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Experimental Study on the ∏ Shaped Coiled Stator Ultrasound Motor

コイル状ステータを用いた ∏ 型構造の超音波モータの検討

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1. Introduction

In an attempt to construct a micro motor, we are developing a coiled stator ultrasonic motor (CS-USM) [1-4]. The main problem for practical use is its low efficiency. To improve the efficient, a quadratic driving method using a closed waveguide was proposed [3]. However, since the transducers were attached to the wave guide, impedance of the closed waveguide was non-uniform and this may cause low efficiency. Therefore a further improvement may be required.

In this paper we propose a new driving method without using a non uniform wave guide, retaining the quadratic exciting method.

2. Working Principle and Design of ∏ Shaped CS-USM

The working principle of the proposed motor is the traveling wave type ultrasonic motor where the elliptical particle movement of the stator in the form of a coil drives the rotor to rotate [5]. In this paper a new method to generate the traveling wave on the coiled stator is proposed.

Figure 1 shows a basic structure of the proposed motor. The motor consists of the rotor, the in the stator form of a coil, and two transducers. The stator forms a closed acoustic waveguide. The length of the straight section from the point A to the point B in counter clockwise is a quarter wavelengths ($\lambda/4$). The section from the point B to the point A including the coil is $(n+3/4)\lambda$ where n is an integer. Two acoustic waveguides 1 and 2 are connected to the closed acoustic waveguide at the points A and B. The two PZT (Lead Zirconate Titanate ceramics) transducers 1 and 2 are attached to the acoustic waveguide 1 and 2. When the PZT 1 and PZT 2 are applied with the electrical signals $V_1 = \cos\omega t$ and $V_2 = \sin\omega t$, a traveling wave, $u(x,t) = A_{\mathrm{m}} \cos(kx-\omega t)$, is generated on the closed waveguide. Where ω, t, k, x and A_{m} are the angular frequency, time, wave number ,the length along the closed waveguide starting from the point A_{m}, and an amplitude.

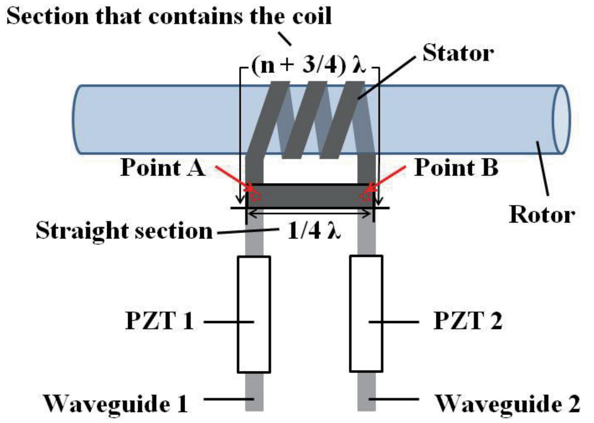

Fig.1 Structure of the Π shaped coiled stator ultrasound motor

3. Experiment

Figure 2 (a) (b) show the motors constructed for $n=1$ (#1) and $n=2$ (#2). The two motors should work at the same frequency. The thickness and the width of the acoustic waveguide are 0.1mm and 0.5mm, respectively. The length of the straight section is 1.5 mm ($\lambda/4$). The lengths of the closed waveguide from the point B to the point A in counter clockwise for $n=1$ and $n=2$ are 10.5mm and 16.5mm, respectively. The waveguide

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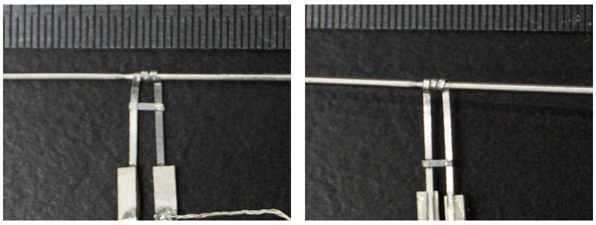
is wound around on the rotor by 3 turns.

The thickness, the width, and the length of the PZT transducer (Fuji Ceramics C-213) are 0.25 mm, and 1.5 mm and 5mm respectively. Figure 3 shows the schematic diagram of the experiment. The function generator (F.G.) 1 and 2 generates two sinusoidal signals whose phase differs by 90 degrees. F.G 2 is triggered by the output signal F.G. 1 to the phase difference by 90 degrees.

First, rotation speed is a function of the frequency is measured for the fixed voltage, to find the resonance frequency. Next, the revolution speed as a function of the applied voltage for the resonance frequency measured. Then, the phases of the voltage signals are reversed, and the revolution speed as a function of the voltage, and the direction of the rotation were measured.



(a) #1 (b) #2

Fig.2 Photograph of the Π shaped coiled stator ultrasound motor

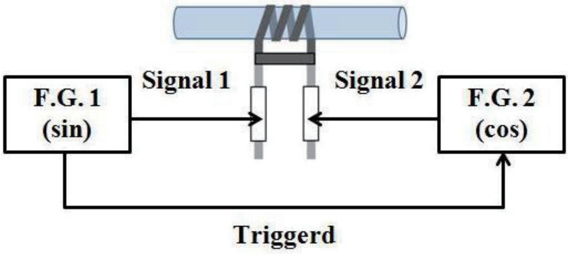


Fig.3 Schematic diagram of a CS-USM drive experiment

4. Results and Discussion

Figure 4 shows the revolution speed as a function of the applied voltage. For the motors #1 and #2, the revolution direction was reversed at the frequency 285 kHz and 315 kHz respectively. The revolution speeds for the forward direction were differed from the reverse direction both for the motors. This may be caused from the fabrication accuracy. Figure 5 shows the performance comparison of the proposed motor and the conventional CS-USM. The proposed motor provides the faster revolution speed compared to conventional CS-USM for the same driving voltage.

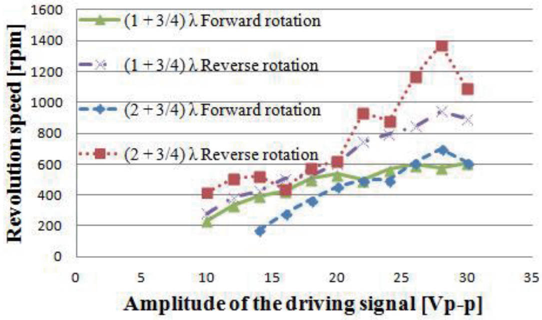


Fig.4 Revolution speed as a function of the amplitude of the driving signal

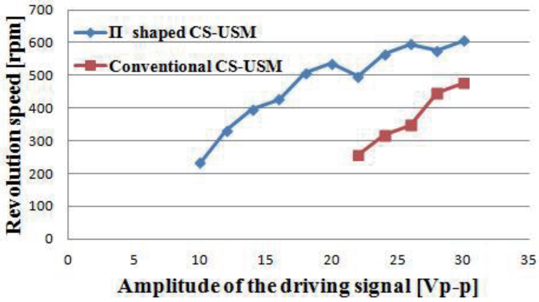


Fig.5 Performance comparison of the Π shaped motor and the conventional CS-USM

5. Conclusion and Future works

We confirmed the driving method of the coiled stator motor without using a non-uniform waveguide, and retaining the quadratic driving method.

The improvements on the structure of the rotor and closed acoustic waveguide are the future problem.

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