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Effects of ultrasonic peening treatment on surface quality of CMT-welds of Al alloys

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ABSTRACT

The porosity number and porosity area percentage of weld beads close to the weld surface reduce after ultrasonic peening treatment. The grains are refined significantly in severe deformation layer and transition layer. The refined grain size is approximately 200 nm on the surface of weld bead after ultrasonic peening treatment. The loads on severe deformation layer and transition layer are larger than those on weld beads without ultrasonic peening treatment with the same indentation displacement in nano-indentation tests. After ultrasonic peening treatment, the elastic modulus of the weld bead surface increases slightly due to the decrease of porosity fraction. The hardness values of severe deformation layer and transition layer increase, which leads to the enhancement of wear resistance of welded joints.

1. Introduction

Cold metal transfer (CMT) is a relatively new welding technology whose distinguishing feature is low heat input. Feng et al. (2009) pointed out that the motions of the filler material are integrated into the welding process and the overall control of the process, which greatly decreases spatter. Chen et al. (2017) reported that CMT welding is characterized by low heat input, excellent gap-bridging ability, and good bead formation. CMT is an advanced version of the conventional gas metal arc welding (GMAW) process without splashing. CMT has a wide range of applications such as for microelectronic devices, locomotives, aerospace, bridges, and steel structures. Kumar et al. (2016) reported that the CMT process can weld aluminum alloys at low dilution levels. The innovative technology provides a perfect solution for thin sheet welding, which has been accepted and adopted by companies in various industries.

Surfacing welding is used to restore the initial shapes of parts and wire and arc additive manufacturing (WAAM) to produce components in a short time. It has been reported that there were a large number of pores in the weld bead with the cladding of aluminum alloys using CMT welding. Gu et al. (2015) reported differently sized hydrogen pores distributed in as-deposited and the post-deposition heat treated WAAM aluminum alloys. Cong et al. (2014) reported that the conventional CMT process produced a larger number of pores than other modes and some pores were larger than 100 μm in diameter. Toda et al. (2009) reported that hydrogen porosity contributes to ordinary ductile fracture. The mechanical properties are deteriorated by porosity. It is necessary to decrease the porosity of welded joints using CMT welding.

The development of ultrasonic peening treatment (UPT) is based on shot peening technology. Its working principle is that ultrasonic peening equipment is used to peen the surface of the welded joint in a short period of time to cause plastic deformation of the surface material resulting in residual compressive stress with a cold processing technology. Zammit et al. (2015) reported that UPT is one of the most promising methods for the cold treatment of metallic materials used in many industries including aerospace, ship and marine, vehicle, railway, and bridge structures. Mordyuk and Prokopenko (2007) reported that UPT could improve the properties of surface layers via nanocrystalline structure, surface compressive residual stresses, and work hardening. Li et al. (2016) reported that UPT could be used for the surface enhancement of metallic materials. Mordyuk et al. (2013a, 2013b) reported that the beneficial compressive residual stresses and surface strengthening were registered in the surface layer after UPT. Most papers study the effects of UPT on fatigue behaviors. Few papers are aimed to evaluate the effects of UPT on porosity.

In this study, the welded joints were treated by ultrasonic peening. The effects of UPT on porosity, grain size, and mechanical properties of welded joints were analyzed.

2. Experimental procedure

In this study, the base material was 6061 aluminum alloy in T6

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Table 1
Chemical composition (wt.%) of base material and filler material.

Material	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
6061-T6	0.4–0.8	≪0.7	0.15–0.4	≪0.15	0.8–1.2	0.04–0.35	0.25	≪0.15	Bal.
ER4043	5.6	0.8	0.3	0.05	0.05	–	0.1	0.02	Bal.

Table 2
Welding parameters for CMT welding.

Welding mode	Wire feed speed (m/min)	Travel speed (m/min)	Wire extension (mm)	Gas flow rate (L/min)
DC-CMT	5	0.3	12	20

condition with dimensions of 200 × 50 × 4 mm^3. The filler material was ER4043 with a diameter of 1.2 mm. The nominal chemical compositions of the base material and filler material are shown in Table 1.

The path and travel speed of the torch was controlled using a 6-axis robot. The wire feed speed was controlled through the remote control unit of a Fronius CMT advanced 4000R welding system. The CMT system was operated in direct current (DC) mode. Before welding, the base material was wiped with alcohol several times to remove impurities such as dust, oil, and grease. To ensure the accuracy of results, three weld beads were obtained with the same parameters. The welding parameters are shown in Table 2.

After surfacing welding, the weld beads were treated by manual ultrasonic peening under the same conditions at room temperature. The UPT process was performed on half of the weld beads in the weld direction; the other section was not treated. An HJ-III type ultrasonic peening device was employed for the UPT process. The diameter of the peening needle was 3 mm and the vibration frequency was 20 kHz. The peening amplitude was approximately 30 μm. The UPT setup is shown in Fig. 1. In the UPT process, the peening needle was always perpendicular to the weld surface. Each weld bead was peened three times to ensure that the weld surface was entirely peened. The non-UPT and UPT weld bead is shown in Fig. 2.

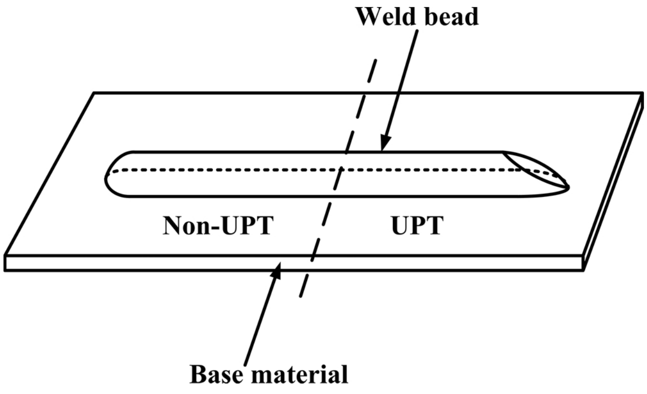

Fig. 2. Non-UPT and UPT weld bead.

The UPT and non-UPT weld beads were cut to 15 mm × 20 mm. Transverse sections of the weld beads were polished employing a standard metallographic procedure. The metallurgical specimens were etched with Keller solution (95 mL H_2O, 1 mL HCl, 1.5 mL HF, and 2.5 mL HNO_3). The microstructures were observed using an optical microscope, scanning electrical microscope (SEM), and transmission electron microscopy (TEM). The load-displacement curves and elastic modulus were obtained using a nano-indenter with a Berkovich diamond indenter at room temperature. The UPT and non-UPT specimens were loaded at a strain rate of 0.1 s^{-1}. The indenter displacement was 2000 nm with constant load for 500 s. An MH-3 Vickers hardness tester was used to measure hardness values. The hardness values of weld bead with UPT and without UPT were measured from the surface to the interior. The measured points were located at the weld bead centerline and the interval between adjacent points was 70 μm. The load was 200 g and the duration was 15 s. An MMW-1 universal wear testing machine, which was a pin-on-disk wear test machine, was used to test the wear resistance with a disk made of Cr12MoV as the counterpart. At

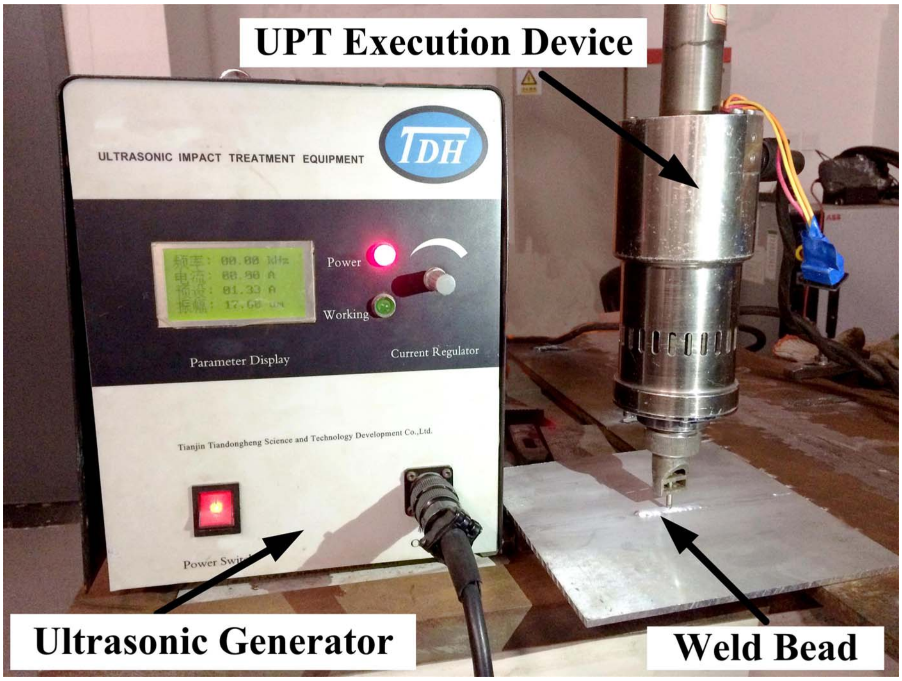

Fig. 1. UPT setup.