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Examination of the inner rotor type coiled stator ultrasound motor using wire acoustic waveguide

ワイヤ音響導波路を用いたインナーロータ型コイル状ステータ超音波モータの検討

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1. Introduction

Recently, intravascular ultrasound (IVUS) systems[1] are actively used for diagnose the progress of arteriosclerosis. We have been developed coiled stator ultrasound motors (CS-USM)[2-5] as ultra-miniature motor for IVUS. Coiled stator with elongated plate-like acoustic waveguide with rectangular cross-section was used in the inner rotor type CS-USM which has been reported.

However, this conventional plate-like acoustic waveguide is difficult to coiled, it is difficult always to keep the same contact state with the rotor. Thus, the CS-USM with coiled stator using the wire acoustic waveguide of circular cross section was considered in this study.

2. Fabrication of CS-USM

The single transducer type CS-USM with circular cross section copper wire acoustic waveguide was fabricated in this study. It was changed to the round wire acoustic waveguide from flat plate acoustic waveguide in the CS-USM. Rotational speed of 1800 rpm is required in IVUS. Wire acoustic waveguide with diameter of 0.3 mm and length of about 40mm is used for fabrication of our CS-USM in this time. Acoustic waveguide is wound four times to a round bar with outer diameter of 0.55 mm for formation of the coiled stator. Acoustic waveguide is bonded with PZT piezoelectric transducer (C213; Fuji Ceramics Inc.) was bonded to one end of wire acoustic waveguide for coiled stator by using a conductive adhesive. The sizes of PZT transducer are thickness of 0.25mm, width of 1mm and length of 5mm. 0.3 mm was used for the rotor. Fabricated CS-USM in this study is shown in Fig. 1. Actual sizes (inner diameter, outer diameter, length of stator and length between the stator tip and end of PZT transducer) of the fabricated CS-USM were measured by using image process software of ImageJ (by NIH). Measured sizes of the CS-USM are shown in Table1. Fabricated CS-USM shown in Fig. 1 is very lightweight of 0.99 g (Except for rotor).

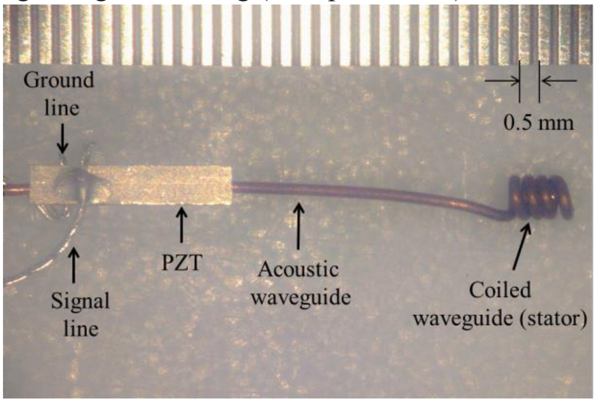

Fig.1 Photograph of single vibrator type CS-USM using wire acoustic waveguide in this study

Table 1 Sizes of fabricated cupper coiled stator in this study

Outer diameter	1.06 [mm]
Inner diameter	0.61 [mm]
Length of stator	1.46 [mm]
Length between the stator tip and end of PZT transducer	13.1 [mm]

3. Experiments

Driving experiment of the fabricated single transducer type CS-USM using wire acoustic waveguide was performed. A schematic diagram of the experiment is shown in Fig. 2. First, vibrating velocity of the coiled stator was measured in the frequency range from 280 kHz to 320 kHz by using Laser Doppler Vibrometer (LDV: Ono Sokki Co.,Ltd.; LV1710) in order to investigate the vibrating behavior of the coiled stator. Maximum vibrating velocity was shown at frequency of 309 kHz. It is thought that the maximum vibrating velocity was shown at frequency of 309 kHz, because the resonant frequency of the PZT

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piezoelectric transducer is 300 kHz.

Next, we selected the driving frequency for the CS-USM. At this time, revolution speed of the fabricated CS-USM was measured with a digital tachometer by changing driving frequency every 1 kHz in the range from 280 kHz to 320 kHz at applied voltage of 32.2 V_{pp}. The relationship between applied voltage to the piezoelectric transducer and revolution speed of the fabricated CS-USM was measured by decreasing of applied voltage every 2 V_{pp} from 32.2 V_{pp} to 2.2 V_{pp} at frequency of 309 kHz.

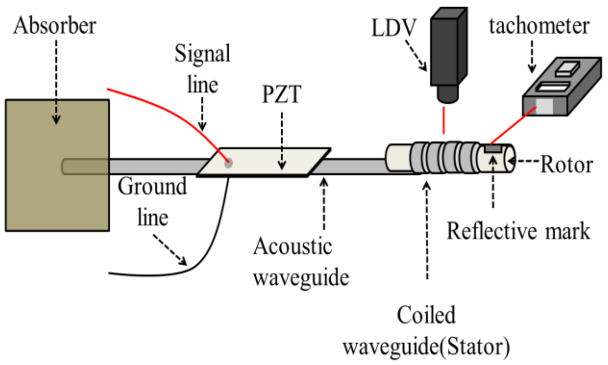

Fig.2 Experimental system for vibrating velocity and revolution speed of the CS-USM using wire acoustic waveguide under test in this study

4. Results

Figure 3 shows the measured result of the relationship between driving frequency and revolution speed of the fabricated CS-USM under test in this study. Since maximum revolution speed of 1793 rpm was recorded at a frequency of 309 kHz, we set the diving frequency was set at 309 kHz in this subsequent measurement. Measured data in this figure shows the average values of 10 times measurements. The relationship between applied voltage to the piezoelectric transducer and revolution speed of the fabricated CS-USM was measured by decreasing of applied voltage every 2 V_{pp} from 32.2 V_{pp} to 2.2 V_{pp} at frequency of 309 kHz. Figure 4 shows the measured relationship between the applied voltage and revolution speed. Measured data in this figure shows the average values of 10 times measurements. CS-USM is frequency 309 kHz, were recorded average 1793 rpm at an applied voltage 32.2 $V_{pp.}$

Maximum revolution speed of 1793 rpm was recorded at applied voltage of 32.2 V_{pp}. and driving frequency of 309 kHz, and the fabricated CS-USM showed stable revolution. In addition, higher revolution speed can be obtained with increase of applied voltage to the PZT piezoelectric transducer in the CS-USM. However, CS-USM did not rotate at the applied voltage lower than 14.4V_{pp}. We think that the vibrating displacement on the surface of coiled stator was too small to contact with the inner surface of the rotor. Elliptical motion of the particles on the coiled stator is difficult to transfer to the outer surface of the inner rotor of the CS-USM.

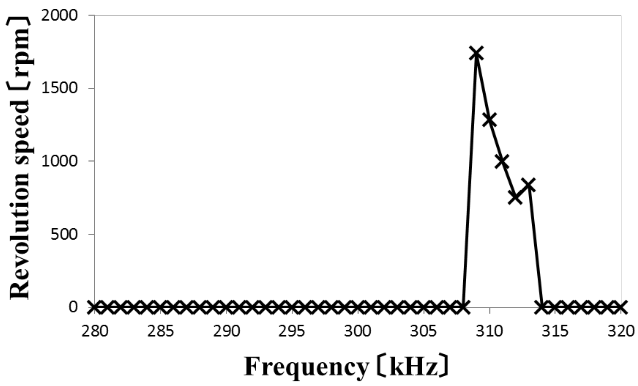

Fig.3 Relationship between the revolution speed and frequency of the CS-USM using wire acoustic waveguide under test in this study

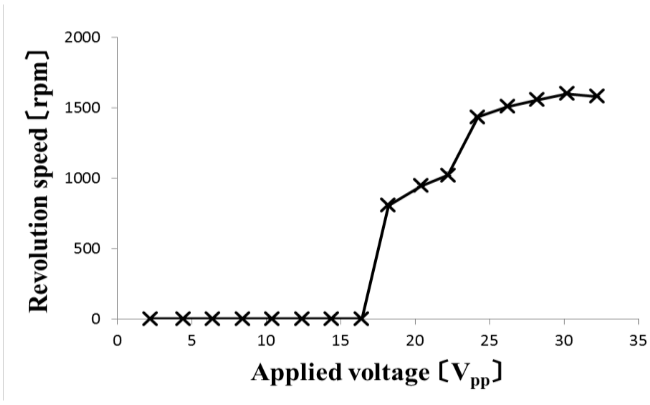

Fig.4 Relationship between the revolution speed and applied voltage of the CS-USM using wire acoustic waveguide under test in this study

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