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# A Note on a Longitudinal and Torsional Type of Ultrasonic Motor with two Stators

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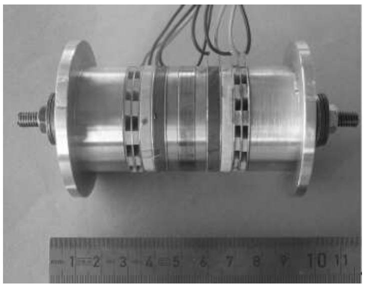
This paper deals with an ultrasonic motor, which consist of one rotor and two stators. The main parts of each stator are one longitudinal and one torsional piezoceramic actuator, which are used to generate the desired elliptical orbit on the stator surface. For the purpose of a high efficiency, the longitudinal and the torsional resonant frequency should ideally coincide with the operational frequency. To match the resonant frequencies, two adjustable rings are added to the stators. The influence of the mass and the position of the rings on the first longitudinal and the first torsional eigenfrequency and their mode shapes is investigated. The experimental results fit very well with the theoretical predictions and show that the adjusting rings can be used to match the eigenfrequencies of the two mode shapes.



## 1 Introduction

A longitudinal and torsional type ultrasonic motor (USM) consists in general of one longitudinal and one torsional PZT transducer to generate two vibrations in normal and tangential direction within the stator. Since S. Ueha firstly presented such a motor in the 1980's [1],[2] more attention has been payed to this type of motor. In this paper a similar motor is under investigation, except that for the purpose of enlarging the contact area, the rotor is placed in the middle of the motor and is driven by two stators, cf. figure 1.



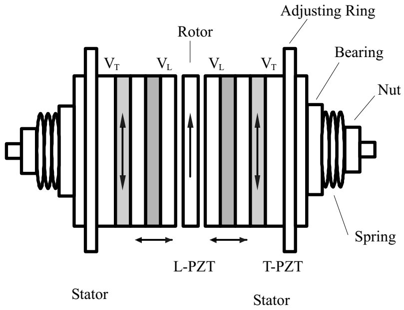



**Fig. 1** Left figure: Picture of the ultrasonic motor, right figure: sketch of the USM

The working principle of this motor is based on the superposition of the torsional and longitudinal vibration mode. The eigenfrequencies of these two mode shapes should coincide and have a temporal phase shift of 90 degree to generate an elliptical orbit on the stator surface to drive the rotor. The friction forces between rotor and stator let the rotor rotate. To match the eigenfrequencies of the two mode shapes, a new mass matching method is used. Two rings which position is adjustable are added at the end of each stator to carry out a fine tuning of the eigenfrequencies after assembly.

## 2 Finite Element Model and Results

A finite element model of the stator is generated to analyze the resonance frequencies of the longitudinal and the torsional vibration modes, the properties of the motor and the influence of the rings. The material parameters used in the models are taken from the manufacturer PI Ceramic, Germany. The longitudinal piezoceramic is of type PIC 181 and the torsional piezoceramic is a PIC 255 ceramic.

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To match the eigenfrequencies of both mode shapes two studies are carried out. Firstly the dependency of the eigenfrequencies on the mass of the ring is investigated. In a next step the influence of the position of the rings on the eigenfrequencies of the system is investigated. The results of these calculations are shown in figure 2. The first longitudinal eigenfrequency of both mode shapes decreases with an increase of the mass of the ring. Both eigenfrequencies show the same tendency when the mass of the ring is changed. Therefore, it is impossible to obtain better results regarding the matching of both mode shapes only by changing the mass of the ring. The right figure shows that the first longitudinal eigenfrequency is more or less independent on the position of the ring while the first torsional eigenfrequency is much affected by this parameter. When the rings are moved to a certain position, the eigenfrequency of the first longitudinal mode shape has the same value as the first one of the torsional mode. The matching frequency can be determined to 20.8 kHz.

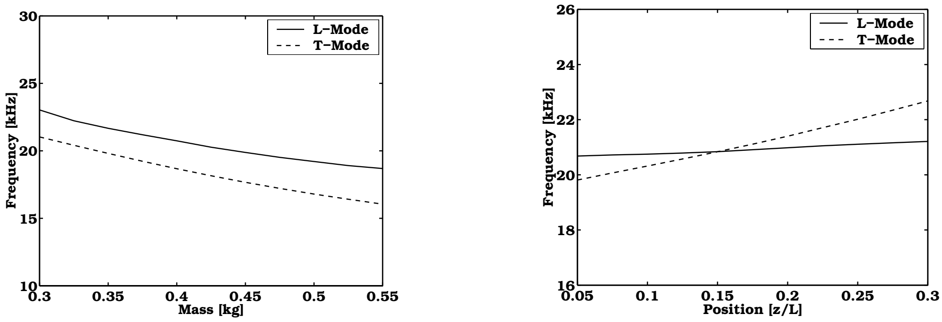


**Fig. 2** Influence of the mass of the ring (left) and position of the ring (right) on the first eigenfrequencies

In the experiments the eigenfrequency of the longitudinal and the torsional vibration are excited with 90 degrees phase shift. The eigenfrequencies of these two vibration modes are measured by a laser vibrometer. As a result the measured eigenfrequency shows a value of 19.5 kHz for the longitudinal mode and 17.7 kHz for the torsional mode respectively, in case the ring is located at the end of the stators, cf. figure 3. The presented ultrasonic motor shows similar behavior as the theoretical predictions. The speed of the rotor reaches 92 rpm at the operation frequency of 19.0 kHz without load. Compared with the FE results, which predicted an eigenfrequency for the longitudinal mode shape of 20.8 kHz, the experimental value of 19.0 kHz shows a quite good correspondence in spite of a lot of simplifications were made in the FE analyzes, e.g. the influence of the glues, the contact between stator and rotor were neglected and the material behavior was assumed to be linear. The idea to use the adjusting rings to fit the longitudinal and the torsional mode eigenfrequencies is obviously successful.

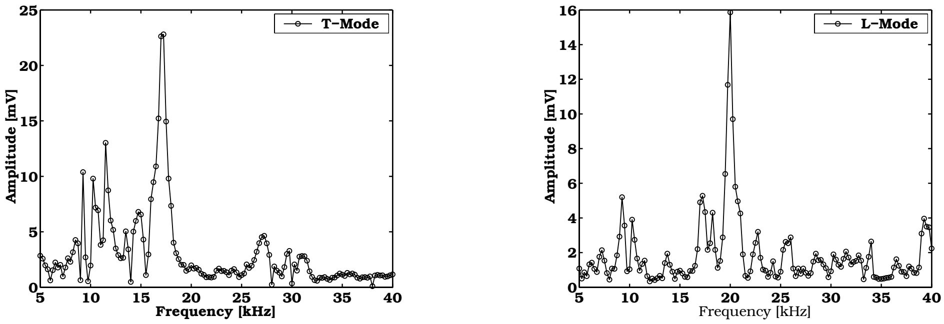


**Fig. 3** Measured surface velocities, left: torsional mode, right: longitudinal mode

## 3 Summary and Outlook

A new longitudinal and torsional piezoelectric ultrasonic motor with two stators is presented in this paper. The two adjusting rings on the stator can be utilized to match the first resonance frequencies of the longitudinal and the torsional mode shapes. A FE model of the stator is generated and the theoretical results show that by changing the position of the rings the first resonance frequency of the longitudinal vibration coincides with the first torsional vibration mode. In the experiments the present motor behaves similar to the theoretical predictions.

## References

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