THE FUTURE TRENDS AND RECENT DEVELOPMENT OF ULTRASONIC MOTORS

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1. INTRODUCTION

Remarkable progress has been made in Japan in the research and development of ultrasonic motros. Three manufacturers have already introduced practical models. In the following, we will divide the course of development of ultrasonic motors and their future applications into four periods (A, B, C and D) from the standpoint of past research and patent applications. We believe that we are now at point C in product development and that point D or practical application will begin next year.

2. Ultrasonic Motors Nearing Practical Application

It is already many years since ultrasonic motors were first discussed as possibly being the ideal motor. What then, is the present state of their development? Figure 1 charts the development of ultrasonic motors and their future according to current development schedules.

In 1960, a Soviet scientist conceived the idea for an ultrasonic motor, but no further progress was made until 1971 when Siemens of West Germany filed for patent on a piezoelectric motor. This was the first wave (point A) in ultrasonic motor development.

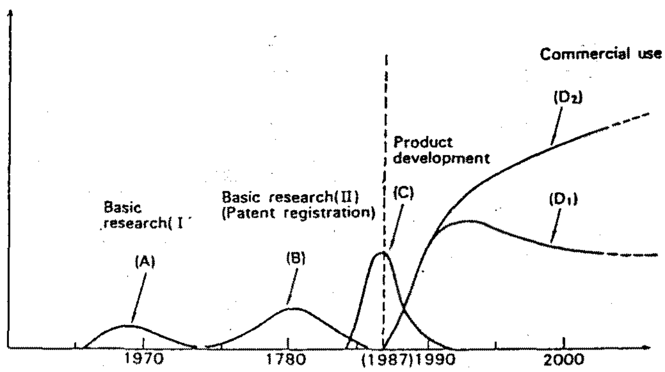
Later, Japanese makers filed their own piezoelectric and ultrasonic motor patents, intended mostly for use in the automatic focusing mechanisms of cameras. These were filed mainly by camera makers.

Wave B began four or five years ago when one of these Japanese engineers, Mr. Sashida, president of Shinsei corporation, unveiled three types of test-manufactured ultrasonic motors. One was a disk bending vibration type, the second a linear type, and the other was a horn-type motor for driving electric fans. They were epoch-making models in the history of ultrasonic motors because they brought with them a glimpse of the future applications possible with this revolutionary technology.

The past one or two years have brought further developments. There are now three systems from Japan — the Standing wave torsion coupler system designed by Mr. Kumada of Hitachi Maxell, the travelling wave system of the Matsushita Electric Industrial Company, and Mr. Sashida's bending wave mode version.

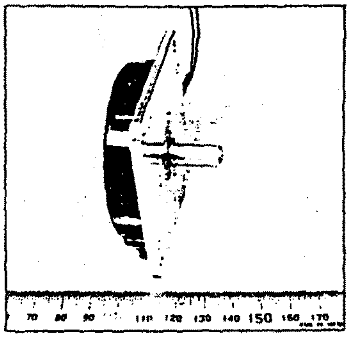
As illustrated in the figure, these developments in the last year and this year represent wave C. This phase is expected to last only two or three years longer as shown in illustration C, and is expected to overlap with phase D, which will start in the latter half of this yer. Ultrasonic motors for special uses will come into use by about 1990. Wave C will differ from wave D only in the economics, service life, reliability and uses of ultrasonic motors, and both will differ from phases A and B in that research and development work will focus on practical application.

Fig. 1: Development of ultrasonic motors and their future outlook



There is a possibility that phase D may develop in either of two directions, D_1 or D_2. The first (D_1) will occur if ultrasonic motors cannot compete successfully with conventional motors in economic efficiency. In this case, they will be used for special purposes because of their characteristic features (small size, light weight and high torque). Growth will not be explosive, but will continue on a steady course.

D_2 will result if ultrasonic motors are made economically competitive with conventional motors. In this case, demand for them will grow rapidly. However, at this point, there is no way to predict which way development will go.



4W-100rpm ultrasonic motor by Shinsei Corp.

3. Economics of Ultrasonic Motors

Let me cite concrete examples here. As shown in Photo 1 and Fig. 1, an ultrasonic motor with a rated power of 4W, 100 rpm, is offered by the Shinsei Corporation.

Both the driver and the motor of this product are made samll in size and light in weight, and appear to be sufficiently competitive as an actuator in function and performance. Since the ultrasonic motor develops a high torque at low speed, it does not require a speed reducer. Further, it is characterized by a high power density (small size and lightweight). If these and other features are taken into account, this ultrasonic motor appears to be sufficiently practical.

When used as an actuator, it is not operated continuously for a long time, so that the drive power supply can be used for two or more ultrasonic motors.

Therefore, it is considered suitable for use as an actuator for automobile electical equipments.

It may also be effectively used for dentists' chairs. Recently, many actuators and ultrasonic devices have come to be used for motor-driven chairs.

As explained above, ultrasonic motors can be used effectively and conveniently depending on purposes. Recently, the production of micromotors has been transferred to overseas bases. However, so far as ultrasonic motors are concerned, this will not happen at least for some time to come.

It is rare that Japan has developed its own unique motor. Ultrasonic motors may be regarded as one such product. However, it is necessary to pay attention here to the fact that unlike conventional motors, the ultrasonic motor should be used as an actuator for a short time use products.

However, it is necessary to pay attention here to the fact that unlike conventional motors, the ultrasonic motor should be used as an actuator for a short time at a rated power. There should be no misunderstanding in this respect. Users are urged to fully understand the advantages and disadvantages of ultrasonic motors.

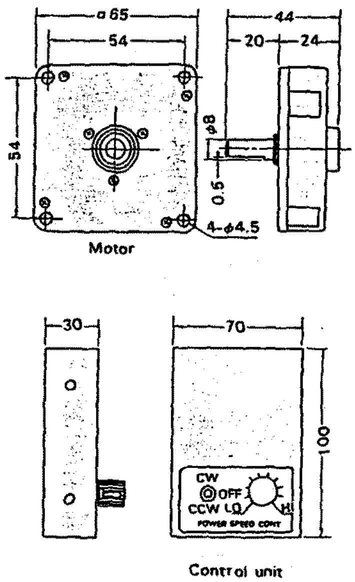


Fig. 2: Dimensions of ultrasonic motor and control unit

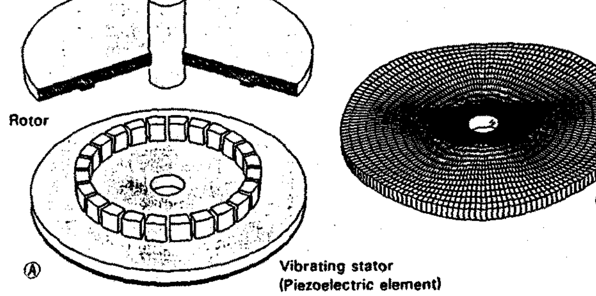


Fig. 3: Disk ultrasonic motor (left) and its displacement distribution pattern

4. 4 Type Ultrasonic Motors

Below are three practional ultrasonic motors designed by Japanese manufacturers. Each motor features a high maximum operation efficiency of about 50 percent.

Matsushita Electric Ind. Co., Ltd.

As shown in Fig. 3-A, this ultrasonic motor consists of a disk vibrator (metal) with a piezoelectric ceramic devices attached to its bottom surface and a disk pressed upon this vibrator by a powerful permanent magnet. Unlike the models by the two other makers, this motor is characterized by the pressure on the vibrator which does not change even when a dimensional change is caused by wear on the contact parts. Further, a number of teeth are located on the disk vibrator to lower the number of vibrations. Fig. 3-B shows the distribution of displacements on the disk type ultrasonic motor, while Fig 4-A shows a ring ultrasonic motor utilizing a similar principle. The distribution of displacements on the circular ring is shown in Fig. 4-B.

The specifications of the two above-mentioned ultrasonic motors are listed in Table 1.

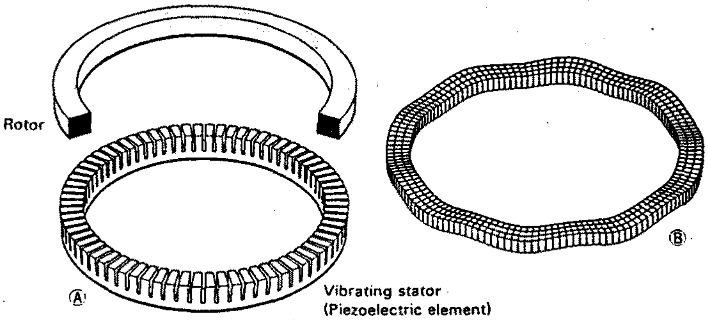
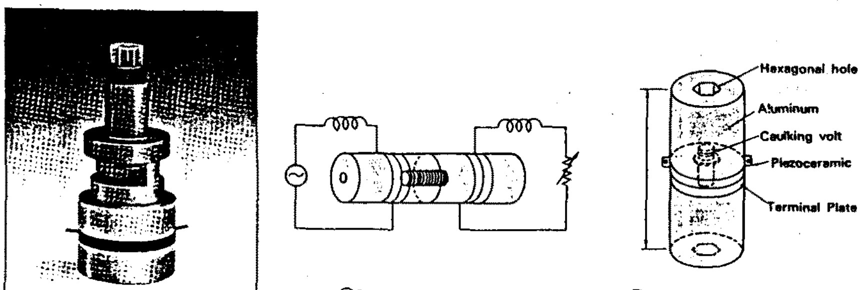


Fig. 4: Structure of ring ultrasonic motor (left) and its displacement distribution pattern



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Ⓑ Dummy load test of Langevin vibrator

Ⓒ Langevin vibrator with caulking volt

Fig. 6: Structure of torsion coupler ultrasonic motor and a Langevin vibrator

Hitachi Maxell

Hitachi Maxell's ultrasonic motor, invented by Mr. Kumada, has a special mechanism called the "torsion couper" (or NEJIRI-KETSUGOSHI) which converts simple vibration to an elliptical motion.

As shown in Fig. 5, simple vibration is converted to a rotary standing wave via a torsion couper. Fig. 6-A illustrates its structure. A powerful vibrator is needed. The Langevin vibrator as shown in Figs. 6-A. B and C is normally used. After a travelling wave is obtained. a rotary disk is pressed on it as in ordinary ultrasonic motors to take out rotary force.

Shinsei Corporation

Shinsei Corporation ultrasonic motor is also an orthodox disk type motor, as shown in Photo 1 and Fig. 2. The drive power supply unit is made compact. The specifications of this motor are listed in Table 2. The motor developing 4W, 100 rpm, weighs 175 grams, and the drive power supply unit 200g. The circuit configuration of the drive power supply unit is shown in Fig. 7. The operation characteristics of this motor are shown in Fig. 8. The maximum efficiency is about 40 percent. As a result of recent improvements, the efficiency has been raised to about 50 percent, says the company.

All these motors are travelling wave ultrasonic motors. Our studies suggest that the travelling wave type is the most promising. As the matter stands today, only Shinsei Corporation that has released a sample model. It is expected that the other makers will offer practical models as early as possible.

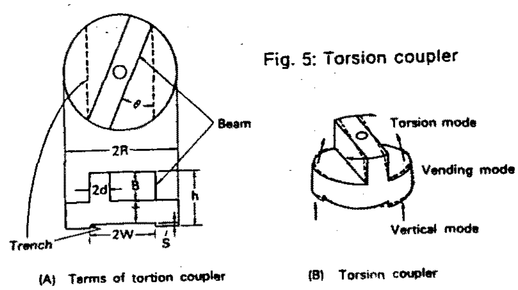

Fig. 5: Torsion coupler

(A) Terms of tortion coupler (B) Torsion coupler

Diameter of torsion coupler	2R	Thickness of beam 2d	
Height of torsion coupler	h	Height of beam	b=H+(T+S)
Thickness of disk	T	Beam length=Beam width=2R	
Depth of trench	S	Angle for beam and trench	θ
Width of trench	2W	Flexure angle of disk	
Length of volt	L	Length of vertical vibrator	H

Table 1: Characteristics of ultrasonic motor
(Matsushita Electric Ind. Co., Ltd.

		Disc-type	Ring-type
Dimensions	Outside diameter	40 mm	50 mm
	Inside diameter	—	42 mm
	Heigh	10 mm	10 mm
	Weight	[illegible]0 g	40 g
Input	Resonant frequency	72 kHz	28 kHz
	Electric power	3.5 W	3.5 W
Output	Nonloading rotation	600 rpm	500 rpm
	Static torque	1.0 kg-cm	1.2kg-cm
	Conversion efficiency	45%	45%

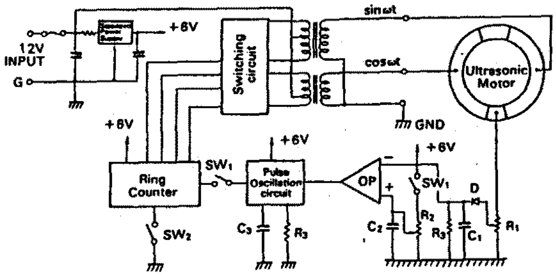

Fig. 7: Example of power supply circuit

Table 2: Specifications of Model USR-60-4-100
(Shinsei Corporation)

Motor

Driving frequency	40 kHz
Rated voltage	100 V rms
Rated torque	3.8 kg-cm
Rated output	4 W
Rated revolution	100 rpm
Rated current	53 mA × 2-phase
Starting torque	6 kg-cm
Holding torque	8 kg-cm
Rotor inertia	72×10^{-3}g-cm Sec^2
Mechanical time constant	1 m Sec
Speed regulation	Less than 1%
Direction	CW and CCW
Lefe	1 million times or more
Temperature Range	−10°C – +50°C
Weight	175g

Control Unit

Input voltage	DC 12 V
Input current	Less than 2A
Output voltage	100 V rms
Oscillation fequency	40 kHz
Feedback	Automatic frequency follow-up system
Remote control	Start, variable speed, Forward/Reverse
Temperature range	−10°C – 50°C
Weight	200 g

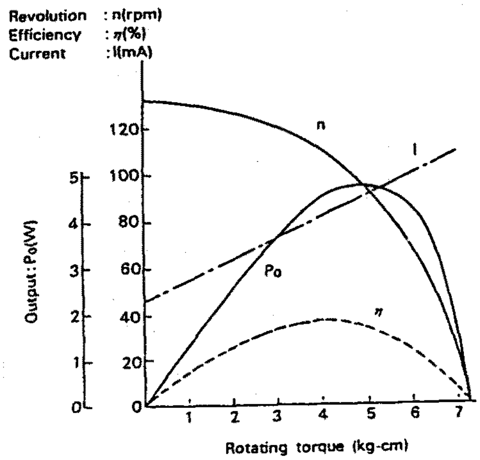

Fig. 8: Performance characteristic of ultrasonic motor

Cannon Corporation

In the case of Cannon Corporation, the purpose was auto-focusing of camera. Fig. 9 shows pair into camera with ultrasonic motor for auto-focusing.

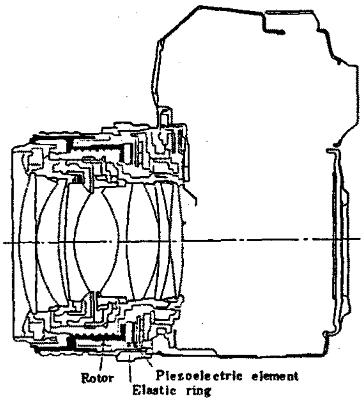

Fig. 9
Auto-focusing camera with Ultrasonic Motor

5. CONCLUSION

In the area of technically feasible special motors, motors and actuators with these and other functions will be in greater demand in the future. The most feasible of these motors appears to be a magnetic and electrostatic variable gap motor or actuator.

The most important features of control motors and actuators are low speed, large thrust, and linear movement, which will be realized most suitable by what we call here motors operating on a new principle. However economically speaking, there are many cases in which these functions can better be achieved by conventional motors equipped with a mechanical reduction device. Therefore, it cannot be said that motors operating on a new principle are necessarily advantageous over conventional ones.