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LINEAR STABILITY OF THE RELATIVE EQUILIBRIA OF A SPACECRAFT AROUND AN ASTEROID

Abstract

Studies on asteroids could provide answers to fundamental questions concerning the past of Solar System. Several missions have been developed with big success, such as NASA's NEAR to Eros and JAXA's Hayabusa to Itokawa. A thorough understanding of dynamical behavior of spacecraft near asteroids is necessary for the mission design. The orbital radius is small in the proximity of an asteroid due to its small dimension. Therefore, the gravitational orbit-rotation coupling of spacecraft can be significant due to the large ratio of its dimension to the orbit radius.

The traditional spacecraft dynamics, in which the spacecraft is treated as a point mass in orbital dynamics and attitude motion is studied on a predetermined orbit, is precise enough on an Earth orbit. However, it no longer has a high precision near small asteroids because of the significant orbit-rotation coupling. Therefore, studies on the full dynamics of spacecraft, in which the orbit-rotation coupling is considered, are of great value. Detailed properties of the full dynamical are useful for the design of new GNC technologies near asteroids, which will be more precise than current technologies developed based on the traditional spacecraft dynamics.

Notice that relative equilibria act as "organizing centers" of the dynamics of the system. It is sufficient to understand the dynamical properties to a big extent by studying the flow at and near the relative equilibria. In this paper, relative equilibria and their linear stability of the full dynamics of a spacecraft around an asteroid are studied with the method of geometric mechanics.

The Poisson tensor, Casimir functions and equations of motion, which govern the phase flow and phase space structures of the system, are obtained in a differential geometric method. The relative equilibria, at which the spacecraft is staying stationary with respect to the asteroid, are determined from a global point of view.

Based on the linearized system, conditions of the linear stability of the relative equilibria are obtained. We find that the linearized system decouples into two entirely independent subsystems: the motions within and outside the equatorial plane of the asteroid. Finally, an example asteroid is considered, and the linear stability is determined in a wide range of the parameters of the spacecraft. It is found that the unstable traditional stationary orbit in the point mass model can be stabilized through the gravitational orbit-rotation coupling, however, at the cost of the reduction of the traditional attitude stability region.