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Clad Linepipe to combat the Corrosion in Pipelines

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Abstract: ***Oil and gas are the essential commodities for the today's life. Every person in the modern life is directly or indirectly using the oil, gas and its products. As the demand of the oil and gas is increasing significantly, the cost of the production needs to be reduced as the mass population can afford the products. It is possible when the production, equipment's and operation cost could be reduced. The one of the major concern for oil and gas producers are the maintenance and operation cost, as pipelines are lifeline for oil and Gas producing facilities because pipeline is the safest mode for oil and gas transportation. Maintenance cost without affecting the integrity of the pipeline is always a challenging job for oil and gas producers. Corrosion is the direct loss to the operating companies which involves the time loss, financial loss and integrity of the equipment may also get affected. Majority of the oil and gas reservoirs are highly corrosive with either high concentration of H_2S or CO_2. The selection of the high quality corrosion resistant material is the requirement of the time to tap the highly corrosive fields. For the pipeline the corrosion can be combated with using the suitable Clad linepipe. In this paper the manufacturing of Corrosion resistant Alloy (CRA) clad line pipe has been discussed. The Clad line pipes were produced from clad plates on which clad layer was metallurgically bonded through explosion bonding route. The backing material for the line pipe was API5L X65MS (Yield strength = 450 Mpa) and CRA layer was Alloy UNS N08825 grade. The procedures for submerged arc welding (SAW) and resistance electro slag (RES) welding were established. The detailed analysis was done for the raw material and CRA clad line pipe. The mechanical properties & Physical properties like Tensile, Impact, Hardness, Bend test, Shear bond test were conducted. The Corrosion properties were analysed as per ASTM, Microstructure analysis was also done.***
Keywords: CRA, RES, API 5LD, Line pipe, Corrosion, Clad

I. INTRODUCTION

The oil and gas have become the essential need for our daily life and the demand is increasing as the population is growing. Majority of the oil and gas reservoirs are highly corrosive and the exploration is a challenge for the producers as the lower cost. The cost can be reduced if the higher production can be achieved without breakdown or maintenance free equipments. For transporting the oil and gas; pipelines are the major contributing factor. If these pipelines are shut down for maintenance or replacement due to corrosion, the operator bears the losses. According to world corrosion organisation, corrosion costs $2.2 trillion to the Global economy or roughly 3% of the world's GDP[1]. Corrosion is a natural process of gradual destruction of materials in presence of the certain environment. To combat the corrosion the operator/producer has to select the suitable materials based on the application and environment. For pipelines the corrosion can be avoided by applying corrosive coatings mostly polymers; however the polymer coatings have some limitation for operating environment. Polymer coatings like PE, PP, epoxy and FBE cannot be used for higher temperature and pressure application. Also these provides the limited resistance to sulphur, Amines, Chloride and oxygen while oil and gas fluid have higher concentration of H_2S, CO_2 gases and Solid particulates such as sodium chloride, Potassium chloride, dirt and grease. H_2S, CO_2 and Chlorides have been causes of corrosion damages [2]. For the challenging environment where high temperature, high pressure and corrosive environment are present[3], the selection of the suitable linepipe is very essential. The high strength linepipe steel is already in use for higher pressure but it has limited resistance to corrosion, to combat the corrosion the Clad linepipe is one of the best economical solution for the pipeline operators. The application of the Clad linepipe is more economical than a solid CRA linepipe. So demand of CRA (Corrosion Resistant Alloy) clad linepipe is arises. Clad linepipe is a bimetallic product. The thin CRA layer is metallurgically bonded with thicker backing material while backing material contributes the structural strength and CRA takes care of the corrosion[4]. The CRA can be metallurgically bonded by techniques includes Hot roll bonding, explosion bonding, centrifugal casting and weld overlaying. CRA of stainless steel and Ni – Alloys are more commonly used in oil and gas industry. The selection of the CRA is based on the service environmental, corrosion behaviour and operating conditions.

In this study the Clad linepipe is evaluated for its manufacturing by JCOE forming technique. The CRA linepipe is produced with a CRA of Alloy UNS 08825 and the backing steel of API 5L X65MS grade. Alloy UNS 08825 is having very good corrosion resistance properties over stainless steel grades like SS304, SS316L etc. The stainless steel CRA layer can only be used for Chloride free environment while Alloy UNS 08825 can be used for higher temperature and chloride containing environment. The backing material is also suitable for sour service application where H_2S is present and having partial pressure.

II. EXPERIMENTAL

The selected Clad plate for the linepipe manufacturing was the metallurgically bonded by explosion bonding process. Explosion process has the controlled chemistry which required for CRA without deteriorating the backing steel properties unlikely happens in weld overlay where dilution is also a major concern. The raw material used for the clad linepipe was selected as backing steel of API 5L X65MS of 16mm thickness and CRA Alloy UNS 08825 is metallurgically bonded. The thickness of the CRA was 3.0mm. The chemistry of the clad plate is given in the table 1 and table 2. All the elements of the backing steel and CRA met the requirement of API 5LD specification.

Element	C	Si	Mn	P	S	Cr	Ni	Mo	Al	Cu
Wt. (%)	0.089	0.299	1.56	0.012	0.0005	0.029	0.063	0.022	0.042	0.023
Element	Ti	V	Nb	Ca	N	B	Al/N	Nb+V+Ti	Pcm	
Wt. (%)	0.004	0.000	0.030	0.0018	0.0046	0.0003	9.13	0.034	0.184	

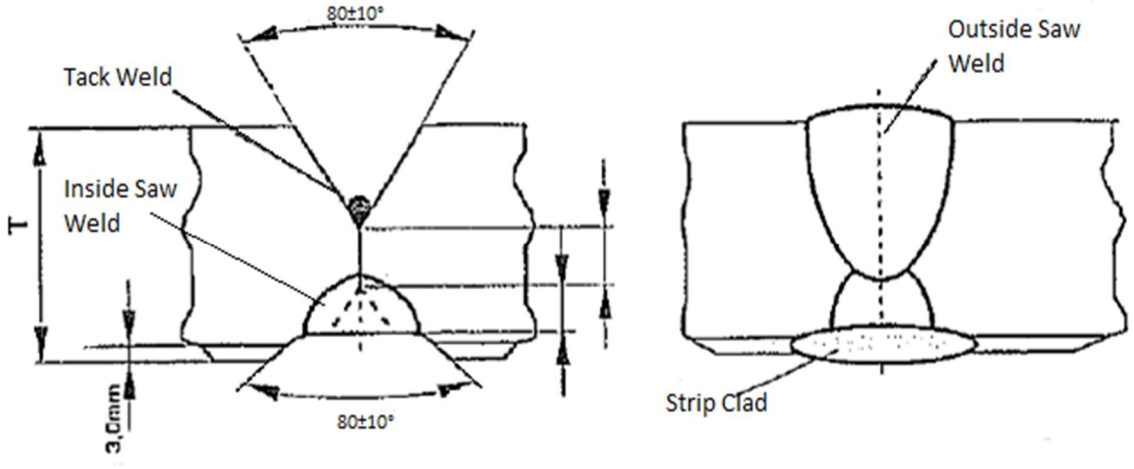
Table #1 Chemistry of the Backing Plate

Element	C	Si	Mn	Ti	S	Cr	Ni	Mo	Al	Cu	Fe
Wt. (%)	0.008	0.29	0.45	0.88	0.005	23.1	39.6	3.19	0.17	2.18	30.4

Table #2 Chemistry of the CRA layer

A. Production of the Clad linepipe

The production of clad lienpipe is done through JCOE technique. The size of the Clad linepipe was 762mm outer diameter (O.D.) and 19.05mm thickness (3mm of CRA layer). The manufacturing of linepipe was done as per API 5LD specification. The plate edge preparation is done prior to pipe forming. A special milling tool had been designed for the compound bevel geometry. The bevel was prepared as per figure # 1



Figure# 1 Compound bevel geometry

The CRA was removed in such a way so that the RES clad strip width can be accommodated for proper edge fusion. Due cares have been taken to avoid the contamination on the CRA layer.

B. Clad linepipe welding

The combinations of GMAW, SAW and RESW (Resistance Electro slag welding) processes have been used. The selection of the welding consumable have been done for backing steel as per the properties required for Linepipe manufactured as per API 5L Specification for Linepipe. The inside SAW was done in such a way that weld metal of SAW do not fuse the adjacent CRA layer, Slightly concavity is kept to avoid CRA layer melting at weld toe. The macro is shown in Figure 2.

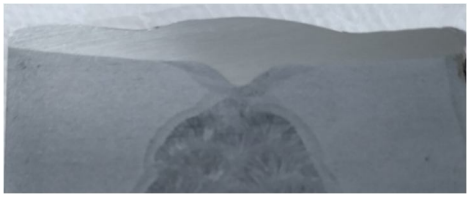


Figure #2 Macro of the complete weld

After Internal welding the external (outside) welding was carried out. The visual and Real-time radiography was done prior to RES welding in ID. The proper cleaning of the inside surface was done to avoid any contamination in the RES cladding. The consumable for the cladding was chosen as per below table # 3.

Element	C	Si	P	S	Cu	Ti	Mn	Ni	Cr	Al
Wt. (%)	0.01	0.07	0.003	0.001	0.01	0.22	0.06	64.5	22.2	0.25
Element	Mo	Fe	Nb							
Wt. (%)	8.6	0.23	3.65							

Table # 3 Chemistry of Cladding Consumable

The RES strip Cladding process was chosen for deposition of CRA layer due to its low dilution capabilities compared to other arc processes. The RESW cladding was done over the inside SAW area as shown in figure # 3.

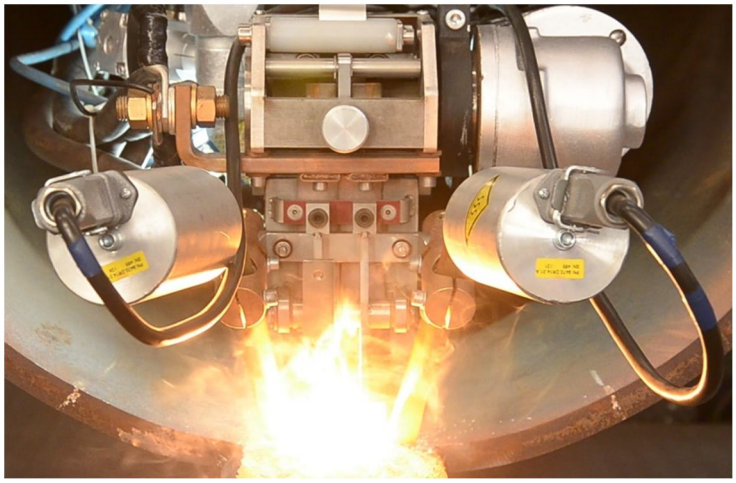


Figure # 3 Resistance Electro slag Strip Cladding inside Pipe

The welding parameters were set after many trials in such way the minimum dilution from the base metal and bead profile can be achieved. After CRA RES cladding/Overlay the pipe is again thoroughly scanned in Real Time radiography to detect any inner welding/Cladding defect. The pipe is then processed by mechanical expansion, Hydro testing and Bevel preparation.

III. RESULTS AND DISCUSSION

Prior to Clad linepipe formation the claded plate was inspected visually and entire surface of the plate have been scanned by automatic ultrasonic machine to find out any discontinuity, disbondment and any raw material defect in CRA and backing plate. After all production processes the pipe was inspected for NDT like ultrasonic, X-Ray Radiography, Magnetic particle Inspection,

Dye penetrant testing and dimensional inspection. The samples were extracted for mechanical testing like tensile, bend test, Charpy impact test, DWTT and Hardness test. The chemical analysis for base metal, CRA layer and Weld metal was conducted.

Figure #4 Bend Test Sample

Figure #4 Shear Bond Test

Tensile Properties	YS (MPa)	UTS (MPa)	YS/UTS	% EL
Observed Value (Transverse Specimen)	498	575	0.87	37

Charpy V Notch Toughness	Base Metal Values (J)	Weld Metal Values (J)	HAZ Values (J)
Test Temperature -10 °C	224,226,228 (Avg. 226 J)	130, 88, 82 (Avg. 100 J)	202, 208, 216 (Avg. 208 J)

Hardness (HV_{10})					
Base	Weld	HAZ	Base (CRA)	Weld (CRA)	HAZ (CRA)
167-172	163-168	155-179	224-237	198-205	164-174

Table # 4 Mechanical Properties Achieved

The result of the mechanical tests are shown in above table #4, from the table we can learn that all the tests met the requirements of API 5L Specification. The corrosion test as per ASTM G48 Method-A and ASTM A262 Practice-E were also conducted. In ASTM A262 Practice-E, the specimen was kept in the test solution for 15 Hours. In ASTM G48 Method-A the test specimens were kept at 22±2 °C for 72 hours in the test solution.

Figure#6 ASTM G48 Tested sample

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After the test completion the specimen were evaluated for the pitting at 20X magnification and the weight loss analysis was also conducted. In the evaluation no significant pitting were observed.

IV. CONCLUSION

A. As the demand increasing for oil and gas an economic method for preventing corrosion in line pipe is CRA Clad linepipe from which the CAPEX cost and OPEX cost can be improved.
B. From Corrosion Test as per ASTM A262 Practice E and Pitting Corrosion Resistance test as per ASTM G48 at 22°C it is evident that we can combat corrosion by using CRA clad line pipe.
C. Mechanical and Chemical Properties well met the requirements of the API 5LD.
D. Shear bond test found satisfactory with bond strength up to 465 Mpa.
E. Guided bend test for complete weld found satisfactory.

V. ACKNOWLEDGEMENT

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