actuator used in spacecraft missions demanding high agility with rapid multi-target pointing and tracking capabilities. They impart such high torques by exchanging momentum with the spacecraft and offer cost, power, mass and reliability advantages over other conventional actuators such as Reaction Wheels in the high torque output range. The torque is generated by changing the direction of the angular momentum vector by gimballing a high momentum wheel about an axis at different rates.

This makes the rate control performance of the gimbal servo system extremely important as it directly affects the manoeuvring and pointing capability of the spacecraft. Variations in gimbal rate could lead to torque errors in spacecraft that hamper the target tracking capabilities. The gimbal position control accuracy affects the imaging quality. Maintaining the servo performance over a wide dynamic range demanded by the spacecraft torque requirements makes the control problem challenging. The low rate control performance is dictated by the rate detection resolution and the effectiveness of disturbance torque mitigation. The non-linear friction of the gimbal bearings, motor torque ripple, rotor unbalance vibrations and the signal transmission components also affect the ultra-low rate control.

The conventional PID controller fares poorly in disturbance mitigation. Hence, aiding control structures have to be added in order to improve the disturbance attenuation. The disturbance torque observer and its compensation algorithm attain good attenuation of the low frequency disturbances but doesn't perform as nicely in the presence of high frequency disturbances such as motor torque ripples and rotor unbalance variations.

This paper discusses the design of control strategies for achieving wide bandwidth control at extremely low levels of gimbal rate in the presence of highly non-linear disturbances. Different control strategies are devised and modeled and the servo performances are analysed and compared for each controller. The controller performance is verified in the hardware under platform fixed and rotating conditions and the hardware test results achieved with the novel adaptive compensation control strategy are presented.