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ADOR WELDING LIMITED
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WELDING PROCESSES AND APPLICATIONS FOR DUPLEX STAINLESS STEELS

INTRODUCTION

In an earlier article on stainless steels, we described the welding of duplex stainless steels. We have received requests for providing more information on this important development. In this article we will discuss welding processes that can be used for welding of these steels as well as precautions to be taken and detail out some applications of these steels.

WHAT ARE DUPLEX STAINLESS STEELS (DSS) AND SUPER DUPLEX STAINLESS STEELS (SDSS)?

Duplex stainless steels contain approximately 50:50 of ferrite and austenite at room temperature. This combination imparts special properties to this group of stainless steels. The austenite phase has general corrosion resistance, good toughness, ductility, high and low temperature properties and good weldability. The ferrite phase has good stress corrosion resistance and good strength. So the duplex stainless steels exhibit a combination of these properties which makes this steel an ideal candidate material for many applications.

Super duplex stainless steels are similar to duplex stainless steels but their pitting resistance is higher than the duplex stainless steels. If the pitting resistance equivalent number (PREN) as calculated by the following formula is more than 40, then that steel

Product Update

CHAMP T400

Inverter based DC welder

- Three phase inverter based, high efficiency and high power factor DC Welder
- Enhanced Reliability due to SMD technology
- High frequency IGBT based Rectifier
- Arc force adjustment on panel
- TIG Welding possible with External HF Unit
- Light weight, compact and portable for easy handling

is designated as SDSS.
PREN= %Cr+3.3(%Mo)+16(%N)

WELDING DUPLEX STAINLESS STEELS

Duplex stainless steels have very good hot cracking resistance due to the high ferrite content; hot cracking is rarely a consideration when welding these steels. The problems mostly associated in welding duplex stainless steels are with the Heat Affected Zone (HAZ) and not with the weld metal. The HAZ problems are: loss of corrosion resistance, toughness, or post weld cracking. To avoid these problems, the welding procedure should focus on minimizing total time at temperature in the "red hot" range rather than managing the heat input for any one pass.

Selection of Base Metal

The importance of the base metal containing sufficient nitrogen has been repeatedly emphasized. If the starting material is cooled slowly through the 700 to 1000 °C (1300 to 1800°F) range, or if it is allowed to air cool into this range for a minute or so prior to water quenching , then those actions have used up some of the "time on the clock" for the welder to complete the weld without any detrimental precipitation reactions occurring . It is important that the metallurgical condition of the material used in actual fabrication is the same quality, with regard to composition and production practice, as the material used to qualify the welding procedure.

Joint Design

For duplex stainless steels, a weld joint design must facilitate full penetration and avoid undiluted base metal in the solidifying weld metal. It is best to machine rather than grind the weld edge preparation to provide uniformity of the land thickness or gap.

Heat Input and Inter Pass Temperature

Exceedingly low heat input may result in fusion zones and HAZ which are excessively ferritic with a corresponding loss of toughness and corrosion resistance. Exceedingly high heat input increases the danger of forming inter metallic phases. To avoid problems in the HAZ, the weld procedure should allow rapid cooling of this region after welding. The temperature of the work piece is important because it provides the largest effect on cooling of the HAZ. As a general guideline, the maximum inter pass temperature is limited to 150°C (300°F) for lean and standard duplex stainless steels and 100°C (210°F) for superduplex stainless steels . That limitation should be imposed when qualifying the weld procedure and the production welding should be monitored to assure that the inter pass temperature is no higher than that used for the qualification. Electronic temperature probes and thermocouples are the preferred instruments for monitoring the inter pass temperature.

Post Weld Heat Treatment

Post weld stress relief is not needed for duplex stainless steels and is likely to be harmful because the heat treatment may precipitate inter metallic phases or alpha prime (475°C/885°F) embrittlement causing a loss of toughness and corrosion resistance. Post weld heat treating temperatures in excess of 315°C (600 °F) can adversely affect the toughness and corrosion resistance of duplex stainless steels. Any post weld heat treatment should include full solution annealing followed by water quenching. Full solution annealing should be considered after autogenous welding, since the microstructure will be highly ferritic if an overalloyed filler metal is not used during welding.

Preheating

As a general rule, preheating is not recommended because it may be detrimental. It should not be a part of a procedure unless there is a special justification. Preheating may be beneficial when used to eliminate moisture from the steel as may occur in cold ambient conditions or from overnight condensation. When preheating to deal with moisture, the steel should be heated to about 100 °C (200 °F) uniformly and only after the weld preparation has been cleaned.

Desired Phase Balance

The characteristic benefits of duplex stainless steels are achieved when there is at least 25% ferrite with the balance austenite. In some of the welding methods, particularly those relying upon flux shielding; the phase balance has been adjusted toward more austenite to provide improved toughness, offsetting the loss of toughness associated with oxygen pickup from the flux.

WELDING PROCESSES

Shielded Metal Arc Welding (SMAW / Stick Electrode)

The coatings of SMAW electrodes are hygroscopic, and the presence of water will substantially degrade their performance. The electrodes should be kept in their factory-sealed container until ready for use. Once the package is opened, the electrodes should be stored in an oven heated to 95°C (200°F) or more to prevent accumulation of moisture that may lead to weld porosity or cracking. Because the flux increases the oxygen content of the weld and, thereby, reduces toughness, it is common for the SMAW electrodes to be balanced near the maximum level of austenite at which the metal will still have the beneficial effects of the duplex structure . The toughness of the weld is well below that of the base metal, but generally it is well above the levels of toughness considered adequate for carbon and alloy steels. An error that has sometimes been made in qualification of the SMAW welds is the use of the ASTM A 923 testing without appropriate adjustment of the acceptance criterion. The lower toughness observed for the SMAW welds are not indicative of inter metallic phases, but is attributed to the oxygen from the flux shielding. Requiring minimum 54 J/40 ft lb at 40°C/°F, which is required for the base metal, leads to inappropriate disqualification of this highly versatile procedure that has been used for years with excellent practical results. The minimum impact energy for the weld metal is 34 J/ 25 ft lb and 54 J/ 40 ft lb for the heat affected zone according to ASTM A 923.

Gas Tungsten Arc Welding (GTAW / TIG)

Most filler metals for duplex stainless steel welding are described as “matching”, but typically they are over alloyed in nickel with respect to the wrought products that they are said to match. Usually there is about 2-4% more nickel than in the wrought product. The nitrogen content is typically slightly lower in the filler metal than in the base metal. It is generally accepted that the more highly alloyed duplex stainless steel weld fillers are suitable for welding the lower alloyed duplex stainless steel products. The “matching” fillers have been reported to give acceptable results when joining duplex stainless steels to austenitic stainless steels or to carbon and alloy steels.

Gas Metal Arc Welding (GMAW / MIG)

GMAW uses a consumable electrode in the form of a continuous wire that is fed through the torch by an automatic feeding system. The filler metals for GMAW of duplex stainless steels are “matching” compositions over alloyed with nickel to achieve the desired phase balance and properties in the as-welded condition.

Flux Cored Arc Welding (FCAW)

Because the flux shielded welding methods tend to produce welds of somewhat reduced toughness, probably resulting from the increased oxygen content in the weld metal, the FCW filler metal is overalloyed with nickel so that the weld metal is more austenitic than the nearly balanced structure of the base metal. Because the composition of fluxes and the production of FCW wire are proprietary, there may be significant differences among the FCW fillers from different suppliers. It is important that production welding by FCW use wire from the same source as used in qualification of procedures to avoid variations in production.

Submerged Arc Welding (SAW)

For SAW, the usual matching duplex filler metal is appropriate. However, it is important to select a correct flux to achieve the desired properties. It is reported that highly basic fluxes give the best impact toughness for the duplex stainless steels.

DUPLEX STAINLESS STEEL APPLICATIONS

Flue Gas Desulfurization

The use of duplex stainless steel has gained acceptance globally and this grade has become the most popular choice for FGD absorbers because of its high strength, good corrosion resistance, and high toughness properties after welding.

Desalination Plants

The benefits of duplex stainless steel for this application are high strength double that of conventional austenitic grades combined with high corrosion resistance. As a result, duplex stainless steel evaporators can be built with thinner plates, requiring less material and less welding. Further benefits include easier handling and less overall environmental impact.

Oil and Gas Industry

In the oil and gas industry, duplex stainless steel has played a crucial role in helping to withstand tough conditions. This is due not only to its corrosion resistance and mechanical strength, but also because its pitting and crevice corrosion resistance is superior to that of standard austenitic alloys, with pitting resistance equivalent numbers (PREN) often exceeding 40.

The main applications for duplex stainless steels are flow lines, process piping systems and equipment like separators, scrubbers and pumps. Subsea the materials are used in down hole production tubing, piping and manifolds, Christmas tree components, flow lines and pipelines transporting corrosive oil and gas. Superduplex (25 % chromium) stainless steels are useful for their resistance to design stress, so they are often used on such items as bar, forgings, castings, sheet, plate, tube, and fasteners. Superduplex stainless steels also have excellent fatigue resistance and galvanic compatibility with other high alloy stainless steels.

Bio Fuels

On land, biofuels (especially ethanol) are a sector in which use of duplex grades is growing. 2205 stainless steel has been used for the biomass to liquid NExBTL plant in Singapore, and S 32101 was selected by Dutch tank builder Oostwouder Tank- & Silobouw BV for its tank farm for Noba Vetveredeling BV in a large-scale biofuel project in the Port of Amsterdam. S 32101 was also specified for the vessels and pipes of Agroetanol's expanded ethanol plant on the island of Händelö in Sweden. The lean duplex stainless steel grades have been used to replace the 300-series austenitic stainless steels for many ethanol service applications.

Food and Drink

In the food and drink industries too, lean duplex stainless steel is proving its worth. The material is being used for two projects in Spain, a food storage depot and a wine storage depot. In the Port of Barcelona Emypro SA constructed food storage tanks entirely from S 32101 as a replacement for EN 1.4301/1.4307 (304 / 304 L) . The wine storage depot, built by Spanish tank builder Martinez Sole for Garcia Carrion in Daimiel in the south of Spain, is the first to use duplex stainless steel: S32101 and 2304 were used in the construction of the roof and uppermost level of all new tanks, as a lower cost alternative to 1.4301/1.4404 (304/316L).

Architecture

Duplex stainless steel continues to play an important role in the construction of bridges, wherever corrosion and saline conditions combine with the need for high load-bearing strength. Two recent examples, both from Asia, are Hong Kong's Stonecutters Bridge and Singapore's Marina Bay Pedestrian Bridge, both of which use duplex grade 2205 stainless steel. For the Stonecutters Bridge, 2000 tons of 2205 duplex plate and pipe were used in 2006.

Welding Consumables for Duplex Stainless Steels (DSS) and Super Duplex Stainless Steels (SDSS) from Ador Welding Ltd.:

The following table gives the consumables for various AWS classifications. Please click on the brand name to know more about the consumables.

AWS CLASSIFICATION	PROCESS	AWL BRAND NAME
E2209-16	SMAW	BETANOX 4462
E2553-16	SMAW	BETANOX 2553
E2595-15	SMAW	BETANOX 2595-15 (UNDER DEVELOPMENT)
ER 2209	GTAW	TIGINOX 2209
ER2594	GTAW	TIGINOX 2594

Please contact us cmo@adorians.com for more information on the welding of Duplex and Super Duplex stainless steels or visit our website www.adorwelding.com

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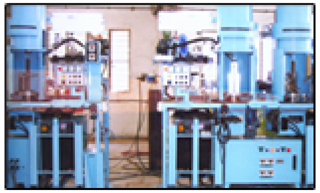

Centre for Engineering Excellence

WELDERS TO THE NATION

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