Experimental Study on the Electromechanical Hysteresis Property of Macro Fibre Composite Actuator

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The hysteresis characteristic in macro fibre composite (MFC) actuator is intimately related to their application in vibration control system. In this paper, the electromechanical hysteresis property of MFC actuator is studied. First, experimental study on the electromechanical behaviours under different voltages and frequencies is carried out, and the hysteretic property of MFC actuator is investigated. A digital signal processing (DSP) system is used to control input voltage and a digital image correlation (DIC) system as noncontact setup is used to obtain the output strain of the MFC actuator in the experiment. The experimental results indicate that the relationship of the voltage and strain displays hysteresis with nonlocal memory. Second, the Preisach model is used to describe hysteresis characteristic of the MFC actuator. In order to improve the accuracy of the model, the modifications are made, in which the experimental data under the quasi-static frequency range and the congruency property are used to establish the modified Preisach model. Finally, the hysteresis characteristics of the MFC actuator predicted from the proposed model are compared with those obtained from the classical Preisach model. The results indicate that the proposed model gives better accuracy than the classical Preisach model, and it is suggested that the present study on the hysteresis model of the MFC actuator can be used in the active vibration control.

1. INTRODUCTION

Macro fibre composite (MFC) actuators are known to possess several salient properties such as durability, surface-comfortability, and higher ability to eliminate vibration in comparison with the conventional piezoceramics actuators. Hence, it is widely recognized to play an essential role in applications ranging from vibration control, structural health monitoring, and energy harvesting.

However, hysteresis behaviour is a major obstacle in applications of MFC actuators. Like many other piezoelectric materials, the MFC actuator exhibits hysteresis property with nonlocal memory, in which the response depends on both the previous extremums as well as the present value of input voltage. If the hysteresis behaviour is not taken into account, the predicted response of the MFC actuator will significantly deviate from accuracy. Therefore, in order to successfully apply the MFC actuator in structural active vibration control, it is necessary to establish a hysteresis model to describe electromechanical behaviour of the MFC actuator.

In the previous study, the approaches of modelling the hysteresis behaviour of piezoelectric actuator are divided into two groups: physical model and phenomenological model. The former models, like Jiles-Atherton model and homogenized energy model, are formulated based on the physical principle of domain wall movements and internal energy losses in the material. Nevertheless, these physical models are difficult to be applied in control system due to the complex physical cause of hysteresis phenomenon of piezoelectric actuator. The phenomenological models are formulated based on a purely mathematical expression that relates the overall input-output relationship without considering the underlying physical essence. Several examples of such models are the generalized Maxwell model, the Prandtl-Ishlinskii model, and the Preisach model. However, the symmetric structures of the generalized Maxwell and the Prandtl-Ishlinskii model limit their accuracy. The Preisach model, which was introduced by Preisach, is a phenomenological hysteresis model. Although it originated in magnetics, the model has been utilized in many other areas later, such as superconductors, electro rheological fluids, shape memory alloys, and piezoelectric materials. Hughes and Wen discussed the unified framework provided by the classical Preisach model for both piezoceramic and shape memory alloy. The identification method based on the input/output data and hysteresis compensation using the classical Preisach model was also demonstrated in their research. Based on the previous research, Ge and Jouaneh developed a tracking control approach for piezoceramic actuator by incorporating the classical Preisach model in the feed-forward loop.

Since the MFC actuator was produced by Smart-Material Corporation, researchers extensively studied the hysteresis...