Duplex stainless steel - Part 2

Part 1

The previous article highlighted some of the problems encountered when welding duplex and superduplex stainless steels, in particular the need to control closely the heat input if an undesirable phase balance or the formation of brittle intermetallic phases are to be avoided.

This requirement has implications with respect to quality control. Variations in weld preparations which would be compensated for by the welder changing his welding technique, wide root gaps for example, may result in a significant change in heat input. Weld preparations therefore need to be more closely controlled than for a conventional stainless steel.

It is recommended that weld preparations are machined for greatest accuracy but, if hand-ground, close attention must be paid to the weld preparation dimensions. Welding supervisors and inspectors also need to understand the importance of heat input control, ensuring that welding is not allowed to take place outside the limits of the qualified procedures with regular checking of welding parameters and interpass temperature.

Hot cracking is rarely a problem due to the high ferrite content but has been observed, particularly in submerged arc welds. Cleanliness of the joint is therefore still important. Machining or grinding burrs and any paint should be removed and the joint thoroughly degreased and dried prior to welding. Failure to do so can affect corrosion resistance and joint integrity.

Hydrogen cold cracking, whilst unusual, is not unknown and can occur in the ferrite of weld metal and HAZs at quite low hydrogen concentrations. It is recommended that the hydrogen control measures used for low alloy steel consumables should apply for duplex consumables. Submerged arc fluxes and basic coated electrodes should be baked and used in accordance with the manufacturer's recommendations; shield gases must be dry and free of contaminants.

Most commercially available welding consumables will provide weld metal with yield and ultimate tensile strengths exceeding those of the parent metal but there is often difficulty in matching the notch toughness (Charpy V) values of the wrought and solution treated base metal.

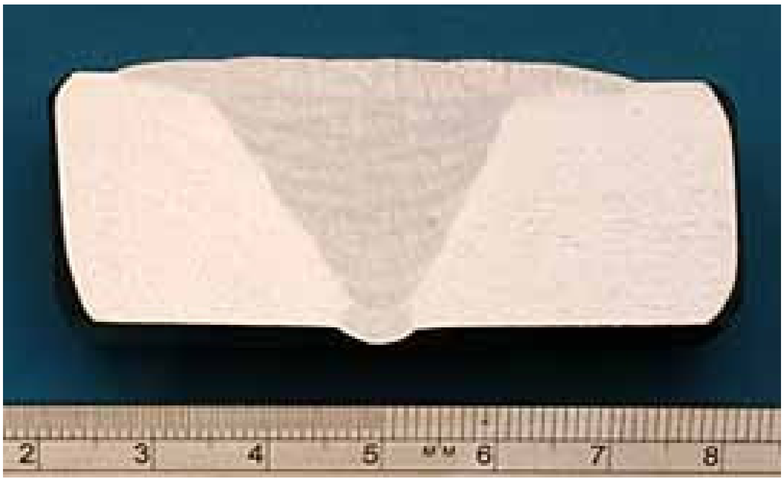
TIG welding gives very clean weld metal with good strength and toughness. Mechanisation has substantially increased the efficiency of the process such that it has been used in applications such as cross-country pipelining. Gas shielding is generally pure argon although argon/helium mixtures have given some improvements by permitting faster travel speeds. Nitrogen, a strong austenite former, is an important alloying element, particularly in the super/hyper duplex steels and around 1 to 2% nitrogen is sometimes added to the shield gas to compensate for any loss of nitrogen from the weld pool. Nitrogen additions will, however, increase the speed of erosion of the tungsten electrode. Purging the back face of a joint is essential when depositing a TIG root pass. For at least the first couple of fill passes pure argon is generally used although small amounts of nitrogen may be added and pure nitrogen has occasionally been used.
TIG welding may be performed without any filler metal being added but is not recommended on duplex steels as the corrosion resistance will be seriously impaired. Filler metals are be selected to match the composition of the parent metal but with an additional 2 to 4% nickel to ensure that sufficient austenite is formed. Any stray arc strikes will be autogenous and must be removed by grinding.

MMA welding is carried out with matching composition electrodes overalloyed with nickel and either rutile or basic flux coatings. Basic electrodes give better notch toughness values. Electrodes of up to 5mm diameter are available with the smaller diameters providing the best control when welding positionally.
MAG welding is generally carried out using wires of 0.8 to 1.2mm diameter, rarely exceeding 1.6mm and of a similar composition to the TIG wires. Shielding gases are based on high purity argon with additions of carbon dioxide or oxygen, helium and perhaps nitrogen. Because of the presence of carbon dioxide or oxygen the weld metal notch toughness (Charpy V values) are less than can be achieved using TIG.

Microprocessor-controlled pulsed welding gives the best combination of mechanical properties. Mechanisation of the process is easy and can give significant productivity improvements although joint completion times may not be as short as anticipated due to the need to control interpass temperatures to below the recommended maximum.

Flux-cored arc welding (FCAW) is used extensively with major productivity gains being possible in both manual and mechanised applications. The flux core is generally rutile; the shielding gas CO_2, argon/20%CO_2 or argon/2%O_2. The presence of carbon dioxide or oxygen leads to oxygen, and, in the case of CO_2, carbon pickup in the weld metal, thus notch toughness is reduced. Metal cored wires are also available that require no slag removal; better suited to mechanised applications than flux-cored wires. Because of differences in flux formulation and wire composition between manufacturers it is recommended that procedure qualification is carried out using the specific make of wire used in production even though the wires may fall within the same specification classification.

Submerged arc welding (SAW) is generally confined to welding thick wall pipes and pressure vessels. Solid wires, similar to those available for TIG welding, are available. Fluxes are generally acid-rutile or basic, the latter giving the best toughness values in the weld metal. As with any continuous mechanised welding process the interpass temperature can rapidly increase and care needs to be taken to control both interpass temperature and process heat input. Because of the need to control heat input the wire diameter is normally limited to 3.2mm permitting a maximum welding current of 500A at 32V although larger diameter wires are available. However, any productivity gains from the use of a large diameter wire and high welding current may not be realised due to the need for interpass cooling.



There is often the need to weld duplex/superduplex steel to lower alloyed ferritic steel, a 300 series stainless steel or a dissimilar grade of duplex steel. The 300 series stainless steels are generally welded to duplex steels with a 309MoL (23Cr/13Ni/2.5Mo) filler metal. Low carbon and low alloy steels may be welded to duplex steels using either a 309L (23Cr/13Ni) or a 309MoL filler metal. These two filler metals, however, have yield and ultimate tensile strengths substantially less than most low carbon/low alloy steels and all duplex steels. This means the designer has to take this reduction of strength into account by increasing the component thickness or the welding engineer has to select a filler metal that both matches the strength of the weaker steel and is compatible with the two parent metals. These considerations narrow the choice to one of the nickel-based alloys such as alloy 82 or, for higher strength, a niobium-free high alloyed nickel filler, such as C22. or 59. Alloy 625 has been used but problems with reduced toughness due to the formation of niobium nitride precipitates along the fusion boundary have resulted in the alloy falling out of favour.

Duplex steel welds are seldom post-weld heat treated. Due to sigma phase formation they cannot be given a heat treatment at the low temperatures of 600-700°C, the normal range for stress relief unless a qualification programme has been undertaken to demonstrate that the loss of toughness is acceptable. If PWHT is required then ideally the whole component must be given a solution anneal at 1000-1100°C followed by a water quench; an impractical operation with most welded structures.
Lastly, any process that heats the steels above 300°C will affect the mechanical properties. Heat straightening to control distortion should therefore not be carried out. The HAZs produced by hot cutting processes like plasma or laser may contain undesirable microstructures. Cut edges that will enter service 'as-cut' must be ground or machined back for a minimum of 2mm to remove the HAZ and ensure there is no loss of toughness or corrosion resistance.

If the cut edges are welded after cutting then the HAZs are generally sufficiently narrow that the effects of the cutting operation are lost although it is recommended that, as above, the edges are ground or machined back 2mm.
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