PIEZOELECTRIC MOTORS & IT'S APPLICATIONS

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Abstract - - *Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress. The word Piezoelectric is derived from the Greek piezein, which means to squeeze or press, and piezo, which is Greek for "push". One of the unique characteristics of the piezoelectric effect is that it is reversible, meaning that materials exhibiting the direct piezoelectric effect also exhibit the converse piezoelectric effect i.e. generation of stress when an electric field is applied. When piezoelectric material like Berlinite, cane sugar, quartz, Rochelle salt, topaz, tourmaline, is placed under mechanical stress, a shifting of the positive and negative charges. When reversed, an outer electrical field either stretches or compresses the piezoelectric material. Piezoelectric effect is very useful within many applications that involve the production and detection of sound, generation of high voltages, electronic frequency generation, microbalances, robotics, medical engineering, high power applications, sensors, piezoelectric motors ultra fine focusing of optical assemblies. It is also the basis of a number of scientific instrumental techniques with atomic resolution, such as scanning probe microscopes. Piezoelectric materials provided the perfect technology upon which Nanomotion developed our various lines of unique piezoelectric motors. Using piezoelectric technology, Nanomotion has designed various series of motors ranging in size from a single element (providing 0.4Kg of force) to an eight element motor (providing 3.2Kg of force). Nanomotion motors are capable of driving both linear and rotary stages, and have a wide dynamic range of speed, from several microns per second to 250mm/sec. The operating characteristics of Nanomotion's motors provide inherent braking and the ability to eliminate servo dither when in a static position. Piezoelectric Motors because having very high voltages correspond to only tiny changes in the width of the crystal, this crystal width can be manipulated with better-than-micrometer precision, making piezo crystals an important tool for positioning objects with extreme accuracy, making them perfect for use in motors, such as the various motor series offered by Nanomotion. Regarding piezoelectric motors, the piezoelectric element receives an electrical pulse, and then applies directional force to an opposing ceramic plate, causing it to move in the desired direction. Motion is generated when the piezoelectric element moves against a static platform.*

Key Words: ***Piezoelectric*** **effect,** ***Nanomotion, Piezoelectric motor,*** **ultrasonic motor, MICROMO***.*

1. INTRODUCTION Piezoelectric Motor is a world-leading developer and manufacturer of groundbreaking micro motors based on piezoelectric materials. Simple, extremely precise and very small, the motors replace traditional. Instrumentation & Control. The piezoelectric or ultrasonic motor was invented by Sadayuki Ueha and Minoru Kurosawa since 1988. It's maximum rotational speed and torque is 240 rpm and 25 m Nm respectively. Over the past decade, there are still many different forms of piezoelectric motors succession was invented, such as, a micro ultrasonic motor was invented by T. Kanda, A. Makino, K. Suzumori, T. Morita and M. K. Kurosawa, its maximum rotational speed is 3850 rpm, but its torque is only 2.5 n Nm. In the same year, K.T. Chau, T. Kanda, Suzuki, A. Kihara, Yoichi Ogahara successively invented different forms of piezoelectric motor. Wherein, the piezoelectric motor was invented by Yosuke Nakagawa its rotational speed is up to 800 rpm, and its torque is up to 0.25 Nm. in 2005 after more than 2000 rpm rotational speed of ultrasonic motors have been developed in succession. In particular, the micro ultrasonic motor was invented by A. Kobayashi and T. Kanda in 2007 and its rotational speed is up to 9600 rpm, and its torque is raised to 5.5 u Nm. In recent years, the new type piezoelectric motors or ultrasonic motors are constantly being innovative. For example, the 2011 year of invention, the multi-block piezoelectric car. Its main structure is a piezoelectric motor of H-shaped and multi-layered form. Its maximum rotational speed and loading is respectively 432 rpm and 496 gw under conditions of 180 V_{p-p} and 19 kHz. In addition, the 2012 year of invention, the H type piezoelectric car. Its main structure is a piezoelectric motor of H-shaped and single layered form. Its maximum rotational speed and loading is respectively 2031 rpm and 289 gw under conditions of 180 V_{p-p} and 22.9 kHz. Under the same driving voltage condition, its rotational speed is 4.7 times the former, while its loading ability is only 0.58 times the former. In the same year, a piezoelectric motor of high actuating force, its loading ability is up to 590 gw, but the maximum rotational speed is only 53 rmp under conditions of 180 V_{p-p} and 25.4 kHz. Until 2013, one kind of rod type ultrasonic motor, its loading ability can be increased to 4130 gw, and its rotational speed is up to 200 rmp under conditions of 180 $V_{p\text{-}p}$ and 33.7 kHz. The piezoelectric motors or ultrasonic motors each having characteristics or advantages.

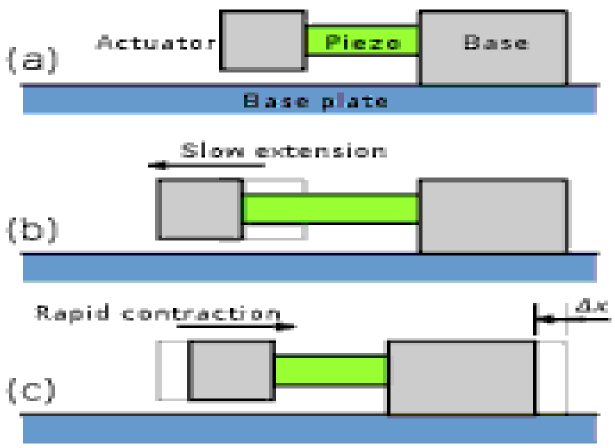

Fig- 1: Piezoelectric Effect.

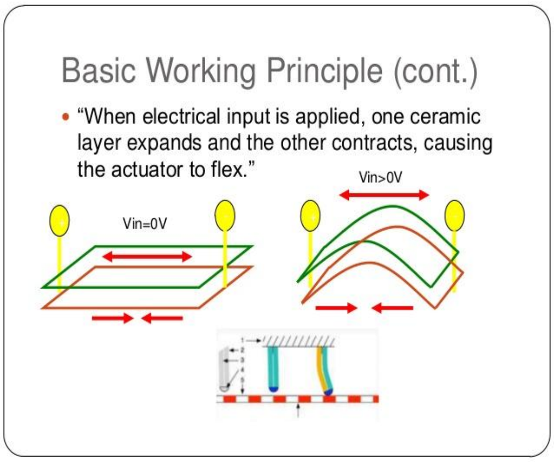

Fig- 2: working principle of Piezoelectric motor.

1.1 OPERATING PRINCIPLE

A piezoelectric motor, bases on utilization of the reverse piezoelectric effect for continuous conversion of electric power into mechanical energy of rotation of the rotor. The piezoelectric motor includes a rotor and a stator, The stator is an empty cylinder with a waist and tapered hole. In addition, the rotor is a kind of a hollow cone. It can be through the preload adjusting module to withstand the stator. As the preload adjusting module is set by the limit element, spring, washer and nut formed. While the shaft is a kind of cylinder with screw thread and stopper, when we provide appropriate driving voltage, frequency, loading and phase angle to the piezoelectric stator, the piezoelectric motor produces rapid rotation. We can also change through the driving phase angle, to change the direction of rotation of the piezoelectric motor. According to the experimental it can pass through the piezoelectric at least one of them incorporating a vibrator of mechanical oscillation, having a piezoelectric device connected to a voltage source and converting electric power into mechanical vibrations. The piezoelectric motor contains no windings and provides considerable driving torques, owing to the stator and rotor being urged against each other. The structure of the piezoelectric motor is determined by the arrangement of the piezoelectric device in the rotor and stator, the type of oscillation being excited, the shape of the piezoelectric device, the arrangement of its electrodes, their shape and electrical connection, as well as by the polarization of the piezoelectric material. Various combinations of these features offer a great variety of structures and designs of the piezoelectric motors, the piezoelectric motor being supplied from a voltage source with supersonic the piezoelectric motor's have rotational speed and loading ability.

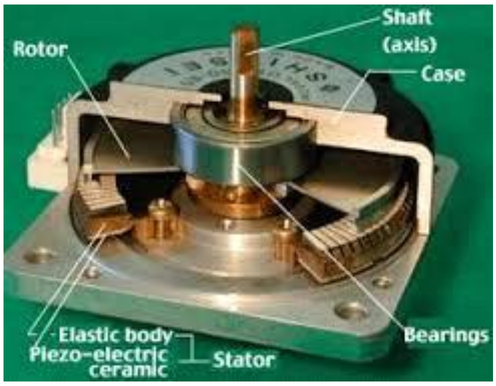

Fig- 3: Piezoelectric motor

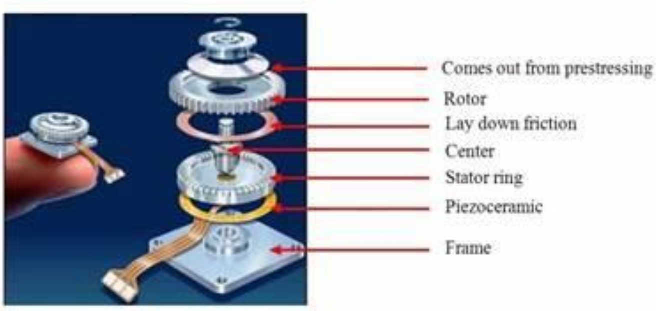

Fig- 4: Piezoelectric motor construction

1.2 TYPES OF PIEZOELECTRIC MOTORS

Piezo Motors are intrinsically vacuum compatible, non-magnetic and self locking at rest. Compared to classical piezo drives they are not limited in travel. The individual drive concepts are optimized for different applications, they differ in their design, size, cost, force & speed and other performance parameters, better intrinsic performance, energy efficient.

Linear Piezo Motors are resonant motors, Piezo Stepping Motors and Inertia Motors. Piezo Motors are intrinsically vacuum compatible, non-magnetic and self locking at rest. Compared to classical piezo drives they are not limited in travel. The individual drive concepts are optimized for different applications, they differ in their design, size, cost, force, speed and other performance parameters.

a) Ultrasonic resonant motors : are characterized by very high speed to 1000 mm/sec and a very compact and simple design (systems down to 8mm in length are available).
b) Linear motors : can achieve much higher forces and picometer range resolution but are more complex and not as fast.
c) Inertial piezo motors : are low cost and compact motors with forces to 10N and speed to 10 mm/sec.

Linear Actuators are also available. Traditional piezo mechanisms: provide short travel, high forces & sub-nm resolution. Electro-magnetic linear motors and air bearing stages are also available.

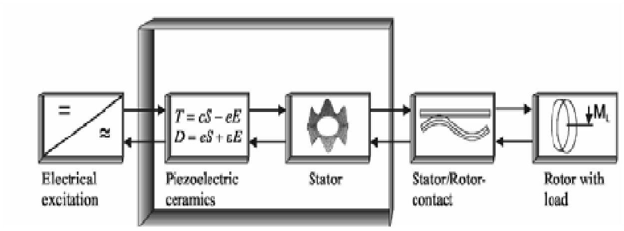

Fig- 5: Working of Piezoelectric motor.

2. ADVANTAGES OF PIEZOELECTRIC MOTORS

(Compared to conventional electromagnetic i.e. EM motors)

• Performance
1000 X's Better Resolution.
100 s Faster Reaction Time.
10 's Greater Torque/Force.
• Scalable Design
1 m O.D. to < 10 mm O.D.
Rotary and Linear Designs.
• Low Cost
Competitive pricing for most models.
• Unique Properties
No gear-head required.
Non-magnetic (options available).
Wide temperature tolerance.
• Low Voltage
V DC, miniature PCB design accommodates many application needs.
• Energy Efficient
Low Energy Requirements.
• Environmental
Ceramic Design Eliminates Ferrous or Copper Metals, High torque, exceptional resolution, fast reaction time, compactness, entirely non magnetic, piezoelectric motors can be used without gear drives & provide certain energy & environmental benefits.

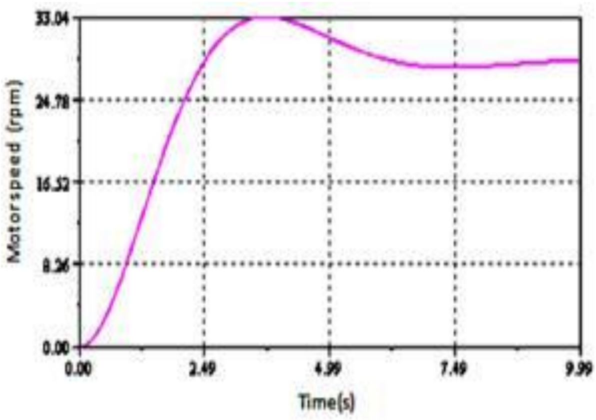

Chart -1: Piezoelectric motor speed without load.

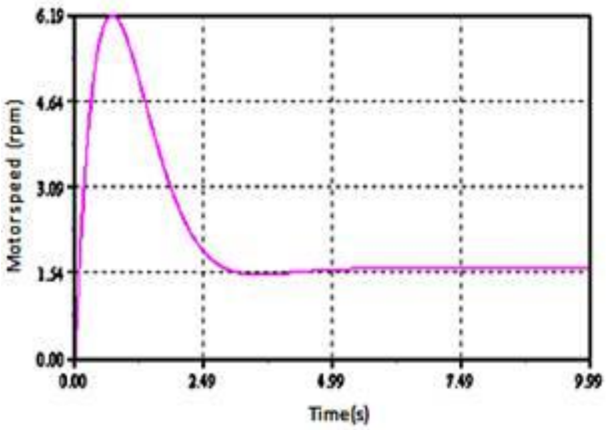

Chart -2: Motor speed as a function of time for a load of 3N.

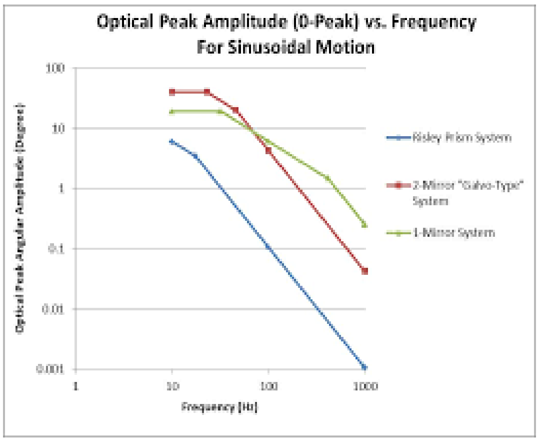

Chart -3: Amplitude vs. Frequency

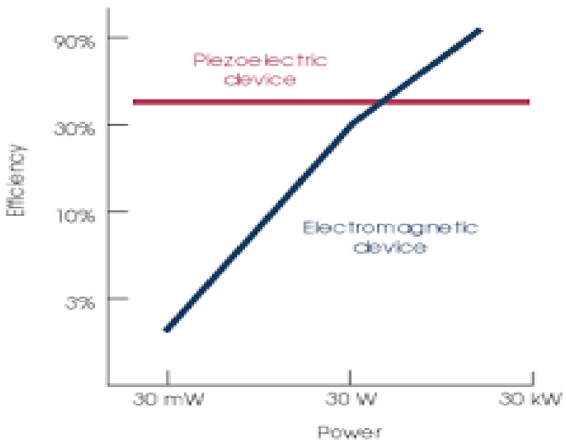

Chart -4: Efficiency vs. Power

3. DISADVANTAGES OF PIEZOELECTRIC MOTORS

1) Piezoelectric motor has inconsistent performance between similar motors, and individual motors. Actual motors tend to be loose, resulting in inefficient performance, inconsistent performance, and premature failure.

2) Piezoelectric motors often must be individually handmade. Thus, the manufacturing process is labor intensive and expensive. In addition, it is difficult to produce large quantities because each motor is handmade. Furthermore, it is difficult to control the manufacturing process.
3) Another disadvantage is tight tolerances are required. As stated above, actual motors tend to be loose, resulting in inefficient performance, inconsistent performance, and premature failure.
4) Another disadvantage is short life and high wear of the motors. For example, attachments between various components fail. In addition, contact points tend to wear quickly and unevenly.

4. APPLICATIONS

1) **Medical & Lab Automation Equipment**:

Medical robotics, drug delivery systems, surgical tools, prosthetics and pharmaceutical dispensing technologies

2) **Aerospace & Defense**:

From small, unmanned ground robots to satellites and rockets for space exploration, MICROMO offers the widest range of high performance, high precision micro motion technology.

3) **Robotic & Factory Automation**

Small coreless motors, brushless dc motors, and stepper motors often play important roles in many applications for robotics and industrial motion control.

4) **Optics & Photonics**

Whether it is an intermittent aperture, filter, lens or reflector adjustment in an optical system or a constant speed chopper or tape drive application engineers can help you select the right combination of components to meet your exact needs.

5) **Instrumentation & Control**

Accuracy and resolution in the micrometer range as well as exactly reproducible test procedures are required in modern measurement and testing technology.

6) **Micro positioning stages**

Manufacturing process control, Fiber-optic positioning Pick-and-place assembly, Camera autofocus, Medical catheter placement, Semiconductor test equipment, Computer disk drives, Robotic positioning, Pharmaceuticals handling underwater transducers, point level sensors, medical products, ultrasonic cleaners, actuators, fish finders, and motors.

5. CONCLUSION

Piezoelectric motors are versatile & useful motor for wide range of applications with low cost, high efficiency, low voltage, small size, low weight require low efficient energy, long life, high force, maintance & lubricants free, compact dimensions & can withstand any atmospheric conditions because of ceramic design. Also the tiny piezoelectric motors i.e. micro motors are very useful in medical fields for complicated surgery. As they offer significant advantages in precision motion control & flow control applications in industries, optics, telecommunications, semiconductors& nanotechnology, aerospace which makes this motor very useful in many fields.

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