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Vibration Characteristics of Ultrasonic Complex Vibration Source for Welding Using Elongated Uniform Rod
細長い一様棒を用いた接合用超音波複合振動源の振動特性

Hayao Ando[1 ‡], Takuya Asami[1], and Hikaru Miura[1] ([1]Nihon Univ.)
安藤　駿[1 ‡]，淺見　拓哉[1]，三浦　光[1] ([1] 日本大学理工学部)

1. Introduction

Ultrasonic welding[1] is useful for bonding different metals, and thus has been studied extensively. We have achieved high welding strengths by using a dumbbell ultrasonic complex vibration source[2]. However, the welding chip in the vibration source was short and the source could only be used for welding between plates at short distance.

In this study, we use an elongated uniform rod with a rectangular cross section as the welding chip in the ultrasonic complex vibration source to allow welding over greater distances, and we examine the vibration characteristics of the vibration source.

2. Ultrasonic vibration source

Figure 1 shows a schematic of the ultrasonic complex vibration source for welding, which consists of a cylindrical duralumin dumbbell step horn with flange (diameter ratio: 1.5), to which a 19 kHz bolt-clamped Langevin torsional transducer and a 27 kHz bolt-clamped Langevin longitudinal transducer are attached. The elongated uniform rod (SUS 303) is connected to the center of the step horn by a nut, which converts the longitudinal and torsional vibrations into the flexural vibration of the rod.

3. Frequency characteristics of the vibration source

The frequency response characteristics of the ultrasonic complex vibration source were measured using an impedance analyzer (ZGA 5920, NF). An effective value of 1 V was applied to each transducer, sinusoidal alternating voltage signals with frequencies of 28–32 kHz and 18–22 kHz were applied to the longitudinal and torsional transducers, respectively, and the conductance at each frequency was measured.

Figures 2 (a) and (b) show the results for when the longitudinal and torsional transducers were driven, respectively. The vertical axis shows the conductance and the horizontal axis shows the frequency. The resonance frequency of the longitudinal vibration was 29.27 kHz and that of the torsional vibration was 18.77 kHz.

4. Vibration locus under no load

The vibration locus of the ultrasonic complex vibration source at the tip of the elongated uniform rod was measured. The

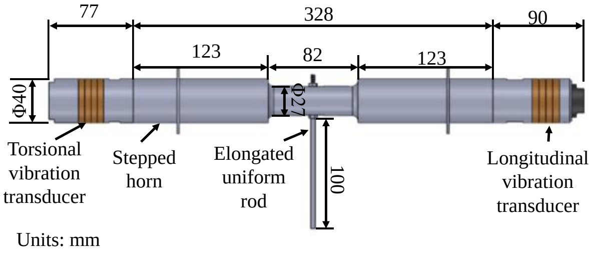
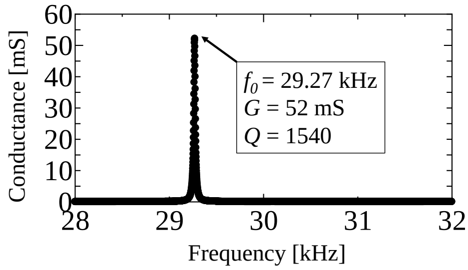
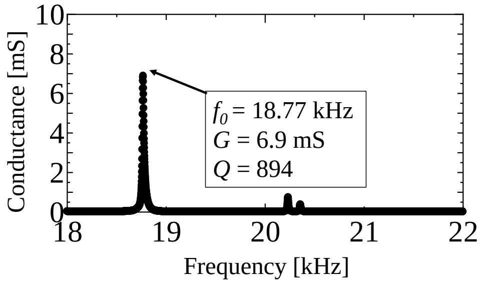


Fig. 1 Schematic diagram of the ultrasonic complex vibration source.



(a) Longitudinal vibration transducer is driven.



(b) Torsional vibration transducer is driven.

Fig. 2 Frequency response of the ultrasonic complex vibration source. f_0 is resonance frequency, G is conductance, Q is quality factor.

E-mail: cshy20003@g.nihon-u.ac.jp, asami.takuya@nihon-u.ac.jp, miura.hikaru@nihon-u.ac.jp

vibrations in the two directions shown in **Fig. 3** were measured using a laser doppler vibrometer at a driving frequency of 18.77 kHz for the torsional vibration transducer and 29.27 kHz for longitudinal vibration transducer, based on the results in Fig. 2. The measurements were performed with only the longitudinal vibration transducer driven at 12 V, only the torsional vibration transducer driven at 14 V, and with both transducers driven simultaneously.

Figure 4 shows the measurement results of the vibration locus under no load. The vertical axis shows the flexural vibration amplitude in the *y* direction and the horizontal axis shows the flexural vibration amplitude in the *z* direction. The black line indicates the vibration locus when only the longitudinal transducer is driven, the red line indicates the vibration locus when only the torsional transducer is driven, and the blue line indicates the vibration locus when the longitudinal and torsional transducers are driven simultaneously. A planar vibration locus was observed even in the conventional vibration source when both vibrators were driven simultaneously.

5. Vibration locus under a static pressure of 50 N

When ultrasonic welding is performed, static pressure is applied at the tip of the welding chip. To determine whether a sufficient vibration displacement amplitude could be obtained even under static pressure, the vibration locus was measured while static pressure of 50 N was applied to the tip of welding chip in the *x*-axis direction through a copper plate and aluminum plate, similar to an object that might be welded. The driving frequencies and the input voltages were the same as those measured under no load.

Figure 5 shows the measurement results. The axes and plot are the same as those for Fig. 4. The vibration locus was planar, which shows that vibration was suppressed under pressurize. Amplitudes of about 4 µm$_{0\text{-}p}$ in the *y* direction and about 5 µm$_{0\text{-}p}$ in the *z* direction were obtained; but, an amplitude of about 5 µm$_{0\text{-}p}$ required for welding is not satisfied. The amplitude could be increased by increasing the voltage and adjusting the resonance frequency.

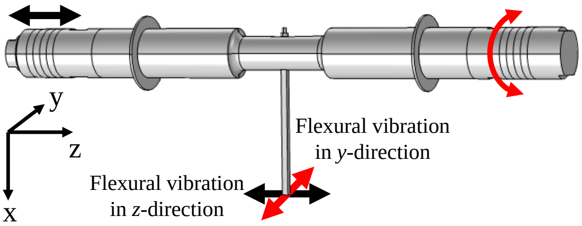


Fig. 3 Diagram of the vibration directions of the vibration source.

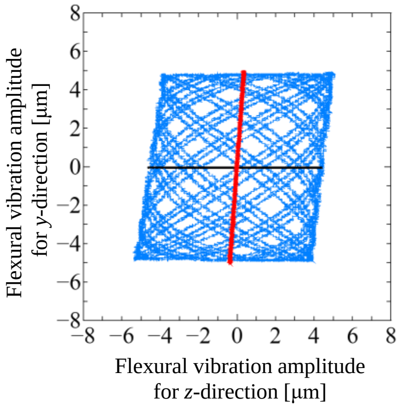


Fig. 4 Vibration locus under no load.

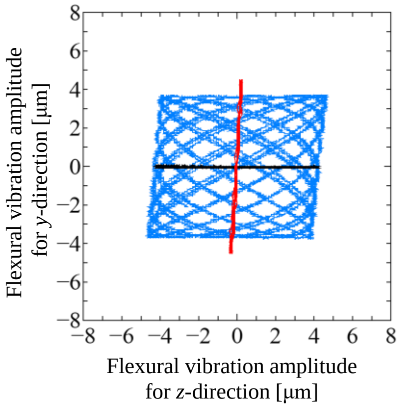


Fig. 5 Vibration locus under a static pressure of 50 N.

6. Conclusion

An ultrasonic complex welding vibration source using an elongated uniform rod with a rectangular cross section as a welding chip was fabricated and its vibration characteristics were measured. A planar vibration locus of about 5 µm$_{0\text{-}p}$ at the tip of the welding chip was obtained even under pressure of 50 N.

References

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2, T. Asami, Y. Tamada, Y. Higuchi and H. Miura. Journal of the Acoustical Society of Japan, Vol. 73, No. 6 (2017) pp. 349-352