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Ultrasonic welding by using planar vibration locus of longitudinal-torsional vibration source consisting of two transducers

2 つの振動子からなる縦－ねじり振動源による面状振動軌跡を用いた超音波接合

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1. Introduction

We are developing an ultrasonic longitudinal -torsional vibration source and ultrasonic vibration assisted manufacturing technology. Ultrasonic welding is an ultrasonic vibration assisted manufacturing technology and a cold metal welding method.[1, 2] Previous studies have demonstrated that the weld strength achieved by ultrasonic welding is improved by applying two-dimensional stress to the welding target. We have proposed using a planar vibration locus for the two-dimensional stress applied to the welding target during ultrasonic welding.[3, 4] The planar vibration locus consists of longitudinal and torsional vibration. We developed a vibration source comprising two transducers with longitudinal and torsional vibration modes to obtain the planar locus.

Here, we describe the properties of the vibration source and investigate welding of a copper plate (C1100) and an aluminum plate (A1050) by using the planar vibration locus.

2. Ultrasonic vibration source

Figure 1 shows the ultrasonic vibration source. The vibration source consists of a bolt-clamped Langevin-type longitudinal vibration transducer (D4427PC, NGK Spark Plug Co., Ltd.), a dumbbell-shaped stepped horn made of A2017 with two flanges, and a bolt-clamped Langevin-type torsional vibration transducer (DAN4419, NGK Spark Plug Co., Ltd.). The length of the stepped horn is 328 mm, which is two wavelengths of the longitudinal and torsional vibration. Both vibration displacement distributions are consistent based on the relationship between the propagation velocity and resonance frequency. The flanges are placed at the node position of the longitudinal and torsional vibration displacement. In addition, the stepped horn has a welding knurling tip of φ3 mm at the center position.

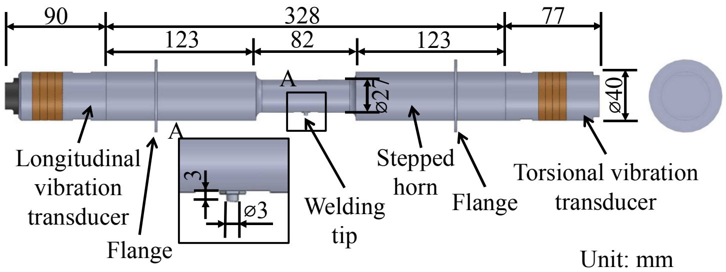

Fig. 1. Ultrasonic vibration source.

3. Free admittance loops

The free admittance loops of the vibration source were measured with the terminal voltage of transducer fixed at 1 V_{rms}. The measurement range of the driving frequency was 29–30 kHz for the driving longitudinal vibration transducer and 18–19 kHz for the driving torsional vibration transducer.

Figure 2 shows the measured free admittance loops of the vibration source, where the vertical axis represents the susceptance and the horizontal axis represents the conductance. The resonance frequency, f_{0L}, the quality factor, Q, and the motional admittance, $|Y_{m0}|$, of the longitudinal vibration were 29.6 kHz, 246, and 10.0 mS, respectively. f_{0T}, Q, and $|Y_{m0}|$ of the torsional vibration were 18.5 kHz, 838, and 15.2 mS,

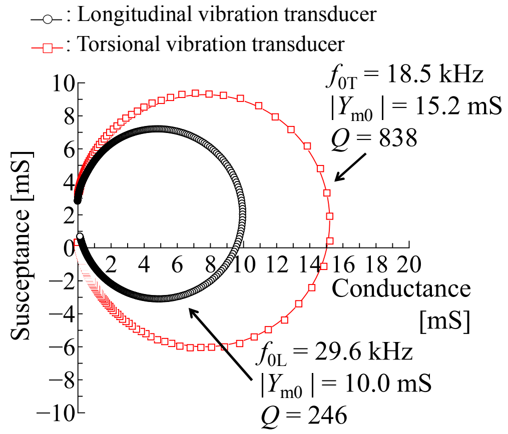

Fig. 2. Free admittance loops of the vibration source.

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respectively.

4. Vibration locus at the welding tip

The vibration loci were measured during driving with each vibration resonance frequency in §3. The longitudinal and torsional vibration displacement amplitudes of the welding tip were measured simultaneously with two laser Doppler vibrometers (LDV-1610, Ono Sokki). The driving voltages of the longitudinal and torsional vibration tranducers were 32 and 6 V_{rms}, respectively.

Figure 3 shows the vibration locus for the longitudinal-torsional vibration at the welding tip. The vertical axis represents the torsional vibration amplitude, and the horizontal axis represents the longitudinal vibration amplitude. The vibration loci of driving only the longitudinal or torsional vibration transducer (black and red lines) were in a straight line in the direction of the longitudinal or torsional vibration. Based on these results, we measured the vibration locus while driving both vibration transducers simultaneously. The experimental results, shown as blue lines, demonstrate that the vibration locus was square planar. The square planar locus was obtained as the sum of the straight loci of the two drive transducers.

5. Welding experiment

A welding experiment was performed using copper (C1100) and aluminum (A1050) plates and varying the static pressure. A longitudinal linear vibration locus, a torsional linear vibration locus, and a longitudinal-torsional planar vibration locus were used. The displacement amplitude of all vibration loci was 8 $\mu m_{p\text{-}p}$. The welding time was 3 s. In addition, the welding strength (tensile shear strength) was measured by shear testing according to Japanese Industrial Standards Z 3136:1999.

Figure 4 shows the experimental welding results obtained by varying the static pressure from 400 to 800 N. The vertical and horizontal axes represent the weld strength and static pressure, respectively. The weld strength for the linear vibration loci reached a peak at 600 N, whereas the weld strength for the planar vibration locus increased with increasing pressure. The maximum weld strength was 382 N at a static pressure of 800 N for the planar locus.

6. Conclusions

In this study, the characteristics of the ultrasonic longitudinal-torsional vibration source and weld strength was determined. The planar vibration locus was obtained by using a longitudinal-torsional vibration source consisting of two transducers. A higher weld strength between copper (C1100) and aluminum (A1050) plates was obtained using a planar vibration locus. In the future, we plan to investigate the cause of the difference in weld strength.

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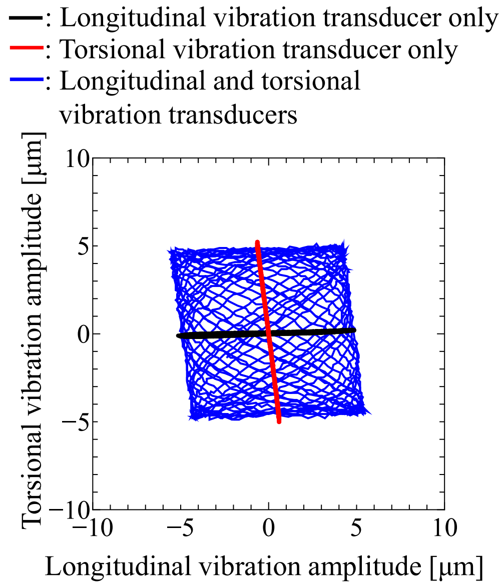

Fig. 3. Vibration loci.

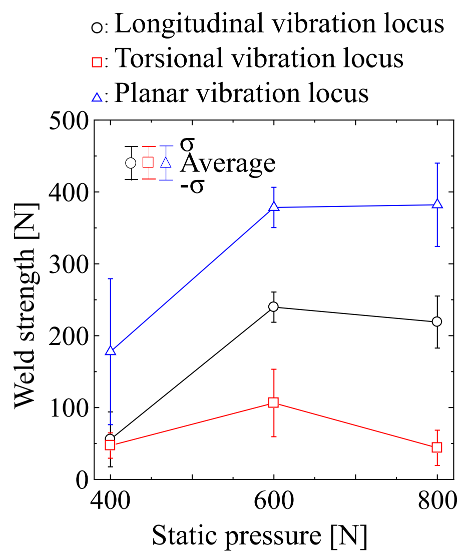

Fig. 4. Relationship between static pressure and weld strength.