Improvement of Welding Technique on Stress Relieve in Large Components

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Abstract

: The residual stresses due to welding the manufactured components or assembled structures need to have stress relieve process before using. It is quite difficult and keeps long time for large components, such as, a high-pressure tank. The application of half bead temper welding technique has been introduced in order to improve the mechanical properties and reduce the residual stress during welding. The residual stresses, mechanical properties and microstructures of welded A516 Gr70 plate steels with shield metal arc welding processes were investigated for three welding techniques: 1) full bead, 2) full bead with post weld heat treatment and 3) half bead temper welding. From tensile tests, all specimens of the three welding techniques ruptured at base metal area. The tensile strength of full bead and half bead temper welded specimens are close and higher than that of the full bead with post weld heat treatment specimen. The elongation property of half bead temper welding technique is much higher than those of the other two techniques. The half bead temper welding reduces the residual stress along the weld direction in the weld bead and in the base metal, while it slightly reduces the residual stress in the HAZ. In the plane across of the weld, the half bead temper welding does not reduce the residual stress

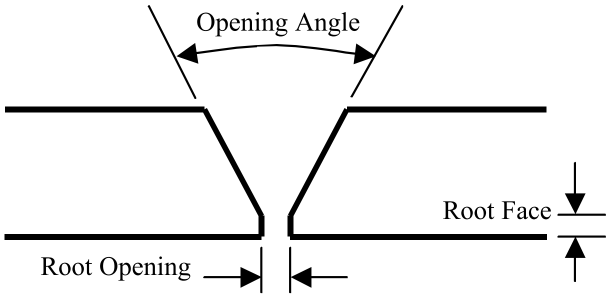
Introduction

The pressure vessels, which made of low alloy carbon steel A516 Gr70 are generally used. The residual stresses due to welding the manufactured components or assembled structures need to have stress relieve process before using. It is quite difficult and keeps long time for large components, such as, a high-pressure tank. The application of half bead temper welding technique has been introduced in order to improve the mechanical properties and reduce the residual stress during welding.

Experimental Procedure

Two pieces of alloy steel plates of A516 Gr70 with the width and length of 45 x 15 mm2 and thickness of 12 mm was welded by shield-metal arc welding method. The filler metal of E-016, which has the same chemical composition and mechanical properties, was used. Three welding techniques: 1) full bead, 2) full bead with post weld heat treatment and 3) half bead temper welding were designed for this experiment. The residual stress of the welded steel plate was measured by using the multi-direction or rosette strain gauge in the three directions of (a) across the welding direction, (b) 45 degree of welding direction and (c) along with the welding direction. The residual stresses were measured in the three positions of base metal, welded metal and heat effected zone. The obtained values were multiply by modulus of elasticity to be the values of residual stress. Tensile test was conducted with testing speed of 10 mm per minute by Shimatsu testing machine. Microscopic structure investigation was also conducted in the three areas of base metal, welded area and heat affected zone. All of the joints in this experiment were designed as the single welded V-groove butt-joint without backing as shown in Figure 1. The mechanical properties of A516 Gr70 steel are as follows: yield strength > 260 N/mm2, tensile strength 485-620 N/mm2. The chemical compositions contain of carbon less than 0.27 %, silicon 0.13-0.45 %, manganese 0.79-1.3 %, phosphorus less than 0.035 % and sulfur less than 0.035 %. The filler metals are E7016 in the AWS classification compared to SFA-5.1 in the ASME specification with the diameter of 3.2 mm, which are used for A516 Gr70 low carbon steel in the welding of boilers and pressure vessels. The temperatures for stress relieve in the post-weld heat treatment are designed between 594 and 649 ∞C. The welding electrical characteristics were followed the handbook of the filler producer (Kobe Steel Co. Ltd., Welding Handbook 1993), which is alterative current between 80 and 130 amperes, potential between 20 and 30 volts and welding speeds are in the range 5-10 cm/min.

Figure 1: The single welded V-groove butt-joint without backing



Results and Discussion

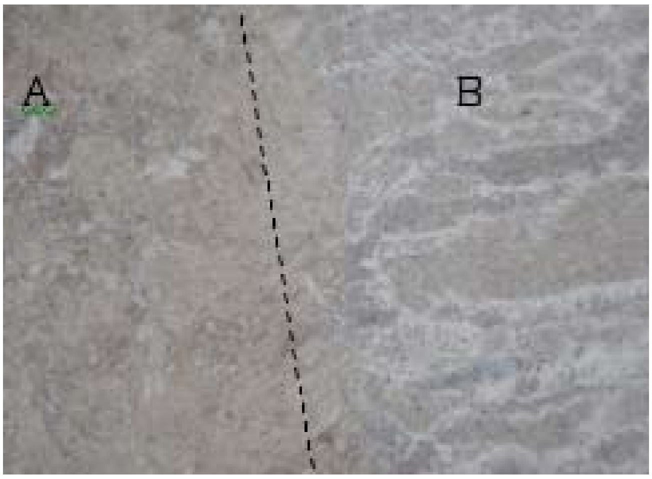
The tensile strength of full bead and half bead temper welded specimens are close and higher than that of the full bead with post weld heat treatment specimen as shown in Table 1, which can be described as the grain growth during heat treatment. The elongation property of half bead temper welding technique is much higher than those of the other two techniques due to the more evenly and adequately dispersed grain refining done by the half bead temper welding technique in the HAZ area of the joint as observed from the microscopic investigation.

Table 1: Yield strength, tensile strength, elongation and modulus of elasticity of specimens welded with various welding technique.

Welding technique	**Specimen Number**	**Yield strength (N/mm2)**	**Tensile strength (N/mm2)**	**Elongation (%)**	**Modulus of elasticity**
FB-01	TS-53	394	561	36.2	0.0051
	TS-54	428	567	36.4	0.0043
	Average	411	564	36.3	0.0047
PW-02	TS-55	370	541	41.4	0.0042
	TS-56	351	540	41.8	0.0054
	Average	360.5	540.5	41.6	0.0048
PW-02	TS-57	412	565	33.6	0.0040
	TS-58	414	578	34.6	0.0037
	Average	413	571.5	34.1	0.00385

The microstructures of the half bead temper welding specimen (Figure 2) show pearlite phase in the heat affected zone(A area) and columnar ferrite in the welded metal(B area). The grain sizes of pearlite phase in the heat affected zone are larger than those in base metal because of grain growth due to heat collection from the half bead temper welding. The porosity could not be found in the heat affected zone and welded area.

Figure 2: Microstructures of heat affected zone(A area) and welded metal(B area) of the half bead temper welding specimen.



The half bead temper welding reduces the residual stress along the weld direction in the weld bead and in the base metal, while it slightly reduces the residual stress in the HAZ. In the plane across of the weld, the half bead temper welding does not reduce the residual stress as illustrated in Figure 3.
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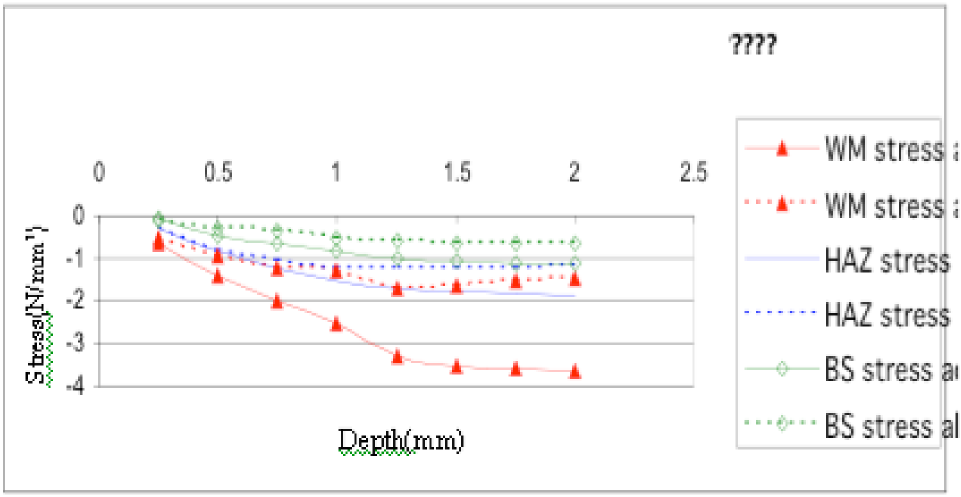
Figure 3: Residual stresses of welded metal, heat affect zone and base metal in the across and along welding directions versus the depth of metals for the half bead temper welding technique.



Conclusion

The tensile strength of full bead and half bead temper welded specimens are close and higher than that of the full bead with post weld heat treatment specimen. The elongation of half bead temper welding technique is much higher than those of the other two techniques.
The half bead temper welding reduces the residual stress along the weld direction in the weld bead and in the base metal, while it slightly reduces the residual stress in the HAZ, and it can improves some mechanical properties of the welded joint.

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