1P4-13

Vibrating conditions of welding sample by ultrasonic metal welding
超音波金属接合における接合試料の振動状態

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1. Introduction

Electric vehicles use large-capacity lithium ion batteries that contain aluminum positive electrodes and copper negative electrodes. To increase the battery capacity, the positive and negative electrodes are connected alternately in series, which requires a technique for welding dissimilar metals[1]. Ultrasonic welding does not use heat, making it suitable for welding metals with different melting points. The method uses a vibration that applies two-dimensional stress[2-4]. We have proposed ultrasonic welding with a planar vibration composed of longitudinal-torsional vibration to which two-dimensional stress can be applied. Our previous studies have revealed that the weld strength can be improved by using planar vibration, and ultrasonic welding with the planar vibration achieved stable welding and a high weld strength regardless of the installation direction of the welding sample[4]. We think that this result may be explained by the vibration propagation in the welding sample differing between welding with linear vibrations and with planar vibrations. Therefore, in this work, we investigated the vibration propagating through the welding tip and the aluminum plate for two types of linear vibrations.

2. Complex vibration source

Figure 1 shows the complex vibration source, which consists of a 27 kHz bolt-clamped Langevin-type longitudinal vibration transducer (D4427PC, NGK Spark Plugs) and a 19 kHz bolt-clamped Langevin-type torsional vibration transducer (DAN4419, NGK Spark Plugs) connected to either end of a cylindrical dumbbell-shaped stepped horn (A2017) with a diameter ratio of 1.5. At the center of the horn, a knurled welding tip for applying the vibration is attached to the object to be welded. **Figure 2** shows (a) the external appearance of the welding tip, (b) the bottom view of the tip of the welding tip, and (c) the cross-sectional view of the tip of the welding tip used in this work. The tip of the welding tip is circular with a diameter of 4.2 mm, and the tip is knurled to prevent the welding sample

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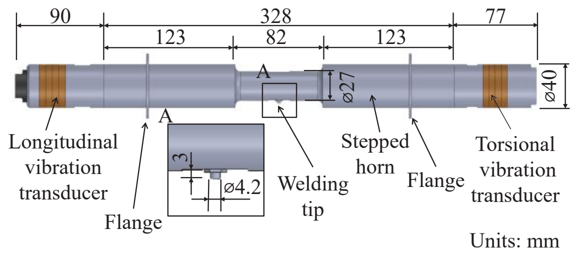

Fig. 1　Ultrasonic complex vibration source.

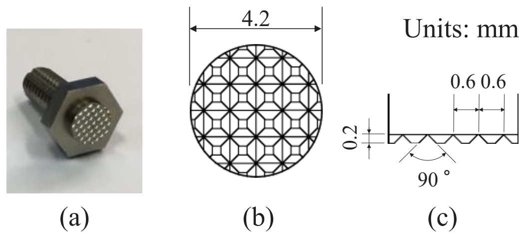

Fig. 2　Welding tip.

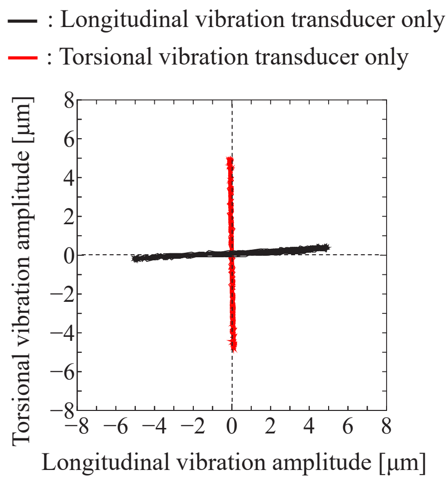

Fig. 3　Vibration loci.

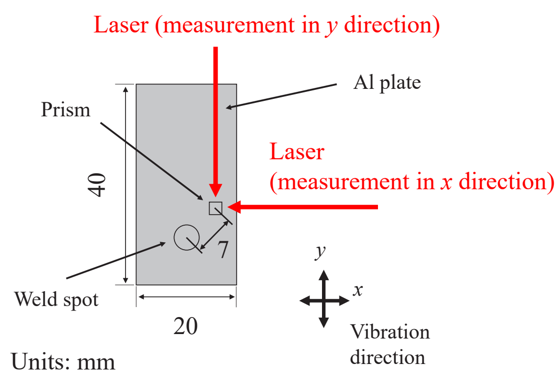

Fig. 4　Schematic of aluminum plate sample.

from slipping.

3. Vibration loci of the welding tip

To confirm the vibration locus obtained from the complex vibration source, the vibration locus at the welding tip was measured with two laser Doppler vibrometers at the resonance frequency (longitudinal vibration of 29.3 kHz, torsional vibration of 18.4 kHz). The driving voltage was 31 V_{rms} for the longitudinal vibration transducer and 8 V_{rms} for the torsional vibration transducer. **Figure 3** shows the results. The horizontal axis indicates the longitudinal vibration displacement amplitude and the vertical axis indicates the torsional vibration displacement amplitude. Straight linear vibration loci were produced by the longitudinal and torsional vibration transducers alone. In the remainder of this work, the linear vibration in the longitudinal vibration direction of Fig. 3 is called the longitudinal vibration, and the linear vibration in the torsional vibration direction is called the torsional vibration.

4. Vibration state of the Al plate during welding

To study the relationship between the welding tip and the vibration of the aluminum plate (A1050) during welding, the response to longitudinal vibration and torsional vibration with time was measured with two laser Doppler vibrometers. **Figure 4** shows an outline of the measurement sample. To measure the vibration of the aluminum plate, a prism with a 2 mm cube on one side to reflect the laser was attached 7 mm from the welding point on the aluminum plate. The longitudinal vibration direction was defined as the *x* direction, and the torsional vibration direction was defined as the *y* direction. The vibration during welding was the longitudinal and torsional vibrations shown in Fig. 3. The welding was performed at a constant static pressure of 500 N and the vibration displacement amplitude of each vibration was constant at 10 $\mu m_{p\text{-}p}$. For the longitudinal vibration, the vibration of the welding tip and aluminum plate in the *x* direction was measured, and for the torsional vibration, the vibration of the welding tip and the aluminum plate in the *y* direction was measured. **Figures 5 and 6** show the measurement results in the *x* and *y* directions, respectively. In both figures, the horizontal axis indicates the measurement time and the vertical axis shows the vibration displacement amplitude. The black line indicates vibration at the welding tip and the red line indicates vibration of the aluminum plate. The vibrations of the welding tip and the aluminum plate were similar for both measurements.

5. Conclusions

In this work, we investigated the vibration state of an aluminum plate during welding using longitudinal vibration and torsional vibration. The vibration of the aluminum plate was similar to that of the welding tip, regardless of which vibration was used. In future work, we will investigate the vibration state of the aluminum plate during welding under various conditions.

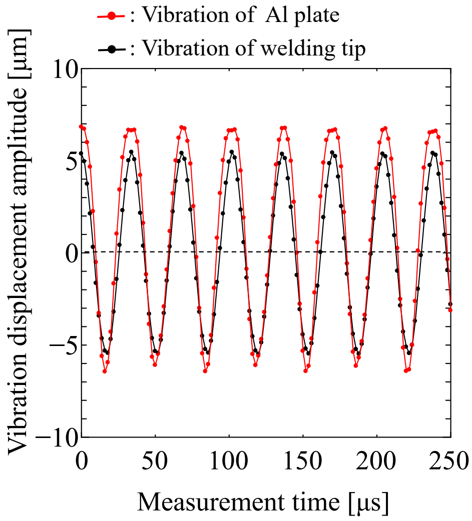

Fig. 5 Vibration characteristics in the *x* direction.

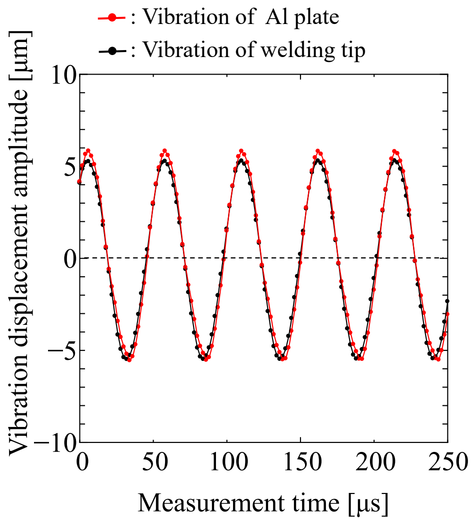

Fig. 6 Vibration characteristics in the *y* direction.

Acknowledgment

This work was supported by KAKENHI Grant Number 15K21409.

References

1. J. Yang and B. Cao: Materials and Design. **74** (2015) 19.
2. J. Tsujino, T. Ueoka, H. Konda and Y. Kimura: Jpn. J. Appl. Phys. **31** (1992) 287.
3. Y. Watanabe, Y. Tsuda and E. Mori: J. Appl. Phys. **32** (1993) 2430.
4. Y. Tamada, T. Asami and H. Miura: Jpn. J. Appl. Phys. **57** (2018) 07LE12.