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Review Article

DEVELOPMENTS IN WELD CLADDING

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Abstract: Weld cladding is a process of depositing a relatively thick layer of filler material of approximately 3mm on the base metal through welding so as to develop surfaces with desired properties. Cladding is usually done to increase the corrosion resistance, wear resistance or hardness of such base metals having inferior properties. Cladding improves the service life of engineering components, and also reduces their cost. In this paper, various weld cladding technique, and effect of process parameters on clad quality including microstructure, mechanical and other cladding properties are discussed.

Keywords: *Weld Cladding, Cladding, Clad bead, Dilution, Microstructure, Corrosion resistance*

1. Introduction

Weld cladding techniques was first developed at Strachan & Henshaw, Bristol, United Kingdom, for use on defence equipment, especially, for various parts of submarines [1]. Through weld cladding, composite structure is developed by fusion welding process. All metals used as fillers may be used for weld cladding. Materials such as nickel and cobalt alloys, copper alloys, manganese alloys, alloy steels, and few composites are commonly used for weld cladding.

Weld clad materials are widely used in various industries such as chemical, fertilizer, nuclear and steam power plants, food processing and petrochemical industries. Various industrial components whose base metals are weld-clad are steel pressure vessels, paper digesters, urea reactors, tube sheets and nuclear reactor containment vessels. Cladding using gas tungsten arc welding is widely used in aircraft engine components to maintain high quality.

In this paper, influence of process parameters, shielding gas, etc., on microstructure, mechanical properties and corrosion resistance of weld clad metals are reviewed. Various methods which can be adopted for improving weld clad quality are also discussed.

2. Various Processes of Weld Cladding

Weld cladding can be done by using various processes such as Submerged arc welding (SAW), Gas metal arc welding (GMAW),Gas tungsten arc welding (GTAW), Flux cored arc welding (FCAW), Submerged arc strip cladding (SASC), Electroslag strip cladding (ESSC), Plasma arc welding (PAW), Explosive welding, etc.

GTAW and PAW are widely used for the cladding operations, and they produce superior quality cladding because they generate high stable arc and spatter free metal transfer [2]. Welding variables and inert gas shielding can be precisely controlled in both GTAW and PAW. Though GTAW and PAW cladding can produce excellent overlay with a variety of alloy materials, but deposition rate is low compared to other processes which limit its application in industries.

Submerged arc strip cladding (SASC) and Electroslag strip cladding (ESSC) are extensively used [3] for cladding large surfaces of heavy–wall pressure vessels. Three most important characteristics of SASC and ESSC are high deposition rate, low dilution and high deposition quality. Deposition rate in ESSC is much more than in SASC because of absence of arc, whereas, dilution in ESSC is less compared to SASC because of the same reason.

Weld cladding is widely done using flux cored arc welding (FCAW) process due to various advantages. With properly established process parameters automation and robotization can be done easily in FCAW [4].

Wear, corrosion and heat resistance of material surface is enhanced by plasma transferred arc (PTA) surfacing [5]. PTA process is also considered as an advanced GTAW process used largely for overlay applications. Various advantages of PTA surfacing are very high deposition quality, high-energy concentration, narrow heat affected zone, less weld distortion, etc. On the other side, demerits of PTA surfacing are low deposition rates, overspray, and very high equipment costs.

Cladding with the use of submerged arc welding (SAW) is applied for large areas, and its fusion efficiency is quite high. SAW can be easily automated and employed specially for heavy section work [5].

Gas metal arc welding (GMAW) is popular among various weld cladding processes, and it is widely accepted by industries due to various characteristics such as, high reliability, all position capability, ease of use, low cost, high productivity, suitability for both ferrous and nonferrous metals, high deposition rate, absence of fluxes, cleanliness and ease of mechanization [6].

3. 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, welding speed, arc voltage, etc.

Weld cladding also depends largely on dilution of weld metal, i.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 [6,7].

3.1. Effect of process parameters on clad bead geometry

Effect of wire feed rate: It was 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 to melt which causes deeper penetration [6,8].

Effect of welding speed: In stainless steel cladding by GMAW, height of reinforcement and weld bead 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 arc (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 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 [5].

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 center 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 center point (90°) to the lower limit (70°) [6].

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 circuit resistance increase with increase in nozzle-to-plate distance which reduces the welding current, and hence, lowers the heat input per unit length of the weld resulting in reduction in fusion area. Ultimately, depth of penetration decreases. It was also observed that arc length increases with increase in nozzle-to-plate distance and hence, the bead width increases due to wider arc area at the weld surface [6].

Effect of welding current: It was observed [5] 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 width and total area.

Influence of oscillation width: With increase in oscillation width, it was found [5] that reinforcement decreases. As oscillation increases, deposited metal got 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 be due to the significant effect of decrease in reinforcement. Total area also increased with increase in oscillation as width increases.

3.2. Various methods adopted for improving weld clad quality

Dilution was controlled by using two wires GTA cladding. Since two wires consume more heat from the arc, hence, less heat is absorbed by the substrate metal, and results in less dilution [8]. Dilution is reduced significantly by using auxiliary preheated filler wire, because heat content of the filler wire is partially controlled by the preheating current (I^2R), whereas main welding current provides remaining energy required for melting the wire. Welding current controls the arc force and heat transmitted to the weld pool, and any decrease in welding current causes decrease in dilution [9].

Pulsed gas metal arc welding (P-GMAW) employed for weld cladding decreases higher carbon dilution responsible for decreased corrosion resistance [10].

Post-weld heat treatment (PWHT) decreases hardness but significant improvement was noticed in weldment regarding thermal fatigue resistance [5].

3.3. 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, wear resistance of cladding layers increases with higher content of WC [10].

Phases constitution of weld clad obtained by depositing AISI 431 martensitic stainless steel depend on cladding speed. It was found [11] 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 dendritic structure 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 aged at 400^0C for 10,000 hrs [12].

Two-phase microstructure was observed in weld cladding of duplex stainless steel by GMAW in which precipitation of gamma (γ) phase was observed during cooling after solidification in single delta (δ) phase. Calculated delta ferrite was less for higher heat input, and reversed effect was observed for lower heat input. It was also noticed that shielding gas effect on ferrite content is not pronounced [13]. It was observed that, both heat input and shielding gas composition affects corrosion property of duplex stainless weld deposit. Weld deposit associated with high heat input suffers more corrosion than with low heat input. It was also found that with increase in argon content in the shielding gas, corrosion property of weld improves.

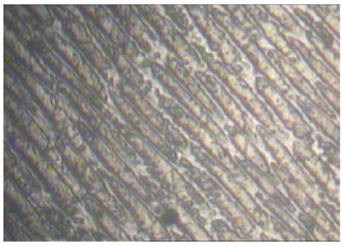

Figure 1.1: Microstructure of a weld clad specimen

Weld cladding of mild steel with 316L austenitic steel was explored using GMAW process. Austenite and interdendritic ferrite phase were observed (Figure 1.1) in the fusion zone. Equiaxed grains were found which increases tensile strength. Figure 1.2 shows microstructure of the HAZ. They found less corrosion during cladding with 150 A weld current and 5.9 mm/s weld velocity under 24 volt setting [14].

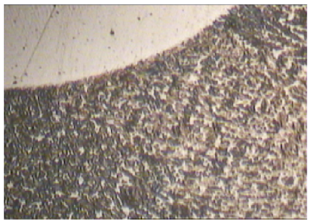

Figure 1.2: Microstructure of Heat affected zone of the lower portion below the interface

4. Concluding Discussion

Success of 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 imparts desired corrosion resistance.

References

[1] Venkateswara, N.R., Madhusudhan, G. Reddy & Nagarjuna, S. 2011, Weld Overlay Cladding of High Strength Low Alloy Steel with Austenitic Stainless Steel– Structure and properties, Mat. & Design, Vol. 32, pp. 2496–2506

[2] Kuo, I.C., Chou, C.P., Tseng, C.F. & Lee, I.K. 2009, Submerged Arc Stainless Steel Strip Cladding—

Effect of Post-Weld Heat Treatment on Thermal Fatigue Resistance, J. Mat. Engg. & Perform., Vol. 18, pp. 154-161.

[3] Patel, M., Madnania, R. H., Chauhanb, B. J. & Sundaresanb, S. 2008, Application of Electroslag Strip Cladding for Reactors in Hydrogen- Based Refinery Service, National Welding Seminar.

[4] Palani, P.K. & Murugan, N. 2006, Development of Mathematical Models for Prediction of Weld Bead Geometry in Cladding by Flux Cored Arc Welding, IJ Adv Manuf Tech., Vol. 30, pp. 669–676.

[5] Siva, K., Murugan, N. & Raghupathy, V.P. 2009, Modelling, Analysis and Optimisation of Weld Bead Parameters of Nickel Based Overlay Deposited by Plasma Transferred Arc Surfacing, Asso. of Comp. Mat. Sc. and Surface Engg., Vol. 1, No.3, pp.174-182.

[6] Kannan, T. & Yoganandh, J. 2010 , Effect of Process Parameters on Clad Bead Geometry and its Shape, Relationships of Stainless Steel Claddings Deposited by GMAW, IJ Adv Manuf Tech, Vol. 47, pp.1083–1095.

[7] Nouri, M., Abdollah, Z.A & Malek, F. 2007, Effect of Welding Parameters on Dilution and Weld Bead Geometry in Cladding, J. Mater. Sci Technol., Vol. 23, No.6, pp.817-822.

[8] Zheng, S., Min, K. & Dayou, P. 1999, Twin Wire Gas Tungsten Arc Cladding , Singapur Inst. Of Manuf. Tech., Technical Report (PT/99/004/JT).

[9] Shahi, A.S. & Pandey, S.2008, Effect of Auxiliary Preheating of the Filler Wire on Qualityof Gas Metal Arc Stainless Steel Claddings, J. Mat. Engg and Performance, Vol.17, pp.30–36.

[10] Madadi, F., Shamanian, M. & Ashrafizadeh, F. 2011, Effect of Pulse Current on Microstructure and Wear Resistance of Stellite6/tungsten Carbide Claddings Produced by Tungsten Inert Gas Process, Surface & Coat. Tech, Vol. 205, pp. 4320–4328.

[11] Hemmati, I., Ocelík., V. & De Hosson, J.Th.M. 2011, The Effect of Cladding Speed on Phase Constitution and Properties of AISI 431Stainless Steel Laser Deposited Coatings, Surface & Coat. Tech., Vol. 205, pp. 5235–5239.

[12] Takeuchi, T., Kameda, J., Nagai, Y., Toyama, T., Nishiyama, Y. & Onizawa, K. 2011, Study on Microstructural Changes in Thermally-Aged Stainless Steel Weld-Overlay Cladding of Nuclear Reactor Pressure Vessels by Atom Probe Tomography, J Nuclear Mat., Vol.415, pp.198–204.

[13] Chakraborty, B. 2011, Study on Clad Quality of Duplex Stainless Steel by Gas Metal Arc Welding Process, M.Tech Dissertation, Mech. Engg, Dept., Kalyani Govt. Engg Col.

[14] Sarkar, A., Khara, B., Sarkar, M. & Mandal, N.D. 2011, Cladding Mild Steel with Austenitic Stainless Steel using GMAW, B.Tech Dissertation, Mech. Engg, Dept., Kalyani Govt. Engg Col.