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Citation	Transactions of JWRI. 2004, 33(1), p. 91-92
Version Type	VoR
URL	https://doi.org/10.18910/8239
rights	
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Micro Welding of Thin Cu Foils with a Direct Diode Laser†

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KEY WORDS: (Direct Diode Laser), (Micro Welding), (Thin Cu Foil), (Weld Bead), (Elliptical Beam)

The feasibility of butt welding of thin SUS304 foils by a direct diode laser system with an elliptical beam shape has been reported in the previous report[1]. In this report, the feasibility of butt welding of thin Cu foils by a direct diode laser system with an elliptical beam shape was investigated.

The experimental apparatus is shown in **Fig 1**. It consists of a micro positioning stage and a direct diode laser with a maximum output power of 500 W and a wavelength of 808 nm. At the focus point, the shape of the beam was elliptical and the beam size was 0.3 x 1.8 mm. The mean power density at the maximum power of 500 W was 92 kW/cm^2. The work distance between specimen and the laser head was 47 mm.

The specimens used were thin Cu (99.95 %) foils of 100 μm in thickness. The length and width were 60 mm and 12.7 mm, respectively. The specimens were fixed on the micro positioning stage using a welding jig. The welding line was precisely aligned with the long axis of the elliptical beam. The micro-positioning stage traveled parallel to the long axis of the elliptical beam as shown in Fig 1. The laser beam irradiated the surface of the specimens at the focal point with the welding conditions shown in **Table 1**.

Figure 2 shows optical microscope photographs of surface and bottom beads welded at various speeds and powers with a 1 mm gap holding jig. At an output power of 350 W, a sound bead was formed at a welding speed of 0.6 m/min. At a welding speed faster than 0.9 m/min, lack of molten metal was occurred because of the smaller heat input, while holes were observed in the weld bead at welding speeds slower than 0.3 m/min. It is conceivable that the holes in the weld bead were caused by condensation of the molten metal due to surface tension. At an output power of 300W, sound beads were not formed in the range from 0.3 to 1.2 m/min. The lack of molten metal occurred with a welding speed of 0.3 mm/min.

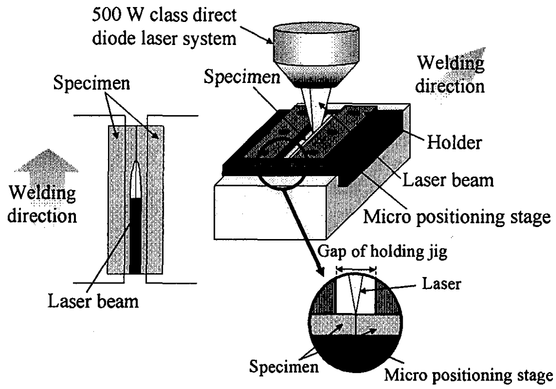

Figure 1 Experimental apparatus for butt welding of thin Cu foils

Table 1 Welding conditions

Gap of holding jig (mm)	Output power (W)	Welding speed (m/min)
1	300	0.3
	350	0.3 - 1.2
3	200	0.3
	250	0.3 - 0.9
	300	0.3 - 1.5
	350	0.3 - 2.1

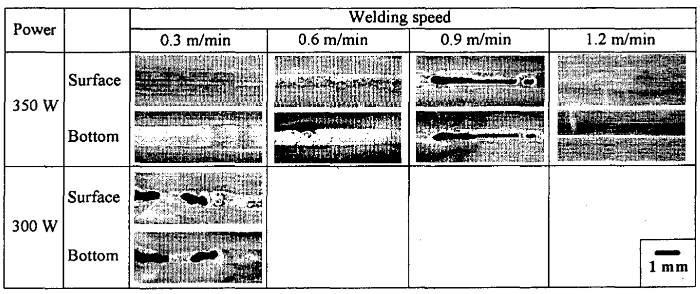

Figure 2 Optical microscope photographs of surface and bottom beads with a 1 mm gap holding jig

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Transactions of JWRI is published by Joining and Welding Research Institute of Osaka University, Ibaraki, Osaka 567-0047, Japan

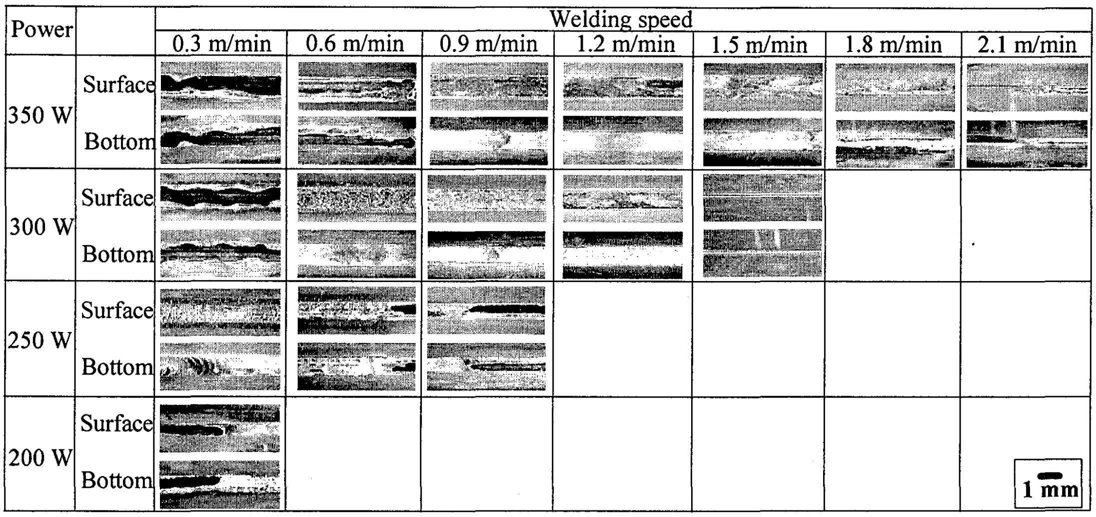

Figure 3 Optical microscope photographs of surface and bottom beads with a 3 mm gap holding jig

These results suggest that heat conduction loss to the holding jig is not negligible. Therefore, butt welding with 3mm gap holding jig was examined.

Figure 3 shows optical microscope photographs of surface and bottom beads welded at various speeds and powers with a 3 mm gap holding jig. At an output power of 350 W, the thin Cu foils were successfully welded in the range from 0.9 to 1.8 m/min. At welding speeds slower than 0.6 m/min, holes were observed. At welding speeds faster than 2.1 m/min, weld beads could not be obtained on the bottom face. A sound bead could be obtained in the range from 0.6 to 1.2 m/min at an output power of 300 W. At welding speeds slower than 0.3 m/min, holes were observed. At welding speeds faster than 1.5 m/min, no weld bead could be obtained on the bottom face. At an output power of 250 W, a sound bead was formed in the range from 0.3 to 0.6 m/min. At welding speeds faster than 0.9 m/min, lack of molten metal was observed. At an output power of 200 W, a sound bead was not formed. It was confirmed that butt-welding of 100 μm thick Cu foil was possible with a 3mm gap holding jig.

Figure 4 shows the comparison of weldable speed areas between 1 mm and 3 mm gap holding jigs. At an output power of 350 W, the weldable speed with 1 mm gap holding jig was only 0.6 m/min. At an output power of 300 W, a weldable speed was not found in the range from 0.3 to 1.2 m/min. In contrast, the weldable speed range at an output power of 350 W is 0.9 to 1.8 m/min with a 3 mm gap holding jig. However, it narrows to 0.6-1.2 m/min at the lower output power of 300 W. The weldable speed range becomes narrower with decreasing output power. The weldable speed area enlarged with higher speed and higher power.

These results are explained as follows, when the bead width is wide, the molten pool cannot be maintained by surface tension melting down by the gravity. In heat conduction type welding, the bead width is determined by the beam interaction time and the beam width. Therefore, it is important to narrow the bead width. This is the reason why the elliptical beam shape is effective for thin film welding. However, the bead width becomes wide by heat conduction at slow welding speeds. Therefore, it is necessary to increase the welding speed and laser power.

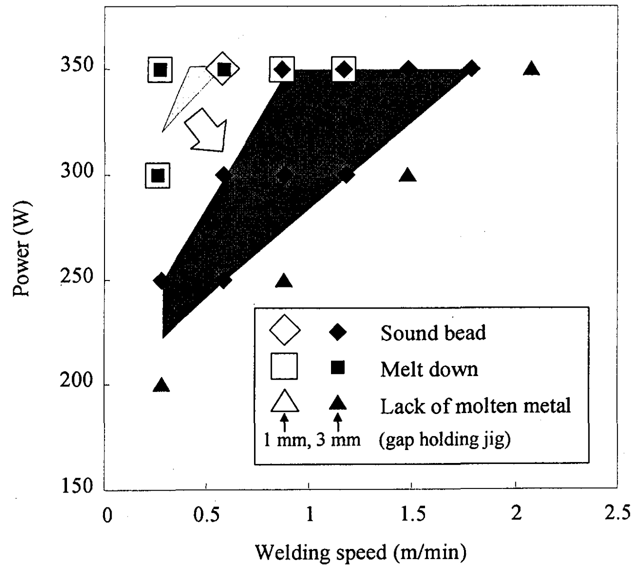

Figure 4 Weldable speed areas of 100μm thin Cu foils

References

1) N. Abe, M. Tsukamoto, A. Morikawa, K. Maeda and K. Namba: Trans. of JWRI, Vol.32, No 1, 2003, p85.