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Identification of Factors Affecting the Selection of Stainless Steel Cladding Process

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Abstract—*Cladding is most widely used in the fabrication industries to fabricate corrosive resistant components at minimum cost with adequate strength. Cladding can be done with the help of many types of welding processes. But the selection of the right type of cladding process is not an easy job. There are many factors which help in the selection of cladding process. . The main objective of this paper is to examine the literature that deals with the factors which affect the selection of cladding process for the stainless steel cladding. This literature review is done to help users select a better cladding process, by considering factors important to them.*

Keywords*: Cladding, Dilution, Bead geometry, Factors, Identification.*

1. INTRODUCTION

Cladding is a surfacing technique in which a thick layer of corrosion resistance material usually stainless steel is made on low carbon steel (Mild Steel) to improve corrosion resistant. The main purpose of cladding is to increase the life on component in corrosive environment economically. Now a day's cladding process becomes more famous in the cost reduction on new components and in the repair of the worn out equipments indifferent industries such as petroleum and gas plants, nuclear and thermal power plants, pharmaceutical companies, food processing plants, agriculture equipments, chemical and fertilizer plants, aviation, mining, naval industry, railway, civil construction & paper and pulp industry etc. Cladding is used to:

- To make corrosion resistant Pipe line in oil and gas industry.
- Fabrication of Equipments for pharmaceutical and food processing industry.
- Fabrication of components for railway and defence departments
- To make fuel rods for nuclear plants
- Repair work for worn out components of gas turbine and water turbine

The quality of the cladded equipments depends on the percentage of dilution and bead geometry, which are affected by the process parameters. Considering various types of cladding materials, cladding of stainless steel is characterised as one material which is most frequently used [1]. The stainless steel cladding process is now defined as the deposition of a stainless steel layer on low carbon steel or low alloy steel plates to produce claddings with anticorrosion surfaces and resistance needed to withstand corrosive environments [2]. Cladding and welding processes have lot of similarity i.e. both uses same equipments. The major difference between cladding and welding a joint is the bead geometry and the percentage of dilution. The metallurgy composition and properties of cladding are highly influenced by the dilution obtained. Controlling the dilution is important factor in cladding, where low dilution is desirable. When the dilution is low, the final deposit composition will be closer to the filler metal and the corrosion resistance of the cladding will be good [3].

Unlike welding process that require high penetration (P) to ensure the resistance of the weld, the desired weld bead geometry in cladding process includes low penetration (P), high bead width (W), high reinforcement (R), and low dilution percentage (D) (Fig.1). This bead geometric characteristic is important for the process which allows covering the largest possible area with the less number of passes, which results in significant savings of time and material [4].

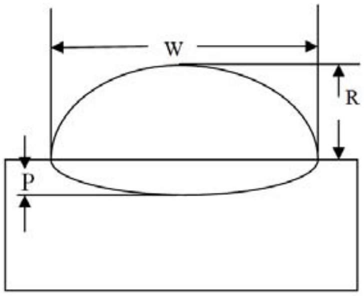

Fig. 1: Desired Bead Geometry for Cladding.

Different cladding Processes: Rolling, explosive welding and fusion welding processes are commonly used for cladding. Fusion welding is generally used in the engineering industry due to its easy and versatile applications and no legal implications of pollution, safety and noise [5]. Different fusion welding processes used in cladding are:

1. Shielded metal arc weld (SMAW) cladding.
2. Gas metal arc weld (GMAW) or metal inert gas (MIG) weld cladding.
3. Gas tungsten arc weld (GTAW) or tungsten inert gas (TIG) weld cladding.
4. Flux cored arc weld (FCAW) cladding.
5. Submerged arc weld (SAW) cladding.
6. Electro slag weld (ESW) cladding.
7. Oxy acetylene weld (OAW) cladding.
8. Plasma arc weld (PAW) cladding.

2. IDENTIFICATION OF FACTORS AFFECTING SELECTION OF CLADDING PROCESS

2.1 Dilution

It is generally defined as the percentage of presence of base metal in the weld metal deposit. If the percentage of base metal in the weld metal deposited is high the percentage of dilution will be high. At higher dilution level of percentage, properties of weld metal deposited are not enhanced up to the expected level. While at the low percentage of dilution level, properties of weld metal deposited are much better because of low percentage of base metal in the deposited metal. Hence the cladding process which produces a low level of dilution percentage is preferred for cladding application [6].

Dilution is strongly influenced by the process parameters, which are welding voltage, welding current, wire or rod feed rate, welding speed, contact tip to work piece distance (CTWD) and gun angle. These process variables exist in all fusion cladding processes and have approximate same type of affect on dilution in all type of cladding processes.

Dilution increases with the increase in welding current as well as increase in the welding speed and it decreases with the increase in CTWD and welding torch angle [7]. Dilution is significantly affected by wire feed rate. It increases with the increase in wire feed rate and open circuit voltage [8]. It is less affected by shielding gas medium and plasma gas flow rate. But it decreases with the increase in stick out or electrode extension [9].

2.2 Reinforcement

It is expressed generally as the height of bead deposited over the surface of base metal and this should be high as possible from the point of view of cladding. Because it reduces the number of passes required to get the desired thickness weld metal deposited. It is also influenced by the process parameters, which are welding voltage, welding current, wire or rod feed rate, welding speed, contact tip to work piece distance (CTWD) and gun angle.

CTWD has not any significant effect on reinforcement height. But reinforcement increases with the increase in welding current and it decreases with the increase in welding speed [10]. Reinforcement height increases with the increase in wire feed rate and decreases with the increase in welding gun angle (>90 degree) in for hand welding [20].

2.3 Bead width

High bead width is desirable in cladding to reduce the number of welding passes to complete the deposition of weld metal. Bead width is influenced by the process parameters, which are welding voltage, welding current, wire or rod feed rate, welding speed, contact tip to work piece distance (CTWD) and gun angle.

Bead width increases with the increase in welding current, welding torch angle and CTWD, but decreases with the increase in welding speed. It also increases with the increase in wire feed rate at constant values of other parameters [19].

2.4 Penetration

It is defined as the depth up to which the base metal melts during cladding. Less penetration is desirable for the cladding process to reduce the dilution. It is strongly influenced by the process parameters, which are welding voltage, welding current, wire or rod feed rate, welding speed, contact tip to work piece distance (CTWD) and gun angle.

Penetration increases with the increase in welding current and welding speed while it decreases with the increase in CTWD and welding torch angle [7]. It is also decreases with the increase in nozzle gun angle (>90 degree) in for hand welding [11].

2.5 Arc efficiency

It is defined as the ratio of energy transferred to the work piece to the energy generated by the arc. Arc efficiency direct affects the performance of the cladding processes. Different cladding processes have different arc efficiency; some of the cladding processes arc efficiencies are shown in the table below:

Welding Process	Arc Efficiency	References
1. GTAW	0.65-0.85	[12], [13]
2. PAW	0.50-0.80	[12]
3. GMAW	0.75-0.89	[14]
4. SAW	0.90-0.99	[15]

Arc efficiency is a function of process parameters i.e. welding voltage, welding current, wire or rod feed rate, welding speed, contact tip to work piece distance (CTWD) and gun angle. Arc efficiencies shown in the above table are the arc efficiency at the optimum condition of the weld.

2.6 Melting efficiency

Total heat generated by the arc is used to heat the base metal and melting the metal. But some part of the heat generated by the arc is lost in the environment called the heat loss in the welding. Melting efficiency can be defined as the ratio of heat required for the melting to the heat delivered into the base metal. In the case of 2-dimensional heat flow maximum theoretical melting efficiency is 0.48 and in the case of the 3-dimensional flow maximum theoretical melting efficiency is 0.37 [15]. For GTAW melting efficiency is limited from 0.21 to 0.37 and for PAW from 0.03 to 0.25 while for FCAW, SAW and GMAW its range is from 0.33 to 0.5. This shows that consumable electrode welding processes has high melting efficiency.

2.7 Deposition rate

The deposition rate is a measure of how much metal can be deposited per unit time. Deposition rate and dilution are the two most important factors in a cladding application .Deposition rate significantly affected by the melting efficiency of the process. High deposition rates are obviously desired for economic reasons when surfacing large parts. Factors effecting deposition rate are discussed below. The deposition rate of the non-consumable electrode arc processes is affected by the current, filler metal feed rate, voltage polarity and cross sectional area. The melting power supplied by the process will be absorbed by the substrate and the filler metal. The filler metal feed rate should be optimized to provide the highest deposition rate and lowest dilution obtainable for a given level of melting power delivered by the process. In consumable electrode arc processes, the deposition rate depends on the current, the electrode extension, voltage polarity and the electrode diameter. In this case, these three variables should be optimized to provide the highest deposition rates without adversely affecting dilution [16]. Deposition rate is major affected by the wire feed rate while welding voltage, welding speed and CTWD has very less effect on the deposition rate [2].

2.8 Fusion rate

It is the rate at which consumable electrode or feeler metal melt during cladding process. It is generally expressed in kg/hour. Fusion rate can be calculated easily with the help of feed rate. Fusion rate is approximate is equal to the feed rate. Fusion rate depends on the process parameters, which are welding voltage, welding current, contact tip to work piece distance (CTWD) and current polarity [26].

2.9 Process yield

Process yield of any process is defined the ratio of deposition rate to the fusion rate. It is generally expressed in the percentage [2]. It is very important factor for the selection of the cladding process from the point of view of the productivity.

2.10 Contact angle

Contact angle is the angle between the tangent to the profile of weld bead and the surface of the base metal as shown in the fig-2. It is very significant deciding factor in the determination of the amount of overlap required in the multi pass cladding process and affects the final surface appearance of the cladded component. It is strongly influenced by the process parameters, which are welding voltage, welding current, wire or rod feed rate, welding speed, contact tip to work piece distance (CTWD) and gun angle. These process variables exist in all fusion cladding processes and have approximate same type of affect on the contact angle in all type of cladding processes.

Contact angle increases with the increase in welding speed. While it first increases and then decreases with the increase in welding voltage and wire feed rate after achieving a certain maximum value. Value of contact angle is maximum at 90 degree nozzle angle and then it decreases with the increase or decrease of the nozzle or gun angle. CTWD has no any significant effect on the contact angle [11, 20].

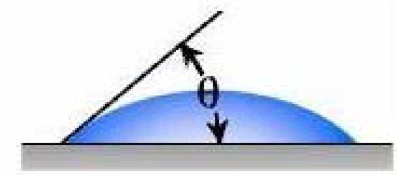

Fig. 2: Contact angle.

2.11 Flux

This factor is considered as the one of the most influential factors by many researchers that affect the slag formation and surface appearance of the cladding in the SAW, FCAW and ESW cladding processes. Kanjilal et.al. [21] shows that flux mixture related variables based on individual flux ingredients and welding parameters have individual as well as interaction effects on responses, viz. weld metal chemical composition and mechanical properties. While this factor is absent in the GMAW, GTAW and the PAW cladding processes. Bang et.al. [22] ,investigated the effects of flux combination on the chemical composition, tensile strength, and impact toughness of the weld metal and interpreted in terms of element transfer between the slag and the weld metal. Physico-chemical properties of fluxes include surface tension, viscosity, heat capacity, thermal coefficients of expansion, grain size etc. These properties of fluxes primarily affect the flux behaviour, bead shape and size, welding speed, current carrying capacity, protection of molten metal, arc stability, slag detachability, capillarity, surface tension and viscosity. Various constituents of a welding flux have major influence on the performance of welding processes and weld bead dimensions. The influence of specific flux additions on arc stability, viscosity, capillarity, slag detachability and weld bead shape need to be better characterized. It can be inferred that we cannot obtain the weld of desired geometry and composition until we consider the physico-chemical characteristics of flux. So, while designing the flux or during selection of welding process parameters the above characteristics should be carefully controlled or selected [23].

2.12 Initial preparation required

Different study determined that initial preparation required is also one of the critical factors that affect the selection of the stainless steel cladding process. Initial preparation consist setting welding parameters (voltage, current, wire or rod feed rate, welding speed, contact tip to work piece distance (CTWD),gas flow rate and gun angle), electrode / filler metal preparation and cleaning of the base metal etc.[24]

2.13. Availability of the Consumables

The researchers observed that availability of the type of consumable affect the selection of cladding process. Because it directly affects the deposition rates as well as process yield and cost of processing. Various type of availability of consumables is electrodes, filler wires, filler rods, powders, fluxes and shielding gas [18].

2.14 Welder skill requirement

This factor directly affects the production as well as the quality of the cladding. This consist fully skilled welder, semi skilled welder and ordinary welder. Fully skilled welder is required generally for the GTAW cladding process. While GMAW, FCAW, PAW, ESW and SAW cladding can be done using semi skilled and ordinary welder because of the highly automation possibility in these processes [17].

2.15 Post welds cleaning

This factor directly affects the production time and the cost of the component. It includes slag and spatter removal. FCAW, ESW and SAW processes requires the removal of the slag and spatter while GTAW, GWAW and PAW cladding process has no any slag formation and has negligible spatter. Welding, almost inevitably, results in some weld zone heat tint. This thickened oxide can limit the corrosion performance if it is not correctly removed and treated. Carbon steel, for example, can contaminate the surface of the stainless steel during the fabrication cycle. There are various sources of contamination of this type, contact with tooling and scaffolding poles for example. If the contamination is not cleaned off, rusty stainless steel can occur. Stainless steel cannot rust, per se; it is the carbon steel contamination that is forming the characteristic red rust. However, this rust should be efficiently removed as it is certainly unsightly and it may lead to premature corrosion failure of the stainless steel [31].

2.16 Ease of automation

Different study determined that ease of automation required is also one of the critical factors that affect the selection of the stainless steel cladding process. This factor directly affects the cost of the equipment for the cladding process and the production time and precision of the cladding process. Different type of processes may be manual, semi-automatic and fully automatic. Number of researchers considered this factor as the advantages of different cladding process [27, 28, 29, 30].

2.17 Position welding capability

It is also an important factor for the selection of welding process [25] and that must also be considered for the selection of the cladding process among the different processes. Different welding potions are horizontal welding, vertical welding, over head welding and root pass welding. SAW cladding process is only suitable for the horizontal position while ESW cladding process is suitable only for vertical position, while GTAW is suitable for all positions of the cladding process [26].

3. CONCLUSION

The main objective of this paper is to highlight the main factors that help in the selection of stain less steel cladding process. The industry willing to purchase cladding process equipment may have a look over these factors. It will also be helpful in academic as well. From this paper, it is seen that dilution and the bead geometry are most important factors in the selection of cladding process.

REFERENCES

[1] N. Murugan and R.S. Parmar, “Stainless steel cladding deposited by automatic gas metal arc welding,” Welding journal, vol. 76, pp. 391-403, 1997.

[2] J.H.F. Gomes, S.C. Costa, A.P. Paiva, and P.P. Balestrassi, “Mathematical modelling of weld bead geometry, quality and productivity for stain less steel cladding deposited by FCAW,” Journal of materials engineering and performance, vol. 21(9), pp. 1862-1872, September 2012.

[3] Welding, brazing, and soldering, ASM Handbook, USA, vol. 6, 1993.

[4] P.K. Palani and N. Murugan, “Optimization of Weld Bead Geometry for Stainless Steel Claddings Deposited by FCAW,” Journal of material processing technology, vol. 190, pp. 291-299, 2007.

[5] S. Rajasekaran, “Surface topography of pulsed current gas metal arc clads,” Surface engineering, vol. 16(6), pp 495-500, 2000.

[6] K. Marimuthu, N. Murugan, “Prediction and optimization of weld bead geometry of PTA hardfaced valve seat rings,” Surf Engineering vol. 19, pp. 143–149, 2003.

[7] T. Kannan and N. Murugan, “Effect of flux cored arc welding process parameters on duplex stainless steel clad quality,” Journal of materials processing technology, vol. 176(2006), pp. 230-239, March 2006.

[8] A.S. Shahi and Sunil Pandey, “Modelling of the effects of welding conditions on dilution of stainless steel claddings produced by gas metal arc welding procedures,” journal of materials production technology, vol. 196(2008), pp. 339-344, May 2007.

[9] Welding hand book, vol. 2, 7th Edition, AWS, 1980.

[10] P.K. Palani and N. Murugan, “Development of mathematical models for prediction of weld bead geometry in cladding by flux cored arc welding,” international journal of advance manufacturing technology, vol. 30, pp. 669-676, March 2006.

[11] B. Senthilkumar and T. Kannan, “Effect of flux cored arc welding process parameters on bead geometry in super duplex stainless steel claddings,” Journal of measurement, vol. 62(2015), pp. 127–136, November 2015.

[12] P.W. Fuerschbach and G.A. Knorovsky, “A study of melting efficiency in plasma arc and gas tungsten arc welding,” Welding Journal, vol. 70(11), pp. 287-297, 1991

[13] H.B. Smartt, A. Stewart and C.J. Einerson, “Heat transfer in gas tungsten arc Welding Process,” Welding Congress, ASM 8511-011, 1985.

[14] A.D. Watkins, H.B. Smartt and C.J. Einerson, “Heat transfer in gas metal arc welding process,” Recent Trends in Welding Science and technology, S.A. David and J.M. Vitek, pp. 19-23, 1990.

[15] N. Christensen, V.L. Davies and K. Gjermundsen, “Distribution of temperatures in arc welding,” British Welding Journal, vol. 12(2), pp 54-75, 1965.

[16] A. Lesnewich, “Control of melting rate and metal transfer in gas-shielded metal arc welding- part I,” Welding Journal, vol. 67 (9), pp. 343-353. 1958.

[17] V. Ravisankar, V. Balasubramanian and C. Muralidharan, “Selection of welding process to fabricate butt joints of high strength aluminium alloys using analytic hierarchic process,” Journal of materials and design, vol. 27(2006), pp. 373-380, January 2005.

[18] V. Balasubramanian, R. Varahamoorthy, C.S. Ramachandran and C. Muralidharan, “Selection of welding process for hardfacing on carbon steels based on quantitative and qualitative factors,” International journal of manufacturing and technology, vol. 40(2009), pp. 887-897, February 2008.

[19] T. Kannan & J. Yoganandh, “Effect of process parameters on clad bead geometry and its shape relationships of stainless steel claddings deposited by GMAW,” Int J Adv Manuf Technol, vol.47(2010), pp. 1083–1095, 2010.

[20] M. Nouri, A. Abdollah-zadeh and F. Malek, “Effect of welding parameters on dilution and weld bead geometry in cladding”, Journal of material science and technology, vol. 23(6), pp. 817-822, 2007.

[21] P. Kanjilal, T.K. Pal and S.K. Majumdar, “Combined effect of flux and welding parameters on chemical composition and mechanical properties of submerged arc weld metal”, Journal of Materials Processing Technology, Vol. 171(2),pp. 223–231, Jan 2006.

[22] Kook-soo Bang, Chan Park, Hong-chul Jung and Jong-bong Lee , “Effects of flux composition on the element transfer and mechanical properties of weld metal in submerged arc welding”, Metals and Materials International, vol. 15(3), pp. 471-477, 2009.

[23] B. Singh, Z. A. Khan and A. N. Siddiquee, “Review on effect of flux composition on its behavior and bead geometry in submerged arc welding (SAW)”, Journal of Mechanical Engineering Research, Vol. 5(7), pp.123 -127, October 2013

[24] Dr. R. S. Parmar, Welding processes and technology, Advani-oerlikon limited, 1988.

[25] S. M. Mirhedayatian, S. E. Vahdat, M. J. Jelodar, and R. F. Saen, “Welding process selection for repairing nodular cast iron engine block by integrated fuzzy data envelopment analysis and TOPSIS approaches”, Materials and Design, vol. 43 (2013), pp. 272–282, 2013.

[26] R. S. Parmar, “Welding Engineering and Technology”, Khanna Publishers, 2010.

[27] P. Sreeraj, T. Kannan and Subhasismaji, “Sensitivity analysis of process parameters in cladding of stainless steel by GMAW”, Machine Design, vol. 5(2013), pp. 1-10, 2013.

[28] De-Xing Peng, “Optimization of Welding Parameters on Wear Performance of Cladded Layer with TiC Ceramic via a Taguchi Approach”, Tribology Transactions, vol. 55, pp. 122-129, 2012.

[29] T. Kannan and N. Murugan, “Effect of flux cored arc welding process parameters on duplex stainless steel clad quality”, Journal of Materials Processing Technology, vol. 176, pp. 230–239, 2006.

[30] L. Juffus, “Welding Principles and Applications”, fourth ed., Delmar Publishers, New York, 1999.

[31] Welding and Post Fabrication Cleaning for Construction and Architectural Applications By Chris Baxter Group Technical Market Support Avesta Polarit Ltd, Sheffield, UK.