TiC COATING ON AISI 304 STAINLESS STEEL BY TUNGSTEN INERT GAS (TIG) CLADDING USING PREPLACED POWDER

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ABSTRACT

In order to improve the hardness and microstructural behaviour of AISI 304 austenitic stainless steel, TiC and TiC- steel composite layer was deposited by tungsten inert gas (TIG) cladding/alloying process. Depending upon the heat input into the molten pool and mixing ratio with steel substrate, TiC clad layer or TiC-steel alloyed layer deposited on or within the steel substrate.

Clad/alloyed layer height/depth and corresponding microstructure was analyzed by FESEM and EDS. The composition of the clad/alloyed layer was assessed by Xray diffraction (XRD), and hardness was measured by Vickers micro indentation hardness tester. Also effect of TIG welding current and scan velocity on the clad/alloyed layer geometry (depth, width and crater depth) and corresponding microstructure was investigated.

Keyword : - *: TIG, Melt depth, Microstructure, Crater depth, Hardness*

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1. INTRODUCTION

Steel components are the most widely used materials in modern industry due to their enormous advantages, which includes its superior mechanical properties, inexpensive manufacturing cost and exact stipulation. In order to increase the productivity the industrial components are working continuously in severe environmental conditions which causes wear and damage of the components. To improve the efficiency and service life, these components required treatments to enhance the surface characteristics. Different surface modification techniques are used to enhance the surface characteristics such as hardness, wear resistance, corrosion resistance of the steel without changing its bulk properties. Surface modification techniques includes application of thin film of functional material with superior surface properties to a substrate or modification of surface characteristic by inclusion of harder ceramic particles.

1.1 DIFFERENT SURFACE TREATMENT TECHNIQUES USED FOR SURFACE MODIFICATION:

1. Different types of hardening methods such as quenching, induction hardening, nitriding, carburizing, deposition techniques such as physical vapor deposition (PVD), chemical vapor

deposition (CVD), sol-gel, electrolytic coating and hardfacing process are some of the commonly used surface treatment method . Also laser cladding, thermal spraying, hot dipping etc. are employed to improve surface properties. Few of them are explained below:

Surface hardening- This can be done by different techniques with an aim to improve the wear resistance of the outer surface of steel components without affecting the inner base metal. It is mainly used to harden the outer surface of the parts subjected to severe working conditions such as high temperature and stresses, dynamic forces, high pressure and infrequent impacts. In this case surface modification is achieved by altering the composition by diffusion of element such as carbon, thus results in the formation of hardened layer .

Different approaches to the various surface-hardening methods are as follows :

1. Thermochemical diffusion methods: These results in the modification of the surface composition by introducing elements such as carbon, nitrogen and boron.

2. Applied energy or thermal methods: These causes no change in the surface composition but improve desired properties by altering the surface structure by producing a quench-hardened surface, without additional alloying species.

3. Surface coating methods: These results in the formation or addition of a new layer on the substrate.

THERMOCHEMICAL DIFFUSION METHODS:

- Carburizing:

It is commonly used for low-carbon steel. It is a process of heating the steel into carbon rich environment at temperatures between 850 and 980 °C followed by quenching to harden the surface layer.

- Nitriding:

In this process, hardening of the steel is achieved by introducing nitrogen into the surface of steel. Temperature range for this process is 500 to 550 °C.

- Carbonitriding:

It is the diffusion of both carbon and nitrogen into the steel which results in the formation of a hardened surface layer. It is done at a lower temperature than carburizing.

- Boronizing:

Boriding or boronizing is a thermochemical diffusion process of boron atoms into the base metal with the formation of hard boron compound at the surface. It is. The process temperature for boronising lies between 700 °C and 1000 °C. It can be applied to any ferrous and nonferrous material, as well as cermet. Improves coefficient of friction and abrasion resistance.

Surface hardness obtained by these methods are typically in the order of 750-1600 HV, and can reach up to a maximum value of 2800 HV for boriding/boronizing.

Applied energy methods: These includes conventional thermal treatments such as flame hardening and induction hardening and high-energy treatments such as laser or electron beams.

- Induction hardening:

It is used to increase hardness, wear resistance and fatigue life through the formation of a hardened surface layer, without affecting the core microstructure. The applied alternating current in the copper coil results in heating of the workpiece placed inside the coil inducing an alternating magnetic field within the workpiece, which causes the temperature of the outer surface of the part to raise within or above the transformation range. The process is followed by immediate quenching. Only martensitic stainless steels can be hardened using this process.

- Flame hardening:

It is the heating of steel by an oxy-flame at a high temperature followed by quenching. It is a hardening process used to increase the hardness and wear resistance of the medium carbon or alloy steels. This results in the formation of a hard and wear resistant surface layer.

 Laser surface heat treatment:
It is commonly used to harden steel and cast iron components, occasionally referred to as laser transformation hardening. In this process metallurgical transformation takes place resulting in the formation of a hardened layer to the base metal by the interaction of material and laser beam. It can be applied to a wide range of materials especially those are relatively tough and cheap. It offers high wear resistance and improved fatigue resistance with minimal distortion. It involves heating the material to the austenization temperature. It includes different methods such as surface melting and surface alloying.

 Surface melting results in modification by heating the base metal followed by rapid solidification thus improving the surface properties such as wear and corrosion resistance.

 In laser alloying desired surface properties are achieved by melting and mixing of alloying elements on the surface without affecting the bulk material.

 Electron beam (EB) hardening:
In this process the surface is hardened by the impingement of a high-velocity electron beam which heats the material to the austenization temperature followed by self-quenching. It results in surface hardening with special characteristics compared to the other heat treatment processes.

SURFACE-MODIFICATION BY DEPOSITION OF COATING:
 Chemical Vapor Deposition (CVD):
It is a chemical process used to deposit a hard and wear resistant coating with metallurgically bonded to the substrate. This process results in thin-film coating on the substrate due to the reaction/deposition of volatile gaseous phases on the surface of the substrate to achieve desired coating.

 Physical vapor Deposition (PVD):
Like CVD, it is also used to produce thin film coating. It is basically a high-temperature vacuum deposition process in which the coating metal is evaporated which forms compound while interacting with so introduced reactive gas containing Nitrogen or Carbon thus deposited on the surface of substrate as thin coating with improved hardness and high quality adhesion. Evaporation of coating material can be done by heating or by bombardment of ions (sputtering) to promote high density. PVD is commonly used in the semiconductors wafers and cutting tool.

 Electroplating:
Electroplating also called as electrodepositing is primarily used to change the surface properties of a workpiece by the deposition of a metal coating to a metallic substrate through an electrochemical process. The coating take place inside a container containing a solution of one or more metal salts and the item to be coated is connected to an electrical circuit. As the current is applied, ions from the solution are attracted towards the cathode and deposited on the workpiece connected to cathode. Steels, nickel and copper based alloys are commonly used materials in electroplating process.

 Electroless plating:
It is an auto-catalytic reaction process used to deposit a coating of nickel onto the surface of a substrate without applying an electric current. This results in a completely uniform deposit, even on complex shapes, to improve wear and/or corrosion resistance. Typically nickel and copper are used in this process.

 Hardfacing:
In this process, a layer of material having superior surface properties is applied to the substrate.

It involves welding and thermal spraying techniques to deposit a hard and wear resistant material to the selected areas of the components. It may also be used to repair worn-out parts. The most common hardfacing materials are nickel alloys, cobalt alloys and iron/chromium alloys used in wear resistance. Different types of hardfacing techniques are as follows:

- Thermal Spraying
- Laser cladding
- Welding
- Thermal Spraying:

In this process, material to be coated is sprayed in melted powder form to the surface of the substrate in order to provide a coating. The powder is melted by an oxy-flame to be sprayed in the form of fine spray. The spray when comes in contact with the surface results in thick coating at a higher deposition rate than any other coating processes such as electroplating, CVD and PVD.

SOME COMMON THERMAL SPRAYING PROCESSES, INCLUDES:

- Plasma arc spraying
- Flame spraying
- High-velocity Oxy/Fuel
- Electric arc spraying
- Detonation Gun
- Laser cladding:

It is one of the laser surface modification process which offers a wide variety of possibilities to alter the microstructure and thus mechanical properties of the surface. It involves melting of a thin layer of substrate surface using a laser beam which then mixes with the melted clad powder alloy in order to form a metallurgical bond. It offers many advantages as compared to different traditional coating methods which includes low dilution, narrow heat affected zone, and low heat input. It results in high intensity coating because of strong metallurgical bonding between the clad layer and the substrate. It has been adopted to deposit different powder mixtures including tungsten carbide-cobalt, stellite on steel, titanium alloy and cast iron substrates. Its applications include turbine blades, engine valve components and boiler firewall.

- Hardfacing by welding:

Weld hardfacing is used to deposit various metals and alloys on the metallic substrate surface with high bonding strength. A wide range of coating materials can be applied. Different welding techniques can be used such as plasma transferred arc (PTA), metal-inert gas (MIG) [, manual metal arc (MMA), tungsten-inert gas (TIG) and submerged arc (SAW).

2. CONCLUSIONS

- From the above experiment, it is observed that TiC coating has been successfully developed on AISI 304 steel.
- The SEM microstructure analysis showed two different types of clad layers for 100 amp and 60 amp applied current.
- At higher value of current i.e. 100 amp, a MMC type mixed zone with low hardness and high layer depth is obtained, while for lower current i.e. 60 amp, a distinguished TiC layer with high hardness but low layer thickness formed over the steel substrate.
- From the clad layer geometry, it is concluded that the dimensions (melt depth, width and crater depth) decreases with a reduced energy input.
- From the FESEM analysis, it is observed that different types of TiC structures were Obtained.
- The microhardness results indicate that the TiC coated steel samples processed at lower current i.e. 60 amp and lower scan speed i.e. 6.5 mm/s exhibited high hardness which is almost 7 times the hardness of the constituent steel.

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