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Research Article
Investigation of Stellite Cladding Bond on Grade 91 Material Using Different Buffer Layers

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Abstract

Wear is the predominant factor that controls the life of any machine part. Metal parts often fail their intended use not because they fracture, but because they wear, which causes them to lose dimension and functionality. Cladding is a process of overlaying an anticorrosive metallic layer on a carbon or low alloy steels to resist corrosion. In a metal-cladding process, a corrosion-resistant metal alloy coating is bonded to a second metal substrate that is vulnerable to corrosion. Cladding involves the preparation of a thick, metallurgically bonded coating between two different metal alloys. The major aim of the investigation is to analyse the bonding strength of the cladding of Stellite 6 alloy carried out with SS 309 and SS 347 as buffer materials on alloy steel base plate SA387 Grade -91Cl 2.

1.Introduction

Different categories of wear exist, but the most typical modes are – Abrasion, Impact, Metallic (metal to metal), Heat, Corrosion etc. Most worn parts don't fail from a single mode of wear, such as impact, but from a combination of modes, such as abrasion and impact etc. Research is going on over years to reduce the wear either in the form of using a new wear resistant material or by improving the wear resistance of the existing material by addition of any wear resistant alloying element etc. Many methods are in practice.

Hardfacing is a technique used to enhance surface properties of a metallic component as a specially designed alloy is surface welded in order to achieve specific wear properties. Surface properties and quality depend upon the selected alloys and deposition processes.

2.1TYPES OF HARDFACING

There are four types of surfacing namely hard facing, buildup, weld cladding, and buttering (ASM 1993).Among these a weld clad is a relatively thick layer of filler metal applied to a base metal for the purpose of providing a corrosion-resistant layer.

The primary objective of Cladding is to impart desirable properties to the surface of a substrate, or to conserve expensive materials by using only a relatively thin surface layer on a less expensive or abundant base metal. This results in considerable economic gains.

2.1 CLADDING FOR WEAR RESISTANCE

Cladding is a process of overlaying an anticorrosive and anti-wear metallic layer on a carbon or low carbon alloy steels to resist corrosion .In metal cladding process, a corrosion – resistant metal alloy coating is bonded to a second metal substrate that is vulnerable to corrosion and wear. Cladding involves the preparation of a thick metallurgically bonded coating between two different metal alloys.

Cladding is the application of build-up of deposits of specialized alloys by means of welding process to resist abrasion, corrosion, high temperature, or impact. Such an alloy may be deposited on the surface, an edge, or merely the point of a part subject to wear. Welding deposits can functionalize surfaces and reclaim components extending their service life [Agustin et al., (2010)]. Welding is a key technology to fulfill these requirements and to apply hardfacing alloys [Kirchgaßner et al., (2008)]. A hard-faced part should be thought of as a composite, with the base material selected for strength and economy and the hard-facing material (which might be unsuitable as well as too costly for use in fabricating the complete part) selected for the specific wearing conditions to which the critical sections of the part will be subjected in service.

Cladding may be applied to a new part during its production, or it may be used to restore a worn-down surface. Hard-facing increases the service life of a part and there by extend the lifetime of machinery equipment efficiently [Kirchgaßner et al., (2008)]. Core components such as crushers are exposed to heavy wear and require efficient surface protection measures to avoid costly downtimes and to reduce costs for expensive spare parts [Kirchgaßner et al.,(2008)]. This process has been adopted across many industries such as Cement, Mining, Steel, Petro-chemical, Power, Sugar cane and Food [Kirchgaßner et al.,(2008)].

2.3 PURPOSE OF CLADDING AND ITS APPLICATIONS

Cladding is applied for the purpose of enhancing resistance to wear, abrasion, impact, erosion, galling, or cavitations. This process is widely used to repair the railway rolling stock, earth moving and agricultural machineries, large gear wheels, conveyor shafts, chutes, turbine parts and innumerable other components (Horsfield 1980).

The difficulty of repair and replacement of active components make it important that the components should have adequate resistance to corrosion and wear. Cladding is mainly employed in many nuclear components imparting corrosion and erosion resistance. Some of the developments are developed to cladding applications are as follows.

1.Hot-wire TIG surfacing.

Hot-wire TIG surfacing was developed for hardfacing of Stainless steel valve seats and wedges. Resistance heating of the Stainless steel wire employed and deposition of the wire on to component is carried out by TIG process.

2.Explosive cladding

Explosive cladded parts are commercially now available in India. Attempts are also being made towards the development for the process for tube to tube sheet welding for the heat exchangers.

3.Stelliting

Hard facing of Stellite components subjected to high temperature service and trim material is valves are generally done by cobalt base alloys(Stellite). The quality requirements of these services are stringent. The surfaces should be free

from porosity and inclusion as surface and under bead cracks are undesirable. Apart from the above, the control of dilution is a predominant factor considered before choosing right process for Stelliting. Plasma arc welding for surfacing of large components by using special cobalt based filler material in the form of continuous wire.

2.2 APPLICATIONS

1 Clad metals are widely used in number of industries like Chemical, Power generation, Paper, Pharmaceutical, and Electro-Chemical, Petrochemical, Nuclear and Thermal Power plants to resist corrosive action of various fluids.
2 Heat exchangers, Pressure valves, autoclaves and other components can be profitably fabricated from such clad plates.
3 Stainless steel, Titanium, Nickel and its alloys, Copper alloys are usually clad on plain carbon or low alloy steel plates.

The cladding layer, most expensive and scarce materials usually forms between 5 and 25% of total thickness and provides the needed surface property such as corrosion or erosion resistance and the backing material, say the Mild steel provides the strength and contributes to the economy. A clad metal is a composite, combining the best properties of its two parent metals in both technical and commercial terms.

Hence making use of clad metals in place of solid metals results in considerable savings in cost of equipment as well as preservation of scarce material.

The various process for cladding of metals are weld deposition hot and cold roll bonding diffusion bonding and explosive cladding etc. Even though technological developments put for inventions and discoveries in every aspect of industrial groove , recent time investigation are concentrated on existing technology and finding at hence things .

In any cladding process, the three important problems are;

*Deposition rate should be higher enough to satisfy the shop requirements.

*Proper dilution level.

*Required chemical composition.

Efforts continue to find effective ways to prevent metals from corroding in very aggressive environment conditions that metal force include high alkalinity, abrasion and acidity. Current metal cladding techniques such as welding are insufficient and costly. A new high every density fusion cladding process has been developed that can be done more efficiently at a lower cost and with a wide of metal alloys.

3. Experimental work

3.1 Materials and preparation

BASE PLATEGRADE SA387 GR91

The base plate used in this project is one that has spread through piping and boiler inducing is an alloy “Grade -91” this is also referred to in various specifications as “T-91”, ‘P-91’ and “P -91” This is a specially modified and heat treated 9% chromium, 1% Molybdenum, Vanadium enhanced (acr-1mov) steel that performs quite well at elevated temperature –usually 1000 F and higher.

3.2 CLADDING MATERIAL:

Applying corrosion resistant materials as a cladding on to cheaper base materials is often the most cost effective Engineering solution Different type of corrosion resistant clad layers are copper based weld overlays , Ni Alloy 625 weld overlays and stellite 21 or stellite 6or ULTIMEN (UNS R 31233) weld overlay. Stellite 6 weld overlay, which is normally used where a combination of corrosion and wear resistance is required is used in this project.

3.3 BUFFER MATERIALS:

SS-309MoL is a rutile electrode used as a buffer layer in this project with better crack resistance and corrosion resistance. It is also suitable for welding dissimilar steels and steels difficult to weld. SS 347 is a Rutile-basic-coated austenitic stabilized steel electrode with approx 8% ferrite. Coating with very low moisture pick up. Soft fusion, without spatters, very easy slag removal, exceptional weld bead appearance, easy restriking. Electrode for joint welding on unsterilized and stabilized austenitic, chemical resistant CrNi-steels at working temperature upto 400°C, for corrosion resistant Cr-steels and alloyed similar claddings.

Table 3.1 Chemical Composition of Grade 91 Material

name	C	Mn	P	S	Si	Cu	Ni	Cr
P 91	0.109	0.408	0.015	0.0009	0.221	0.053	0.286	8.904
Mo	Al	Nb	V	Ti	Zr	N		
0.853	0.011	0.078	0.19	0.002	0.005	0.0519		

Table 3.2 Mechanical properties of Grade 91 Material

Material	Yield strength MPa	Ultimate Tensile Strength MPa	Elongation%	Temp. bend
Normalized and Tempered	568	710	24	20 degree C

Table 3.3 Nominal Composition (mass %) and physical properties of Stellite 6

CO	Cr	W	C	Others	Hardness	Density	Melting range
Base	27-32	4-6	0.9-1.4	Ni,Fe,Si,Mn, Mo	37-45 HRC 400-490 HV	8.46 g/cm3	2340-2540 °F 1285-1395 °C

Table 3.4 Nominal Composition (mass %) and physical properties of SS 309 & SS 347 Buffer materials.

Material	C	Mn	Si	P	S	Ni	Cr	Mo
SS-309	0.031	0.85	0.81	0.029	0.009	13.20	22.79	2.24
SS-347	0.02	1.95	0.45	0.015	0.01	10.0	20.0	0.1

4. Results and discussion

4.1 Room temperature tensile test

- This test is conducted in universal tensile testing m/c UTE -60 at room temperature 28°C.
- The two tensile specimens of SA387 Grade 91plate with Stellite 6 cladding using 2 different buffer layers SS 309 & SS347 are prepared.
- These specimens are prepared as per AWS B4.0M:2000 and ASTM E8/E8M standard respectively.
- It is proved that SS 347 buffer layer have more tensile strength than SS 309

Table 4.1 Tensile test results

Buffer Layer	UTS in MPa	Position of fracture
SS 309	598	Base Metal
SS 347	642	Base metal

Fig-1: Universal tensile testing m/c

1.2 Bend Test

The bend test is conducted to find out the ductility of the buffer layer. This test is conducted in UTN 60 bend testing m/c.
Two types of bend test is conducted

i) Root bend - root side is bent at 180° angle
ii) Face bend - Face side is bent 180° angle

The two bend specimens are of SA387 Grade 91plate with Stellite 6 cladding using 2 different buffer layers SS 309 & SS347 are prepared. The specimens are prepared as per AWS (B4.04:0M: 2000).

Table 4.2 Bend test results

Specimen	Face Bend	Angle of opening	Remarks	Root Bend	Angle of opening	Remarks
SS 309	Broken in to 2 pieces	10	Failed	Broken in to 2 pieces	18	Failed
SS 347	12 mm open discontinuity	15	Failed	12 mm open discontinuity	18	Failed

It is concluded from the bend test result that cracks appeared in the plate as both buffer layers are failed. It is proved that both joints have Brittle property and SS 347 has better bonding when compared to SS 309.

Fig-2:Universal bending m/c

4.3 Micro hardness measurements

Micro indention hardness measurement is performed across the specimens to obtain the hardness profiles in the Base metal, heat affected zone, the Stellite and buffer layers at a load of 500g in the interval 1000 micron distance by using micro indention hardness tester(Vickers Hardness Tester).It is found that Hardness of SS 347 buffer layer is more than SS 309 buffer layer.

Vickers Hardness in Vertical

Buffer layer	At Stellite	At Buffer layer
SS 309	501.2	361.3
SS347	552.2	424.4

Vickers Hardness in Horizontal

Buffer layer	At base plate	At Stellite	At HAZ	At Buffer layer
SS 309	294	459.6	296.1	381
SS347	351.2	598.6	276.4	440.9

4.4 Macro & Microstructure

Micro test is conducted by optical microscope at different focal length to find out the microstructure present in the weld metal, HAZ, weld interface, Root interface and base metal.

Metallography procedure is used to study the microstructure of base metals, weld metals and heat affected zone and microstructure changes

The recording observed under metallurgical microscope can be the effective way to analyse the effects

Of buffering layers SS 309 & SS347.

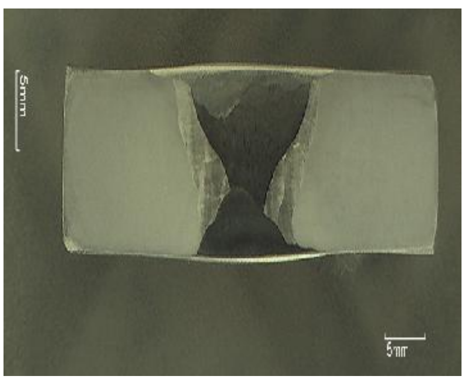

Fig-4 Macrostructure with buffer layer SS309

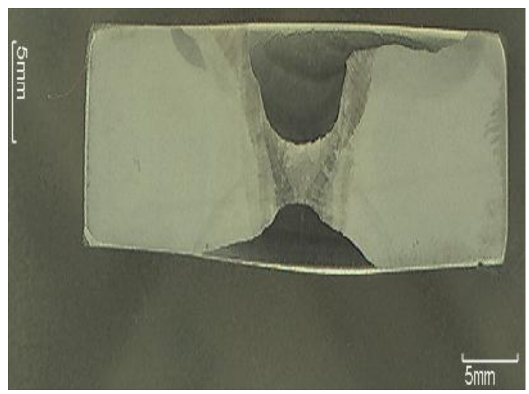

Fig-5 Macrostructure with buffer layer SS347

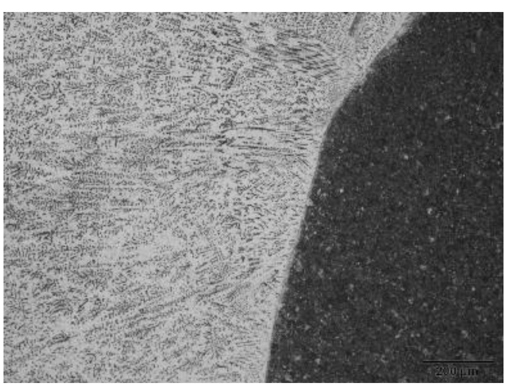

Fig-6 Microstructure of Interface Base Metal - buffer SS309 - 100X

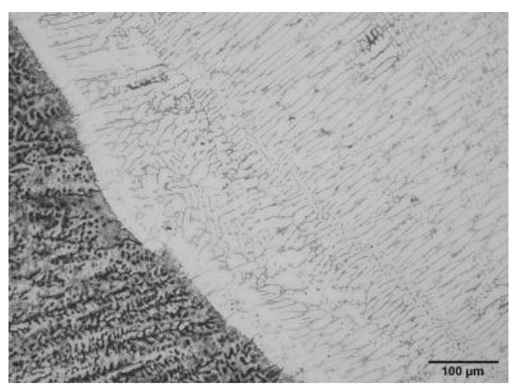

Fig-7 Microstructure of Interface stellite - Buffer layer SS309 -200X

Fig-8 Microstructure of Interface Base metal -Buffer layer SS 347-100X

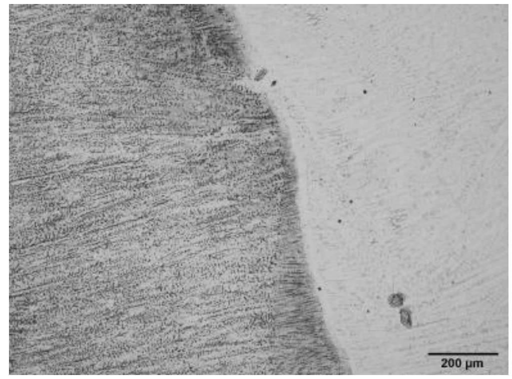

Fig-9 Microstructure of Interface Stellite Buffer Layer- SS 347-100X

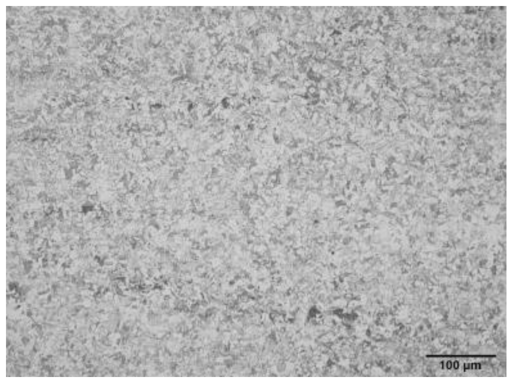

Fig-10 Microstructure of Base metal Gr 91-200X

Microstructure reveals the better bonding of SS 347 is observed with lesser dilution as compared to SS 309.

Conclusion

Based on the experiments and test results of the work, it is concluded that:

- It is proved that SS 347 buffer layer have more bonding strength than SS 309.
- It is concluded from the bend test result that the both joints have brittle property and SS 347 is more ductile and tougher than SS 309.
- .The hardness test shows the Hardness of SS 347 buffer layer is more than SS 309 buffer layer.
- The microstructure review indicates better bonding and dilution for SS 347 buffer layer.
- Hence it can be concluded that SS 347 buffer layer is better for Cladding of Stellite 6 over the base plate SA387 Grade 91 material.

References

1. AgustínGualco, Hernán G. Svoboda, Estela S. Surian and Luis A. de Vedia., "Effect of welding procedure on wear behaviour of a modified martensitic tool steel hardfacing deposit", Materials & Design, Elsevier, Volume 31, Issue 9, October 2010, Pages 4165–4173.
2. Kirchgaßner, M., Badisch, E., Franek, F. "Behaviour of iron-based hardfacing alloys under abrasion & impact", Wear, Vol. 265 (5-6), pp. 772-777
3. Balasubramanian, V., Lakshminarayanan, A.K, Varahamoorthy,R. and Babu,S., "Predicting the Dilution of Plasma Transferred Arc Hardfacing of Stellite on Carbon Steel Using Response Surface Methodology", Metals and Materials International, Vol. 14, No. 6 pp. 779-789, 2008.
4. Balasubramanian, V. and Babu, S., "Application of Response Surface Methodolody to Prediction of dilution in plasma transferred arc hardfacing of stainless steel on Carbon steel", J. of Iron and steel Research, Vol. 16, Issue 1, pp. 44-53,2009
5. Siddhart Pant and Swati Bhardwaj,"Propertieties and Welding Procedure for Grade 91 AlloySteel", International journal of Engineering Resaerch and Technology, ISSN 0974-3154 Volume 6,Number 6(2003),pp 767-772.
6. Devinder Pal Singh, Mithilesh Sharma,JaspalsinghGill "Effect of Post weld Heat Treatment on the Impact Toughness and Microstructural Property of P-91 steel weldment", International journal of Research in Mechanical Engineering & Technology, Volume 3

,Issue 2, Mar-Oct 2013.

7. Arivazhagan, B., Kamaraj, M.,"A Study on Factors Influencing Toughness of Basic Flux-cored Weld of Mdified 9Cr-1Mosteel", Journal of Materials Engg. And Performance, 2010
8. Coleman, K., Newell, W.F.,"Welding the new generation Cr-Mo alloys for high-temperature service", Welding Journal,pp. 29-33, 2006
9. William, F., Newell, J.,"Welding and Postweld Heat Treatment of P91 Steels", International & AWS Welding Show, Chicago,pp33-36,2010.
10. Daniela Polochova ,Marie SVOBODAVA and Josef Uzel,"Comparison of Mechanical properties of P91 Steel Depending on Temperature and annealing Time",21-22.11.2012,COMAT 2012,Recent trends in Structural materials,Plzen,CzechRepub,EU.
11. M.Sebastini,V.Mangione,D.DeFelics, E,Bemprad,"Wear Mechanismsm and in-service Surface modification of s stellite 6 CO-CR Alloy", Wear 290-291(2012)10-17,University of Rome,00146Rome,Italy
12. Fredrik Stenarson, FritjofTibblin," Evaluation of phase relations in weldoverlays of 316, 309MoL and SKWAM ", 2013, Dept. of Material Science and Engineering, Royal Institute of Technology, Stockholm.
13. Jhon C. Lippord and Damian J Kotecki, Welding Metallurgy and weldability of Stainless Steels,Hoboken, NJ,USA:Jhon Wiley,2005
14. Erich Folkhard, Welding Metallurgy of Stainless Steels,Wien,Austria,Spinger-Verlag,1988
15. K H LO,C.H.Shek,andJ.K.L.Lal," Recent development in Stainless Steels,"Physics and Materials Science,City University of HongKong,April26,2009.
16. G.Venkaraman, S.Arunagiri and A.Srinivasalu ,"Influence of Microstructures on cracks propagation in Stainless steel Weld mteals.Vol. 122, 2002, 33-37.
17. W.Schwarz and H.Warlimont "A new series of CO-based amorphous alloys and their application as cladding materials. Materials Science and Engineering A226-228(1997) 1098-1101.