E Root Pass Welding of Duplex Stainless Steel Pipeline Girth Welds without Backing Gas

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Introduction

There is interest within the pipeline industry to implement duplex stainless steel (DSS) instead of carbon steel due to the increase in corrosion resistance and strength of DSS. A disadvantage of using DSS is the high skill required by the welder to produce an acceptable root pass. The root passes are typically deposited using gas tungsten arc welding (GTAW) with a specialized backing gas shield. If an alternative root pass welding procedure could be developed using shielded metal arc welding (SMAW), gas metal arc welding (GMAW), or flux-cored arc welding (FCAW) without the use of backing gas, DSS could be a cost-effective alternative for applications originally designed for carbon steel. Another disadvantage of DSS is the difficulty in achieving the low-temperature toughness required by pipeline companies for field welds. If solutions to these disadvantages could be developed, then the use of DSS would dramatically decrease the tonnage of material required as well as improve the corrosion properties of the pipeline.

Approach

Initial root pass welding trials were conducted using several different filler metals and welding processes on 8-in. diameter by 0.25-in. wall thickness 2205 DSS pipe. The root pass trial welds were visual inspected to determine the acceptability of the root profile. From the results of the root pass welding trials; one process/consumable combination was selected as a baseline welding procedure. A complete joint was welded using the baseline process/consumable combination and radiographed, and then compared to ASME B31.3 requirements for acceptance. The baseline welding procedure was given to BP and ConocoPhillips for validation. The validation consisted of welders experienced with pipeline girth welding determining the productivity of the baseline welding procedure. In addition to the standard testing required by the ASME Section IX and API1104 codes, toughness testing was performed on the completed field welds. The toughness testing results for the field welds were compared to the toughness testing results for welds made using variations of the baseline welding procedure in an attempt to determine the necessary measures to increase the weld metal toughness.

Results and Discussion

Several variations in joint design, welding technique (push/drag), process and consumable combination were used during the initial root pass welding trials. FCAW resulted in an inconsistent root bead profile, the exact cause of which was not determined. The GMAW process was unable to produce an acceptable root bead profile that was ‘sugar’ free on the backside. The most promising root bead profile was produced using DCEP SMAW with E2209-17 electrodes. It is important to note that, when welding vertical down, a large drag angle was needed to allow the welding arc to force the weld pool out of the joint to allow complete penetration of the root.

The SMAW baseline welding procedure was transferred to BP and ConocoPhillips for field validation. Each welder was able to produce high quality welds using the baseline welding procedure within a short period of time. Several important observations were made during the field validation. Firstly, the electrodes used during the field validation were from a different manufacturer than the electrodes that were used during the development trials. This observation would indicate that the electrode manufacturer, not just the classification, would need to be specified on the welding procedure. Secondly, the type and manufacturer of the power supply had a dramatic effect on weldability. Inverter power supplies yielded the best results with all DSS electrodes used; where as generator power supplies yielded only moderate results. Finally, since no backing gas was used during the welding, it was important that the slag be left on the backside of the root pass prior to welding the hot pass. The slag continued to shield the backside of the root during welding of the hot pass.

A trained welder produced one PQR weldment using the baseline welding procedure on 2205 DSS pipe. The weldment passed to the requirements of ASME Section IX and API 1104, but BP and ConocoPhillips require additional testing which supplements the testing required by the industry codes. The qualification weldment passed BP's and ConocPhillips' maximum-allowable hardness requirement and the accelerated corrosion requirement but failed the meet the minimum-required toughness. The toughness values at the weld centerline were below the minimum requirements and were attributed to the oxygen content of the weld metal.

In an attempt to increase the toughness of the weld metal, additional welds were made using the baseline procedure which was modified to allow for a lower oxygen welding process and/or more basic welding consumable. The root beads were deposited using SMAW with the original E2209-17 electrode and with a more basic E2209-17 electrode. The fill and cap passes were deposited using FCAW, GMAW, or SMAW with the more basic E2209-17 electrodes. The completed baseline procedure variation welds were radiographically inspected and deemed to be acceptable to B31.3 requirements.

The lowest oxygen weld produced the highest toughness values and the highest oxygen weld produced the lowest toughness values, but the remaining data did not correlate oxygen content directly with toughness. These results show that both the welding process and the oxygen content have an effect of the toughness of the weld metal. The highest toughness weld was produced using SMAW with the original E2209-17 electrode for the root and GMAW for the fill and cap passes. The results from the highest toughness weld would indicate that the fill passes have a larger effect on the weld metal oxygen content than the root pass. The SMAW/GMAW process combination that produced the highest weld metal toughness values (50.6 ft*lbs average/ 46.5 ft*lbs minimum) exceeded BP's and ConocoPhillips' toughness requirements (45 ft*lbs average/ 40 ft*lbs minimum).

Conclusions

SMAW was found to be the best process to produce an acceptable root beads in DSS pipeline girth welds without backing gas. GMAW was found to be the best process to reduce the oxygen content of the fill passes thus improving toughness. Procedures have been developed that would produce acceptable welds according to ASME Section IX and API 1104 but have not yet been qualified.