Modeling Rate-Dependent and Thermal-Drift Hysteresis through Preisach Model and Neural Network Optimization Approach*

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Abstract. Smart material actuators like Piezoelectric(PZT) are widely used in Micro/Nano manipulators, but their hysteresis behaviors are complex and difficult to model. Most hysteresis models are based on elementary quasistatic operators and are not suitable for modeling rate-dependent or thermal-drift behaviors of the actuators. This work proposes a Preisach model based neurodynamic optimization model to account for the complex hysteresis behaviors of the smart material actuator system. Through simulation study, the rate-dependent and the thermal-drift behaviors are simulated via Bouc-Wen model. The μ-density function of the Preisach model is identified on-line through neurodynamic optimization method to suit for the varied rate of the input signals. The output of the actuator system is predicated in realtime based on the on-line identified μ-density plane. It is shown experimentally that the predicated hysteresis loops match the simulated PZT loops very well.

Keywords: Hysteresis, Preisach Model, Bouc-Wen Model, Neurodynamic optimization.

1 Introduction

Smart material actuators like piezoceramic (PZT) with advantages of high output force, large bandwidth and fast response time have found increasing applications in micro/nono technology. Nevertheless, like many other intelligent materials, the PZT possesses a natural hysteresis characteristics which brings a severe positioning error to the system and affects the performance of the system especially for those cases requiring precise micromanipulation [1]. Even worse, the hysteresis is rate-dependent, that means, increasing with the rate of input driving signal of the PZT, the hysteretic loop is varied and becomes larger and rounder. This characteristics not only bring errors to the system, but also causes

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troubles to the compensator and controller, because it brings difficulty in modeling and even causes some close-loop controller instability.

Various methods were developed to model the hysteresis problems, such as the Preisach model [2], Maxwell model [3], Duhem model [4], Bouc-Wen model [5], Prandtl-Ishlinskii model [6][7], Ishlinskii hysteresis (IM) model [8][9], and ANN models [10], etc. But most of those works are focused on canceling stationary hysteresis problems, however, many applications of the PZT are in the situations of dynamic environment, and the hysteresis behavior are drifting caused by the thermal property of the PZT. Therefore, finding a model with characteristics of less time consuming, rate-dependent and high accuracy compensation for a real time control system is very necessary. In this research, the numerical expression of the classical Preisach model is introduced, the μ density function is identified on-line via neural network optimization method, and the performance of the μ density functions are verified by numerical simulation experiment. The good agreement between the measured and predicted curves shows that the classical Preisach model is an effective way for modeling the hysteresis of the piezoceramic actuator system. The proposed method can be extended to model electromagnetic actuators as well [11].

2 Experimental Setup and Simulation Model

The experimental setup is shown in Fig.1. The dSPACE is a realtime system running in Matlab simulink(real time instrument)RTI environment. The adopted dSPACE is with DS1005 DSP board and DS2001 and DS2002 in the chases, but only DS1005 board is used here to run the simulation models in current research. It is adopted to simulate the hysteresis as well as the realtime on-line predication ability of the proposed rate-dependent and thermal-drift hysteresis model in a real time environment.

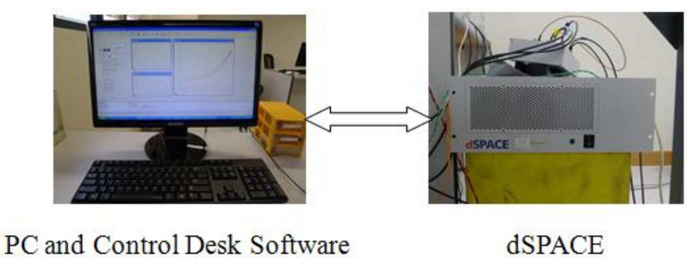

Fig. 1. Realtime simulation hardware

Bouc-Wen model is adapted to simulate the piezoelectric actuators, which can be described as follows [5]:

$$\begin{aligned} y(t) &= \dot{u} - h \\ \dot{h} &= \alpha\dot{u} - \beta|\dot{u}|h - \gamma\dot{u}|h| \end{aligned} \tag{1}$$