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Dissimilar metals welding using longitudinal-torsional complex vibration source
－Welding strength characteristics due to different weld time－

縦－ねじり複合振動源を用いた異種金属接合
—接合時間の違いによる接合強度特性—

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1. Introduction

In electric vehicles and other applications, large-capacity lithium-ion batteries are required, and technology to weld dissimilar metals is required for their production. Because ultrasonic welding does not use heat, it is possible to weld even metals with different melting points. In addition, ultrasonic welding has been shown to be effective when the vibrations produce two-dimensional stress [1,2].

In a previous study, we performed a welding experiment with planar vibration, and the tensile shear and cross tensile strengths were measured. As a result, it was shown that the intensity obtained by planar vibration was higher than that of linear vibration [3,4].

In this study, a welding experiment was performed in which the welding time was changed to examine the effect of the welding time on the tensile shear and cross tensile strengths in welds formed by planar vibration.

2. Complex ultrasonic vibration source

Figure 1 shows the complex ultrasonic vibration source for generating planar vibration. The complex ultrasonic vibration source has a structure in which a 27-kHz bolt-clamped Langevin-type longitudinal vibration transducer and a 19-kHz bolt-clamped Langevin-type torsional vibration transducer are connected to both ends of a cylindrical duralumin dumbbell-type step horn (diameter ratio 1.5) [5]. At the center of the step horn, a circular knurled welding tip with a diameter of 4.2 mm was attached .

Figure 2 shows the loci of vibration displacement at the welding tip. The vibration displacement when the longitudinal vibrator and the torsional vibrator are driven were made to have the same vibration velocity (maximum value ~0.8 m/s) at the welding tip. The driving frequency was 29.32 kHz for the longitudinal vibrator and 19.15 kHz for the torsional vibrator with no load. The horizontal axis shows the amplitude of the longitudinal vibration displacement, and the vertical axis shows the amplitude of the torsional vibration displacement. The vibration displacement was measured for 10 ms. In the figure, only the longitudinal vibrator (black line) and torsional vibrator (red line) are each driven with linear loci, and when both vibrators are driven (blue line) simultaneously, they are driven with a planar locus.

3. Welding method and tensile testing method

The welding samples were aluminum plates (A1050, length 42 mm, width 20 mm, thickness 0.5 mm) and copper plate (C1100, length 40 mm, width 20 mm, thickness 2.0 mm).

The welding was performed by fixing the copper plate with a precision vice, placing an aluminum plate on it, raising the precision vice up to the complex ultrasonic vibration source, and vibrating the welding tip by adding a sine wave

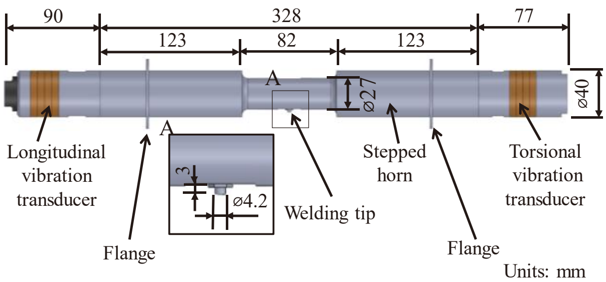

Fig. 1. Complex ultrasonic vibration source.

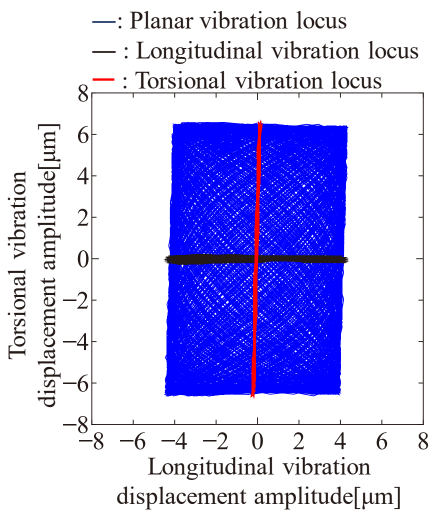

Fig. 2. Ultrasonic vibration loci.

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signal to the transducers.

The measurement of weld strength was performed by tensile shear test (JIS Z3136) pulling in the shear direction of the weld sample and cross tensile test (JIS Z3137) pulling in the thickness direction of the weld sample.

4. Welding experiment

The welding experiment was performed by changing the welding time to examine the relationship between the welding time and tensile shear and cross tensile strengths in the weld formed with planar vibration. In addition, welding with only linear vibration was also performed for comparison.

The welding condition was a weld time of 0.2-1 s and pressure of 500 N. The three types of vibration loci shown in Fig. 2 were used. Welding was performed five times under each condition.

Figure 3 shows the relationship between weld time and the average tensile shear strength. The horizontal axis shows the weld time, and the vertical axis shows the tensile shear strength. The error bar in the figure shows the standard deviation (± 1σ). The figure shows that the tensile shear strength was highest when planar vibration was used. Between 0.2 s and 0.4 s, the tensile shear strength of the weld formed with longitudinal vibration was higher than that of the weld formed with torsional vibration.

Figure 4 shows relationship between weld time and average cross tensile strength. The data are shown in the same manner as in Fig. 3, except that the vertical axis is cross tensile strength. The figure shows that the cross tensile strength is highest when planar vibration is used. In addition, the cross tensile strength of the weld formed with longitudinal vibration is higher than that of the weld formed with torsional vibration.

These results show that the weld formed with planar vibration has a higher tensile shear strength and cross tensile strength than a weld formed with linear vibration. We found that longitudinal and torsional vibrations tend to contribute to different tensile shear and cross tensile strengths.

5. Conclusions

In this paper, we conducted a welding experiment in which the weld time was changed while performing welding with planar or linear vibration. As a result, we found that greater strength was obtained in a shorter weld time with planar vibration compared with linear vibration.

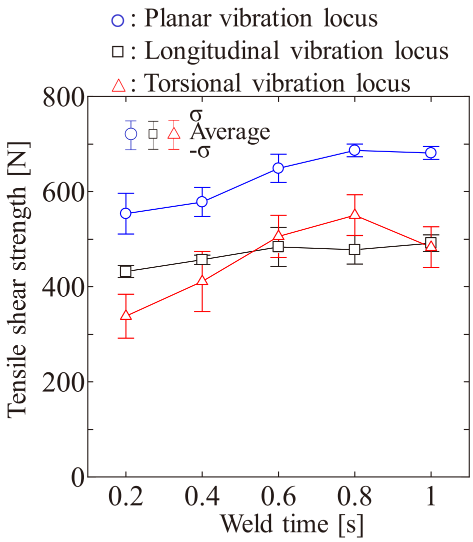

Fig. 3. Relationship between weld time and tensile shear strength.

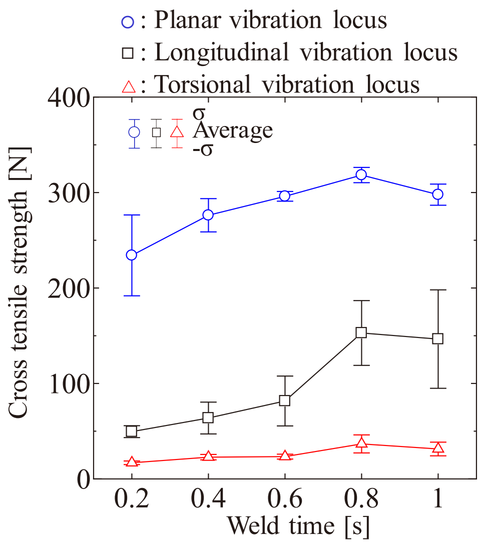

Fig. 4. Relationship between weld time and cross tensile strength.

Acknowledgment

This study was subsidized by JSPS Research Institute grant number 19K14863.

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