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SPACE DEBRIS SYMPOSIUM (A6)
Space Debris Removal Concepts (6)

Author: Ms. Natalia Ortiz Gómez
University of Southampton, United Kingdom, N.Ortiz-Gomez@soton.ac.uk

Dr. Scott Walker
University of Southampton, United Kingdom, sjiw@soton.ac.uk

EDDY CURRENTS APPLIED TO DE-TUMBLING OF SPACE DEBRIS: ANALYSIS AND VALIDATION OF APPROXIMATE PROPOSED METHODS

Abstract

Existent studies on the evolution of the space debris population show that both mitigation measures and active debris removal methods are necessary in order to prevent the current population from growing. Active debris removal methods, which require contact with the target, show complications if the target is rotating at high speeds. Observed rotations go up to 50 deg/s combined with precession and nutation motions. "Natural" rotational damping in upper stages has been observed for some debris objects. This phenomenon occurs due to the eddy currents induced by the Earth's magnetic field in the predominantly conductive materials of these man made rotating objects. The idea presented in this paper is to submit the satellite to an enhanced magnetic field in order to subdue it and damp its rotation, thus allowing for its subsequent de-orbiting phase. The braking method that is proposed has the advantage of avoiding any kind of mechanical contact with the target. A deployable structure with a magnetic coil at its end is used to induce the necessary braking torques on the target. This way, the induced magnetic field is created far away from the chasers main body avoiding undesirable effects on its instruments. Existing solutions for the analysis of eddy currents require time-consuming finite element models to solve a Poisson equation throughout the volume. These FEM should be performed in each time step of the numerical integration of Euler equations. The first part of the paper looks into simpler ways of obtaining an approximate solution for the induced torque in metallic shells and metallic flat plates. The second part compares the approximate mathematical approach with the analytical solutions available for certain canonical forms. In addition, the braking time and magnitude of the induced torques are computed for certain simple geometries considering different ratios of conductive vs. non-conductive material. Contributions are also made in the field of the numerical integration of the rotational dynamics equations with an external torque depending on its own intrinsic movement. As a result of this, the induced precession has been successfully analysed and is hereinafter presented in this paper. All in all, a comprehensive engineering method is presented for the de-tumbling of non-cooperative objects. The proposed approach shows noticeably promising results as the braking process may only last several days depending on the design parameters. The applicability limits are discussed and the main areas of improvement are identified.