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Basic Study on Ultrasonic Metal Welding by Planar Vibration Locus

面状振動軌跡を用いた超音波金属接合の基礎検討

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1. Introduction

The vibration locus used in conventional ultrasonic metal welding is usually linear. Problems with conventional ultrasonic welding methods include welding strength depending on the orientation of the welding target, which is assumed to be caused by the directionality of the vibration locus[1)]. Therefore, we have developed a new method for metal welding which uses an ultrasonic complex vibration source with diagonal slits of the vibration converter by driven at two separate frequencies. In a previous study, we showed that the vibration locus obtained by this method is planar, with no specific orientation[2)].

In this study, the strength of welding performed by using planar and linear vibration loci is measured in the case of welding a copper plate to an aluminum plate.

2. Ultrasonic Vibration Source

Figure 1 shows the ultrasonic vibration source of the welding tip and a clamp for applying pressure. The vibration source consists of a 20 kHz bolt-clamped Langevin-type transducer (D45520), an exponential horn for amplitude amplification (amplification factor: ≈4.6; 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: curved). 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: 1.0 mm; depth: 3.5 mm; inclination angle: 35°; number of slits: 8[3)].

Next, a clamp is used to apply pressure at the welding tip. By using an electric motor, constant force is applied from the lower side of the vise in order to maintain contact between the welding tip and the welding target.

The experimental procedure for welding is as follows: an aluminum plate (material: A1050; length: 40 mm; width: 20 mm; thickness: 0.5 mm) is placed on a copper plate (material: C1100; length: 40 mm; width: 20 mm; thickness: 2.0 mm) fixed in the vise. Next, static pressure is applied by the welding tip to the aluminum plate, followed by the application of vibration.

3. Welding Experiment Using Aluminum and Copper Plates

First, the vibration loci the welding tip were measured in preparation for the welding experiment. The vibration loci for a driving frequency of 18.1 kHz and for two driving frequencies (18.1 and 18.9 kHz) applied simultaneously were plotted for the point of the welding tip. The longitudinal and torsional vibration were measured simultaneously with two laser Doppler vibrometers (LV-1710, Ono Sokki) when a pressure of 100 N was applied at the welding tip.

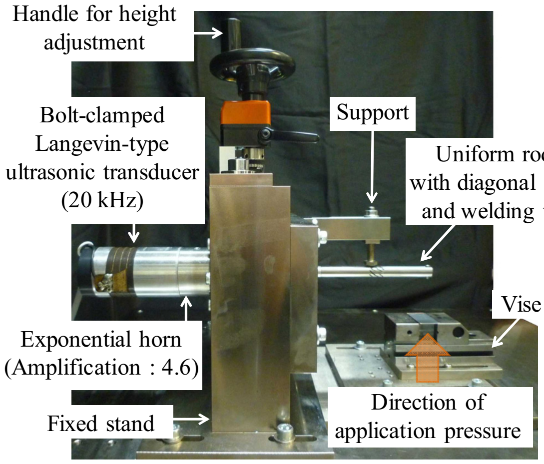
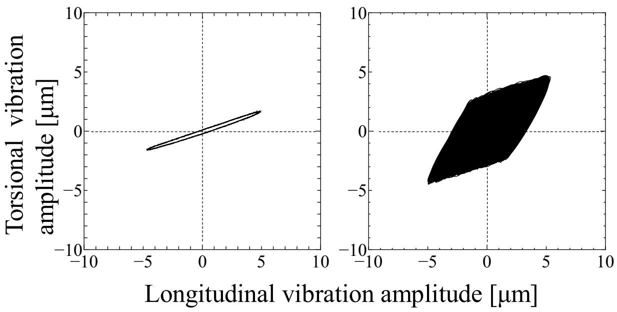


Fig. 1　Vibration source and clamp.



(a) One driving frequency: 18.1 kHz　(b) Two driving frequencies: 18.1 + 18.9 kHz

Fig. 2　Vibration loci in welding.

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Figure 2 shows the plots of the vibration loci, where (a) shows the vibration locus for a single driving frequency and (b) shows the vibration locus for two driving frequencies. Clearly, the vibration locus is linear in (a) and planar in (b). The planar locus was obtained as a sum of the linear loci for the two individual driving frequencies.

Next, a welding experiment using aluminum and copper plates was carried out. The welding experiment was performed by varying the welding time or the static pressure. 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$\mu m_{p\text{-}p}$) shown in Fig. 2 were used in the experiment. In addition, the welding strength (tensile shear strength) was measured by shear testing according to Japanese Industrial Standards Z 3136:1999 "Specimen dimensions and procedure for shear testing resistance spot and embossed projection welded joints".

3.1 Dependence of Welding Strength on Welding Time

Figure 3 shows the experimental results obtained by varying the welding time (static pressure: 100 N). The vertical and horizontal axes represent the welding strength and the welding time, respectively. The welding strength for both the linear and planar loci increases with increasing the welding time for the first 20 s, after which the rate of increase becomes small and the welding strength remains almost the same in the range of 20-60 s. Welding using the planar locus resulted in higher welding strength for the same welding time as compared with the linear locus.

3.2 Dependence of Welding Strength on Pressure

Figure 4 shows the experimental results obtained by varying the static pressure (welding time: 20 s). The vertical and horizontal axes represent the welding strength and the static pressure, respectively. Clearly, for both the linear and the planar locus, the welding strength increases with increasing the pressure. At the same pressure, the welding strength for the planar locus was higher than in the case of the linear locus. In both sets of experiments, the welding strength for the planar locus was about 1.7 times higher in comparison with that for the linear locus.

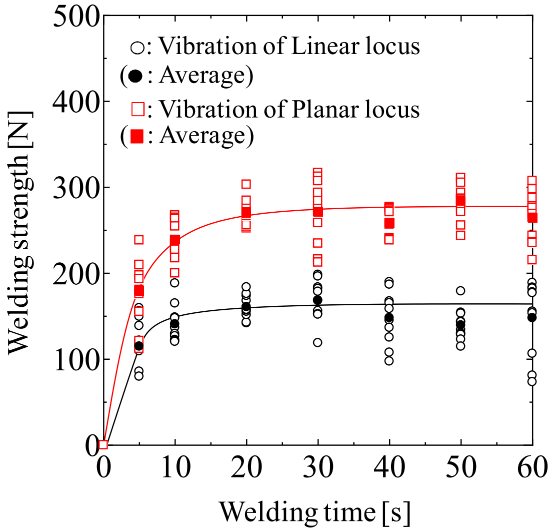

Fig. 3 Relationship between welding strength and welding time.

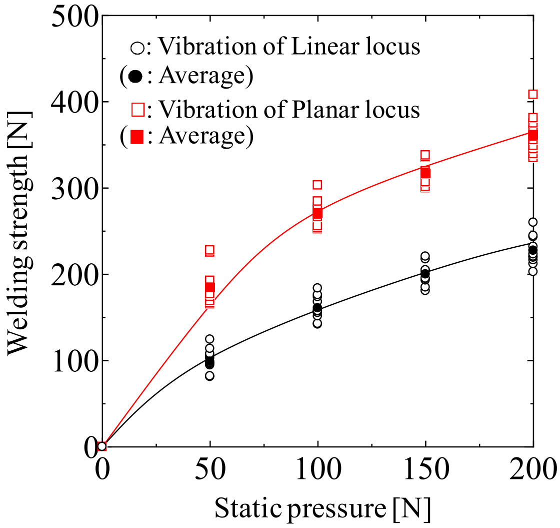

Fig. 4 Relationship between welding strength and static pressure.

4. Conclusions

In this study, we investigated ultrasonic metal welding by using linear and planar vibration loci at the welding tip in the case of welding a copper plate to an aluminum plate. The welding strength was measured by varying the welding time or the pressure. We found that the welding strength for the planar locus exceeded that for the linear locus by a factor of about 1.7 within a short time. The planar locus had no orientation. For this reason, we consider that the aluminum plate vibrated easily, inducing stronger vibration at the interface between the copper and aluminum plates compared with the linear locus.

References

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