Paper ID: 6705

ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (3)

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ATTITUDE DYNAMICS OF A PENDULUM-SHAPED CHARGED SATELLITE

Abstract

The space in the vicinity of the Earth is an electromagnetic environment with collision-less plasma and Earth's intrinsic magnetic field. Satellites are naturally charged in such plasma environment, which motivates researches to relax the satellite charging to preclude malfunction due to discharging effect. This paper is based on an opposite philosophy that positive charging may be used for an active control of the satellite's dynamics. Recently, there have been several studies on the use of the Coulomb forces between charged satellites to control the relative geometry, and on the use of Lorentz force as an interaction between a charged satellite and the Earth's magnetic field. The present paper proposes a novel concept of a pendulum-shaped charged satellite in low Earth orbit, and investigates its attitude dynamics and control methodology. The pendulum shaped satellite consists of two charged spheres with mass-less rod connecting them. Gravity-gradient torque acting on this satellite with an elongated shape is a well-known attitude stabilization torque. This paper proposes a new controllable torque induced by positively charging the satellite by using ion and/or electron emitters. A charged satellite moving under the Earth intrinsic dipole magnetic field produces Lorentz force on the charged portions, and hence magnetic torque (called Lorentz torque hereafter) when the signs of two charges are opposite to each other. This paper analyses the attitude dynamics of a pendulum-shaped charged satellite, where a non-tilted dipole is assumed for the Earth's magnetic field, and a circular, equatorial, low Earth orbit is assumed. We focus on the pitch angle motion as a preliminary study and investigate it with analytical formulation and numerical simulations. Depending on the initial condition, the satellite pitching motion behavior is divided into librational or rotational motions. We found that the ratio of Lorentz torque to the gravity gradient torque is important for stability and instability of the attitude motion, and this parameter yields the bifurcation in terms of stability regions. We also confirmed the possibility of the attitude control by changing the charge amount. We can apply this Lorentz torque concept to keep the attitude to various directions other than the nadir-zenith diretion, to change the attitude direction to another state, and to make the satellite spin by positively controlling the charge amount. These results can be applied to a new satellite attitude control system by charge control with extremely high specific impulse.