Ultrasonic Welding Technology for Solar Thermal Collector

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Abstracts

A solar thermal collector is a solar collector specifically intended to collect heat: that is, to absorb sunlight to provide heat. A flat plate is the most common type of solar thermal collector, and is usually used as a solar hot water panel to generate solar hot water. A flat plate collector consists basically of an insulated metal box with a glass or a plastic cover and a dark-colored copper absorber plate. Solar radiation is absorbed by the copper absorber plate and transferred to water that circulates through the collector in copper tubes.

Ultrasonic welding is an industrial technique whereby high-frequency ultrasonic acoustic vibrations are locally applied to work pieces being held together under pressure to create a solid-state weld.

In this study, we developed solar collector ultrasonic welding machine with digital controlled power supply and tested various welding conditions such as welding pressure, welding amplitude, welding speed. Welding speed was considered in 2~12m/min. The width of ultrasonic welds was increased with welding amplitude by 2.2~2.5mm. The fracture load of ultrasonic welds showed 20% higher than domestic products.

Key Words : Ultrasonic welding, Solid state welding, Solar thermal collector, Tinox Cu plate

1. Introduction

A solar thermal collector is a solar collector specifically intended to collect heat: that is, to absorb sunlight to provide heat. A flat plate is the most common type of solar thermal collector, and is usually used as a solar hot water panel to generate solar hot water. A flat plate collector consists basically of an insulated metal box with a glass or a plastic cover and a dark-colored copper absorber plate. Solar radiation is absorbed by the copper absorber plate and transferred to a water that circulates through the collector in copper tubes.[1]

The copper plate of solar thermal collector has a special surface coat that makes harmful effect on the fusion weld such as laser and resistance seam welding. Thin thickness(about 0.2mmt) of solar thermal collector will also make a distortion and a defect on the weld. This makes the efficiency of the solar collector lowered. In case of brazing or soldering, they use a chemical preparation and a flux material that have the limitation of automation and environment.

Ultrasonic welding is an industrial technique whereby high-frequency ultrasonic acoustic vibrations are locally applied to work pieces being held together under pressure to create a solid-state weld.[2-4]

In this study, we developed solar collector ultrasonic welding machine with digital controlled power supply and tested various welding conditions such as welding pressure, welding amplitude, welding speed.

2. Experimental Procedure

Ultrasonic machine for solar collector with digital controlled power supply(Fig.1(a)) was used for the test. Fig.1(b) shows the welded solar thermal collector. As shown in Table 1, main variables of ultrasonic welding are welding speed, welding pressure, welding amplitude.

Materials used in this study are Tinox coated copper plate(thickness: 0.2mmt), copper tube(16mm diameter, 1mm thickness). Before the welding, the specimens were cleaned by ultrasonic cleaning in acetone. After that the welding was performed using ultrasonic welding machine. The vibration direction was perpendicular to the pressure of horn direction and parallel to the weld interface.

To evaluate the microstructure of the weld interface, we acquired the cross section specimen at 100mm from the welding start. After that we observed the welded interface using OM, SEM, and TEM.

Tensile test was performed for the measurement of fracture strength, using 7ea welded specimens in each condition.

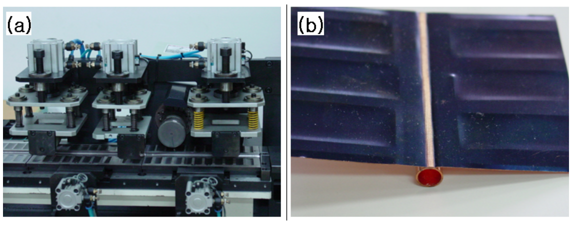


Fig.1 (a) Ultrasonic seam welding machine (b) Welded solar thermal collector

Table 1 Ultrasonic welding conditions

Welding parameters	Ranges
Power	3 kW
Frequency	20kHz
Welding speed	2~12m/min
Pressure	26~76psi
Amplitude	10~70㎛

3. Results and discussion

3.1 Welding condition and bead width

We evaluated the effect of the welding amplitude on the welding bead. The welding amplitude was changed between 10 to 70㎛ at a constant welding speed(4m/min) and welding pressure(26psi).

Fig.2 shows the effect of the welding amplitude on the bead width. As shown in the graph, the bead width depended on the welding amplitude which was increased proportionally.

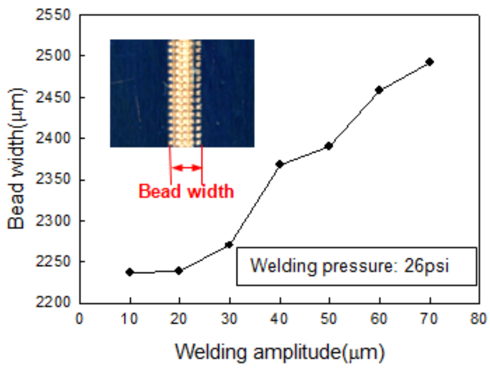


Fig.2 Effect of the welding amplitude on the bead width

3.2 Welding condition and strength

Fig.3 shows the effect of the welding pressure on the fractured load. The welding pressure was changed between 26 to 76psi at a constant welding amplitude(20㎛) and welding speed(2m/min).

The fracture load was proportionally increased with welding pressure in the range of 26psi to 56psi, but decreased at over 56psi pressure.

The failure mode depends on the welding pressure. The fracture on the high pressure occurred around the boundary of the welding area. That is because there was observed the decrease in the thickness of the welding area.

Fig.4 shows the effect of the welding amplitude on the fractured load. The welding amplitude was changed between 10 to 70㎛ at a constant welding pressure(26psi) and a welding speed(2m/min).

The fracture load was not changed in the range of a deviation. The graph showed also low fracture load(20～25kgf) except for 30㎛.

The amplitude would affect the contact surface of solar collector which is directly contacted with the sonotrode. If the effective pressure was not applied on the surface, the plastic deformation was not occurred at the welding interface.

Fig.5 shows the effect of the welding speed on the fractured load. The fracture load was proportionally increased with welding speed in the range of 6 to 10m/min, but decreased at over 10m/min.

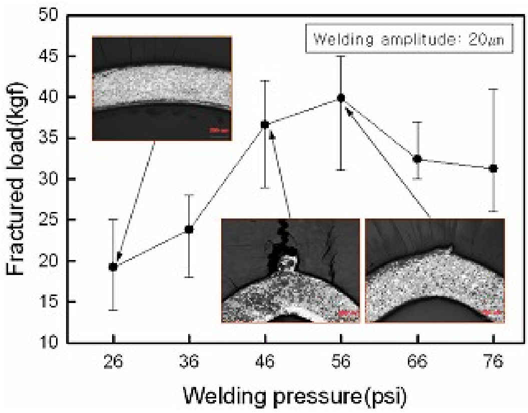


Fig.3 Effect of the welding pressure on the fractured load

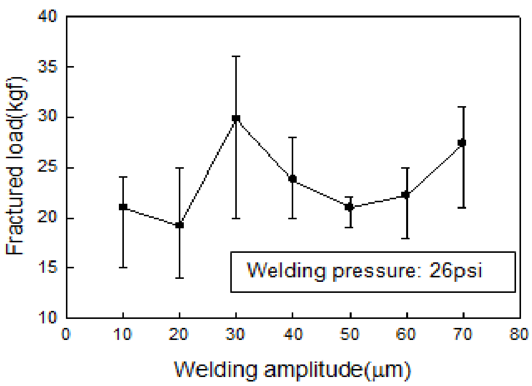


Fig.4 Effect of the welding amplitude on the fractured load

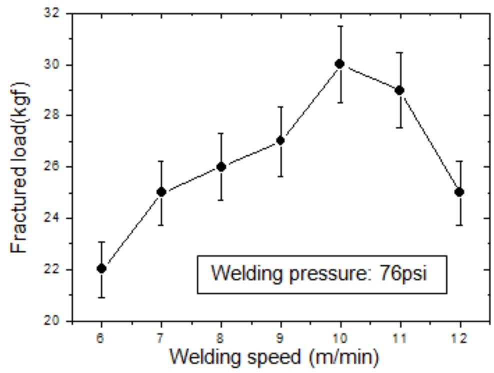


Fig.5 Effect of the welding speed on the fracture load

3.3 Microstructure of welded zone

Fig.6 shows the cross sectional microstructure of ultrasonic welded solar thermal collector using OM. As shown in the picture, the surface of the copper plate was deformed by the wedge of the sonotrode.

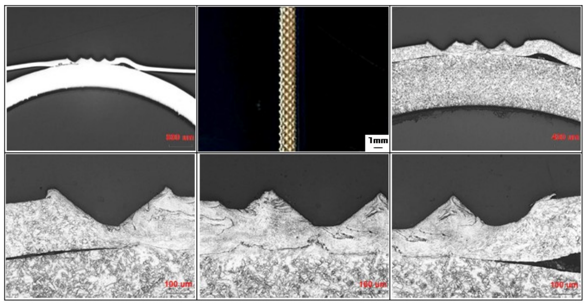


Fig.6 Cross sectional microstructure of ultrasonic welded solar thermal collector (welding speed: 4m/min, pressure: 76psi)

The formation of the ultrasonic weld between two metallic surface has been attributed to (a) the localized melting or heating arising from friction, elastic hysteresis and plastic deformation, (b) mechanical interlocking, (c) interfacial bonding and (d) a chemical bonding involving diffusion.[3]

Fig.7 shows the weld interface with welding pressure 26~56 psi at a constant welding amplitude.

The weld interface at the low magnification OM shows that it is not fully welded, but it may be misunderstood by the differency of the polished surface. The magnified SEM image shows the fully welded interface.

The welding pressure affected the weld interface and increased the welding strength from 19.6kgf to 39kgf.

In order to closely examine microstructures near the weld interface, we tried observing the region with TEM. The specimens were prepared using the FIB[Focused Ion Beam] machine, SII NanoTechnology- SMI3050SE.

Fig.8 shows the images of BFI[Bright Field Image] near the weld interface. The oxide on the surface was observed at the tip of the weld interface.(Fig.8(a)) Fig.8(b) shows the center of the weld interface. The stirring zone of copper plate and tube was observed. When we examined the distribution of oxide in the mixed zone by EDX(spot diameter: 10nm), arrow zone showed the oxide.

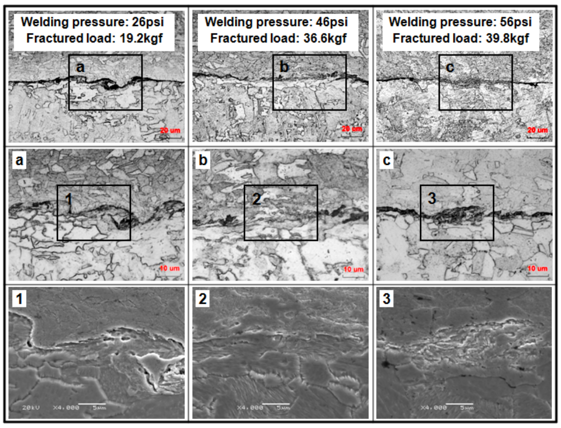
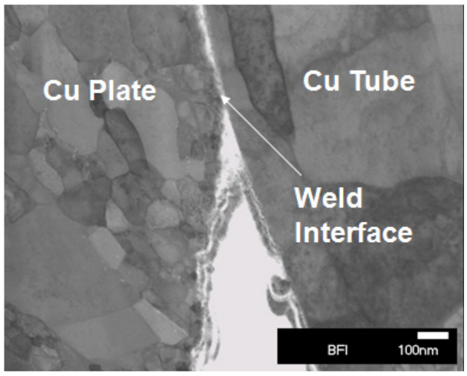
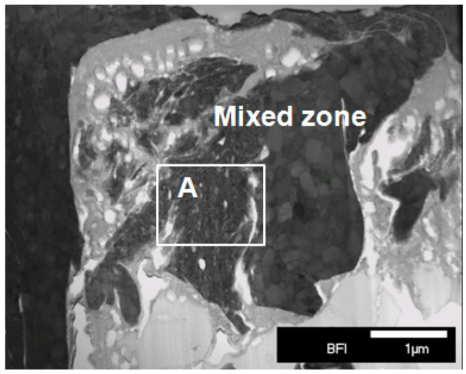


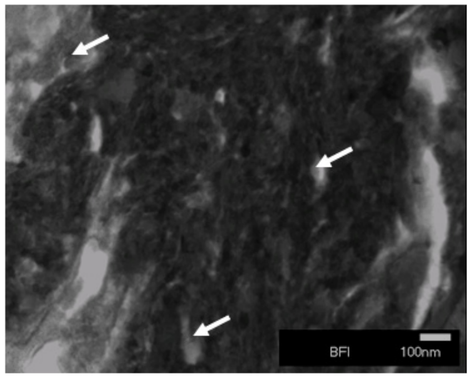
Fig.7 Weld interface with welding pressure(welding amplitude: 20㎛)



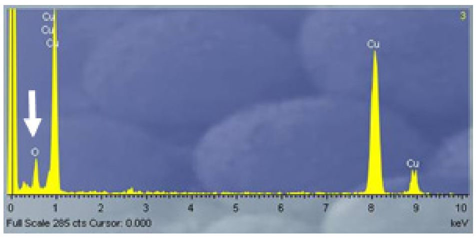
(a)



(b)



(c)



(d)

Fig.8 TEM image of ultrasonic weld (a) Tip of the weld interface (b) Mixed interface (c) Magnification of A (d) EDS peak of arrow zone

4. Conclusions

1. The bead width depended on the welding amplitude which was increased proportionally.

2. The fracture on the high pressure occurred around the boundary of the welding area. That is because there was observed the decrease in the thickness of the welding area.

3. Because the effective pressure was not applied onto the surface, the fracture load was not changed with the welding amplitude in the range of a deviation.

4. The welding pressure affected the weld interface and increased the welding strength.

References

1. S.A.Kalogirou: Prog.Energy Comb. Sci. **30**(2004) 231
2. H.Abdel-Aleem et al.: J.of JWS, **21-4** (2003), 492-498
3. H.P.C.Daniels: Ultrasonics, **3-4**(1965), 190-196
4. K.C.Joshi: Welding Journal, **50-12** (1971), 840-848
5. P.W.Turner et al.: Welding Journal, **52-8** (1973), 359-369
6. C.J.Yeh: Welding Journal, **53-6** (1974), 252-260
7. T.J.Kelly et al.: Welding Journal, **60-4** (1981), 29-31