L-43

Development to Hole Machining by Ultrasonic Complex Vibration
-Vibrator Driven by Two Resonance Frequencies-

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Abstract: Complex vibration sources that use diagonal slits as a longitudinal-torsional vibration converter have been applied to ultrasonic motors, ultrasonic rock drilling, and ultrasonic welding. However, there are few examples of the application of these sources to ultrasonic machining in combination with an abrasive. Accordingly, a new method has been developed for machining of holes in brittle materials by using the ultrasonic longitudinal and torsional vibrator with a diagonal slit of converter. In this paper, the complex vibration characteristics were measured at the case of the vibrator driven by the signal adding longitudinal and torsional resonance frequencies.

1. Introduction

Currently, the combination of ultrasonic vibration and polishing slurry is used as an effective method to machine holes in brittle materials. We have investigated the use of ultrasonic longitudinal-torsional vibrator with the diagonal slits of converter for the machining of holes.[1] So far, the vibrator had been driven at a single resonance frequency. Therefore, the vibration trajectory of longitudinal-torsional vibration of the tip side had become a straight line trajectory or elliptical trajectory. In order to further improve the machining accuracy and machining speed, we assumed that the intricate vibration trajectory obtain by applying two different frequencies. In this paper, the vibration trajectory was measured at the case of the vibrator driven by the signal adding longitudinal and torsional resonance frequencies.

2. Ultrasonic vibration source

Figure 1 shows the ultrasonic vibration source. The ultrasonic vibration source consists of a 20 kHz bolt-clamped Langevin-type transducer, an exponential horn for amplitude amplification, and the uniform rod with diagonal slits. Figure 2 shows a uniform rod (slits center position x = 58 mm). The dimensions are as follows: length, 120 mm; cross-sectional area of transducer side, S_1; cross-sectional area of tip side, S_2; and the cross-sectional areas ratio, S_1/S_2, 1.0. The horizontal axis in Fig. 2 indicates the measurement position x along the length of the sources.

The exterior appearance of the diagonal slits is shown in Fig. 3. Furthermore, slits center position x was the two conditions. x = 58 mm is obtained the maximum

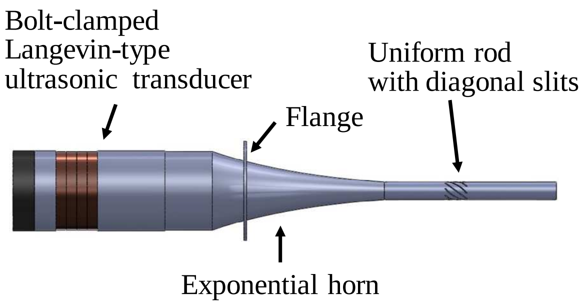


Fig. 1 Ultrasonic vibration source.

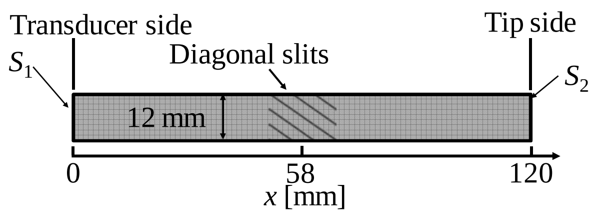
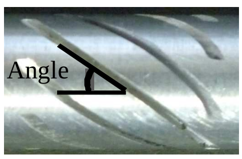


Fig. 2 Uniform rod with diagonal slits (slits center position: x = 58 mm).



Center position: x = 58, 30 mm
Slit length: 19 mm
Slit groove width: 0.5 mm
Slit depth: 3.5 mm
Slit inclination angle: 35°
Slit number: 8

Fig. 3 Appearance of the diagonal slit part and the slits condition used in this study.

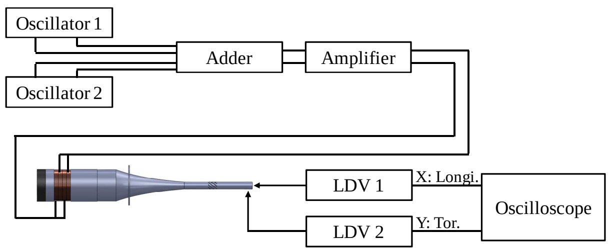


Fig. 4 Measurement circuit.

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complex vibration at the longitudinal resonance. In the case of x = 30 mm, the only longitudinal or torsional vibration are obtained by longitudinal or torsional resonance, respectively.[2]

3. Vibration trajectory of longitudinal-torsional vibration at the tip side

The vibration trajectories were generated of the tip side of the uniform rods in case of the signal of at the longitudinal or torsional resonance frequency and the signal of adding the longitudinal and torsional resonance frequencies. The measurement circuit is shown in Fig. 4. In the figure, an experiment measuring longitudinal-torsional vibration amplitude at the tip side was conducted by two laser Doppler vibrometer (LDV). Table 1 shows the measurement conditions. Measurements were carried out at these conditions. Figures 5, 6 and 7 show the vibration trajectory for the longitudinal-torsional vibration at the tip side. The vertical and horizontal axes represent the torsional vibration and the longitudinal vibration amplitude, respectively. According to Figs. 5 and 6, the vibration trajectories are a simple straight line trajectory or elliptical trajectory in both cases of slits center position and resonance frequency. This is because vibrator driven by a single longitudinal or torsional resonance frequency. On the other hand, Fig. 7 shows the intricate vibration trajectory. It was found that an intricate vibration trajectory is obtained by the signal adding longitudinal and torsional resonance frequency. The slits center position x = 30 mm is lager vibration trajectory compared to x = 50 mm. We considered that the maximum longitudinal vibration can be applied effectively for the processed object in the case of x = 30 mm.

4. Conclusions

The vibration trajectory was measured at the case of the vibrator driven by the signal adding longitudinal and torsional resonance frequencies. In the result, intricate vibration trajectory was found to be obtained by applying the two resonance frequencies.

References

1) T. Asami and H. Miura : The 20th International Congress on Acoustics (2010) 448.

2) T. Asami and H. Miura : Jpn. J. Appl. Phys. **50** (2011) 07HE31.

Table 1 Measurement condition.

	Slit center position x = 58 mm		
	Longitudinal resonance	Torsional resonance	Longitudinal + Torsional
Frequency [kHz]	19.25	18.55	19.25+18.55
Input voltage [V_{p-p}]	25	25	25+25
	Slit center position x = 30 mm		
	Longitudinal resonance	Torsional resonance	Longitudinal + Torsional
Frequency [kHz]	19.49	19.10	19.49+19.10
Input voltage [V_{p-p}]	25	25	25+25

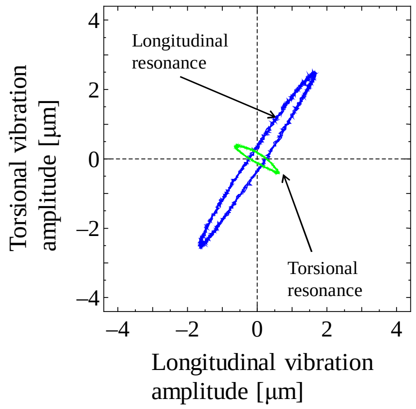

Fig. 5 Vibration trajectory in the case of x = 58 mm.

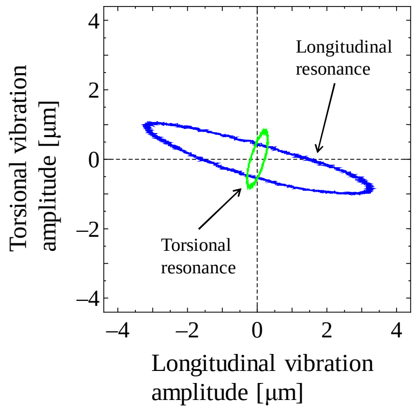

Fig. 6 Vibration trajectory in the case of x = 30 mm.

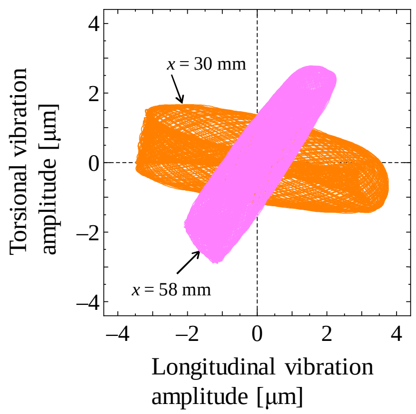

Fig. 7 Vibration trajectory at vibrator driven by two resonance frequencies.