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Analysis of the stator/rotor-contact in a two stators hybrid transducer type ultrasonic motor

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This paper presents the procedure to understand the contact mechanism of the hybrid transducer type piezoelectric ultrasonic motor with two stators by using finite element analysis. First, the vibration mode of a stator will be calculated and analyzed using the commercial finite element program package ANSYS. The computed resonance frequencies of the stator will be presented in the frequency domain, in term of input admittance analysis. After that the distribution of the elliptic path of motion of a particle on the stator surface area will be studied. Finally, the contact condition between the stator and the rotor will be addressed in the computation. The normal displacement, normal velocity and tangential velocity of a point on stator surface area will be calculated.

1 Introduction

To predict the overall behavior of the two stators hybrid transducer type ultrasonic motor which was proposed by Yi et al [1] , the effects of the contact forces on the vibration of the stator should be taken into account. However, the majority of publications in this field only examined the traveling wave contact type of motors. For the intermittent contact type of motors like this motor, most studies are essentially experimental [2]. It is necessary to construct the corresponding model for the intermittent contact type motors to understand its contact condition and to estimate the overall behavior of this type motor.

2 Finite Element Modeling and Numerical Results

The finite element analysis was carried out using ANSYS 11.0 finite element code from Swanson Analysis Systems, Inc., because ANSYS allows the inclusion of multi-field piezoelectric elements. The structure of the motor's stator is composed of two main parts, which are elastic solid parts and piezoceramic parts. The elastic solid parts (metal parts) are modeled using 3D solid element SOLID45, which is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y and z direction.The SOLID5 element, a 3D coupled-field solid finite element, which has eight nodes having up to six degrees of freedom plus electrical potential (voltage), was used for the piezoelectric materials both for the longitudinal PZT and the torsional PZT.

2.1 Harmonic Analysis

In the simulation of the piezoelectric motor, the piezoceramics are excited with sinusoidal electrical voltage before and after tuning the eigenfrequencies of the longitudinal and the torsional vibration mode via modal analysis. Harmonic analysis allows us determining the frequency response of the motor's stator. The results (Fig.1 and Fig.2) verified that both modes of vibration have almost the same eigenfrequency at 27.6 kHz, so this motor can reach a high efficiency in operation.

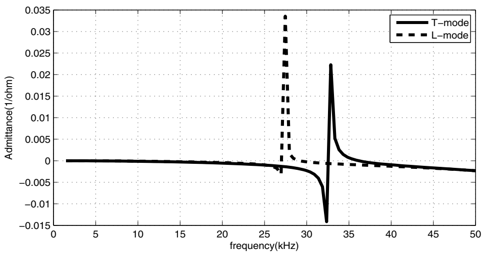

Fig. 1 Difference of two vibration frequencies before tuning.

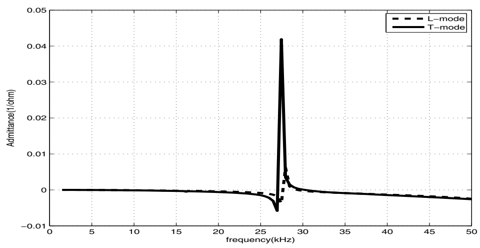

Fig. 2 Degeneration of two vibration frequencies after tuning.

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2.2 Elliptical trajectory on the stator surface

The ellipses of trajectories on the stator surface are obtained through a transient analysis in ANSYS. For the solution of transient problem, ANSYS uses an implicit Newmark method for integration. In the figures below, the ellipses of the motion of the motor for two distinct damping ratios are represented: with 0.3% and with 0.5% damping ratio. These graphs were obtained by plotting ANSYS-results with MATLAB. The results show that the addition of the structural damping in the motor reduces the displacement amplitude together with the change of phase, evidenced by the angle of inclination Θ of the ellipse axis, This is shown in Fig.3 and Fig.4 below.

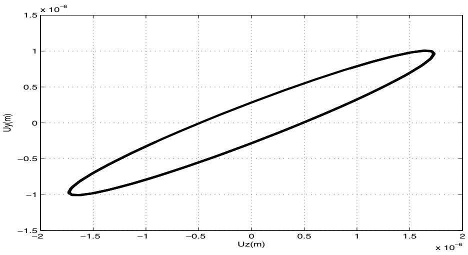

Fig. 3 Visualization of the elliptical movement.

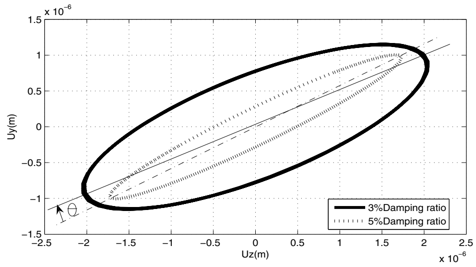

Fig. 4 The elliptical movement for different structural damping.

2.3 Contact Modeling and Results

The contact between the stator and the rotor of a two stators hybrid transducer type ultrasonic motor is modeled using surface to surface contact elements that use the augmented Lagrangian method. The surface area on one side of the motor's stator is identified as the contact surface. The surface area of a rotor on the same side with the contact surface of a stator is set as the target surface. TARGE170 is used to represent the 3D target surface for the associated contact element CONTA173. The contact elements themselves overlie the solid elements describing the boundary of the flexible body and are potentially in contact with the target surface, defined by TARGE170, which can be discretized by a set of target segment elements and is paired with its associated contact surface by a shared real constant set.

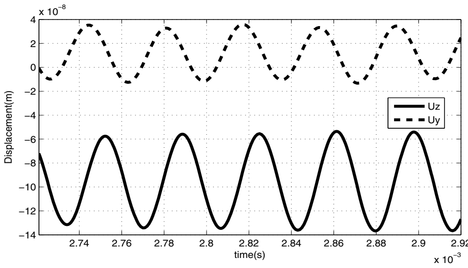

Fig. 5 Displacement at the contact surface.

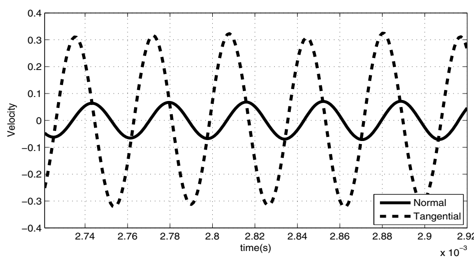

Fig. 6 Velocity at the contact surface.

The phase difference between the longitudinal displacement Uz and the tangential displacement Uy, in Fig.5,is $\pi/2$.The motion of a particle on the contact interface area between the rotor and the stator is elliptic. From the amplitude and phase difference between normal and tangential velocity depicted in Fig.6 shows that the tangential velocity Vy of the material point becomes maximum when the normal displacement Uz reaches its maximum (normal velocity=0).

3 Conclusions and Outlook

The finite element contact analysis of the stator/rotor-contact in a two stators hybrid transducer type ultrasonic motor is performed using the commercial FEM software package ANSYS 11.0 in this study. As a future work, prototype of the motor in study will be built with the size smaller than the first prototype which was proposed by Yi et al [1]. In addition, the effects of viscoelastic friction layer contact between the stator and the rotor will be studied and simulated, with different pre-loads and driving frequencies, on the contact condition of contact interface between the stator and the rotor of this motor.

References

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