iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: IV Month of publication: April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4520

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

A Review on Cladding Process to Improve Metal Properties

Kaushik sharma[1], Shailendra deva[2], Ravindra kumar[3,]
[1]PG Scholer [2, 3]Associate professor, Department of Mechanical Engg. SRMSCET, Bareilly

Abstract: Cladding on a surface may refer two main functions; one is to improve surface dependent properties like resistance to wear under abrasion, erosion and corrosion, and the other is to enhance the bulk dependent properties like hardness, strength, etc. that is known as hard facing. Clad components are expected to have capabilities of serving its specific function in a hostile environment for a sufficiently long time economically. For this, there is increasing demand of clad components in various industries like chemical, naval, mining, agriculture, power generation, etc. On the other hand, tool manufacturers use cladding techniques more and more in producing tools like rollers, dies, jaws, etc. which should possess high hardness and large compressive strength. Cladding through welding is one popular and versatile method. In this paper, various methods, especially, different welding techniques, used for depositing a layer to cover a surface, and in particular, cladding, are discussed mentioning their applications. Various characteristics of clad components are reviewed with reference to parametric optimization, microstructure and corrosion resistance properties.
Keywords: Cladding, Welding, Microstructure, Corrosion resistance.

I. INTRODUCTION

Materials which survive under severe condition for long are adopted in industries either as bulk structural materials that are much costly, or to cover some low grade cheap materials to improve their service life [1]. Different methods used to serve the purpose economically are coating, plating, buttering, cladding, metal spraying, etc. The use of coating in a modern manufacturing industry is continuously increasing to improve product performance. Coatings are used in electrical/electronic appliances, anti-corrosion and numerous wear resistant components, etc. Deposition of thin layers in the order of few microns is known to be surface coating [2]. One such application is to coat a cutting tool that may have a thickness ranging from 2 to 15 µm deposited and bonded to the tool substrate. Aim of this coating is to generate a layer with quite high hardness and low friction to achieve good wear resistance by reducing adhesion and sticking [3]. Sprayed coatings are normally applied to a thickness of 75 to 180 µm to provide adequate corrosion resistance [4].

Plating is another popular metal deposition method by means of electrolysis. This process is mainly limited to electrically conductive materials. Main aim of plating is to enhance corrosion and/or erosion resistance properties as well as strength of the parent material [5]. Chromium and nickel plating are commonly used in plastic injection moulds made of steel, etc. Plating may help preventing seizure and galling, reducing friction, increasing surface hardness and suppressing corrosion of the substrate [6].

Another surfacing process is buttering in which a layer is formed on the substrate surface to facilitate proper bonding of weld overlay. In absence of buttering, bonding between these base materials usually becomes quite poor, or even, may not be feasible. The composition of buttering layer is different from weld metal and parent metal. In case of mild steel (AISI 1020) and stainless steel (304L) joining, one buttering paste made of nickel powder, ferro-vanadium and ferro-titanium powders were deposited [7] onto the joining surfaces of both materials in an investigation. Then GTAW was done. Subsequent layers were deposited on joining buttered surfaces by means of SMAW using Inconel 182 consumables. Unlike coating, in cladding, material of several millimeters is deposited [8] on a corrosion-prone material for protecting it from corrosion and/or imparting high strength on the surface to increase service life of the parent material. Cladding does not change the microstructure of the base material [9] as this process creates a new surface layer with a different composition than that of base material. In general, cladding layer is harder than the base material. Compared with other techniques used for surface treatment by means of material deposition, cladding has some distinct advantages. It provides high hardness, corrosion and/or erosion resistance, good bonding and favourable microstructure [10, 11].

When cladding is used to improve hardness of the surface of a component, it is called hardfacing. In case of alloy steel, cladding on low carbon steel by means of welding, heat input plays a significant role for achieving higher hardness of the surface [12]. Basically weld cladding is permanent joining of two dissimilar ferrous or non-ferrous metallic materials in which one is known as substrate and the other is clad material deposited through coalescence formation. Different aspects are to be considered while undertaking weld cladding without any defect [13]. One major difficulty is the possibility of formation of cracks caused by dissimilar contraction

©IJRASET (UGC Approved Journal): All Rights are Reserved

of cladding materials as well as the substrate [1, 14]. To overcome this problem, different crack prone elements could be eliminated from the electrode, and multilayer deposit along with the provision of buffer layer was tried [1] to reduce the possibility of formation of crack. Use of tubular electrode and suitable preheating were also done to help prevent crack propagation [14]. For successful dissimilar metal joining between carbon steel and stainless steel, fatigue crack growth behaviour was explored in another work [15]. Thermal spraying is another technique of placing initial coating onto substrate. This method was used to improve properties of thermally sprayed metals, alloys, composites, and ceramics applied as biomedical coatings, thermal barrier coatings, wear resistant coatings, corrosion resistant coatings, and wear resistant coatings engraved with laser beams [16, 17]. The present paper contains an overview on different cladding processes, and weld cladding particular. The area of applications of cladding is mentioned. Weld cladding processes are discussed with regard to microstructure and their corrosion resistance properties.

II. METHODS OF CLADDING AND APPLICATION AREAS

Cladding can be done by several processes like rolling, strip cladding, different types of welding, viz. electric resistance welding [18], shielded metal arc welding (SMAW), submerge arc welding (SAW) [19], overlay welding, electroslag welding (ESW), gas tungsten arc welding (GTAW) [20], flux cored arc welding (FCAW) [21], gas metal arc welding (GMAW), laser beam welding (LBW), oxyacetylene welding process, powder welding by laser [11], pulsed gas metal arc welding process (GMAW-P), tubular core covered electrodes, plasma process (Hot-wire), submerged arc welding process (SAW) (submerged arc strip cladding and strip ESW surfacing), electroslag cladding, friction cladding, laser engineering net shaping (LENS), etc. Cladding by explosive welding uses an explosive detonation as the energy source to produce a bond between metal components. It can be used to join virtually any metal combination, that are metallurgically compatible or that are known as non-weldable by conventional processes.

In recent years, weld cladding processes are being applied widely in numerous industries such as chemical, and fertilizer plants, aviation, mining, agriculture, power generation, food processing, etc. as a cost effective engineering solution. These are used to deposit a surface protective layer on corrosion-prone low carbon or low alloy steel against corrosive environment [9, 22]. Weld overlay cladding techniques were originally developed at Strachan & Henshaw, Bristol for applying on Defense (Navy) components subjected to extreme pressure and shock loading. These clad components come in contact with sea water, but needed less maintenance. Cladding techniques were employed in sub-sea components [23] for making outer layer to be corrosion resistant against corrosive saltwater solution. A number of parts of the submarine pressure hull were clad with Inconel 625 [24]. Pressure vessels used in power plants were reportedly clad to provide anti-corrosive as well as strong surface layer to survive severe working conditions at elevated temperature. Residual stresses developed in clad pressure vessels were evaluated, and these data were used in its designing process [25]. Cladding was also tried to provide for enhanced performance of components in service, or to repair worn or corroded components [26]. Another new popular technique, namely, laser direct metal deposition (LDMD) is an additive technique based upon the mechanism of fusing metallic powders delivered by either a lateral or coaxial nozzle to a base metal or substrate to build three-dimensional objects directly from a computer aided design (CAD) model. Applications of the laser direct metal deposition process have been found in the aerospace and automotive industries for repair and tooling [27].

III. CLADDING BY WELDING

Cladding can be done by various ways; among them welding is an effective and popular process applied for cladding. Various welding methods, namely, resistance welding, different arc welding processes like GMAW, SMAW, GTAW, etc., electro-slag welding, different types of non-traditional welding, like plasma arc welding, laser welding, as well as different hybrid welding processes are applied [29] to make clad parts successfully. Among different welding procedures, arc welding is mostly employed for cladding in practice. However, some welding processes other than arc welding are also applied. Resistance welding is one such relatively uncommon process utilized for cladding. In one application of resistance welding, 1mm thick wear resistant clad layer of composite metal powder of 110~160 μm sized STL-1 (Co-Cr alloy) and 100 μm sized MBF-15 (Ni based brazing alloy) were applied to clad 1.9 mm thick mild steel plate [28] to possess enhanced wear resistance. In submerged arc welding, surfacing (i.e. cladding) was performed by using strip electrodes [27, 30], when multilayer vessels could be fabricated by cladding with gas shielded welding processes [31]. Another process called plasma transferred arc welding was used to produce strong cladding of stainless steel over carbon steel with low dilution by selecting proper parameters [32]. In electroslag cladding with strip electrodes, high deposition rate and low dilution made the process cost-effective for marine applications [33]. GTAW was found to be an effective cladding procedure for stainless steel. By controlling process parameters within proper limit, quality clad layer could be achieved [34]. In cladding operations, weld beads of nickel-based alloys were deposited on a base plate of carbon or mild steel by the application of hot wire TIG technology employed by Babcock & Wilcox [35]. The quality of the weld can be further enhanced

©IJRASET (UGC Approved Journal): All Rights are Reserved

by controlling process parameters. In an experimental work, clad layer of duplex stainless steel done [36] on low alloy steel by GMAW process was investigated. It was observed that weld bead geometry was greatly influenced by heat input. Linear relationships were established among heat input and weld bead geometry parameters like width, height, penetration, etc. by regression analysis which was found to match with real data. In a special type of laser cladding, metal powder was used on cladding material in which specially designed nozzles offered the possibility of forming and guiding powders into a precise jet or beam, analogous to wires used in traditional thermal spraying [37]. Laser cladding using powder could be performed in two distinct ways. In the first process, powder was pasted on the surface by some adhesive and then the clad was formed by laser beam. In the second process, powder was pneumatically fed into the melt pool on a substrate surface so that powder jet and laser beam were focused on the same area and the clad was formed on the surface; the second process was named ‘blown powder method. Laser coating, an overlay deposition process, was applied on the surface of the base material through melting the coating material in the form of a powder or wire. Among different techniques, laser cladding was reported to provide low dilution and low heat input to the component [38]. Recently different hybrid welding processes like CO2-Laser GMAW were employed to control droplet transfer mode by selecting proper range of parameters to get quality cladding [39].

IV. CLADDING MICROSTRUCTURE

Clad part exhibits various properties which are much dependent on their microstructure. Various phases are formed due to high heat input, cooling pattern and various alloying elements present in the filler as well as in the substrate. Particular phase and alloying elements present are responsible for the mechanical properties and corrosion resistance against a particular corrosive environment. Cladding being basically a dissimilar welding, mixing of elements in two different materials is happening in coalescence or bead region. This also causes different properties at the bead from the substrate and filler metal. The effect of chromium was explored [40] in a SMAW cladding. Chromium was seen to impair impact toughness, although it promoted increase in the percentage of acicular ferrite (AF). In addition, it was observed that an increase in carbon content promoted further decrease in impact toughness due to the higher volume fraction of the (Mertensite/Austenite) constituent. Some coating containing typical elements increased wear resistance property significantly. In a work, plasma transferred boride coating on 1082 steel increased wear resistance by four orders to that of steel substrate [41]. The same type of coating on the same substrate was done by SMAW also [42]. Gas tungsten arc welding was used to overlay with a Ti-Ni cladding onto the SUS 304 and AISI 1045 steel substrates. By examining the microstructure and composition of overlays, it was observed that due to mixing of materials within weld bead and rapid solidification during cladding, overlays showed a feature of dendrites surrounded by various precipitates. The hardness of overlay was found to be higher than that of Ti-Ni intermetallic filler wire by about three times. This produced high hardness and cavitation-erosion resistance of overlay. This significantly increased cavitation-erosion resistance of the steel substrate in a corrosive atmosphere containing 3.5 wt% NaCl solution [43]. Welding process itself is one of the major factors that influences a lot in achieving desired microstructure. Stainless steel overlay was made [44] on low carbon steel using three different processes, viz. TIG, high current pulsed arc and constricted plasma arc to compare their effectiveness. For GTAW arc cladding, using filler metal only beyond 3.2 mm diameter, the clad layer became stainless steel with less than 50% dilution. For pulsed arc cladding, the complete stainless steel microstructure demanded a large diameter filler metal at a pulse frequency of 500 Hz. However, the plasma arc cladding could be achieved in such a way that the conversion into stainless steel on the mild steel surface occurred with the microstructure of cellular austenite in clad layer and cellular dendritic austenite containing phase in fusion boundary region. It was observed that for the formation of stainless steel microstructure, layer on the mild steel could be yielded by using large diameter filler metal, giving below 50% dilution through localized and constricted arc [45]. During an investigation, multi-pass cladding using SMAW was carried out by nitrogen alloyed martensitic steel on continuous casting roll for increasing wear resistance properties. Formation of carbides was reported to be difficult to prevent, particularly in the inter-bead and reheated zones. After welding, the martensite should be tempered for additional carbide precipitation. The precipitation of chromium-rich carbides may cause chromium depletion in the surrounding matrix. This phenomenon is known as sensitization. The sensitized region exhibited reduced corrosion resistance and high susceptibility to nucleation of pit and the initiation of stress corrosion cracks while in service . In stainless steel clad carbon steels, microstructure changed as a result of diffusion of carbon and other elements at the interface depending on the temperature values reached during the production process. In such a carbon steel, ASTM A 515 Gr. 60 was cladded by hot rolling with AISI 304L steel [46]. Bonding at the interface between base material and stainless steel cladding material, obtained by hot rolling, in similar in experiments was characterised by large amount of inter-diffusion of carbon towards the austenitic side and substitutional elements towards the ferritic side. This microstructure was found to depend on rolling parameters, heat treatment and cooling rates. A narrow band of cladding line, parallel to the original interface, followed the ferritic

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

grain profiles, and separated the base metal from the austenitic layer. The stainless steel region was far from the cladding line with microstructure characterized by recrystallized equiaxed austenitic grains free from carbide precipitation. Clad layer characteristics of duplex stainless steel on low alloy steel by GMAW was investigated in another work [47]. The clad layer was found to have good corrosion resistance property. It possessed better low-temperature impact strength. It was observed that concentration of nitrogen in weld deposit had been influenced by heat input and shielding gas mixture, and these exerted great effect on microstructure, low temperature toughness and resistance to pitting corrosion [48].

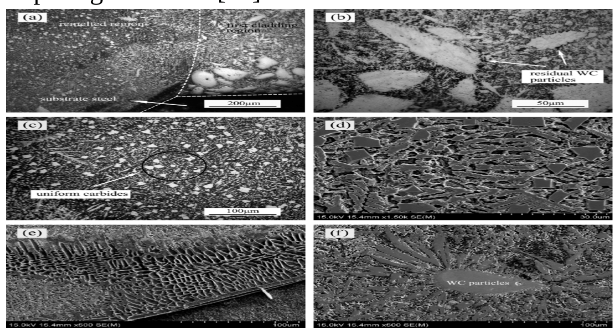


Fig:-1 Microstructure of cladding layer

V. CORROSION RESISTANCE PROPERTIES BY CLADDING

Cladding layer, or The overlay, aims at protecting a corrosion-prone cheap substrate against severe atmosphere. Clad material needs to have corrosion resistance property to enhance the service life of a component, and usually these clad materials are found to be costly. Butt joints involving 2205 duplex and 316L austenitic stainless steels were done using submerged arc welding. 15 mm thick plates were welded with dulex stainless steel electrode with heat input in the range of 1.15-3.2 kJ/mm. It was shown that the place where stress corrosion cracking mostly occured was at the heat affected zone at duplex stainless steel side of weld joints. This phenomenon was reportedly due to formation of large number of coarse ferrite grains and acicular austenite precipitates at that zone. High heat input did not deteriorate stress corrosion cracking resistance of welds [49].

It was observed that laser powder cladding of L316 austenite stainless steel powder on carbon steel substrate showed similar anti-corrosion characteristics with the conventional weld clad specimens using the same compositions of substrate and cladding [50]. Cladding with austenite steel on low alloy steel by GMAW process was investigated in a work. Enhanced property of resistance to pitting corrosion was mostly revealed [51]. GMAW cladding by duplex stainless steel greatly enhanced the corrosion resistance property. In one experiment, the influence of heat input on corrosion resistance was investigated. Heat input is the function of welding current, welding current (directly proportional) and weld travel speed (inversely proportional). It has been observed that welding current and welding travel speed mostly influence heat input, and so also the corrosion resistance property [52].
The contributions of pure mechanical erosion, electrochemical corrosion of grey cast iron, copperbased alloys and stainless steels were determined in a consive atmosphere of distilled water and 3.5% NaCl solution at 23°C. The effect of corrosion on the overall cavitation erosion–corrosion ccurred mostly in grey cast iron and mild steel, and grey cast iron, and negligible in stainless steels. Stainless steels were undergone pure mechanical erosion in 3.5% NaCl solution in the presence of cavitation in consequence of hostile condition for the growth of pit. [53]. In short, it can be stated that considerable improvement in service life of a component can be obtained as was observed in different investigations, through depositing a surface clad layer on to the substrate surface.

VI. CONCLUSION AND FUTURE WORK

From the above discussion, it is understood that several techniques have been developed for producing a clad layer on low grade steels. Different welding processes, such as GMAW, GTAW, SMAW, LBW, etc. and some hybrid (combination of two welding processes) welding processes, like CO2 -laser-GMAW, LMDT, etc. have been employed to yield quality weld cladding to be used in a wide spectra in various sector industries for enhancing mechanical properties like hardness, cold-toughness, etc. as well as corrosion resistance. Mechanical properties of clad part could be improved by providing proper heat input. Heat input is set by controlling by controlling welding current, welding voltage and weld travel speed. On attaining desired microstructure of clad part, mechanical properties as well as anti-corrosion properties under different reactive environment could be improved significantly. Some new developments regarding weld cladding techniques, their areas of application, microstructures obtained and corrosion resistance properties in clad components are also discussed in this paper.

©IJRASET (UGC Approved Journal): All Rights are Reserved

REFERENCES

[1] Bhanu Kiran, V.T., Krishna, M., Praveen, M. and Pattar, N., Numerical Simulation of Multilayer Hardfacing on Low Carbon Steel, International Journal of Engineering and Technology, Vol.3, No.1, pp.53-63, 2011

[2] Groover, M.P., Fundamentals of Modern Manufacturing Materials, Processes and Systems, Wiley Publication Ltd., New Delhi, pp.660-684, 2012

[3] de Lacalle, L.N.L., Lamikiz, A., de Larrinoa, J.F. and Azkona, I., Advanced Cutting Tools, Chapter 2, http://www.springer.com/cda/content/.../cda.../9781849964494-c1.pdf, accessed on February 02 2014

[4] Dennis, J.K. and Such, T.E., Nickel and Chromium Plating, Woodhead Publishing Ltd. And ASM International, Cambridge, England, 1993

[5] ASM Handbook, Corrosion, Environments and Industries, Vol.13C, ASM International, p.76, 2006

[6] Metal Coating Processes, Manufacturing Process II, Unit 4, http://www.ignou.ac.in/upload/ Unit-4.pdf, accessed on February 02 2014

[7] Rathod, D., Choudhary, H. and Pandey, S., Microstructure and Weldability Evaluation of Dissimailar Metal Joint Using Paste Technique for Buttering Layers, Proceedings of the National Conference on Trends and Advances in Mechanical Engineering, Faridabad, India, pp.584-589, 2012.

[8] Nadkarni, S.V., Modern Arc Welding Technology, Oxford & IHB Publishing Co. Pvt. Ltd., New Delhi, pp.615-616, 1988

[9] Saha, M.K., Mondal, A., Hazra, R. and Das, S., An Overview on Cladding through Gas Metal Arc Welding, Proceedings of the National Welding Seminar, Jamshedpur, India, 2015

[10] Schneider, M., Laser Cladding with Powder, Ph.D. Thesis Submitted to University of Twente, Enschede, Netherlands, 1998

[11] Khanna, O.P., A Textbook of Welding Technology, Dhanpat Rai and Sons Publications, New Delhi, 1994

[12] Gualco, A., Svoboda, H.G., Surian, E.S. and de Vedia, L.A., Effect of Welding Procedure on Wear Behaviour of a Modified Martensitic Tool Steel Hardfacing Deposit, Materials & Design, Vol.31, No.9, pp.4165–4173, 2010

[13] Dupont, J.N. and Kusko, C.S., Martensite Formation in Austenitic/Ferritic Dissimilar Alloy Welds, Welding Journal, Vol.1, pp.51-54, 2007

[14] Bhanu Kiran, V.T., Krishna, M., Natraj, J.R. and Kumar, S., Development and Characterization of a Electrode Deposition Procedure for Crack-Free Hardfacing of Low Carbon Steel, International Journal of Engineering and Technology, Vol.4, No.1, pp.95-106, 2012

[15] Krishnaprasad, K. and Prakash, R.V., Fatigue Crack Growth Behavior in Dissimilar Metal Weldment of Stainless Steel and Carbon Steel, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, Vol.3, No.8, 1016-1022, 2009.

[16] Pawlowski, L., Thick Laser Coatings: A Review, Journal of Thermal Spray Technology, Vol.8, No.2, pp.279-295, 1999

[17] Vilar, R., Laser Alloying and Laser Cladding, Material Science Forum, Vol.301, pp.229-252, 1999.

[18] Lee, J.W., Nishio, K., Katoh, M., Yamaguchi, T. and Mishima, K., The Performance of Wear Resistance Cladding Layer on a Mild Steel Plate by Electric Resistance Welding, Welding in the World, Vol.49, No.9/10, pp.94-101, 2005.

[19] Pandey, S., Development of Advanced Gas Metal Arc Welding Process, Proceedings of the Workshop on Welding Technologies, Chandigarh, India, 1999.

[20] Chen, H., Chen, P.N., Hua, P.H., Chen, M.C., Chang, Y.Y. and Wu, W., Microstructure and Abrasive Wear Properties of Fe-Cr-C Hardfacing Alloy Cladding Manufactured by Gas Tungsten Arc Welding (GTAW), Journal of Metals and Materials International, Vol.19, No.1, pp.93-98, 200

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

[22] Venkateswara, N.R., Madhusudan Rao, G. and Nagarjuna, D.D., Weld Overlay Cladding of High Strength Low Alloy Steel with Austenitic Stainless Steel– Structure and Properties, Materials & Design, Vol.32, No.4, pp.2496-2506, 2011

[23] Berridge, D.R., Corrosion-Resistant Alloy Cladding of Subsea Components, Proceedings of the Offshore Technology Conference, Houston, Texas, USA, 2011

[24] Smith, L., Engineering with Clad Steel, Nickel Institute Technical Series, http:// w w w . n i c k e l i n s t i t u t e . o r g / ~ / M e d i a / F i l e s / T e c h n i c a l L i t e r a t u r e / 10064_EngineeringWithCladSteel2ndEd.pdf, accessed on November 16 2015

[25] Dupas, P. and Moinereau, D., Evaluation of Cladding Residual Stresses in Clad Blocks by Measurements and Numerical Simulations, Journal de Physique IV, Vol.6, pp.187-196, 1996

[26] Shah, K., Pinkerton, A.J., Salman, A. and Li, L., Effects of Melt Pool Variables and Process Parameters in Laser Direct Metal Deposition of Aerospace Alloys, Materials and Manufacturing Processes, Vol.25, pp.1372–1380, 2010

[27] Lee, J.W., Nishio, K., Katoh, M., Yamaguchi, T. and Mishima, K., The Performance of Wear Resistance Cladding Layer on a Mild Steel Plate by Electric Resistance Welding, Welding in the World, Vol.49, No.9/10, pp.94-101, 2005

[28] Das, D. and Das, S., Developments in Weld Cladding, Reason- A Technical Magazine, Vol. X, pp.13-16, 2011

[29] Mallaya, U.D. and Srinivas, H.S., Effect of Magnetic Steering of the Arc on Clad Quality in Submerged Arc Strip Cladding, Welding Journal, Vol.72, pp.289s-293s, 1993

[30] Parmar, R.S., Welding Engineering and Technology, Khanna Publishers, New Delhi, 2010.

[31] Jayachandrana, J.A.R. and Murugan, N., Investigations on the Influence of Surfacing Process Parameters over Bead Properties during Stainless Steel Cladding, Materials and Manufacturing Processes, Vol.27, pp.69-77, 2012

[32] Oh, Y.K., Devletian, J.H. and Chen, S.J., Low-Dilution Electroslag Cladding for Shipbuilding, Welding Journal, Vol.79, pp.37-40, 1990Lee, S.H., Saito, Y., Park, K.T. and Shin, D.H., Microstructures and Mechanical Properties of Ultra Low Carbon it Steel Processed by Accumulative Roll Bonding Process, Materials Transactions, Vol.43, pp.2320-2325, 2009

[33] Dupas, P. and Moinereau, D., Evaluation of Cladding Residual Stresses in Clad Blocks by Measurements and Numerical Simulations, Journal de Physique IV, Vol.6, pp.187-196, 1996.

[34] Mondal, A., Saha, M.K., Hazra R. and Das, S., Influence of Hat Input on Weld Bead Geometry Using Duplex Stainless Steel Wire Electrode on Low Alloy Steel Specimens, Cogent Engineering, Vol.3, pp.1-14, 2016

[35] Arnold, J. and Volz, V., Laser Power Technology for Cladding and Welding, Journal for Thermal Spray Technology, Vol.8, No.2, pp.243-248, 1999.

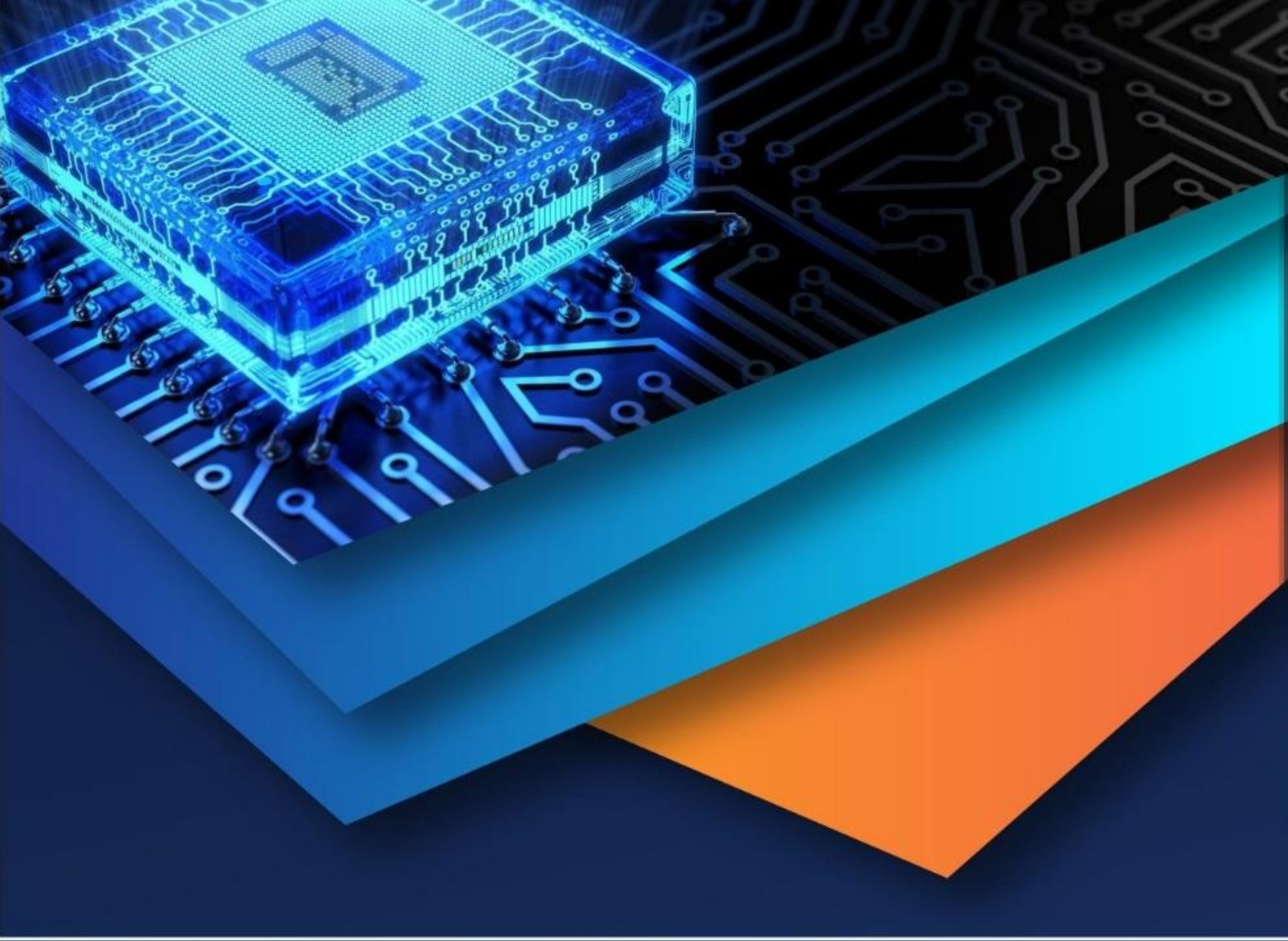
[36] de Oliveira, U., Oceli´k, V. and de Hosson, J.Th.M., Analysis of Coaxial Laser Cladding Processing Conditions, Surface & Coatings Technology, Vol.197, No.2-3, pp.127-136, 2005

[37] Chen, Y.B., Feng, J.C., Li, L.Q., Li, Y. and Chang, S., Effects of Welding Positions on Droplet Transfer in CO2 Laser–MAG Hybrid Welding, The International Journal of Advanced Manufacturing Technology, Vol.68, No.5-8, pp.1351-1359, 2013

©IJRASET (UGC Approved Journal): All Rights are Reserved

[38] Jorge, J.C.F., Souza, L.F.G. and Rebello, J.M.A., The Effect of Chromium on the Microstructure/ Toughness Relationship of C–Mn Weld Metal Deposits, Materials Characterization, Vol.47, No.3-4, pp.195-205, 2001
[39] Bourithis, L., Papaefthymiou, S. and Papadimitriou, G.D., Plasma Transferred Arc Boriding of Low a Carbon Steel: Microstructure and Wear Properties, Applied Surface Science, Vol.200, No.1-4, pp.203-218, 2002
[40] Eroglu, M., Boride Coatings on Steel Using Shielded Metal Arc Welding Electrode: Microstructure and Hardness, Surface & Coatings Technology, Vol.203, No.16, pp.2229- 2235, 2009
[41] Chen, J.M., He, J.L., Chen, K.C. and Chang, J.T., Gas Tungsten Arc Welding of Titanium Nickel Overlay on Carbon Steel and Stainless Steel for Cavitation Erosion Resistance, Key Engineering Materials, Vol.479, pp.81-89, 2011
[42] Ishida, T., Formation of Stainless Steel Layer on Mild Steel by Welding Arc Cladding, Journal of Material Science, Vol.26, No.23, pp.6431-6435, 1991
[43] Missori, S., Murdolo, F. and Sili, A., Microstructural Characterization of Stainless-Cladded Carbon Steel, Metallurgical Science and Technology, Vol.19, No.2, pp.21-24, 2001
[44] Chakrabarti, B., Das, S., Das, H. and Pal, T.K., Effect of Process Parameters on Clad Quality of Duplex Stainless Steel Using GMAW Process, Transactions of the Indian Institute of Metals, Vol.66, No.3, pp.221-230, 2013
[45] Kacar, R. and Acarer, M., An Investigation on the Explosive Cladding of 316L Stainless Steel- DIN-P355GH Steel, Journal of Materials Processing Technology, Vol.152, No.1, pp.91- 96, 2004
[46] Chen, J., Hsieh, C., Hua, P., Chang, C., Lin, C., Wu, P.T. and Wu, W., Microstructure and Abrasive Wear Properties of Fe-Cr-C Hardfacing Alloy Cladding Manufactured by Gas Tungsten Arc Welding (GTAW), Metals and Materials International, Vol.19, No.1, pp.93-98, 2013
[47] Metallurgical and Materials Transactions A, Vol.44, No.10, pp.4671-4699, 201
[48] Labanowski, J., Stress Corrosion Cracking Susceptibility of Dissimilar Stainless Steels Welded Joints, Journal of Achievements in Materials and Manufacturing Engineering, Vol.20, No.1- 2, pp.255-258, 2007
[49] Khara, B., Mondal, N.D., Sarkar, A. and Das, S., On Cladding Performance of Austenite Stainless Steel over Low Alloy Steel Plates Using Metal Arc Welding, Indian Welding Journal, Vol.49, No.1, pp.75-81, 2016
[50] Verma, A.K., Biswas, B.C., Roy, P., De, S., Saren, S. and Das, S., On the Effectiveness of Duplex Stainless Steel Cladding Deposited by Gas Metal Arc Welding, e-Proceedings of the International Conference of the International Institute of Welding, Seoul, Korea, 2014
[51] Kwok, C.T., Cheng, F.T. and Man, H.C., Synergistic Effect of Cavitation Erosion and Corrosion of Various Engineering Alloys in 3.5% NaCl Solution, Material Science Engineering: A, Vol.290, No.1-2, pp.145-154,100

©IJRASET (UGC Approved Journal): All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)