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A stiffness model for control and analysis of a MEMS hexapod nanopositioner

- Hongliang Shi[a],
- Hai-Jun Su[a, ,],
- Nicholas Dagalakis[b]

Abstract

This paper presents a stiffness-based kinematic model for analysis and control of a Micro-Electro-Mechanical Systems (MEMS) flexure-based hexapod nanopositioner that was previously built by the National Institute of Standards and Technology (NIST). This nanopositioner is capable of producing high-resolution motions in 6 degrees of freedom (DOF) by actuating three planar X–Y positioning stages. Given a large number of flexure-based nanopositioners, the modeling and controller design has been a challenging task due to their inherent structural complexity and difficulties in measuring 6DOF positioning accuracy. In this paper, we discuss kinematic models for developing an open loop controller and an analytical approach routine for this nanopositioner. These models include a novel model for calculating the nonlinear stiffness of the X–Y positioning stage and a stiffness-based Jacobian matrix of the hexapod mechanism for the controller. Compared with Finite Element (FE) simulations, we conclude that the mean error of the X–Y stage control model is 1.93 % within a 55 μm range of motion. To validate the control model, the top platform is commanded to trace a circle of diameter 20 μm. The result shows a mean error of 3.38 %.

Keywords

- Nanopositioner;
- Flexure mechanism;
- Hexapod platform;
- Stiffness;
- Control;
- Kinematic model