International Journal of Research in Engineering, Science and Management
Volume-1, Issue-10, October-2018
www.ijresm.com | ISSN (Online): 2581-5782

Nickel Chromium Overlay on SS410 by MIG Cladding Process

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***Abstract*—MIG cladding overlaid nickel chromium on low strength alloy SS410.The overlay cladding comprises a transition layer and corrosion resistant layer and wear resistant layer .Overlaying specimens of transition layer with different thickness were researched The mechanical properties of cladding were tested by micro hardness wear test and other methods .The result showed that the mechanical properties of specimen with Ni-Cr welding wire as cladding wire When the layer thickness is changed ,the performance of overlay cladding is essentially unchanged .The organization of overlay cladding in group of specimens are similar.**

***Index Terms*—Cladding, Cathode, Dual polarity**

I. Introduction

The change in polarity to operate at this ratio has been used in some situations, in spite of the inadequate properties of the arc and the metal transfer when the electrode is a cathode. Examples of applications have been found which enable the filling of joints lacking regularity in automated operations and control of the deposits geometry in coating welding. In these cases, the variation in polarity occurs at frequencies much lower than the frequency of the electricity distribution network. Therefore, the designation of dual-polarity direct current is more suitable than for cases in which the frequency is close to that of the distribution network. In these alternating current is more appropriate. For these frequencies, applications have involved the welding of aluminum and its alloys via the MIG/MAG process

II. Plasma Transferred Arc WELDING (PTAW) Process

A. Applications of PTAW process

PTAW has proved technical and commercial advantages in several avenues in industrial applications. They include the welding of stainless steel tubing and making circumferential joints on stainless steel pipes. Also, PTAW finds application in welding of titanium missile casing, 18% nickel maraging steel, Type 410 stainless steel and 4130 steel in aerospace applications (N. Murugan 2000) [2]. PTA cladding has been extensively used in applications like surfacing of valves in internal combustion engines, pump components and valve components in hydraulic machineries and reactors of nuclear industries. It is used for hard facing the worn out components and parts of earth movers, drilling equipment, impact hammers etc. (Dutra jc2009) [7]. Apart from these, PTA cladding plays a vital role in automotive, agricultural, plastics, manufacturing and cement industries in producing anti corrosion and wear resistant coatings called as claddings. Studies pertaining to the wear behavior of commonly used steel and the effects of surfacing materials overplayed on it were also reported (Ushio1999) [8].

B. Types of Stainless Steels

Stainless Steel comes in five main types. Ferritic stainless steels are generally the least expensive, but don't have as broad an application. Martensitic stainless steels can be hardened by quenching and tempering and are used mainly in cutlery, general engineering and aerospace. When hardened, they can become brittle, and so are not hardened all the way or are not used in general construction. Austenitic stainless steels are the most widely used and they are the most corrosion-resistant. Duplex stainless steels are a mixture of ferritic and austenitic to enhance strength and corrosion resistance. The final type is precipitation hardening stainless steels. They too can be strengthened by heat treatment. Stainless steel is generally more expensive than other building materials.

1) Austenitic Stainless Steels

The group of alloys which today make up the family of stainless steels had their beginning in 1913 in Sheffield, England. Harry Brearley was trying a number of alloy combinations with steel for making gun barrel and noticed that samples cut from one of these trial heats did not rust and were in fact difficult to etch. When he investigated this curious material, it contained about 13% chromium and this lead to the development of the stainless steels for which Sheffield became famous. Stainless steels are iron-based alloys containing a minimum of about 10.5% chromium and this forms a protective self-healing oxide film which has their characteristic "stainlessness" or corrosion resistance.

2) 'L' grade in stainless steels and their significance

The low carbon "L" grades are useful where welding or other high temperature exposure will occur. The low carbon is one way of delaying or preventing grain boundary carbide precipitation (often referred to as sensitization or weld decay) that can result in intergranular corrosion in many corrosive service environments. The low carbon content increases resistance to this problem. AISI 316 L stainless steel contains an addition of molybdenum that gives it improved corrosion resistance.

3) Sensitization in AISI 316 L stainless steels

One of the possible welding defects of austenitic stainless steels is sensitization. At the temperatures between 540 – 850 ºC the chromium carbides form along the austenite grains. This causes depletion of chromium from the grains resulting in decreasing the corrosion protective passive film. This effect is called sensitization. Sensitization is depressed in low carbon steels (0.03%) designated with suffix 'L' (304L, 316L). Formation of chromium carbides is also avoided in stabilized austenitic stainless steels (321, 347) containing carbide forming elements like titanium, niobium, tantalum, zirconium. Stabilization heat treatment of such steels results in preferred formation of carbides of the stabilizing elements instead of chromium carbides.

4) Applications of AISI 316 L stainless steels

The worldwide consumption of stainless steel is increasing. There is a growing demand from the building and construction industry where stainless steel is used for its attractive appearance, corrosion resistance, low maintenance and strength. Typical application includes food preparation equipment, boat fittings, architectural paneling and railings, chemical containers, heat exchangers and threaded fasteners, woven screens for mining, quarrying, water filtration, etc.

C. Clad Bead Geometry

The relationship between arc welding parameters and weld bead geometry is a complex phenomenon since a number of factors are involved in it. But it is essential to have this information for welding procedure development and for understanding the mechanism of weld bead formation. Bead geometry incorporating the penetration, reinforcement and bead width as shown in Fig 1 forms the valuable configuration of any weld bead.

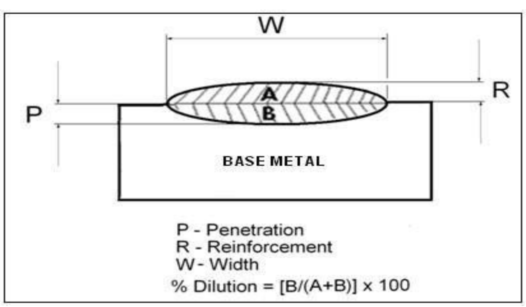

Fig. 1. Cross section of a typical clad bead

They found that pulsed current GMAW process was beneficial for cladding due to thicker deposition, lower dilution and depth of fusion, higher hardness of the cladding and lower hardness of the interface a model, which correlates depth of penetration and mass and heat transfer to the weld pool in GMAW. This model was used to predict the depth of weld pool for a range of welding process variables encompassing variations in voltage, current, travel speed, electrode size and rate of deposition of filler metal, arc length, and mode of mass transfer. They found that the theoretical depth of penetration was a suitable indicator of the measured depth of the weld pool for conditions of short arc transfer, streaming transfer, and transition from short arc to free flight transfer. The experiments were conducted based on four-factor, five-level central composite rotatable design with full replication technique and the mathematical models were developed using multiple regression method.

D. Dilution and Its Control

Dilution is the change in composition of a welding filler metal caused by the admixture of the base metal or previous weld metal in the weld deposit. It is measured by the percentage of base metal or previous weld metal in the weld bead. It will reduce the effectiveness of the surfacing process and reduces the corrosion, wear and high temperature resistance of the overlay. Stated that the dilution reduces the alloying elements and increases the carbon content in the clad layer which led to the decrease in corrosion resistance properties. The percentage of delta ferrite content was also reduced which mitigated other related metallurgical problems like corrosion, wear and high temperature resistance of the cladding .reported that greater the extent of dilution, lower the hardness of the resultant clad layer. The optimum degree of dilution was found to lie between 8% and 11% for maximum hardness. Stated that the weld bead cross sectional area increased with the increase in the welding current and arc voltage but it decreased with the increase in the welding speed and wire diameter. Reported that during SAW, the area of penetration increased rapidly as the welding speed increased for a given constant heat input but area of reinforcement had mixed trend. The nozzle to plate distance had a negative effect on all the bead parameters except bead width and total volume of the weld bead which influenced the weld dilution.

Weld dilution is an inter alloying phenomenon of a surfacing alloy with a base metal and is usually expressed as a percentage of the base metal in weld. Also, the microstructure of the coating depends on the composition of the welding powder and the welding procedure adopted like the preweld and post weld heat treatment that are used to develop the coating. The wear resistance and other desirable properties of coatings were degraded as dilution was increased. Many authors reported that using different electrodes and varying the welding procedure with the same electrode could affect the microstructure and properties of the deposits by varying their deposition chemistry reported that the effect of dilution in the Ni based hard facing alloys such as was greater than in the Co based stellites, which could be due to the difference in melting temperature range between the austenitic SS and the hard facing deposit being higher for Ni based alloys (1223-1338 K) than that of the stellite alloys (1553-1663 K).

E. Design of Experiments

A designed experiment is a test or series of tests in which purposeful changes are made to the input variables of a process or system so that the reasons for changes in the output response may be identified. Experimental design methods play an important role in process development and process trouble shooting to improve performance. The objective in many cases may be to develop a robust process, that is, a process being affected minimally by external sources of variability. The application of experimental design techniques early in process development could result in improved process yields, reduced variability and closer conformance to nominal or target requirements, reduced development time and overall. Experimental design based on sound statistical principles must give a thorough understanding of overall process using a limited number of experiments. Well-chosen experimental designs maximize the amount of "information" that can be obtained for a given amount of experimental effort.

F. Experimental Design

The experimental design is a powerful problem solving technique that assisted engineers for tackling process quality problems effectively and economically. There are many types of experimental designs classified according to the treatment of factor combinations and the degree of randomization of experiments. These designs are available to be used for different types of situations. Among the designs, central composite design is one of the response surface designs which can be used to explore a regression model to find a functional relationship between the response variable and the factors involved, and to find the optimal conditions of the factors. An experimental design is said to be rotatable if the variance of the predicted response y at some point x is a function only of the distance of the point from the design center and is not a function of direction (Medeiros et al 1989). Ratability is a very important property in the selection of a response surface design. Central composite design is rotatable and consists of a 2k factorial or fractional factorial (coded to the usual ±1 notation) augmented by 2k axial points

G. Response Surface Methodology

Response surface methodology (RSM) was formally developed in 1951 by Box and Wilson and their colleagues at the Imperial Chemical Industries in England. Their objective was to explore relationships such as those between the yield of a chemical process and a set of input variables presumed to influence the yield. Since the pioneering work of Box the RSM has been successfully used and applied in many diverse fields such as chemical engineering, industrial development and process improvement, agricultural and biological research, even computer simulation. Fitting and analyzing response surface is greatly facilitated by the proper choice of an experimental design. When selecting a desirable response surface design, some features are considered. For example, the design should provide a reasonable distribution of data points throughout the region of interest, it should allow model adequacy, including lack of fit, to be investigated and it should not require a large number of runs, etc. Normally, for developing second order regression models, Box-Wilson central composite design and Box Behnken design can be used. In mechanised and robotic applications, an accurate means of selecting the welding procedures and of predicting the shapes of the weld beads that will be deposited has become increasingly. Mathematical models were developed to predict weld bead geometry and dilution in automatic stainless steel surfacing by MIG welding. The direct and interaction effects of process parameters on bead geometry were studied and investigated that the RSM could be employed to visualize the effects of process parameters on bead dimensions.

H. Effects of Cladding Process Parameters on Clad Bead Geometry and Their Optimization

The set of values of the input variables which result in the most desirable response values is called the set of optimum conditions. The first step in the process of seeking optimum conditions is to identify the input variables that have the greatest influence on the response. Generally, the fewer the number of variables that have an effect on the response, the easier it is to identify them. Once the important variables are discovered, the next step is to postulate a model which expresses the response of interest as a function of the variables. The sequence of fitting and testing the model forms and the eventual selection of a model are the prelude to the determination of the optimum operating conditions for a process. Many researchers performed investigations to optimize penetration, dilution and other bead parameters using different techniques, namely, gradient loss function algorithm. In the process of optimization, once the important input variables are identified, the next step is to postulate a model which expresses the response of interest as a function of the variables. The sequence of fitting and testing the model forms and the eventual selection of a model are the prelude to the determination of the optimum operating conditions for a process. Reported the selection of process parameters for obtaining optimal weld pool geometry in the tungsten inert gas (TIG) welding of stainless steel with the modified Taguchi method to analyses the effect of each welding process parameter on the weld pool geometry.

I. Evaluation of Residual Stress in Stainless Steel cladding

1) Residual stress

Residual stress is the stress that exists within a material without application of an external load (Silva RGH 2013) [11]. It can also be described as the stress which remains in a body that is stationary and at equilibrium with its surroundings. Nowadays there are several residual stress measurement techniques are in use. Some are destructive, while others can be used without significantly altering the properties of component (Barhorst S 1984) [12].

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J. Testing For Soundness of Stainless Steel Cladding

Claddings are often tested for soundness, strength and toughness by means of mechanical tests, which are destructive in nature. The quality of the clad, in terms of ductility of the clad metal and HAZ as well as the presence of defects particularly lack of fusion, are most frequently checked by means of a bend test. Bend test shows the influence of welding parameters and welding conditions on the plastic properties of the clad layer and joining between base metal and clad layer. Lesnewich A (1958)[20] conducted bend tests and reported that, during cladding of austenitic stainless steel by MIG welding the weld dilution plays a significant role to in promoting hot cracking. This behavior could be attributed to the formation of chromium carbides leading to a loss of ductility and hence an increase in cracking susceptibility was noticed. Murugan and Parmar (1997) [2] carried out side bend test on stainless steel claddings made using MIG welding. They reported that overlays surfaced at optimum dilution condition possessed good ductility and strength. It also revealed the absence of martensite, carbides and sigma phase in the overlays, which could cause embrittlement and reduce ductility of overlays.

K. Wear Resistance of Stainless Steel Cladding

During welding of stainless steel, the amount of carbon above 4% had increased the abrasion resistance of iron based hardfacing alloys due to the formation of primary carbides. The chromium content had influenced only secondary effects on their abrasion resistance. Had reported that within the iron based family of hard facing alloys there are a number of microstructures which provide varying degrees of resistance to abrasion, with varying microstructures like ferrite, bainite, martensite, austenite and carbides. Patchett(2007)[19] evaluated the weld overlays deposited by the GTAW processes and reported that the higher cooling rates yielded microstructures with finer grains and improved resistance to galling wear. Wear behavior of different hard facing electrodes deposited on top bearing plate of a coal crusher unit. Their results showed that different hard facing electrodes as well as the weld procedure variation using similar electrodes had large effects on low stress abrasion resistance of the hardfacing deposit. Such effects on the abrasion resistance were mainly attributed to the variation in deposit chemistry and microstructures. Marques C (2012)[21] reported the influence of welding process and post weld heat treatment on the abrasive wear resistance of iron based (Fe-6Cr-0.5C) hard facing alloys and found that dilution reduced the wear resistance whereas heat treatment improved it. The influence of the alloy composition, heat treatment, welding parameters, sliding condition and microstructure on the abrasive wear behavior of Fe-Cr-C base hard facing alloy coatings was reported.

L. Corrosion Resistance of Stainless Steels

Corrosion is it is the reverse of extractive metallurgy, as the Materials tend to go back to their original status, due to their oxidation with the surrounding. Weld metals are more prone to corrosion attacks as compared to wrought base metals because they are compositionally and micro structurally inhomogeneous. The solidification process introduces segregation of minor and major alloying elements, porosity cracking, formation of secondary phases etc. in the weld. Moreover, welding defects such as porosities, inclusions along with residual stresses, precipitation of deleterious secondary phases strongly influence the corrosion behavior of the welded structures. Pitting corrosion occurs much faster in areas where microstructural changes have occurred due to welding. In the sensitized condition, the steels are quite susceptible to inter granular corrosion in chloride and caustic environments resulting.

M. Corrosion Resistance of Stainless Steel Claddings

Although stainless steel is resistant to corrosion, it is not immune in chloride containing environments. It is a problem in stainless steel when exposed to chlorine and hydrochloric acid. Nickel containing materials such as austenitic stainless steel have been used for marine applications for many years. Nickel-chromium-molybdenum (Ni-Cr-Mo) alloys have been used in reactor vessels in the production of acetic acid for more than 20 years. These alloys are a cost-effective alternative to nickel chromium (Ni-Cr) stainless steels because of good resistance to oxidizing corrosive media; Ni-Mo alloys have good resistance to reducing corrosive media. Molybdenum, in combination with chromium, stabilizes the passive film in the presence of chlorides, and is especially effective in increasing resistance to pitting and inter granular corrosion. Austenitic stainless steels are one of the best choices, as they combine very good corrosion behavior with excellent mechanical properties especially when using ‘L’ grades, characterized by very low carbon. The austenitic structure provides a combination of excellent corrosion, oxidation and sulfidation resistance with high creep resistance, toughness, and strength at temperatures greater than 565°C. They are, therefore, often used in refineries for heater tubes and heater tube supports and in sulphur and hydrogen plants. They are susceptible, however, to grain boundary chromium carbide precipitation (sensitization) when heated in the range of 540°C to 820°C.

N. Corrosion Measurement Methods

Corrosion measurement is the quantitative method by which the effectiveness of corrosion control and prevention techniques can be evaluated. It provides the feedback to enable corrosion control and prevention methods that are to be optimized. Corrosion measurement employs a variety of techniques to determine how corrosive the environment is and at what rate metal loss is being experienced. The following are the techniques adopted for measurement of corrosion of SS claddings .Of the techniques listed above, Corrosion weight loss coupons and Potential dynamic measurements form the core of industrial corrosion monitoring systems.

O. Metallurgical Characterization of Stainless Steel Cladding

1) Micro hardness survey in stainless steel cladding

Hardness variation across the cross-section of the hard-faced deposit is a very good indicator of extent of dilution from the base metal and its effect on the property of the deposit. Found that in the hardness distribution across the deposit, 316 L SS substrate interface, the hardness adjacent to the interface was lower than that of the undiluted deposit. The hardness of the deposit increased almost linearly from 350 VHN at the interface to about 600 VHN at 2.5 mm away from the interface, beyond which there was no significant increase in hardness carried out the micro hardness measurements on the polished transverse cross section of laser clad specimens prepared with three different laser power levels. They found that the microhardness value of the laser clad deposit was critically dependent on the processing parameters. An increase in heat input during laser cladding served to reduce hardness and laser cladding carried out at a laser power of 1.5 kW with scan speed and powder feed rates of 5 mm/sec and 6 g/min respectively, resulted in a clad deposit with an abrupt transition in micro hardness across the substrate/clad interface. Reported that the hardness of the iron based overlay increased with the distance from the interface in the coating which was primarily attributed to dilution. Dilution results in an overlay having a composition different from that of the electrode owing to mixing of the molten base metal with the electrode material during welding. The author concluded that the higher hardness of overlay produced by TIG welding compared to SMA welding could possibly be due to less dilution of TIG than SMA welding.

2) Microstructural studies in stainless steel cladding

At ambient temperature, wrought stainless steel alloys of AISI 300 series are entirely austenitic and have homogeneous structure, while welds contains certain amounts of delta ferrite, which is retained at room temperature after solidification due to rapid solidification and have inhomogeneous structure. Microstructural modifications that took place during the deposition of AISI 304L stainless steel substrate over structural steel using PTAW process and investigated the soundness of the weld towards mechanical, metallurgical, and corrosion resistance properties of the weld. They studied the formation of delta ferrite microstructure in stainless steel weld with the Fe-Ni-Cr ternary phase diagram. Hence, vertical section at 70% iron content of the ternary phase diagram was plotted and is called as pseudo-binary diagram. Figure 2.7 shows the pseudo binary diagram for alloys with 70% Fe and represents the solidification sequence shown by the majority series of AISI 300 alloys.

III. Conclusion

As per the all results we under gone that cladding on the ss410 material with nickel chromium overlay gives the high strength with low cost it gives more corrosion resistance, wear resistance and hardness on the low strength base material.

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