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Piezoelectric Pressure Sensor and Their Application – A Review

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Abstract: *The main aim of this review paper is to represent a general study performance of pressure, which describes the phenomenon of pressure measurement and its types. The basic types of pressure sensor and their technical advancements, limitations and significant is also discussed in this paper. Now a days the Piezo-electric Sensor are very convenient to detect the pressure distributions over surface of the material. The Piezoelectric Sensor is used to detect the vibration. In this study an attempt has been taken to discuss the various form of pressure sensors are used in the different application.*

Keywords: *Pressure measurement, Pressure sensor, Piezo-electric sensor, Pressure distribution and their application.*

I INTRODUCTION

Pressure is one of the most important physical parameter in our environment. Basically pressure is defined as the force divided by the area over which that force is

i.e – (1)

where and A is a applied force and area where the force is applied. This equation suggests target force equals larger pressure when area remains constant [8].

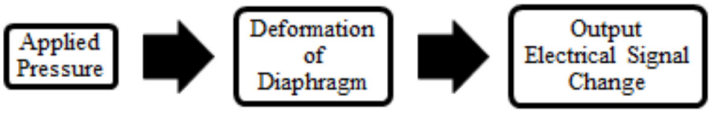

Fig 1: Basic operating principle of pressure sensor [6]

Pressure is significant parameters in such various disciplines as thermodynamics, aerodynamics, acoustic, fluid mechanics, solid mechanics and biophysics. The fluid physical properties of pressure is generally distinguish between two main categories: Gas and Liquid.

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The gas pressure is a pressure of a gas in a tank is the force exerted by gas on the walls of the tank per unit area. The equation of ideal gas:

T (2)

where, P is the Pressure, V is the Volume and T is the Temperature of the gas, n is the number of molecule and using K_B is the Boltzmann constant. The liquid pressure is total pressure of sum of the static pressure the pressure due to entered forces and dynamics pressure, by applying Bernoulli's theorem:

$$P_t = P_s + P_d = P_s = 1/2\ \rho v^2 \quad (3)$$

where, P_t is the Total pressure ,P_s and P_d is the Static and Dynamic pressure, V is the act at Local velocity, ρ is the liquid density[2]. Basically pressure sensor is an electronic device used to detect the various pressure of an element state. When the pressure is applied to the sensor, the elements inside the sensor, for example diaphragm will deform. The different physical characteristics of pressure are discussed. A brief look at the measurement types and various sensor models in the following sections of this paper.

II Measurement Types

One of the earliest methods of pressure instrument is liquid column instrument. It is based on the ability of a compressed medium to force liquid up a tube several type of liquid column instruments are as follows:

i) U tube manometer ii) Large bore mercury barometer iii) Fortin barometers iv) kew pattern barometer.

As number of quite different principles are utilized in pressure measuring instrument often the pressure may be deformation by measurement of the mechanics deformation of a sensing element that undergoes elastic deformation as the pressure difference across its surface changes. Such mechanical deformation may be sensed in a number of ways:

i) A series of mechanical levers to give a direct display of the deformation ii) Resisted measurement in a strain gages iii) Capacitance measurement iv) Change in frequency of a resonating element under tension or compression. When the pressure is very low and the mechanical deflection is therefore too small to be measured, indirect mean are used such as thermal conductivity ionization or viscosity that is dependent on the number of density of molecules [2].

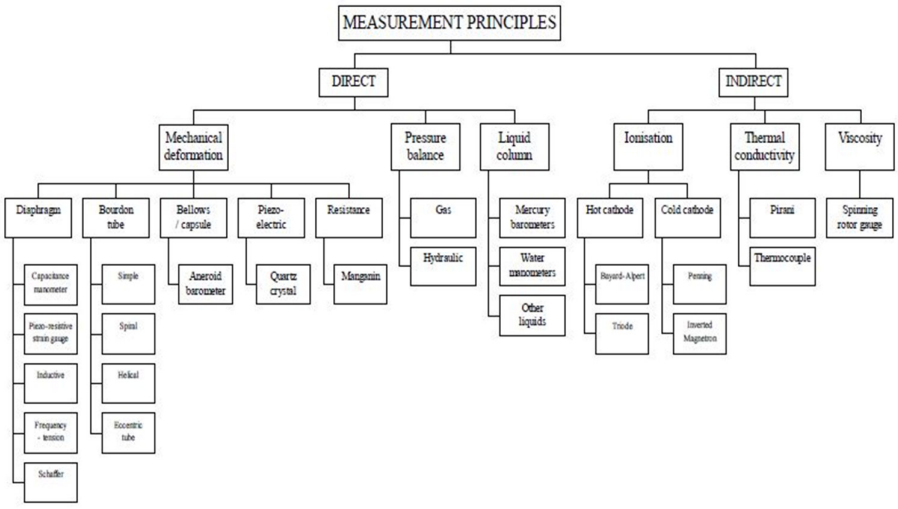

Fig 2: Measurement Principle types [2]

Different types of pressure measurement also included as follows: Absolute pressure measurement, Differential pressure measurement and Gauge pressure measurement. Those pressure measurements are used in all the industries and also robotics, either directly or indirectly control as a substitute for touch. The pressure measurement is explained briefly as follows: Absolute pressure measurement is measure the relative to perfect vacuum, this measurement used to barometric or altitude related pressure measurement. The absolute pressure measurement is also called perfect vacuum and its state that there is no element appears in this particular atmosphere

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[9]. Differential pressure measurement is measures static or dynamic or total pressure with reference to an unspecified variable pressure p2. In other words of differential pressure sensor measure the difference between these two pressures, there are applied pressure and reference pressure. In other type of pressure measurement is gauge pressure measurement its measure and senses the pressure with reference to the ambient atmospheric pressure[6][9].

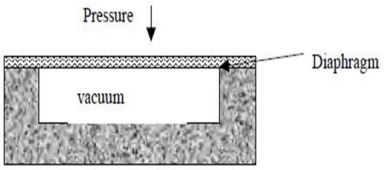

Fig 3:Absolute Pressure Sensor[6]

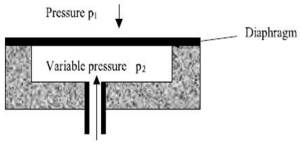

Fig 4:Differential Pressure Sensor[6]

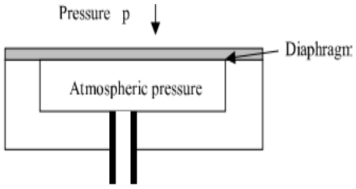

Fig 5:Gauge Pressure Sensor[6]

III Pressure Sensors

Based on the type of application pressure sensor can be categorized into many types with different application purpose. The following types of pressure sensors are mainly used. Strain gauge type, Capacitive pressure sensor, Immersible pressure sensor, Deformation pressure sensor, MEMS sensor, Resonant pressure sensor, Piezoresitive pressure sensor, Piezo electric pressure sensor etc. Strain gauge type sensor is similar to a wheat stone bridge in their working and this assembly is the ratio of resistances of two adjacent arms connected to one end of the battery should be equal to that of other two arms connected to another end of battery. In this case of strain gauge, one arm of the wheat stone bridge is connected to a diaphragm. The diaphragm changes the output in the bridge to vary. A voltage would be generated proportional to every deviation from the normal balanced condition, so every single compression or expansion movement of the diaphragm will produce an output indicating a change in pressure conditions. Since resistance change is the main cause for potential difference, these sensors area also termed as Piezo -resistive type of pressure sensors [11].

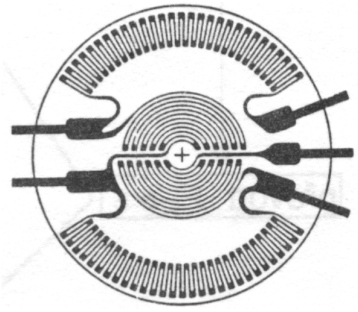

Fig 6:Strain Gauge[11]

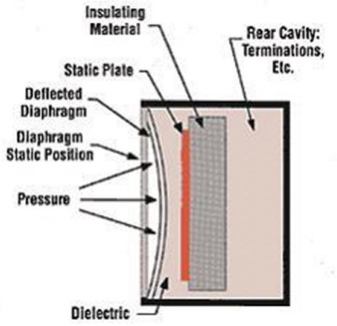

Fig 7: Capacitance type pressure sensor [11]

The capacitive pressure sensor consists of two metal plates and a dielectric sandwiched sensor them. In capacitive pressure sensor, one of the metal plates is permitted to move in and out. So this capacitance connected between them changes due to varying distance between the movable plates. This movable plate is connected to a diaphragm movement of the diaphragm would affect the attached metal plates position and capacitance would vary. These sensors are ineffective at high temperatures, are widely used at ambient temperatures range due to their linear output [10].

The micro-electromechanical system (MEMS) is a pressure sensor create micro-miniature electronic mechanical devices. It is sensing device that can detect and measure the external pressure and it can response to the measured pressure by having some mechanical movement. The material used to fabricated MEMS pressure sensor is a micro-sized [1].

Piezoresistive pressure sensor is used to detect the applied pressure and it will change in its resistance when it is submitted to the pressure. This pressure sensor is consists of an elastic diaphragm mounted with Piezoresitive sensor. When the pressure applied to the diaphragm it's deformed and the Piezoresitive element will change its resistance. This sensor is implemented together with Wheatstone bridge circuit to convert the change in resistance into the change in electrical potential. It is also provides some advantages [7].

Piezoelectric pressure sensor will detect the applied pressure by changing its electrical potential as the output of sensor. It is commonly used in smart structrual systems as both sensors and actuators. Piezoelectric materials as sensors since the mechanical deformation of the piezoelectric material can be detected by its electrical response. Piezoelectric crystals develop a potential difference (i.e. voltage is induced across the surfaces) whenever they are subjected to any mechanical pressure. These sensors have the crystal mounted on a

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dielectric base so that there is no current leakage. Attached to the crystal is a horizontal shaft to which a diaphragm is connected. Whenever the diaphragm senses pressure, it pushes the shaft down which pressurizes the crystal and voltage is produced [11]. When comparing with Piezoresitive pressure sensor, this type of pressure sensor provides only a change in electrical potential, not the change in electrical resistances. When an applied pressure is applied, the diaphragm of piezoelectric pressure sensor is deformed. Most commonly used piezoelectric pressure sensor is consists of metalized quartz or ceramic material as sensing element Piezoelectric sensor is investigated structural faults and very susceptible to shock and vibration [5].

IV Theory of Operation - Piezoelectric Pressure Sensor

The active element of an accelerometer is a piezoelectric material. Fig 8 illustrates the piezoelectric effect with the help of a compression disk. It looks like a capacitor with the piezoceramic material sandwiched between two electrodes. The force applied perpendicular to the disk which produces a charge production and a voltage at the electrodes. This principle is used in piezoelectric sensor. When a pressure is applied to the sensor, this will result in change in electrical potential. The sensing element of piezoelectric pressure se sensor is mostly made from Quartz Crystal element such as quartz or ceramics.The stronger crystal is stressed it will produce more positive charge will be generated. When the crystal is generated positive charge from the crystal results in a flow of electrical charge. That means an electrical potential is produced between the crystal and the base in the pressure sensor. This relationship between generated potential *V* and the charge Q

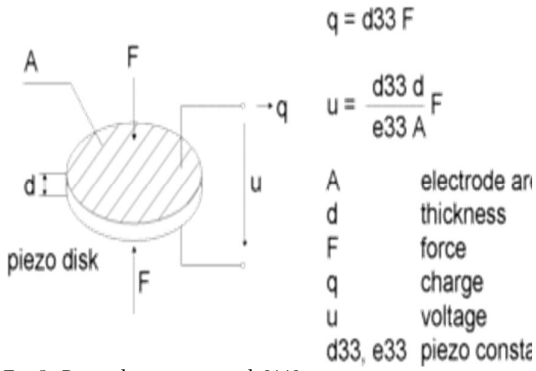

Fig 8: Piezoelectric principle[11]

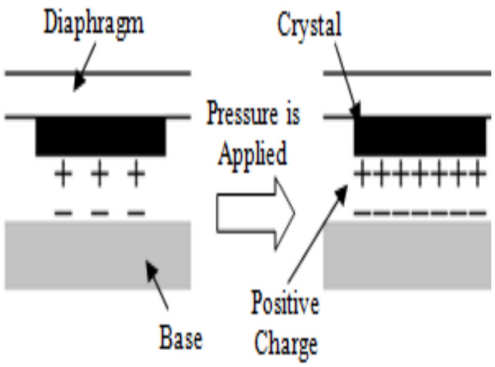

Fig 9:Piezoelectric Pressure Sensor[6]

$$V = \frac{Q}{C} \quad (4)$$

where C is the capacitance between the crystal and the base of piezoelectric pressure sensor. From(4) it can be said that the generated voltage is directly proportional to the generated charge from the crystal. When the applied pressure is increased, more charges is generated, therefore the generated voltage is also increased [6].

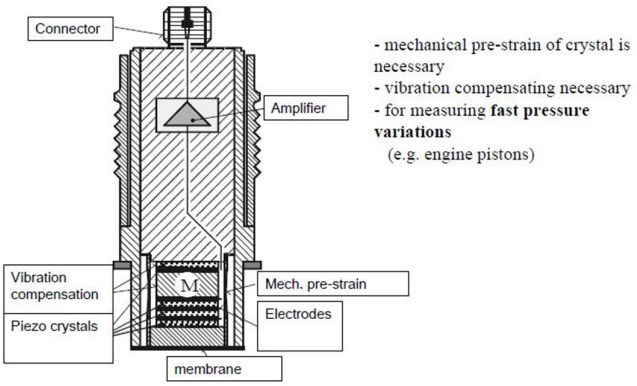

Fig 10: Construction of Piezoelectric

The piezoelectric pressure sensors are available in various shapes. It measure dynamic pressure on the materials. Dynamic pressure measurement including turbulence, blast, ballistics, and engine combustion require sensors with special capabilities. These capabilities include fast response and ruggedness, high stiffness, extended ranges and the ability to measure quasi static pressure. Now a days piezoelectric pressure sensor applied to the various application. In vibrating system is used in piezoelectric pressure sensor. The

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piezoelectric pressure sensor is detecting the dynamic pressure in all the material. The piezoelectric pressure sensor is used in Flow sensors and flow meters, Thickness gages, Level sensors, Diagnostic medical ultrasound, Accelerometers, Hydrophones, Microphones and Musical Pick-ups.

Conclusion

The Pressure sensor is an electronic device used to detect and measure the external pressure. Piezoelectric pressure sensor offers unique capabilities which are not found in other sensing technology. As discussed, there are certain merits and demerits depending on their particular application. It measure dynamic pressure on the mechanical material. In this paper the details of pressure sensor is discussed in detail.

References

1. A. Ghosh, S. Roy and C.K.Sarkar, "Design and Simulation of MEMS Based Piezoresitive Pressure Sensor for Enhanced Sensitivity", in IEEE international Conferences on Energy Efficient Technology for Sustaniability, pp.918-922.2013.
2. "Guide to the measurement of Pressure and Vacuum", Institute of Measurement and Controls.
3. "How to Measure Pressure with Pressure Sensor", National Instruments, (online). Available: http://www.ni.com/white-paper/3639/en.(Accessed:04 Dec 2014).
4. A.Migreon and A.E.Lenel," Modern Sensors Handbook", Chapter 1: Pressure Sensors, 2013.
5. V.Mohammadi, S. Torkian, E. Masumi, M.H.Sheikhi, A.Barzegar and S.Mohammadi,"Design, Modeling and Optimization of a Piezoelectric Pressure Sensor Based on Thin-Flim PZT Diaphragm Contain of Nanocrystgalline Powders", in IEEE Internaional Symposium on Mechatro ics and its Application, 2009.
6. Nurul Amziah Md Yunus, Izhal Abdul Halin, Nasri Sulaiman, Noor Faezah Ismail, "Valuation on MEMS Pressure Sensors and Device Application", International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol: 9, No: 8.2015.
7. P.K.Rathore and B.S Pawar," Design and Optimization of a CMOS MEMS Integrated Current Mirror Sensing Based MOSFET Embedded Pressure sensor", In IEEE international Conference on Control Application, pp.442-448, 2013.
8. S.Sathyanaratanan and A.V. Juliet, "Design and Simulation of Touch Mode MEMS Capacitive Pressure Sensor", in IEEE International Conference on Mechanical and Electrical Technology, pp. 180-183, 2010.
9. SMARTEC,"About Pressure Sensor", pp.1-7.The Netherlands.
10. M.Shahiri, B.A. Ganji and R.Sabbaghi,"Desgin and Simulation of High Sensitive Capacitive Pressure Sensor with Slotted Diaphragam ", in IEE International Conferences on Biomedical Engineering,pp.484-489,2012.
11. www.http://pressure sensor pdf

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