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CLADDING- A MODERN TECHNIQUE TO PRODUCE CORROSION RESISTANT SURFACES

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Abstract : Weld cladding is a process of depositing thick layer of corrosion resistant material usually over carbon steel plates to improve its corrosion resistance properties and main problem faced in stainless steel cladding is the selection of process parameters for achieving the required clad bead geometry and its shape relationships Different categories of stainless steels are employed as the cladding material However, mechanical and corrosion resistant properties of cladded components depend on the clad bead geometry Therefore, it is essential to study the effect of process parameters on the bead geometry to enable effective control of these parameters Iron-aluminum-based weld cladding is also used as corrosion resistant coatings for boiler tubes in coal-fired power plants Although these alloys have excellent high-temperature corrosion resistance, Fe-Al weld cladding is susceptible to hydrogen embrittlement cracking at elevated aluminum concentrations Addition of chromium to iron aluminum alloys have been found to improve corrosion resistance, and could potentially increase the service life of the coating In this paper a brief review on this technique is presented

Keywords GMAW, Weld bead parameters, Dilution, Hydrogen embrittlement, Corrosion resistance

1. Introduction

Corrosion weakens the steel structure causing its failure Though corrosion cannot be eliminated fully, it can be reduced to certain extent Corrosion resistant protective layer is deposited over the less corrosion-resistant substrate by a process called weld cladding This technique is mainly employed to improve the service life of engineering components, and to reduce their cost, either by rebuilding repeatedly or by fabricating to produce a composite wall section In recent years, weld cladding processes have been developed rapidly, and are now applied in numerous industries such as chemical, fertilizer, nuclear and steam power plants, food processing, and petrochemical industries Various welding processes employed for cladding are shielded metal arc welding (SMAW), submerged arc welding (SAW), gas tungsten arc welding (GTAW), plasma arc welding (PAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), electro slag welding (ESW), oxy-acetylene gas welding, and explosive welding Among the processes employed for weld cladding, GMAW is widely accepted by the industries due to the following advantages as suggested by Lucas [1]

1 High reliability
2 All position capability
3 Ease of use
4 Low cost
5 High productivity
6 Suitability for both ferrous and nonferrous metals
7 High deposition rate
8 Absence of flux
9 Cleanliness and ease of mechanization

The mechanical strength of the (GMAW) clad metal is influenced not only by the composition of the metal but also by the clad bead shape The clad bead shape is an indication of bead geometry The acceptable clad bead geometry depends on wire feed rate, welding speed, arc voltage, etc Hence, the relationship between input process parameters and bead parameters are necessary to study the clad bead geometry and its shape relationships This may be achieved by the development of mathematical models

2. Cladding

According to Kannan and Murugan [2], the term weld cladding usually denotes the application of a relatively thick layer (approximately 3 mm) of weld metal for the purpose of providing a corrosion-resistant surface. In modern industry, increasing use is being made of clad materials as a means of achieving the optimum balance of strength, special surface properties, and economy. Some of the typical base metal components that are weld-cladded include the internal surfaces of carbon and low-alloy steel pressure vessels, paper digesters, urea reactors, tube sheets, and nuclear reactor containment vessels. Among the various welding processes employed, GMAW process has become a cost effective choice for cladding smaller- and medium-sized areas due to its superior quality, all position capability, and ease of mechanization.

3. Dilution

Kannan and Murugan [2] defined dilution as the ratio of the cross section of weld metal below the original surface to the total area the weld bead measured on the cross section of the weld deposit. Various combinations of procedural parameters like primary parameters viz. welding current, voltage, welding speed, and secondary parameters like polarity, electrode size, wire stick out, welding position/inclination, arc shielding, electrode oscillation, welding technique, additional filler metal etc., that affect dilution, can be incorporated into a procedure. Various processes like SAW, GTAW, PAW, GMAW, ESW, FCAW, Strip cladding, Explosive welding, etc., have been used for cladding operation with an aim of minimizing dilution to as low value as possible without sacrificing the joint integrity. This requires a thorough understanding and proper control over a number of variables, which affect dilution. Use of hot filler additions in various conventional processes like TIG, LBW, PAW, etc., have been reported to affect dilution to a significant extent.

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

Shahi and Pandey [3] investigated the effect of auxiliary preheating of the solid filler wire in mechanized gas metal arc welding (GMAW) process by using a specially designed torch to preheat the filler wire independently, before its emergence from the torch on the quality of the single layer stainless steel overlays. External preheating of the filler wire resulted in greater contribution of arc energy by resistive heating due to which significant drop in the main welding current values, and hence, low dilution levels were observed. Metallurgical aspects of overlays such as chemistry, ferrite content, and modes of solidification were studied to evaluate their suitability for service, and it was found that claddings obtained through the preheating arrangement, besides higher ferrite content, possessed higher content of chromium, nickel, and molybdenum and lower content of carbon as compared to conventional GMAW claddings, thereby giving overlays with superior mechanical and corrosion resistance properties. The findings of this study not only establish the technical superiority of the new process, but also, justify its use for low cost surface applications due to its productivity-enhanced features.

5. Effect of Chromium on the Weldability and Microstructure of Fe-Cr-Al weld Cladding

Regina et al. [4] studied the effect of chromium on Weldability and microstructure of Fe-Cr-Al weld cladding. *Iron-chromium-aluminum-based alloys are* good corrosion resistant weld claddings because they exhibit excellent oxidation and sulfidation resistance in a wide range of high-temperature environments. These alloys rely on both aluminum and chromium additions for increased corrosion protection, and it has been shown that the corrosion resistance of these alloys in simulated low NOx environments improved with an increase in aluminum and chromium concentrations. Recent studies have indicated that Fe-Cr-Al-based alloys require approximately 7.5–10 wt-% aluminum and chromium additions up to ~ 5 wt-% to remain protective in a wide variety of low NOx-type atmospheres. However, work to date has shown that weld cladding that contains the brittle FeAl and/or Fe_3Al inter metallic are susceptible to cracking due to environmental embrittlement. Liu et al. [5] was one of the first investigators to demonstrate that premature cracking of FeAl and Fe_3Al inter metallic is due to hydrogen embrittlement. Room-temperature ductility of FeAl and Fe_3Al inter metallic alloys was investigated under carefully controlled environments. The FeAl and Fe_3Al alloys each exhibited significant ductility (~12% elongation) when tensile tested under high-vacuum or pure oxygen environments (i.e., with no water vapour). The introduction of water vapour into the test chamber decreased the ductility significantly down to 2–4%. Hydrogen embrittlement of the inter metallic phases has been attributed to their general lack of ductility coupled with the generation of hydrogen that occurs when aluminum reacts with water vapor to liberate free hydrogen via the reaction $2Al + 3H_2O \longrightarrow Al_2O_3 + 6H^+ + 6e^-$. While many theories for hydrogen embrittlement exist, the presence of hydrogen in these alloys is expected to cause embrittlement by significantly lowering the cleavage strength. This type of mechanism is also believed to be responsible for cracking observed in Fe-Al cladding that contains the inter metallic phases in which Al reacts with water vapour in the arc to liberate hydrogen. This, coupled with residual stresses from welding, can cause cracking in Fe-Al cladding that contains the FeAl and Fe_3Al phases. For example, it has previously been reported that Fe-Al cladding produced with both the GTAW and GMAW processes were subject to this cracking phenomenon when the aluminum concentration in the weld deposit was greater than approximately 8–11%Al, and this Al range represents the composition over which the intermetallics begin to form in the cladding. Cracks that formed on welds were observed in a zone where they stopped at the base metal. This type of cracking would provide direct paths through the corrosion-resistant weld coatings, and thus allow corrosive gas species to attack the underlying substrate. Weld cladding containing these types of cracks would essentially provide no corrosion protection at cracked areas and would be unacceptable for these applications.

Another work has shown that the use of a minimum 350°C preheat temperature combined with post weld heat treating at a minimum of 750°C can be used to alleviate the cracking in the weld cladding. Experiments conducted under a controlled welding chamber has also shown that reduction of the water vapour content helps eliminate the cracking. However, these remedies are not practical for most applications in which a relatively large amount of surface area must be clad for corrosion protection under industrial processing conditions. In these applications, the most practical route to avoiding the problem is to identify weld compositions that are resistant to cracking under processing conditions that utilize typical shielding gases and no preheat or post weld heat treatment. In view of this, the influence of Cr on the Weldability of Fe-Al alloys warrants further consideration. It has also been shown [5] that the ductility of alloys exhibiting the inter metallic phases can be improved significantly with Cr additions, while Cr is also beneficial to corrosion resistance. They study the effect of Cr on the weld cladding microstructure and corresponding cracking susceptibility of Fe-Al weld cladding conditions without the use of preheat or post weld heat treatment.

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

According to Kannan and Murugan [2], most of the engineering applications require both high strength and corrosion resistant materials for long term reliability and performance. Often strength is achieved by the use of steels which do not possess the required corrosion resistance. To obtain attributes of high strength and corrosion resistance, the surface of steel may be cladded with a metallurgically compatible corrosion resistant alloy. The characteristics desirable in such a cladding alloy are reasonable strength, Weldability to the steel, resistance to general and localized corrosion attack, and good corrosion fatigue properties. A clad material giving excellent corrosion resistance and Weldability is duplex stainless steel. These have chloride stress corrosion cracking resistance and strength significantly greater than that of the 300-series austenitic. In recent years, weld cladding processes have been developed, and are applied in chemical and fertilizer plants, nuclear and steam power plants, food processing and petrochemical industries, etc.

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

1. High deposition rates, especially for out-of-position welding
2. More tolerant of rust and mill scale than GMAW
3. Simpler and more adaptable than SAW
4. Less operator skill required than GMAW
5. High productivity than SMAW
6. Good surface appearance
7. Good radiographic standard quality
8. Minimum electrode wastage

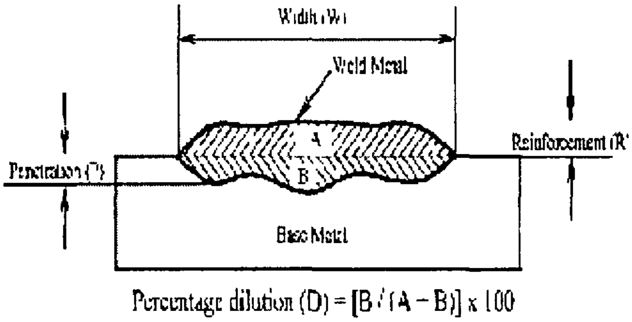

Fig 1. : Weld bead geometry.

7. Concluding Discussion

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

- Dilution increases with the rise in welding current and welding speed and decreases with the rise in nozzle tip distance and welding torch angle
- Reinforcement increases with the rise in welding current and nozzle tip distance and decreases with the rise in welding speed and welding torch angle
- Weld bead width increases with the rise in welding current nozzle tip distance and welding torch angle and decreases with the rise in welding speed
- Penetration increases with the rise in welding current and welding speed, and decreases with the rise in nozzle tip distance and welding torch angle
- Bead width increases with the increase in welding current at all levels of welding speed But the rate of increase in bead width with the increase in welding current decreases significantly with the increase in welding speed
- Increase in welding torch angle decreases penetration when welding speed is high but penetration slightly increases with the increase in welding torch angle when welding speed is low
- Percentage dilution decreases with the increase in nozzle tip distance at all levels of welding current But the rate of decrease in percentage dilution with the increase in nozzle tip distance decreases significantly with the decrease in welding current

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