A

Seminar report

On

Ultrasonic Motor

Submitted in partial fulfillment of the requirement for the award of degree
Of Bachelor of Technology in Electronic

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Preface

I have made this report file on the topic **Ultrasonic Motors**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

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ABSTRACT

Ultrasonic motors are characterized by the absence of noise during operation, High torque weight ratio, highly accurate speed and position control etc. The advantages of ultrasonic motors make them open to a wide range of applications and technologies.

These are operated using ultrasonic vibrations to obtain a driving force, which then drives the motor using friction. When a voltage with a resonant frequency greater than 20kHz is applied to the piezoelectric element attached on an elastic body(stator),the piezoelectric element will expand and contract ,causing ultrasonic vibrations on the stator. The working principle is based on a traveling wave as its driving force.

INTRODUCTION

All of us know that motor is a machine which produces or imparts motion, or in detail it is an arrangement of coils and magnets that converts electric energy into mechanical energy and ultrasonic motors are the next generation motors.

In 1980,the world's first ultrasonic motor was invented which utilizes the piezoelectric effect in the ultrasonic frequency range to provide its motive force resulting in a motor with unusually good low speed, high torque and power to weight characteristics.

Electromagnetism has always been the driving force behind electric motor technology. But these motors suffer from many drawbacks. The field of ultrasonic seems to be changing that driving force.

DRAWBACKS OF ELECTROMAGNETIC MOTORS

Electromagnetic motors rely on the attraction and repulsion of magnetic fields for their operation. Without good noise suppression circuitry, their noisy electrical operation will affect the electronic components inside it. Surges and spikes from these motors can cause disruption or even damage in nonmotor related items such as CRTs and various types of receiving and transmitting equipments. Also , electromagnetic motors are notorious for consuming high amount of power and creating high ambient motor temperatures. Both are undesirable from the efficiency point of view. Excessive heat energy is wasted as losses. Even the efficiently rated electromagnetic motor has high input to output energy loss ratios.

Replacing these by ultrasonic motors would virtually eliminate these undesirable effects. The electromagnetic motors produce strong magnetic fields which cause interference. Ultrasonic motors use piezoelectric effect and hence no magnetic interference.

PRINCIPLE OF OPERATION

PIEZOELECTRIC EFFECT

Many polymers, ceramics and molecules are permanently polarized; that is some parts of the molecules are positively charged, while other parts are negatively charged. When an electric field is applied to these materials, these polarized molecules will align themselves with the electric field, resulting in induced dipoles within the molecular or crystal structure of the material. Further more a permanently polarized material such as Quartz(SiO2) or Barium Titanate(BaTiO3) will produce an electric field when the material changes dimensions as a result of an imposed mechanical force. These materials are piezoelectric and this phenomenon is known as Piezoelectric effect. Conversely, an applied electric field can cause a piezoelectric material to change dimensions. This is known as Electrostriction or Reverse piezoelectric effect. Current ultrasonic motor design works from this principle, only in reverse.

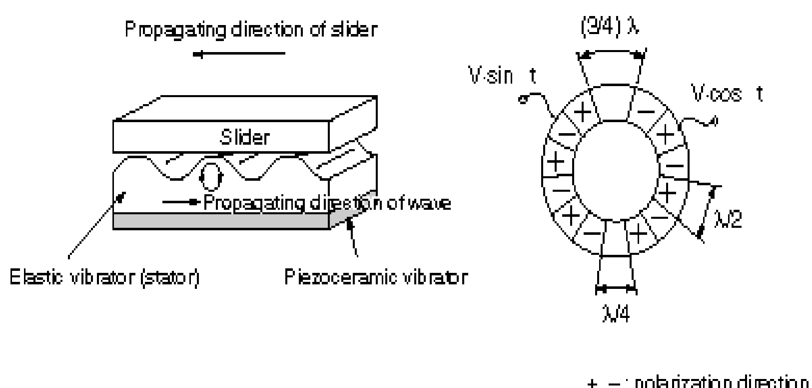


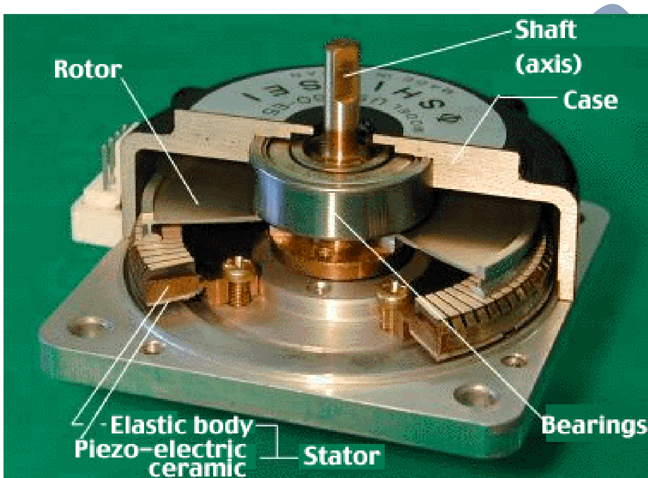
Figure Principle of traveling-wave ultrasonic motors

When a voltage having a resonance frequency of more than 20KHz is applied to the piezoelectric element of an elastic body (a stator),the piezoelectric element expands and contracts. If voltage is applied, the material curls. The direction of the curl depends on the polarity of the applied voltage and the amount of curl is determined by how many volts are applied.

Eg:Quartz,Rochelle salt,Tourmaline,Lead Zirconium Titanate

It therefore does not make use of coils or magnets. It is a motor with a new concept that does not use magnetic force as its driving force. It also overcomes the principles of conventional motors. The working principle is based on a traveling wave as the driving force. The wave drives the comb of the piezoelectric ring. When applied, the piezoelectric combs will expand or contract corresponding to the traveling wave form and the rotor ring which is pressed against these combs start rotating.

CONSTRUCTION



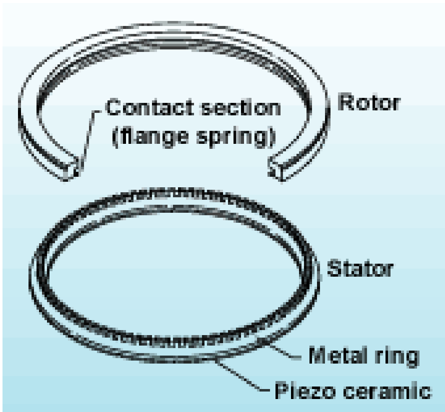
Ultrasonic motor construction tends to be simpler than EM type motors. Fewer assembly parts mean fewer moving parts and consequently less wear. The number of components required to construct an USM is small thereby minimizing the number of potential failure points.

As the ultrasonic motor uses ultrasonic vibrations as its driving force,it comprises a stator which is a piezoceramic material with an elastic body attached to it,and a rotor to generate ultrasonic vibrations. It therefore does not use magnets or coils. Therefore there is no problem of magnetic field and interference as in the case of electric motors. In ultrasonic motors, piezoelectric effect is used and therefore generates little or no magnetic interference.

Constructionally,a stator and a rotor are coupled to form an ultrasonic motor. On one side of the metal stator, the piezoceramic is glued on.It is an element that generates ultrasonic vibrations when a high frequency voltage is applied. Ultrasonic motors make use of a ring shaped piezoelectric crystal with segments having sequentially reversed polarity.On the other side of the metal stator,comb tooth grooves are set up.The rotor (dynamic body) is pressed tightly against this side of the stator metal surface so that they are adhered together closely.

PIEZOELECTRIC CERAMIC

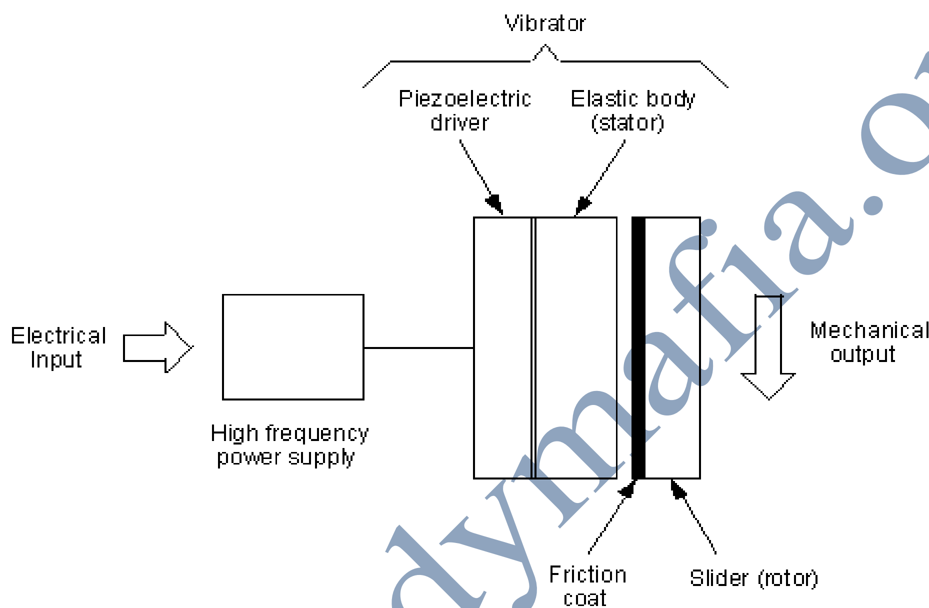
The piezoelectric ceramic used in the ultrasonic motor is an element that generates ultrasonic vibrations when a specified high frequency voltage is applied. The piezoelectric ceramic itself expands and contracts when high frequency voltage is applied. This phenomenon is called electrostriction. The piezoelectric ceramic is glued onto one side of the metal stator. The ultrasonic vibration generated travels in a single direction while flexing the elastic body. They proceed like the waves on the surface of the sea. They proceed while swelling and falling. The ultrasonic vibration that proceeds in this manner is known as a progressive wave.



The progressive wave exists in our day to day lives. A good example would be a big pond in a park. When there is no wind, the surface of the pond is as still as a mirror. If a stone is thrown into this pond, ripples are generated from where the stone hit the water and spread out to the shore. This spreading of the ripple is the progressive wave. The progressive wave is a wave moment that spreads. A small gap between the piezoelectric ceramic and the rotor ring enables the piezoelement to expand and collide with the rotor when a voltage is applied.

COMB TOOTH GROOVES

Comb tooth grooves are created on the stator surface that adheres to the rotor. These are devised to make the amplitude of elliptic motion large and to reduce abrasions. Further feature of comb tooth is to amplify vibrations. The grooves also allow the dust created by friction to escape and thus keeps the contact surface dust free.

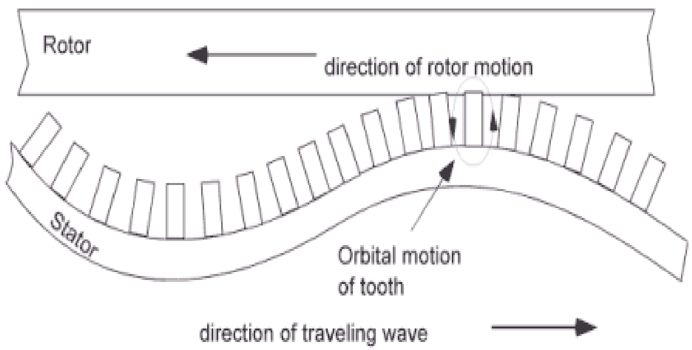


So the ultrasonic motors are well known for their low speed operation. Torque ratings averaging ten times greater than a comparably sized electromagnetic motor can be achieved.

Voltage inputs vary with piezocrystal assembly. That is, if the piezoring assembly is of a thinner design, the voltage requirements will be less than that of a thicker type piezo ring assembly. Power requirements for the Ultrasonic motor usually rate in the low range.

WORKING

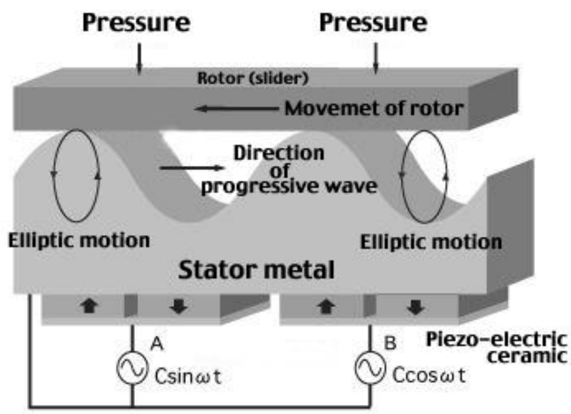
When a voltage having a resonance frequency of more than 20 KHz is applied to the piezoelectric element of an elastic body(a stator),the piezoelectric element expands and expands and contracts. The piezoelectric ring is divided into two groups of alternated polarities, which are driven simultaneously by cyclic signals that are ninety degrees out of phase, to produce a traveling wave of flexural vibrations. The third input lead is ground and attached to the ring itself. It acts as a common return to both the out of phase input leads.



A stator and a rotor (dynamic body) are coupled to form an ultrasonic motor. The dynamic body is pressed against the side of the stator metal surface which the piezoelectric ceramic is not glued on.Comb tooth grooves are created on this side. The rotor (dynamic body) is pressed tightly against this side of the stator metal surface so that they are adhered together closely. As the progressive wave travels and undulates through this contact surface, some areas of the surface of the rotor which is tightly adhered to the stator are contacted by the vertices of the wave and some areas are not. At this time, at the vertices of the progressive wave that contacts the rotor surface, an elliptic motion is generated.

The locus of the elliptic motion points to the opposite direction of the progressive wave traveling on the stator surface. At the same time, it has a vertical elliptic motion in contrast to the horizontal undulation of the progressive wave that travels on the stator surface. Reversing the polarity of the input power will reverse the direction of rotation.

The rotor and stator are pressed against each other with strong pressure to create tight adhesion. The progressive wave travels along the circumference of the stator while undulating. Only the vertexes of the progressive wave contact the rotor surface and an elliptic rotary motion is generated at each vertex. Affected by the elliptic rotary motion, the rotor is impelled to rotate. As the direction of the locus of the elliptic motion is opposite to the direction of the progressive wave, the rotor affected by it also rotates in the opposite direction of the progressive wave. When the progressive wave travels along the circumference of the stator clockwise (CW), a counterclockwise (CCW) elliptic rotary motion is generated at the vertex of the wave contacting the rotor surface. The rotor contacting the vertex is impelled by the CCW elliptic rotary motion and rotates CCW. This is the driving principle of the ultrasonic motor



Thus we can say that the general principle of operation of ultrasonic motors is to generate gross mechanical motion through the amplification and repetition of micro deformations of the active material.

There are two power transformations involved in the running of ultrasonic motors.

1. Electric energy is transformed into mechanical vibrational energy of the stator by converse piezoelectric effect.
2. Vibrational energy of the stator is transformed into continous moving energy of the rotor (moving part) due to frictional interaction between the stator and rotor.

CHARACTERISTICS OF USM

1. Low speed
2. High torque
3. Large holding torque
4. Quick response
5. Super responsibility and controllability
6. Absence of magnetic action (composed of nonmagnetic materials)
7. Noiseless
8. Compact and lightweight (Absence of winding wires)
9. Simple construction
10. Absence of gear mechanism
11. Dust free
12. Applicable in vaccum

LOW SPEED AND HIGH TORQUE

A regular DC motor is characterized by its high speed and low torque.It therefore requires a reduction gear mechanism to attain low speed and high torque. The ultrasonic motor allows low speeds of 10 to 100 revolutions per minute at high torque. It therefore does not require a reduction gear mechanism and allows direct drive.

SELF HOLD FEATURE

Since the rotor and the stator are strongly and closely adhered together , the motor continues to retain holding torque , which acts as a brake function, even after the power is turned off. The ultrasonic motor does not require an electromagnetic brake.

SUPERB RESPONSIBILITY AND CONTROLLABILITY

The ultrasonic motor has the same drooping characteristics as that of the DC motor. Moreover as the inertia of the rotor is little, the braking power from the motor's friction is large and thus enables superb responsibility. Since its speed control is also possible in step less regulation and its mechanical time constant is 1 ms or below, the ultrasonic motor excels in controllability as well. It provides high precision speed control and position control.

ABSENCE OF MAGNETIC MOTION

As the ultrasonic motor does not use coil or magnets as its driving force, it does not generate magnetism. It can be operated without influence of magnetism even in strong magnetic fields.

COMPACT, LIGHTWEIGHT AND NOISELESS

As the USM does not require coils, it has a simple and lightweight structure. Further more, as it doesn't require reduction gear due to its low speed, and uses ultrasonic vibrations in ranges not audible to the human ear, its running noise is extremely quiet. Only 2 ms are needed to start the motor from zero.

ADVANTAGES OF USM

- A large holding force or torque at rest, without power supply
- A low AC voltage excitation
- A large actuating force or torque at low speed
- A silent, non magnetic behaviour
- A short time response
- A very good micro positioning capability
- Ultra small size can be easily miniaturized.
- Dust free

DISADVANTAGES

In order for the combined longitudinal vibration of longitudinal and torsional vibrations at the interface between stator (the vibrating body that produces ultrasonic elliptical motion) and rotor to efficiently propel the rotor, the longitudinal and torsional vibrations must exhibit simultaneous resonance drive. In other words, the longitudinal resonance frequency and the torsional resonance frequency must be made to match. This can be easily done under weak field conditions, but the torsional resonance frequency tends to become higher than the longitudinal resonance frequency when driven under the strong field conditions of actual motors. To make the longitudinal and torsional resonance frequencies match, the first requirement to make the rotor lighter. This involves reducing the height of the rotor, but this change in shape reduces the rigidity of the rotor, which makes it difficult to produce high torque. It is also necessary to increase the friction force to an extreme degree, but this inevitably put excessive stress on the bearings which causes the bearings to wear out and shorten the life of the motor. It is difficult to obtain high torque from an ultrasonic motor if it is miniaturized beyond a certain point.

APPLICATIONS

1. Lens actuator for automatic focusing of cameras.
2. Watch movements
3. Roll screen motor for automatic open close actions.
4. Positioning in satellite reception devices.
5. Actuators in strong magnetic field
6. Sonar
7. Air and fluid pumps
8. Robotics and microrobotics
9. Powered heat rests in luxury cars
10. Print heads in dot matrix printers
11. Magnetic levitation trains
12. MEMS Technology
13. Magnetic Resonance Imaging (MRI)
14. Electrical appliances for household use
15. Optical equipment
16. Automobile interior products
17. Locking and clamping mechanisms
18. Substitute for pneumatic or hydraulic cylinders
19. Accurate positioning for coordinate plotter
20. Operation of shutters or blinds
21. Actuators for VCRs or CD players
22. Head actuator for floppy disk drives and hard disk drives
23. Servomotor for pen recorders, plotters
24. Film rewind mechanism in cameras
25. Paper feeding mechanisms for printers, faxes and copying machines
26. Feeding mechanisms for telephone cards
27. Flow regulating valves
28. Constant flow pumps
29. Tube pumps
30. Chucks and clamps

CONCLUSION

Utilising the large piezoelectric coefficients and high dielectric constants of ferroelectric thin films, it is possible to micro fabricate USMs on silicon substrates. By using ferroelectric thin films of lead zirconate titanate (PZT) a two order of magnitude improvement over bulk ceramic materials is obtained in break down strength.

This characteristic in combination with high dielectric permittivity leads to a three order of magnitude improvement over electrostatic micro motors in terms of energy densities. Stator rotor interaction is achieved through frictional coupling and inherent gear down creates motors which run at low speeds with high torque.

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