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OSCILLATIONS OF A SPACECRAFT WITH TETHER

Abstract

In modern times, tethered space systems have received significant focus from researchers across a broad range of applications. In the majority of publications devoted to an analysis of space tethered systems, the object of the investigation is the tether and the end-point, in which the spacecraft is regarded as a point mass. However, the study of the motion of a spacecraft with a tether relative of the own mass center is very important in modern science. The motion about of a mass centre of a spacecraft with a tethered system, designed to launch a re-entry capsule from an elliptic orbit is considered. The direction and value of the tethered force is varied in the deployment of the tethered system. If the point of application of the tethered force does not coincide with of the mass centre of the spacecraft, then oscillations with variable amplitude and frequency occur. In this paper we assume that the law of variation of the tethered force and the trajectory of the load, attached to the tether, are known and we study the oscillations of the spacecraft as a rigid body under the action of the tethered force and the gravitational moment. The mathematical model is derived using Lagrange's equations including tether vibrations and oscillations of the spacecraft relatively of the proper mass center. For some special cases approximate and exact solutions of the non-linear differential equations of the motion about of the mass center the spacecraft are obtained in terms of elementary functions and elliptic Jacobi functions. These solutions can be used also for the determination an undesirable additional microaccelerations on the spacecraft caused by vibrations of the tether. If the tether is elastic, then vibrations of the tether initiate small periodic disturbances, affecting the spacecraft. On the other hand, depending on the ratio between the spacecraft's moments of inertia and tethered system parameters, points of unstable equilibrium can appear in phase space. These two factors lead to chaos and irregular behavior of the spacecraft in its motion about a centre of mass. The paper contains bifurcation analysis, phase space study, and analytic solutions for separatrixes. The considered mechanical system performs chaotic motion near separatrixes under the influence of small disturbances. Results of the study can be useful also for the analysis of gravitational stabilization systems with space tethers and for studying the behavior of the spacecraft with the tether.