Welding stainless steels without impacting corrosion resistance

Michael Fletcher, a metallurgist with extensive experience in welding and NDT and a consultant to Huntingdon Fusion Techniques HFT® and other manufacturers across the globe, explains why welding and weld finishing can cause in stainless steel to corrode and some of the ways that weld purging solutions can be used to minimise this risk.

Most industries using stainless steels do so because of their resistance to corrosion. Industry sectors such as dairy, food and pharmaceutical manufacturers and the semi-conductor producers are major users, since the end products must be contamination free and the presence of any corrosion products can have serious consequences.

Stainless steels and other alloys containing chromium owe their resistance to corrosion to the formation of a very thin (10-5 mm) transparent surface layer of chromium oxide. This layer provides a passive film that acts as a barrier to penetration by an invasive environment. When heated to a high temperature in the presence of oxygen this film increases in thickness until it becomes visible – the colour becomes darker with increasing film thickness.

At a critical film thickness the film becomes unstable and begins to break down. The fractured zones created offer sites for localised corrosion. Four principle mechanisms are involved: Crevice corrosion; Pitting corrosion; Stress corrosion cracking; and Microbiologically induced corrosion (MIC).

Crevice corrosion is the localised corrosion of a metal surface attributable to the proximity of another metal such as a weld. It is a locally accelerated type of corrosion and is one of the major corrosion hazards in stainless steels.

Figure 1: Crevice corrosion adjacent to a stainless steel pipe weld.

Pitting corrosion produces attacks in the form of spots or pits and takes place at points where the passive layer might be weakened. It occurs in stainless steels where oxidation has reduced the passivity. Once the attack has started, the material can be completely penetrated within a short time.

Stress corrosion cracking (SCC) is characterised by cracks propagating either through or along grain boundaries. It results from the combined action of tensile stresses in the material and the presence of a corrosive medium. It can be induced in some stainless steels by adverse heat treatments such as those occurring in weld heat affected zones.

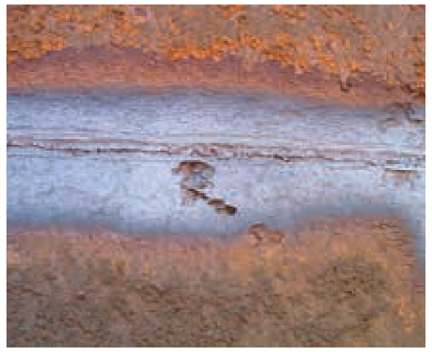

Figure 2: Stress corrosion cracking in welded joint.

Microbiologically induced corrosion is promoted or caused by micro-organisms, typically in industries related to food and beverage processing. It is usually referred to by the acronym 'MIC' and is common in welded sections.

Weld decay of stainless steel

Reduction in the protective chromium content can lead to a phenomenon known colloquially as 'weld decay'. During welding of stainless steels, local sensitised zones (ie, regions susceptible to corrosion) often develop. Sensitisation is due to the formation of chromium carbide along grain boundaries, resulting in depletion of chromium in the region adjacent to the grain

boundary, which produces very localised galvanic cells.

If chromium carbide depletion reduces the chromium content to below the necessary 12% required to maintain the protective passive film, the region will become sensitised to corrosion, resulting in susceptibility to intergranular attack.

Reduction in mechanical strength

Another consequence of chromium loss during welding is the effect on mechanical properties. In chromium/molybdenum/vanadium materials, for example, developed for their high temperature creep resistance, enhanced hardenability, wear resistance, impact resistance and machinability, any reduction in chromium content can affect these properties.

Stainless steel welded joints are common problem areas. Well made, they offer a smooth transition from one section to another, high strength and are cosmetically attractive. However, the welding process itself can lead to significant loss of corrosion resistance in the joint area and a reduction in mechanical properties unless precautions are taken to prevent oxidation.

The welding process

Welds carried out on almost all metals with inadequate inert gas coverage will oxidise. The effect is even noticeable with many stainless steels. To some, the discolouration due to oxidation is an inconvenient feature that can be removed after welding, but this may be difficult and, in any case, costly, especially if access is restricted.

Unfortunately, any oxidation can result directly in a reduction in corrosion resistance and in some cases loss of mechanical strength. This is significant in dairy, food, pharmaceutical and semiconductor pipe applications where stainless steels are employed principally for their resistance to corrosion.

The inert gas used routinely during fusion welding to protect against oxidation needs careful consideration. It will come as a surprise to many that oxygen contents as low as 50 ppm (0.005%) in this protective gas is rarely totally effective.

Effective protection is thus essential and this is achieved by surrounding al of the surfaces around the joint being welded with an inert gas such as argon or helium. The gas shield associated with a GTAW torch will protect the upper surface of the joint, but the inside surfaces of pipes and tubes also need special attention.

Dedicated equipment and procedures have evolved over the past 25 years to achieve this. Called weld purging, this technology meets the need for total internal protection.

Figure 3a: The result of an unprotected underbead in welded austenitic stainless steel.

Figure 3b: To ensure no discolouration occurs, the oxygen content needs to be reduced to 20 ppm (0.002%).

Pipe and tube purging

Systems for weld root protection are based on sealing the inside of a pipe on either side of the weld zone, then displacing the air with an inert gas. The seals must be reliable and leak tight, effective and easy to insert and remove. The inert gas must be of a quality commensurate with the need to protect the molten metal. Gas flow should be laminar to maintain a high level of protection and pressure controlled to

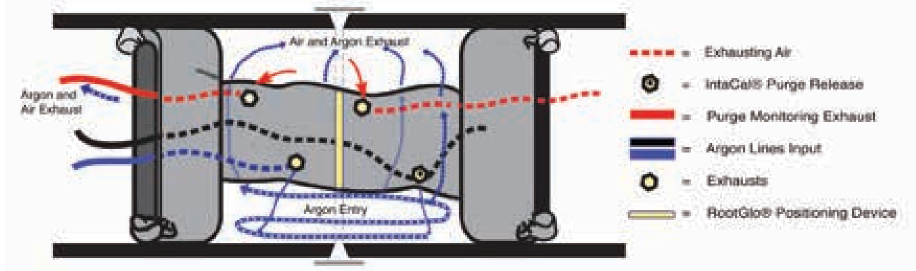

Figure 4: A diagram representing pipe and tube purging concepts.

offer adequate coverage but without expelling molten metal from the joint.

Early and with hindsight, primitive systems involved the use of paper, card, wood and polystyrene discs. Often these provided at best poor sealing and on occasions burst into flames, while satisfactory removal after welding presented challenges. Ensuring that all oxygen had been removed during purging was left entirely to the skill and experience of the operator.

There were regular incidences where protection proved to be inadequate and the joint had to be re-made with consequent expense and loss of time. It comes as a surprise that these practices are still used, even by some prominent fabrication companies across the world.

The most effective solutions are based on the use of inflatable dams and fully integrated systems are now available covering pipe and tube diameters from between 25 and 2 400 mm.

Residual oxygen measurement instruments

Any effective weld purge process needs to be supported by suitable oxygen detecting equipment. Weld purge monitors have now been developed to meet the need for reliable, robust and sensitive measurements. For reactive and refractory alloy welding these must be capable of accurately measuring oxygen levels down to 10 ppm.

As an example, the PurgEye® 600 instrument manufactured by Huntingdon Fusion Techniques reads down to 10 ppm with extreme accuracy and has a display range from 1 000 to 10 ppm.

The entire Argweld product range is supported by an extensive library of publications including Technical Notes,

Figure 5: The inflatable PurgElite® system from the Argweld ® range for tubes of between 25 and 610 mm in diameter. Diameters up to 2 235 mm can be accommodated using QuickPurge® systems.

Figure 6: The Argweld® PurgEye® 600 monitor has a USB connection and data logging capability allowing the operator ease of data transfer without the need for a computer connection.

White Papers, Conference Proceedings and peer-reviewed International Articles. These are available on-line by application to Huntingdon Fusion Techniques Ltd.

Conclusion

Resistance to corrosion is clearly a significant issue in applications where pipework cleanliness is crucial in ensuring product quality. The use of globally well-proven accessories such as purging equipment and monitoring instruments is vital if loss of chromium during welding is to be prevented.