DSTA 2021 dys-ta.com
16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Damping of Vibrations of an Elastic Beam by Means of an Active Dynamic Damper in the Presence of Disturbances

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Abstract: We consider the problem of dampening the load, attached at the end of the elastic beam, by means of an active dynamical damper with a mass moving along the guide. The system is controlled by the force of the interaction between the damper and the load. A bounded feedback control is proposed which brings the system to a prescribed equilibrium state in a finite time even in the presence of disturbances, for example, the forces of dry friction.

Keywords: linear mechanical system, control synthesis, disturbances, stabilization in a finite time

1. Introduction

We consider the problem of damping oscillations of a load attached to the end of an elastic beam, using an active a dynamic damper with a translationally moving mass. The control variable is the force of interaction between the damper and the load. Systems of this type are used, for example, in a spacecraft, where the platform P (Fig. 1) with measuring devices is placed, using a long rod 1, at a considerable distance from the body of the spacecraft SC. To damp the lateral oscillations of the rod a controlled damper located on the platform itself, can be used. The damper consists of a guide 2 perpendicular to the axis of the rod, and a movable mass 3 driven along the guide by an electric motor.

Since the damper guide is limited in size and due to the restricted possibilities of the drive, it is natural to imposed constraints on the displacement of the mass relative to the platform and on the control force. In [1], a feedforward control is constructed which meets such constraints and drives the system to a prescribed state in a finite time. The Kalman approach is used for designing the control as a linear combination of the basis solutions of the uncontrolled system.

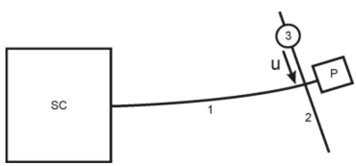

Fig. 1.

In the present paper, keeping the constraints mentioned, we assume also that a friction force with unknown and variable parameters acts between the mass and the guide, preventing accurate positioning of the platform. The presence of the friction force as an unknown disturbance makes us construct a feedback (not feedforward) control.

2. Control problem and control algorithm

Under certain simplifying assumptions, in dimensionless variables the equations of motion can be written in the form

$$\dot{z} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & -2 & 0 & 0 \\ 0 & 0 & -3 & 0 \end{pmatrix} z + \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} (u+v). \tag{1}$$

The following constraints are imposed on the control force u, the disturbance v, and the phase variables z:

$$|u| \le U, \quad |v| \le \rho U, \quad U > 0, \quad 0 \le \rho < 1, \quad |p^{\mathrm{T}} z| \le 1 \tag{2}$$

(the constant vector p depends on mass-inertial and technical characteristics of the system).

The problem is to construct a feedback control $u(z)$ that satisfies constraints (2) and brings system (1) to the coordinate origin for sufficiently small ρ.

The approach used is based on [2]. We introduce the matrix

$$Q = \begin{pmatrix} 20 & -180 & 420 & -280 \\ -180 & 2220 & -5880 & 4200 \\ 420 & -5880 & 16800 & -12600 \\ -280 & 4200 & -12600 & 9800 \end{pmatrix}$$

and define the function $T(z)$ by the equation

$$(Q\delta(T)z, \delta(T)z) = U^2/5,$$

where $\delta(T) = diag\{T^{-1}, T^{-2}, T^{-3}, T^{-4}\}$. The control function

$$u(z) = -\frac{10}{T(z)} z_1 + \frac{90}{T^2(z)} z_2 - \frac{210}{T^3(z)} z_3 + \frac{140}{T^4(z)} z_4 - z_2$$

solves the above problem.

3. Concluding Remark

The proposed approach can be used to control the dynamics of various technical objects, in particular, precise positioning systems.

Acknowledgment: The study was supported by the Government program (contract AAAA-A20-120011690138-6).

References

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