Accepted Manuscript

Motion type analysis of a piezoelectric-actuated vibratory micro-robot in hybrid stick-slip-jump mode

Hadi Jalili, Hassan Salarieh, Gholamreza Vossoughi

PII: S0022-460X(18)30574-1

DOI: 10.1016/j.jsv.2018.08.024

Reference: YJSVI 14315

To appear in: *Journal of Sound and Vibration*

Received Date: 5 October 2017

Revised Date: 23 August 2018

Accepted Date: 29 August 2018

Please cite this article as: H. Jalili, H. Salarieh, G. Vossoughi, Motion type analysis of a piezoelectric-actuated vibratory micro-robot in hybrid stick-slip-jump mode, *Journal of Sound and Vibration* (2018), doi: 10.1016/j.jsv.2018.08.024.

Motion Type Analysis of a Piezoelectric-actuated Vibratory Micro-robot in Hybrid Stick-Slip-Jump Mode

Hadi Jalili[1], Hassan Salarieh[2*], Gholamreza Vossoughi[3]

Department of mechanical engineering, Sharif University of Technology, Tehran, Iran
Email: [1]hadi.jalili.n@gmail.com, [2]salarieh@sharif.edu, [3]vossough@sharif.edu
* Corresponding Author, Tel: +98 21 6616 5538

Abstract

In this paper, the stick-slip-jump motion of a micro-robot with two perpendicular vibratory actuators is studied. A practical model of this micro-robot is designed and fabricated with two Langevin type piezoelectric actuators, which are driven by harmonic voltages. Depending on the amplitude and frequency of the driving voltages of the micro-robot actuators, as well as their phase difference, the type of the motion dynamics and the states of the contact points in the motion (slipping or jumping) are determined. Considering the conditions of the contact points of the micro-robot, the motion is based on the combination of the friction drive principle (stick-slip) and jumping phenomenon. A finite element model of the micro-robot is used to investigate the motion type of the micro-robot in the stick-slip-jump mode. Because there exist various states of motions in the stick-slip-jump mode, the exact analytical study is very complicated. Therefore, in this study, the type of motion (stick-slip-jump) and the condition for the start of the movement have been investigated and determined by the FEM (Finite Element Method) analysis.

Keywords:

Micro-robot, Stick-slip-jump mode, Hybrid motion, Piezoelectric actuator, Finite element method (FEM).

1- Introduction

Micro-robots are suitable for applications in many areas because of their many advantages such as small size, low cost, and high precision. Most applications can be found in the fields of medicine [1], observation and surveying [2], and inspection and micromanipulation [3]. In general, it can be concluded from the literature that the term micro-robot refers to a robot that performs specific tasks at micro-scales such as MEMS (Micro Electromechanical systems) micro-robots [3-7] or a robot whose volume is up to several cubic centimeters [8-12].

Up to now, many micro-robots with different mechanisms have been introduced [13-15]. One important class of micro-robots is mobile micro-robots that use a variety of mechanisms for motion [8, 16-19]. Motion mechanisms of mobile micro-robots are classified on the basis of four principles of motion: walking, driving inertia (stick-slip), asymmetric frictional force, and worm-shape motion [15].

Motion mechanisms of most micro-robots are usually based on the friction drive principle that leads to stick-slip motion. This principle has two parts: the slip generation and the slip variation [3]. There are various devices to generate the slip and to vary the slip in each cycle, such as shape memory alloy actuators [12], piezoelectric actuators [9, 20], magnetic actuators [21], electrostatic actuators [4], thermal actuators [7], and rotary centripetal-force actuators [22]. The friction coefficient of the surface is very effective in this type of motion. Many studies have been conducted in this field by considering different friction models [23] such as the Coulomb dry friction model [24, 25], LuGre friction model [24, 26], and Dahl friction model [27]. In stick-slip mode, the micro-robot motion can be provided by the legs movement, but the moving legs are not needed in general [3, 24, 25, 28].