Flexible Supporting and Fixing Method for Hybrid Ultrasonic Motor Using Longitudinal and Torsional Vibration Modes

Lin Yang, Chunsheng Zhao
State Key Laboratory of Mechanics and Control of Mechanical Structures,
Fundamental Science on Precision Driving Laboratory
Nanjing University of Aeronautics and Astronautics,
No. 29 Yudao Street, Nanjing 210016, China
yanglin@nuaa.edu.cn

Abstract:

A new flexible supporting and fixing method for hybrid ultrasonic motor using longitudinal and torsional vibration modes is presented. A motor casing is used to support and fix the motor, which has dual concentric bearings in opposite shell sides and a fixing column. The axis of the motor has two extended parts outside the both sides of the motor. Once the motor has been assembled completly, the two extended parts of the motor axis will be inserted into the concentric bearings, which supports the motor and restricts the X, Y degrees of freedom (DOF) and ROTX, ROTY rotating DOF of the motor. The motor has a flexible fixing piece which placed near the piezoelectric ceramics, the fixing piece is thin enough to have flexibility and it is fixed on the fixing column with glue, which restricts the Z DOF and ROTZ rotating DOF of the motor. The experiment results show that the motor working frequency with supporting and fixing changes little, compared with the frequency without the supporting and fixing, and the motor can works smoothly and steadily.

Key words: Flexible, ultrasonic motor, Longitudinal and Torsional, supporting and fixing.

1 Introduction

Hybrid ultrasonic motors using longitudinal and torsional vibration modes (LTUM)[1,2] have great practical and potential applications in optical instrument, medical device, and sunshade and energy efficiency in buildings due to its large output power with small diameter. As the LTUM needs longitudinal and torsional vibration modes to work and the nodal planes of the two modes do not conincide, it is difficult to find a suitable orthogonal plane along the shaft to support and fix the motor, especially when the motor diameter is small. In recent researches, a nodal plane of the two vibration modes is chosen to set a rigid flange to support and fix the motor[4-6], but it dose not consider the flexibility of the flange. When the motor diameter is large, the effects of the rigid supporting on the two vibration modes is small, and the motor can work properly, however, when the motor diameter is small, the effects of the rigid supporting on the two vibration modes can not be ignore as the rigid supporting may significantly change the working modes, so the motor can not work.

In order to make the LTUM with small diameter work properly in the application methioned above, a new flexible supporting and fixing method for LTUM with small diameter is presented. Taking a LTUM with diameter in 5mm as a research object, the flexible supporting and fixing structures are described, the dynamics simulations of the stator with and without fixing structure are developed by using ANSYS, and the vibration experiments for the stator and experiments for the whole motor with flexible supporting and fixing structures are also carried out.

2 Flexible supporting and fixing method

2.1 Structure of the motor

The LTUM with a mode converter is taken as the research object, as shown in Fig. 1.

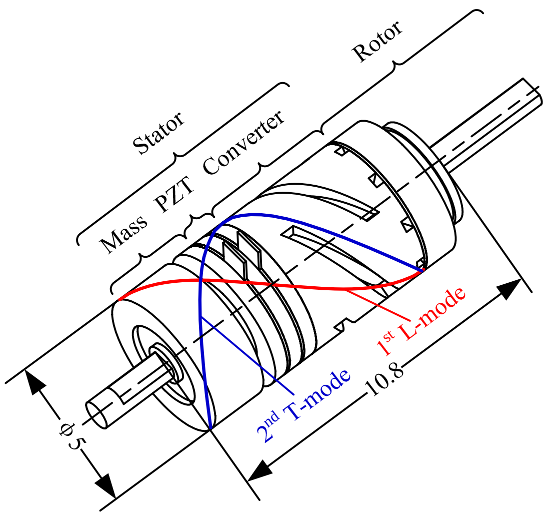

Fig. 1: Structure of the motor

The motor has two parts, one is the stator, and the other is the rotor. The stator consists of mass, a group of PZT, and converter, and PZT is sandwiched by mass and converter, here the converter is used to convert the longitudinal vibration mode to torsional vibration mode. The diameter

DOI: http://dx.doi.org/10.2314/IWPMA_63

of the motor is 5mm, and the length of the motor is 10.8mm. The first longitudinal vibration mode (1st L-mode) and the second torsional vibration mode (2nd T-mode) are chosen as working modes.

2.2 Flexible supporting and fixing method

The DOFs of the whole motor are X, Y, Z, ROTX, ROTY, and ROTZ, as shown in Fig. 2a. It can be found that the nodal plane location of the 1st L-mode (L-NP) is different from the two nodal plane locations of the 2nd T-mode (T-NP1 and T-NP2). T-NP1 and T-NP2 are located in the mass and the converter respectively, which cannot be used to set fixing device, so the fixing device should be set to L-NP. In the method, an annular copper sheet with a long foot is set between PZT and the converter, which has suitable thickness to possess flexibility. If the foot of the sheet is fixed, the Z and ROTZ DOFs of the stator will be restricted. However, the X, Y, ROTX and ROTY DOFs of the stator must to be restricted, and the ROTZ DOF of the rotor should be free, then the motor can work properly. To solve this problem, two bearings are used to support two ends of the motor shaft, as shown in Fig. 2b.

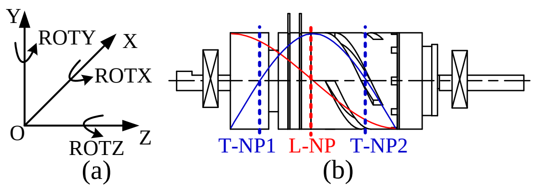

Fig. 2: DOFs of the motor and the supporting method

2.3 Flexible supporting and fixing structure

The motor should be assembled in a motor base, as shown in Fig. 3. The motor base in Fig. 3 is a simplified structure, which is used to explain the supporting and fixing structure. In the motor base, there are three columns, the first column is used to fix the fixing foot, which is glued to the column, and the second and third columns is used to set two bearings, the motor shaft is supported by bearings.

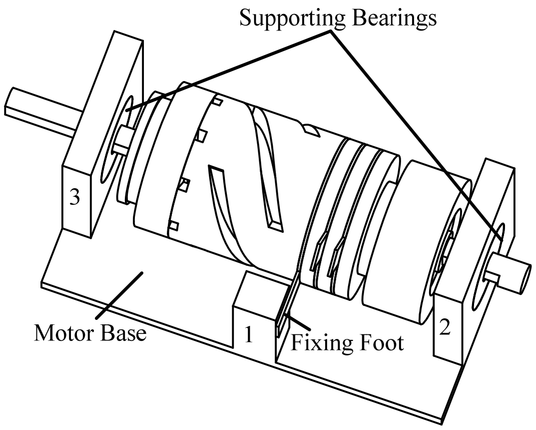

Fig. 3: Motor base and flexible supporting and fixing structure

3 Simulation and analysis of flexible fixing

The working mode of the stator is shown in Fig. 4. And the thickness of fixing sheet is important to the vibration modes.

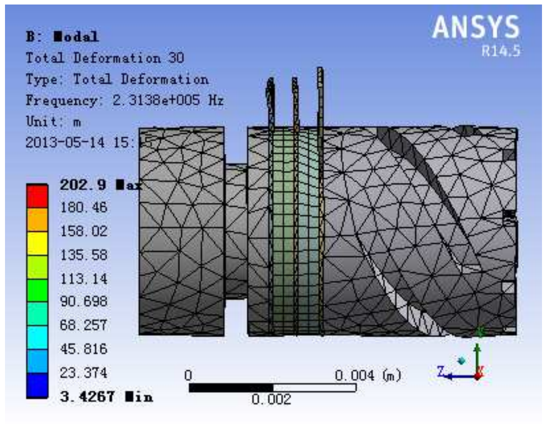

Fig. 4: Working mode of the stator

Taking the thicknesses of the fixing sheet as research object, the frequency differences can be found from Tab. 1. While the thickness of the fixing sheet increases, the difference between frequencies of the working mode with and with no fixed support increases obviously. To ensure the flexibility and strength of the fixing sheet, the thickness of 0.1mm is chosen to use.

Tab. 1: Frequency differences under various thicknesses of the fixing sheet

Thickness (mm)	Frequency(Hz) No fixed support	Frequency(Hz) Fixed support	Δ (Hz)
0.05	232270	232740	470
0.1	231380	232340	960
0.2	228360	230170	1810

Experiment

Setting the thickness of the fixing sheet as 0.1mm, and the frequency of the working mode with no fixing is tested using PSV-300F-B Doppler laser vibrometer, as shown in Fig. 5. The frequency with fixing in application is 212.2 kHz, as shown in Fig. 6, which agrees well with the testing frequency 211.64 kHz. It can be seen that the device has enough flexibility to decrease effect of fixing on vibration modes.

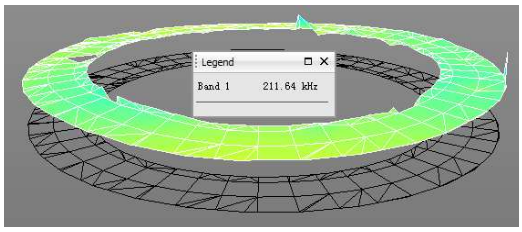

Fig. 5: Frequency testing

Fig. 6: Motor in application

DOI: http://dx.doi.org/10.2314/IWPMA_63

Conclusions

This paper represents a new flexible supporting and fixing method for LTUM, the location and the flexibility of the fixing sheet is discussed, and the experimental investigation of proto-type has validated the results of the numerical analysis.

References

[1] Lin S Y. High power ultrasonic longitudinal-torsional compound transducers[J]. Progress in Natural Science. 2001, 11: S45-S48.

[2] Guo J F, Gong S J, Guo H X, et al. Force transfer model and characteristics of hybrid transducer type ultrasonic motors[J]. Ieee Transactions on Ultrasonics Ferroelectrics and Frequency Control. 2004, 51(4): 387-395.

[3] Tsujino J, Ueoka T, Otoda K, et al. One-dimensional longitudinal-torsional vibration converter with multiple diagonally slitted parts[J]. Ultrasonics. 2000, 38(1-8): 72-76.

[4] Tsujino J, Ueoka T, Sano T, et al. Ultrasonic complex vibration welding system using 100 kHz one-dimensional longitudinal-torsional vibration converter[J]. 2000 Ieee Ultrasonics Symposium Proceedings, Vols 1 and 2. 2000: 695-698.

[5] Tsujino J, Suzuki A. Load characteristics of ultrasonic motor with a longitudinal-torsional converter and various nonlinear springs for inducing static pressure[J]. 2001 Ieee Ultrasonics Symposium Proceedings, Vols 1 and 2. 2001: 545-550.

[6] Tsujino J, Ihara S, Harada Y, et al. High frequency complex vibration systems using a complex vibration converter with diagonal slits[J]. 2003 Ieee Ultrasonics Symposium Proceedings, Vols 1 and 2. 2003: 699-702.

DOI: http://dx.doi.org/10.2314/IWPMA_63