ELECTROCHEMICAL CORROSION OF TI COATINGS DEPOSITED BY WIG WELDING ON SURFACE COMPONENTS STEEL

Elena Simona CUTEAN, Ion MITELEA, Viorel - Aurel ŞERBAN, Mircea BURCĂ

Politehnica University of Timişoara, Faculty of Mechanical Engineering, Timişoara, Romania, EU,
cuteansimona@yahoo.com, ion.mitelea@mec.upt.ro, serban@mec.upt.ro, mircea.burca@mec.upt.ro

Abstract

Due to the ongoing development of industry, the production processes must be carried out in safety and economical conditions. In this regard, one of the solutions is the use of welding technologies in the field of surface engineering by using filler materials that ensure high functional properties of the deposited layers. This field is based on a series of processes that modify the physical state of the pieces surface in order to improve the operational performance, to increase the lifetime and to obtain economic benefits. The welding processes are applied to pieces that are subjected to complex stresses during operation in order to achieve an effective protection. The materials selected for the deposition must resist in extreme environmental conditions maintaining the properties imposed. Among these, titanium and its alloys are materials with relatively low specific weight, excellent mechanical properties, very good corrosion resistance and a high level of bio-compatibility, but also a higher cost compared to steels. This paper presents the replacement of some titanium alloys pieces, which are working in corrosive environments, by steel pieces, which surfaces are coated with titanium, using TIG welding technique. The deposited layers are analyzed by optical and electronic microscopy, and the results show a good interpenetration of the materials used, no discontinuities and defects. The electrochemical corrosion tests in various environments show good electrochemical corrosion resistance of the combined system layer - substrate.

Keywords: Welding; deposition; layers; titanium; corrosion tests

1. INTRODUCTION

Corrosion involves the deterioration of a material as it reacts with its environment. Corrosion is the primary means by which metals deteriorate. The consequences of corrosion are many and varied and the effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than the simple loss of a mass of metal. Allowing corrosion is not cost efficient and can inhibit productivity; understanding and preventing corrosion is important for maintaining infrastructures and machinery or any products that face corrosion. [1]

The prevention of corrosion reduces both the economic and safety-related damages associated with the process. Carbon steel, the most widely used engineering material, accounts for approximately 85%, of the annual steel production worldwide but its relatively limited corrosion resistance. The cost of metallic corrosion to the total economy must be measured in hundreds of millions of euro per year. Because carbon steels represent the largest single class of alloys in use, both in terms of tonnage and total cost, it is easy to understand that the corrosion of carbon steels is a problem of enormous practical importance. [2]
Physical qualities of titanium make it a preferable material used by automobiles, aerospace, jewelry and many other industries. It has been known for its high strength and toughness, durability and low density, and ability to withstand high and low temperatures. The corrosion resistance and biological compatibility of titanium are another two attributes very useful in a variety of applications. Steel is corrosive, rusts, stains, and is heavier than titanium. Steel's density is 7.85 g/cm^3, and titanium has 56% that of steel. [3] Its main disadvantage is the high cost price, for this reason, some parts and machine components which are working in corrosive environments, are made from less expensive materials, their functional surfaces being covered with titanium. [4]

For this reason, are made continuous research to reduce the costs of the components but also to ensure high surface properties (wear, corrosion). A convenient variant in terms of the cost to obtain components with high corrosion resistance is to apply to engineering surfaces field by covering the parts made of steels with corrosion resistant materials. [5]

The paper presents the experimental results on deposition of titanium layers by TIG welding technique to improve the corrosion performance of the components.

2. EXPERIMENTAL PROGRAM

2.1 Materials used

The materials are classified as basic materials, steel S235 and copper/titanium in the form of coil wire used deposited layer. Component's steel used by deposited WIG welding have a 3.5 mm thickness and characterized according EN 10025-5 by a high content of carbon, the chemical composition being exemplified in the following table:

Table 1 Steel chemical composition EN 10025-5

Type material	C	Si	Mn	Pb	Sb	N	Cr	Cu
S235	Max. 0.13	Max. 0.40	0.20÷0.60	Max. 0.035	0.035	0.009	0.40÷0.80	0.25÷0.55

The cooper wire used in the WIG welding process has a 1.2 mm diameter and titanium wire has a 1.6 mm diameter. The first deposited is the cooper layer that ensures the quality and the adhesion layers deposited by WIG welding and avoids technological defects encountered during the experimental process.

A copper wire OK Autrod 19.12 is intended for spray arc welding of pure and low alloy copper using pure argon as the shielding gas. It can be used for welding the following qualities: electrilyitic tough pitch copper, oxygen-free copper and phospgorous deoxidized copper.

The classification and characterization of copper wire OK Autrod 19.12 is achieved according AWS A5.7: ER Cu DIN 1733: S-Cu Sn Werkstoff Nr. 2.1006. In table number 2 is specified the chemical composition of copper wire used for the first WIG welding deposited layer .

Table 2 Typical Cu wire composition [%]

Cu	Sn	Si	Mn
Min 98	0.7	0.25	0.25

The materials specified to obtain good corrosion toughness for the deposition and especially resistance to corrosive chemicals/oxidized is titanium. So the steel pieces are coated with commercial solid titanium wire, using WIG welding technique. The main characteristics of the wires titanium are presented in **Table 3**. [6]

Table 3 Wires Titanium Base [6]

Chemistry	Diameters	Product	Form	Applications
Titanium Pure				Datasheet DSMTS-0088
Ti 99,8+	1.6 mm	Metco Titanium	Solid Wire	• Biocompatible, high strength to weight ration, corrosion resistant

2.2 WIG welding equipment

For the experimental program was used WIG welding technique, welding equipment model MW300Fronius from Mechanics Faculty, Materials and Manufacturing Engineering Department, Timisoara.

TIG (Tungsten Inert Gas) welding also known as GTA (Gas Tungsten Arc) in the USA and WIG (Wolfram Inert Gas) in Germany, is a welding process used for high quality welding of a variety of materials, especially, Stainless Steel, Titanium and Aluminium. [8]

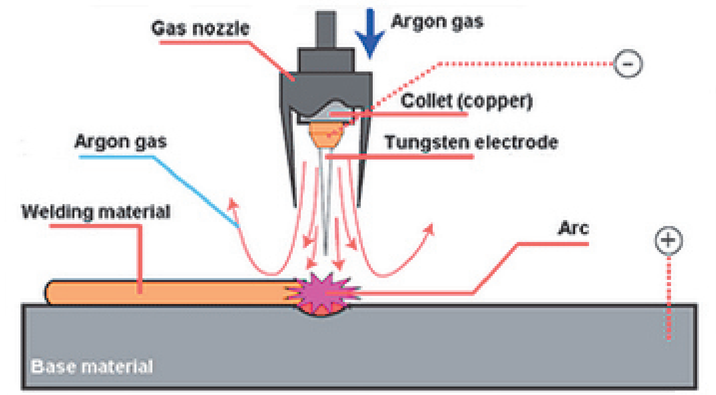

Fig. 1 Principle of WIG welding [7]

In the atmosphere of the inert gas, argon gas, the arc between the tungsten electrode and the base material (Steel) is produced and the base material (work piece) and the welding material (Cu/Ti wires) fuse due to the heat by the arc. The base material and the welding material melt for an instant. The arc irradiation is intermittently made and the weld bead is built up. Therefore the heat affection against the base material is reduced. [7]

2.3 Preparation of samples

After the WIG welding deposit of the cooper and titanium layer, the final piece surfaces is elaborated by rectification proceses to obtain a clean and quality surfaces.
For corrosion resistance determination of deposited coatings and the substrate, the samples must be round and have 15 mm diameter and 4 mm thickness. The samples are prepared with abrasive water jet cutting because the structure deposited layer should not be modified in any way.

3. RESULTS AND DISCUSSION

Corrosion behavior was determined using an electrochemical cell and a potentiostat/galvanostat model AUTOLAB PGSTAT302N, equipment from Chemistry Faculty, Timisoara. The applied potential was ± 200mV vs OCP in cathodic and anodic direction, the scan speed being 2 mV/s for NaCl and for HCl. For corrosion resistance determination of titanium coatings and the steel substrate (S235) the samples were tested in electrochemical environment of sodium chloride (3% NaCl) and acid (0.5 M HCl).

It was analyzed the corrosion behavior of two samples: steel S235 (OLC); titanium deposited layer with the steel substrate (Ti-wig).

Corrosion comportment in sodium chloride (3% NaCl)

By logarithmic scale representation and drawing the tangents to the cathodic branch, it was determined the anodic corrosion current values (Icorr) and the corrosion potential (Ecorr) (**Table 4**).

Table 4 Parameters values of the corrosion test in 3%NaCl solution

	Anodic slope [V/dec]	Cathodic slope [V/dec]	Corrosion potential [V]	Current density [A/cm²]	Corrosion rate [mm/year $^{-1}$]
S235 (OLC)	0.102	0.564	-0.491	$3.6*10^{-5}$	0.40
Ti-WIG	0.105	0.19	-0.267	$1.7*10^{-6}$	0.01

Comparing the values from the table it is observing that Icorr was shifted from $3.6*10^{-5}$ A/cm^2 value for steel at $1.7*10^{-6}$ A/cm^2 for titanium deposited layers. The shifting of current density as low values indicates a improved corrosion resistance. Moreover, the corrosion rate decreases from the value of 0.40 mm/year^{-1} for the steel parts, to 0.01 mm/year^{-1} for titanium layers deposited by WIG welding. In **Fig. 4** are presented the polarization curves for the steel S235 (OLC) and titanium deposited layer with the steel substrate (Ti-WIG), after the corrosion test in 3% NaCl solution.

Corrosion comportment in 0.5 M HCl acid

The test results of the steel substrate and the titanium coatings deposited by WIG welding method (Ti-WIG) in 0.5 M HCl acid are presented in **Table 5**.

Table 5 Parameters values of the corrosion test in 0.5 M HCl solution

	Anodic slope [V/dec]	Cathodic slope [V/dec]	Corrosion potential [V]	Current density [A/cm²]	Corrosion rate [mm/year^{-1}]
S235 (OLC)	0.097	0.161	-0.487	$32.2*10^{-4}$	2.55
Ti-WIG	0.093	0.140	-0.477	$6.3*10^{-5}$	0.73

It is observing that Icorr was shifted from the value of $32.2*10^{-4}$ A/cm^2 for steel at a lower value of $6.3*10^{-5}$ A/cm^2 for the sample deposited with titanium by WIG welding. It also noted that the steel sample presents a low corrosion resistance in acid solution. It is also observing an increased corrosion resistance of the corrosion rate from 2.55 mm/year^{-1} for steel parts, to 0.73 mm/year^{-1} for the parts coated with titanium by WIG welding method. **Fig. 5** presents the polarization curves of samples tested in 0.5 M HCl solution.

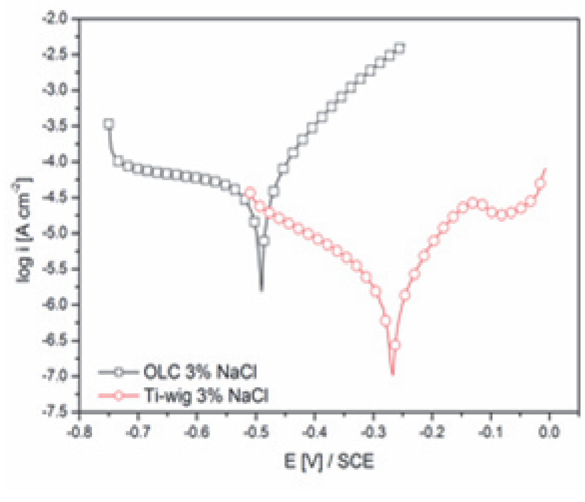

Fig. 2 Polarization curves of the tested sample in 3 % NaCl solution

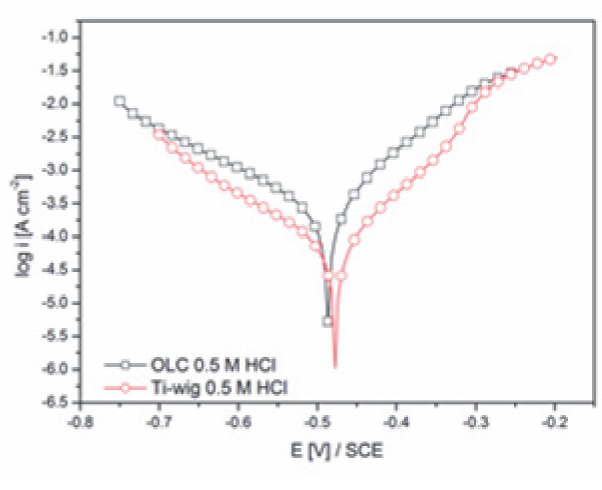

Fig. 3 Polarization curves of the tested sample in 0.5 M HCl solution

After corrosion tests in electrochemical environment of sodium chloride (3% NaCl) and acid (0.5 M HCl) the corroded surfaces of each sample (steel, titanium WIG deposited layer) were investigated by scanning electron microscopy. The following images show the result obtained.

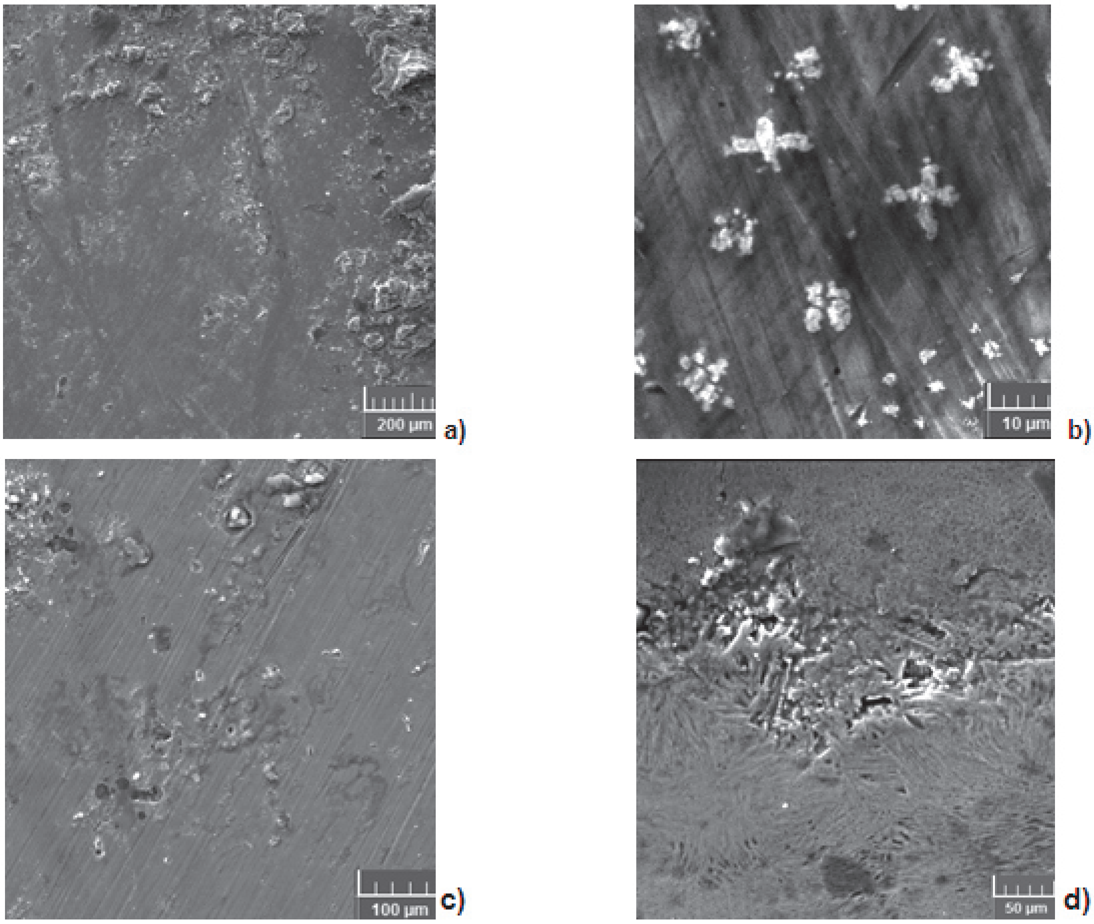

Fig. 4 Corroded surfaces a) Steel 3%NaCl, b) Ti 3%NaCl, c) Steel 0.5 M HCl, d) Ti 0.5 M HCl

The coated samples with titanium by WIG welding method attest a superior quality with higher corrosion properties (**Fig. 5**).

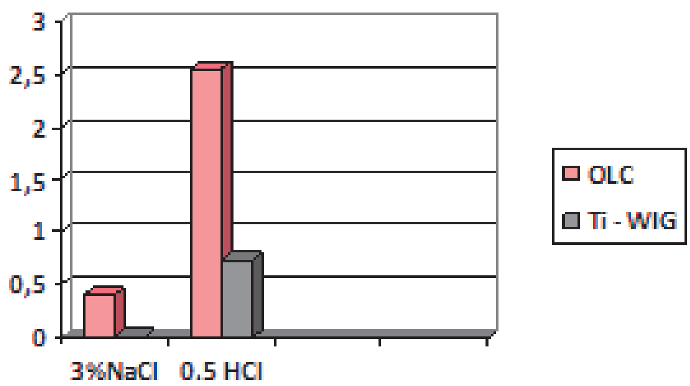

Fig. 5 Corrosion rates of the metallic substrate and titanium layer tested in 3% NaCl solution respectively 0.5 M HCl

CONCLUSION

The corrosion of metal is an unwanted chemical process and also a process that can't be stop. It can be reduced with passive corrosion protection methods, coating methods of metal surfaces with materials that have a high resistance in extreme and aggressive environment.

WIG welding is a process with high extent of universality that can be used for practical welding of any metallic materials. The welding can be realized in any position. The deposited by WIG welding coatings are characterized through excellent quality, due to greatly inert gas protection.

The surfaces of steel components in both corrosive environments (3%NaCl; 0.5 M HCl) are characterized through a continue corrosion, the whole surface is affected by the action of aggressive environment.

Corrosion tests show that titanium layer deposited by WIG welding method have a high resistance in 3% NaCl solution compared with the steel substrate (S235), and the results of testing in 0.5 M HCl solution show good values of the corrosion resistance only for the titanium layer; low corrosion resistance of the steel parts is due to the aggressive environment for this material.

ACKNOWLEDGEMENTS

„This work was partially supported by the strategic grant POSDRU/159/1.5/S/137070 (2014) of the Ministry of National Education, Romania, co-financed by the European Social Fund - Investing in People, within the Sectoral Operational Programme Human Resources Development 2007-2013".

REFERENCES

[1] STUARD, M. D., P.E. S.E., ASCE, F., SEI, F., SECB. MgtEng. *Metal Deterioration*, 2013.

[2] FOUDA, A.S., ALI, H., AZALY, El., AWAD, R. S., AHMED, A.M. *New Benzonitrile Azo Dyes as Corrosion Inhibitors for Carbon Steel in Hydrochloric Acid Solutions,* Int. J. Electrochem. Sci., 9 (2014) 1117 - 1131.

[3] http://www.differencebetween.net/object/difference-between-steel-and-titanium , March 23, 2010.

[4] CUTEAN, E.S., ROSU R. A., MITELEA, I. *HVOF spraying Tehnique of Titanium on Steels Surfaces Components,* ISBN 978-80-87294-29- , Metal 2012 Conference Proceedings.

[5] SPIECE, H.J. *Surface engineering of aluminium and titanium alloys: an overview*, Surface Engineering Vol.26, No 1/2 2010, pp. 126-134.

[6] METCO, Sulzer. *Thermal Spray Materials Guid*. Issue: May 2012. Pag. 37/52.

[7] http://www.argofile.co.jp/en/products/industry/mw/dy