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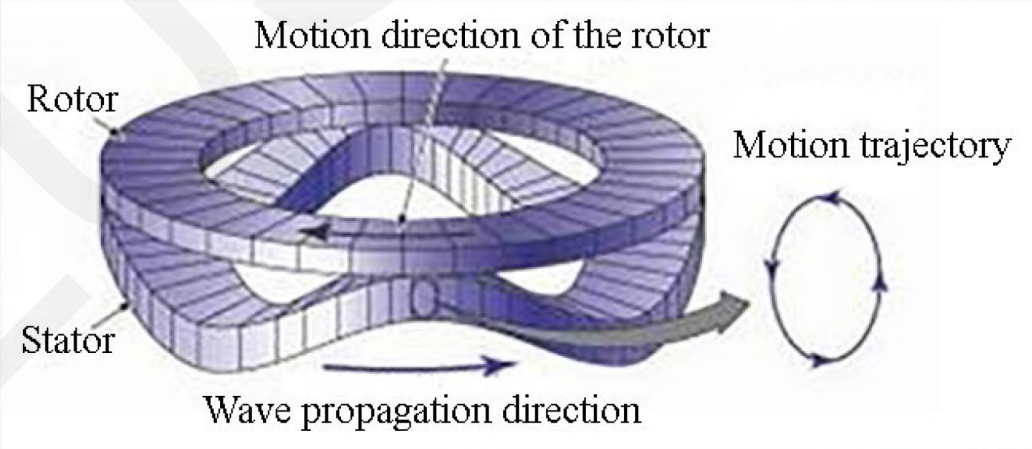
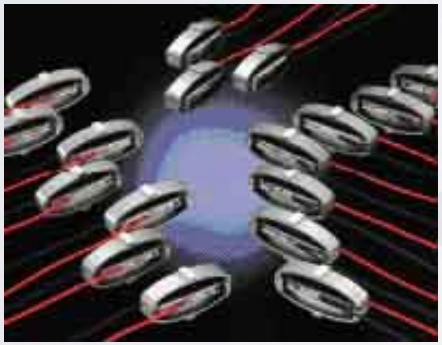
Design of an ultrasonic motor with multi-vibrators

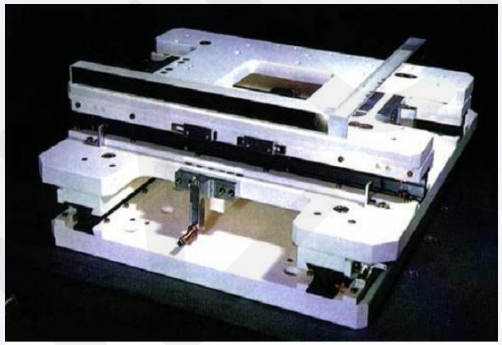


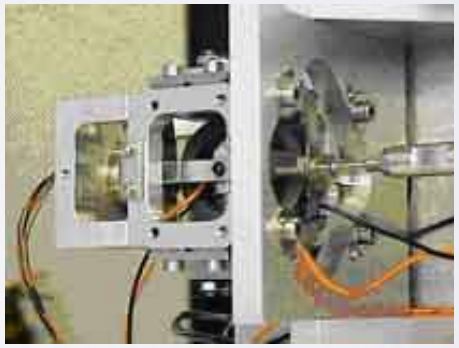
Key words:
Ultrasonic motor (USM), Standing wave, In-plane vibration, Multi-vibrator

Application of USMs

USMs are widely used in robotics, precision instruments, and aerospace engineering. Researchers have noted a specific increase in the bandwidth and output torque of multi-vibrator motors (Jin et al., 2011; Park and He, 2012; Hou et al., 2013; Zhao, 2010; Zhu et al., 2010; Oh et al., 2012). Therefore, multi-vibrator motors have become a popular research topic.

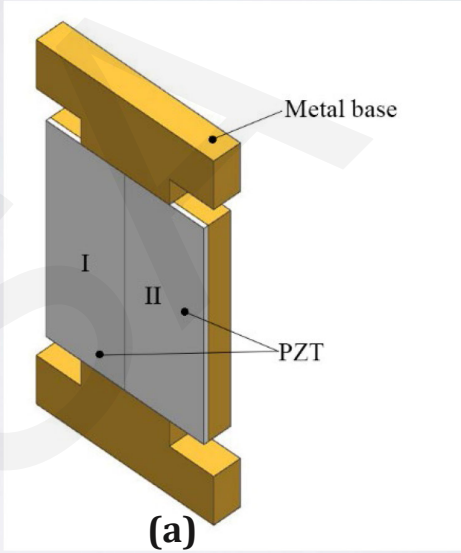






Motor design

- linear motors using in-plane longitudinal and bending modes have been mass-produced and widely used because of increased performance and compactness.
- The proposed cylindrical motor based on the circumferential plane vibration is constructed by folding multi planar vibrators.



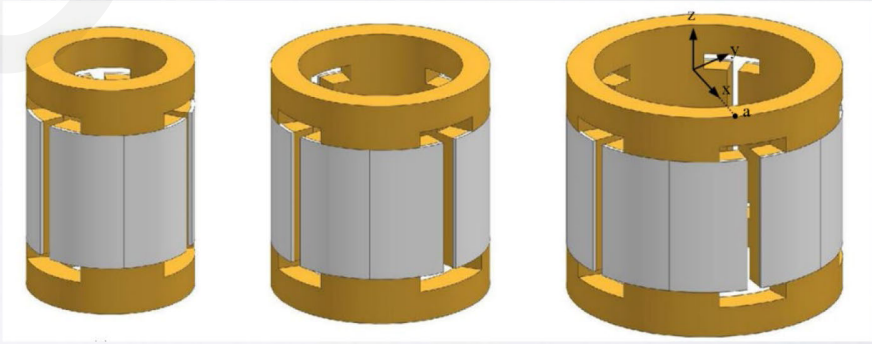
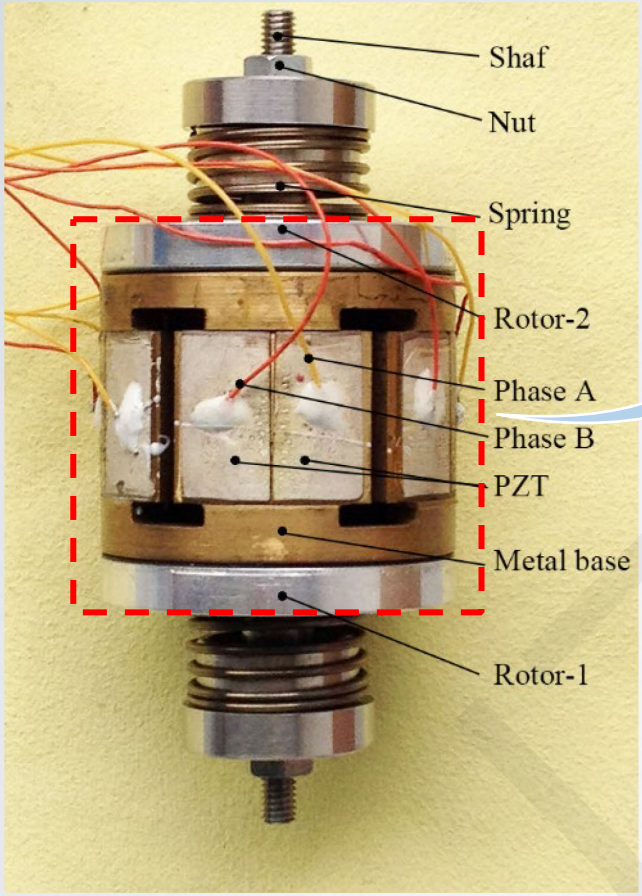
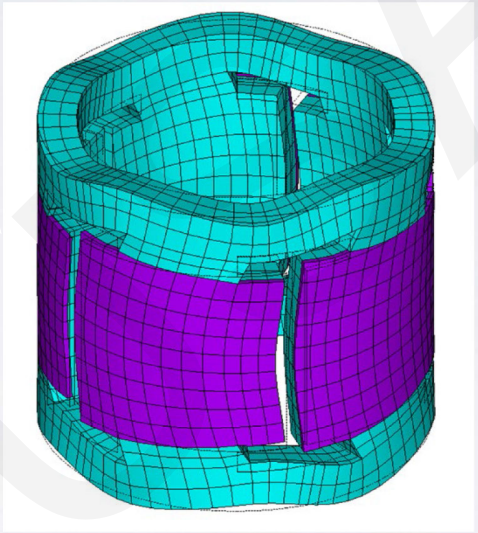


Figure 1. Design method of the proposed circumferential plane USM, a) a linear vibrator using in-plane longitudinal and bending modes, b) the proposed rotary motor constructed by folding different number of planar vibrators.

Motor structure



(a)



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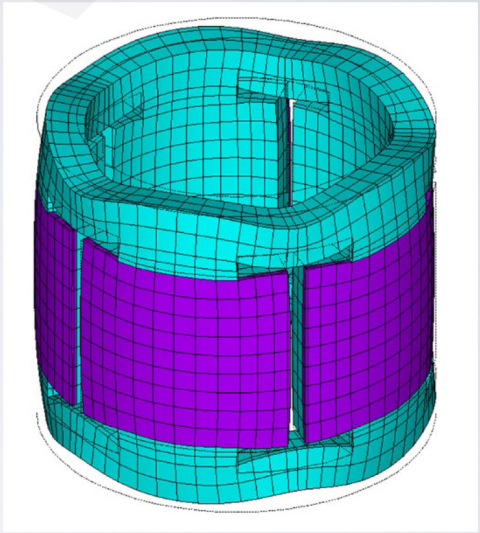
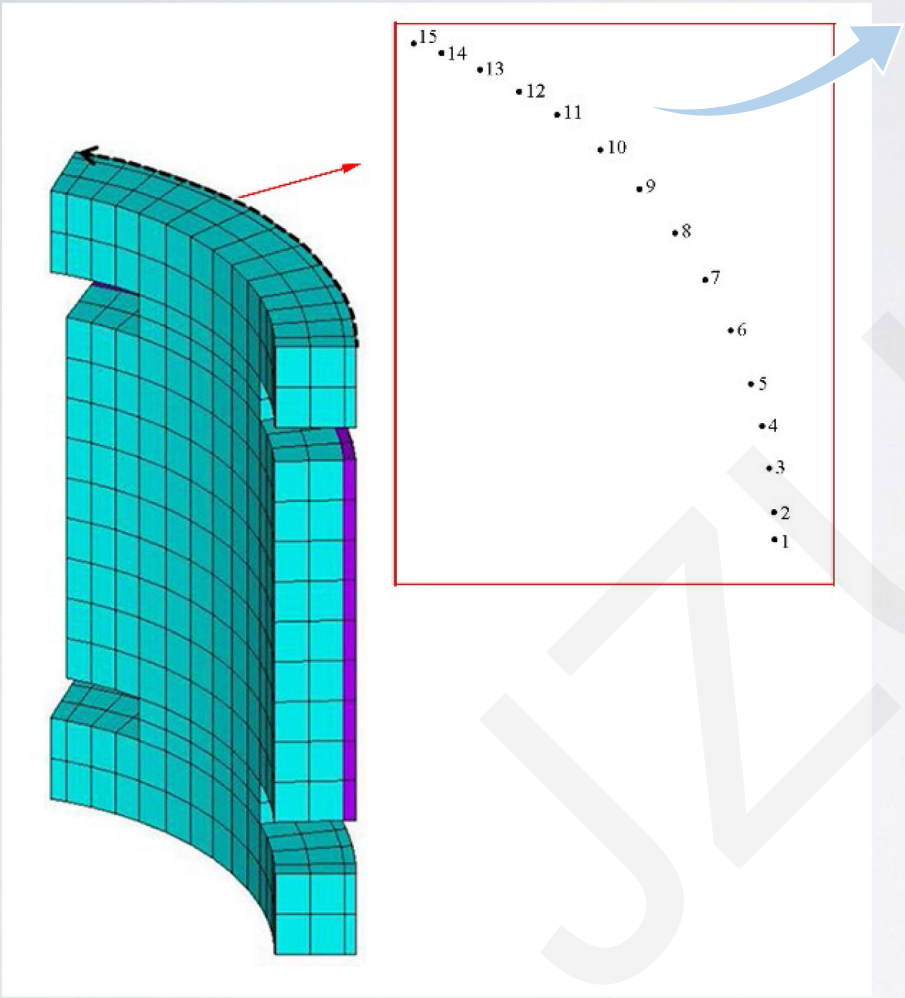


(c)

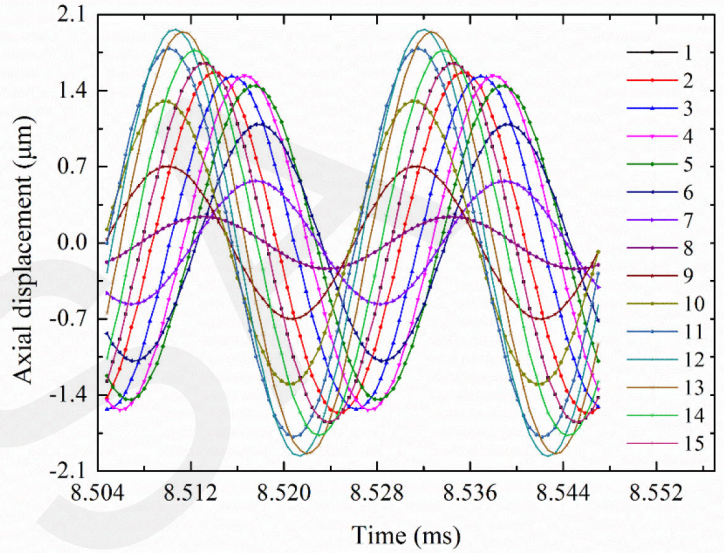
Working modes

Figure 2. Design of the proposed USM, a) the motor structure, b) the torsional mode of the stator indicated by dotted lines in Fig.2a, c) the longitudinal mode of the stator.

Simulations



(a)



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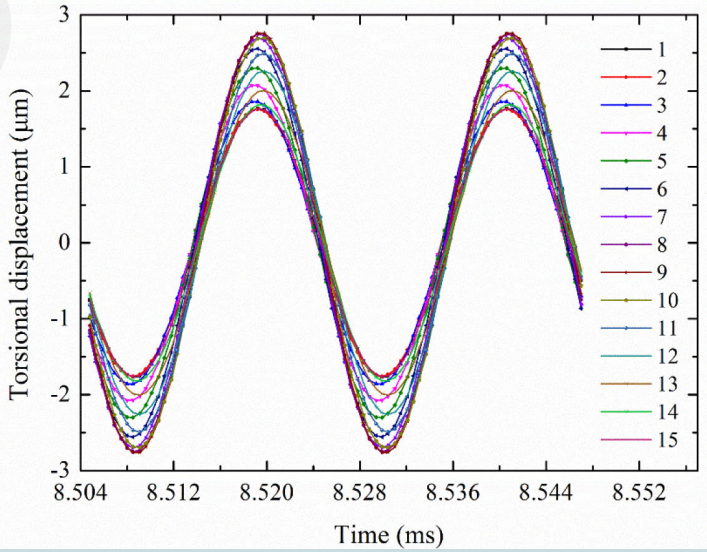
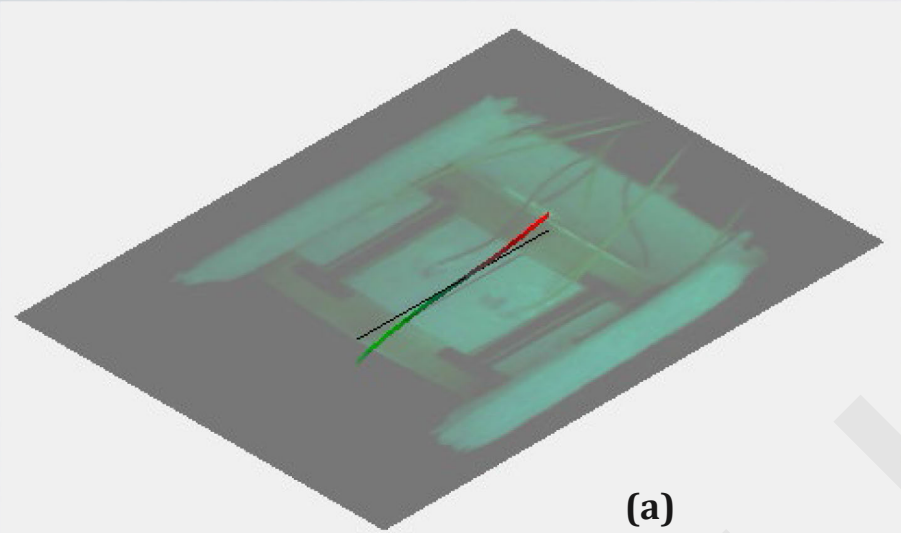


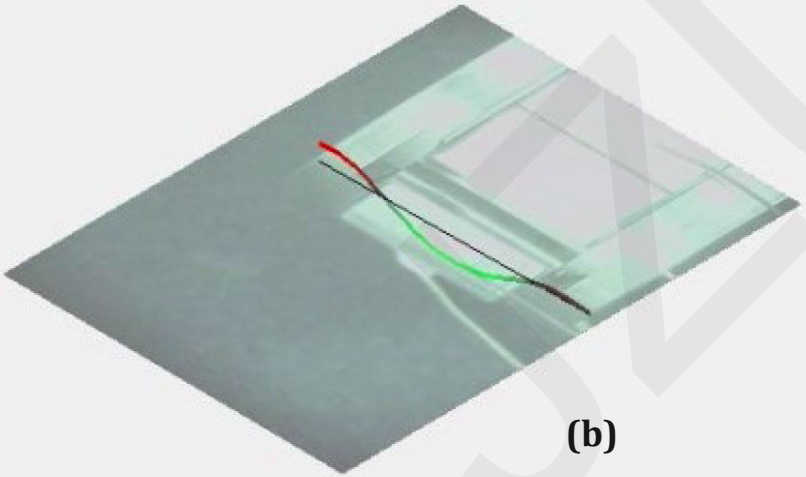
(c)

Figure 3. The obtained displacement curves of the selected 15 nodes, a) the selected 15 nodes on the surface of a vibrator, b) the longitudinal displacement curves of the 15 nodes, c) the torsional displacement curves of the 15 nodes.

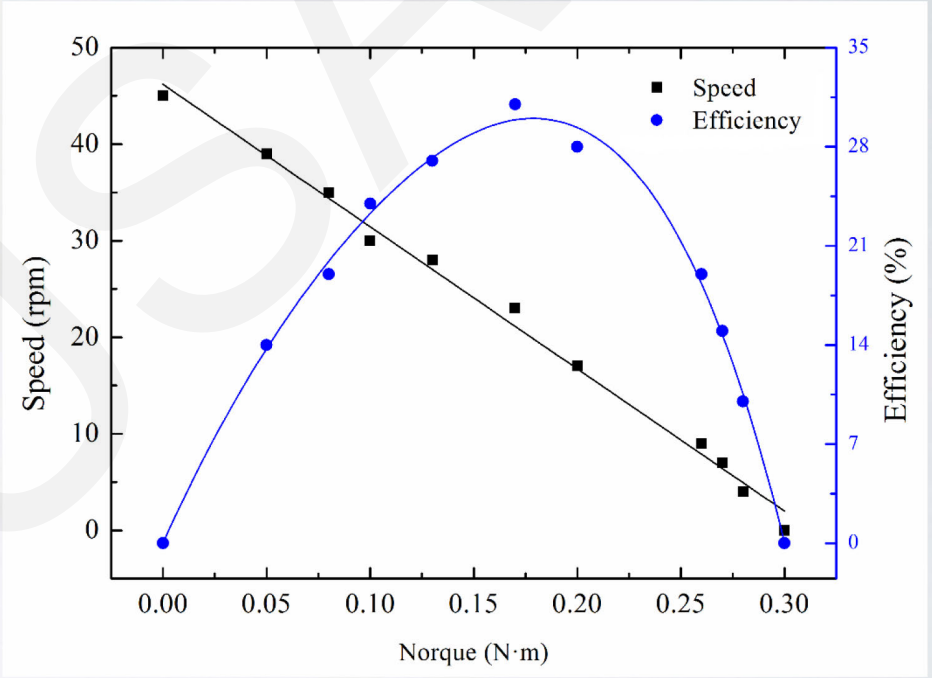
Experiments



(a)



(b)



(c)

Figure 4. The experimental results of the designed USM, a) the measured longitudinal vibration curve of the stator, b) the measured torsional vibration curve of the stator, c) the load characteristics of the motor.

Research Priorities

Research Priorities:

- Development of the existing in-plane vibration concept (*x*-*y*).
- A modal transformation method is proposed. This paper uses the differences in the bending vibration directions of the vibrators to form the torsional vibration of the stator.
- The vibrators and stator are excited to the resonance state, thereby improving the motor efficiency.
- Compared with Langevin-type vibrators, the vibrator is more suitable for miniaturization.
- Verifying the mechanism of synchronous drive by using multi-vibrators.
- The dimensions of the designed motor can be scaled down.
- The motor overcomes asynchronous issues that occur in traditional multi-vibrator motors during coordinated operations. The design method can serve as a theoretical basis for the design of multi-vibrator motors and promote the application of USMs in parallel operation.