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ANALYZING THE STABILIZATION OF A TUMBLING SATELLITE USING FINITE ELEMENT METHODS

Abstract

A detailed three-dimensional finite element model (FEM) is used to model and capture the effect of energy dissipation on a tumbling satellite. The motivation of this study is the observation that defunct satellites can be driven into complex rotation states by the "Yarkovsky–O'Keefe–Radzievskii–Paddack" (YORP) Effect, which has been implicated in the evolution of asteroid rotation states. For this study, we focus on the effect of satellite deformation as a factor for energy dissipation using a finite element analysis. This model is developed for simulating the energy dissipation in flexible dynamics with three axis acceleration, which imitates the effect of tumbling motion. Based on these simulation results, we feedback the effect of the energy dissipation into the body rotational dynamics. Our simulation model comprises a simple solar array panel and body components. Numerical simulation is conducted by solving two sets of equations: one damping equation based on finite element analysis, and the Euler equations for rigid body dynamics. The deformation of the satellite at each time step is estimated by finite element analysis using a damping equation. The three-dimensional accelerations are distributed across each node of the model from the center of mass to simulate the tumbling motion. Using the results of the deformation, the inertia moments and products of inertia are updated. This sets up the time varying inertia matrix. After establishing the time varying inertia matrix, it is applied to the rigid body dynamics. Through the rigid body dynamics, its rotation state is updated and taken into finite element dynamics again as a second step, with this sequence repeating. Because the changes in the moments and products of inertia are very small, the kinetic energy does not change dramatically. However, there is a slightl difference with nominal analysis in long term simulation. A higher stiffness model will need longer calculation time. The amount of energy dissipation is determined by comparing these dynamical results with the nominal analysis, which only has principal inertia matrix terms. Additionally, the inertia matrix derivative is used to compute the energy dissipation rate. Analyzing the amount of energy dissipation and the resulting changes in rotation rate reveals the detumbling process. This analysis can be used to develop better models for energy dissipation in non-uniformly rotating debris and defunct satellites.