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DESIGN AND SIMULATION OF MEMS BASED MICRO MOTORS

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ABSTRACT

Micro machined motors are recent development in electrical machines which offers higher torque at lower speeds. As compared to conventional electromagnetic motors, they are very compact in size and their components are in the ranges of micrometer (µm). Micro motors are of different types based on their speed and torque characteristics. Electromagnetic and electrostatic motors are bulky and weight due to the presence of gear box for rotary motion. It also provides low torque and low speed. On the other hand, piezoelectric motors have a number of advantages. They are small and compact provides greater force and torque. Piezoelectric micro motor can be further classified into impact drive, inchworm and ultrasonic micro motor. This paper focuses on the study of piezo inchworm motor which is based on the piezoelectric actuators to move a shaft with nanometer precision. The piezo inchworm micro motors are commonly used in biomedical applications such as scanning tunneling microscope and patch clamping of biological cells. COMSOL software is used to analysis and simulates the process.

Key words: Inchworm motor, Piezoelectric, COMSOL.

INTRODUCTION

Miniaturization of systems is required in aerospace, satellites, aircrafts, automobiles, marine and biomedical applications, where weight and size are important. We can integrate arrays of subsystems that manipulate or control on a small scale. These are micro-systems, and have been possible because of inventions such as microelectronics; VLSI (Very Large Scale Integration) and MEMS (Micro Electro Mechanical System).MEMS are 3D structures, involving mechanical moving components and electronic materials. They are economical, consume less power, and are faster, reliable and accurate. They enable complex and versatile functions. A lot of effort has been spent over the last decade in the field of MEMS. One of

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the major fields of applications is the micro motors where it is aimed to reduce their dimensions. They find applications in micro robot, lens focusing systems in cameras, in surveillance camera platforms, in biomedical and aerospace engineering. In these applications, the important requirements of motor are high torque at low speeds, self-locking, low rotor inertia, quiet operation and light weight.

Nima Ghalichechian et al. (2008) classified the Design, fabrication and characterization of a rotary micro motor supported on micro ball bearings. Journal of micro electromechanical systems, vol.17,no 3,june 2008.

Parul parag patel et al. published a paper in Design and simulation of a Piezoelectric ultrasonic micro motor. M.S. Ramaiah Institute of technology, Bangalore.

Pranay kanti podder, Dhiman Mallick, Dip Prakash Samajdar and Anirban Bhattacharyya in Design, simulation and study of MEMS based Micro-needles and Micro pump for Biomedical applications. Journal of academia.edu/3467511.

Shaun P. Salisbury et al. (2004) presented a paper on the design considerations for complementary inchworm actuators.

Edward Williams et al. (2014) performed the design and analysis of a large force piezo electric inch worm motor with novel force duplicator.

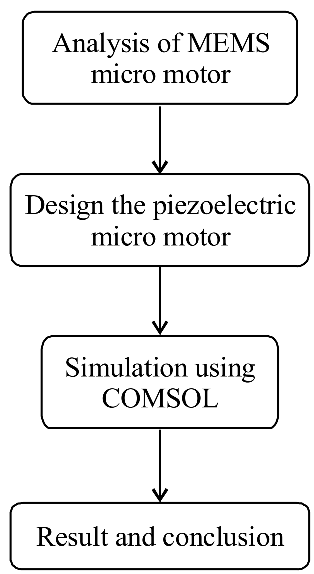

Fig. 1: Flowchart of micro motor process

EXPERIMENTAL

The working and design is given below:

A. Working of Piezo electric inchworm micro motor

A piezoelectric micro motor uses inverse piezoelectric effect i.e. when an electric voltage is applied to a piezoelectric material, it deforms mechanically. These motors basically have two parts – a stator and a rotor. Stator converts electrical energy of the piezoelectric element into oscillations, at one of its resonant frequencies, in the ultrasonic range. The inchworm motor uses three piezo actuators. The actual process of the inchworm motor is a six step cyclic process. The six step cyclic process is shown in Fig. 2.

Step 1: Clamp A is activated while clamp B is disengaged

Step 2: The extender extends

Step 3: Clamp B is activated. Both the clamps are now on

Step 4: Clamp A relaxes

Step 5: The extender relaxes/returns to its original shape.

Step 6: Clamp A is engaged.

Electrification of the piezo actuators is accomplished by applying a high bias voltage to the actuators in step according to the "Six Step" process described above. To move long distances the sequence of six steps is repeated many times in rapid succession.

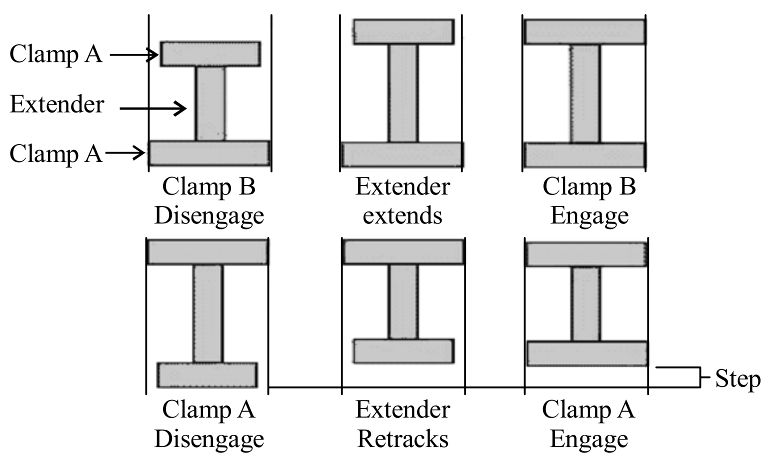

Fig. 2: Steps of Piezo inchworm motor

Once the motor has moved sufficiently close to the desired final position, the motor may be switched to an optional fine positioning mode. In this mode, the clutches receive constant voltage (one high and the other low), and the lateral piezo voltage is then adjusted to an intermediate value, under continuous feedback control, to obtain the desired final position

Design of Piezo electric inchworm micro motor

A piezo electric inchworm motor accumulates a number of small displacements to obtain large linear displacement without compromising on the force ability

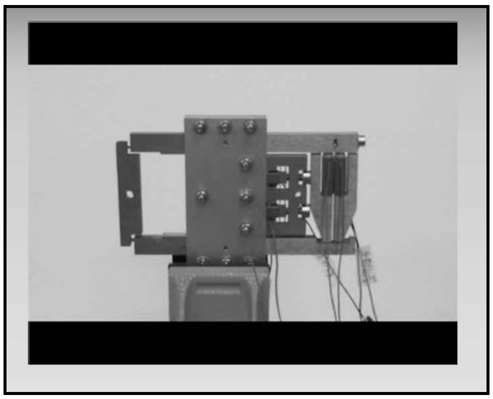

Fig. 3: Piezo inchworm motor

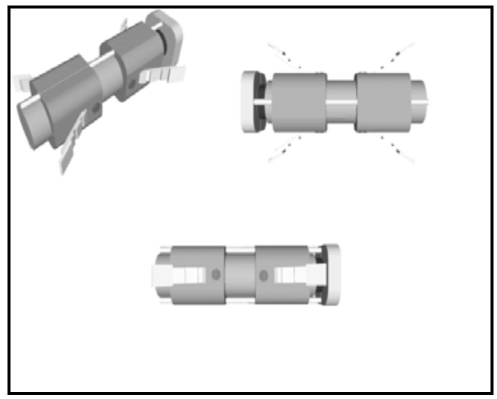

Fig. 4: Piezo inchworm motor

In conventional inchworm control, the clamp signals are sequenced with the extender signal such that the clamping clamp is completely engaged before the unclamping clamp begins to release

C. Piezo electric inchworm motor with application

The above sketch explains the miniature of an inchworm robot running with a single motor. It consists of four clamps which are working as actuators and the extender mechanism that produces a linear displacement

The dimensions of the robot is given below:

L = 4.5 cm   W = 2 cm

Modleing using comsol

The high force density and good dynamic properties of piezo electric material makes it an attractive technology for actuator applications

The 2D model of piezo inchworm micro motor were created by using COMSOL. In order to perform the structural analysis, we choose application modes > MEMS Module > Structural mechanism > Solid stress strain from model navigator

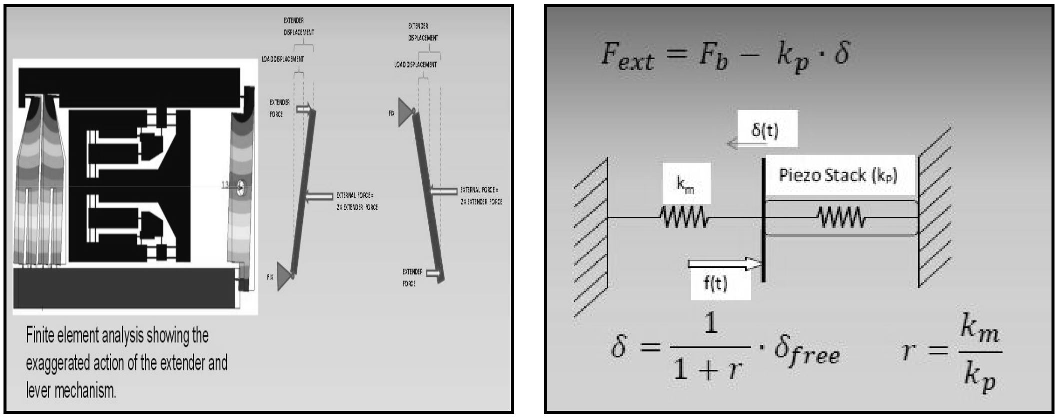

Fig. 5: Piezo electric behaviour

Blocked force	160.9 N
Free displacement	231 μm
Maximum stress (free displacement)	233 MPa
Maximum stress (blocked)	559 MPa
Stiffness in actuating direction	694.4 N/mm
Amplification (mechanical)	4.278

Piezo electric iwm behaviour

Piezo electrical IWM are well suited to applications requiring moving a relative large load accurately. An inchworm motor can hold a large load in position without consuming significant power. It is designed to hold a load in a power off mode i.e. fail to safety. An inchworm motor using a switch mode power supply can be used for energy scares application. A piezo inchworm motor accumulates a number of small displacements to obtain large linear displacement without compromising on the force ability

RESULTS AND DISCUSSION

By comparing the behavior of piezo electric material the inch worm motor was designed and tested with the load limit. The results are given below.

Results for the IWM with force duplicator.

Blocked force	103 N	
Free displacement	134 µm	144 µm
Stiffness of the extender	0.768 N/µm	0.711-0.763 N/µm
Stall load	51.2 N	30.5 N

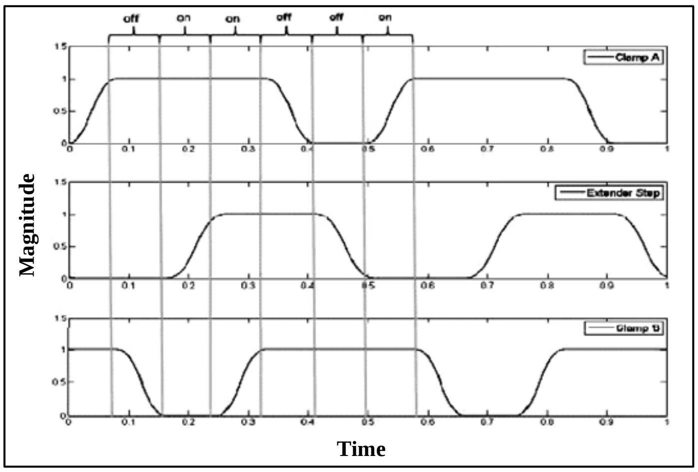

Fig. 6: Control signals

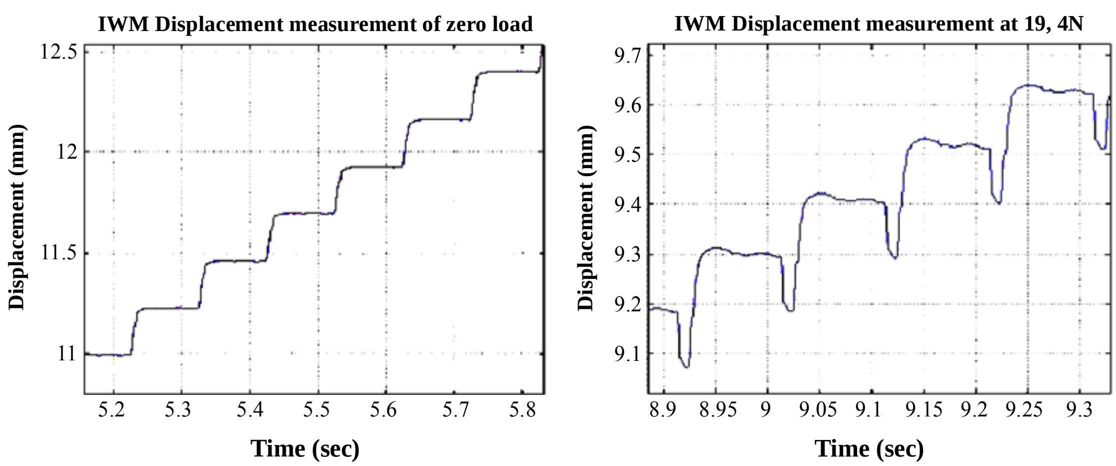

Fig. 7: Load limit of inch worm motor

CONCLUSION

In this research a new and novel embodiment for a piezoelectric IWM utilizing a beam mechanism has been designed built and tested. A simple method was derived to calculate the stall load of an IWM based on empirical observations. Experimental testing showed that this method gave adequate precisions of the stall limit for an IWM for both the conventional design and the IWM with the force duplicator. It was observed during testing that the load applied to a IWM reduces the displacement of the extender actuator used in the motor.

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