2P3-4

Vibration analysis of tactile sensor using complex resonator with longitudinal-torsional vibration converter

縦ねじり変換器を有する複合振動子を用いた触覚センサの振動解析

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1. Introduction

Various piezoelectric vibratory tactile sensors have been proposed for measuring the softness and hardness of an object [1-5]. They make use of the resonance frequency changes on resonators, which are induced when their vibrating indenters are brought into contact with an object. The sensitivity of the tactile sensor in terms of the frequency change is inversely proportional to the equivalent mass of the resonator [6]. The equivalent mass is dependent on the vibration mode of resonator. Then, the sensitivity could be high when utilizing the complex vibration modes of the resonator. In the field of high power ultrasonics, the ultrasonic mortors utilising the complex vibration mode were already studied using the longitudinal-torsional vibration converter to realize a large torque [7]. In this paper, the complex resonator for tactile sensor using the longitudinal- torsional vibration converter is analyied using the finite element method.

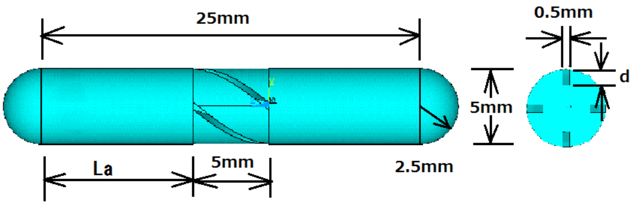
2. Structure of tactile sensor

The complex resonator with the longitudinal-torsional vibration converter is adopted as a tactile sensor. Figure 1 shows the finite element model of complex resonator. The longitudinal-torsional vibration converter consists of cylinder with 4 diagonally slits in Fig.1(a) and 8 diagonally slits in Fig.1(b). The resonance frequency, vibration mode and displacement of the complex resonator are calculated by the finite element method. The dimentions and the material constants of the resonator are shown in Table 1 and 2, respectively.

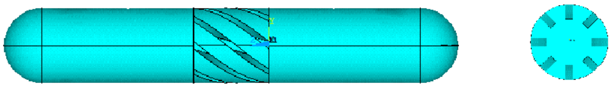
3. Results of finite element analysis

3.1 Calculated results of resonance frequencies

Figure 2 shows the calculated results of resonance frequencies on the complex resonator composed a converter with 4 slits in Fig.1(a). When the silt depth of the converter increased, the resonance frequencies in first torsional and longitudinal modes decreased gradually. The resonance frequency in second torsional mode hardly changed.



(a) converter with 4 slits



(b) converter with 8 slits

Fig.1. FEM model of complex resonator.

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

Length L	Converter length Lc	Diameter D	Indenter radius r
25	5	5	2.5
Slit width Ws	Slit depth d	Converter location La	
0.5	variable	10	

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

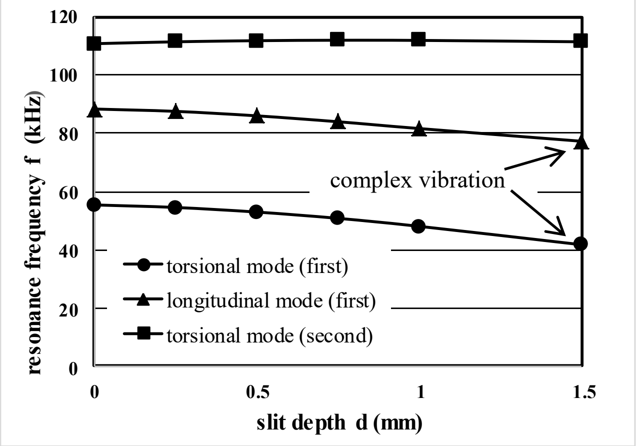


Fig.2. Calculated results of resonance frequencies 1 (converter with 4 slits).

The complex vibrations were confirmed in first torsional vibration and first longitudinal vibration in the case of d=1.5mm. On the other hand, Fig.3 shows the calculated results of resonance

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frequencies on the complex resonator composed a converter with 8 slits in Fig.1(b). As in the results shown in Fig.2, the resonance frequencies showed a tendency to decrease. The rate of decrease in resonance frequency was larger than when using the complex resonator composed a converter with 4 slits. From the calculated results in Fig.3, it was confirmed that the complex vibrations were obtained in first torsional mode and first longitudinal mode at d=1.0 and 1.5mm.

3.2 Displacement analysis of complex vibration mode

Figure 4(a) and 4(b) show the vibration displacement of the complex resonator with a frequency of 33kHz at d=1.5mm in Fig.3. It was confirmed that this vibration mode was a complex mode combined a torsional mode and a longitudinal mode. Figure 5 shows the relative displacement distribution of the complex resonator in Fig.4. The relative displacements are expressed as U_x/U_{max} and U_z/U_{max}, where U_x is the vibration displacement in x direction at the side face of the resonator, U_z is the displacement in z direction at the center one and U_{max} is the maximum displacement of the resonator. Comparing the displacement of U_x/U_{max} with that of U_z/U_{max}, it can be seen that the torsional vibration is the main mode because the displacement of the side face on the resonator is larger than the displacement of the center one. On the other hand, Fig.6 shows the relative displacement distribution of complex resonator on 71kHz at d=1.5mm in Fig.3. It is clarified that this complex vibration is mainly a longitudinal mode superimposed by a torsional mode.

4. Conclusion

The characteristics of complex resonator using a longitudinal-torsional converter were examined by the finite element method. It was clarified that the conditions for causing the complex vibration combined a longitudinal mode and a torsional mode. This work is partially supported by a grant from Ishinomaki Senshu University.

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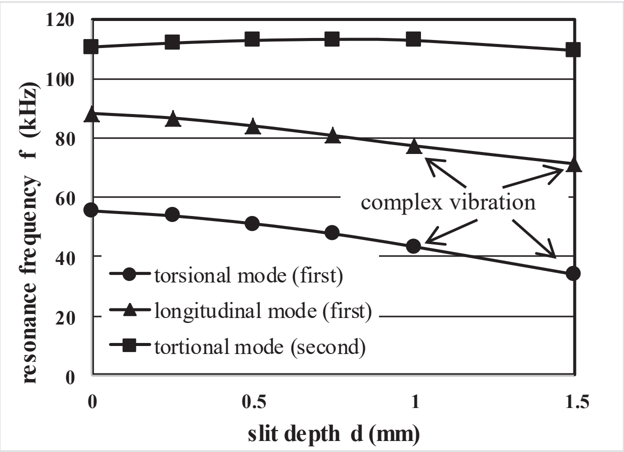
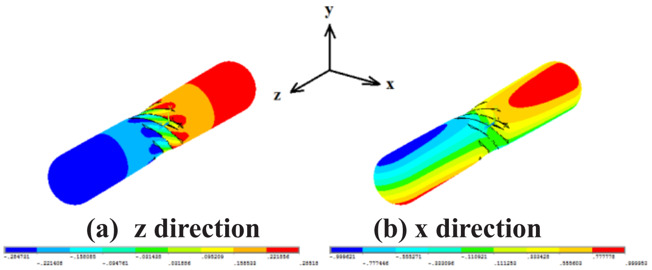


Fig.3. Calculated results of resonance frequencies 2 (converter with 8 slits).



(a) z direction

(b) x direction

Fig.4. Vibration displacements of complex resonator on 33kHz at d=1.5mm in Fig.3.

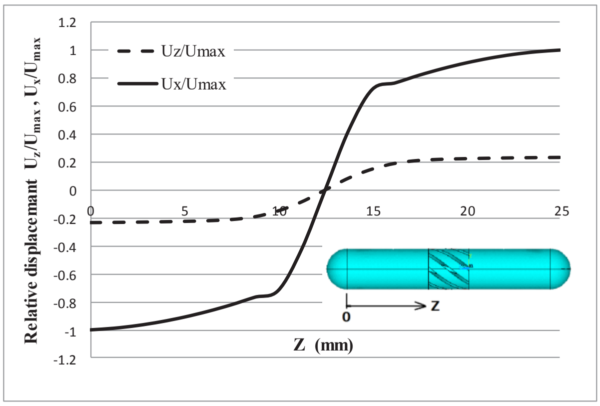


Fig.5. Relative displacement distribution of complex resonator in Fig.4.

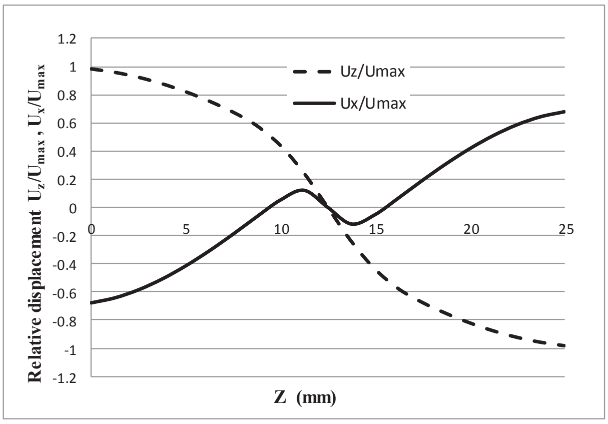


Fig.6. Relative displacement distribution of complex resonator on 71kHz at d=1.5mm.