Sliding mode observer based hysteresis compensation control for piezoelectric stacks

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1 Abstract

The piezoelectric stacks (PS) are widely used in high-precision control system due to their pushing force capabilities, fast responses and high positioning accuracies. In this study, we establish a Luenberger-wise observer for compensating the hysteresis effect in PS actuator, and an observer-based robust controller.

2 Problem statements

Strong hysteresis nonlinearity which carried by piezoelectric materials inevitably compromises the performance of the PS. Specifically, hysteretic effect may induce 10%∼15% positioning error at low frequency for open-looped systems, and error is even larger at high frequency.
For depicting the characters of PS system, many mathematic models have been made. The classical Bouc-Wen hysteresis model was modified by[Wen (1976)]. The model contains two sets of differential equation to describe the relationship between input driving voltage $u(t)$ and displacement $x(t)$ of the actuator, it can be stated as follows

$$m\ddot{x}(t) + b\dot{x}(t) + kx = k[du(t) - h(t)] \tag{1}$$

$$\dot{h}(t) = \alpha d\dot{u}(t) - \beta|\dot{u}(t)|h(t) - \gamma\dot{u}(t)|h(t)| \tag{2}$$

The block diagram of the observer-based compensation system is shown in Figure 1. Within this framework, the hysteresis observer proposed is given by

$$\begin{cases} \dot{\xi}(t) = T\tilde{A}\tilde{X}(t) + T\tilde{B}\bar{u}(t) + |u_2(t)|TM_1\tilde{X}(t) \\ \qquad + u_2(t)T\Gamma|\tilde{X}(t)| + L[y(t) - \hat{\tilde{C}}X(t)] \\ \hat{\tilde{X}}(t) = \xi(t) + Ny(t) \end{cases} \tag{3}$$

and the robust controller is given by

$$\begin{aligned} u(t) =& k^{-1}\{-k_1[z_2(t) - k_3z_1(t)] - A_1[z_1(t) + r(t)] \\ & - A_2[z_2(t) + \dot{r}(t) - k_3z_1(t)] - \check{\phi}\,\mathrm{sgn}[\sigma(t)] + \ddot{r}(t) \\ & - k_3\dot{z}_1(t) - k_2[\sigma(t) + k_4\mathrm{sgn}(\sigma(t))]\}. \end{aligned} \tag{4}$$

The experiment platform and the control performance are shown in Figure 2 and Figure 3.

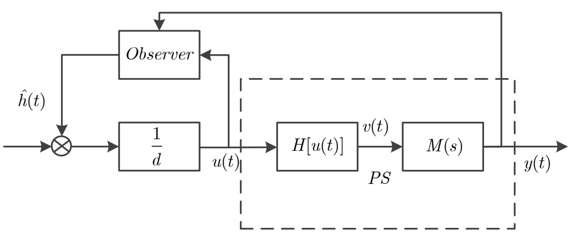

Figure 1: The Framework of the observer-based compensation system

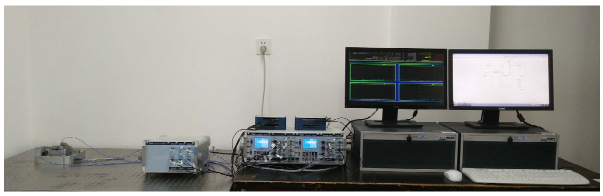

Figure 2: Experimental platform

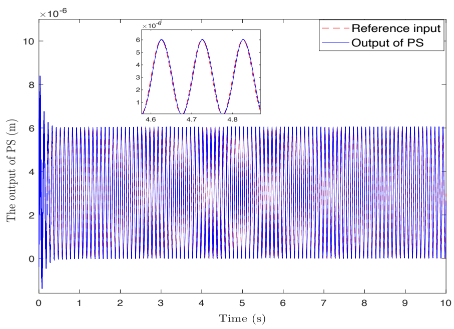

Figure 3: The output of the PS actuator

References

[Wen (1976)] Wen YK (1976) Method for random vibration of hysteresis systems. *Journal of the Engineering Mechanics Division 102(2): 249-263.*