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Modeling of Deformation and Energy Dissipation

for a Tumbling Body

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Several factors cause changes of spin rate and axes of rotational bodies such as space debris and small asteroids, even artificial satellites. Although these factors cannot be simply categorized, the Yarkovsky-O'Keefe-Radzievskii-Paddack (YORP) is considered as primary effects on the rotational body as external torque. On the other hand, structural friction and sloshing of liquid are thought as internal causes of rotational change. Again, these causes are not simple, since they interact with each other within a system. For example, if spin rate is changed due to external torque, sloshing and structural frictions occur inside the system.

A better understanding of de-tumbling could contribute to active debris removal and satellite servicing and undergoing RPO(Rendezvous and Proximity Operation) missions. De-tumbling, rotational axis in the body, and relaxation times are crucial pieces of information to conduct these missions. Currently, spin rate change and de-tumbling are found via ground observation and YORP simulation. However, to fully reveal the mechanisms of the change in spinning conditions, its internal energy dissipations are needed.

Therefore, this study explores the interaction between de-tumbling and its internal energy dissipation in a defunct satellite. To capture structural effects on the rotational body, FEM(Finite Element Methods) are used as analysis methods. Based on simple satellite body and rotational dynamics, internal energy dissipation is modeled with variations of damping, spinning conditions, and its mechanical sensitivity such as mass and stiffness matrices. This modeling helps us to reduce computational time which generally needs a long term simulation and tiny damping cases. Also, this modeling is able to estimate relaxation time of de-tumbling. To validate internal energy dissipation theory, it is evaluated with actual mission program with considering sloshing dissipation.