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# Ultrasonic welding of copper plate and aluminum plate by complex vibration
# 複合振動を用いたアルミニウム板と銅板の超音波接合

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## 1. Introduction

Ultrasonic welding uses no heat and is suitable for welding metals with different melting points. However, conventional ultrasonic welding produces joints with low weld strengths and the weld strength depends on the installation direction of the welding target[1)]. In addition, the vibration locus used in conventional ultasonic metal welding is usually linear. Therefore, we have developed an ultrasonic complex vibration source for ultrasonic welding using a planar locus obtained at driven at two separate frequencies simultaneously. In previous studies, it is clear that the weld strength is higher when increasing the static pressure for the planar vibration trajectory than the linear vibration trajectory[2)].

In this study, a copper plate and an aluminum plate were used as welding targets, and welding time and weld strength obtained by using linear and planar vibrations were examined.

## 2. Ultrasonic vibration source

**Figure 1** shows the ultrasonic vibration source with the welding tip. The vibration source consists of a 20 kHz bolt-clamped Langevin-type transducer, an exponential horn for amplitude amplification (material: A2017), and a uniform rod (diameter: 12 mm; length: 122 mm; material: SUS303) with diagonal slits and a welding tip (diameter: 3 mm; length: 3 mm; tip end: irregularity). The parameters of the diagonal slits for generating longitudinal-torsional vibration at the welding tip are as follows: center position, 61 mm from the junction of the exponential horn and the uniform rod; length: 19 mm; width: 3.5 mm; inclination angle: 35°; number of slits: 8[3)].

**Figure 2** shows a photo of the ultrasonic vibration source and pressurizer. The pressure necessary for welding at the welding tip is applied by raising the precision vice.

The experimental procedure for welding is as follows. An aluminum plate (material: A1050; length: 40 mm; width: 20 mm; thickness: 0.5 mm) is a placed on top of a copper plate (material: C1100; length: 40 mm; width: 20 mm; thickness: 0.5 mm) fixed in the vise. Next, static pressure is applied at the welding tip to the aluminum plate, followed by the application of ultrasonic vibration.

## 3. Vibration trajectory at the time of welding

To investigate the vibration loci, the longitudinal and torsional vibration amplitude of

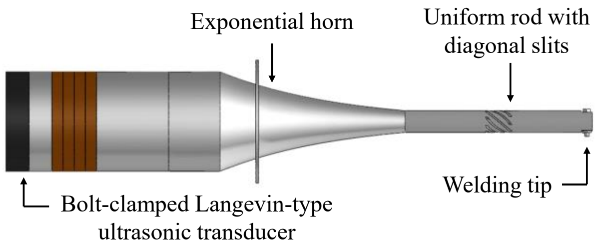



Fig. 1. Ultrasonic vibration source of the welding tip.

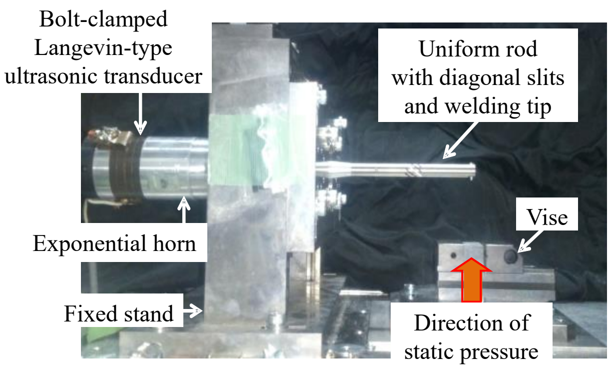
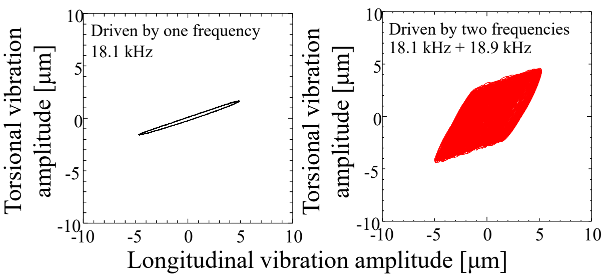



Fig. 2. Photograph of ultrasonic welding machine.




(a) Linear vibration locus

(b) Planar vibration locus

Fig. 3. Vibration loci during welding.

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the welding tip during welding were measured. The measurement was carried out simultaneously with two laser Doppler vibrometers when a pressure of 100 N was applied at the welding tip. **Figure 3** shows the linear and planar vibration loci during welding. The horizontal and vertical axes represent the longitudinal vibration amplitude and the torsional vibration amplitude, respectively. Figure 3(a) shows that the vibration locus for a single driving frequency (18.1 kHz) was linear. Figure 3(b) shows the vibration locus for two driving frequencies (18.1 kHz and 18.9 kHz) was planar.

## 4. Dependence of weld strength on welding time

A welding experiment using aluminum and copper plates was performed. First, the welding time was varied (static pressure: 200 N) for both the linear locus (longitudinal vibration amplitude: 10 $\mu m_{p\text{-}p}$) and the planar locus (longitudinal vibration amplitude: 10 $\mu m_{p\text{-}p}$; torsional vibration amplitude: 8.5 $\mu m_{p\text{-}p}$). Each experiment was carried out 10 times. The weld strength (tensile shear strength) was measured by shear testing according to Japanese Industrial Standards Z 3136. **Figure 4** shows the weld strength as a function of welding time for the linear and planar loci. The horizontal and vertical axes represent the welding time and the weld strength, respectively. The weld strength for the linear locus increases with increasing welding time for the first 10 s, and then the rate of increase becomes small between 10 and 20 s. The weld strength for the planar locus increases with increasing welding time for the first 5 s, and then the rate of increase becomes small between 5 and 20 s. The weld strength for the planar locus is higher than for the linear locus. Therefore, the planar locus is better than the linear locus for welding of different metals.

**Figure 5** is based on Fig. 4 and shows the relationship between electric energy (horizontal axis) and weld strength (vertical axis) for the linear and planar loci. The weld strength for both the linear and planar loci increases with increasing electric energy up to 500 W·s, and then the rate of increase becomes small from 500 to 1200 W·s. Welding using the planar locus is higher strength for the same electric energy as compared with the linear locus. From this result, it became that the planar locus is higher strength than the linear locus at the same electric energy.

## 5. Conclusions

In this study, the weld strength was measured as a function of the welding time. The weld strength was higher after a shorter welding time and at a lower electric energy for the planar vibration trajectory than for the linear vibration trajectory.

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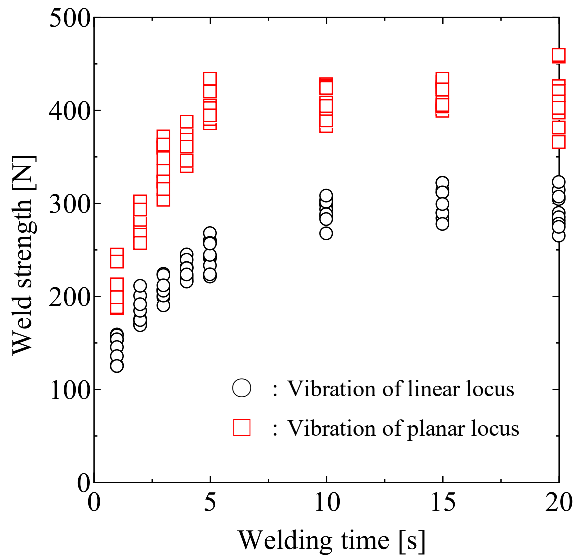


Fig. 4. Relationship between welding time and weld strength.

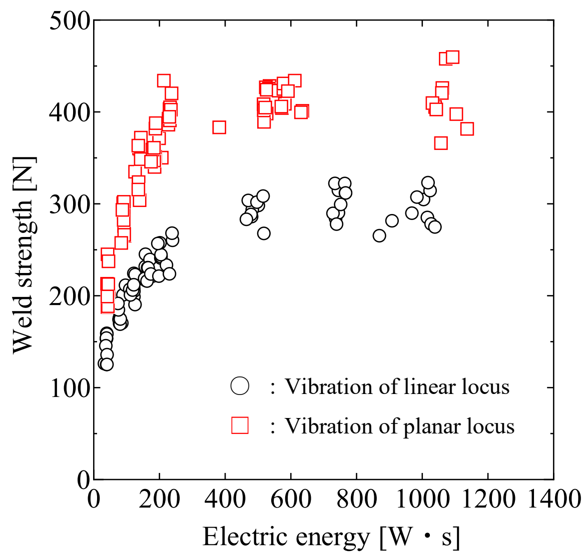


Fig. 5. Relationship between electric energy and weld strength.