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THE RESTRICTED ORBITAL DYNAMICS AND ITS EQUILIBRIUM POINTS OF A SPACECRAFT AROUND AN ASTEROID

Abstract

The great interest in small primitive bodies has translated into an increasing number of small body missions. NASA's NEAR and JAXA's Hayabusa have been very successful asteroid missions. The orbital radius is very small in the proximity of a small asteroid. Therefore, the gravitational orbit-attitude coupling of spacecraft can be significant due to the large ratio of its dimension to the orbit radius.

The full dynamics, in which spacecraft is modeled as a rigid body to consider the orbit-attitude coupling, has been proposed with a higher precision than the traditional spacecraft dynamics, in which the spacecraft is treated as a point mass in orbital dynamics, and the attitude motion is studied on a predetermined orbit.

Our studies on full spacecraft dynamics show that the gravity gradient torque is very small near an asteroid, nearly zero. The effect of orbital motion on the attitude motion is neglectable, whereas studies show that the attitude motion has a significant effect on the gravitational force and orbital motion. A long-term control of attitude against the exterior perturbations can be achieved at cost of the electricity power generated persistently by solar arrays; whereas the orbital control is much weaker, and properties of natural gravitational dynamics need to be fully utilized for saving of fuel consumption.

Then, we can assume that the attitude is controlled ideally, and we only focus on the orbital motion with a controlled attitude, i.e., so-called restricted orbital dynamics. Traditional dynamics and restricted orbital dynamics proposed here are two different approximations of full spacecraft dynamics. In traditional dynamics, attitude motion is treated as a restricted problem on a predetermined orbit, whereas in restricted orbital dynamics orbital motion is treated as a restricted problem at a predetermined attitude. Traditional dynamics is applicable when the spacecraft is very small in comparison with orbital radius and orbit-attitude coupling is negligible, such as around Earth. Restricted orbital dynamics is applicable near a small asteroid, when the orbit-attitude coupling is significant and the attitude is easy to control.

Equations of restricted orbital dynamics are obtained and its equilibrium points are investigated. We find out two kinds of equilibria: on-axis and off-axis equilibria, which are located on and off equatorial principal axes of the asteroid respectively. We find that affected by orbit-attitude coupling at a proper attitude, the position of the spacecraft can be located at any longitude within the asteroid equatorial plane without orbital control.