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PROBABILITY OF SPACECRAFT'S CAPTURE INTO RESONANCE AROUND ASTEROIDS EXPLOITING 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 will slowly encounter and pass-through ground-track resonances when transferring from a high-altitude orbit to a low-altitude one. During the transfer, there is a probability that it is captured into the ground-track resonances, i.e., the commensurability between the revolution period of the spacecraft around the asteroid and the rotational period of the asteroid around its axis. This brings about perturbation on the spacecraft and resultantly the large variations of its orbital eccentricity and inclination. For the safe mission design, it is necessary to investigate the phenomenon in more depth.

The aim of this paper is to investigate the probability of a CubeSat's capture into resonance around an asteroid by applying the adiabatic invariant theory (AIT). The AIT is a semi-analytical and powerful tool to detect the capture into resonance by identifying the noticeable change of the adiabatic invariant value when the capture happens. Though 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. Firstly, the analytical expression of the Hamiltonian of the dynamics is defined considering the asteroid's irregular gravitational field up to the second order. Then, the Hamiltonian is reduced to a pendulum-like Hamiltonian through canonical transformation and its phase-space is characterized. Thirdly, the change in the energy balance when the system crosses the separatrix is approximated with numerical quadrature. Finally, 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 previously mentioned probability of capture. Taking the example of DAWN mission, this tool is developed 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 analyze efficiently the probability of spacecraft's capture into resonance around asteroids.