# THEORETICAL AND EXPERIMENTAL CONTRIBUTIONS CONCERNING THE PROPOSED MODEL FOR THE DISC-TYPED ROTARY ULTRASONIC MOTOR

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***Abstract** - In this work the proposed model for type-disk, ultrasonic motor rotating, elliptic movement to surface beam. A sinusoidal vibration of the vertical displacement in the z-direction, Assume that the vertical displacement of the neutral plane, equals the product of the slope of the neutral plane and half of the beam height, the tangential velocity vs at the upper surface is given.*

**Keywords:** elastic-body, sinusoidal vibration, ultrasonic.

## 1. Introduction

Employing the fundamental theories for ultrasonic motors, we will extend to applying them to rotary ultrasonic motors. Instead of a beam, we now consider an elastic-body ring shown in figure 1 below.

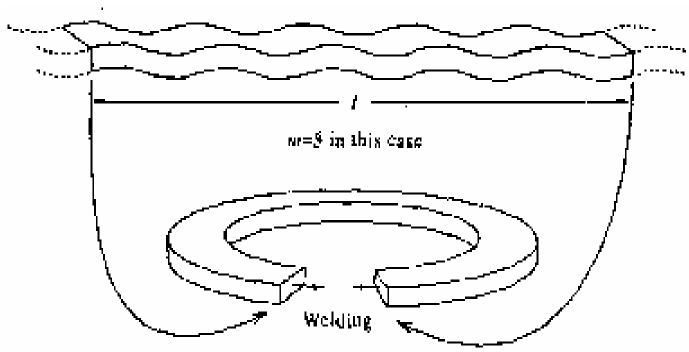


***Fig. 1.** Visualization from a beam to a ring.*

Treating the beam as an infinite body that carries flexural waves. Cutting a length equal to the wavelength multiplied by m times and joining the two ends together forms a ring. A sinusoidal vibration of the vertical displacement in the z-direction can be expressed as:

$$w_n = C_m sim\left(\omega_m t - \frac{2m\pi}{l}x + \phi_m\right) + D_m \sin\left(\omega_m \frac{2m\pi}{l}x + \varphi_m\right) \qquad (1)$$

where fm and m are appropriate phase angles and l is equal to the wavelength multiply by m. The relationship between the vibrational mode number n, and the number of waves cycles present on the ring is:

$$n = 2m \qquad (2)$$

## 2.Elliptical motion at the beam’s surface

Figure 2 below illustrates how points on a beam’s surface rotate in a counter-clockwise direction as the flexural wave travels from left to right. Assume that the vertical displacement of the neutral plane can be describe by :

$$w = \xi_o \sin(\omega t - kx) \qquad (3)$$

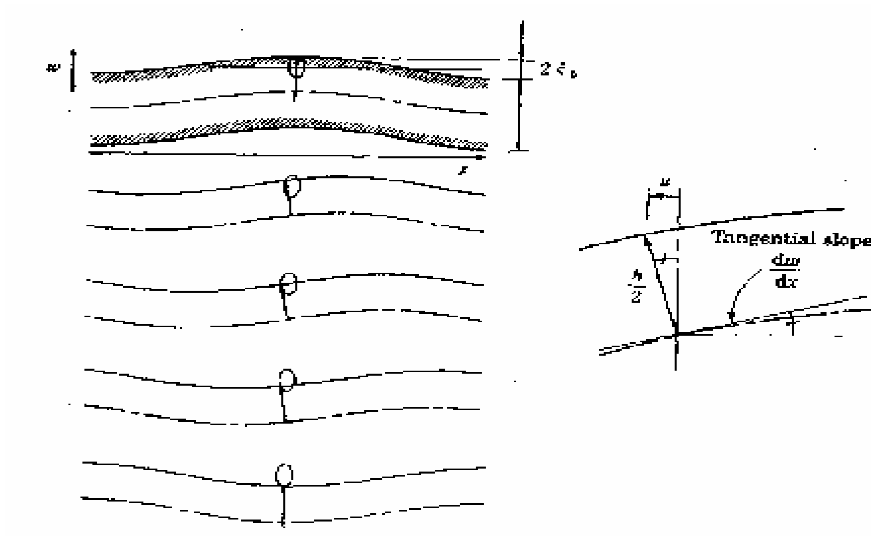


*Fig. 2. Points at beam's surface rotate counterclockwise in an elliptical motion.*

As depicted in figure 2, the displacement u in the x direction equals the product of the slope of the neutral plane and half of the beam height.

$$u = ( k\xi_o h/2) \cos(\omega t - kx ) \quad (4)$$

Since $k = 2\pi/\lambda$, we obtain,

$$u = ( \pi\xi_o h/\lambda ) \cos(\omega t - kx) \quad (5)$$

We observe that the ratio of the minor to the major axis of an ellipse is given by $\pi h/\lambda$.By differentiating equation (5) with respect to time, we will derive the tangential velocity of each point at the beam's surface as follows,

$$\frac{du}{dt} = \frac{-\omega\pi\xi h}{\lambda}\sin(\omega t - kx) \quad (6)$$

We have assumed that phases A and B are identical except with a $90^0$ phase difference in position and time . Let $\xi_A$ and $\xi_B$ be the amplitudes at the neutral plane of phases A and B respectively Then we will have, $w = \xi_A \sin \omega t \sin kx + \xi_B \cos \omega t \cos kx$

$$u = -\frac{h\vartheta w}{2\vartheta x} \quad (7)$$

The tangential velocity vs at the upper surface is given by

$$v_s = \frac{\vartheta u}{\vartheta t} = -\frac{h\vartheta^2 w}{2\vartheta x\vartheta t} = -\frac{hk\omega}{2}\left(\xi_A \cos\omega t\cos kx + \xi_B \sin\omega t\sin kt\right) \quad (8)$$

To find the position of the crest, we let $\partial w/\partial x = 0$. Thus,

$$\xi_A \sin \omega t \cos kx = \xi_B \cos \omega t \sin kx \quad (9)$$

From this equation, we obtain the following,

$$\cos kx = \frac{\left(\xi_B \big/ \xi A\right)\cos wt}{\sqrt{\left[1 + \left(\xi_B / \xi_A\right)^2 \cot^2 wt\right]}} \tag{10}$$

$$\sin kx \frac{1}{\sqrt{1 + \left(\xi_B / \xi_A\right)^2 \cot^2 wt}} \tag{11}$$

Substituting these terms into Equation (8), we acquire the tangential velocity at the,

$$\left[v_s\right]_{top} = \frac{-\left(hk\,\omega/2\right)\xi_A \xi_B}{\sqrt{\left[\xi_A^2 \sin^2 wt + \xi_B^2 \cos^2 wt\right]}} \tag{12}$$

Since k=2π/λ,

$$\left[v_s\right]_{top} = \frac{-\left(hk\omega\right)\xi_A \xi_B}{\lambda\sqrt{\left[\xi_A^2 \sin^2 wt + \xi_B^2 \cos^2 wt\right]}} \tag{13}$$

When , $\xi_A = \xi_B = \xi_o$,

$$\left[v_s\right]_{top} = \frac{-\left(hk\omega\right)\xi_0}{\lambda} = \frac{-\left(\frac{h}{2}\right)\xi_0 \omega}{\left(\lambda/2\pi\right)} \tag{14}$$

According to Equation (14), we know that the velocity in the transverse direction is equal to $\xi_o\omega$ . By knowing this fact, the velocity of the crest is obtained at the end of the shorter arm. Taking moment about the fulcrum point at the neutral plane of the beam, we arrive with the conclusion that the longer arm of the lever has a length $\lambda$ of divided by 2π while the shorter arm has a length h/2. This analogy applied directly to the actual motor where the comb teeth are considered to be short arms of the lever. The comb teeth are regarded as a row of the levers as shown in Figure 3.

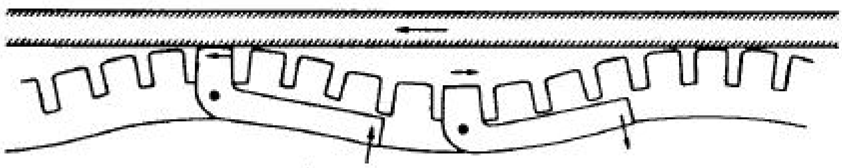

***Fig. 3.*** *The 'lever' principle modeling the comb teeth of an ultrasonic motor.*

### 3. Conclusions

1° A rotary ultrasonic motor has a resolution limit. An ultrasonic motor can produce extremely fine position changes until the sub-nanometric field and small variations in operating voltage can be converted into continuous movements;

2° Piezo positioning systems can produce a force of tens of thousands of Newtons (units operating there that can support loads of several tons), making movements with nanometer resolution;

3° Experimentally it is found that ultrasonic motors have a response time of microseconds Odin;

4° Elements of an ultrasonic motor operates without wear. An engine displacement based on dynamic ultrasonic solid no-wear.

5° Experimentally been found not require lubrication. Ultrasonic motors do not need any lubricant and makes them ideal for high vacuum applications.

6° Ultrasonic motors can operate at cryogenic temperatures. Piezo effect is based on electric fields and produce up to near zero degrees Kelvin is only important point Curie temperature.

**References**

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