GMAW-P Welding of Copper-nickel Pipe Joints for Shipbuilding Applications

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Introduction

Virtually all ship designs utilize copper-nickel alloys. Applications include fire mains and other seawater/freshwater piping, tanks, and structures such as rope guards and fairings. Copper-nickel pipe joints are typically welded with manual gas tungsten arc welding (GTAW). Inherently slow travel speeds and low deposition rates limit productivity. The implementation of pulsed gas metal arc welding (GMAW-P) can yield significant productivity benefits for semi-automatic, mechanized, and robotic applications through faster travel speeds and increased deposition rates.

Copper-nickel has historically been very challenging to weld with the GMAW process. Many modern digitally controlled power sources enable precise tailoring of the welding program and are capable of rapidly responding to changes in the welding arc. The combination of an advanced GMAW welding system, an optimized welding program, and optimized procedures enables more precise control of the arc and the weld pool. This makes GMAW-P a strong candidate for the welding of copper-nickel piping. With funding provided by NSRP-ASE, EWI worked with Vigor Industrial and another U.S. shipyard to develop and implement GMAW-P procedures for the fabrication of copper-nickel pipe joints. Procedures developed and tested during this program showed significant gains in productivity.

Application

All the butt joints for this project were made between two 90/10 copper-nickel pipe sections using a backing ring of the same alloy (Figure 1). Pipe sections were 6-in. schedule 10, with outside diameter of 6.625-in. and 0.134-in. nominal wall thickness. MIL-RN67 copper-nickel wire of 0.035-in. diameter was selected as the welding consumable along with argon/helium shielding gas. For procedure qualification of this joint type, NAVSEA Technical Publication S9074-AQ-GIB-010/248 requires visual testing, liquid penetrant testing, radiographic testing, tensile testing, and bend testing (two root and two face bends).

Butt joints with backing rings are fabricated in both the pipe shop and onboard the ship. About 20% of the applications can be fabricated in the pipe shop by rotating the butt joint beneath a stationary torch

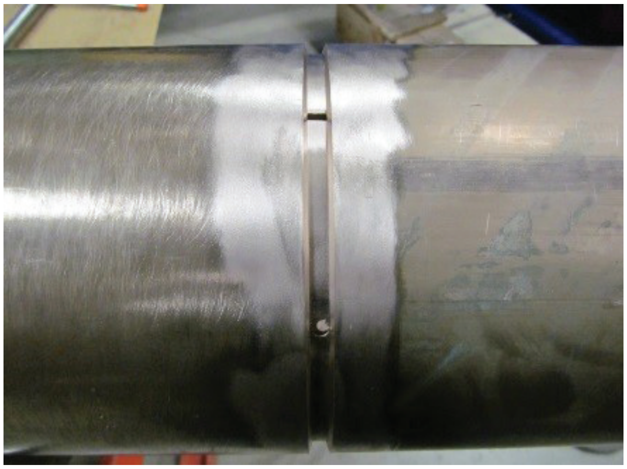

Figure 1: Butt joint with backing ring.

(1G-R position). The other 80% cannot be rotated during fabrication. Robotic GMAW-P procedures for fabricating the butt joint in the 1G-R position and the 5G position (pipe is fixed with the axis horizontal) were first developed for implementation in the pipe shop. Semi-automatic GMAW-P procedures were then developed for fabricating the 1G-R butt joints and the 5G position joints for all position welding in both the pipe shop and onboard the ship.

Productivity comparisons are based on shipyard welding procedure specifications for manual GTAW. GTAW butt joints are produced in the 1G-R and 5G positions using 3 passes, with approximate travel speed of 3-ipm for each pass. Total arc-on time is about 20.8 minutes.

Robotic GMAW-P Welding Procedure Development

Robotic GMAW-P procedures were developed for butt joints in the 1G-R (pipe rotated) and 5G (pipe fixed) positions. Butt joints produced with the robotic GMAW-P procedures did not require inter-pass grinding: only wire brushing was performed. Commercially off-the-shelf welding programs were used for these joints, since the torch position for a given procedure was consistently maintained by the robot.

A butt-joint weld made in the 1G-R position using the robotic GMAW-P procedure is shown in Figure 2. The robotic GMAW-P procedures used two passes at average travel speed of 7.9 ipm, and total arc-on time of 5.3 minutes. This procedure enabled a 33% reduction in the number of passes and a 75% reduction

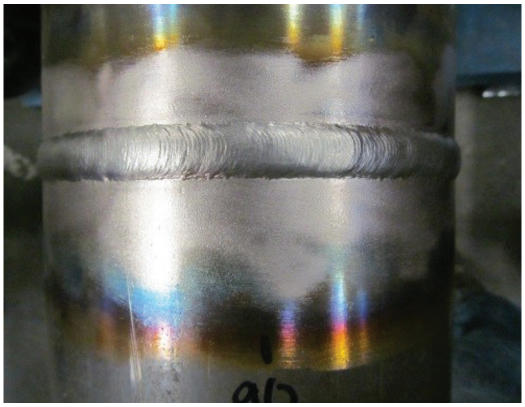

Figure 2: Robotic GMAW-P butt-joint weld produced in the 1G-R position at Vigor Industrial.

in the total arc-on time, compared to the manual GTAW procedures currently used by the shipyard to produce butt joints in the 1G-R position. This weld met visual, liquid penetrant, and radiographic testing requirements, but was not subjected to mechanical testing (others were tested later).

A photo and a macrograph from the butt-joint weld produced in the 5G position using the robotic GMAW-P procedure are shown in Figure 3. The robotic GMAW-P procedures developed for producing these butt joints used an orbital pattern with the start and stop of each pass coinciding with the 11:00 position. Three passes were used at average travel speed of 7.4 ipm, and total arc-on time of 8.4 minutes. These procedures had the same number of passes as manual GTAW but enabled a 60% reduction in the total arc-on time. The weld met all procedure qualification requirements of NAVSEA Technical Publication S9074-AQ-GIB-010/248.

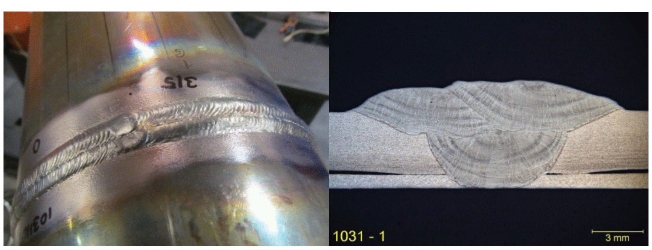

Figure 3: Robotic GMAW-P butt-joint weld produced in the 5G position at EWI.

Semi-Automatic GMAW-P Welding Procedure Development

Semi-automatic (i.e. manual) GMAW-P procedures were developed for producing butt joints in the 1G-R (pipe rotated) and 5G (pipe fixed) positions. A welding program that was custom designed and optimized for this application by OTC-Daihen was used with an OTC Daihen advanced GMAW welding system to develop optimized GMAW-P procedures for producing the butt joint semi-automatically in the 1G-R and 5G positions. This combination of advanced GMAW welding system, optimized welding program, and optimized procedures provided adequate control of the arc characteristics even with the changes in contact tip-to-work distance (CTWD) and torch work and travel angles that inherently occur during semi-automatic welding in a V-groove joint.

A photo and macrograph from a butt-joint weld produced in the 1G-R position using the developed semi-automatic GMAW-P procedure is shown in Figure 4. This weld was produced in two continuous 360-degree passes at average travel speed of 8.9 ipm, and total arc-on time of 4.8 minutes. Interpass cleaning was performed using a stainless-steel brush. These procedures enabled a 33% reduction in the number of passes and a 77% reduction in the total arc-on time, compared to the manual GTAW procedures currently used by the shipyard to produce butt joints in the 1G-R position. The weld met all procedure qualification requirements of NAVSEA Technical Publication S9074-AQ-GIB-010/248.

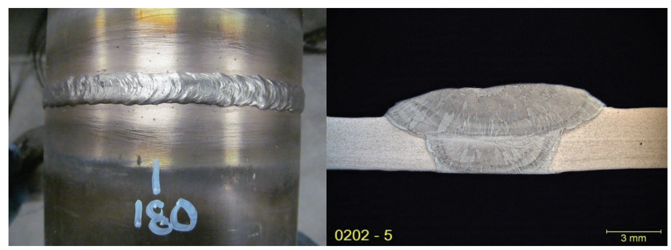

Figure 4: Semi-automatic butt-joint weld produced at Vigor Industrial in the 1G-R position.

A photo and macrograph from the butt-joint weld produced in the 5G position using the developed semi-automatic GMAW-P procedure is shown in Figure 5. Two passes were used to produce this weld. For each pass, welding was performed from the 12:00 position to the 6:00 position with tie-ins at approximately 12:00, 4:00, 8:00, and 6:00. The start/stop locations were dressed prior to pass 2, in addition to wire brushing. The average travel speed for the two passes was 6.8 ipm, and the total arc-on time was 6.5 minutes. These procedures enabled a 33% reduction in the number of passes and a 69% reduction in the total arc-on time, compared to

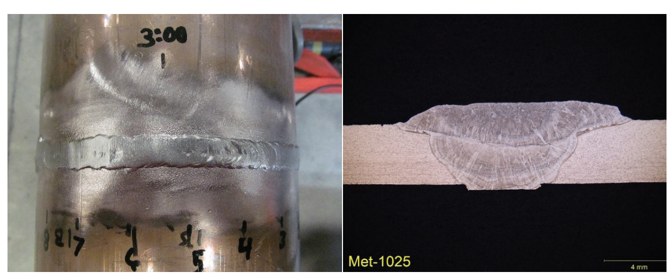

Figure 5: Semi-automatic butt-joint weld produced at EWI in the 5G position.

the manual GTAW procedures currently used by the shipyard to produce butt joints in the 5G position. The weld cap of pass 2 required some dressing prior to nondestructive testing to remove excess reinforcement and to smooth areas in the weld cap that could trap penetrant during penetrant testing. The weld met all procedure qualification requirements of NAVSEA Technical Publication S9074-AQ-GIB-010/248.

Conclusions

GMAW-P procedures that can be applied both in the shipyards' pipe shop and onboard the ship were developed for producing the butt joint with a backing ring in 6-in diameter 90/10 copper-nickel pipe using MIL-RN67 wire. By combining advanced GMAW welding systems with optimized welding procedures, the barriers that have historically limited the use of the GMAW-P process for copper-nickel pipe joints were overcome, with significant gains in productivity. Compared to the shipyard's corresponding qualified manual GTAW procedures:

- Robotic GMAW-P procedures for producing the butt joint with the backing ring in the 1G-R and the 5G positions (using an orbital approach) provided a 75% and 60% reduction in total arc-on time, respectively; and,
- Semi-automatic GMAW-P procedures for producing the butt joint with the backing ring in the 1G-R and the 5G positions (using downward progression) provided a 77% and 69% reduction in the total arc-on time, respectively.

Recommendations

The feasibility of semi-automatic GMAW-P for all-position welding of copper-nickel pipe joints was demonstrated using an advanced GMAW welding system with an optimized welding program and optimized procedures. Semi-automatic GMAW-P procedures for producing the butt joint with the backing ring in the 5G position may require dressing the start and stops between individual segments. Also, the weld cap of pass 2 may require post-weld dressing prior to nondestructive testing to reduce reinforcement and to smooth areas that could trap penetrant during penetrant testing. The 5G position semi-automatic GMAW-P procedure will also require highly skilled welders to implement. It is recommended that shipyards consider the development of all-position GMAW-P welding procedures for this application using an orbital track-based positioning system. The orbital track-based GMAW-P approach would enable all-position welding of copper-nickel pipe joints both in the pipe shop and onboard the ship using less skilled welders and without the need for significant dressing operations. The robotic and semi-automatic GMAW-P procedures for producing the butt joint with backing ring in the 5G position can be leveraged during the development effort to provide quick implementation of the orbital track-based GMAW-P approach.

Acknowledgements

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