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LABORATORY-SCALE DEMONSTRATION OF A DISTRIBUTED MAGNETORQUER ARRAY FOR THE ATTITUDE CONTROL OF LARGE SPACE STRUCTURES

Abstract

Distributed magnetorquer arrays have recently been proposed as an attitude control strategy for large, lightweight space structures [1]. Such arrays offer a low-power and robust form of attitude control for large spacecraft, and simulation has demonstrated that structural deformations are reduced during slew manoeuvres when compared to centralised torquing strategies. In Ref. [1], control algorithms were developed for such arrays, including an implementation of the well-known 'Bdot' de-tumbling control law, and a quaternion error-feedback control law used to demonstrate slew manoeuvres.

This paper will describe the design, assembly and experiments performed using a Distributed Magnetorquer Demonstration Platform (DMDP), which has been developed to test the attitude control algorithms developed in [1], using a spherical air bearing and magnetic field generated by a Helmholtz cage. The DMDP consists of 48 magnetorquers, arranged with two perpendicular torquers at the nodes of a 5x5 grid, 25 cm in length. The magnetorquers have been purpose built for the DMDP and have been characterised by measuring the axial magnetic field at a number of points, resulting in a calculated value for the magnetic dipole moment of 0.03 Am^2. A key feature of the DMDP is that each torquer has only 3 possible states, off, or on with positive or negative polarity. The torque produced by the array is then scaled by activating different numbers of magnetorquers, removing the need for each magnetorquer to be individually driven by a pulse width modulation (PWM) signal. This is achieved using a two-input H-bridge circuit, so that the three states of the magnetorquer are addressed by two input signals, set high or low by the controller. The control algorithms of Ref [1] are implemented on a desktop PC, which receives IMU data from the DMDP and then returns magnetorquer switching commands via Bluetooth.

Preliminary attitude dynamics simulations have been performed using rigid-body Euler equations, and the measured and expected physical properties of the DMDP. These results suggest that the DMDP will be capable of performing 90° slew manoeuvres in a time of order 60 s. The paper will detail the construction of the DMDP, and present results of attitude control experiments. Experimental data will then be compared with the numerical results of simulation, verifying the control algorithms and mathematical modelling of Ref. [1].

[1] Robb, B., McRobb, M., Bailet, G., Beeley, J., and McInnes, C., "*Distributed Magnetic Attitude Control for Large Space Structures,*" Submitted to Acta Astronautica, (2021).