Piezoelectric vibration control for all-clamped panel using DOB-based optimal control

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A B S T R A C T

Considering the spillover and harmonic effect in real active vibration control, a novel composite controller based on disturbance observer (DOB) for the all-clamped panel is presented. The single-mode of the piezoelectric panel can be regarded as a second-order system. The unmodeled error of the current controlled mode, harmonic effects, uncontrolled mode effects, etc., are regarded as the lumped disturbances which can be estimated by the DOB, and the estimated value is used for the feed-forward compensation design. Then, an optimal linear quadratic regulator (LQR) strategy is employed for the feedback design. In order to solve the difficulty of determining the weight matrices of LQR, a chaos optimization method based on logistic map is proposed. So the weight matrices can be tuned automatically. Combining with a new transient performance function, the optimal weight matrices can be obtained. The composite controller can effectively suppress the lumped disturbances of the all-clamped panel. Experiment comparisons with conventional LQR are given to verify the effectiveness of the proposed method.

1. Introduction

The active control techniques in smart structures have been a very top research topic in recent years. In particular, many researchers have studied the problems of vibration control in the panel since the panel is a fundamental element in many structures [1–15,35]. In these papers, different types of control schemes have been proposed. One important type controllers is referred as adaptive feed-forward controllers [1–7,10]. We all know that the feed-forward controllers are always based on the model of structure, thus such controllers can often achieve very high level of vibration attenuation and may have a good performance when they are applied to vibration control problems involving periodic disturbances. But they are less effective to deal with the irregular types of disturbances and may bring many problems, such as nonlinear feedback loop which may be undesirable for the reliability and stability of the system.

The other type controllers considered in the vibration control literatures are feedback controllers designed with stability control techniques [1,3,6,8–15,35]. But these feedback methods usually cannot react directly and fast to reject the effects caused by unmodeled dynamics and harmonic effects, although these control methods can finally suppress them through feedback regulation in a relative slow way. The only exception is the sliding-mode control method, which shows a good robustness to disturbances. However, it faces an unavoidable application problem—chattering phenomenon [14]. The vibration suppressing performance may be degraded when the system meets severe disturbances, which are very common for practical vibration structures.

One efficient way to improve vibration suppressing performance in such cases is to introduce a feed-forward compensation part into the feedback part. Real active vibration control systems always have different disturbances, such as unmodeled dynamics, harmonic effects, uncontrolled mode effects and so on, which are regarded as the lumped disturbances, and it is impossible to measure them directly. So disturbance estimation techniques have to be developed. Thus, a composite control method based on disturbance observer (DOB) is obtained. The DOB-based control method was originally presented by Ohnishi in 1987 [16]. Following this direction, many DOB-based control methods have been reported in different applications because of their simplicity and powerful ability to compensate the disturbances, e.g., robotic systems [17], missile system [18], hard disk drive system [19,20], inverted pendulum systems [21], and general control systems [22–25,38].

The optimal linear quadratic regulator (LQR) method, known as less sensitive to system errors, is often widely employed in the active control of deterministic vibratory systems [8,10–12]. The feedback controller is designed to minimize the performance index or cost function in quadratic form, which is dependent on the choice of the state weighting matrix Q and the input weighting matrix R. So, these weighting matrices should be appropriately selected to...