CHAPTER - 1

INTRODUCTION

In the recent times a number of new materials have been developed to meet the needs of the different industrial sectors. Among the varieties of Stainless steels, Duplex Stainless steels have been playing a major role in the areas of chemical and petrochemical processing industries, nuclear power industries, etc., owing to their excellent properties, especially corrosion resistance.

Duplex stainless steels belong to a family of grades combining good corrosion resistance with high strength and ease of fabrication. Their Mechanical properties are between those of the austenitic and ferritic stainless steels but tend to be closer to those of the ferritic and carbon steel. The resistance to pitting and crevice in chloride environment is a function of chromium, molybdenum, and nitrogen content. The outstanding properties of DSS are mainly due to the phase balance i.e., the ferrite-austenite ratio.

With the development of duplex stainless steels, which have the combination of the best of the properties of austenitic and ferritic stainless steels, viz., higher yield strength coupled with excellent corrosion/stress corrosion cracking resistance compared to austenitic stainless steels and better formability and lower transition temperature than ferritic stainless steels, these steels have been identified as the promising materials for the process industries and are being widely employed in various industries, viz., petrochemical, off-shore platforms, oil and gas, paper and pulp, etc.

Most of the industrial components made of these duplex stainless steels are fabricated primarily by welding using almost all the conventional welding processes like Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW), Submerged Arc Welding (SAW) Etc.,

The outstanding properties of DSS are mainly due to the phase balance i.e., the ferrite-austenite ratio.

There are two ways to control the ferrite / austenite ratio.

Control Heat Input (H.I), slightly higher H.I. more than 1.5 to 2.5 KJ/mm.

Lowering the Cr eq /Ni eq ratio, towards 2.25[1]

During cooling rate from 1200 to 800°C, coarsening of ferrite grains (Grain growth) has influence on toughness controlled by Cr eq / Ni eq ratio. Lower the ratio, higher the solvus less the ferrite grain growth. Or Control Heat Input.

Through this research work, the idea is to increase nickel in the weld metal composition to promote more austenite formation by raising the ferrite solvus in the solidifying weldments so immediately after it pass through ferrite solvus temperature. More austenite can be produced [1]

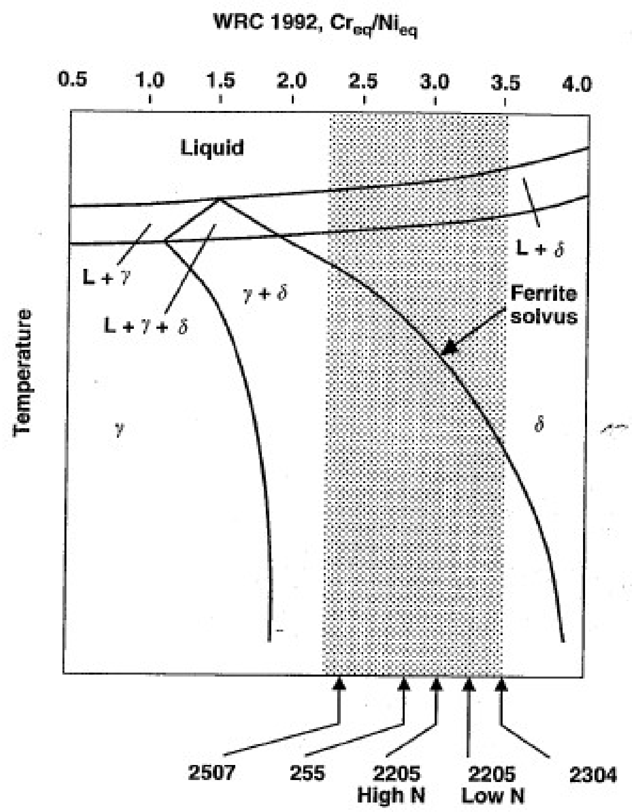

Figure 1.1 Elevated temperature region of a Pseudo binary phase diagram for duplex stainless steel compositions. Shaded region represents the range for commercial alloys. Source[1]

As can be seen in Figure 1.1 from the chemical composition, Duplex Stainless Steels have high ratio of Cr eq to Ni eq (Ferrite promoting elements to Austenite promoting elements) which is ranging from 2.25 to 3.5 for commercially available Duplex stainless steels.

Duplex steels solidify as 100 % ferrite. Because of having higher ferrite to austenite ratio at high temperature (above the ferrite solvus), the alloys remain 100% ferrite.

Below the ferrite solvus, austenite can only nucleate and grow by solid state transformation mechanism. So practically any Hot metal working operations and annealing process of these are usually conducted below ferrite solvus, where austenite and ferrite remain in equilibrium by controlling the processing temperature at cooling rate from that temperature, the ferrite and austenite proportion and distribution of phases can be controlled in the wrought Duplex Stainless steel.

Findings of the literature survey mention that there has been a lack of data to support a minimum ferrite content requirement for DSS weld metal to provide resistance to chloride stress corrosion cracking (CSCC). Various organizations require 30 to 60%, 30 to 70 Ferrite Number, 35 to 75%, etc.

There are two concerns about the minimum ferrite content requirement: 1. maintaining required minimum yield strength and 2. Providing resistance to chloride SCC.

Dr. D.J.Kotecki in his work [2] reported on yield strength issue and found that yield strength was maintained down to as low as 30 FN (about 21% ferrite), and no ferrite lower limit was identified. & no further investigation is made into SCC resistance.

Among Industrial clients, there has been dispute over this issue of required minimum ferrite content. The issue doesn't involve GTAW or GMAW because the low oxygen content (typically less than 150 ppm) of the weld metal provides high toughness at relatively high ferrite content, so filler metal manufacturers can aim for about 50% ferrite in their filler metal without concern about toughness. But for flux shielded filler metals (SMAW, FCAW, SAW), the higher oxygen content (typically 600 ppm or more) reduces toughness, so the filler metal manufacturer aims for weld metal deposits at the low end of specified ferrite ranges in order to meet toughness requirements at 40° C. There is, of course, a degree of variation in weld metal ferrite content and in reproducibility of measurement.

So it happens fairly often that a fabricator measures a little less than the specified ferrite requirement, or the fabricator measures above the specified limit but his customer measures ferrite content for the same lot of filler metal and obtains a value below the specified limit. As a result there is a battle over whether or not the filler metal is acceptable and a delay in the project results while the parties to the dispute try to resolve it. This wastes a lot of time and money.

Metallurgical point of view, DSS requires solidification as 100% ferrite and formation of austenite only in the solid state. This mode is responsible for both high yield strength and resistance to chloride SCC. The WRC1992 diagram indicates 100% ferrite solidification at as low as 20 Ferrite Number (about 14% ferrite).

Another important observation is that the WRC-1992 diagram indicates the relationship between FN and Ni is not linear.

So Present work has been carried out by collaborating with a reputed filler metal manufacturer to investigate required minimum ferrite content to obtain required minimum yield strength and resistance to chloride stress corrosion cracking. Under this project, the filler metal producer provided electrodes aimed at the low end of normal DSS ferrite specifications, and below, and we have examined the SCC resistance and the yield strength of the welded joint.

Testing tensile properties by a round all weld metal tensile specimen as found in AWS A5.4 specification for stainless steel covered electrodes (1/2 inch or 12.7 mm diameter) or as found in ISO 157921 (10 mm diameter, joint type 1.3, as referenced in ISO 3581) were also carried out.

By doing all weld metal tests, we tried to avoid any complications from the base metal and HAZ. Also, yield strength is meaningless in a transverse tensile test.

To evaluate the stress corrosion cracking tendency in Chloride containing environment, ASTM G123 Standard Test method for Evaluating Stress-Corrosion Cracking of Stainless Alloys with Different Nickel Content in Boiling Acidified Sodium Chloride Solution has been employed in the present study.

The specimens from each heat has been subjected to boiling acidified 25 % NaCl (by mass) acidified to pH 1.5 with phosphoric acid (H_3PO_4) was Used.

The specimens from each heat were immersed in the boiling acidified solutions for 1000 hrs (Nearly 4 weeks), periodically specimens were examined at 20 X magnification for Stress induced corrosion cracks as per schedules mentioned in ASTM G 123[3]

This test method is intended to simulate cracking in water, especially cooling waters that contain chloride. It is not intended to simulate cracking that occurs at high temperatures (greater than 200°C or 390°F) with chloride or hydroxide.

However, the use of Duplex Stainless Steels is limited to the temperature range -20 to +300° C due to precipitations of the detrimental phases above 300 °C [1]

To vary (reduce) the ferrite content, the electrode manufacturer has been requested to prepare sample quantity of SMAW electrodes with increasing the Ni content starting from the standard Ni level in the 2209 electrode design. Increasing the Ni content, leaving all other elements as in the standard composition, has the benefit of leaving the pitting resistance index (PREN) unchanged while the ferrite content is reduced. Moreover, adding or subtracting nitrogen in the electrodes composition or Nitrogen gas purging was not advisable because that would change the PREN and confound the results. Therefore Cr, Mo and N were held constant. Only nickel was varied in the electrode composition because changing nickel does not change the PREN.

By far, 2209 is the most common of the duplex stainless steel electrodes.

The aim of the present research work is as under:-

To establish a required minimum ferrite content for meeting specified minimum yield strength.

To establish a relationship between minimum ferrite content and SCC resistance under chloride environment with the welded 2205 alloy

To understand the effect of nickle variation on the tensile and impact properties and stress corrosion and pitting corrosion resistance properties.

To achieve desired phase balance of Austenite to Ferrite.

To compare industrially practised ferrite measurements methods in terms of consistency and accuracy in FN and Percentage ferrite values.

To test the welding filler / electrodes for matching minimum mechanical and corrosion properties requirement specified in ASME BPVC SEC IX Code.

To evaluate the stress corrosion resistance of welded joint without changing the pitting resistance equivalent number (PREN) values.

To examine the effect of filler metal nickel content variation on Ferrite Number (FN), Percentage ferrite and microstructure, mechanical & corrosion properties of weld joints while keeping other formulation as Cr, Mo and nitrogen constant.