Employing innovative construction techniques, particularly those involving corrosion resistant alloys in field construction environments, can raise complex issues, especially regarding the welding procedures necessary to achieve stringent quality control requirements. Developing the necessary construction processes, such as testing and evaluating welding procedures, often becomes a long, arduous task that requires technical adjustments and innovative solutions to problems encountered. However, once the issues that surface have been resolved, the right alloy and construction techniques can translate into a cost effective material solution for the client, providing a high degree of reliability and durability.

Seeking such a material, Syncrude Canada, Ltd considered several high alloy materials to determine the one most suitable for the construction of a new flue gas desulfurisation (FGD) scrubber unit and all associated tankage for the company’s UE-1 (expansion) project. Syncrude’s primary selection criteria included high uniform and localised corrosion resistance with excellent thermal stability.

Syncrude chose Alloy 59 (UNS N06059), which was used as both solid plate and cladding on carbon steel for the FGD unit. However, in conjunction with the vessel design, this particular alloy presented significant fabrication challenges. The very large size of the structure required a significant amount of alloy welding in a field construction environment rather than a dedicated alloy shop environment. The welding procedures also needed to be carefully designed so as not to degrade the alloy’s material properties during construction, particularly its corrosion resistant capabilities.

The Syncrude project
Syncrude is the world’s largest producer of crude oil extracted from the oil sands deposits found in northeastern Alberta. It has been estimated that there are 1.7 trillion bbls of crude oil in place in these oil sands deposits, of which 300 billion are recoverable using current technologies. More than 30% of Canada’s oil production is derived from the oil sands deposits, and this is projected to increase to 50% by 2010.

To produce this crude oil, the oil sands deposits must first be surface mined. This occurs primarily through the use of a truck and shovel operation. Then a high percentage (> 90%) of the bitumen contained in the oil sands is recovered using water extraction processes. The product is upgraded into a sweet light crude called Syncrude Sweet Blend (SSB), which has amongst the lowest sulfur content of any crude available in North America.

As part of the UE-1 Project, a new incinerator FGD unit is being constructed. The FGD unit will remove approximately 95% of the sulfur dioxide from a new CO boiler and tail gas incinerator flue gas. In the unit, sulfur dioxide reacts with an ammonium sulfate slurry to form ammonium sulfate crystals, a marketable product that will then be sold as fertilizer.

Alloy 59
A design life of 20+ years and a run length of 36 months are required for the FGD absorber vessel and associated tankage. Consequently, Syncrude gave careful consideration to the materials used in the FGD construction. After conducting extensive laboratory tests on various candidate alloys, their corrosion resistance and metallurgical properties, the UE-1 Project team selected Alloy 59 as the most suitable, cost effective material for the construction of the vessel.

First developed in the 1980s, Alloy 59 is part of the Nickel-Chromium-Molybdenum family, which, according to various FGD industry experts, is the only family of alloys that can provide 20+ years reliability with minimal maintenance. Syncrude tested the corrosion rate of Alloy 59 along with other alloys in the Ni-Cr-Mo family by placing welded and unwelded test
coupons of each alloy into a saturated ammonium sulfate solution with 10,000 ppm chlorides and a pH of 1. The solution was then heated to a temperature of 93 °C (200 °F). This particular solution and corrosion test was designed specifically to simulate an extreme service environment for the FGD vessel.

Based on the results of this test, Alloy 59 was determined as having the lowest general corrosion rate in this ammonium sulfate solution. In addition, test coupons were heat treated to simulate multiple pass welding, and Alloy 59 showed no signs of pitting attack (localised corrosion). Syncrude decided to use all Alloy 59 weld wire (single alloy weld wire) to weld the solid Alloy 59, as well as the hot roll bonded Alloy 59 clad plates, including the carbon steel plate backing material.

Weld testing and weld procedure qualification
On selecting Alloy 59 to provide corrosion resistance for its new FGD scrubber vessel, Syncrude contracted CB&I, an engineering, procurement and construction company, to perform the onsite fabrication of the unit. All welding procedure development work, including welding process evaluation, welding technique evaluation, procedure qualification, welding and mechanical testing, were performed in CB&I’s welding laboratory in Plainfield, Illinois. Corrosion Testing Laboratories Inc. of Newark, Delaware, USA, performed all the corrosion testing for qualification of the weld procedures CB&I developed.

The Syncrude FGD unit is one of the largest in the world, with a bottom section 70 ft in diameter and an upper section 50 ft in diameter, as well as a 20 ft diameter stack on top of the vessel, bringing its total height to 310 ft. Alloy 59 was used in the absorber vessel, its hold tank and the primary underflow tank as 3.2 mm cladding over carbon steel, while 1.6 mm cladding was used in the unit’s stack and transition cone. Solid Alloy 59 was also used for some areas of high velocity ammonium sulfate slurry service, such as the top 10 ft of stack shell. Overall, approximately 770 t of clad and solid Alloy 59 plate were used in the fabrication of the structures.

As the final design for the FGD unit required the use of carbon steel backing material, it was determined early on that the weldments in the clad plate would consist of a backing material weld and a clad restoration weld. The entire joint thickness would be welded with Alloy 59 material (Figure 1).

However, the use of carbon steel backing material presented several challenges to the preservation of Alloy 59’s corrosion resistance and thermal stability. One such challenge involved the use of post weld heat treating (PWHT) at 593 °C (1100 °F) to maintain the required mechanical properties of the carbon steel. The specific concern was that the PWHT, as well as welding with multiple passes, would cause the formation of metallurgical phases detrimental to the alloy’s corrosion resistance.

Another challenge was the clad restoration welds that were somewhat diluted by the carbon steel backing material, and were thus more susceptible to increased levels of iron and carbon, which often degrade the material’s corrosion resistance. Other risks are contaminants such as sulfur, phosphorus, lead and other low melting point elements. These contaminants, which can often embrittle or reduce corrosion resistance, come from such sources as markers; temperature indicating crayons; lubricating grease or fluids; and fuels. As such, it was critical to remove any contamination prior to welding to maintain corrosion resistance.

Given these challenges, the initial task was to develop the appropriate material handling procedures, construction techniques, welding procedures and field quality control techniques necessary to ensure the alloy materials and weldments exhibited the corrosion resistance and thermal stability that dictated the Alloy 59 selection in the first place.

CB&I developed detailed material handling procedures and construction welding techniques that promoted alloy cleanliness and prescribed methods for detecting and cleaning surface contamination. In addition, Syncrude and CB&I jointly developed a preliminary testing programme to establish limits on welding heat input and chemistry dilution and to determine the effectiveness of certain corrosion tests and cleaning techniques.

Based on preliminary weld test results, it was determined that two tests would be used to confirm the general and localised corrosion resistance of the procedure qualification weldments. For the first test, each qualification plate was placed in an ammonium sulfate solution similar to the FGD service environment in order to confirm the general and localised (crevice) corrosion of the procedure qualification weldments.
Failure analysis

CB&I and Corrosion Testing Laboratories initiated a metallurgical failure analysis of these four specimens, in which both untested specimen materials and (as failed) materials were examined (Figures 2 and 3). Based on this analysis, the following determinations were made:

- Pitting only occurred in the weld metal, as the base metal and adjacent parent material during the GMAW welding process.
- Surface imperfections on the weld metal were present on three samples. There were high iron levels in these imperfections.
- Weld pass interfaces in the final GMAW layer contain embedded particles (or inclusions), which were high in iron.

As it was apparent that the high iron areas were potential initiation sites for localized corrosion, each step of the welding and cleaning processes was re-evaluated for possible sources of iron contamination. In this evaluation, attention was given to the stainless steel power brushes that were used to remove an adherent black powder deposited on the surface of the weld and adjacent parent material during the GMAW welding process.

Analysis showed that the stainless steel power brushes were depositing iron from the bristles. Once the problem had been identified, CB&I proposed using solid Alloy 59 power brushes as an alternative cleaning method, which quickly alleviated any problem of interpass iron contamination. Upon retesting the procedures, all weldments met the acceptance criteria.

Conclusion

Throughout the preliminary and weld procedure qualification testing, several adjustments were made to the processes and techniques for welding, handling and cleaning Alloy 59. These changes ensured that alloy cleanliness was maintained throughout all stages of fabrication; that PWHT or multiple pass welding did not cause sensitisation; and that dilution of the alloy weld metal was tightly controlled and kept below critical levels. The effectiveness of each effort was monitored and confirmed through chemical analysis and thorough corrosion testing. As a result, the final procedures and techniques selected preserved the properties of Alloy 59, and ensured the material used to construct the FGD vessel would provide the required durability and reliability.

Despite the obstacles, Syncrude, CB&I and Corrosion Testing Laboratories finalised procedures and techniques that preserved the general and localised corrosion resistance and thermal stability of Alloy 59, resulting in a successful and cost effective expansion project for Syncrude Canada.

Although new construction materials such as Alloy 59 often require a long process of testing and analysis, the benefits that can be derived from such alloys often outweigh the associated costs and challenges. By identifying specific challenges early in the project, and making the necessary evaluations and adjustments to existing material handling procedures, construction techniques, welding procedures and field quality control techniques, projects such as the Syncrude expansion can be completed on time and within budget in an efficient manner.

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