Optimum Driving of Magnetostrictive Amorphous Wire Micro-Motor

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Abstract

Characteristics of a magnetostrictive vibration micro-motor were investigated in relation to a supporting position of a magnetostrictive amorphous wire for optimization of the motor. It was found that a vibration of the wire resembled a vibration mode of both ends free and a maximum rotational speed was obtained by supporting the nodes of vibration.

PACS codes: 85.70. *Keywords:* Amorphous Wire; Large Gyromagnetic Effect; Magnetostriction; Magnetostrictive Vibration

High-speed mechanical rotation of magnetostrictive amorphous wire around its wire axis in an ac longitudinal field was reported as a large gyromagnetic effect[1]. We reported it originates from the mechanical vibration caused by magneto-elastic resonance[2]. Because of its simple structure and high rotational speed, the micro-motor of amorphous wire is very attractive for micro-machine and/or micro-sensor application[3],[4]. Effective transformation of resonance energy into mechanical rotation is needed for such an application with high output. In the magneto-elastic resonance micro-motor, the wire is supported by fulcrums that can disturb the resonance vibration. In the present work, optimization of micro-motor driving is explored by changing the fulcrum position.

A short piece of amorphous $Fe_{77.5}Si_{7.5}B_{15}$(at.%) wire with 36 mm length and 0.125 mm diameter was used for the motor. The saturation magnetostriction of the wire is about +30 x 10^{-6}. The wire was put in a helmholtz coil as shown in Fig. 1. In the coil, the wire was inserted through 1 mm diameter holes in two polyethylene terephthalate (PET) films at two positions, as shown in Fig. 2. One wire end was attached to a glass plate. Excitation frequency of a drive field was set at the resonance frequency of 63.6 kHz depending on the wire length. The ac field of 2 Oe and dc bias field of 10 Oe was applied to the wire along the axial direction to obtain a magnetostrictive vibration that causes the motor rotation. Rotational speed was measured as a function of position of two supporting fulcrums.

Fig. 3 shows a rotational speed as a function of the top and bottom supporting position. When the bottom supporting position, x_1, was about 6 mm, the maximum rotational speed was obtained. In this case, the rotational speed reached a peak at the top supporting position, x_2, of 28 mm. As a result, the wire exhibited the maximum rotational speed of 2500 rpm when the bottom and top fulcrums of PET film were positioned at 6 mm and 28 mm away from the bottom end of the wire, respectively. The positions of two PET fulcrums correspond to 17% and 78% of wire length from the wire end, as shown in Fig. 4.

In the case of longitudinal vibration with free boundary

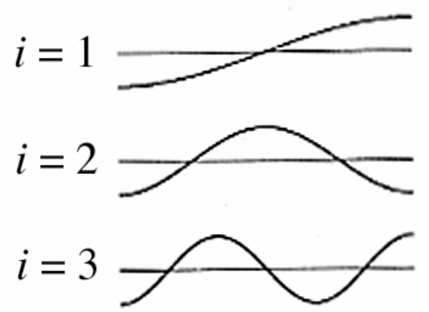

Fig. 5. The natural mode function, $U_i(x)$, at longitudinal vibration.

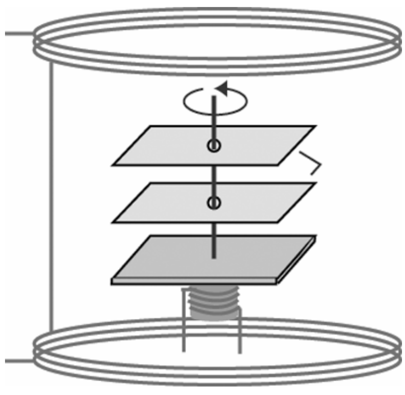

Fig.1. Experimental set-up for the study.

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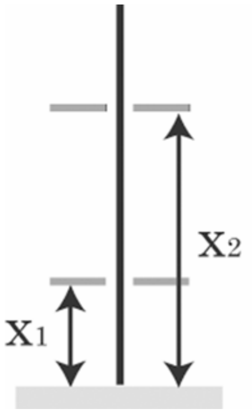

Fig. 2. Supporting position x_1, x_2.

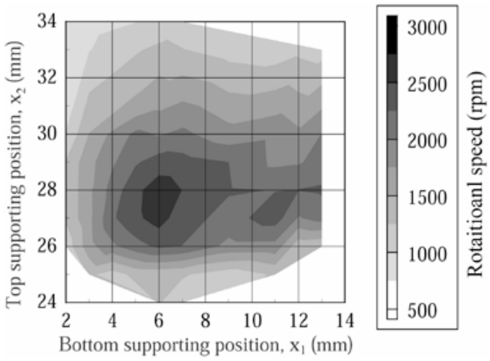

Fig. 3. The rotational speed as a function of the top and bottom supporting position.

condition at the wire ends, resonance frequency, ω_i, and natural mode function, $U_i(x)$, are given as follows[5].

$$\omega_i = \frac{i\pi c}{l} \tag{1}$$

$$U_i(x) = \cos\frac{i\pi}{l}x \quad (i = 1,2,3\ldots) \tag{2}$$

Where, c is longitudinal wave velocity, l is length of the wire, and x is position on the wire, respectively. The position at $U = 0$ expresses nodes of the vibration at magneto-elastic resonance. Therefore, it is simulated that nodes of wire are positioned at 25% and 75% of wire length when i equals 2, as shown in Fig. 5. It is clear that the position of the PET fulcrums is similar to that of the nodes at the vibration mode of both ends free when the maximum rotational speed was obtained.

From these values, it seems that supporting of the nodes of the vibration by PET fulcrums does not disturb extremely the rotation of the wire. In other word, the supporting holes on the PET film do not contribute to the transformation from magneto-elastic vibration to mechanical rotation of the wire. We have considered that

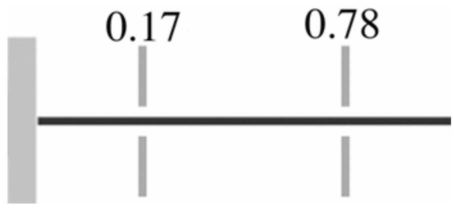

Fig. 4. The supporting position that the maximum rotational speed was obtained.

the transformation occurs at the bottom end of the wire on the glass plate.

It was found that the vibrating configuration of the wire is close to the vibration mode of both ends free and the maximum rotational speed was obtained by supporting the wire at the nodes of vibration.

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