Behavior of AISI SAE 1020 Steel Implanted by Titanium and Exposed to Bacteria Sulphate Deoxidizer

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Abstract. A hybrid technology to treat solid surfaces with the pulse high voltage and electric arc discharges of low pressure with a three-dimensional ion implantation technique (3DII) is applied. This technology is used to protect AISI SAE 1020 steel against a microbiological corrosion. The titanium ion implanted steel samples (coupons) are subjected to a medium of bacteria sulphate deoxidizer (BSD) which are very typical of the hydrocarbon industry and are potentially harmful for structures when are in contact with petroleum and some of its derivatives.

The used technology aims to find an effective hybrid procedure to minimize the harmful effects of bacteria on AISI SAE 1020 steel. The hybrid technology efficiency of superficial titanium implantation is estimated through the measurements of the point corrosion characteristics obtained after testing both the treated and non-treated coupons. The three-dimensional surface structures of the samples are reconstructed with help of a confocal microscope.

1. Introduction
The problem of the control over the microbiological corrosion is quite notorious for the hydrocarbon segments of the metal-mechanic industry. The costs to prevent and correct microbiological corrosion damages caused in the process of extraction and transportation of hydrocarbon are very high, for example, in the USA these costs are estimated as much as 2 billion dollars per year (Buck, E., \textit{et al.}, 1996; Koch G. H., \textit{et al.}, 2001). However difficult it may be to evaluate accurately the costs, the estimations show that about 40\% of the corrosion damages of the interior walls of the tubes fabricated
for natural gas transportation can be attributed to the microbe activity (Pund, et al., 1998). The recovery costs of the damages caused by the hydrogen sulphate produced by the bacteria sulphate reducer (BSR) (Zuo et al., 2004) amount to 4 to 6 billion dollars.

In Colombia, the costs associated with metal corrosion have been estimated as 1300 million dollars per year, which almost equals 1.2% of the Annual Revenue (Arroyave et. al., 1997), with 30 or 40% of which corresponding to the losses caused by biological corrosion (Srivastava, V., 1992). For this reason, the problem of the control over the microbiological corrosion is highly important both for science and economy.

Plasma technologies which can significantly change the composition and structure of metal surfaces through diffusion, deposition and implantation processes can be a good alternative to the chemical technologies which are used to reduce corrosion damages. The plasma processes are realized in the high voltage and arc discharges (Dougar V. et al, 2003).

A set of preliminary experiments to test the efficiency of titanium ions implantation into metals as a method for attenuating of corrosion processes in low carbon metals is being carried out at the Industrial University of Santander and the Corporation for the Investigation of the Corrosion (CIC).

2. Experimental
The dimensions and geometry of the surface defects of metal samples exposed to the bacteria sulphate reducer are determined. The samples are coupons of cylindrical geometry of 25.4 mm in diameter and 5 mm in height; their surface is treated by emery papers of 1200 (the roughness of 0.003 nm). The coupons are exposed to high voltage pulse discharges in the atmosphere of titanium vapour produced by an arc discharge. Then the samples in static conditions are introduced into the 0.03% salt solution (which is used as reference to the water of the petroleum production) enriched by BSR to be kept there for 50 days. The images of the coupons surface topography are reconstructed by a high resolution microscope with the aim to determine the difference between the inoculated coupons and non-inoculated coupons as well as the plasma treated and plasma non-treated ones.

3. Material
The coupons are made out of AISI SAE 1020 steel because this type of steel is the material used for gravimetric and bio tests in the hydrocarbon industrial segment in accordance with the ASTM G1-03, ASTM G4-01, NACE RPO775-05 standards and the Basic Corrosion Course, chapter 7 of the NACE.

4. Set-up
The experimental procedure consists in the solution media treatment of the coupons not inoculated and inoculated without any implantation treatment as well as the coupons, non-inoculated and inoculated, but subjected to titanium ion implantation (see table: 1).

| Table 1. Implantation parameters |
|----------------------------------|
| Process | Time | High Voltage | Frequency | Pressure | Duration Pulse | Element |
|---------|------|--------------|-----------|----------|---------------|---------|
| Sputtering | 25 min | 5 Kv | 30 Hz | 3.2 – 2.5 Pa | 0.25 ms | N2 |
| Sputtering | 10 min | 5 Kv | 30 Hz | 0.28 – 0.25 Pa 0.25 ms | Ti |
| Implantation | 10 min | 10 Kv | 30 Hz | 0.31 – 0.28 Pa 0.25 ms | Ti |

*a These must be set to 0 cm. In addition, please make sure the Mirror Margins option is not selected.

The experiments evidence the coloration and turbidity of the solution has changed due to the corrosion product, with a greater degree in the case of the non-implanted coupons (see Figure 1, 2 y 3).
5. Results

After the 50 days exposure of the treated samples in the aqueous solution, the local defects appear on the surface samples due to the bacteria activity. Fig. 2 shows the coupons surfaces both on the non-implanted and the titanium ions implanted samples (see Figure 3). The dimensions of the local defects on an analyzed area of 142x106 m$^2$ are determined as 2 m in diameter, 3 m in depth for the implanted coupons with the help of the microscope of brilliant field image 01M ZIISS. For the non-implanted coupons, an area of 284x212 m$^2$ is chosen. The geometry of the defects on the coupon surfaces is as follows: the diameters are 15 - 30 m and the depths are 8 – 15 m (as shown in Figure 4).
6. Conclusions
The titanium implantation technique is found efficient for protecting the AISI SAE 1020 steel surfaces from the BSR bacteria actions: it reduces the defect dimensions to 0.003 mm. The preliminary results make it possible to use the suggested method to protect some other types of steel from the microorganism aggression.

7. Recommendations
The bacteria behaviour in time should be further studied because of the metabolic processes that can form titanium oxides causing still greater defects.

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