Simulation of Piezoelectric Actuator using ANSYS

Shahzadi Tayyaba, Nimra Tariq and Muhammad Waseem Ashraf

***Abstract* – Devices deal with electrical and mechanical components are known as microelectromechanical system (MEMS) and leads to microfluidics. Such devices have shown promising results over the last few years in automotive, robotics and medical fields. This paper confers piezoelectric actuator having polydimethylsiloxane (PDMS) membrane attached with piezoelectric disk. ANSYS has been used for simulation and analysis. The alternating voltage of 25 V-150V with frequency of 250 Hz has been applied on piezoelectric actuator. The performance of actuator quantities such deflection, stress were explored. This research paper compromises of useful data to develop the enhanced design of MEMS based piezoelectric actuator.**

***Index Terms* – ANSYS, MEMS, PDMS Membrane, Microfluidic, Piezoelectric disk..**

I. INTRODUCTION

Microfluidics devices have shown significant possibilities for improving diagnostics and biology research. Their dimension lies in micrometer or tens of micrometers range. The advancements of microfluidic technologies, such as prompt sample processing and the accurate fluid control have made them attractive to replace customary tentative methodologies. Microelectromechanical System (MEMS) are the micromechanical devices entrenched with electrical system or electronics that are fabricated with the help of integrated circuit manufacturing and micro-machining process where materials are shaped by engraving away micro layers. Silicon is the most popular material used for MEMS for its semiconductor, physical and commercial properties. Microelectromechanical System comprises of sensor, mechanical actuators, elements and common silicon substrate based electronic and electrical devices. The sensors in MEMS gather information from the surroundings through measurements of optical, mechanical, biological, thermal, chemical and magnetic phenomena. Information obtained from some decision making sensors is processed by the electronic devices to direct the actuators to respond by positioning, regulating, moving, sifting and pumping thus controlling the desired result or objective. The conversion of electric signal into an accurate physical displacement is done by piezoelectric actuators e.g. stroke. The minute control movement for piezoelectric actuators is provided to be used for finely adjustment of lenses, mirrors, machining tools or other equipment. Small-volume pump movement is controlled by piezoelectric actuators. Piezoelectric actuators are useful for controlling the hydraulic valves or special-purpose motors. There are two different types of piezo actuators defined as stack actuators and stripe actuators. When the piezoelectric material is imperiled to mechanical stress, it makes an electrical charge. From the past few years, piezoelectric sensors and actuators are in demand. In 1999, a researchers reported on space structures with rapid development and with high performance flexible mechanical system [1]. In 2001, it was reported that the acoustic flowing in micro fluid mixing and pumping had massive attractive features as compared to other techniques to actuate the fluid in micro channels [2]. The most inclinations in piezoelectric actuation, designs and fabrication were reported in 2000 [3]. Hua et al. 2002 reported that vigorous control elements for microfluidic uses are made by electrochemical actuation [4]. Qiu et al. 2003 reported the fabrication process of FG piezoelectric actuators and also the fabricated actuators [5]. Fu et al. 2005 reported on the fabrication and design of a piezoelectric polymer based unimorph cantilever actuator having an electroplated coating of a nickel composite [6]. Jang et al. 2006 reported that a stand-alone micropump system emanates from driving circuits and a piezoelectric actuation includes a peristaltic micropump [7]. Ramanamurthy et al. 2007 reported that piezoelectric micro valve was useful for automated drug delivery or control of fluids in micro reactor system with dimensions of 19 mm x 19 mm x 7mm, an inlet diameter of 200 μm, a dead volume of 0.33μl and steady-state-flow-rate of about 240 cm [8]. Lerch, 2007 reported a technique for the examination of piezoelectric means based on limited constituent designs where the essential electro elastic equations leading piezoelectric means were explained arithmetically [9]. Maess et al. 2007 reported on piezoelectric tube actuators with extended modeling approach with the combination of finite element analysis (FEA) and model order lessening (MOR) techniques [10]. Ronkanen reported high voltage amplifier needed for the control of piezoelectricity and piezoelectric actuator [11]. Zeng et al. 2009 reported that inkjet scheme centered on piezoelectricity was principally compelled by the requirement for improved filling thickness and jetting enactment [12]. Chen et al. 2010 reported on piezoelectricity actuated chip having low-voltage of less than 10 Vp-p and low-power of less than 0.1 mW [13]. Johari et al. 2011 reported the piezoelectrically actuated valve less micropump *(*PAVM). PAVM used PZT Pb(ZrTi)O*x* ceramic plate curves when a voltage was applied to the piezoelectric actuator [14]. Ashraf et al. 2012 reported on design, simulation and analysis of MEMS based piezoelectric actuator for microfluidic devices [15]. Rebeiz et al. 2013 worked on a scheme for a piezoelectric actuator in pumps [16]. Nguyen et al. 2013 reported on membrane actuators centered on epitaxial and buffer layers using silicon

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technology [17]. Lee et al. 2014 worked on the energy collecting enactment of a piezoelectric stack actuator and investigated a shock event theoretically [18]. Liu et al. 2015 reported molding and mechanism of piezoelectric inertia based friction actuators [19]. Choi et al. 2016 wrote a book on piezoelectric actuators applications and working [20]. Gao et al. 2017 reported working advancements on piezoelectric actuator by using $BaTiO_3$ ceramics actuator [21]. Gorissen et al. 2017 studied elastic actuators for robotic applications [22]. Cheng et al. 2017 worked on low-price, microfluidic fluorescence-activated cell categorization based microchip integrated actuator [23]. Piezoelectric actuators array was reported for optimal voltage distribution [24]. Piezo electric actuator for large displacement about 50 µm was presented [25]. In recent years, extensive work on actuators has been reported based on applications and mechanical parameters like shape memory alloy and piezoelectric [26]. Here, authors have performed ANSYS based simulation of actuator for high flow rate of PZT micropump.

II. SIMULATION

The membrane design shape considered in simulation is rectangular and disk is square form. The simulation is performed by set element using ANSYS. For simulation, the dimensions of PDMS membrane are: Length = 2 cm, thickness = 0.25cm and width = 1 cm. Dimensions of piezoelectric disk are: Length = 1 cm, thickness = 0.25 cm and width = 1 cm. ANSYS software tool has been used in computational fluid dynamic analysis. The geometry of polymeric piezoelectric actuator is shown in Fig. 1a. After making 3D model, material properties of polymeric piezoelectric actuator has been defined and then meshing was executed as shown in Fig. 1b.

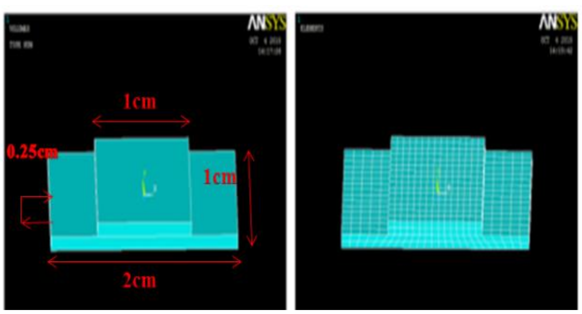


Fig. 1. (a) 3D view of PZT actuator (b) 3D view of PZT actuator mesh model

Then preliminary boundary conditions of 3D based actuator have been well-defined in ANSYS. The voltage 25V to 150V has been applied on polymeric piezoelectric actuator. Outcome of bending for 25V, 50V, 75V, 100V, 125V and 150V has been exposed in Fig. 2.

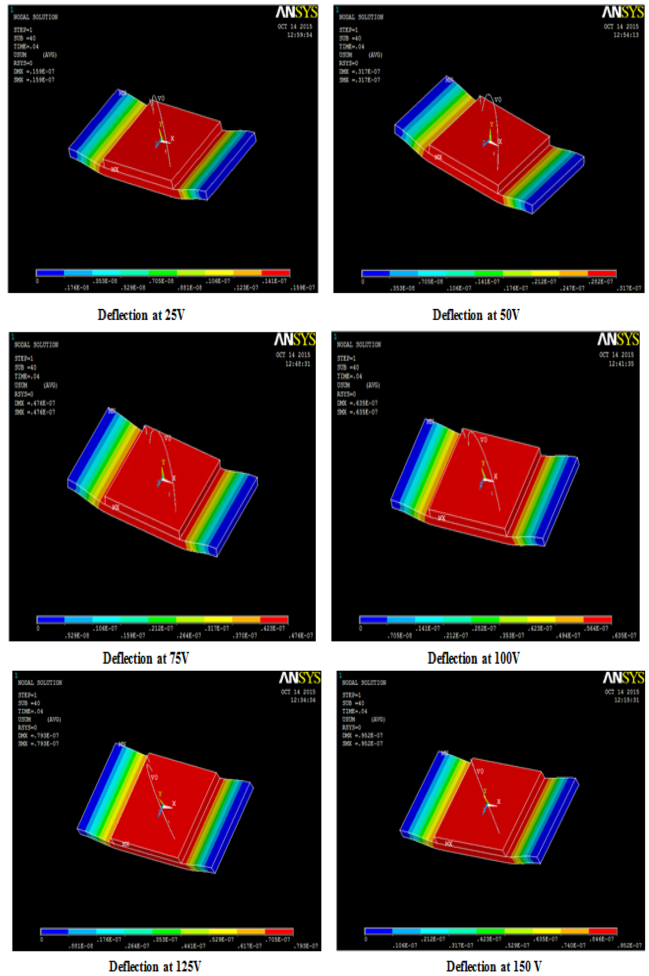
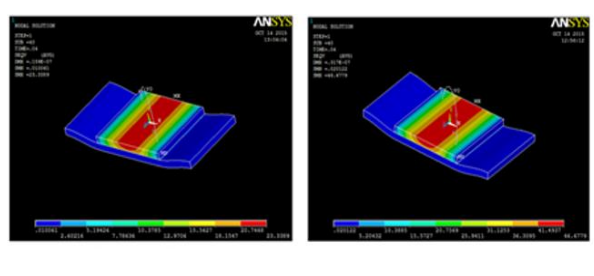


Fig. 2 Deflection at 25V, 50 V, 75 V , 100V , 125V , 150V

In piezo actuator, stress (T_r^P) is important factor and can be calculated by the standard equation [27].

$$T_r^P = -\frac{E d' V_0}{(1-\sigma)h} \quad (1)$$

Here, d is coupling coefficient of piezo element. The influence of stress on polymeric piezoelectric actuator has been calculated and shown in Fig. 3.



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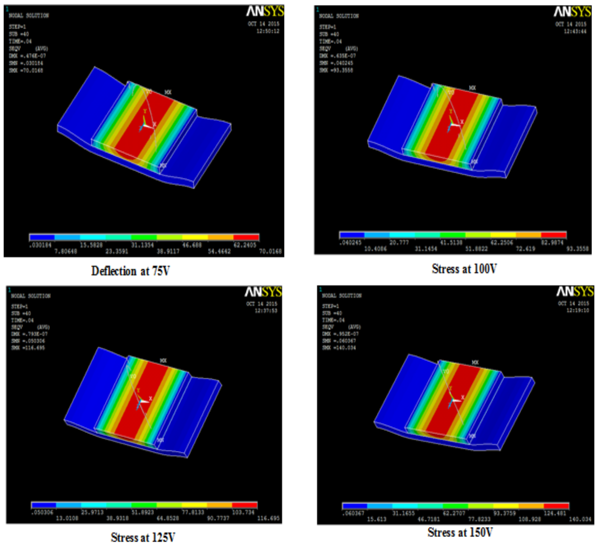

Fig. 3 Stress at 25V, 50V, 75V, 100V, 125V, 150V

III. RESULTS AND DISCUSSION

The PDMS membrane deformed at diverse location of membrane for functional voltages from 25V to 150V and frequency of 250 Hz. The variation is measured along the length of the membrane. The actuator with piezoelectric property has measurement in centimeter assortment for extraordinary high flow rate in micropump for use in particular applications. The PDMS membrane displacement increases due to the excitation voltage across the membrane. The effects of stress and deflection have been calculated through structural analysis. When applied voltage rises then deflection also rises as shown in Fig. 4.

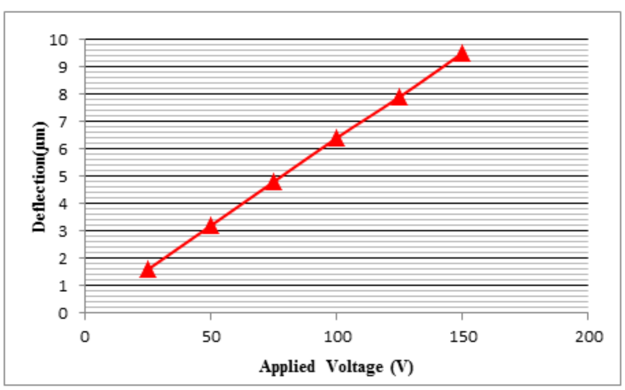

Fig. 4 Voltage Vs deflection

When applied voltage rises then stress also rises as shown in Fig.5.

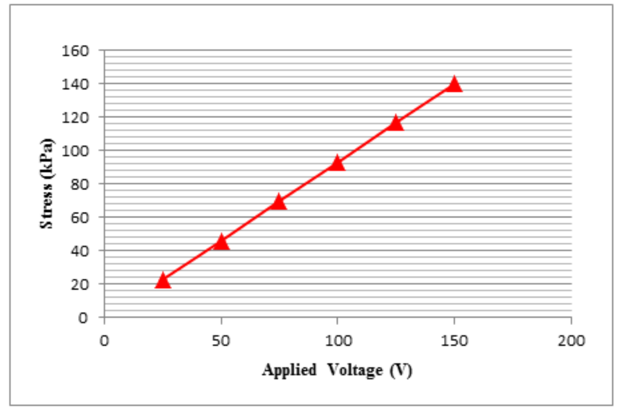

Fig. 5 Voltage Vs stress

The simulation plots show relationship of deflection, voltage and stress at voltage range of 25V to 150V with increment of 25 V. The material behavior was demonstrated with mechanical motion through simulation and detected that it was under elastic limits.

IV. CONCLUSION

Here, simulation has been performed for polymeric piezoelectric actuator. The structural analysis of polymeric piezoelectric actuator has been conducted in set element software ANSYS parametric design language. Stress and deflection deviations were evaluated at pragmatic voltage with given values of 25V to 150V. The simulation was carried at the incremental voltage of 25V. These incremental voltage values result into change in actuator outputs like bending that has direct impact on flow rate. The obtainable information offers suitable facts to progress the optimum design of piezoelectric actuator. The dimension of actuator is intended to be made in centimeter range rather than micrometer because when used in micropumps, it gives high flow rate.

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