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REACTION-WHEELS BASED AOCS FOR HIGH-POINTING ACCURACY AND STABILITY

Abstract

Current and future science and Earth observation missions are becoming increasingly demanding in terms of high-pointing accuracy and stability combined with competing requirements on fast re-pointing slew maneuvers, including fast settling time. A reaction-wheels based pointing architecture represents an attractive solution for these missions. The high torque level of reaction-wheel sets offers high agility, while no actuators transition between slew mode and fine-pointing mode is required. Moreover a flexible re-pointing schedule and mission extension are enabled at almost no cost since only limited by the fuel consumed for station keeping and wheel de-saturation. In addition, wheels-only is a standard well-known AOCS architecture with comparatively lower mass and cost than other pointing architectures. The use of AOCS with reaction wheel actuators in a significant number of operational and upcoming NASA missions with extremely high-pointing stability, such as Kepler or JWST, is testimony to their competitive properties. Nevertheless, for a wheels-only based AOCS to achieve robust and high-pointing performances a number of challenges must be overcome. Besides microvibrations, reaction-wheels exhibit disturbances due to random low-frequency fluctuations and transient changes of the friction torque. The characterization, modelling and suppression of these friction torque instabilities represent a critical element for the AOCS design. This paper presents a reaction-wheel based AOCS design and verification approach for high-pointing accuracy satellites founded on three key points: optimized actuator configuration, controller design for high performance and robustness against uncertain friction torque instability effects, and high accuracy attitude estimation. The configuration optimization has the scope to minimise the impact of friction torque instabilities on the spacecraft axes and wheel rate changes, which in turn limit the unbalance forces and torques. The controller design approach is a precise and systematic method that leads to robust and high performance pointing control. It is based on frequency domain metrics and methods in line with the ESA Pointing Error Engineering Handbook, and guarantees an optimized closed-loop bandwidth selection for maximum robustness against friction torque instabilities and sufficient stability margins. Resulting pointing performances are driven by attitude knowledge. Therefore, a robust and well-proven concept to ensure high-accuracy attitude knowledge and fully compensated latency based on optimal fusion of measurements from attitude sensors and the gyro unit is provided. The Euclid mission has been used as study-case. Pointing performances in the order of tens of milliarcseconds over several hundreds seconds are achieved, even in presence of degraded AOCS equipment that significantly exceeds its performance specifications.