31st IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Generic Technologies for Small/Micro Platforms (6A)

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PERFORMANCE CHARACTERIZATION OF REACTION WHEELS FOR A SMALL SATELLITE ASTRONOMICAL OBSERVATION MISSION

Abstract

Reaction wheels are a critical part of any small satellite three-axis attitude control system. While some data identifying the performance bounds of reaction wheels is generally provided by the manufacturer, it is of interest to gain an in-depth understanding of the behaviour and performance of the wheel at a variety of speed and torque settings - particularly the settings which are expected to be actuated on orbit to ensure that the pointing requirements of the mission are met.

A common assumption of simplistic attitude actuator models is that the actuator can achieve any performance inside of the maximum performance range with the same behaviour in terms of noise and control errors, which is not realistically the case. Due to the nature of spacecraft attitude control systems, it is challenging to execute system-level testing on the ground while still subject to Earth's gravity. Methods for verifying attitude hardware performance on the ground are critical to developing attitude control systems and confidently ensuring that they will perform as expected on orbit.

Performance characterization consists of determining a number of performance constants at a range of power settings to represent the possible variance of power available to the wheels from the spacecraft's power system on orbit. Firstly, a test to determine the friction of the wheel is performed. Secondly, the step response of the controller is determined. Third, a test profile to determine the maximum torque limits of the wheel. Telemetry such as wheel speed, voltage and current draw, and temperature are logged during the tests.

One other particularity of reaction wheels is the occurrence of regenerative braking power generation. Obtaining data for experimentally-verified regenerative braking performance is critical to ensuring that the design of the spacecraft's power system can handle receiving power from the wheels and avoid causing harm to the power system hardware or other connected hardware. The regenerative braking power is measured using an engineering model of the spacecraft's battery to create a test that is as representative as possible of the hardware that will be onboard the spacecraft. Additionally, the power draw and torque performance are dependent on temperature, so the regenerative braking power must be measured at both the upper and lower operating temperature ranges of the wheel.

Behaviour characterization of an engineering model reaction wheel and performance evaluation of four flight model reaction wheels is being completed on a small satellite at the UTIAS Space Flight Laboratory.