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Survey, Experiment and Improvement of Micro Actuator Positioning for Precise Grinding by Neural Network

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ABSTRACT

Precise grinding of fine shaped pieces with various arithmetic needs micro positioning and rapid movement of a work piece. Moreover, with regard to dressing of super abrasive grinding wheels, precise positioning of a dresser on the grinding wheel for achieving desired depth is needed. Piezoelectric actuators are convenient for micro positioning systems. Inherent hysteresis is one of the drawbacks in the use of these actuators. Neural networks can be used for this modeling. Ignoring the force can increase the positioning error remarkably. In this paper, the neural network is used for hysteresis modeling with attention to the important effect of loaded force. After modeling, the inverse hysteresis model is used as a compensator in a feed forward way to linearize the input-output relationship. Then using a PID closed loop controller and selecting a suitable coefficient for it, the maximum error was decreased to less than 2 percent of the working amplitude.

KEYWORDS

Piezoelectric, Hysteresis, Neural Networks, Compensator.

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1- INTRODUCTION

Piezoelectric actuators are widely used in micro-positioning and ultra-precision manufacturing systems. However, one of the drawbacks of the piezoelectric actuator is the existence of hysteresis. Hysteresis is a multi-valued mapping and is non-differentiable, thus it presents a challenge in the control of systems with piezoelectric actuators. Without modeling and incorporating hysteresis in the controller design, hysteresis often severely limits system performance such as giving rise to undesirable inaccuracies or oscillations, even leading to instability. Therefore, it is necessary to find a model describing the behavior of hysteresis so that the corresponding controller based on the obtained hysteresis model can be designed to eliminate the harmful effect of hysteresis. In recent decades, there have been several models proposed to describe the hysteresis, such as the Preisach model [1], the KP hysteron model [2], the PI model [3], and the Bouc–Wen model [4].

Among those models, the Preisach model is the most popular one, since it contains the basic features of the hysteresis phenomena in a conceptually simple and mathematically elegant way. It has been widely used to model some smart materials such as ferromagnet, piezoceramic, and shape-memory alloy.

However, it is not convenient to tune the parameters online in order to adapt to the change of operating environment. Moreover, another drawback of the Preisach model is that it is not easy to determine the values of the distribution function of the model.

Recently, artificial neural networks have been applied to modeling of hysteresis. In this method, the Presach model was considered as the superposition of the outputs of a set of elementary hysteresis operators. Then the weights function of those operators was determined by neural networks.

Another proposed model is a feedforward neural network-based hysteresis model. This neural model was composed of two blocks. The first one was a block with memory that was constituted by a set of play operators. The second one was a memoryless function approximated by a feedforward neural network. The above-mentioned neural network-based methods are useful for modeling hysteresis. However, the drawbacks still exist, such as the fact that the procedure of realization is rather complicated.

In order to control systems with hysteresis, the most common approach is to construct an inverse model of hysteresis. Gang Tao and Kokotovic [5], presented a simple parameterized hysteresis model and developed a corresponding inverse model for it. As the parameterized hyteresis model could not describe the real hysteresis accurately, the derived inverse model would result in large error.

Xinlong Zhao and Yonghong Tan [6], proposed a novel hysteresis operator to construct an expanded input space to transform the multivalued mapping of hysteresis into a one-to-one mapping which enables neural networks to approximate the behavior of hysteresis.They developed the same expanding operator for modeling the corresponding inverse model.

In this paper, a combination of time delay feed forward neural network and ordinary feed forward neural network is proposed for modeling direct hysteresis and inverse hysteresis. This structure is much simpler than the method of Xinlong Zhao and Yonghong Tan.

Compared with the previous-stated methods, the proposed neural network-based hysteresis or inverse hysteresis model has a rather simple architecture.

Since unlike other same researches the important effect of loaded force on the actuator is included, this has decreased the positioning error remarkably, especially when these actuators are used in the precise grinding or machining operations.

2- COMPENSANTION OF HYSTERESIS

A usual way to deal with hysteresis is utilizing inverse hysteresis models as compensator. However, it is known that hysteresis is a non-smooth nonlinear function with multivalued mapping. It is rather difficult to obtain an inverse model directly based on the obtained hysteresis model. The neural networks can be applied to the modeling of both hysteresis and inverse hysteresis.

In order to eliminate the effect of hysteresis, the inverse

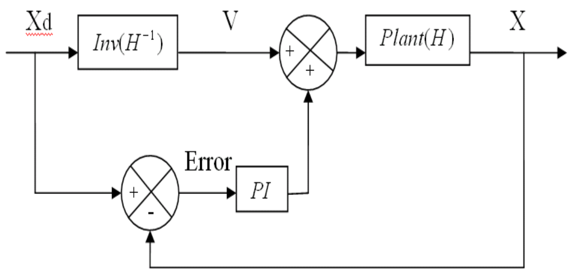

Figure1-Structure of closed loop controller

hysteresis model is utilized in a feed forward scheme as a hysteresis compensator. In order to improve the tracking performance of this compensator, especially for multifrequency feeding signals, a closed-loop controller was utilized. The corresponding system architecture is shown in Figure 1.

In this architecture, the proposed neural network-based inverse hysteresis model is used as a direct inverse model controller to cancel the oscillation or vibration caused by the hysteresis.

It is clear that the inverse hysteresis model can suppress the influence of hysteresis and improve the signal tracking performance.

The tracking of this system for a multifrequency feeding signal is shown in Figure2 and the tracking error is shown in Figure3.

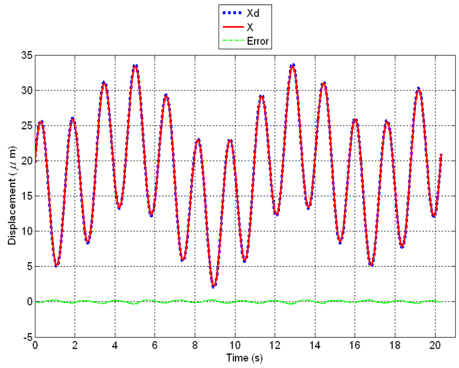

Figure2-Signal tracking

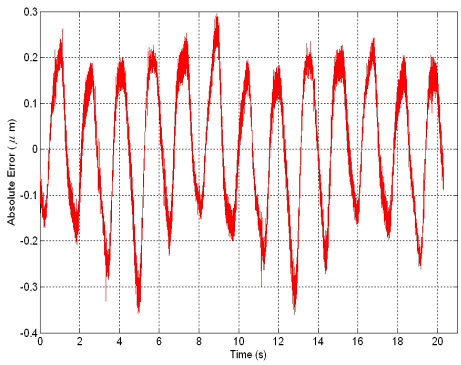

Figure3- Error of signal tracking

The equation of this complicated signal is.

3- CONCLUSION

Piezoelectric actuators are convenient for micro positioning systems. Inherent hysteresis is one of the drawbacks in the use of these actuators. Precise control of this actuator under changing of environmental and operational conditions, without modeling of hysteresis, is impossible. Neural networks can be used for this modeling. In the previous researches in this field, the important effect of loaded force on the actuator is ignored.

In this paper, the neural network is used for hysteresis modeling with attention to the important effect of loaded force.

After modeling, inverse hysteresis model is used as compensator in a feed forward way to linearize the input-output relationship. Then using a PI closed loop controller and selecting a suitable coefficient for it, the maximum error was decreased to less than 2 percent of the working amplitude. Since similar research without considering the force effects, has been achieved to the maximum error of about 3% , the result of this paper is convenient.

The hysteresis loop before and after compensating is shown in Figures 4 and 5.

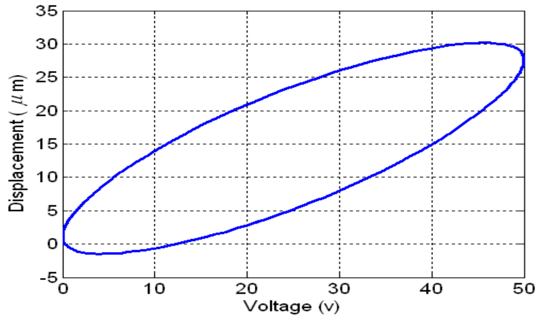

Figure4- Hysteresis loop before compensation

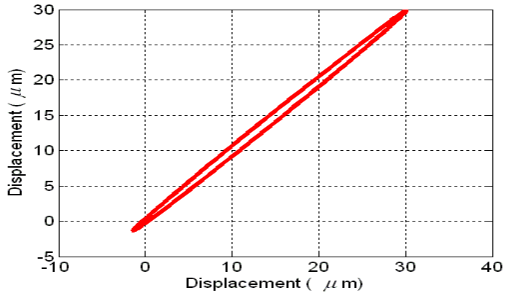

Figure5- Hysteresis loop after compensation

$$X_d(t) = -5\times(-36+2\cos(0.2t)+4\cos(0.4t) +10\cos(0.8t)+20\cos(4t))\times10^{-3} \quad (1)$$

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