INNOVATION AND APPLICATION OF PIEZOELECTRIC MATERIALS: A THEORETICAL APPROACH

Ashutosh Pandey [1], Shivam Shukla [2], Vishakha Shukla[3]

[1,2]*Mechanical Engineering, United Group of Institutions, Allahabad, (India)*

[3]*Electronics & Communication Engineering, United Group of Institutions, Allahabad, (India)*

ABSTRACT

The coming era of world has moved to an exceptional leading contest of innovations and inspiration. In this paper, an attempt has been made to propose the existence and need of piezoelectric materials in the day to day technology, in order to secure the outstanding wasted energy, which can be easily stored and can be utilized in some useful work. There is a lot of mechanical energy which is produced in millions of works ranging from snores of sleep to the vibrations of a jet or rocket. These vibrational energies can be easily transformed to another form and can be utilized further with the help of these piezoelectric materials. This paper contains some of the modes and methods of working field of piezoelectric materials.

Keywords :Piezoelectric, Ferroelectrics, Sonar, Pyroelectricity, Etymology

1. INTRODUCTION

Materials always have had a large influence on society. This was obvious in the Stone Age, Bronze Age, and Iron Age. We have named these eras by the most advanced material in that period, since these materials determine and limit the state of technology at the time. Also in modern society, the influence of materials is still present. However, nowadays the materials as such are not as visible anymore as they used to be. They are more and more embedded in complex devices and high-tech systems that make whole economies exist and function in an efficient way. Piezoelectric materials are among these 'invisible' materials that are widespread around us, although they are unknown to the public at large. Mobile phones, automotive electronics, medical technology, and industrial systems are only a few areas where piezoelectric components are indispensable. Echoes to capture the image of an unborn baby in a womb make use of piezoelectricity. Even in a parking sensor at the back of our car, piezoelectric material is present.

1.1 What Is Piezoelectric Material?

The word 'piezoelectricity' is derived from the Greek word piezien, which means to squeeze or press. Piezoelectric materials are those materials (notably crystals and certain ceramics) which have the ability to generate an electrical potential in response to applied mechanical stress. In other words using piezoelectric

materials mechanical energy can be converted into kinetic energy and vice-versa, and the phenomenon used in it is called piezoelectricity or piezoelectric effect.

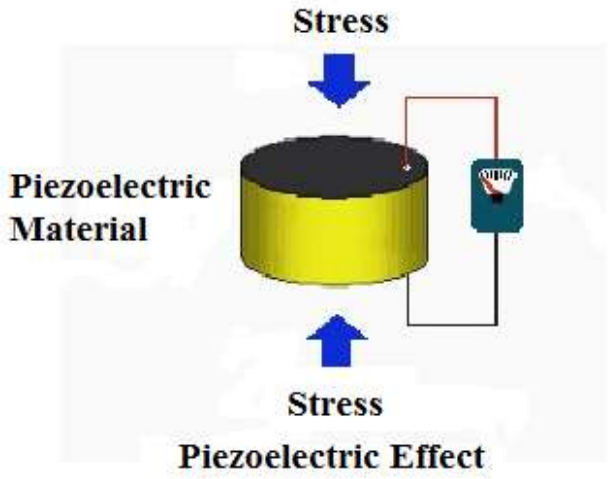

Fig. 1 Piezoelectric Effect

1.2 How Piezoelectric Materials Work

A piezoelectric material is made up of both positively and negatively charged particles arranged in such a way that all the positively and negatively charged particles are grouped about the same central point. If two opposite faces of a crystal are placed under pressure, the crystals can be slightly flattened and distorted and the charged particles moving up the crystals are pushed together and spread out sideways. The change is such that the average position of negative charge particles shifts slightly with respect to the same of positive charge particles. This means there is separation of positive and negative charges, which caused a potential difference between two faces crystal. The output voltage and power is directly proportional to the pressure applied. The output voltage is in mill volts and the output power is in microwatts. So for achieving bigger voltages crystals can be achieved in cascading manner.

By planting piezoelectric materials in place where vibrations are frequently placed, like, shoes, sidewalls, floors, mobile or laptop key boards, lathe and other machine tools, the power can be harvested and can be used in charging mobile phones, laptops etc.

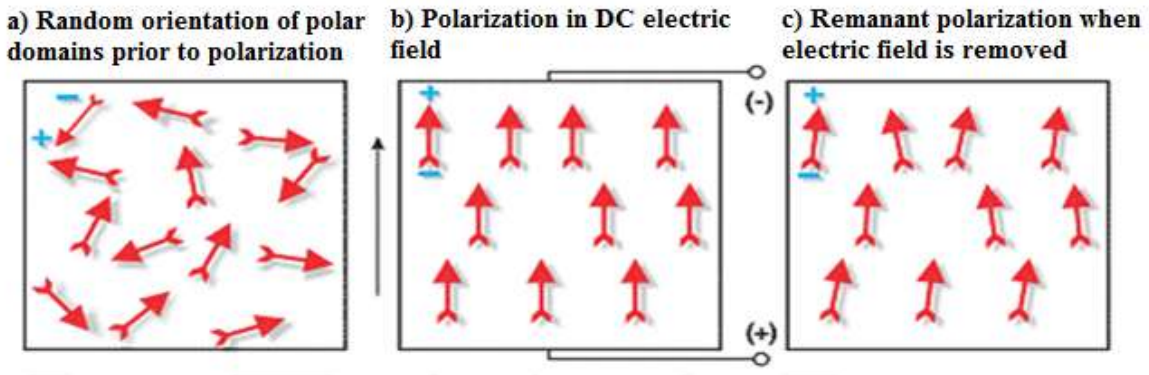

Fig. 2 Phenomenon of Piezoelectricity

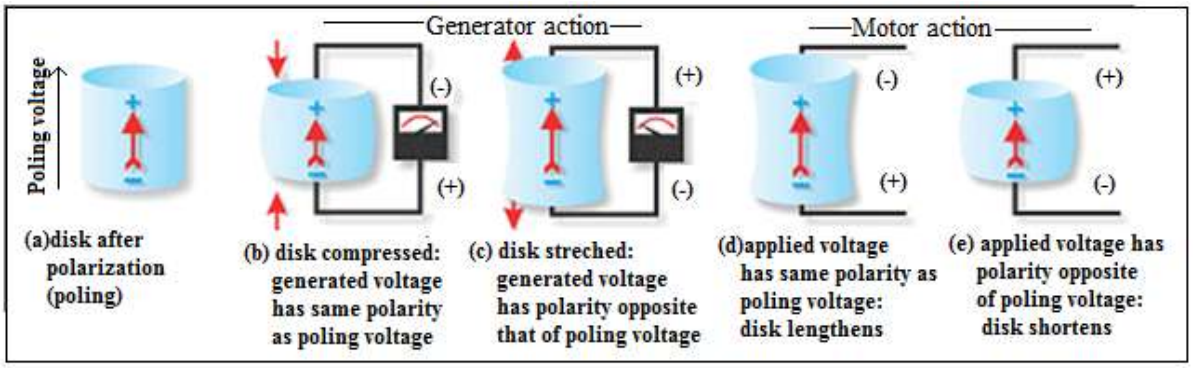

Fig. 3 Effect of Polarization

The material has the ability to convert mechanical energy into electric energy and vice versa.

The direct piezoelectric effect is when these materials are subjected to mechanical stress; generate an electric charge proportional to that stress.

The inverse piezoelectric effect is that these materials become strained when an electric fields applied, the strain again being proportional to the applied field. Clever use of piezoelectric materials enables the realization of a wide variety of technical functions.

1.3 Where Piezoelectric Materials Do Exist

Piezoelectric materials fall under the category of active materials which also includes magnetostructive materials, shape memory alloys, magneto neo logical and electro neo logical fluids and ionic polymers.

The major advantages of these materials are their compactness, lightweight, low power consumptions, case of integration into critical structural areas, case of activation through electrical signals, higher operating frequency and low cost. They are light weight robust inexpensive and come in variety of forms ranging from thin rectangular patches to complex shapes used in MEMS fabrication.

1.4 Practical Application And Scope

The phenomenon of materials that can convert mechanical energy into electric energy – and vice versa – carried out for several practical applications by means of discovering new piezoelectric materials and to develop new devices. In the present era piezoelectric materials has find its use in a vast range of applications as like mentioned:

(i) Conventional Machining.

Piezoelectric-materials are very suitable materials because of their:

a) High frequency band width (up to3 kHz range).

b) High dynamic stiffness (>100 N/µm).

c) Compact size and ability to produce high forces (>10 N).

Used in micro machining operations like diamond turning, ring type stack actuators 25mm Outer diameter, 20mm long and 2 high long width capacitance sensors were responsible for measuring the motion of total relative to arm and a base surface.

Machining sinusoidal grid surface used a piezoelectric tube actuator with a band width of several nanometres.

(ii) Ultrasonic Assisted Machining

In ultrasonic assisted machining- used as ultrasonic vibration generator to provide efficient vibration to the total assembly because they can easily convert high frequency electrical energy into mechanical vibrations.

(iii) Active and Passive Vibration Control

Among the several source of vibrations the suppuration chatter has been extensively investigated by many researchers. Chatters are self exited vibrations caused by modulation of cutting forces to change in uncut chip thickness. These vibrations are smaller in magnitude and higher in frequency than those typically found in other mechanical systems.

(iv) Wave Energy Converter through Piezoelectric Polymers

The capability of harvesting electrical energy from mechanical vibrations in a dynamic environment through piezoelectric transducers has been the topic of discussions for many years. Unused power exists in various forms such as vibrations, flowing water, wind, human motion and shock waves. Recent developments over global warming have renewed interest in the ocean energy conversion. The exploitation is heavily supported by the EU. Effective systems for high energy production are based, for example, on overtopping and oscillating water column systems. This note is part of a study that investigates alternative methods, and in particular a device that is based on the piezoelectric effect. Such effect has been mainly used in relation with low consumption systems like portable electronic devices such as mp3 players, mobile phones, GPS receivers or sensors of remote sensing systems or transmitters which are conventionally powered by batteries.

The advantage of a piezoelectric power supply is that it is ecological, embedded, and it does not need any maintenance. In this study we used piezoelectric polymers (PVDF) to convert ocean wave energy into electrical power. Due to viscous and fluid pressure exerted by the wave movement, the system is bending. The resulting undulating motion of the system resembles like the movement of a sea plant in the ocean ground. The capacity to sustain a high strain (3%) and to generate mill watts to many watts depending on the mechanical system makes piezoelectric polymer an interesting material in ocean energy and harvesting devices

II RECENT INNOVATIONS IN PIEZOELECTRIC MATERIALS

1. In piezoelectric inertia actuator acting as attuned vibrational observer to suppress chatter in tuning.
2. Force and torque sensors generally employ sensing that converts the applied force as torsional load into deformation of an element piezoelectric crystal has wider scope in this field.
3. Used in force transducers consist of the structure which deforms under the force, offer considerably high frequency response and long term stability.
4. In combined tool dynamometer to study the dynamic and static loading of tool. Strain gauge measures the static force and piezoelectric strips measure the dynamic force.
5. These days' magnetostructive devices are being more popular for measurement purpose. But it is for torque and force measurement in rotating shaft because there is no direct contact required to structure surface.
6. Piezoelectric sensors technology is particularly suitable for measuring acoustic emission, in machining process. For this a piezoelectric thin film sensor is deposited on a shim and located between cutting tool inserts and tool holder.

7. Used in vibration sensors of machining operations. The piezoelectric sensor are placed as close as possible to the cutting, e.g. on the shank, the tool post, the head stock or spindle.
8. In two piezoelectric force sensors rings in a direct driven motor spindle for online monitoring of machining.

III CONCLUSION

On the basis of available literature and research, piezoelectric materials can be suggested as a better replacement to traditional materials. Piezoelectric materials are that type of material which can create electricity when subjected to a mechanical stress. They will also work in reverse i.e., generating a strain by the application of an electric field.

The inherent advantage of these materials are their versatility in various fields such as in electrical, mechanical, marine, automobile engineering development and research organizations Apart from these the concept of piezoelectric material is also applicable in advancement of shape memory alloys, MEMS and NEMS devices etc.

REFERENCES

[1] Anil Kumar International Journal of Scientific & Engineering Research Volume 2, Issue 5, May-2011

[2] Alfredo Vazquez Carazo, Department of R&D Engineering, Face Electronics, LC 427 W. 35th Street, Norfolk, Virginia 23508, U.S.A

[3] Ghosh, T.; Kundu, T.; Karpur, P. Efficient use of Lamb modes for detecting defects in large plates. *Ultrasonic's* **1998**, *36*, 791-801.

[4]Cheng, J.Q.; Taheri, F. A smart single-lap adhesive joint integrated with partially distributed piezoelectric patches. *Int. J. Solids Struct.* **2006**, *43*, 1079-1092.

[5] Crawley, E.F.; Deluis, J. Use of piezoelectric actuators as elements of intelligent structures. *AIAA J.* 1987, *25*, 1373-1385.

[6] Ewang C. Choan, Energy Harvesting & Storage USA 7-8 November 2012 Washington DC, USA

[7] Amit Bhansaali, (university of Mumbai) piezoelectric energyharvesting: Developments, challenges, future.

[8] W.H. Liao and T.H.NG, Sensitivity Analysis and Energy Harvesting for a Self-Powered Piezoelectric Sensor, *Journal of Intelligent Material Systems and Structures*, **Vol. 16**, October 2005, Smart Structures Laboratory, University of Hong Kong.

[9] H. Sodano, D.J. Inman, G. Park, Comparison of Piezoelectric Energy Harvesting Devices for Recharging Batteries, *Journal of Intelligent Material Systems and Structures*, **Vol. 15**, 2005.

[10] Texas Instruments Incorp. Data Sheet UCC3975, UCC3976, UCC3977, Multi-topology piezoelectric transformer controller, SLUS499A, November 2001.

[11] T.Ninomiya, M.Shoyama, T.Zaitsu, T.Inoue, "Zero-Voltage Techniques and their Application to High-Frequency Converter with Piezoelectric Transformer," IEEE 1994

[12] S.Hamamura, T.Zaitsu, T.Ninomiya, M.Shoyama, *Noise Characteristics of Piezoelectric Transformer DC-DC Converter*, (IEEE PESC'98 Record, May 1998) pp. 1262-1267.