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Vibration Analysis of the Complex Bar Resonator with Longitudinal-torsional Vibration Converter

縦ねじり変換器を有する複合型細棒振動子の振動解析

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1. Introduction

In the field of high power ultrasonics, the ultrasonic rotating devices utilising the complex vibration mode were already studied using longitudinal-torsional vibration converter to realize a large torque [1]. The authors have already reported that the complex bar resonator capable of simultaneously driving the longitudinal mode and the torsional mode can be realized by inserting a longitudinal-torsional vibration converter into a part of the resonator [2)-4)]. In this study, the characteristics between the length of the converter and the complex vibration displacements were calculated by the finite element method. First, the relationship between the resonance frequency of the resonator and its complex vibration mode was analyzed with respect to the length of the converter. Next, the displacement distributions of the complex vibration mode of the resonator were analyzed and the complex vibration displacement ratio was examined. Furthermore, the relationship between the insertion position of the converter and the vibration characteristics was clarified.

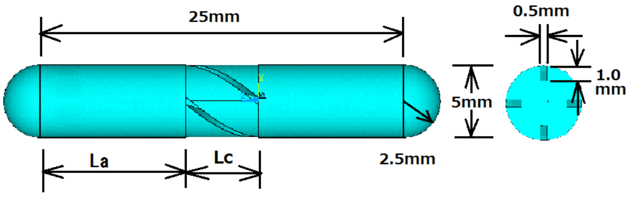
2. Structure of complex bar resonator

Figures 1 shows the finite element model of the complex bar resonator with a longitudinal-torsional vibration converter. The resonator with 4 diagonally slits on a convertor is shown in Fig.1(a), and the resonator with 8 diagonally slits is shown in Fig.1(b). The resonance frequency, vibration mode and displacement of the complex bar resonator were calculated by the finite element program of ANSYS ver.16 (Cybernet Co., Ltd.). The dimentions and the material constants of the resonator are shown in **Table 1** and **2**, respectively.

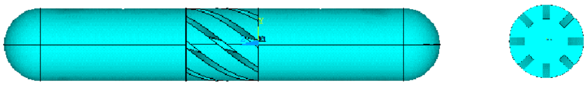
3. Results of finite element analysis

3.1 Calculated results of complex vibration ratio

Figure 2 shows the calculated results of resonance frequencies on the complex resonators. When the converter length of Lc increased, the resonance frequencies in the torsional and the longitudinal modes decreased gradually. The complex vibrations



(a) converter with 4 slits



(b) converter with 8 slits

Fig.1. FEM model of complex bar resonator.

Table 1. Dimensions of resonator (Unit: mm).

Length L	Converter length Lc	Diameter D	Indenter radius r
25	variable	5	2.5
Slit width Ws	Slit depth d	Converter location La	
0.5	1.0	variable	

Table 2. Material constants of resonator.

Young's modulus E (N/m^2)	1.99×10^{11}
Poisson's ratio σ	0.34
Density ρ (kg/m^3)	7900

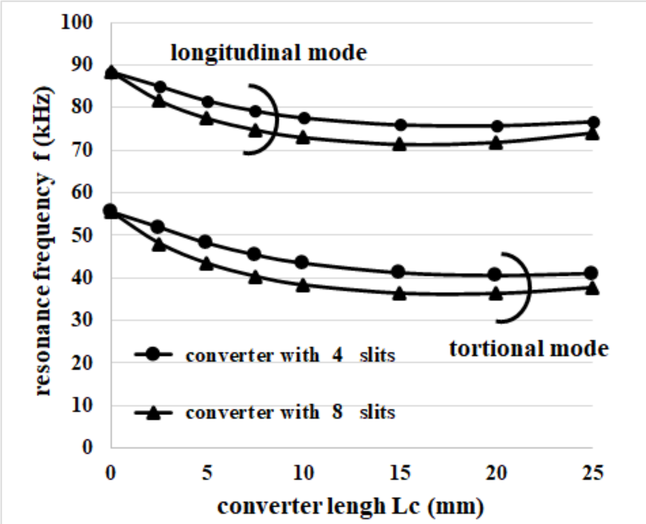


Fig.2. Calculated results of resonance frequencies.

of the longitudinal and the torsional mode were confirmed except the case for Lc=0mm.

Figure 3 shows the vibration displacement of the complex bar resonator with a frequency of 77kHz at Lc=5mm in Fig.2. It was confirmed that this

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complex vibration was mainly a longitudinal mode superimposed by a torsional mode. **Figure 4** shows the examined results of the complex vibration displacement ratio when the converter length is changed. The complex vibration ratios between the longitudinal mode and the torsional mode were expressed as $U_x/U_{z\ max}$ and $U_z/U_{x\ max}$. The complex vibration ratio of $U_x/U_{z\ max}$ was mainly a longitudinal mode superimposed by a torsional mode. The ratio of $U_z/U_{x\ max}$ was mainly a torsional mode superimposed by a longitudinal mode. It became clear that the complex vibration ratio increased as the converter length increased. At the same converter length, the complex vibration ratio became larger when the main vibration was longitudinal mode.

3.2 Vibration characteristics of complex bar resonator

The characteristics of a complex vibration were examined in which the main vibration was longitudinal mode and the secondary vibration was tortional mode. **Figure 5** shows the vibration characteristics of complex bar resonator in case that Lc=5mm depending on the insertion position of the converter with 8 slits. The relative displacement distribution of the complex bar resonator was shown in Fig.5(a). The relative displacement was expressed as U_z/U_{max}, where U_z was the displacement in z direction at the center of the resonator and U_{max} was the maximum displacement of the resonator. When the converter was in the center of the complex bar resonator, the resonator would vibrate symmetrically. In case that the insertion position of the converter deviated from the center, asymmetrical vibration displacement characteristics could be obtained. The elastic strain distribution of S_{zz} in main longitudinal mode was shown in Fig.5(b). If the position of the converter deviated from the center of the resonator, the maximum strain value decreased. It was found that the maximum strain value was obtained at the place where the converter was inserted.

4. Conclusion

The vibrational characteristics of complex bar resonator using a longitudinal-torsional converter were examined by the finite element method. It was clarified that the vibrational characteristics when the length and insertion position of the converter were changed.

References

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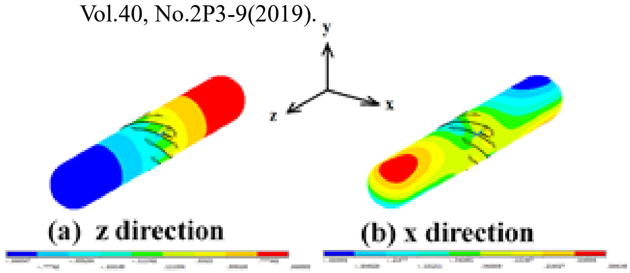


Fig.3. Vibration displacements of bar resonator.

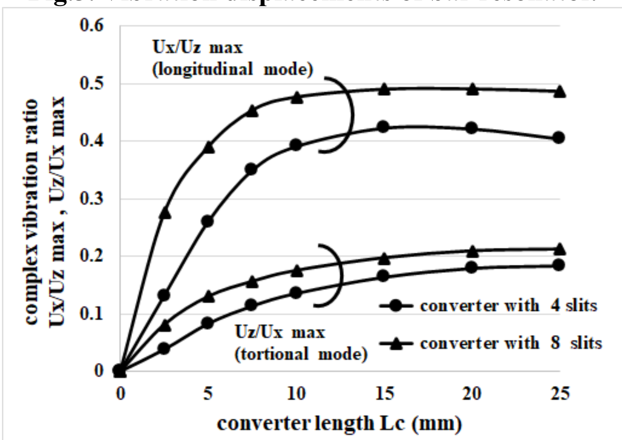
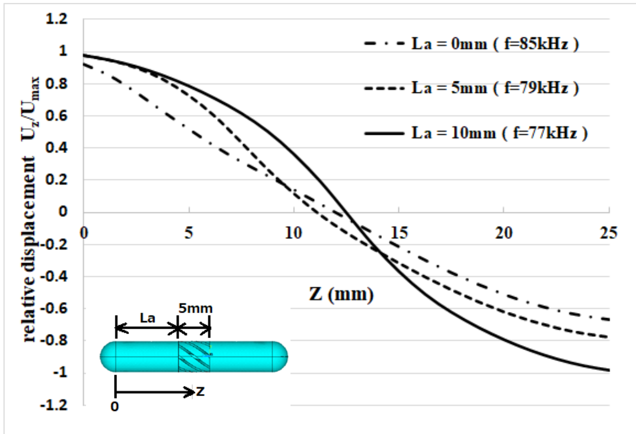
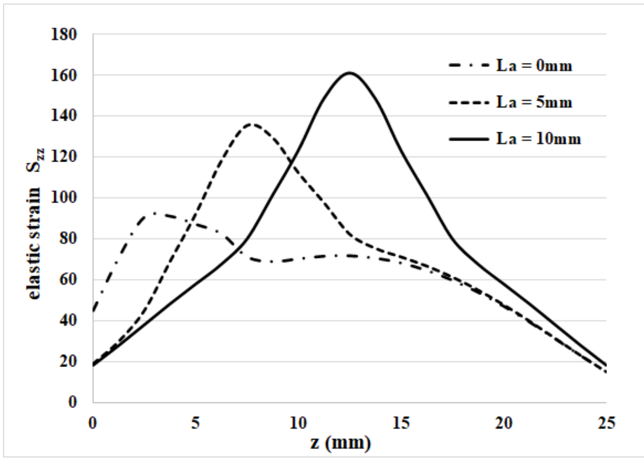


Fig.4. Characteristics of complex vibration ratio.



(a) relative displacement distribution.



(b) elastic strain distribution.

Fig.5. Vibration characteristics of the complex bar resonator (Lc=5mm).