Active Noise and
Vibration Control Methods
Krakow - Krasiczyn, Poland
June, 11 - 14, 2007
www.vibrationcontrol.pl

ACTIVE CONTROL OF A TWO DEGREES-OF-FREEDOM BUILDING-GROUND SYSTEM

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Keywords: active control, constructions stabilization, 2-DOF dynamical systems

1. Introduction

Active control of building structures has been widely studied theoretically, using a variety of control strategies [5]. Control of structural dynamics basically means regulation of the corresponding characteristics for the purpose of providing its controlled response to the effect of the external dynamic loads.

During the last decade, a rapid development has been observed in the field of structural control. Although these achievements in civil engineering are quite recent, it needs to ensure the comfort and safety of occupants and protect the integrity of the structure. There are studied many theoretical and experimental problems of control in order to reduce structural vibrations under any unpredictable conditions [1, 2].

The use of active control on a passively base isolated building model is proposed in [4] to counteract vibrations due to a low power excitation. The base isolated building is modeled as a three degrees-of-freedom rigid body. The rotation at the center of this model of building is controlled by means of vertical synchronized actuators. The control methods which are applied to the base isolated model and then compared are as follows: optimal control, eigenvalue assignment using state and output feedbacks.

A method for design of supplemental dampers in multistory structures is presented in [6]. Active optimal control theory is adapted to design linear passive viscous or viscoelastic devices dependent on their deformation and velocity. The theory using a linear quadratic regulator is used to exemplify the procedure. With the use of Ricatti equation the design is aimed at minimizing a performance cost function, which produces a most suitable minimal configuration of devices while minimizing their effect.

A progression visible in investigations of earthquake resistant structures from passively controlled base-isolated structures to actively controlled structures has now led to hybrid structures. As it is shown in [7] a hybrid actuator-damper-bracing control system can be composed of viscoelastic dampers and hydraulic actuators in the form of the passive and active controllers, which are installed on the brace and connected to the building floor. The intelligent control strategy is designed to maximally utilize the passive damper and to minimally utilize the active energy. Thus, the passive controller of the hybrid system is designed for small moderate earthquakes and the active controller works for large earthquakes. The hybrid control system is studied under existing earthquake records and the ground motions together with assumption of tectonic movements of seismic plates.

A generalized minimum variance algorithm for the control of civil engineering structures is described in [3]. The algorithm needs the knowledge of the seismic excitation model to drive the autoregressive moving average exogenous model of the structure. The control is designed such that the variance of the generalized cost function is minimized. To demonstrate the effectiveness of this control technique, some simulation tests using a single degree-of-freedom structure were performed.

2. Problem Statement

The active control of buildings concerns on constructions being analyzed on the base of a general approach. Control of the investigated not subjected to any external loading two degrees-of-freedom continuous dynamical system represents a little particular case of the active control law used in the paper. There is derived a controlling scheme applied to the analyzed 2DOF system, which after an initial placement disturbance x_0 at any initial time t_0 evaluates until the moment of time t_f is reached. The system is not influenced by any external disturbances affecting it from the surrounding environment.

Let the following system of differential equations be given as follows

$$\dot{x}(t) = A(t)x(t) + B(t)u(t), \qquad x(t_0) = 0, \tag{1}$$

where: A – ($n\times n$) matrix of structure parameters,
B – ($n\times n$) matrix of executing (regulatory) elements,
x – the n-dimensional state vector of the system.

Our task focuses on searching for the control force $u(t)$ that would satisfactorily minimize the cost function J in time $t = t_f$:

$$J = \frac{1}{2}x(t_f)^T\theta(t_f)x(t_f) + \frac{1}{2}\int_{t_0}^{t_f}\begin{bmatrix} x(t) \\ u(t)\end{bmatrix}^T \begin{bmatrix} Q & T \\ T^T & R\end{bmatrix}\begin{bmatrix} x(t) \\ u(t)\end{bmatrix}dt, \tag{2}$$

where: θ, Q, T, R – dependent on time t symmetric weighting coefficients matrices.

3. Riccati equation

Let us assume the existence of such an expression representing the cost function

$$J = \theta(x,t)\big|_{t_0}^{t_f} + \int_{t_0}^{t_f}\varphi(x,u,t)dt. \tag{3}$$