PIEZOELECTRIC ULTRASONIC MOTOR AND ITS INTRO

NAYAN RAJU WASNIK

ABSTRACT: What is piezoelectric motor and the small introduction to the piezoelectric ultrasonic motor is given . Classification is given in the form of block diagram . Principle of operation and the historical background is explained with merits , demerits ,applications and necessary development .

INTRODUCTION:

Conventional electromagnetic motors were invented over 150 years ago. Through the years their designs have evolved to achieve greater efficiencies that dominate the electric motor industry today. However, one of the current limitations with small electromagnetic motors is their lower efficiency. This is especially true for electromagnetic motors smaller than one cubic centimeter Note that a wrist watch motor with a rotor diameter less than 1 mm φ still requires a relatively large (10 mm) coil for its activation, despite its low efficiency less than 1%. MEMS devices based on Silicon electrostatic actuation are too small in size with very small force, and do not endure against the component shaking/shock test.

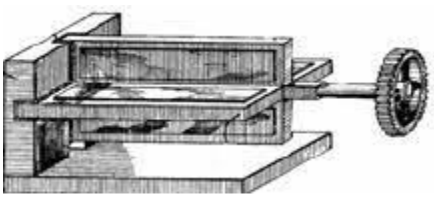
In office equipment such as printers and floppy disk drives, market research indicates that tiny motors smaller than 1 cm^3 would be in large demand over the next ten years. However, using the conventional electromagnetic motor structure, it is rather difficult to produce a motor with sufficient energy efficiency. Piezoelectric ultrasonic motors, whose efficiency is insensitive to size, are superior in the mm-size motor area.

In general, piezoelectric and electrostrictive actuators are classified into two categories, based on the type of driving voltage applied to the device and the nature of the strain induced by the voltage: (1) rigid displacement devices for which the strain is induced unidirectionally along an applied dc field, and (2) resonating displacement devices for which the alternating strain is excited by an ac field at the mechanical resonance frequency (ultrasonic motors).

The first category can be further divided into two types: servo displacement transducers (positioners) controlled by a feedback system through a positiondetection signal, and pulse-drive motors operated in a simple on/off switching mode, exemplified by dot-matrix printers. The AC resonant displacement is not directly proportional to the applied voltage, but is, instead, dependent on adjustment of the drive frequency. Although the positioning accuracy is not as high as that of the rigid displacement devices, very high speed motion due to the high frequency is an attractive feature of the ultrasonic motors. Servo displacement transducers, which use feedback voltage superimposed on the DC bias, are used as positioners for optical and precision machinery systems. In contrast, a pulse drive motor generates only on/off strains, suitable for the impact elements of dot-matrix or ink-jet printer.

PIEZOELECTRICAL MOTOR:

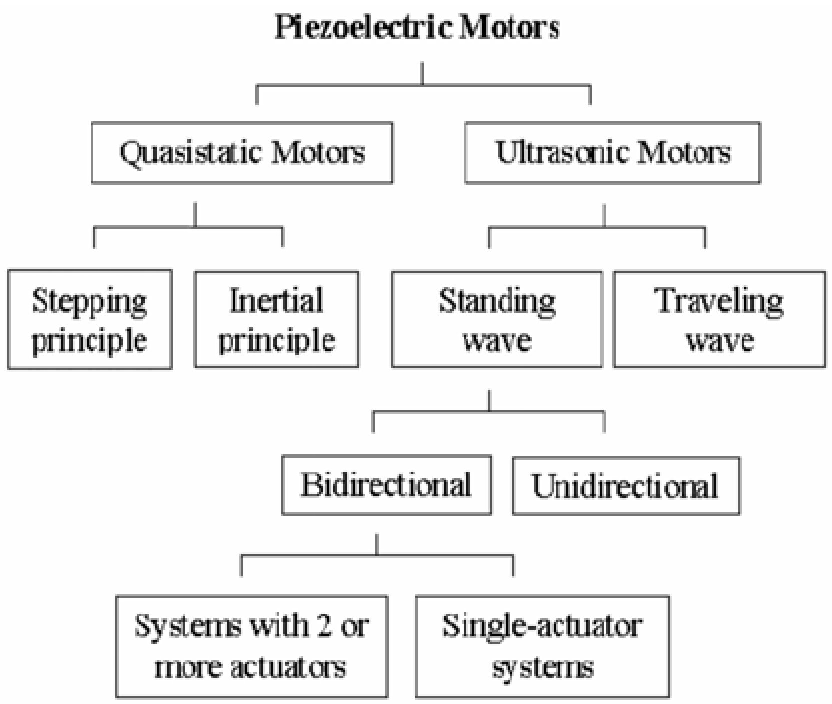
Piezoelectric actuators are electro-mechanical energy transducers ,they transform electrical energy into motion using the inverse piezoelectric effect .The travel range of the simple piezo actuator is very small ,being limited by the maximum possible deformation of the piezoceramic material .Piezoelectric motor are electro –mechanical drive system in which the limited displacement of the piezoceramic element is converted into the unlimited rotary or translatory motion of the rotor or the slider .The displacement of the piezoceramic in the desired direction of the motion is transferred to the rotor or slider over an intermittent frictional coupling



Piezoelectric Motor

Since from the origin many development has been seen in the field of piezo motors. They can be classified by working principal, geometry, or the type of oscillation excited in the piezoceramic.

Below figure shows a classification based on the mix of the possibilities , chosen from the pragmatic point of view.



PRINCIPLE OF OPERATION:

In contrast to the well-known electromagnetic motors (as well as to new designs with electrostatic motors), which base on forces in magnetic (or electric) fields, the piezoelectric effect products forces in conjunction with deformation of shape. Hence, the fixed and the moving part of a piezoelectric motor have to be in contact with each other while the force is acting. Thus, at the location where the force is transmitted to the moving part, the motion of the moving part is limited by the elastic properties of the motor. In order to produce a steady motion, the force-transmission can only be one part of a complete working cycle: during a second part of the cycle a retraction of the piezo electrically elongated part of the motor has to take place without (or with little) transmission of force.

In general, this is achieved by superimposing a second - at best orthogonal -cyclical deformation over the first one in such a manner that the contact pressure between fixed part and moving part is high during forward movement - thus allowing high forward forces to be transmitted - and low or even zero during retraction . This process can be called a mechanical rectification of motion.

In order to achieve a more or less continuous transmission of force to the moving part of the motor, several general solutions arc possible:

1) A single force-transmitting location can act with a very short cycle time (high frequency), such that the gaps in force transmission are overcome by the inertia of the moving part .
2) A multiple number of force-transmitting locations can be used during alternate phases of a complete operating cycle.
3) In the extreme case of II, the location of forcetransmission can vary continuously with time, thus producing a really continuous transmission of force.

High motor speed and motor power need large displacements during one cycle of operation and short cycle times. Large displacements can be achieved by use of mechanical resonances for the deformation modes. In this case the deformations become more or less sinusoidal. Both have to take place at the same frequency (in special cases an integer frequency ratio is possible), the phase shift of the two deformations being approximately 90" for maximum speed. Operating frequencies in the ultrasonic range are advantageous not only with respect to power output, but they are also necessary with respect to the noise emission of the motor. Thus resonant piezoelectric motors are often called ultrasonic motor.

HISTORICAL BACKGROUND:

The first patent concerning piezoelectric motors seems to be the US Patent of Williams and Brown from 1942. They proposed several ways to produce rotatory movements, using a multitude of piezoelectric bending elements. They already recognized the importance of using resonances for high drive speeds: the use of power line frequency as operating frequency was proposed. Ultrasonic operating frequencies were beyond the technological possibilities of that time.

In the seventies with the advent of high power piezoelectric ceramics new activities on piezoelectric motors started, concentrating first on motors using simple oscillators which move to and fro in an acute angle to a surface, thus driving the surface forward by frictional force and gliding back on the surface during retraction. The retraction being first mentioned by Barth, it was discussed in detail by a very comprehensive patent of Vishnevsky et al. of the Kiew Polytechnical Institute, which also covered other types of usable oscillators. As one problem of the motors the limited lifetime of the contact surface due to gliding friction was recognized.

By 1980 a book on piezoelectric motors was published in Russia by the same group of authors, dealing with many theoretical and practical aspects of the design of such motors. Unidirectional and bidirectional motors are discussed , driving circuits for these motors are presented.

Little later, Sashida in Japan proposed several patents on the use of travelling waves in a rotary motor, the waves being produced through superposition of two bending modes excited by piezoelectric ceramics. One big advantage of this motor is the continuous force transmission between stator and rotor, since the location of the force transmission rotates continuously with the travelling wave . This significantly reduces the problems of lifetime of the contact surface between stator and rotor. Sashida's motor produces up to 4 W mechanical power: forward displacement speeds at the contact surface are in the range of 0.4 m/s.

Probably triggered by the work of Sashida , many Japanese activities started in the following years. Researchers at many companies tried different configurations of oscillators. Akiyama gave a review of different ultrasonic motor realized up to 1986. The same author published a book on ultrasonic motors in 1986. Tomikawa published a systematical review of possible combinations of oscillation modes to be applied in oscillatory motors.

Especially three Japanese publications should be mentioned: Kumada designed a motor with a torsional mode of oscillation; 2 W mechanical power and 0.2 m/s speed at the contact surface can be calculated from the given motor data. Kuribayashi uses travelling waves in a rod to produce a linear motor: he only achieved 15mW and a speed of 0.1 m/s. A more powerful drive for linear motors is investigated by Tomikawa et al. several Watts are reached, and speeds of 0.3 m/s.

In Europe two research teams have published results concerning piezoelectric motors. One company reports on a motor using a bar-resonator as driving element. 2.5 W mechanical power are reached, and speeds of 0.3 m/s. Another company uses the travelling wave principle and reports a maximum power of more than 8 W and speeds of 0.3 m/s .

MERITS AND DEMERIS OF THE ULTRASONIC MOTOR :

Merits

1. Low speed and high torque –Direct drive

2. Quick response, wide –Excellent controllability velocity range, hard brake –Fine position resolution and no backlash

3. High power/weight ratio and high efficiency

4. Quiet drive

5. Compact size and light weight

6. Simple structure and easy production process

7. Negligible effect from external magnetic or radioactive fields, and also no generation of these fields

Demerits

8. Necessity for a high frequency power supply

9. Less durability due to frictional drive

10. Drooping torque vs. speed characteristics Classification and Principles of Ultrasonic motor.

GENERAL PROPERTIES OF PIEZOELECTRIC MOTOR:

1) Piezoelectric motors offer several positive features, which make them attractive for a lot of applications

2) Much higher torque compared to conventional drives of the same volume

3) Generation of low speeds

4) Adjustable down to zero, without the need for gearing

5) Large holding torque at rest without additional elements and without energy supply

6) Extremely high dynamics and excellent controllability

7) Quiet running in the audible range

8) Compact design possible

9) Simple mechanical components

10) No magnetic fields and hence no electromagnetic disturbance

APPLICATION OF ULTRASONIC MOTOR:

Piezoelectric motors are especially well suited for fast positioning applications, where high dynamics, no need for gearing and inactive holding torque are advantageous. Piezoelectric motors arc relatively simple in their mechanical parts. but in addition they need electronic circuits. With the necessity of electronic motor control for variable speed drives and bus controlled drives even with standard electromagnetic motors, this is not a disadvantage for piezoelectric motors.

Conceivable applications for piezoelectric motors are all kind of positioning motors in cars. office technology and consumer goods, but also in satellites and medical equipment. Power demands of 2 W up to 50 W are typical. Window winders, gearless window wipers, seat adjustors, heating and ventilation flap operation, drives for paper feeders and writing head adjustment of printers, and lens focus motors are just some example of the first application.

THE ULTRASONIC MOTOR DEVELOPMENT REQUIRED:

For the further applications of ultrasonic motors, systematic investigations on the following issues will be required:

(1) Low loss and high vibration velocity piezo-ceramics

(2) Piezo-actuator designs with high resistance to fracture and good heat dissipation

(3) USM designs:

(a) Displacement magnification mechanisms (horn, hinge-lever)

(b) USM types (standing-wave type, propagating-wave type)

(c) Frictional contact part

(4) High frequency/high power supplies

CONCLUSION:

Ultrasonic motor already have a long development history behind them. Many different implementations and the working principle have been developed will be improved and patented. Piezoelectric ultrasonic motor combine several interesting feature such as high torque at low rotational speed ,simple design and good controllability ,which makes them very attractive and promising as actuator. In the future piezoelectric motor with reduced losses , higher motor power and larger motor dimensions will be possible .

References:

1) K. UCHINO , [1] S. CAGATAY,[1] B. KOC,[2] S. DONG,[3] P. BOUCHILLOUX[4] & M. STRAUSS[5]
[1]International Center for Actuators and Transducers, Mater. Res. Inst .,the Penn State University, University Park, PA, USA
[2]Mechatronics Eng. Dept., Atilim University, Ankara, Turkey
[3]Materials Sci. and Eng., Virginia Polytech Institute, Blacksburg, VA, USA
[4]Adaptronics, Troy, NY, USA 5HME, Newburyport, MA, USA
Submitted December 17, 2003; Revised February 26, 2004; Accepted March 9, 2004
2) H.-P. Schoner
3) K. Spanner Physik Instrument GmbH and Co .KG Karlsruhe , Germany
4) HANS-PETER SCHONER Daimler-Benz AG, Research Institute Frankfurt, D-6000 Frankfurt 71

5) Kenji Uchino International Center for Actuators and Transducers, Intercollege Materials Research Laboratory, The Pennsylvania State University, University Park, PA 16802, USA

6) Akio KUMADA Tsukuba Research Lab, Technical Division Hitachi Maxwell Ltd., Mitsukaido ,Ibaraki 300- 25, Japan

6) JORG WALLASCHEK Heinz Nixdorf Institute Universitat GH Paderborn 33095 Paderborn Germany

7) SCOTT L. SHARP, [1] JEFFERY S. N. PAINE[2] AND JONATHAN D. BLOTTER[3],*

[1] Orbital Sciences Corporation, Arizona, USA

[2] Dynamics Systems and Materials, Tennessee, USA

[3]Department of Mechanical Engineering, Brigham Young University, Utah, USA

8) KENJI UCHINO and BURHANETTIN KOC International Center for Actuators and Transducers, Materials Research Laboratoy .The Pennsylvania State University, University Park, PA 16802, USA

9) MAXIMILIAN FLEISCHER, DIETER STEIN, AND HANS MEIXNER