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Longitudinal and Torsional Vibration Characteristics of Hollow-type Stepped Horn Required for Hole Machining by Complex Ultrasonic Vibration
超音波複合振動による穴あけ加工のための
中空型ステップホーンの縦 - ねじり振動特性

Takuya Asami† and Hikaru Miura (College of Science and Technology, Nihon Univ.)
淺見拓哉‡，三浦 光（日大・理工）

1. Introduction

Currently, laser, water jet and wire electric discharge machining are used for hole machining of brittle material such as ceramic materials. The disadvantages are that conventional equipment is large and the structure is complex. To resolve this issue, a new method using the ultrasonic longitudinal and torsional vibration of a hollow-type stepped horn for hole machining is developed. We foresee that with this method equipment can be simplified and miniaturized. Our preceding study focused on longitudinal vibration characteristics of a hollow type stepped horn.[1)] Another previous study used a hollow-type stepped horn with a joined cutting tip with diagonal slits.[2)] In the present paper, ultrasonic vibration sources of a hollow-type stepped horn with a diagonal slits vibration converter and a uniform rod with a diagonal slits vibration converter are used. The characteristics of the longitudinal and torsional vibration of the ultrasonic vibration source were examined and clarified when the center position of the diagonal slits and the number of diagonal slits were varied.

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 (amplification factor, approximately 4.7; material, duralumin), and a hollow-type stepped horn or uniform rod, with dimensions as shown in **Fig. 2** and **Fig. 3**.

Figure 2 shows the hollow-type stepped horn with a diagonal slits vibration converter. Fig. 3 shows the uniform rod with a diagonal slits vibration converter. The dimensions of the hollow-type stepped horn in Fig. 2 are as follows: length, 120 mm; cross-sectional area of transducer side S_1, 113 mm^2 (diameter 12 mm); cross-sectional area of tip side S_2, 28.1 mm^2; depth of the hollow part, 60 mm; cross-sectional ratio S_1/S_2, 4.0. The dimensions of the uniform rod in Fig. 3 are as follows: length, 120 mm; cross-sectional ratio S_1/S_2, 1.0.The exterior appearance of the diagonal slits is shown in **Fig. 4** Slit conditions are as follows: length, 15 mm; width, 0.5 mm; depth, 0.0-3.0 mm; degree, 45 deg.

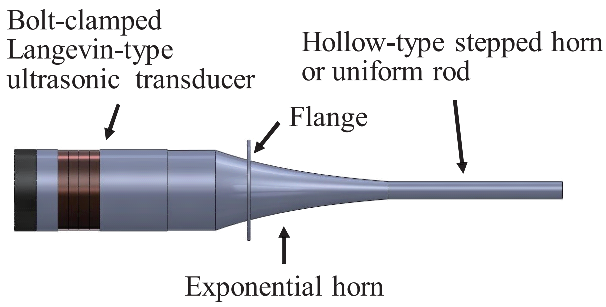


Fig. 1 Ultrasonic vibration source.

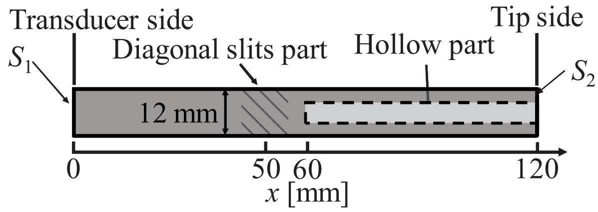


Fig. 2 Hollow-type stepped horn with diagonal slits.

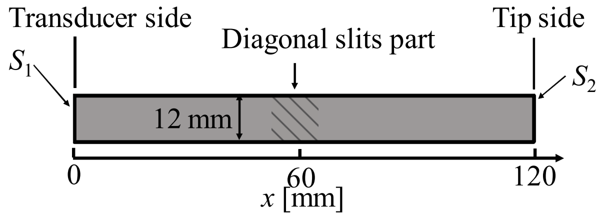
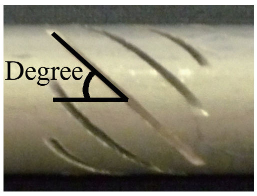


Fig. 3 Uniform rod with diagonal slits.



Slit length, 13 mm
Slit groove width, 0.5 mm
Slit depth, 0.0-3.0 mm
Slit degree, 45 degree
Slit number, 2-8

Fig. 4 Appearance of the diagonal slit part.

Email address: csty10001@g.nihon-u.ac.jp

3. Relationship Between Number of Diagonal Slits and Longitudinal and Torsional Vibration Characteristics of Hollow-Type Stepped Horn

To study the relationship between the number of slits and the longitudinal and torsional vibration characteristics, the longitudinal and torsional vibration at the tip side was measured by varying the number of slits in the range of 0-8 at intervals of 2.[3] The experiment was conducted with the longitudinal vibration amplitude of the transducer side fixed at 0.2 μm (effective value). Slit conditions are as follows: center position of diagonal slits, x=50 mm.

Figure 5 indicates the results. The vertical and horizontal axes in Fig. 5 represent the longitudinal or torsional vibration amplitude (0 to peak value) and the number of diagonal slits. According to Fig. 5, first, longitudinal vibration amplitude was almost the same value for different values of the diagonal slits number. Second, torsional vibration amplitude increased with the number of diagonal slits. This transformation shows that the torsional vibration was proportional to the number of diagonal slits in the range of 0-8.

4. Relationship Between Center Position of Diagonal Slits and Longitudinal and Torsional Vibration Characteristics of Uniform Rod

To study the relationship between the center position of diagonal slits and the longitudinal and torsional vibration characteristics, the longitudinal and torsional vibration at the tip side was measured by varying the center position of diagonal slits in the range of x=30-80 mm. The experiment was conducted with the longitudinal vibration amplitude of the transducer side fixed at 0.2 μm (effective value), Slit conditions are as follows: number of the slits, 8.

Figure 6 indicates the results. The vertical and horizontal axes in Fig. 6 represent the longitudinal or torsional vibration amplitude (0 to peak value) and the center position of diagonal slits. According to Fig. 6, first, longitudinal vibration amplitude increased when the center position of diagonal slits approaches the tip of the uniform rod. Second, the transformation of torsional vibration increased when the center position of the diagonal slits approaches the node position of longitudinal vibration (x=58 mm), the torsional vibration peaked at the time of the node position of longitudinal vibration (x=58 mm).

5. Conclusions

The longitudinal and torsional vibration characteristics of the ultrasonic vibration source required for hole machining were investigated in this paper. The issues clarified in this paper were as follows. First, the torsional vibration amplitude varied by the number of diagonal slits when the longitudinal vibration amplitude remained the same value. Second, the maximum torsional vibration amplitude of the tip side was obtained when the center position of diagonal slits was x=58 mm. This result indicates that the center position of diagonal slits is the best condition at the time of the node position of longitudinal vibration. This condition was the best to obtain the maximum value of the torsional vibration amplitude.

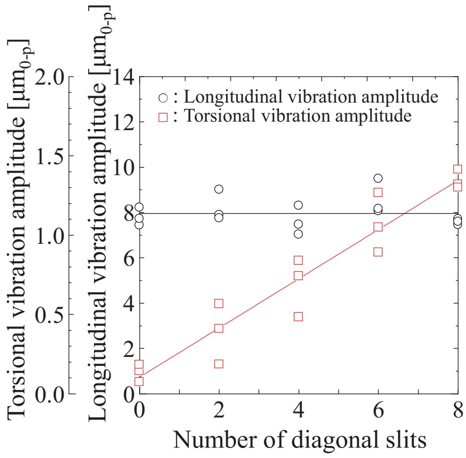


Fig. 5 Relationship between number of diagonal slits and longitudinal or torsional vibration amplitude.

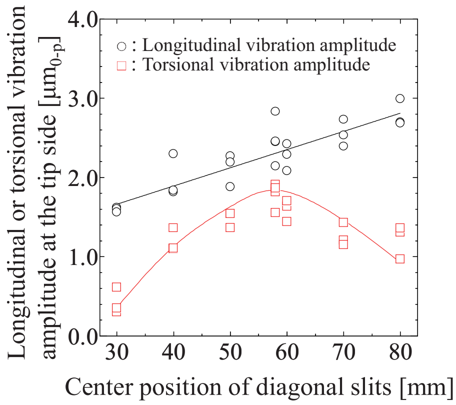


Fig. 6 Relationship between center position of diagonal slits and longitudinal or torsional vibration amplitude.

References

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2) H. Miura : Jpn. J. Appl. Phys. **47** (2008) pp. 4282.
3) T. Asami and H. Miura : The 20th International Congress on Acoustics (2010) 448.