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Generation of Rotary Motion Using Straight Moving Ultrasonic Motors
直線動作型超音波モータを用いた回転機構の検討

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1. Introduction

Recently, ultrasonic motor (USM) is utilized mainly as parts of digital camera, for example zoom function and auto focus. USM is compact size and moves very silently compared with other motors, and it has good positioning performance. Also, it can be used in strong electromagnetic field because it isn't affected by electromagnetic interaction. However, it doesn't have many applications yet. Precision devices, robots and medical machines are considered to be main applications and many institutions proceed research and development. Conventional USM is rotary type, and straight motion is generated from rotary motion. General liner USM needs long stator and many vibration devices, but it is difficult for vibration wave to travel long distance. Therefore, liner USMs are utilized as limited applications, for example actuator and liner stage.

In this study, we propose a new generation method of rotary motion using straight moving USM. The USM which we used is developed based on new tecnology but the structure is very simple. By applying these characteristics to our configuration we achieve rotary motion, which provides possibility of new practical application for USMs.

2. Principle of straight moving USM

Fundamental principle of the USM which we used is bending vibration produced by piezoelectric bimorph device. As shown in **Fig.1**, the bimorph device consists of two piezoelectric ceramic films bonded to both sides of metal or elastic film element. The polarization direction of ceramic films are opposite to each other as shown in the figure. Therefore, when alternating voltage is applied to the bimorph device, one piezoelectric film contracts while the other expands, which produces bending vibration as also shown in the figure. To generate straight movement like a moving piston, a shaft is attached to one side of the bimorph device as shown in **Fig.2**. We also use this type of straight moving motor to study and develop a new rotary motor.

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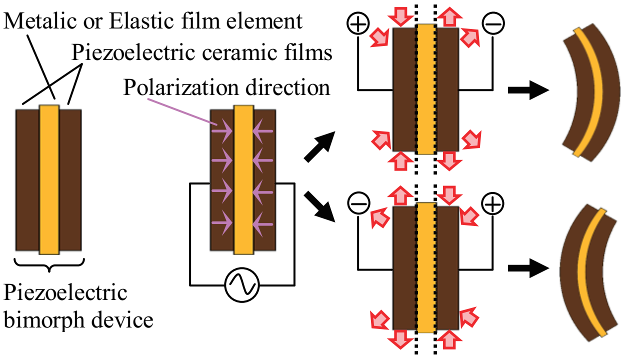


Fig.1 Structure of piezoelectric bimorph device and principle of bending vibration

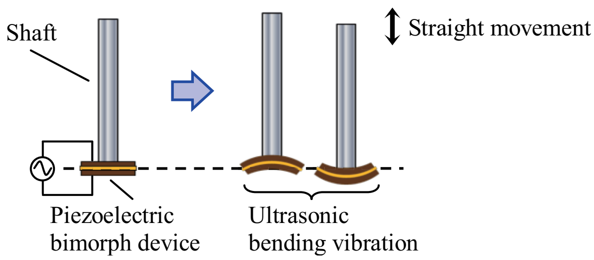


Fig.2 Principle of straight movement

3. Method of generating rotary motion using straight moving USM

3.1. Synthesization of circular motion from two straight movements

First we consider synthesizing circular motion using two straight movements. As shown in **Fig.3**, using complex variable a circularly moving point is expressed as $z=re^{j\omega t}=r(\cos\omega t+j\sin\omega t)$. The real part corresponds to the movement along x axis, while the imaginary part to that along y axis. Therefore, if we can make movements of $\cos\omega t$ and $\sin\omega t$ along x and y axes respectively, it is possible to synthesize the circularly moving point.

In our proposal, two straight moving USMs, (a) and (b), are connected perpendicularly to each other as shown in **Fig.4**. The USM(a) produces the movement along x axis, while the USM(b) along y axis. Precise explanations about these movements are illustrated in **Fig.5**. **Fig.5** (a) and (b) correspond to driving voltage waveforms which are applied to the USMs (a) and (b) respectively. At $\omega t=0$, **Fig.5** (a)'s $cos(0)=1$ and **Fig.5** (b)'s $sin(0)=0$ are applied to the USMs. The connection point moves toward positive x direction due to the voltage of $cos(0)=1$ to the USM(a), which results in **Fig.5** (c)'s Point 1/1'. At $\omega t=\pi/2$, $cos(\pi/2)=0$ and $sin(\pi/2)=1$ are applied to the USMs, and the connection point moves toward positive y direction, which results in **Fig.5** (c)'s Point 2/2'. Similar phenomena occur at $\omega t=\pi$ and $3\pi/2$, which leads to **Fig.5** (c)'s Point 3/3' and 4/4'. Thus, the circular movement of the connection point can be synthesized by **Fig.4**'s structure and **Fig.5** (a) and (b)'s driving voltages.

3.2. Proposed model to generate rotary motion

We propose a new configuration which can generate rotary motion to a sphere and a rod with hemispherical end. As shown in **Fig.6**, three pairs of **Fig.4**'s connected straight moving USMs are arranged at each apex of a triangle. When a sphere or a rod with hemispherical end are contacted to three connected points, they are forced to rotate. Switching of driving voltages between $cos\omega t$ and $sin\omega t$ provides reverse rotation.

4. Conclusion

We study generation of rotary motion using straight moving USMs. Our proposal consists of two procedures. The first is synthesizing circular motion using two perpendicular USMs. The second is to form the configuration which drives rotary movement. We will make experiments according to our proposal next step.

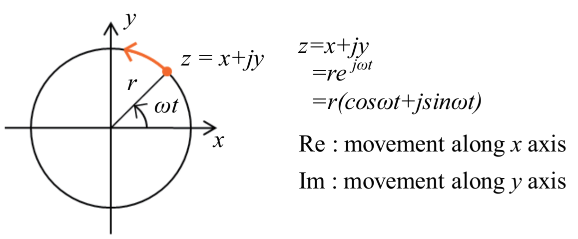


Fig.3 Expression of circular motion using complex

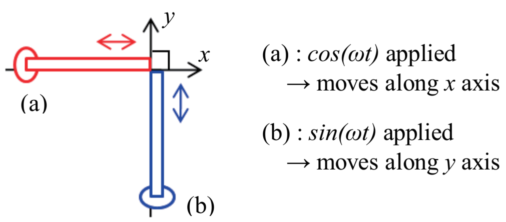
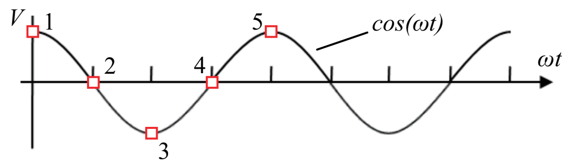
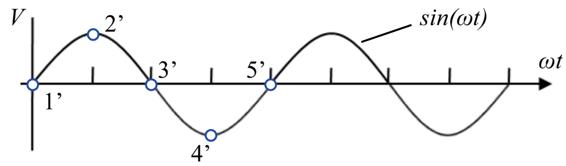


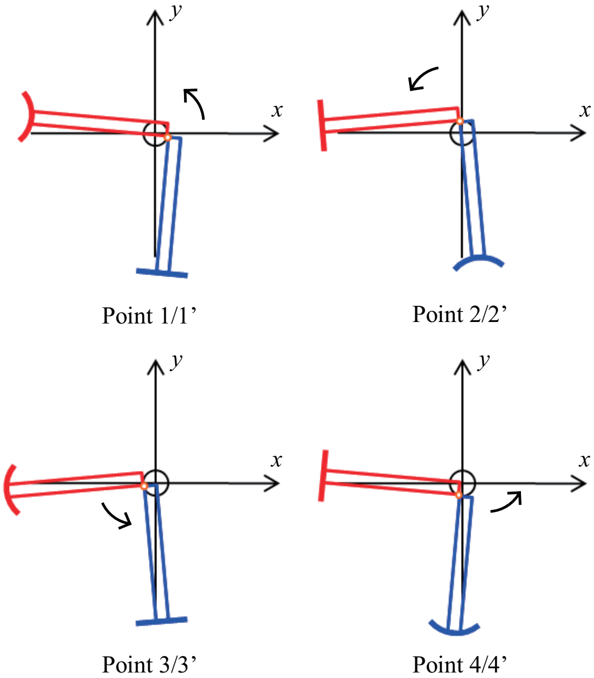
Fig.4 Method for setting two straight moving USM



(a) Driving voltage waveform applied to the USM(a)



(b) Driving voltage waveform applied to the USM(b)



(c) Position of the connection point at driving voltages from 1/1' to 4/4'

Fig.5 Synthesization of circular motion from two straight movements

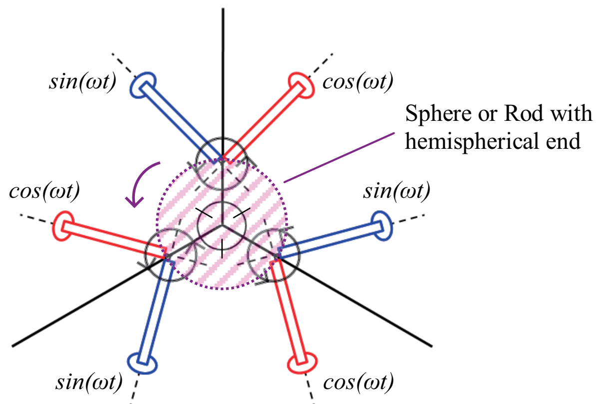


Fig.6 Model to generate rotary motion using straight moving USMs