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Perturbed rotational motions of a spheroid with cavity filled with a viscous fluid

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Abstract

We consider a motion about the center of mass of a spheroid with a cavity filled with a viscous fluid. It is assumed that the velocity of the fluid is sufficiently high, so the corresponding Reynolds number is small. The torque of forces acting on the body by the viscous fluid in the cavity is determined by the method developed in the works of F.L. Chernousko. Asymptotic approach permits to obtain some qualitative results and to describe nonlinear evolution of angular motion using simplified averaged equations and numerical solution.

Keywords

Spheroid, cavity, viscous fluid, rigid body, averaging

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Introduction

A satellite or a spacecraft in its motion about the center of mass is affected by the torques of forces of various physical nature. It is influenced by the gravitational, aerodynamic torques, the torques due to the light pressure, and the torques due to the motions of masses inside the body. These motions may have various causes, for example, the presence of fluid in the cavities in the body (for example, liquid fuel or oxidizer in the tanks of a rocket). Therefore, there is a necessity to study the problems of the dynamics of bodies with cavities containing a viscous fluid, to calculate the motion of spacecraft about the center of mass, as well as their orientation and stabilization. The mentioned torques, acting on the body, are often relatively small and can be considered as perturbations. It is natural to use the methods of small parameter to analyze the dynamics of rigid body under the action of applied torques. The method applied in this paper is the Krylov–Bogoliubov asymptotic averaging method.

The problems of the dynamics of a rigid body with cavities containing a viscous fluid are significantly more difficult than in the case of ideal fluid. An important contribution to the solution of this problem has been made by the works of Chernousko et al.[1,2] They considered the motion of a rigid body with a cavity filled with a viscous fluid. These studies showed that solving the problems of dynamics of a rigid body with viscous fluid can be subdivided into two parts: the hydrodynamic and dynamic ones, which can greatly simplify the initial problem. An asymptotic solution is obtained that describes the evolution of the motion of a body with a fluid of high viscosity in a cavity over a long time interval.

In the paper,[3] the initial period of the rotation of a body with a cavity containing a high-viscosity fluid was investigated with the help of the boundary layer method. The study of Smirnova[4] is devoted to studying of the stabilizing effect of a viscous fluid in a cavity on the rotation of a top around the given axis. In Baranova and Vil'ke,[5] the inertial motion of a rigid body with a spherical or ellipsoidal cavity filled with a viscous fluid is studied by the asymptotic method. Fast rotational motions about the center of mass for a dynamically asymmetric satellite with a cavity filled with a fluid of high-viscosity under the influence of the gravitational and light pressure torques and medium resistance are studied.[6–9] A numerical analysis of the change in the vector of the moment of momentum of a rigid body with a cavity filled with a viscous fluid

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