An Overview onWeld Cladding

Somnath Mahapatra[1], Amit Laha[2], Arpita Dey[3], Ajit Mondal[4], Bholananda Bhowmik[5]

[1] Student, (ME- B.Tech), Camellia Institute of Technology , Madhyamgram, Kolkata-700129, Email ID: somnathmahapatra6@gmail.com

[2]Protem Lecture in Camellia Institute of Technology , Madhyamgram, Kolkata-700129, Email ID: amit.laha07@gmail.com

[3]Protem Lecture in Camellia Institute of Technology , Madhyamgram, Kolkata-700129, Email ID: arpita.dey002@gmail.com

[4] Asst. Prof. in Camellia Institute of Technology , Madhyamgram, Kolkata-700129, Email ID: mondalajit830@gmail.com

[5]Prof. in Camellia Institute of Technology , Madhyamgram, Kolkata-700129, Email ID: b_bhowmik@hotmail.com

Abstract: Cladding is a process of depositing a relatively thick layer of filler material on a carbon or low alloy steel base metal. It enhances production economies by enabling the use of a cheaper, more machinable parent material coated with expensive metals and alloys for achieving desired properties in specific areas of products. It finds the use in chemical and fertilizer plants, nuclear power plants, pressure vessels, agricultural machines and even aircraft and missile components. Also, it has been used widely for maintenance and repair of railway rolling stock as well as points and junctions, earth moving and agricultural machinery, large gear wheels, conveyor shafts, chutes, turbine components and innumerable other components. The various applications of weld cladding include the internal surfaces of carbon and low alloy steel pressure vessels, paper digesters, urea reactors, tube sheets, nuclear reactor containment vessels, and hydro-crackers .

Most accepted method of employed in weld cladding is GMAW. It has got many advantages such as high reliability, low cost, easy to use etc. Nowadays in order to compete in the market industries have to reduce the cost of the product to achieve this process parameters have to be optimized to get minimum values. The mechanical strength of clad metal is highly influenced by the composition of metal but also by clad bead shape. This is an indication of clad bead geometry. It mainly depends on wire feed rate, welding speed, arc voltage etc.

Keywords: ***cladding, GMAW, corrosion, weld bead geometry***

Introduction

Weld cladding is a process of depositing a thick layar of a corrosion resistance material over a corrosionprone metal to improve its corrosion resistance. Mechanical and corrosion resistance properties of clad components depend on clad bead geometries, clad composition and quality of bonding, which are controlled by process parameters. Weld cladding is not only used to increase corrosion resistant properties of a surface ,but also is employed to repair a worn out component to restore its original working condition, such as turbine blades in a power plant[1, 2]. Weld clad materials are widely used in various industries such as chemical, fertilizer, nuclear and steam power plants, food processing and petrochemical industries [3].

History of Cladding

Weld cladding techniques was first developed at Strachan & Henshaw, Bristol, United Kingdom, for use on defense equipment, especially, for various parts of submarines [4, 5].

Technologies Commonly Used for Cladding

Technologies commonly used for cladding are:

- Thermal spraying
- Laser-based methods
- Arc welding

Thermal Spraying

In this technique, the base material is coated with the clad material (metal, ceramic, or plastic). The clad material is melted by a heat source, and is projected as a spary on the surface of the substrate. Here the bond between the base metal and the deposited metal is purely mechanical.This gives rise to the problem of poor wear resistance, and the dilution is zero [6]. The most commonly types of this technique are:

- Flame spraying
- Arc spraying
- Plasma spraying
- High-velocity oxyfuel technique

Laser-Based Methods

In laser cladding, fusion between the clad material and the base metal is obtained by the thermal energy obtained from a laser source. Compared to other processes, laser cladding needs quite low rate of dilution, since the base metal to a small thickness is required to be for achieving the required metallurgical bonding with the clad material. Following type of lasers are used for cladding:

- CO2 laser
- Various forms of Nd:YAG lasers
- Fibre lasers
- Diode lasers

Application of laser cladding is limited by fairly high initial investment, and in some cases, the requirement of the size of the setup (as in CO, lasers) creates certain limitations in its application [6].

Arc Welding

In arc welding techniques for cladding, the required metallurgical bond between the base metal and the clad material can be obtained by melting them by an arc, and sudsequent fusion of the moltel metal forms the clad layer. In most cases, a shielding gas is used to isolate the metal pool from the atmosphere. Arc welding techniques used for cladding are:

- Plasma arc welding (PAW)
- Plasma transferred arc (PTA)
- Gas tungsten arc welding (GTAW)
- Gas metal arc welding(GMAW)
- Submerged arc welding(SAW)
- Flux cored arc welding(FCAW)
- Electro slag welding(ESW)

Arc welding process offers high productivity with a strong metallurgical bond, but it suffers from high dilution rate which is undesirable for a good cladding [6].

Gas Metal Arc Welding Used for Weld Cladding

Among various arc welding processes for weld cladding, gas metal arc welding (GMAW) is considered as one of the best processes due its various advantages to produce good quality weld. These advantages are:

- High reliability
- All position capability
- Ease to use
- Low cost
- High Productivity
- Suitable for both ferrous and non-ferrous metals
- High deposition rate
- Absences of fluxes
- Cleanliness and ease of mechanization

One of the various advantages of gas metal arc welding is its adaptability to weld different metals and cladding process which basically involves coating of base material with a layer of a different material superior in hardness, and others properties than the base material. In this process problems like slag inclusion, porosity, etc. does not arise because flux is not used [6].

Weld Clad Quality

Clad Bead geometry has a significant role in weld cladding because the strength of clad metal depends largely on bead geometry. Clad bead geometry is a function of wire feed rate, arc voltage etc.

Weld cladding also depends largely on dilution of weld metal. e., the ratio of cross section of weld metal below the original surface to the total area of the weld bead measured on the cross section of the weld deposit. Successful weld cladding needs a good profile weld bead and minimum dilution [7].

Various Methods Adopted for Improving Weld Clad Quality

Dilution was controlled by using two wires GAT cladding. Since two wires consume more heat from the are, hence, less heat is absorbed by the substrate metal, and results in less dilution . Dilution is reduced significantly by using auxiliary preheated filler wire, because heat content of the filler is partially controlled the preheating current (l R), whereas main welding current provides remaining energy required for melting the wire. Welding current controls the are force and heat transmitted to the weld pool, and any decrease in welding current causes decrease in dilution [9]. Pulsed gas metal are welding (P-GMAW) employed for weld cladding decreases higher carbon dilution responsible for decreased corrosion resistance Post-weld heat treatment (PWHT) decreases hardness but significant improvement was noticed in weldment regarding thermal fatigue resistance resistance [9].

Microstructure of Weld Clad and Corrosion Resistance

It was observed that weld cladding performed with pulsed current results in finer and more homogenous solidification structures and lower dilution levels. Dilution level increases with increase in current intensity and causes decrease in hardness. In the microstructure of Stellite6/WC cladding layers increases with higher content of WC. Phases constitution of weld clad obtained by depositing AISI 431 martens stainless steel depend on cladding speed. It was found that with increase in cladding speed, cell spacing decreases due to higher solidification rate. No changes were observed in phase constitution for multi-layer cladding due to refinement of the solidification structure. Hardness reduces, and wears rate increases as dendrites refines and stabilizes the parent austenite phase in single-layer claddings, with high cladding speed. In thermally-aged stainless steel, Cr spinodal decomposition was observed in the weld clad at 400 C for 10,000hrs [9].

Effect of process parameters on clad bead geometry

Effect of Wire Feed Rate

It observed that with increase in wire feed rate, depth of penetration, height of reinforcement, and weld bead width increases. With increase in wire feed rate welding current also increases resulting in an enhanced power per unit length of the weld bead and higher current density, causing larger volume of the base metal which causes deeper penetration [7].

Effect of Welding Speed

In stainless steel cladding by GMAW, height of reinforcement and weld width decrease with increase in welding speed. Heat Input per unit length of weld bead reduces with increase in welding speed, and less filler metal is applied per unit length of the weld. Increase in welding speed also decreases penetration of weld metal [6]. In weld cladding by plasma transferred are (PTA) process, effect of increase in welding speed was found the same as it was for cladding by GMAW. In PTA process, with the increase in speed, it was observed that reinforcement increases in speed, it was observed that reinforcement increases to some optimal value, and then decreases with further increase in speed, because, with high welding speed, amount of powder deposited per unit length of bead decreases [8].

Influence of Welding Gun Angle

Experimental results depicted that in forehand welding (i.e., gun angle>90), depth of penetration , height of reinforcement, and weld bead width decrease gradually with increase in welding gun angle from its enter point (90)to the upper limit (110). Same effects are also observed for backhand welding (i.e., gun angle <90), when gun angle decreases from its centre point (90)to the lower limit (70) [9].

Nozzle Tip Distance (NTD) and Its Effect

It was observed [4] that with increase in nozzle-tip-distance, depth of penetration increase at first , and then sharply decreases. On the other hand, Kannan & Yoganandh [6] found out that with increase in nozzle-to-plate distance, weld bead width and height of reinforcement increases. This is because resistance increase with increase in nozzle -to-plate distance which reduces the welding current, and hence, lowers the heat inpu per unit length of the weld resulting in reduction in fusion area. Ultimately, depth of penetration decreases. It was also observed that are length increases with increase in nozzle-to-plate distance and hence, the bead width increases due to wider are at the weld surface [9].

Effect of Welding Current

It was observed that with increase in welding current, penetration increases significantly. This happens because with increase in welding current heat input to the base metal increases to a large extent resulting in gradual increase in dilution, weld with and total area [9].

Influence of Oscillation Width

With increase in oscillation width, it was found [5] that reinforcement decreases. As oscillation increases, deposited metal god distributed along the width resulting in decrease in reinforcement. Penetration decreases slightly as weld width increases due to increase in oscillation. It was also observed that with increase in oscillation, dilution increases, and this may by due to the significant effect of decrease in reinforcement. Total area also increased with increase in oscillation as width increases [9].

Dilution

Kannan and Murugan [10] defined dilution as the ration of the cross section of weld metal below the original surface to the total area the weld bead measured on the cross section of the weld deposit. Various combinations of procedural parameters like primary parameters viz. Welding current, voltage, welding speed and secondary parameters like polarity, electrode size, wire stick out, welding position/inclination, arc shielding, electrode oscillation, welding technique, additional filler metal etc. That affect dilution, can be incorporated into a procedure. Various processes like SAW, GTAW, PAW, GMAW, ESW, FCAW, Strip cladding, Explosive welding, etc, have been used for cladding to as low value as possible without sacrificing the joint integrity. This requires a thorough understanding and proper control over a number of variables, which affect dilution. Use of hot filler additions in various conventional processes like TIG, LBW, PAW, etc. have been reported to affect dilution to a significant extent.

Effect of Auxiliary Preheating of the Filler Wire on Quality of Gas Metal Arc Stainless Steel Cladding

Shahi and pandey [11] investigated the effect of auxiliary preheating of the solid filler wife in mechanized gas metal are welding (GMAW) process by using a specially designed torch to preheat the filler wire independently, before its emergence from the torch on the quality of the single layer stainless steel overlays. External preheating of the filler wire resulted in greater contribution of arc energy by resistive heating due to which significant drop in the main welding current values, and hence, low dilution levels were observed. Metallurgical aspects of overlays such as chemistry, ferrite content, and modes of solidification were studied to evaluate their suitability for service, and it was found that claddings obtained through the preheating arrangement, besides higher ferrite content, possessed higher content of chromium, nickel, and molybdenum and lower content of carbon as compared to conventional GMAW claddings, thereby giving overlays with superior mechanical and corrosion resistance properties. The findings of this study not only establish the technical superiority of the new process, but also, justify its use for low cost surface applications due to its productivity- enhanced features.

Effect of Chromium on the Weldability and Microstructure of Fe-Cr-Al Weld Cladding

Regina et al. [12] studied the effect of chromium on weldability and microstructure of Fe-Cr-Al weld cladding. Iron-chromium-aluminum-based alloys are good corrosion resistant weld claddings because they exhibit excellent oxidation and sulfidation resistance in a wide range of high-temperature environments. These alloys rely on both aluminium and chromium additions for increased corrosion protection, and it has been shown that the corrosion resistance of these alloys in simulated low NOx environments improved with an increase in aluminum and chromium concentrations. Recent studies have indicated that Fe-Cr-Al-based alloys require approximately 7.5-10 wt-% aluminum and chromium additions up to 5 wt-%to remain protective in a wide variety of low NOx-type atmospheres. However, work to data has shown that weld cladding that contains the brittle FeAI and/or Fe3 Al inter metallic are susceptible to cracking due to environmental embrittlement. Liu et al.[5] was one of the first investigators to demonstrate that premature cracking of FeAl and Fe3 Al inter metallic is due to hydrogen embrittlement Room-temperature ductility of FeAl and Fe3 Al inter metallic alloys was investigated under carefully controlled environments. The FeAl and Fe3 Alloys each exhibited significant ductility (12% elongation) when tensile tested under high-vacuum or pure oxygen environments (i.e., with no water vapour). The introduction of water vapour into the test chamber decreased the ductility significantly down to2-4% Hydrogen embrittlement of the inter metallic phases has been attributed to their general lack of ductility coupled with the generation of hydrogen that occurs when aluminium reacts with water vapour to liberate free hydrogen via the reaction 2Al +3H2O -> Al2O3 +6H+ +6e- While many theories for hydrogen embrittlement exist, the presence of hydrogen in these alloys is expected to cause embrittlement by significantly lowering the cleavage strength. This type of mechanism is also believed to be responsible for cracking observed in Fe-Al cladding that contains the inter metallic phases in which Al reacts with water vapour in the arc to liberate hydrogen. This, coupled with residual stresses from welding, can cause cracking in Fe-Al cladding that contains the FeAl and Fe3Al phases. For example, it has previously been reported that Fe-Al cladding produced with both the GTAW and GMAW processes were subject to this cracking phenomenon when the aluminium concentration in the weld deposit was greater than approximately 8-11%Al, and this Al range represents the composition over which the intermetallics begin to form in the cladding. Cracks that formed on welds were observed in a zone where they stopped at the base metal. This type of cracking would provide direct paths through the corrosion-resistant weld coatings, and thus allow corrosive gas species to attack the underlying substrate. Weld cladding containing these types of cracks would essentially provide no corrosion protection at cracked areas and would be unacceptable for these applications.

Effect of Flux Cored Arc Welding Process Parameters on Duplex Stainless Steel Clad Quality

According to Kannan and murugan [10], most of the engineering applications require both high strength and corrosion resistant materials for long tern reliability and performance. Often strength is achieved by the use of steels which do not possess the required corrosion resistance. To obtain attributes of high strength and corrosion resistance, the surface of steel may be cladded with a metallurgically compatible corrosion resistant alloy. The characteristics desirable in such a cladding alloy are reasonable strength, Weldability to the steel, resistance to general and localized corrosion attack, and good corrosion fatigue properties. A clad material giving excellent corrosion resistance and weldability is duplex stainless steel. These have chloride stress corrosion cracking resistance and strength significantly greater than that of the 300-series austenitic. In recent years, weld cladding processes have been developed, and are applied in chemical and fertilizer plants, nuclear and steam power plants, food processing and petrochemical industries, etc.

The biggest difference between welding a joint and cladding is the percentage dilution illustrated in Fig. 1. The composition and properties of cladding are strongly influenced by the dilution obtained. Control of dilution is important in cladding, where typically low dilution is desirable. When the dilution is low, the final deposit composition will be closer to that of the filler metal and the corrosion resistance of the cladding will also be maintained. Various welding processes employed for cladding are shielded metal arc welding (SMAW), submerged arc welding (SAW), gas tungsten arc welding (GTAW), plasma are welding (PAW), gas metal arc welding (GMAW), flux cored are welding (FCAW), electro slag welding (ESW), oxy-acetylene gas welding (GW), and explosive welding. FCAW is widely used in industries due to the following features :

.

1. High deposition rates, especially for out-of-position welding.
2. More tolerant of rust and mill scale than GMAW.
3. Simpler and more adaptable than GMAW.
4. Less operator skill required than GMAW.

5. High productivity than SMAW.

6. Good surface appearance.

7. Good radiographic standard quality.

8. Minimum electrode wastage.

Concluding Discussion

Following concluding remarks can be made on different investigations on cladding techniques.

- Weld cladding mainly depends on proper selection of process parameters. Clad quality is characterized by microstructure of cladding, and clad bead geometry, especially, dilution that needs be as less as possible. Suitable cladding impacts desired corrosion resistance.

- Dilution increases with the rise in welding current and welding speed and decreases with the rise in nozzle tip distance and welding torch angle.

- Weld bead width increases with the rise in welding current, nozzle tip distance, and welding torch angle and decreses with the rise in welding speed.

- Penetration increases with the rise in welding current and welding speed, and decreases with the rise in nozzle tip distance and welding torch angle.

- Among various welding processes for weld cladding, gas metal arc welding (GMAW) is considered as one of the best process.

References

[1] V. Kumar, G. Singh, M. Z. K. Yusufzai, Effects of Process Parameters of Gas Metal Arc Welding on Dilution in Cladding of Stainless Steel on Mild Steel, MIT International Journal of Mechanical Engineering, Vol. 2, No. 2, pp. 127-131, 2012.

[2] P. Sreeraj , T. Kannan , S. Maji, Optimization of Process Parameters of Stainless Steel Clad Bead Geometry Deposited by GMAW Using Integrated SA-GA, International Journal of Research in Aeronautical and Mechanical Engineering, Vol.1, No.1, pp. 26-52, 2013.

[3] Recommended Practices for Gas Metal Arc Welding, AWS C5.6-89.Wikipedia, the free encyclopedia.htm, 2001.

[4] N.R. Venkateswara, G. Madhusudhan, G. Reddy, S. Nagarjuna, Weld Overlay Cladding of High Strength Low Steel With Austenitic Stainless Steel- Structure and Properties, Materials & Design, Vol.32, pp.2496-2506, 2011.

[5] P.K. Palani, N. Murugan, Development of Mathematical Models for Prediction of Weldbead Geometry in Cladding by Flux Cored Arc Welding, International Journal Advanced Manufaturing Technology, Vol.30, pp.669-676, 2006.

[6] S. Das, A.K. Verma, A Brief Overview on Cladding Techniques With a Reference to Weld Cladding using Gas Metal Arc Welding, A Technical Magagine, Vol-X, pp. 13-16, 2011.

[7] T. Kanna, J. Yoganandh, Effect of Process Parameters on Clad Bead Geometry and its Shape of Stainless Steel Claddings Deposited by GMAW, International Journal Advanced Manufacturing Technology, Vol.47, pp.1083-1095, 2010.

[8] K. Siva, N. Murgun, Modelling, Analysis and Optimisation of Weld Bead Parameters of Nickel Based Overlay Deposited by Plasma Transferred Arc Surfacing, Association Of Composite Material Science And Surface Engineering, Vol. 1, No.3 pp. 174-182, 2009.

[9] D. Das, S. Das, Developments In Weld Cladding, A Technical Magagine, Vol-X, pp.13-16, 2011.

[10] T. Kannan, N. Murgur, Prediction of Ferritic Number of Duplex Strainless Steel Clad Metals Using RSM, Welding Journal, pp. 91/s-100/s, May, 2006.

[11] A. S. Shahi, S. Panday, Effect of Auxiliary Preheating of the Filler Wire on Quality of Gas Metal arc stainless Steel Cladding, Journal of Materials Engineering and Performance, Vol.17, pp. 30-36, 2008.

[12] J. R. ReGina, J. N. Dupont, A. R. Marder, The Effect of Chromium on the Weldability and Microstructure of Fe-Cr-Al Weld Cladding, Welding Journal , Vol.86, pp. 170/s-178/s, 2007.