Experimental Study of Laser Interferometry Based Motion Tracking of a Flexure-Based Mechanism

Umesh Bhagat, Monash University, Australia

Bijan Shirinzadeh, Monash University, Australia

Yanling Tian, Tianjian University, China

ABSTRACT

This paper presents an experimental study of laser interferometry-based closed-loop motion tracking for flexure-based four-bar micro/nano manipulator. To enhance the accuracy of micro/nano manipulation, laser interferometry-based motion tracking control is established with experimental facility. The authors present and discuss open-loop control, model-based closed-loop control, and robust motion tracking closed-loop control for flexure-based mechanism. A comparative error analysis for closed-loop control with capacitive position sensor and laser interferometry feedback is discussed and presented. Model-based closed-loop control shows improvement in position and motion tracking over open-loop control. Robust control demonstrates high precise and accurate motion tracking of flexure-based mechanism compared to the model-based control. With this experimental study, this paper offers evidence that the laser interferometry-based closed-loop control can minimize positioning and tracking errors during dynamic motion, hence realizing high precision motion tracking and accurate position control.

Keywords: *Closed-Loop Motion Tracking, Flexure-Based Mechanism, Laser Interferometry, Micro/Nano Mechanism, Motion Control*

INTRODUCTION

Ultra-precision manipulation is one of the very important techniques for the micro/nano engineering and for many applications in manufacturing and medical sciences. Precise control and accurate motion tracking at micro/nano level is a requirement for present and future automation systems. Such precise actuation and control can be achieved with piezoelectric actuator driven flexure-based mechanisms. These mechanisms are highly appropriate platforms for micro/nano manipulation (Chung, Choi, & Kyung, 2006; Li & Xu, 2010; Spanner & Vorndran, 2003; Speich & Goldfarb, 1998; Tian, Shirinzadeh, & Zhang, 2009). Flexure-based mechanisms

DOI: 10.4018/ijimr.2011070103

have no backlash, zero friction and negligible hysteresis, and can offer unlimited motion resolution (Paros & Weisbord, 1965; Mohd Zubir & Shirinzadeh, 2009; Smith, 1997; Tian, Shirinzadeh, & Zhang, 2010). However, piezoelectric actuators possess non-linearities including the hysteresis and creep/drift effects. The presence of such non linearities cannot guarantee positioning accuracy and precise motion tracking of the flexure-based mechanism. However, in the past decade, increased demand for high-precision micro/nano motion tasks has generated high level of research interests in precise positioning and accurate motion tracking of micro/nano manipulators. Many appropriate closed-loop control strategies have been proposed to achieve the desired motion tracking of piezoelectric actuator-driven flexure-based mechanisms (Bashash & Jalili, 2008; Liaw & Shirinzadeh, 2008, 2009; Motamedi et al., 2010; Rakotondrabe, Haddab, & Lutz, 2009; Saeidpourazar & Jalili, 2006; Shiou et al., 2010; Xu & Li, 2009, 2010). An important component associated with closed-loop control of micro/nano multi-axis manipulator is the sensing and measurement of motion characteristics. Use of interferometry-based sensing to measure changes in position, length, distance and optical length is well demonstrated in recent past (Sommargren, 1987; Speckle 2010; Optical Metrology, 2010). Laser interferometry-based sensing and measurement system is capable of delivering sub nanometer accuracy when used for displacement measurement (Lee, Yoon, & Yoon, 2011; Minoshima, 2010; Schott, 2010; Schuldt et al., 2010; Shelley, 2007; Zeng & He, 2009; Zhou, Zhang, & Cheng, 2009). There has also been a number of research studies carried out on laser interferometry-based motion control for flexure-based mechanisms (Qi, Zhao, & Lin, 2007; Yeh, Ni, & Pan, 2005; Zhang & Menq, 2007) and it shows immense potential for further research.

Research proposed in this work is motivated by our previous efforts in the control of the flexure-based mechanism driven by piezoelectric actuators (Liaw, Shirinzadeh, & Smith, 2007, 2008b), as well as model-based control, and a robust motion tracking control (Liaw, Shirinzadeh, & Smith, 2008a). In model-based closed-loop control, we use supposed knowledge of system parameters to design the motion controller. The robust motion tracking control is employed in such a way that, it adapts the unknown system parameters, piezoelectric actuators nonlinearities, and external disturbances in the micro/nano manipulation system. In this study, the primary research objective is to track a specified motion trajectory using laser interferometry-based motion control. The secondary research objective is to validate experimental results for positioning accuracy and tracking performance with error analysis for capacitive position sensor and laser interferometry-based sensing and measurement technique.

The model of a piezo driven flexure-based micro/nano manipulator is described before presenting model-based and the robust motion tracking controller designs. Further, measurement error analysis and experimental study is detailed and results are presented and discussed ahead of conclusion.

MODEL OF FLEXURE-BASED MICRO/NANO MANIPULATOR

In our study the flexure-based manipulator mechanism is constructed by using flexure hinges. Therefore, the manipulator is monolithic structure, and hinges are assumed to be compliant in bending about one axis but rigid about the cross axes. The flexure hinge used is a notch-type hinge and the schematic of such hinge is shown in Figure 1.

The flexure hinge is simple in shape and operation and the design of four-bar flexure-based mechanism is detailed in our previous study (Liaw et al., 2008a). A lumped parameter dynamic model which combines the flexure-based mechanism and the piezoelectric actuator is formulated for the purpose of high-precision motion control. This is achieved by extending the model of a piezoelectric actuator, which is shown in Figure 2, and is described by Eq. (1),

Related Content