Adaptive backstepping control of a class of hysteretic systems

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ABSTRACT

A backstepping-based adaptive control is designed for a class of one degree of freedom hysteretic system. The true hysteretic behavior does not need to be known for the controller design. A polynomial description is assumed with uncertain coefficients and an uncertain residual function. These uncertainties are bounded and lump the discrepancies between the adopted description and the real hysteretic behavior. The adaptive controller is able to handle these uncertainties and make the closed loop globally uniformly ultimately bounded when the system is subject to an unknown excitation from which a bound is known. The efficiency of the approach is tested by numerical simulations on a hysteretic system under a seismic excitation. This system is mathematically described by the differential Bouc-Wen model, which is widely used in structural dynamics.

Keywords: Hysteretic systems, structural control, base isolators, adaptive control, backstepping

1. INTRODUCTION

Hysteresis is one of the classes of nonlinearities that have attracted a lot of interest in recent years within the context of analysis and control of dynamic systems. Hysteresis is encountered in a wide variety of processes in which the input-output dynamic relations between variables involve memory effects. Examples are found in biology, optics, electronics, ferroelectricity, magnetism, mechanics, structures, among other areas. This paper is primarily concerned with hysteresis in mechanical and structural systems. In these systems, hysteresis appears as a natural mechanism of materials to supply restoring forces against movements and dissipate energy.[1,2] This mechanism has been exploited in recent years in the design of hysteretic damping devices and vibration isolation schemes as those encountered in seismic base isolated buildings.[3–5] Another recent source of interest for hysteresis in mechanical and structural systems comes from the new "smart" materials and devices used for vibration control. Materials such as shape memory alloys[6] and electro/magnetorheological fluids[7,8] have been proposed for this purpose, which exhibit complicated hysteretic behaviors.

While there is an extensive literature about physical characterization and mathematical modelling of hysteretic systems in different areas, only a few references are found reporting feedback controllers in the general literature on control systems.[9–12] In structural systems, feedback controllers in the presence of hysteretic components have been primarily encountered when dealing with smart actuators and base isolation schemes. A passivity-based controller has been recently proposed for a class of shape-memory alloys actuators.[13] In the case of base isolated buildings, feedback control problem arises when the hysteretic isolators are coupled with active controllers acting on the base within a hybrid scheme. One way of addressing this problem has been to consider a linear model of the structure and the isolator, which is augmented with a nonlinear term describing the hysteretic restoring forces. Stochastic optimal control[14] and covariance control[15] have been proposed based on a stochastic linearization of the hysteresis nonlinearity. Another works have presented hybrid schemes in which stabilizing nonlinear controllers have been derived considering that the hysteresis nonlinearity can be treated as an unknown uncertain function under linear bounds.[16,17]

In a related vein, this paper considers a one degree of freedom system described by a model with a linear part and a nonlinear hysteretic restoring force. This force has not to be known for the controller design, but it is

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