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Examination of the outer rotor type coiled stator ultrasound for intravascular
血管内超音波診断を目的としたアウターロータ型コイル状ステータ超音波モータ

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1. Background

CS-USM was developed for application to the intravascular treatment equipment and diagnostic equipment by Prof. Tadashi Moriya in Tokyo Metropolitan University et al. in 2005[1]. This is an ultraminiature ultrasound motor with traveling wave type coiled acoustic waveguide as stator, and which rotor is rotated by the traveling wave.

We've been studying the coiled stator ultrasound motor(CS-USM) using the hydrothermally synthesized PZT polycrystalline film or piezoelectric ceramics vibrators[1-5].

However, it was difficult to insert our conventional CS-USM into the blood vessels because the driving transducers were existed perpendicular to a rotor of these CS-USM.

Furthermore, it is thought that it is difficult to equip an imaging ultrasound transducer to the conventional CS-USM, because the rotor rotated inside of the coiled stator in the conventional CS-USM.

Therefore, we developed the outer rotor type CS-USM which rotor and driving transducers exist coaxially and rotor rotates outside of the coiled stator for practical application in this study.

2. Driving principle

When traveling wave propagates on the acoustic waveguide, the particles on the surface of acoustic waveguide draw an elliptic trajectory.

When the rotor is pressed against the acoustic waveguide by pressurization, motion such as scratching the rotor is generated by elliptical movement of the particles on the acoustic waveguide surface, and the rotor is driven in the direction of opposite to the traveling wave by the generated frictional force[6].

In CS-USM, the rotor can be placed in both inside and outside of the coiled stator, because the coiled acoustic waveguide is used as the stator.

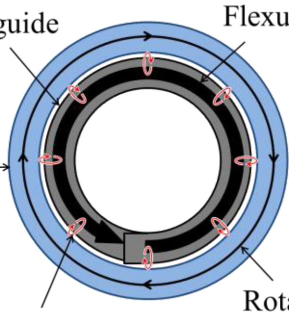

Fig.1 Operation principle of the outer rotor type coiled stator type Ultra-Sound Motor (CS-USM)

3. Fabrication

A SUS304 stainless steel acoustic waveguide with a thickness of 50 µm, width of 0.3mm was wound on a SUS304 stainless steel pipe having an outer diameter of 1.08 mm. After that, it covered with a SUS304 pipe having inner diameter of 1.22 mm in order to suppress the spread of the coiled acoustic waveguide, and shape of the coiled stator was fixed by heat treatment.

Next, lead zirconate titanate piezoelectric ceramics transducer (C213 ; Fuji Ceramic Corporation) having thickness of 250 µm, length of 5 mm and width of 1 mm was adhered on the acoustic waveguide using an epoxy-based conductive adhesive EPO-TEK H20E.

A coiled stator portion of the fabricated CS-USM is shown in Fig.2.

Outer diameter of the coiled stator was measured using ImageJ that is a free image processing software developed in NIH.

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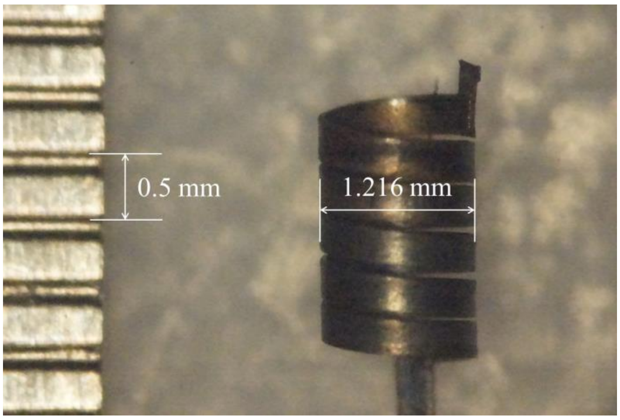

Fig.2 Fabricated CS-USM using coiled SUS304 stainless steel acoustic wave guide and C213 lead zirconate titanate piezoelectric transducers in this study

4. Experiments

Measured vibration velocity on the surface (contact surface with the rotor) of the coiled acoustic waveguide stator of the fabricated CS-USM using LDV was the maximum at driving frequency of 284 kHz.

The relationship between applied voltage to the piezoelectric transducers and revolution speed of the CS-USM was measured by setting at frequency of 284 kHz based on the above measured results. Schematic diagram of our measurement system for the characteristics of fabricated CS-USM is shown in Fig. 3.

Output voltage from a function generator was amplified with a power amplifier and applied to the piezoelectric transducer of the fabricated CS-USM, The revolution speed of the outer rotor of the CS-USM was measured by using Laser tachometer. The laser reflective tape was pated to a portion of the outer surface of the outer rotor for reflecting the laser light from the laser tachometer.

In this study, forward direction of the revolution means revolution direction of the rotor in the same direction as winding direction of the coil.

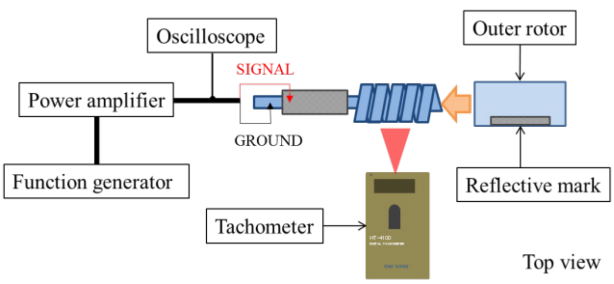

Fig.3 Setup diagram of the experimental

5. Results

The measurement results of drive experiments in the above is shown in Fig.4.

In this data, the applied voltage means the measured voltage between both electrodes of the piezoelectric transducer of the CS-USM which is measured by an oscilloscope.

We decided that forward direction of the rotor revolution was the revolution direction in the same direction as the coil winding direction of the coiled stator.It was found from Fig. 4 that the revolution speed increased in accordance with increase of the applied voltage.

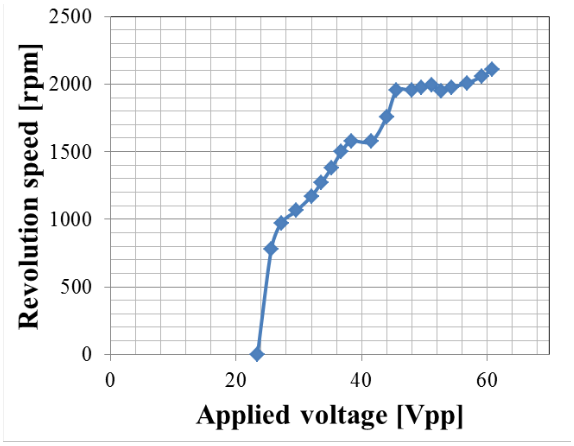

Fig.4 Measured relationship between applied voltage and revolution speed of the rotor of the fabricated CS-USM in this study.

The effect of the single transducer type outer rotor CS-USM fabricated in this time was obviously lower than the conventional dual transducer type CS-USM.

The rotor did not rotate with applied voltage lower than 21 Vpp. The reason is thought that vibration amplitude was too small to transfer the elliptical motion of particles on the surface of the coiled acoustic waveguide stator to the rotor.

6. Future works

We will consider the appropriate rotor inner diameter for the coiled stator in our future work.

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