iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VIII **Month of publication:** August 2020

DOI: https://doi.org/10.22214/ijraset.2020.31130

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VIII Aug 2020- Available at www.ijraset.com

Review of PZT Piezoelectric Valve

Ashok Kumar[1], Deepak Kumar[2]
[1, 2]*Department of ECE , OITM. hisar*

Abstract: ***In the world of electrically controlled pneumatic valves, solenoid valves are the absolute standard. Nevertheless, piezo valves offer many advantages over the prominent solenoid valves and open entirely new areas of application.***
Low energy consumption and no heat generation: Thanks to their capacitive principle, piezo valves require virtually no energy to maintain an active state. The valves do not generate heat Piezo technology is ideal for use in the "very-low-power" range of battery-powered devices. Piezoelectric valves made with piezo technology offer many advantages. They are small, lightweight, extremely precise, durable, fast, and save energy.
Keywords: PZT, Piezoelectric, Actuator, Valve.

I. INTRODUCTION

Piezo elements are electromechanical transducers. With the direct piezoelectric effect, a piezo element converts mechanical forces (pressure, tensile stress, or acceleration) into a measurable voltage. The inverse piezoelectric effect is precisely the opposite — a piezo element is deformed when a voltage is applied to it, thus generating mechanical motion or oscillations. Basic piezo elements can take the form of disc transducers, bender actuators, and piezo stacks. The bender actuator has a rectangular shape. Its primary element is a piece of piezo ceramic material that has been rendered conductive on both surfaces (Figure 3.1). This ceramic material is joined on one side to a conductive substrate. The conductive surfaces of the ceramic layer and the substrate function as electrodes. If a voltage is now applied to these electrodes, the ceramic material expands in the direction of the electric field. In most applications bender actuators are fixed at the front end, so this results in a bending motion at the free end. Bender actuators are available in multiple versions with different forces and actuator motion, and are well suited for use in pneumatic valves.

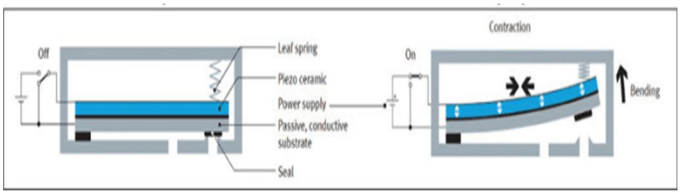


Figure 1: The function of the bender actuator in the piezo valve.

A disc transducer is also a very simple piezo element. It takes the form of a thin ceramic disc bonded to a metal substrate. To generate an electric field, the circular area on the surface of the disc must be metalized. If a voltage is now applied to this substrate and the electrode on the ceramic, the ceramic (as is also the case with the bender actuator) expands in the direction of the electric field and the disc becomes thicker, while at the same time its diameter becomes smaller. Together, the metallized area and the passive substrate act like a bimetallic strip and cause the overall system to bend in a spherical direction. This bending effect can be used in micropumps.
Stack transducers (piezo stacks) are stacked piezo discs that are connected in series mechanically and in parallel electrically. In contrast to disc transducers, operation is not triggered by the bending of a composite material but by direct expansion in the direction of the field. This configuration allows only short strokes — maximum 0.2% of the overall height — but with enormous actuating forces ranging up to several kilonewtons. Applications include liquid valves and micro positioning.

II. LITERATURE REVIEW

A. K. Srinivasa Rao et al. [2019] presented a work on "Design and optimization of MEMS based piezoelectric actuator for drug delivery systems". This article presents the piezoelectric principle based an actuator is design for a micropump, which is suitable for drug delivery systems. The natural frequency and stress analysis have been performed to determine the reliability of the device in terms of minimum safety factor. We have observed the uniform deflections of the actuators by varying the thicknesses of the piezoelectric layer of the actuator. The design of the actuators is considered in circular and rectangular geometry. The materials are selected appropriately such that the component is biocompatible and can be used in biomedical applications. Among the various considerations made on dimensions and geometry, it is observed that the circular piezoelectric actuator undergoes a high displacement of 2950 lm at an infinitesimal thickness of 0.1 lm. At minimum safety factor of one, the maximum stress and voltage the actuator can hold is 596 GPa and 8500 V respectively. [1]

©IJRASET: All Rights are Reserved

B. F.R. Munas et. al. [2018] presented a work on "Design and Simulation of MEMS Based Piezoresitive Pressure Sensor for Microfluidic Applications" This paper presents the design and simulation of MEMS based piezoresistive pressure sensor for microfluidic applications. Geometrical parameters are very much considerable when designing microstructure of the pressure sensor. Hence, an analysis is carried out by changing the dimensional parameters of three different diaphragm geometries namely square shaped diaphragm, circular shaped diaphragm and cross sectional beam shaped diaphragm respectively. This is performed in three dimensional mesh plots using Matlab. The Finite Element Method (FEM) analyses are performed in COMSOL and by comparing the results, the square type diaphragm is chosen as best diaphragm geometry for the microfluidic applications. In addition, modal analysis is carried out by using Ansys to identify the natural frequency of the best diaphragm geometry. Also Piezoresistive sensing elements are designed and simulated by performing coupled field analysis using COMSOL Multiphysics. Simulation results reveal that piezo resistive square type pressure sensors have high sensitivity in a wide range of pressures.[2]

C. Pawel Andrzej Lask [2017] presented a work on "Proportional valve with a piezoelectric actuator". In this paper, a slotted proportional valve for use in pneumatic and hydraulic systems. There is a growing demand for both hydraulic and pneumatic ultrafast proportional valves. The conducted analysis of literature confirms the lack of such solutions for proportional valves. The currently used pneumatic systems for selection and segregation of parts and objects require ultrafast valves. The presented solution for the proportional valve can significantly improve and accelerate this type of technological processes. Furthermore, fast proportional valves can be successfully used for positional control of pneumatic and hydraulic drives. The article presents the design of a slotted divide valve and sets the maximum mass flow rate for service roads.[3]

D. Juan J. Rojas et al. [2015] carried out a research on "Design and Simulation of A Piezoelectric Actuated Valveless Micropump". In this work, we design and simulate a valve less, diaphragm-based, piezoelectric micro pump. The piezoelectric actuator is a PZT-5H piezo-disk, the diaphragm is a borosilicate glass plate. All the simulations were made using COMSOL Multiphysics software. First, the piezoelectric actuator and membrane thicknesses were chosen by means of a stationary simulation, using the piezoelectric devices module we simulate the deformation of the membrane under different voltages, using different combinations of membrane and piezo actuator thicknesses. From the obtained results we decided to use a 100 µm membrane and a 50 µm piezo actuator. Using this geometry we build a simplified symmetric 3D model to be used in the pump simulation. A complete system simulation with one way coupling between the piezoelectric devices module and the fluid structure interaction module was made. It is considered to have no backpressure. The results obtained for inlet, outlet and net flow are showed in this document.[4]

E. Mohammadreza Kamali et al. [2014] presented a work on "Study on the Performance and Control of a Piezo-Actuated Nozzle-Flapper Valve with an Isothermal Chamber". This paper deals with A new integrated nozzle-flapper valve equipped with a piezoelectric actuator and an isothermal chamber has been developed and studied in detail. The designed single stacks valve controls the pressure and flow rate simply, effectively, and separately. This idea can easily be used in the pilot stacks of a two-stacks valve as well. Application of isothermal condition in the valve load chamber eliminates the dynamic malfunction that may persist from temperature variation within the valve load chamber; consequently, the governing equations for the prediction of pressure dynamics in the chamber are much more accurate and simpler. The valve has been equipped with a stacked type piezoelectric actuator which has a unique behaviour. Furthermore, stiffness, in the selected actuator, is enhanced against the thrust of the discharging flow from the nozzle, thus decreasing the complexity of dynamic equations of the valve. A detail mathematical model and simulation was developed to study the dynamic performance analysis of the proposed valve. An experimental test rig was built to validate the results of simulations. The unique features and performance of the proposed valve were studied thoroughly. The valve's governing equations are nonlinear in nature, and some variables of the equations are a source of some uncertainties; sliding mode approach was used to control the steady and unsteady pressure and output flow rate of the valve.[5]

F. Nayana.L et. al. [2015] presented paper on "Design and Simulation of Valveless Piezoelectric Micropump" In this paper some discrete parts of a valveless piezoelectric micropump for drug delivery system is designed and simulated. The core components of the micropump are actuator unit that converts the reciprocating movement of a diaphragm actuated by a piezoelectric actuator into a pumping effect and Nozzle/diffuser elements that are used to direct the flow from inlet to outlet. Simulations are performed for actuator unit and diffuser/nozzle element individually, using Comsol software. The simulation results show that displacement of PZT actuator is directly proportional to the applied electric field. Flow is greater at contraction and lower at expansion for the diffuser/nozzle elements.[6]

©IJRASET: All Rights are Reserved

G. Chulhee Han et. al. [2018] presented paper on "A Piezoelectric Actuator-Based Direct-Drive Valve for Fast Motion Control at High Operating Temperatures" In this paper experimentally investigates the control performances of a piezostack actuator direct-drive valve (PADDV) operating at high temperatures. In this study, the PADDV system is designed based on special specifications featuring a high operating temperature (150 °C) and wide control bandwidth (200 Hz). After manufacturing the PADDV with design limitations such as size and maximum input voltage to the piezostack actuator, the displacement of a spool located inside the valve system, which is directly related to the flow rate, is controlled at several different temperatures and motion frequencies. In order to undertake this, the PADDV ystem is installed inside a heat chamber equipped with air vessels and pneumatic–hydraulic cylinders. The piezoelectric actuator is partially insulated using an aerogel to prevent permanent damage due to high temperatures above 120 °C, which is higher than the Curie temperature. To control the valve system, a PID (proportional–integral–derivative) controller is realized in which control gains are properly tuned using fuzzy logic according to the change of temperature and frequency. It is shown from the experimental results that the proposed PADDV with thermal insulation can provide the target dynamic motion of 200 Hz at 150 °C by implementing the fuzzy-based PID controller.

H. Niyomwungeri Bruno et. al. [2019] presented paper on "Development of a piezoelectric high speed on/off valve and its application to pneumatic closed-loop position control system" In this paper the authors concluded that The use of smart materials-based high speed on/off valve has exhibited the potential to replace traditional servo and proportional valves in fluid power systems. In this paper, a novel pneumatic high speed on/off valve driven by a piezoelectric stack actuator is developed and its dynamics are studied. For an upstream gauge pressure of 0.5 MPa, the valve exhibited a large flow rate of up to 86 L/min. Furthermore, to study the ability of this novel high speed on/off valve to be applied in closed-loop control systems, a real-time position control system is realized using a PID controller. In order to prove its feasibility and effectiveness, a number of closed-loop trajectory tracking experiments are conducted on a pneumatic cylinder. The system is proved feasible and the results demonstrate good tracking performance.

I. M Griener et. al. [2017] presented paper on "Fast piezoelectric valve offering controlled gas injection in magnetically confined fusion plasmas for diagnostic and fuelling purposes" In this paper In magnetically confined fusion plasmas controlled gas injection is crucial for plasma fuelling as well as for various diagnostic applications such as active spectroscopy. We present a new, versatile system for the injection of collimated thermal gas beams into a vacuum chamber. This system consists of a gas pressure chamber, sealed by a custom made piezo valve towards a small capillary for gas injection. The setup can directly be placed inside of the vacuum chamber of fusion devices as it is small and immune against high magnetic fields. This enables gas injection close to the plasma periphery with high duty cycles and fast switch on/off times . 0.5 ms. In this work, we present the design details of this new injection system and a systematic characterization of the beam properties as well as the gas flowrates which can be accomplished. The thin and relatively short capillary yields a small divergence of the injected beam with a half opening angle of 20 deg. The gas box is designed for pre-fill pressures of 10 mbar up to 100 bar and makes a flowrate accessible from 1018 part/s up to 1023 part/s. It hence is a versatile system for both, diagnostic as well as fuelling applications. The implementation of this system in ASDEX Upgrade (AUG) will be described and its application for line ratio spectroscopy on helium will be demonstrated.

J. Nayana.L et. al. [2015] presented paper on "Design and Simulation of Valveless Piezoelectric Micropump" In this paper Pneumatic valves made with piezo technology offer many advantages. They are small, lightweight, extremely precise, durable, fast, and save energy. Piezo valves do not need energy to maintain a switching status, and therefore generate almost no heat. What's more, piezo valves can potentially be operated without any noise. Another key advantage is that they always work proportionally.

III. OPERATION OF PIEZO VALVES

Piezo elements in the shape of bender actuators are primarily used in pneumatic valves. The performance of piezo valves depends on the strength of the electric field — the greater the field strength, the better the performance of the actuator and the valve. Unlike solenoid valves, piezo valves do not need holding current to maintain a switching state. The piezo valves require a higher supply voltage than do solenoid valves, but that is significant only during the switch-on phase. Even then, the switch-on energy consumed is well below the actuation power levels normal in pneumatics

©IJRASET: All Rights are Reserved

IV. ADVANTAGES OF PIEZO VALVES

In the world of electrically controlled pneumatic valves, solenoid valves are the absolute standard. Nevertheless, piezo valves offer many advantages over the prominent solenoid valves and open entirely new areas of application.

Low energy consumption and no heat generation: Thanks to their capacitive principle, piezo valves require virtually no energy to maintain an active state. The valves do not generate heat if high-frequency control is not used (because that requires frequent switch-on energy). The energy balance increases along with the required switching frequency. Piezo technology is ideal for use in the "very-low-power" range of battery-powered devices.

1) *Intrinsic Safety:* "Intrinsic safety" is increasingly specified as the required degree of protection for environments with potentially explosive atmospheres. An electrical system is intrinsically safe if the greatest amount of energy it can store is not enough to cause ignition of the atmosphere in the event of a fault. Piezo valves are an ideal way of meeting this requirement, which makes them usable in many potential applications.
2) *Switching Speed:* Piezo valves can be incredibly fast, easily reaching the sub-microsecond range. These valves are often the best solution for applications where speed plays a decisive role. Such applications include high-speed sorting systems and closed-loop control circuits in general, as this type of circuit usually works better the faster the individual components react.
3) *Proportionality:* Proportionality is an intrinsic characteristic of piezo technology. Since ultimately all pneumatic processes in an application are analog, this is an unbeatable advantage — there is no need for pulse-width modulation and the associated noise problems as a means of trying to achieve a certain proportionality when switching solenoid valves. This means that piezo valves are very resistant to wear and need only minimal energy input. Combined with their short response times, the proportionality of piezo valves make them well suited to function as actuators for all higher-level control systems.
4) *Anti-Magnetic:* Piezo technology can also be used without any risk of failure in areas with a high magnetic field strength, such as in magnetic resonance tomography (MRT).
5) *Minimal Weight:* The fact that piezo valve housings are usually plastic (without iron and copper) make them very portable.
6) *Low costs:* This technology can be mass-produced if large quantities are required. For example, piezo-ignited lighters are available for very little money.
7) *Long Service Life:* When a system is designed correctly, piezo drives can achieve an unusually high number of operating cycles. They consist of a single solid-state working component with no wearing parts that might be subject to friction.

V. CONCLUSION

Piezoelectric valves must generate enough pressure, so that there should be no leakage and value should be intact, value should have good control and should have great control. Piezoelectric valves made with piezo technology offer many advantages. They are small, lightweight, extremely precise, durable, fast, and save energy. Piezo valves do not need energy to maintain a switching status, and therefore generate almost no heat. What's more, piezo valves can potentially be operated without any noise. Another key advantage is that they always work proportionally.

Piezo valves can be a better alternative to conventional solenoid valves, especially in applications requiring directly controlled proportional valves. They provide gentle and safe speed control for pneumatic cylinders, and work well in medical applications, laboratory automation, manufacturing, and even motor vehicles.

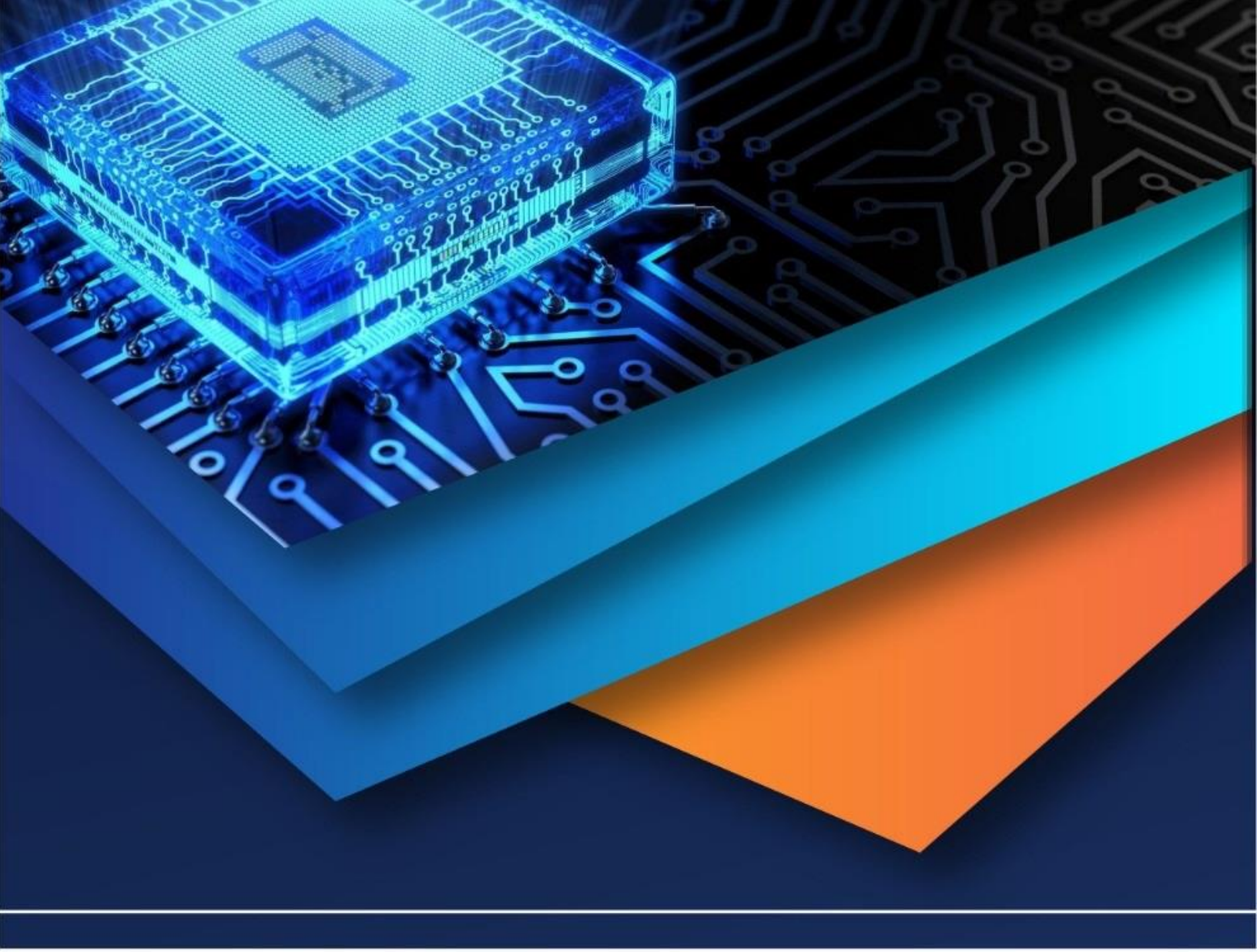
REFERENCES

[1] K. Srinivasa Ra, Md. Hamza, P. Ashok Kumar, K. Girija Sravani, "Design and optimization of MEMS based piezoelectric actuator for drug delivery systems", springer microsystem technology, 2019.
[2] F.R. Munas, Y.W.R. Amarasinghe, P. Kumarage, "Design and Simulation of MEMS Based Piezoresitive Pressure Sensor for Microfluidic Applications", IEEE, Moratuwa Engineering Research Conference (MERCon), 2018.
[3] Pawel Andrzej Laski, "Proportional valve with a piezoelectric actuator". EPJ Web of Conferences 143, 02064 (2017).
[4] Juan J. Rojas, Jose E. Morales, " Design and Simulation of A Piezoelectric Actuated Valveless Micropump", Excerpt from the Proceedings of the 2015 COMSOL Conference in Boston.
[5] Nayana.L, Dr. Premila Manohar and Supriya Babu, " Design and Simulation of Valveless Piezoelectric Micropump", Excerpt from the Proceedings of the 2015 COMSOL Conference in Pune.
[6] Pawel Andrzej Laski; "Proportional valve with a piezoelectric actuator", Journal of EDP Sciences, Vol. 21 No. 2, pp 304-309, Feb. 2017.
[7] Jiantao Wang, Xiaolong Zhao, Xiafei Chen and Haoren Yang "A Piezoelectric Resonance Pump Based on a Flexible Support" Journal of Micromachines 2019, 10, 169.
[8] Chulhee Han, Seung-Bok Choi, and Young-Min Han "A Piezoelectric Actuator-Based Direct-Drive Valve for Fast Motion Control at High Operating Temperatures"; Excerpt from the Proceedings of the COMSOL Conference, Boston, pp 317-322, 2010.
[9] G.K. Ananthasuresh, K.J. Vinoy, K.N. Bhat, S. Gopalakrishnan, V.K.Aatre; "Micro and Smart Systems" Wiley –India; First Edition, pp 115-129 2010.

©IJRASET: All Rights are Reserved

[10] J. Varona, E. Saenz, S. Fiscal- Woodhouse, A.A. amoui; " Design and Fabrication of a Novel Microgripper Based on Electrostatic Actuation" , 52nd IEEE International Midwest Symposium on Circuits and Systems, pp 827-832, Aug. 2009.
[11] Badariah Bais, Burhanuddin Yeop Majlis; "Low-g Area-changed MEMS Accelerometer using Bulk Silicon Technique" American Journal of Applied Sciences Vol.5, Issue 6, pp 626-632, 2008.
[12] Stephen A. Wilson a., Renaud P.J. Jourdain "New Materials for Micro-scale Sensors and Actuators: An Engineering Review" Materials Science and Engineering R: Reports, Vol. 56, Issue 6, pp 119–129 2007.
[13] W. Merlijn van Spengen, Erwin C. Heeres "A Method to Extract the Lateral and Normal Component of the Motion from the Capacitance Change of a Moving MEMS Comb Drive" Journal of Micromechanics and Microengineering, Vol. 17, No. 3, pp 447-451, 2007.

©IJRASET: All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)