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Ultrasonic Complex Vibration Welding Using One Longitudinal Wave-length Mode Diagonal Slit Complex Vibration Converter
一波長縦振動モードの斜めスリット複合振動変換器を用いた超音波複合振動溶接

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1. Introduction

Ultrasonic complex vibration welding using two-dimensional vibration stress have been proved very effective for welding of same and dissimilar metal specimens. Required vibration amplitude and static clamping pressure are one-third or quarter and obtained welding strength are larger compared with conventional welding system using linear vibration. Larger and uniform weld area and weld strength are obtained independent of welding position and direction. Complex vibration could be obtained using multiple vibration systems crossed at adequate angles and one-dimensional vibration system using diagonal slit complex vibration converter driven by a longitudinal vibration source.

19.5 kHz, 2 kW complex vibration welding systems using half wave-length longitudinal vibration mode complex vibration converter with various exchangeable complex vibration welding tip have been developed.

These welding systems have been proved very effective for various welding specimens such as Li-ion battery and various electronic devices.

2. Ultrasonic complex vibration welding systems

Required vibration amplitude decreases as ultrasonic frequency becomes higher. Required vibration amplitudes of 27 kHz and 40 kHz welding systems become 62% and 34% of vibration amplitude of 19.5 kHz system [1)]. To secure sufficient working space, 27 kHz and 40 kHz one longitudinal wave-length mode complex vibration converters using various exchangeable welding tips were developed. The diagonal slit complex vibration converter was designed using equivalent transmission line method and FEM.

2. 1 27 kHz complex vibration converter

Fig. 1 shows 27 kHz complex vibration welding system using 38-mm-diameter, one longitudinal vibration mode complex vibration converter with 12-mm-diameter half wave-length transverse complex vibration welding tip. The welding tip could be installed in four positions at the free edge part of the converter using a connecting bolt.

Fig. 2 shows the configuration of the complex vibration system and longitudinal and torsional vibration distributions along the converter and a longitudinal driving system.

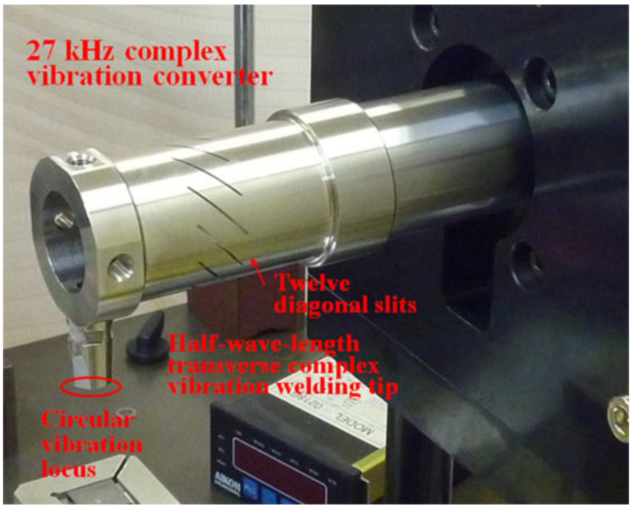

Fig. 1 27 kHz ultrasonic complex vibration welding system (SUS304) using a 38-mm-diameter, one longitudinal wave-length mode diagonal slit complex vibration converter with 12-mm-diameter complex vibration welding tip.

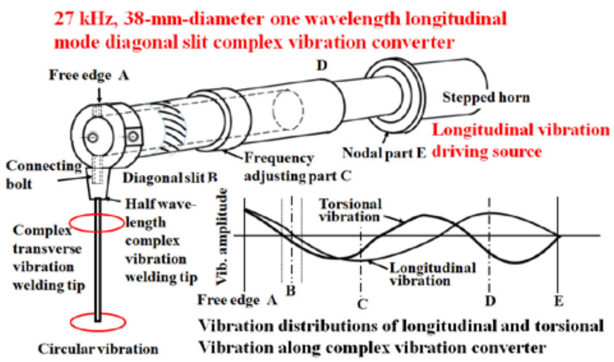

Fig. 2 Longitudinal and torsional vibration distributions between free edge of 27 kHz, 38-mm-diameter, one longitudinal vibration wavelength complex vibration converter and nodal position of

stepped horn of longitudinal driving system.

Fig. 3 shows free admittance loops of 27 kHz complex vibration system without and with power factor compensation inductance Lc. Quality factor Q and motional admittance |Ymo| change 2402 to 480 and 13 to 291 mS. Q decreases but |Ymo| increases by Lc, and the complex vibration system can be driven effectively.

Fig. 4 shows free admittance loop of the complex vibration system with a welding tip installed in a welding system with Lc = 3.45 mH. Motional admittance |Ymo| is large as 127 mS. **Fig. 5** shows elliptical vibration locus at the welding tip measured using two laser Doppler vibrometers with same transmission characteristics.

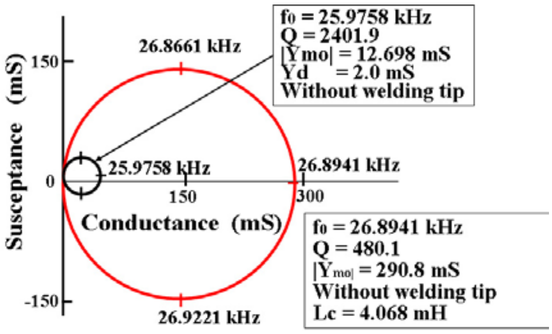

Fig. 3 Free admittance loops of 27 kHz complex vibration system without welding tip.

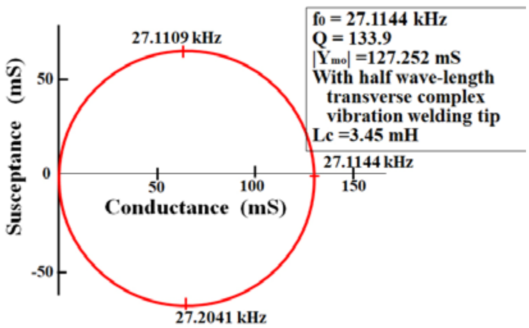

Fig. 4 Free admittance loop of 27 kHz complex vibration system with half wave-length transverse complex vibration welding tip and Lc = 3.45 mH.

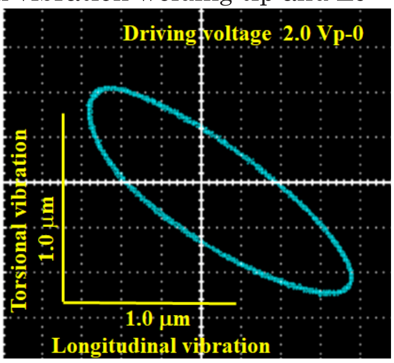

Fig. 5 Elliptical vibration locus of half － wavelength complex transverse vibration welding tip.

2. 2 40 kHz complex vibration converter

Fig, 6 shows 40 kHz complex vibration welding system using 30-mm-diameter, one-longitudinal vibration mode complex vibration converter with 10-mm-diameter half wave-length complex transverse vibration welding tip. The welding system has sufficient working space and various welding tips could be installed at the free edge of the converter using a connection bolt.

Fig. 7 shows free admittance loops of 40 kHz complex vibration system without and with power factor compensation inductance Lc. Quality factor Q decreases but |Ymo| increases by Lc, and the complex vibration system can be driven effectively.

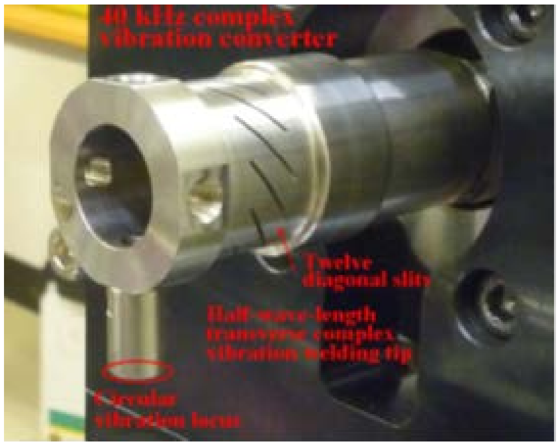

Fig. 6 40 kHz ultrasonic complex vibration welding system (SUS304) using a 30-mm-diameter, one longitudinal wave-length mode diagonal slit complex vibration converter with a half wave-length welding tip.

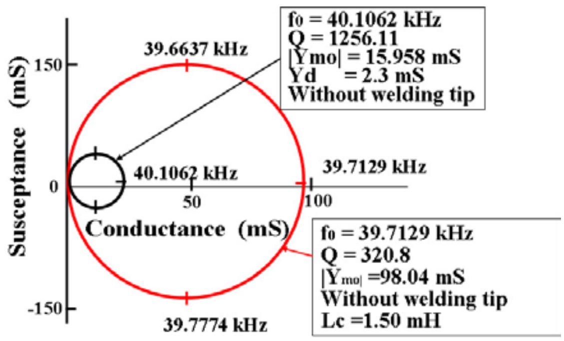

Fig. 7 Free admittance loops of 40 kHz ultrasonic complex vibration system without and with a power factor compensating inductance Lc.

3. Conclusions

27 kHz and 40 kHz complex vibration systems using exchangeable welding tips and with sufficient working space were developed. The welding tip vibrates in circular to elliptical vibration locus.

References

[1] J. Tsujino, Recent development of ultrasonic welding, Proc. IEEE IUS, 191-200, 1995.