The 42nd Annual Conference of the IEEE Industrial Electronics Society, October 23-26, 2016,
Palazzo dei Congressi, Florence, Italy

Finite-Time Stabilization of Ultrasonic Motor With Stochastic Compensator for Chattering Phenomena

Hiroyuki YOSHINO*, Yûki NISHIMURA* and Kanya TANAKA**

Abstract

Ultrasonic motors are attracting attention because of having characteristics such as high-torque in low-speed, high responsively and electromagnetic compatibility. However, they have strong nonlinearity because of having frictions as driving sources generated by piezoelectric effects and having the dynamics changing depending on temperature of the motors. Those physical characteristics cause the difficulty of deriving mathematical models and control laws [1]. This motivates constructing simple mathematical models and simple controllers having a robustness property for modeling errors. In this direction, the servo control problems are investigated in [2]. Because the investigations imply that we should, absolutely, allow the system models having nonlinearity between the input and the output, a positioning control system is derived based on a state-space model with considering the nonlinearity in [3]. To develop the controller so that they have further rapid stabilization and further precise settling accuracy, we consider employing the concept of finite-time stabilization. However, in theory, the finite-time convergence property results in discontinuous phenomena when just achieving the target position. This yields that, in practical experiments, chattering-like phenomena occur about the target position [4] as with sliding mode controls. Because the phenomena are obstacles for precise controls, we should attenuate them by providing compensators. In this paper, we propose a new compensator for the chattering-like phenomena by dealing with them as Gaussian white noises appearing about the target position only. This treatment enables us to employ stochastic stability analysis [5]; that is, we can evaluate the effects of the compensator by theoretical analysis while the phenomena appear in practical experiments only. Furthermore, the compensator keeps finite-time convergence to the target points different from adding time intervals of no control (dead time).

References

[1] N. W. Hagood IV and A. J. McFarland: Modeling of a piezoelectric rotary ultrasonic motor, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency control, 42-2, 210/224, 1995.
[2] F.A. Rahman, Y. Murata, K. Tanaka, Y. Nishimura, S. Uchikado, and Y. Osa: Variable gain type PID control using PSO for ultrasonic motor; Proc. 5th International Workshop on Computational Intelligence & Applications IEEE SMC Hiroshima Chapter, 2009.
[3] Y. Nishimura, K. Tanaka, Y. Wakasa and H. Nakamura: Robust angle regulation for ultrasonic motor using CLF-based controller; Proc. IECON 2011, 2011.
[4] Y. Nishimura, H. Yoshino and K. Tanaka: Positioning control of ultrasonic motor using homogeneous finite-time control, Transactions of The Institute of Systems, Control and Information Engineers, 29-6, 235/241, 2016 (in Japanese).
[5] R. Z. Khasminskii. Stochastic Stability of Differential Equations, Second Edition, Springer, 2012.

*Department of Mechanical Engineering, Graduate School of Science and Engineering, Kagoshima University, **Department of Electrical and Electronic Engineering, Graduate School of Science and Engineering, Yamaguchi University