3P4-11

Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 451-452
20-22 November, 2013

# Dynamic Vibration Analysis of Ultrasonic Power Circulation-type Quadratic Excitation Method for Coiled Stator Ultrasonic Motor

コイル状ステータ型超音波モータ用超音波パワー循環型直交駆動法の動的振動解析

Masasumi Yoshizawa[1†], Seiya Ishikura[1], Norio Tagawa[2], Takasuke Irie[3], Tadashi Moriya[4], ([1]Tokyo Metropolitan College of Industrial Technology, [2]Design, Tokyo Met. Univ. [3]Microsonic Co., Ltd., [4]Professor Emeritus of Tokyo Met. Univ.)
吉澤 昌純 [1†], 石倉 誠也 [1], 田川 憲男 [2], 入江 喬介 [3], 守屋 正 [4] ([1]都立産技高専; [2]首都大 システムデザイン, [3]マイクロソニック㈱, [4]首都大名誉教授)

## 1. Introduction

In order to find medical use such as intravascular ultrasound devices (IVUS), a traveling-wave-type miniature ultrasonic motor using a helical coiled waveguide as a stator, called CS-USM (Coiled Stator Ultrasonic Motor), has been developed.[1-3] Owing to its simple structure, the CS-USM can be made smaller than the conventional ultrasonic motors. However, the torque of the CS-USM is not sufficient for practical applications. To improve the energy efficiency of the CS-USM, we have developed an ultrasonic power circulation-type quadratic excitation method (UPC-QEM).[4] The method based on quadratic excitation has a loop structure for ultrasonic power circulation.

In this study, for confirmation of the performance of the UPC-QEM, the dynamic vibration of the CS-USM driven by UPC-QEM was analyzed.

## 2. Principle

The basic form of the UPC-QEM is shown in Fig. 1. A propagation wave is generated by superimposing two standing waves whose phase differs by 90 degree in time and phase.[5] The length of the waveguide loop is equal to integer multiples of the wavelength (λ) of the ultrasonic wave. The transducer excites the standing wave at the natural resonance frequency. The standing wave excited at the transducer 1 is given by

$$u_1(x,t) = A\sin kx \sin \omega t \,. \qquad (1)$$

Here $x$, $\omega$, $k$, and $A$ represent the coordinate, the angular frequency, wave number and amplitude of the flexural wave. Similarly, the standing wave whose phase differs by 90 degree in time and phase exited at the transducer 2 is given by

$$u_2(x,t) = A\cos kx \cos \omega t \,. \qquad (2)$$

The traveling wave is given by

$$\begin{aligned} u(x,t) &= u_1(x,t) + u_2(x,t) \\ &= A\sin kx \sin \omega t + A\cos kx \cos \omega t \,. \\ &= A\cos(kx - \omega t) \,. \qquad (3) \end{aligned}$$

If it is needed to rotate the rotor in the reverse direction, those exited signals are changed in the form from "Sin" to "Cos" or from "Cos" to "Sin", respectively.

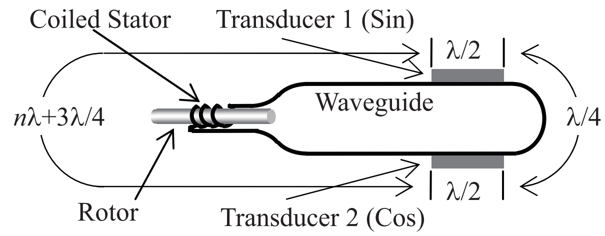



Fig. 2. Basic form of UPC-QEM.

## 3. Experiment

Figure 3 shows the configuration of the prototype CS-USM driven by UPC-QEM. The transducer was made of PZT (Lead Zirconate Tinanate ceramics) ceramics (Fuji Ceramics C-213, polarized in the thickness direction) of 3 mm width, 10 mm length, and 0.25 mm thickness. The $k_{31}$ of the transducer was 34 %. In this experiment, a stainless steel wire with a diameter of 0.28 mm and length of 65 mm was used for the waveguide. The diameter of the rotor was 1.0 mm. The waveguide was wound around the rotor by 4 turns. The natural resonance frequency of the loop structure was 164 kHz.

Figure 4 shows the image of the prototype CS-USM for used in these experiments and measurement points of the vibration. Figure 5 shows the schematic diagram of the dynamic

yoshizawa@acp.metro-cit.ac.jp

vibration analyzing system. Rectangular signals having amplitudes of 40 $V_{PP}$ with a frequency of 164 kHz were applied to the PZTs. The phase of the rectangular signals differ by 90 degree each other. The vibration of the CS-USM was measured by the Green Laser Vibrometer (NEOARK Corporation VMS-100) and analyzed by the analyzing soft (Catec Inc. CAT System, ME'scopeVES).

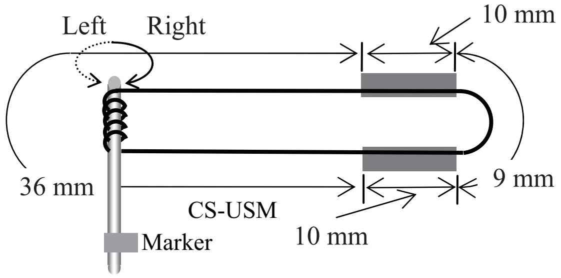



Fig. 3. Configuration of the prototype CS-USM driven by UPC-QEM.

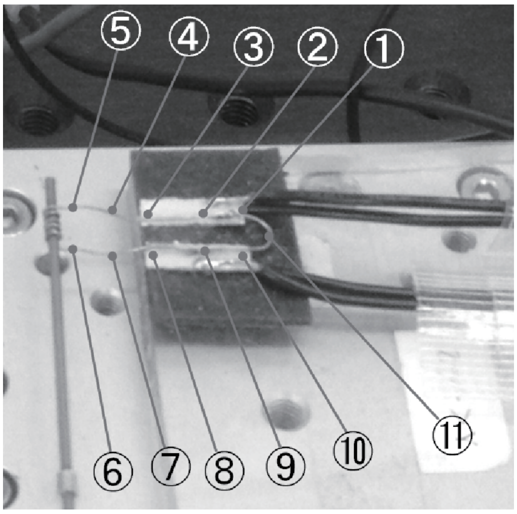



Fig. 4. Overview of prototype CS-UMS and measurement points.

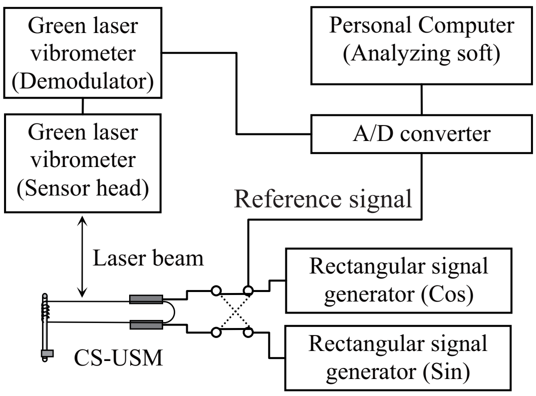
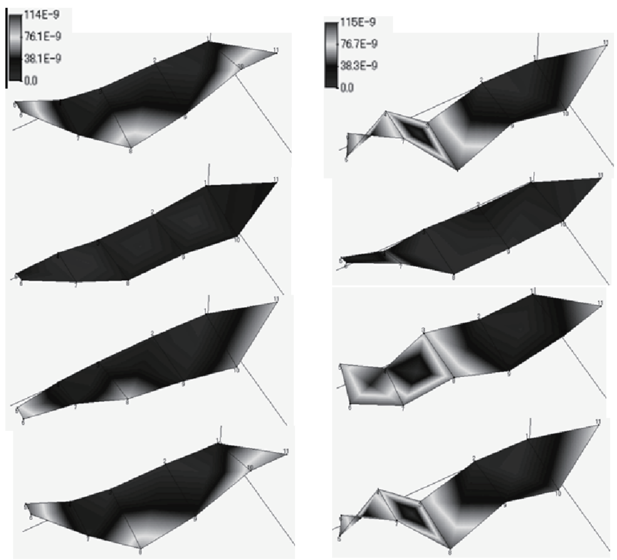



Fig. 5. Schematic diagram of experiment.

## 4. Results and discussion

Figure 6 shows the measurement results of the vibration pattern. From this figure, we confirmed that this mechanism allowed making the traveling waves both directions. However, the traveling wave was weak. As the prototype CS-UMS is made manually, the position of those PZT were not appropriate. It is necessary to improve the assemble accuracy.



(a) Left (b)Right

Fig. 6. Vibration patterns.

## 5. Conclusion

The dynamic vibration of the CS-USM driven by UPC-QEM was analyzed.

**Acknowledgements**

This study was supported by the NEOARK Corporation and the Catec Inc.

**References**

1. T. Moriya, Y. Furukawa, Y. Akano, and A. Nakajima: IEICE Tech. Rep. US2005-29 (2005) [in Japanese].
2. M. Tanabe, S. Xie, N. Tagawa, T. Moriya, and Y. Furukawa: Jpn. J. Appl. Phys. **46** (2007) pp.4805-4808.
3. M. Tanabe, S. Xie, N. Tagawa, and T. Moriya: Jpn. J. Appl. Phys. **47** (2008) pp.4262-4264.
4. K. Kato, M. Yoshizawa, N. Tagawa, T. Irie, and T. Moriya: Proc. Symp. Ultrason. Electron. 33(2012) pp.475-476.
5. K. Uchino: Piezoelectric Actuators and Ultrasonic Motors (Kluwer Academic, Dordrecht, 1997) Chap. 9. P.269.