Vibration and Welding Characteristics of a 27 kHz Complex Vibration Source Using Longitudinal Vibration Disk and Six Bolt-clamped Langevin Type PZT Transducers

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1. Introduction Vibration characteristics of a large capacity ultrasonic complex vibration source using six driving longitudinal vibration systems with bolt-clamped Langevin type PZT longitudinal transducers (BLT) 40 mm in diameter, a longitudinal vibration disk for integrating multiple BLT transducers and a complex transverse vibration catenoidal horn are studied. Using the complex vibration ultrasonic welding system, various thick metal plates can be welded continuously at multiple positions with larger and more uniform welded area than those welded using a conventional system using linear vibration.

2. Configuration and Driving Method of Complex Vibration Source (1) Configuration of complex vibration source Configuration of a 27 kHz large capacity complex vibration source using a longitudinal vibration disk with six driving longitudinal vibration systems is shown in Fig.1. The complex vibration source consists of a longitudinal vibration disk 395 mm diameter and 40 mm in thickness (aluminum alloy, JISA5056B), a complex transverse vibration catenoidal horn 50 mm in diameter (stainless steel, SUS304B) installed in the center of the disk, a stepped horn (stainless steel, SUS304B) for supporting the vibration source and six longitudinal vibration system 27 kHz BLT transducers of 40 mm diameter. The complex transverse vibration catenoidal horn is installed normally in the center loop position of the disk.

The driving longitudinal vibration system consists of a 40-mm-diameter BLT transducers and a catenoidal horn (aluminum alloy, JISA5056B). Six driving longitudinal vibration systems are installed opposite side of the disk and driven in an anti-phase vibration mode. The two vibration systems have two types of BLT transducer, which have normal and reverse polarity stacks of PZT rings. This transducers pair is connected in a parallel and driven longitudinal in one longitudinal wavelength. Three vibration system pairs installed in the disk in 120° angle each other.

(2) Driving method of a complex vibration source The vibration system pair with two BLT transducers with normal and reverse polarities are connected in parallel and driven in an anti-phase mode. Three driving vibration system pairs are driven simultaneously using a arbitrary waveform generator with variable phase output voltage and three 500 W static induction transistor power amplifier with vibration difference of 120°. Almost circular vibration locus is obtained at the welding tip.

3. Vibration Characteristics of Complex Vibration Source Figure 2 shows the free admittance loops of the 27 kHz complex vibration source with power factor compensating inductance Lc (0.192mH) at no load and loaded conditions. Quality factor are 370 and 300. Using the inductance Lc, quality factor decreases due to the loss of the in-

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Fig. 1. Configuration of a large capacity complex vibration source using a stainless steel catenoidal complex transverse vibration horn with a welding tip, a stepped complex transverse vibration rods with a flange for supporting the vibration system and a longitudinal vibration disk with six ha bolt-clamped Langevin type PZT longitudinal vibration transducers.

Fig. 2. Free admittance loops of the the complex vibration source measured from a transducer pair which are installed in the opposite side of the disk, at no load condition and at loaded condition under static clamping force 980 N.
ductance, but motional admittance increases to about 380 mS.

4. Welding Characteristics of the Complex Vibration Systems

(1) Figure 3 shows the relationships between static clamping force and weld strength for 1.2-mm-thick aluminum alloy plate specimens welded with Li-grease inserted between the surfaces. Vibration amplitude 3.8 to 4.5 µm<sub>p-o</sub> Welding time 2.0 (s) constant. Maximum weld strength 1525 N is obtained.

(2) Figure 4 shows the relationships between welding time and weld strength for 1.2-mm thick aluminum alloy plate specimens welded with Li-grease inserted between the surfaces. Vibration amplitude 4.3 to 5.8 µm<sub>p-o</sub>, 1176 N constant. Maximum weld strength 1685 N is obtained.

(3) Figure 5 shows the relationship between vibration amplitude and weld strength of 1.2-mm-thick aluminum alloy plate specimens welded using a 27 kHz complex vibration welding equipment shown in Fig. 1. Aluminum alloy plate specimens were welded with weld strength almost equal to the material strength using welding tip vibration amplitude of 5.98 µm<sub>p-o</sub>, which is very small compared with conventional systems. Figure 6 shows conditions of two lapped 1.2-mm-thick aluminum alloy plate specimens after tensile tests welded using the complex vibration system with Li-grease inserted between the welding surfaces.

4. Conclusions

Configuration of 27 kHz large capacity ultrasonic complex vibration source with complex longitudinal vibration disk and a complex vibration rod using multiple BLT transducers were proposed and studied. Three transducers pairs were driven simultaneously using three transformers, three 500 W SIT power amplifiers and an arbitrary waveform generator with three output voltages of phase difference 120° and almost circular locus was obtained. Aluminum alloy plate specimens of 1.2-mm thick were welded with weld strength almost equal to the material strength using the complex vibration welding tip at vibration amplitude of about 6 µm<sub>p-o</sub>. Weld strength about 1700 N was obtained per welded spot area of 1.2-mm-thick aluminum alloy plates.

Reference