ISSN 1064-2307, Journal of Computer and Systems Sciences International, 2019, Vol. 58, No. 5, pp. 667–673. © Pleiades Publishing, Ltd., 2019.
Russian Text © The Author(s), 2019, published in Izvestiya Akademii Nauk, Teoriya i Sistemy Upravleniya, 2019, No. 5, pp. 3–9.

CONTROL IN DETERMINISTIC SYSTEMS

Time Quasi-Optimal Deceleration of Rotations of a Gyrostat with a Moving Mass in a Resistive Medium

L. D. Akulenko[a,*], T. A. Kozachenko[b,], and D. D. Leshchenko[b,***]**

[a] *Institute for Problems in Mechanics, Russian Academy of Sciences, Moscow, 119991 Russia*

[b] *Odessa State Academy of Civil Engineering and Architecture, Odessa, Ukraine*

**e-mail: gavrikov@ipmnet.ru*

***e-mail: kushpil.t.a@gmail.com*

****e-mail: leshchenko_d@ukr.net*

Received January 28, 2019; revised April 19, 2019; accepted May 20, 2019

Abstract—The problem of time quasi-optimal deceleration of the rotations of a rigid body that includes elements with distributed and lumped parameters is studied. It is assumed that the body contains a spherical cavity filled with a highly viscous fluid (at small Reynolds numbers) and a viscoelastic element that is modeled by a moving mass connected to the body by a strong damper. The moving mass models loosely attached elements in a space vehicle, which can significantly affect the vehicle's motion relative to its center of mass during a long period of time. In addition, the body is affected by a small medium resistance torque and a small control torque localized in a ellipsoidal domain. The problem is solved asymptotically based on the procedure of averaging the unperturbed precession over the phase. A numerical solution is obtained.

DOI: 10.1134/S1064230719050022

INTRODUCTION

The analysis of objects containing elements with distributed and lumped parameters is of interest both from the theoretical and practical points of view. Constructive results for systems containing quasi-rigid bodies have been obtained. These models assume that the motion is close to the motion of perfectly rigid bodies. The influence of nonidealities can be taken into account using asymptotic methods of nonlinear mechanics. It is reduced to including additional disturbing torques in the Euler equations of the angular motion of a fictitious rigid body. The dynamics of the motion of rigid bodies with internal degrees of freedom was studied, e.g., in [1–5].

Significant effort was spent on the analysis of the passive motions of rigid bodies with a cavity filled with a highly viscous fluid [2, 3, 6]. Uncontrolled motion of rigid bodies in a resistive medium was studied in [3, 4, 7, 8]. However, the control of the rotations of quasi-rigid bodies using lumped (applied to the body) torques, which is important for applications, has been studied less (see [4, 9–12]).

In this paper, we consider time quasi-optimal problem of decelerating the rotations of a dynamically symmetric rigid body with a cavity filled with a highly viscous fluid. A moving mass is attached to a point on the body's symmetry axis by a viscoelastic damper. In addition, the body is affected by the external torque of the resistance force of a viscous medium.

1. STATEMENT OF THE PROBLEM

We consider controlled rotations of a dynamically symmetric rigid body with a spherical cavity filled with a highly viscous fluid [2, 3]. In addition, a moving mass is attached by a viscoelastic damper to a body immersed in a resistive medium [1, 3].

Based on the approach described in [9], the approximate Euler equations of the controlled rotations of the body in the body-related reference frame are written as

$$\dot{\mathbf{G}} + \boldsymbol{\omega} \times \mathbf{G} = \mathbf{M}^u + \mathbf{M}^p + \mathbf{M}^v + \mathbf{M}^r. \tag{1.1}$$