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

Subaru Kudo (Ishinomaki Senshu Univ.)

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),2)]. The authors have already reported that the complex bar resonator capable of simultaneously driving the longitudinal mode and the torsional mode could be realized by inserting a longitudinal-torsional vibration converter into a part of the resonator [3)- 6)]. In this study, the characteristics between the number of slit on converter and the complex vibration displacements were calculated by the finite element method. First, the relationship between the resonance frequencies of the bar resonators and these complex vibration modes were analyzed with respect to the number of slit on the converter. Next, the displacement distributions of the complex vibration modes of the resonators were analyzed and the complex vibration displacement ratios were examined. Furthermore, the relationships between the number of slit on the converter and the vibration characteristics were clarified.

2. Structure of complex bar resonator

Figure 1 shows the finite element model of the complex bar resonator with a longitudinal-torsional vibration converter. The resonator with 2 diagonally slits on a convertor is shown in Fig.1(a), and the resonator with 3 diagonally slits is shown in Fig.1(b). The resonance frequencies, vibration modes and displacements of the complex bar resonators were calculated by the finite element program of ANSYS ver.16 (Cybernet Co., Ltd.). The dimentions and the material constants of the bar resonator are shown in **Table 1** and **2**, respectively.

3. Results of finite element analysis

3.1 Calculated results of resonance frequencies

Figure 2 shows the calculated results of resonance frequencies on the complex bar resonators. When the slit depth of the converter increased, the resonance frequencies in the torsional and the longitudinal modes decreased gradually. The complex vibrations of the longitudinal and the torsional mode were confirmed except the case for d=0mm.

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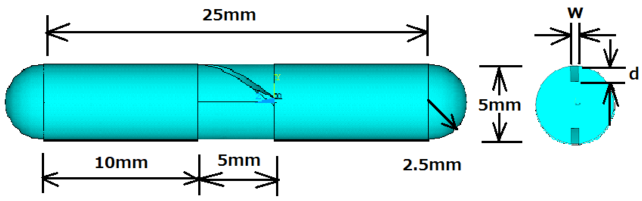
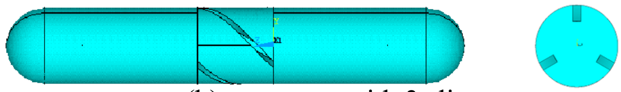
kudou@isenshu-u.ac.jp



(a) converter with 2 slits



(b) converter with 3 slits

Fig.1. FEM model of complex bar resonator.

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

Length L	Converter length Lc	Diameter D	Indenter radius r
25	5.0	5	2.5
Slit width W	Slit depth d	Converter location La	
variable	variable	10.0	

Table 2. Material constants of bar resonator.

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

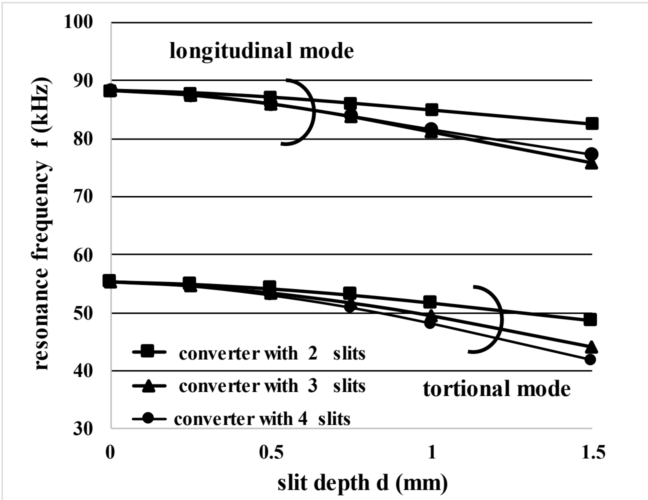


Fig.2. Calculated results of resonance frequencies. (w=0.5mm)

3.2 Displacement analysis of complex vibration modes

Figures 3(a) and **3(b)** show the vibration displacement of the complex bar resonator with 3 slits of d=1.0mm in Fig.2. It was confirmed that this vibration mode was a complex mode combining a main longitudinal mode superimposed by a torsional mode. **Figure 4** shows the relative displacement distribution of the complex vibration mode on the bar resonator in Fig.3. The relative displacements are expressed as U_x/U_0 and U_z/U_0, where U_x is the vibration displacement in the x direction at the side face of the resonator, U_z is the displacement in the z direction at the center axis and U_0 is the maximum displacement of the resonator. Comparing the displacement of U_x/U_0 with that of U_z/U_0, the longitudinal vibration is the main mode because the maximum displacement of the center axis on the resonator is larger than the maximum displacement of the side face.

3.3 Analysis of complex vibration displacement ratio.

Figure 5 shows the examined results of the complex vibration displacement ratio in the case that d=1.0mm. The complex vibration ratios between the longitudinal mode and the torsional mode are expressed as U_x/U_{zmax}. The ratio of U_x/U_{zmax} is mainly a longitudinal mode superimposed by a torsional mode. It became clear that the complex vibration ratio increased as the slit width increased. As the slit width was 0.5mm or more, the vibration ratios were almost the same. On the other hand, **Fig.6** shows the characteristics of complex vibration ratio U_x/U_{zmax} in the case that w=0.5mm. It became clear that the ratio of U_x/U_{zmax} increased as the slit depth increased. At the same slit depth, complex vibration ratio became larger when the number of silt on the converter was large.

4. Conclusion

The vibrational characteristics of complex bar resonator using a longitudinal-torsional converter were examined by the finite element method. The characteristics of complex vibration displacement ratios were clarified when the number of slits on the converter were changed.

References

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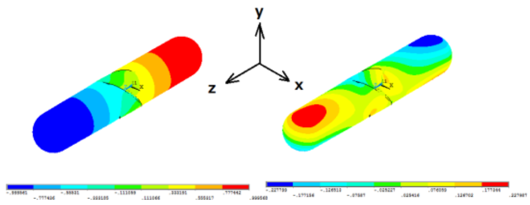

Fig.3. Vibration displacements of bar resonator (slit number 3, d=1.0mm,w=0.5mm, f=81kHz).

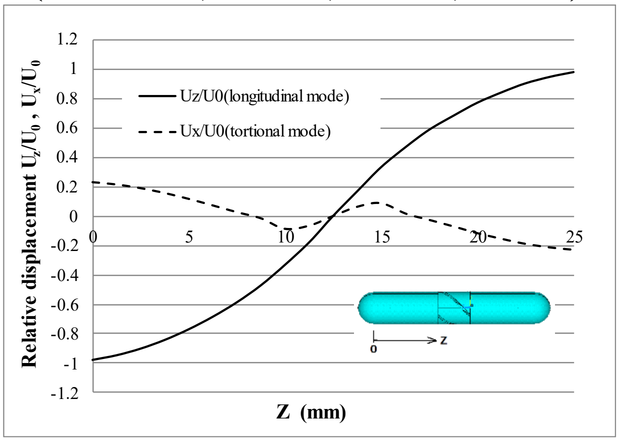

Fig.4. Relative displacement distribution of complex bar resonator in Fig.3.

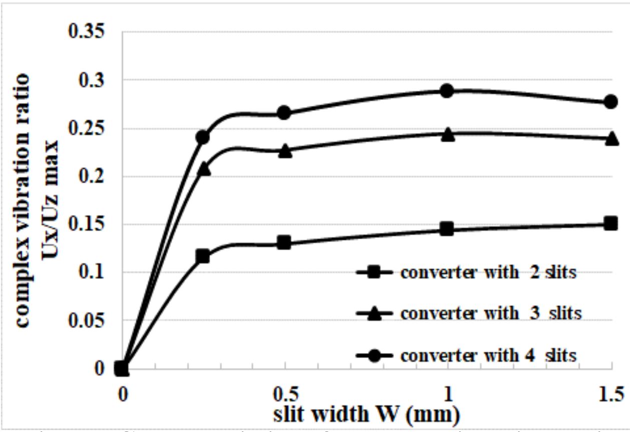

Fig.5. Characteristics of complex vibration ratio I (d=1.0mm).

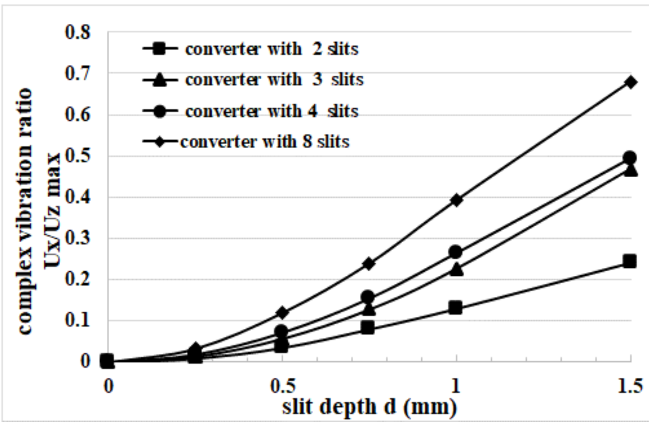

Fig.6. Characteristics of complex vibration ratio II (W=0.5mm).