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PROBABILITY OF SPACECRAFT'S 1:1 RESONANCE CAPTURE AROUND AN ASTEROID WITH THE ADIABATIC INVARIANT THEORY

Abstract

In recent years, the applications of CubeSats to long duration missions such as deep space exploration missions have become more and more popular due to their low cost and efficiency. With the low-thrust propulsion system, the spacecraft slowly transfer from a high-altitude orbit to a low-altitude one, during which it encounters and passes through the ground-track resonances i.e. the commensurability between spacecraft's orbital motion around the asteroid and the rotational motion of the asteroid around its axis. There is a probability that the spacecraft is captured into these resonances, which brings about significant perturbation on the spacecraft and resultantly the large variations of its orbital eccentricity and inclination. For the robust mission design and safe mission operations, it is necessary to investigate the phenomenon in detail.

The aim of this paper is to apply the adiabatic invariant theory (AIT) to investigate of the probability of a CubeSat's capture into resonance around an asteroid. The AIT is a semi-analytical and powerful method to detect the capture into resonance by identifying the noticeable change of the adiabatic invariant value when the capture happens. Although it has been widely applied to the celestial mechanics problems, this is the first research to apply it to address the similar problem in astrodynamics. The first two steps of applying AIT, i.e. the modelling with the Hamiltonian dynamics and the canonical transformation to a pendulum-like Hamiltonian, have been investigated in our previous work. This work focuses on the last two steps of the estimation process using the AIT. Firstly, the change in the energy balance when the system crosses the separatrix is approximated with numerical quadrature and then the probability of capture is obtained as a function of the approximated energy balance. With the inputs of the initial state of the spacecraft and the magnitude and direction of the low thrust, this research develops a tool to systematically estimate the probability of capture. Taking the example of DAWN mission to asteroid Vesta, this tool is applied to investigate the spacecraft's 1:1 resonance with Vesta and the probability of capture into this resonance. Finally, the results are validated with Monte Carlo simulations.

This research contributes to the state-of-art in the field of astrodynamics by systematically and efficiently analyse the probability of spacecraft's capture into resonance around asteroids.