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SUBMERSIBLE-ARC WELDING OF BUTT JOINTS OF AN36 SHIPBUILDING SHEET STEEL ON BOTH SIDES IMMEDIATELY AFTER PLASMA CUTTING

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Single-sided submerged arc welding (SAW) is a fairly promising process; however, the need for preheating and simultaneous heating of the edges to be welded significantly complicates this process [1]. In many cases, double-sided submerged arc welding is the preferred method for joining shipbuilding structures made from plate blanks produced by plasma cutting [2].

To determine the parameters for submerged arc welding, plates of AH36 shipbuilding steel with a thickness of 12 mm, cut by water–air plasma, were used. The chemical composition of AH36 steel is given in Table 1. The edges of the samples for subsequent welding were prepared by plasma cutting so that they immediately had a V-groove with an opening angle of θ = 60–90°. In the SAW experiments, 18 butt-welded specimens were produced from 36 plates measuring 450 × 150 mm.

Table 1. Chemical composition of AH36 steel.

Grade	C	Si	Mn	P	S	Al	Ti	Cu	Cr	Ni	Mo	Nb
AH36	0.14	0.15	0.95	0.015	0.063	0.035	0.013	0.013	0.03	0.006	0.016	0.034

Of the 18 specimens, nine were used to study the magnitude of deformation, while the remaining specimens were used to assess the strength of the welded joints. A digital caliper with a sensitivity of 0.01 mm was used to measure dimensional changes due to deformation. Tensile tests, impact toughness tests, and microstructural analyses were applied to evaluate the strength of the welded joints, while the other specimens were used for deformation measurements.

Thirty-six plates were cut from 12 mm thick AH36 steel using water–air plasma cutting. The rolling direction was predetermined, and all parts were cut so that the welds would be perpendicular to the rolling direction. Thus, plates measuring 450 × 150 × 12 mm were welded horizontally along their 450 mm length. For welding 24 plates, the root pass was performed using a ceramic backing with gas metal arc welding (GMAW) at a constant welding speed prior to the SAW process. For welding 12 plates, a welding groove was used, and these specimens were welded from both sides. Single-sided SAW was not applied. The plates were then flipped, the weld metal was cleaned with a radial grinding disc to expose a clean root surface, and a single-pass SAW was applied. The chemical composition of the welding wire and flux used in the welding experiments is given in Table 2. The welding parameters and technical specifications used in the experiments are presented in Table 3.

Table 2. Chemical composition of welding wire and flux.

Welding wire	C	Si	Mn	P	S
Hyundai H14 (Ø3.2 мм)	0.10	0.29	1.56	0.022	0.011
Flux	C	Si	Mn	P	S
Geka Eliflux BFB S2	0.07	0.35	1.50	-	-

Table 3. Submerged Arc Welding (SAW) Parameters.

Experiment number	Welding backing with groove	Welding method	Welding current, A	Speed, cm/min		Heat input, kJ/mm
				First pass	Second pass	
1-10	C-7	GMAW + SAW	400	43	35	1.92
2-11	C-7	GMAW + SAW	425	43	36	2.01
3-12	C-7	GMAW + SAW	450	43	37	2.10
4-13	WC†	SAW	400	42	35	1.94
5-14	WC	SAW	425	42	35	2.06
6-15	WC	SAW	450	42	35	2.18
7-16	C-12‡	GMAW + SAW	400	34	28	2.45
8-17	C-12	GMAW + SAW	425	34	28	2.61
9-18	C-12	GMAW + SAW	450	34	28	2.76

Notes: *C-7 – ceramic lining with a 7 mm gap (one-sided seam); †WC – without ceramic lining (double-sided seam); ‡C-12 – ceramic lining with a 12 mm gap (one-sided seam).

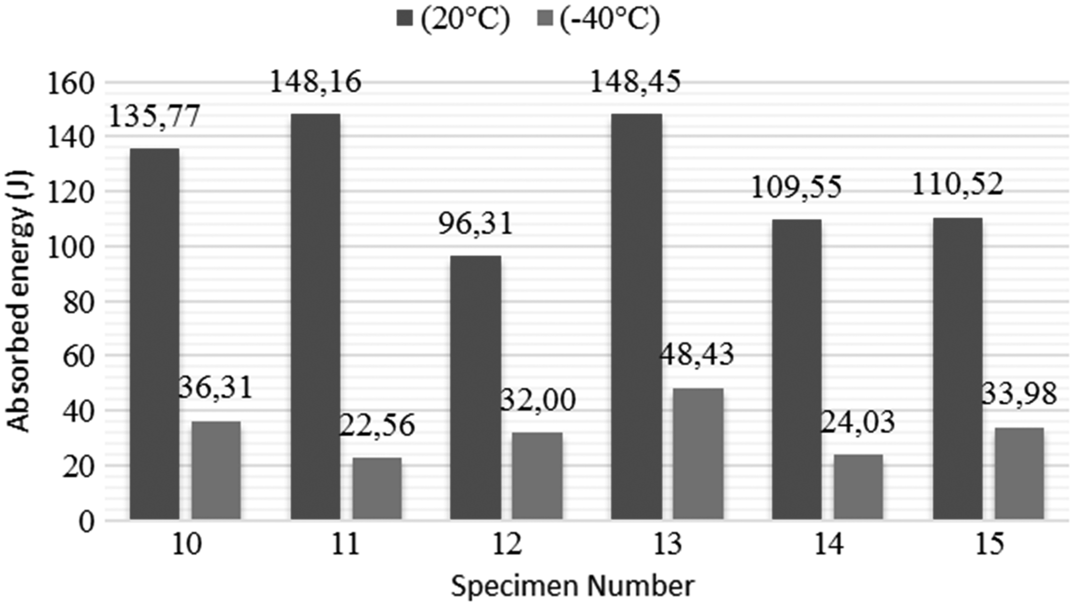

Fig. 1. Charpy impact strength test results.

Specimens for destructive testing—tensile, Charpy impact, and bend tests to determine mechanical properties—were prepared from welds produced in each of the 10–18 experiments. The absorbed energy of the specimens at two different test temperatures (+20 °C and –40 °C) is shown in Fig. 1. The highest energy was recorded for specimen 13 at +20 °C, while the lowest energy was observed for specimen 12. In addition, specimen 13 exhibited the highest energy at –40 °C, whereas specimen 11 showed the lowest absorbed energy at –40 °C. These results indicate that the double-sided submerged arc welding method of plasma-cut edges enhances weld strength.

Different microstructures were observed depending on the alloying elements, temperature gradient, and crystal growth rate during the solidification of the weld metal. In low-carbon and low-alloy weld metal, structures formed according to the cooling rate may include grain boundary ferrite, acicular ferrite, pearlite, and martensite. Analysis of the weld metal microstructure images revealed that the structure mainly consists of acicular ferrite (needle-like regions), although polygonal ferrite is also formed in some areas.

Conclusions:

1. Tensile tests of welded specimens showed that the strength of the weld metal was equal to or higher than that of the base metal. This indicates that the quality of single- and double-sided submerged arc welding of edges produced by plasma cutting without additional mechanical processing is acceptable.

2. According to the tensile test results, cracks in all specimens occurred outside the weld zone in the base metal. The microstructure of the weld metal mainly consists of acicular ferrite.

3. The highest absorbed energy was observed in the specimen with a double-sided weld at both testing temperatures using the Charpy method (+20 °C and –40 °C), indicating a higher impact toughness of the weld metal produced by double-sided welding.

References

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