Chaos control in AFM system using sliding mode control by backstepping design

Cheng-Chi Wanga, Neng-Sheng Pai b, Her-Terng Yauc,∗

a Department of Mechanical Engineering, Far-East University, No. 49, Jung-Hwa Road, Hsin-Shih Town, Tainan 744, Taiwan, ROC
b Department of Electrical Engineering, National Chin-Yi University of Technology, Taichung 411, Taiwan, ROC
c Department of Electrical Engineering, Far-East University, No. 49, Jung-Hwa Road, Hsin-Shih Town, Tainan 744, Taiwan, ROC

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Abstract
This paper presents a robust algorithm to control the chaotic atomic force microscope system (AFMs) by backstepping design procedure. The proposed feedback controller is composed by a sliding mode control (SMC) and a backstepping feedback, so its implementation is quite simple and can be made on the basis of the measured signal. The developed control scheme allows chaos suppression despite uncertainties in the model as well as system external disturbances. The concept of extended system is used such that a continuous sliding mode control effort is generated using backstepping scheme. It is guaranteed that under the proposed control law, uncertain AFMs can asymptotically track target orbits. The converging speed of error states can be arbitrary turned by assigning the corresponding dynamics of the sliding surfaces. Numerical simulations demonstrate its advantages by stabilizing the unstable periodic orbits of the AFMs and this method can also be easily extended to elimination chaotic motion in any types of chaotic AFMs.

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1. Introduction

The atomic force microscope (AFM) provides a powerful tool for surface analysis applications in the nano-electronics, materials and biotechnology fields. Specifically, AFM-based system provide additional capabilities and advantageous relative to other microscopic methods with regard to studies of surfaces and structures by providing reliable measurements at the nano-scale [1]. A typical configuration for AFM is a probe which is formed by a tiny tip attached to a cantilever. As the tip is brought close enough to the sample surface, atomic force interaction is induced and causes the dynamics of the tiny tip, consequently the dynamics of the cantilever, to change. Such a dynamic change is measured by a sensor whose signal can be used to infer the ultrasmall atomic force.

The micro-cantilever of AFMs may exhibit chaotic motion under certain conditions. This matter has been experimentally observed in Refs. [1–5]. Theoretical studies, based on the techniques of Melnikov theory, have been performed in Refs. [3,6] to prove the existence of chaotic invariant sets and to determine the region in the space of physical parameters where chaotic motion is present. In 2006 [7], Hu and Raman used systematic experiments on a variety of micro-cantilevers under a wide range of operating conditions and showed that dynamical responses of AFM micro-cantilevers may bifurcate from periodic to chaotic oscillations near the transition from the non-contact to the tapping regimes. The existence of chaotic