

Duplex 2209 Weld Overlay by ESSC Process

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ABSTRACT

In the modern world of industrialization the wear is eating metal assets worth millions of dollars per year. The wear is in the form of corrosion, erosion, abrasion etc. which occur in the process industries like oil & gas, refineries, cement plants, steel plants, shipping and offshore working structures. The equipments like pressure vessels, heat exchangers, hydro processing reactors which very often work at elevated temperatures face corrosion in the internal diameter. Duplex 2209 weld overlay on ferrous material is developed for high corrosion resistance properties and having high productivity by Electroslag strip cladding process due to its less dilution ~10% as compared to SMAW, GTAW or FCAW process. Because of Low Dilution ~10% undiluted chemistry can be achieved with single layer as compared to other weld overlay processes. The facility was developed in-house to carry out weld overlay by ESSC and Testing.

I. INTRODUCTION

Duplex stainless steel are called “Duplex” because they have a two-phase microstructure consisting of grains of ferritic and austenitic stainless steel. When duplex stainless steel is melted it solidifies from the liquid phase to completely ferritic structure. As the material cools through temp above about 1040 deg C to room temperature, about half of the ferritic grains transfer to austenitic grains. The result is a microstructure of roughly 50% austenite and 50% ferrite. This is accomplished by increasing Chromium and decreasing Ni as compared to ASS grades & by adding Nitrogen (a strong austenite promoter) to speed the rate up of austenite formation during cooling[1].

A minimum 10.5% Chromium is necessary to form a stable Chromium passive film that is sufficient to protect steel against atmospheric corrosion. The corrosion resistance of SS increases with increasing Chromium content. Chromium is a ferrite former, meaning that the addition of Chromium promotes the BCC structure of iron. At higher Chromium contents, more nickel is necessary to form an austenite or duplex structure. Higher Chromium also promotes the formation of intermetallic phases. Chromium also increases the oxidation resistance at elevated temperatures.

Molybdenum acts to support Chromium in providing pitting corrosion resistance to stainless steels. When the Chromium content of a SS is at least 18%, addition of Mo become about three times as effective as Chromium addition against pitting and crevice corrosion in Chloride-containing environment. Molybdenum is a ferrite former and also increases the tendency of a SS to form detrimental intermetallic phases. Therefore, it is

restricted to less than about 7.5% in ASS and 4% in Duplex SS[1,2].

Nitrogen increases the pitting and crevice corrosion resistance of austenite and Duplex SS. It also increases strength and is most effective solid solution strengthening element and low cost element. The improved toughness of nitrogen bearing duplex SS is due to their greater austenite content and reduced intermetallic content. Nitrogen does not prevent the precipitation of intermetallic phases but delays the formation of inter-metallics enough to permit processing and fabrication of duplex stainless steel. Nitrogen is added to highly corrosion resistant austenite and duplex stainless steels that contain high chromium and molybdenum contents to offset their tendency to form sigma phase. Nitrogen is the key element, apart from aiding austenite formation, it plays a role in partitioning of alloying element Cr, Mo between ferrite and austenite.

During welding, there is a danger that the austenite formed from ferrite from heating, will contain only the low amount of N that was in the ferrite from which it was formed. If heating time is sufficient, Nitrogen can diffuse from the original austenite to restore equilibrium. But, if the heating time is too short, the so called secondary austenite will have low N & therefore lower pitting corrosion resistance.

Nitrogen helps to alter phase stability, making austenite stable to higher temperature, & this prevents welds from becoming excessively ferritic and disturbing the desirable 50 to 50 ratio[1,6].

1.1 Characteristics of Duplex stainless steels

- Excellent resistance to stress corrosion cracking

- Very high mechanical strength
- Excellent resistance to pitting and crevice corrosion
- High resistance to general corrosion in a variety of environments
- Low thermal expansion
- High resistance to erosion corrosion and corrosion fatigue
- Good weldability

- Lower life cycle cost[1]

Duplex stainless steel is having higher critical crevice corrosion temperature as well as critical pitting corrosion temperature as compared to austenitic stainless steel material as shown in below Fig.1 and Duplex stainless steel is having lower corrosion rate than austenitic stainless steel in formic acid Concentration as shown in Fig.2[2,5]

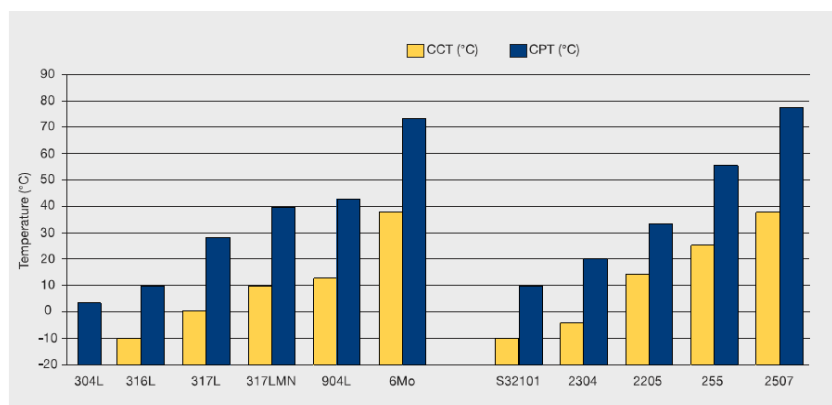


Fig. 1

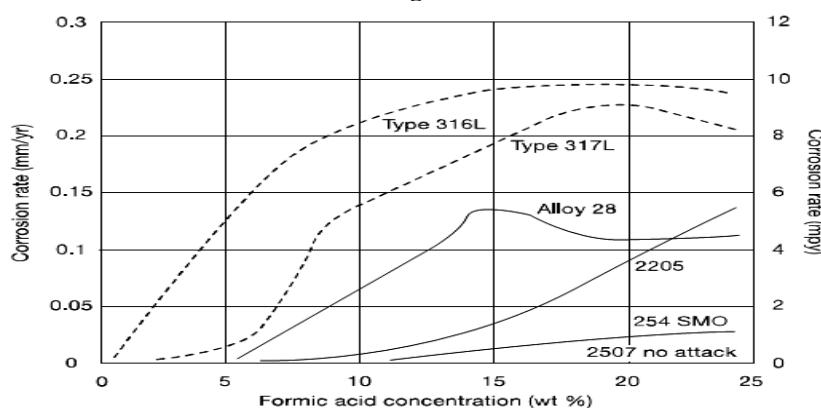


Fig. 2

1.2 Chemical Composition of Duplex 2209

Element	% Composition
Nickel	8.5-10.5
Chromium	22-24
Molybdenum	2.5-3.5
Carbon	0.04 max
Manganese	0.5-2.0
Sulfur	0.03 max
Silicon	1.0 max
Phosphorous	0.04 max

Table 1

Cladding is a welding process in which a material with desired properties is deposited on the surface of a base material. The common C/Mn or low alloyed inexpensive base metal has mainly a load carrying function. The deposited sophisticated material imparts surface properties such as corrosion resistance; wear resistance, erosion and

pitting etc., to the substrate. To the manufacturer of pressure vessels, surfacing techniques are getting more and more important. Components reach sizes such that their fabrication calls upon the use of clad materials[3,6].

There are different processes to obtain a clad material:

- Clad plates produced by rolling which are mostly only available in standardized dimensions and grades
- Explosion clad plates
- Clad plates made by welding

Further Clad Plates made by welding can be done using various techniques:-

- Submerged arc welding (Wire electrode)
- Submerged arc welding (Twin Wire electrode)
- Submerged arc welding (Strip Electrode)
- Electro slag strip welding

- Shielded metal arc welding
- Flux cored arc welding

Among all the welding processes submerged arc and electro slag strip cladding offer maximum deposition rate, better bead characteristics and trouble free operation using unsophisticated welding equipments[6,7].

In selecting a particular weld overlay and cladding system, the following criteria may need to be considered: Deposit rate (kg/hr), productivity hardness, corrosion resistance, availability of consumables with the required metallurgical and mechanical properties, welding techniques, Quality of weld & automation technologies.

II. PROCESS DESCRIPTION

The electro slag strip cladding is a technique, in which a strip electrode is continuously fed into a shallow layer of electrically conductive flux. The heat required to melt the strip, the slag forming flux and the surface layer of the base metal is generated by resistance heating due to the welding current flowing through the molten conductive slag. In relation to the submerged arc

strip cladding, the penetration and hence the dilution are reduced in electro slag strip cladding because the absence of arc, typical dilution levels lying between ~10% [4]. The use of a conductive slag and resistance heating instead of an electric arc permits higher current densities to be used in ESSC without increasing penetration. Thus deposition rates higher than that possible with SASC can be achieved in ESSC without increasing the degree of dilution[2,3,4].

The flux used in ESSC contains, in addition to oxides like Titanium oxide and iron oxide. A large quantity fluoride of Calcium and Sodium in order to achieve the required electrical conductivity. The high Calcium fluoride content in the flux has been shown to decrease dilution level and also reduce the oxygen content in the deposited cladding to a level which is just one third compared to submerged arc surfacing. Furthermore the solidification rate of the electroslag weld metal is lower, facilitating the escape of gases and the rise of slag particles to the surface. This reduces porosity and inclusion content[2,3,8].

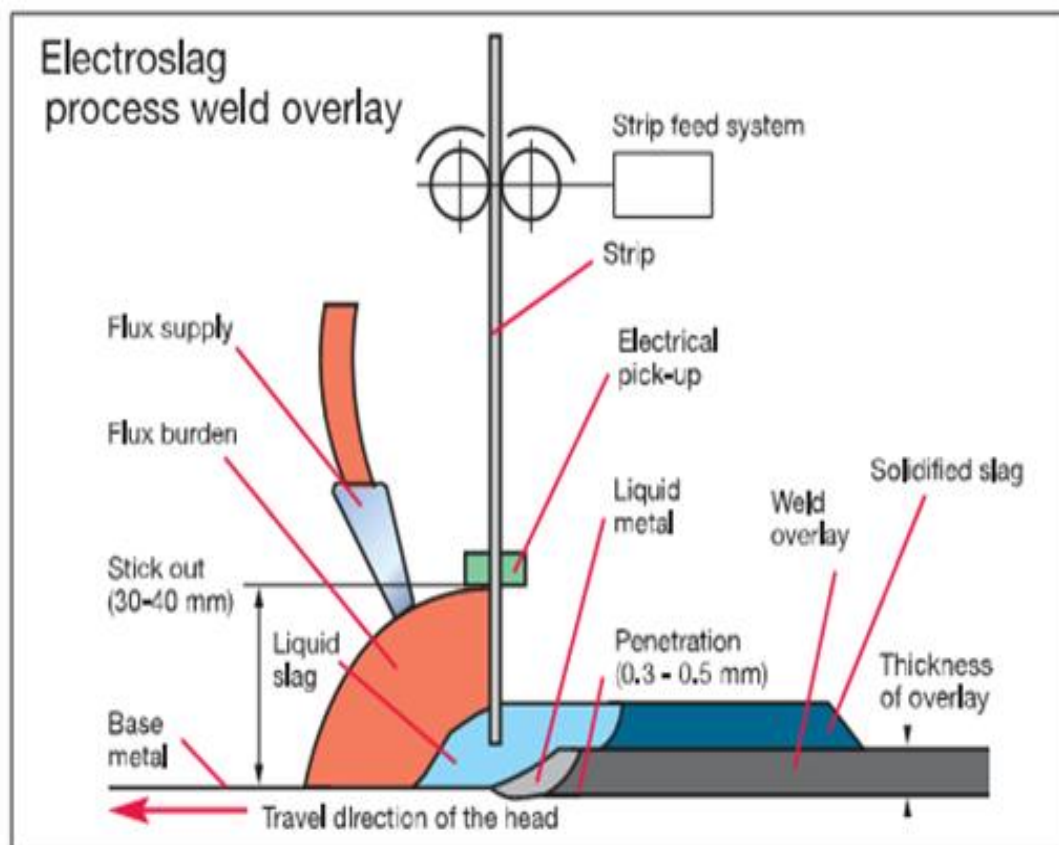
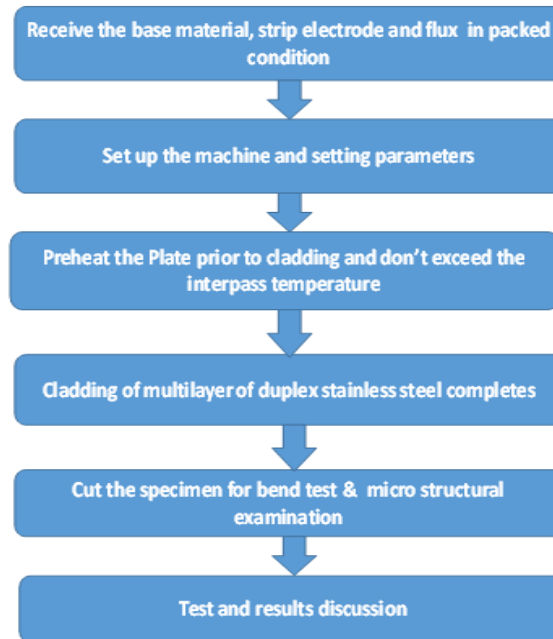


Fig.3

III. EXPERIMENTATION AND TESTING

Discuss the detail about the experimental data, base metal, filler metal, and welding procedure, welding parameters of welded specimen and testing.

3.1 Experimentation was conducted as per following flow chart



Flow chart shows how experimentation was conducted

3.2 Base Metal and Strip Metal

The base plate of SA 516 Grade 70 low carbon steel of 60 mm received in normalized heat treated condition. The strips used were of S.S

309LMo as a buffer lyer and Duplex 2209 as a clad layer .Table 3.1 shows the chemical composition of base metal & strips used.

Elements	Base Metal	SS 309 LMo	Duplex 2209
Carbon, C	0.27	0.04	0.04
Silicon, Si	0.15 - 0.40	1.0	1.0
Sulfur, S	0.035	0.03	0.03
Phosphorous, P	0.035	0.04	0.04
Manganese	0.85 - 1.20	0.5-2.5	0.5-2.0
Chromium	-	22-25	22-24
Nickel	-	12-14	8.5-10.5
Molybdenum	-	2-3	2.5-3.5

Table 2

3.3 Welding Parameters

Material thickness : 60 mm
 Plate size : 500 X 300 X 60 mm thick
 Joint design : weld overlay on CS base plate
 Strip for barrier : Sandvik 21.13.3L (~ EQ

309LMo)
 Strip for Clad : Sandvik 22.8.3L (~ EQ 2209)
 Flux : Sandvik 37S
 Weld Bead Height : 9-10 mm- Double Layer



Fig.3 Barrier Layer



Fig.4 Clad Layer



Fig.5 Specimen Marking & Preparation

Parameters	Range
Welding current (I)	1150-1300 A
Voltage (V)	24-26V
Travel Speed	170-180 mm/min
Pre heat	100 degree Celsius
Interpass	Max 175
Electrode extension (Stick Out)	25-30 mm
Height of Flux	30-35mm
Polarity	DCEP

Table 3

3.4 Post Weld Heat Treatment (PWHT)

PWHT was performed at 610 -620⁰ C for 135 minutes after completion of testing with heating rate 50⁰ C/ hr and cooling rate 40⁰ C /hr.

IV. RESULTS

- ✓ Visual Examination : Bead Finish- Good
- ✓ Non Destructive Testing
 - Dye Penetrant Testing : Acceptable as per ASME Sec IX .
 - Ultrasonic Examination : Satisfactory



Fig.6

- ✓ Macro Examination : No porosity, No Lack of Fusion & complete fusion of weld metal & base metal

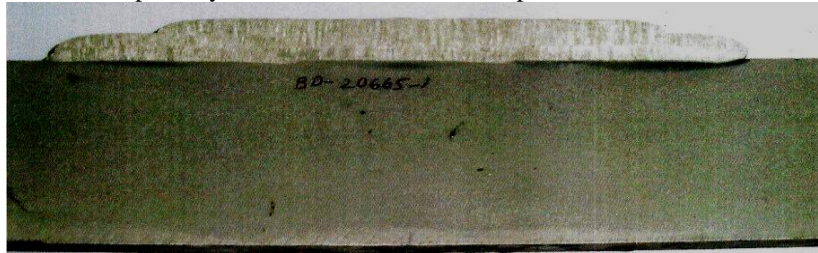


Fig.7

- ✓ Bend Test : satisfactory



Fig.8



Fig.9

Test Performed	Number of Sample Tested	Degree of Bend	Acceptance Standard	Results
Side Bend Test	4	180 ⁰	ASME Sec IX	Satisfactory

- ✓ Chemical Composition was found satisfactory from 4mm fusion line

Height (mm)	% Element					
	C	Ni	Cr	Mo	Mn	N
Reqd value	0.04 Max	8.5-10.5	22-24	2.5-3.5	0.5-2.0	0.08-0.20
Top	0.016	8.70	22.57	3.05	1.16	0.16
8.0	0.019	9.02	22.32	3.06	1.19	0.16
7.0	0.018	9.34	22.08	3.04	1.18	0.15
6.0	0.020	9.31	21.83	3.03	1.23	0.14
5.0	0.018	9.30	21.75	3.07	1.18	0.14
4.0	0.019	9.39	21.70	3.03	1.22	0.14
3.0	0.040	*12.17	*16.55	*2.41	1.32	0.011

- ✓ CORROSION TESTING AS PER ASTM 923 METHOD C

Result observed: satisfactory

Acceptance criteria

The corrosion rate is calculated in accordance with the weight loss & it should be less than 10 mdd(milligrams per square decimeter per day)

Initial weight of specimen : 43.161g
Weight after 24 hours : 43.1603 g
Weight loss : 0.0007 g (0.70 mg)
Corrosion rate : 2.2150 mdd (acceptable)

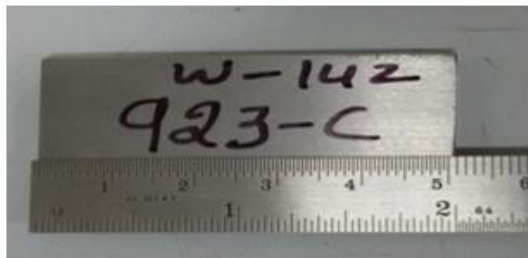


Fig.10 Corrosion Specimen (ASTM 923 METHOD C)

V. CONCLUSION

Typical to weld Duplex 2209 welded successfully meeting the requirement of ASME Sec IX & Sec IIC.

VI. SCOPE OF FUTURE WORK

As a future work, we will establish corrosion test as per customer requirement such as ASTM G-48 method A-pitting corrosion & method B –Crevice Corrosion, ASTM G-36 etc.

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