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DUAL ATTITUDE AND PARAMETER ESTIMATION OF PASSIVELY MAGNETICALLY STABILIZED SPACECRAFT

Abstract

Many nano satellites use passive magnetic stabilization consisting of a combination of permanent dipoles for alignment to the local magnetic field and magnetically permeable material for damping. Passive magnetic stabilization systems are especially suited to nano satellites as they are low mass, require no electrical power and can achieve local pointing to within about 10 degrees.

On large spacecraft, high precision attitude determination can be performed using high performance sensors such as star trackers and inertial grade gyros. Nano satellites are constrained by small budgets for power, mass and volume that negate the use of such high performance sensors. Precision attitude determination can still be performed on a nano satellite with fewer, lower performance sensors, but an estimator that incorporates an accurate spacecraft dynamics model is required. Magnetically permeable materials exhibit non-linear time variant behavior that makes integrating their dynamics into a motion model non-trivial. Several models exist that accurately describe the behavior of a sample of magnetically permeable material in isolation. However direct application of these models to the material as installed in a spacecraft has met with limited success to date, with observed attitude profiles disagreeing with pre-launch simulations. To improve model fidelity, on-orbit parameter estimation can be performed to further tune the laboratory measurements until observed attitude profiles can be reproduced. Magnetically permeable material is included in a passive stabilization design to remove excess kinetic energy following separation, and it is during this de-tumbling phase that the magnetic properties can best be estimated.

In this paper, a dual estimation problem is formulated that simultaneously solves for the attitude of the spacecraft during the post-separation de-tumbling phase and performs parameter estimation on the magnetic properties of the permeable material. As a full dynamics model is employed, the algorithm can operate in the limited sensing environments typically encountered in small satellites. The dual magnetic parameter and spacecraft attitude estimation algorithm is tested with orbit data from the NASA Ames Research Center O/OREOS nano satellite and the University of Michigan RAX-1 satellite that were both launched in November 2010. The O/OREOS bus has no dedicated attitude sensors, but the algorithm is applied during the de-tumbling phase using only solar panel current readings. The physically similar RAX-1 satellite included additional attitude sensors allowing algorithm performance to be independently verified.