International Journal of Innovative
Computing, Information and Control
Volume **6**, Number **7**, July **2010**

 ISSN 1349-4198
pp. **2965–2975**

VIBRATION CONTROL OF A FLEXIBLE ARM EXPERIMENTAL SYSTEM WITH HYSTERESIS OF PIEZOELECTRIC ACTUATOR

Seiji Saito, Mingcong Deng, Akira Inoue and Changan Jiang

Division of Industrial Innovation Sciences
Graduate School of Natural Science and Technology
Okayama University
3-1-1 Tsushima-Naka, Okayama, 700-8530, Japan
deng@suri.sys.okayama-u.ac.jp

Received March 2009; revised July 2009

Abstract. *In this paper, an operator-based nonlinear vibration control of a flexible arm experimental system using piezoelectric actuator with hysteresis is discussed. The piezoelectric actuator exhibits hysteretic effects in the output displacement responses, which can cause inaccuracy and undesirable oscillations, where Prandtl-Ishlinskii(PI) model is used to describe the hysteresis. In order to compensate the hysteretic effects, using the model, and based on the concept of Lipschiz operators and robust right coprime factorization, nonlinear vibration controllers are proposed to the experimental system. Further, a tracking operator design method is given to ensure the tracking performance of the considered system. Finally, simulation results and experimental results are presented to support the effectiveness of the proposed design method.*
Keywords: Operator, Flexible arm, Piezoelectric actuator, Prandtl-ishlinskii(PI) model, Robust right coprime factorization

1. **Introduction.** The attenuation of vibration is one of the practical problems in many engineering fields and the vibration problem of flexible arms has attracted attention of many researchers. For example, in order to improve the work efficiently, the robot which is used for the transportation of a liquid crystal panel, has been improved to have faster operational speed and lighter weight. For such a robot, the attainment of the desired vibration levels is difficult by decreasing the stiffness and the damping effect, therefore the vibration control is an important subject. Meanwhile, piezoelectric actuator is light weight and high operational speed and the piezoelectric actuator can be bounded or embedded along a robot arm easily, so the piezoelectric actuator has been proved to be effective control device for active control of flexible arm vibration. In general, the piezoelectric actuator has hysteresis. Because of the existence of the hysteresis, the system using the piezoelectric actuator usually exhibits undesirable oscillations and even instability. So far, for the vibration control of a flexible arm experimental system using the piezoelectric actuator, an operator-based nonlinear system control technique has been given in [1]. However, in [1], the hysteresis of the piezoelectric actuator is not considered. On the other hand, [2] proposed a new controller for the actuator having hysteresis characteristic. It considered the 1st vibration mode of the flexible arm, based on the concept of Lipshitz operators and robust right coprime factorization [3, 4], a vibration control system was designed and a tracking operator was also considered [5]. Prandtl-Ishlinskii (PI) model was adopted to describe hysteresis [6]. Using PI model, a nonlinear compensator was introduced to compensate the hysteretic effects. In order to make the nonlinear system with PI model be BIBO stable, PI model is decomposed into two parts, namely, invertible part and disturbance part [7]. But the effectiveness of the controller was only confirmed