CONFIGURATIONS OF LARGE CAPACITY ULTRASONIC COMPLEX VIBRATION SOURCES WITH A STEPPED COMPLEX TRANSVERSE VIBRATION ROD

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Abstract

Configurations of large capacity ultrasonic complex vibration sources with multiple longitudinal transducers are proposed and studied. The ultrasonic complex vibration systems with circular and elliptical vibration locus are effective and essential for new applications in various industries. The complex vibration source of 27 kHz consists of a complex transverse rod with a welding tip (titanium alloy), a complex vibration rod with a flange and stepped part for holding the system (stainless steel), a one wavelength longitudinal vibration disk (aluminum alloy) and six bolt-clamped Langevin type PLT transducers installed along the circumference of the disk at angle 60˚. Three transducer pairs installed opposite sides of the disk are driven simultaneously using three driving systems with three transformers at phase difference 120˚, and the disk is driven in circular locus. The transverse vibration rod installed in the center of the disk is driven transversally and the welding tip of the transverse vibration rod vibrates in circular locus.

1. Introduction

The ultrasonic complex vibration systems with elliptical to circular locus are effective and essential for new high power applications in various industries including automobile production. As an example, ultrasonic welding of various thick metal plates becomes possible which is almost impossible using a conventional system with linear vibration, but large capacity complex vibration sources are required. It have been shown that, using a complex vibration weld tip, weld area and weld strength become larger than that obtained using a conventional system. Furthermore, weld area become uniform and also large weld strength is obtained independent of the weld position, and also ultrasonic continuous seam welding of thick metal plates are available[1]-[5].

Configurations of large capacity ultrasonic complex vibration sources with a stepped complex transverse vibration rod using multiple transducers are proposed and studied.

Transverse vibration rods were installed normally the both sides of the center parts of the circular longitudinal vibration disk (220 mm in diameter) that six 27 kHz driving longitudinal transducers (40 mm in diameter) were installed in its outer side surface at angle difference of 60˚. The complex transverse vibration rod (titanium alloy: 50 mm and 60 mm in diameter) has two stepped parts for vibration velocity transformation and a welding tip.

Two transducers installed in opposite part are driven longitudinally with the same vibration phase and the transducer pair and the disk part are driven in 2 wavelengths longitudinal vibration mode using a transformer.

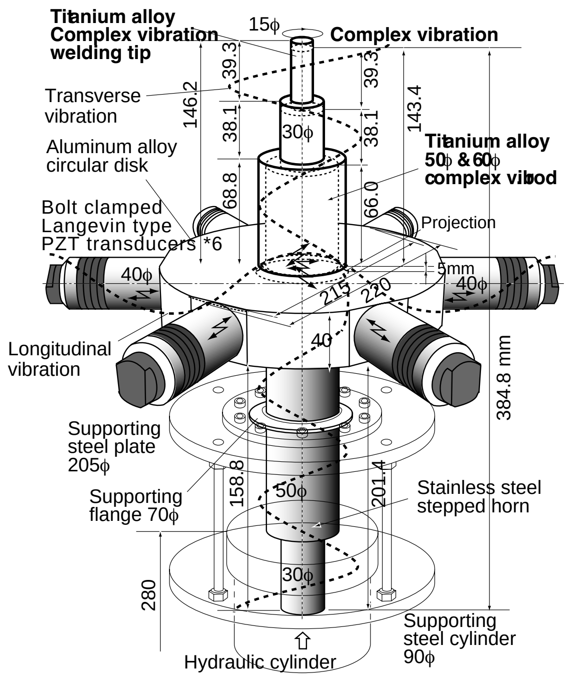

Figure 1: Configuration of a 27 kHz ultrasonic complex vibration source using six bolt-clamped Langevin type longitudinal transducers, an aluminum alloy longitudinal vibration circular disk and titanium alloy and stainless steel complex transverse vibration rods installed in the center of the disk that vibrate in circular locus.

The transverse vibration rod installed normally in the longitudinal vibration loop of the disk center is driven transversally by the transducer pair. The velocity of transverse vibration rod is amplified at the two stepped part and the welding tip vibrates in large amplitude. Each transducer pair is installed at angle difference of 120˚. Three transducer pairs were driven simultaneously using three transformers, three 500 W static induction transistor power amplifiers and an arbitrary waveform generator with three output voltages of phase difference 120˚ and the outer and the center part of the disk are driven in circular loci. The complex transverse vibration rods installed at the center vibration loop position of the disk are driven transversally and vibrate in circular locus. Six transducers may be independently driven directly without transformers using six power amplifiers with phase difference of 60˚. The driving voltages and phase differences may be adjusted slightly to obtain circular locus in the cases where the vibration characteristics of the transducers are somewhat different

This large capacity complex vibration source may be applied effectively to welding of aluminum automobile bodies and also joining of aluminum window sashes, etc.

2. Configuration of the complex vibration source

Figure 1 shows the configuration of the complex vibration source with six bolt-clamped Langevin type PZT transducers (BLT). The complex vibration source of 27 kHz consists of a complex transverse rod with a welding tip (titanium alloy), a complex vibration rod with a

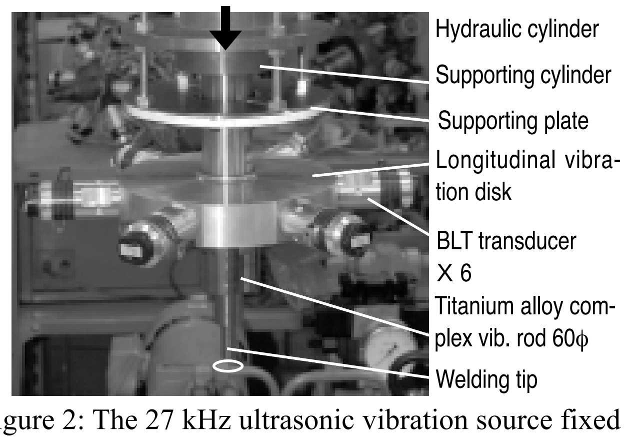

Figure 2: The 27 kHz ultrasonic vibration source fixed to a hydraulic cylinder of a welding frame using a stepped complex transverse vibration rod with a supporting flange.

flange and a stepped part for holding the system (stainless steel), a circular longitudinal vibration disk (aluminum alloy) and six bolt-clamped Langevin type PZT transducers. Transverse vibration rods were installed normally the both sides of the center parts of the circular longitudinal vibration disk (220 mm in diameter) that six 27 kHz driving BLT transducers (40 mm in diameter) were installed its outer side surface. The complex transverse vibration rod with a welding tip (50 mm and 60 mm) has two stepped parts for vibration velocity transformation and a welding tip. The complex vibration rod (50 mm in diameter) installed the opposite side of the disk is fixed in the holding system using a stepped part and a flange as shown in Fig.2. The complex vibration system is fixed to a hydraulic cylinder of a welding frame for inducing static pressure to welding specimens.

3. Driving of the complex vibration source

A block diagram of the driving system is shown in Fig.3. One longitudinal transducer pair is driven in the same phase and the transducer pair and the disk vibrate in 2-wavelength longitudinal vibration mode through a transformer (transforming ratio is 1:1:1) using a 500 W static induction power amplifier. Three transducer pairs are driven simultaneously by three transformers, three 500 W static induction transistor power amplifiers and an oscillator with three output voltages of phase difference 120˚. The driving voltages are $v_1(t) = V_1 \sin(\omega_0 t)$, $v_2(t) = V_2 \sin(\omega_0 t \pm 120^\circ)$ and $v_3(t) = V_3 \sin(\omega_0 t \pm 240^\circ)$. The direction of the circular loci is counterclockwise or clockwise according to positive or negative sign in the equation. The transverse vibration rod is driven in circular locus and almost circular vibration locus was obtained at the surface of the free edge of the complex

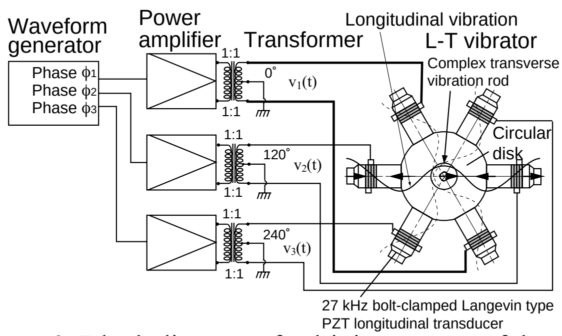

Figure 3: Block diagram of a driving system of the complex vibration source with six bolt-clamped Langevin type longitudinal transducers.

transverse vibration rod. The transverse vibration rod is driven in circular locus and almost circular vibration locus was obtained at the surface of the free edge of the complex transverse vibration rod. Driving three transducer pairs simultaneously with vibration phase difference 120˚, the complex transverse vibration rod vibrates in circular locus or elliptical locus in the case where the vibration characteristics of the transducers are somewhat different. The six transducers of the complex vibration source may be driven without transformers using six independent driving systems with phase difference 60˚.

4. Vibration characteristics of the complex vibration source

Transverse vibration distributions along the titanium alloy complex transverse vibration rods 50 mm and 60 mm in diameter are shown in Figs.4. One pair of the BLT transducer pair is driven. The transverse vibration rods installed at the center of the circular disk are driven normally by the center part of the longitudinal vibration disk. Driving voltage is kept at 10 Vrms. The center rods vibrate in a transverse vibration mode with four transverse vibration nodes at each side. Vibration amplitudes at the free edge of the stepped transverse rods 50 mm and 60 mm are increased 7 and 9 times by the two

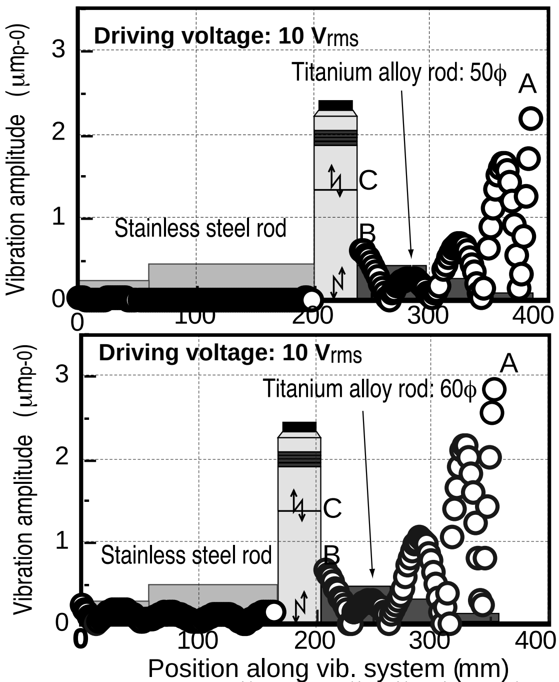

Figure 4: Transverse vibration distributions along the titanium alloy transverse vibration rod 50 mm and 60 mm in diameter and stainless steel transverse vibration rod 50 mm in diameter.

stepped parts compared with the center driving part. Vibration velocity along the stainless steel rod for supporting the system is small compared with the titanium alloy complex vibration rod with a welding tip.

Figure 5 shows the relationships between driving voltage and transverse vibration amplitude at the free edge of the transverse vibration rods made of aluminum alloy, stainless steel and titanium alloy that have two stepped parts, and radial vibration of the outer part of the disk. Vibration amplitude 12.5 μm (peak-to-zero value) is obtained at 150 Vrms in the case of the titanium alloy vibration rod 60 mm in diameter.

Figure 6 shows vibration loci at a free edge of the complex transverse vibration rod 50 mm and 60 mm in diameter in the case where three BLT transducer pairs are driven simultaneously. The vibration locus is slightly elliptical due to the difference of the vibration characteristics of the three BLT transducer pairs.

Figure 7 shows vibration distribution along the support-

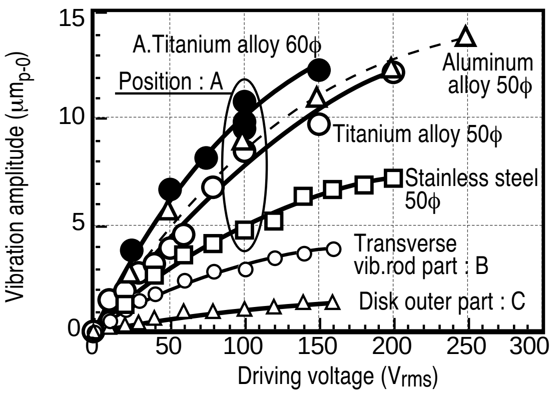

Figure 5: Relationship between driving voltage and transverse vibration amplitudes of aluminum alloy, stainless steel and titanium alloy complex vibration rods with two stepped parts and radial vibration amplitude of outer side of the longitudinal vibration disk.

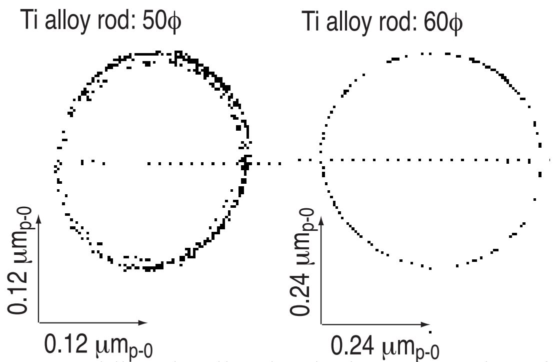

Figure 6: Welding tip vibration loci at a free edge of the titanium alloy complex vibration rods 50 mm and 60 mm in diameter.

ing flange and circular plate (205 mm in diameter). Vibration amplitude at inner part of the supporting flange decreases at outer part and vibration amplitude along the supporting disk decreases further and very small compared with that at inner part of the flange.

Free admittance loops of the complex vibration source at free condition and installed condition in supporting jigs are shown in Fig.8. Quality factor and motional admittance |Ymo| in the case where the vibration system is installed are so large as 2541 and 505.8 mS.

5. Conclusions

Configurations of large capacity ultrasonic complex vibration sources with a stepped complex transverse vibration rod using multiple transducers are proposed and studied.

Transverse vibration rods were installed normally the

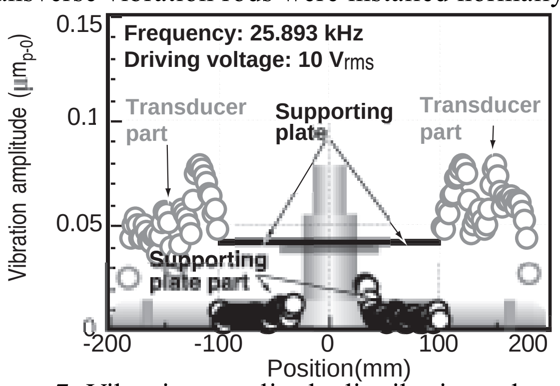

Figure 7: Vibration amplitude distributions along the flange and the supporting disk (200 mm in diameter) and the BLT transducers at frequency of 25.893 kHz. Driving voltage: 10 Vrms constant.

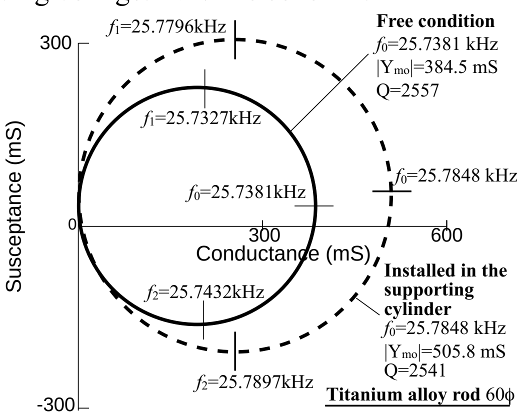

Figure 8: Free admittance loops of the complex vibration source measured from a longitudinal driving transducer pair at free condition and at installed condition in the welding frame with a fixing jigs using a steel supporting disk (20 mm n thickness and 205 mm in diameter).

both sides of the center parts of the circular longitudinal vibration disk (220 mm in diameter) that six 27 kHz driving longitudinal transducers (40 mm in diameter) were installed its outer side surface. The titanium alloy complex transverse vibration rod with a welding tip (50 mm and 60 mm in diameter) has two stepped parts for vibration velocity transformation and velocity ratio N = 7 was obtained.

Two transducers installed in opposite part are driven longitudinally with the same vibration phase and the transducer pair and the disk part are driven in 2 wavelengths longitudinal vibration mode using a transformer. Three transducer pairs are driven simultaneously using three transformers, three 500 W static induction transistor power amplifiers and an arbitrary waveform generator with three output voltages of phase difference 120˚, and almost circular locus was obtained.

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