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FUEL-FREE ANGULAR MOMENTUM UNLOADING USING THE INTERPLANETARY MAGNETIC FIELD IN SMALL-SIZED SPACECRAFT

Abstract

This paper describes a new method for the unloading operation of the angular momentum in reaction wheels (RWs) by using an electromagnetic coil in an interplanetary small-sized spacecraft. In this method, for interplanetary missions, an electromagnetic coil generates torque by interacting with the interplanetary magnetic field (IMF) for the angular momentum unloading. Nowadays, several small-sized spacecraft are applied for a variety of interplanetary missions such as UNITEC-1, INSPIRE, and MarCO. According to the requirement of size, the small-sized spacecraft needs a small number of actuators. In addition, the small-sized spacecraft also needs high reliability structure, small mass, and power consumption actuators for deep space exploration missions. Generally, RWs generates torque to stabilizes the attitude of the small-sized spacecraft. However, disturbances produce angular momentum for RWs with active attitude control. The angular momentum needs other actuators such as thrusters to generate the reverse torque for unloading. Especially, the thruster has high accuracy for the unloading operation. However, the thruster has complex structure, high mass, and high power consumption. In order to reduce mass, reduce power consumption, and increase reliability, the small-sized spacecraft should avoid the propulsion system. Therefore, the aim of the proposed method is to use the electromagnetic coil to generate torque for the angular momentum unloading by using the IMF. The electromagnetic coil has advantages as less complicated, lighter, and higher reliability than thrusters. In addition, the electromagnetic coil does not need fuel for operation like the propulsion system. In this proposed method, the electromagnetic coil generates torque by the cross-product between the magnetic field and the magnetic moment. Nevertheless, the electromagnetic coil cannot generate the magnetic torque along the magnetic moment direction in the z-axis. Therefore, the electromagnetic coil can unload the angular momentum in the x-y plane respect to body coordinates. In order to achieve the angular momentum unloading for all axes, the electromagnetic coil changes attitude to generate magnetic torque in remain directions, and the angular momentum is unloaded by the cross-product method. This strategy is provided by the optimal control using linear quadratic regulator (LQR). In particular, the attitude and the angular momentum are considered as state variables in the state equation. Numerical results are conducted by simulations. The simulation shows the efficiency of the unloading operation by using the IMF for deep space exploration missions.