Journal of Information Systems and Communication
ISSN: 0976-8742 & E-ISSN: 0976-8750, Volume 3, Issue 1, 2012, pp.-179-181.
Available online at http://www.bioinfo.in/contents.php?id=45

SIMULATION OF SHAPED COMB DRIVE AS A STEPPED ACTUATOR WITH IMPROVED SLIPPAGE FOR MICROTWEEZERS APPLICATION

ANURAG SINGH[1] AND VIJAY KUMAR ANAND[2]

Ambala College of Engineering & Applied Research, Devsthali, Ambala Cantt- 133101, Haryana, India.
*Corresponding Author: Email- [1]just_sangwan@yahoo.com, [2]ervijay2222@gmail.com

Received: January 12, 2012; Accepted: February 15, 2012

Abstract- Finite element analysis is used to simulate electrostatic actuated, shaped comb drives operating under dc conditions (zero actuating frequency). A dynamic multiphysics model is developed using the arbitrary Lagrangian-Eulerian (ALE) formulation. The present work shows how the different shapes of the comb drives affect the displacement versus actuation voltage curve. A new jagged shape has been tried so as to improve the slippage existing with earlier shape and designs. Results show the coupled interaction between the electrostatic and mechanical domains of the transducer. The analysis is based on the evolution of electrostatic force versus comb finger engagement. The relationship between incremental lateral displacement and actuation voltage illustrates the potential for stepped movement for a shaped comb drive. In addition, through numerical simulations, this project determines an optimum design for a dc-actuated comb drive, which has controllable force output and stable engaging movement.
Keywords- Microtweezers, MEMS, Comb drive, FEM, ALE

Citation: Anurag Singh and Vijay Kumar Anand (2012) Simulation of Shaped Comb Drive as a Stepped Actuator with Improved Slippage for Microtweezers Application. Journal of Information Systems and Communication, ISSN: 0976-8742 & E-ISSN: 0976-8750, Volume 3, Issue 1, pp.- 179-181.

Introduction

Capacitance-based sensors and actuators have been extensively used in micro electromechanical systems (MEMS) devices [1,2]. Among different devices, the most commonly used and analysed is the comb drive [3]. The MEMS comb drive is a laterally driven mechanical actuator activated by electrostatic forces. The basic design of a comb drive relies on the theory of parallel-plate capacitors, which in turn is a function of the plates' area and shape. In the case of a comb drive, the parallel plates are an array of interdigitated fingers, which are generally rectangular. The device has a constant force-to-displacement relationship, which is a function of the change in capacitance with respect to engagement, rather than total capacitance. Rectangular comb drives have been used as actuators for several different applications, including micromotors, conveyors, sensing devices and microgripper devices.

Later, shaped comb drives were introduced as a means to tailor the rate of change of capacitance with respect to the lateral displacement. Designs presented in literatures [4,5] were used to stiffen and weaken resonator springs and hence offer more controllability over the device operation. These tunable *resonators* were introduced as a means to achieve more linear force-engagement profiles. The present work discusses a new move-and-lock mechanism based on a shaped comb drive design. The main use for such device is as a microtweezers actuator for application in areas such as biological sample handling, MEMS assembly processes and other activities where precision micromanipulation and force-controlled interaction are required.

Design Concept

This project introduces an adaptation to the jagged-shaped comb drive as shown in Fig 1, analysed in [6], in that the force-displacement is not linear, but it is also not constant, as in the case of rectangular comb drives. Instead, a stepwise continuous response of force versus displacement occurs.

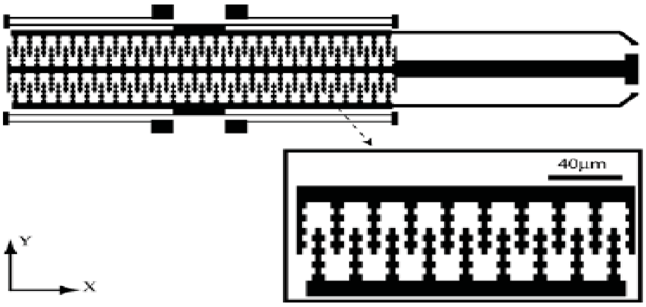

Fig. 1- Illustration of the design for the shaped comb drive as a Microtweezers actuator. The blow-up image shows a representation of a jagged-edge.

The move-and-lock mechanism is based on the change in the distance between the comb fingers with respect to engagement, which in turn is a function of the actuation voltage. Hence the structure behaves as a variable capacitor following the rate of change in ∂C/∂Y, as seen in equation (1).

$$F_{es} = \frac{\partial W_e}{\partial Y} = \frac{1}{2}\frac{\partial C}{\partial Y} V_o^2 \qquad (1)$$

The geometry simulated corresponded to a set of 10 fixed fingers and 9 movable fingers.. The designs had a few dimensions in common, namely the length of each finger, which was 60 μm long with notches at 5 μm intervals, and the structural thickness of 2 μm. The set of movable fingers start at a rest position corresponding to a 31μm engagement. The design of Fig. 2 has minimum 1μm, intermediate 7μm and maximum 13μm gap distances between fingers. This symmetric jagged comb drive design suffers with slippage problem. Now our new proposed shape (Fig 2) of comb drive is able to overcome the problem of slippage considerably. The gripping pads and final microtweezers testing are left for future work.

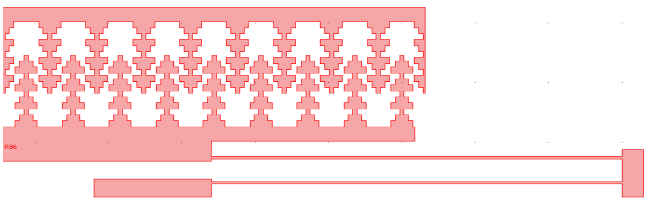

Fig. 2- Illustration of the proposed design for the shaped comb drive as a Microtweezers actuator

Numerical Modeling

The electrostatic problem discussed in this paper can be physically described by:

$$E = -\nabla V \qquad (2)$$

It follows that, since the comb drive is a capacitive device with air as the dielectric material, the region where the problem is defined is charge free (ρv=0). The electrostatic problem is then described by the Laplace equation (3) in rectangular coordinates.

$$\nabla^2 V = \frac{\partial^2 V}{\partial X^2} + \frac{\partial^2 V}{\partial Y^2} + \frac{\partial^2 V}{\partial Z^2} = 0 \qquad (3)$$

The objective of the FEM analysis is to find the potential distribution which satisfy equation (3) for a given electrode geometry at a predefined actuation potential Vo. The electrostatic force derived from the equation (1) serves as the load force for the mechanical displacement, according to equation(4).

$$F_{mech} = k\Delta Y \qquad (4)$$

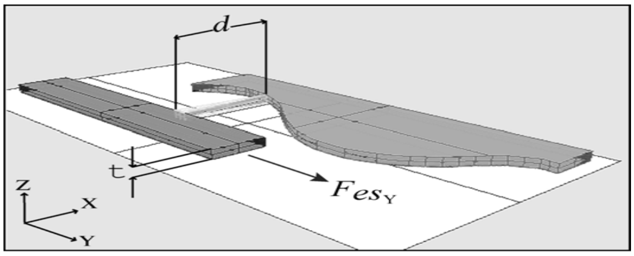

Fig. 3- Schematic description of the variable gap distance between a rectangular and an arbitrary shape comb finger.

The coupled electrostatic-mechanical problem is solved by a FEM parametric analysis, which uses the ALE formulation. All simulations were performed in the FEM software package COMSOL 3.5a using three multiphysics modes: *electrostatics*, *plane stress* and *moving mesh*.

Results

The solution shows a noticeable variation at the force gradient with respect to actuation voltage, shown in Fig. 4.

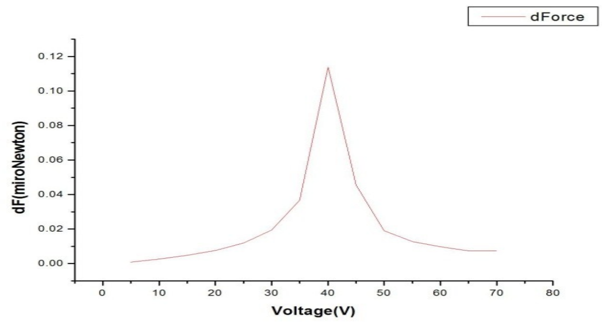

Fig. 4- Electrostatic force generated as a function of Actuation Voltage.

The jagged edge shaped produces a variable rate of change in force with respect to engagement. The first step in displacement occurs at about 30V (Fig. 5).

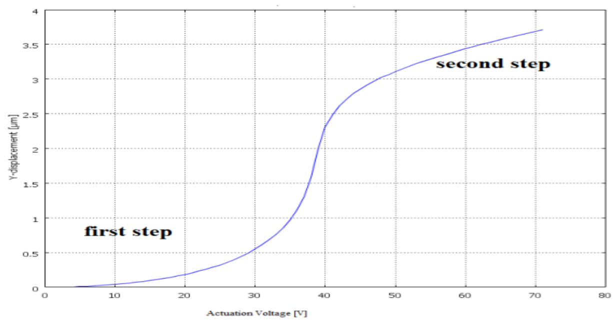

Fig. 5- Comb finger displacement as a function of Actuation Voltage.

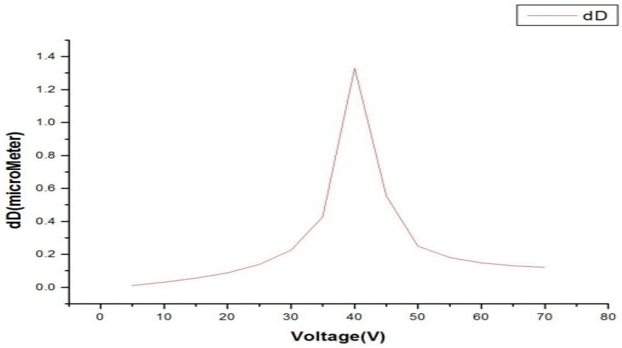

Fig. 6- Gradient displacement as a function of Actuation Voltage.

By observing the slope of the curve, it is possible to infer an increase in rate of change of displacement, which implies that the movable comb finger were in locking position before going into moving state. The displacement increases sharply as a function of increase in voltage after 30V (Fig 6). But after 50V the displacement rate decreases significantly as a function of voltage. Ideally, the structure should almost lock in place preventing any Y direction movement. The slippage obtained with this proposed geometry is less than the design proposed in literature [6].

Conclusions

Based on the results, the concept of step movement was illustrated. Regarding the numerical tools itself, the ALE formulation proved better suited for a multiphysics analysis than two independent electrostatic and mechanical investigations:. The use of ALE allows an investigation of the comb drive as a system instead of a composition of individual components. The slippage obtained with the design is significantly less but the maximum total displacement is limited to 4 μm.

Acknowledgements

The authors wish to acknowledge the Central Electronics Engineering Research Institute, Pilani, Rajasthan, India.

References

[1] Lu C., Lemkin M.A., Boser B.E. (1995) *IEEE J. Solid-State Circuits* 30, 1367-1373.
[2] Garcia E.J., Sniegowski J.J. (1995) *International Conference on Solid-State Sensors and Actuators, Stockholm, Sweden*, 365-368.
[3] Tang W.C., Nguyen T.C.H., Howe R.T. (1989) *Technical Digest IEEE Micro Electro Mechanical Systems Workshop,* 53-59.
[4] Jensen B.J., Mutlu S., Miller S., Kurubayashi K., Allen J.J. (2003) *J. Microelectromech. System* 12(3), 373-383.
[5] Ye W., Mukherjee S., MacDonald N.C. (1998) *J. Microelectromech. System* 7(1) 16-26.
[6] Isabelle P.F., Harouche C. Shafai, Richard Gordon (2006) *Design and simulation of a microtweezers using a controlled displacement comb drive*, 340-342.