Effect of Plasma Treatment in the Corrosion Resistance of API 5L X65 Steel

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RESUMO

Os tratamentos de superfície por plasma são técnicas avançadas utilizadas para melhorar a resistência à corrosão, desgaste e fadiga dos materiais. Entre os principais processos estão a nitretação e a deposição de filmes finos por plasma, como o PACVD (Plasma-Assisted Chemical Vapor Deposition)**.** Durante esses tratamentos, o plasma gera íons que interagem com a superfície do aço, promovendo a difusão das espécies e formando camadas endurecidas, que atuam como barreiras contra agentes corrosivos. Esses processos são realizados em atmosfera e temperatura controladas, evitando deformações e preservando as propriedades mecânicas do aço. Além disso, o uso do plasma garante uniformidade**,** aderência **e** controle preciso das propriedades da camada tratada, tornando essas técnicas ideais para aplicações em ambientes agressivos. Neste trabalho, o uso do plasma sobre a superfície do aço carbono API 5L X65 resultou em uma melhoria significativa nos valores de resistência à transferência de carga em meio de NaCl 3,5% (m/v)**.**

Palavras-chave: corrosão, tratamento de superfície, plasma

Introduction

The key to controlling corrosion reactions is to reduce or interrupt the electron transfer rate from the medium to the metal substrate. This can be achieved through various protection strategies, with emphasis on the optimized selection of materials, the use of corrosion inhibitors, sacrificial metals, and especially the application of coatings and surface treatments. Among advanced protection techniques, plasma surface treatments have proven to be highly effective, as they create thin, hardened layers on the metal surface that act as barriers, preventing direct interaction between the substrate and the aggressive environment. The plasma nitriding and plasma-assisted thin film deposition processes are examples that, in addition to improving corrosion resistance, also increase surface hardness and wear resistance. During these treatments, plasma generates reactive ions that interact with the metal surface, promoting the diffusion of species that form protective compounds. Moreover, the use of plasma allows for precise control over the properties of the treated layer, ensuring high adhesion and uniform distribution of protective layers. These features make plasma treatments ideal for applications in aggressive environments, where protection against corrosion is essential to prolong the service life of materials (1-3).

Experimental

Three processes were evaluated for obtaining and depositing plasma on the surface of API 5L X65 steel. In all processes, the plasma was generated by a pulsed power source (Pinnacle Plus +, Advanced Energy brand). The conditions tested for each process were as follows:

1. **Nitriding:**

Working gas: 60% N_2 + 40% H_2; Operating pressure: 1.5 torr; Treatment time: 90 minutes; Voltage: -350 V; Frequency: 100 kHz Temperature: between 343-347 °C.

2. **Oxidation:**

Working gas: 20% Ar + 80% O_2; Operating pressure: 0.49 torr; Treatment time: 20 minutes; Voltage: -360 V; Frequency: 100 kHz; Temperature: between 349-351 °C.

3. **Ar/H_2:**

Working gas: 80% Ar + 20% H_2; Operating pressure: 0.80 torr; Treatment time: 30 minutes; Voltage: -350 V; Final temperature: 368 °C.

After the treatments, the steels were characterized by Electrochemical Impedance Spectroscopy (EIS), using a PGSTAT204 potentiostat/galvanostat from Metrohm. The data were analyzed using NOVA 2.1.8 software

Results and Discussion

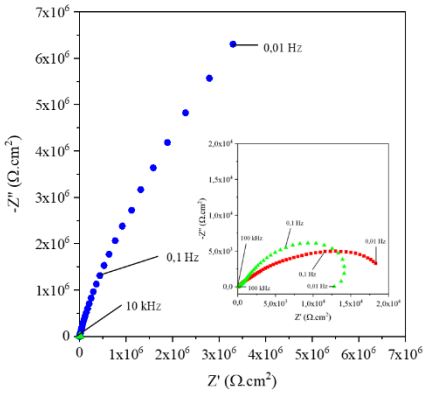

Figura 1. Nyquist plot for steels treated by **nitriding**, **oxidation**, and **Ar/H_2**. Frequency range: 10 kHz to 1 mHz, Disturbance amplitude: ± 0.01 V, in a 3.5% (w/v) NaCl solution.

Table 1. Electrochemical data for pure and plasma-treated API 5L X65 steel.

Sample	OCP (V)	Rct ($\Omega.cm^2$)
API 5L X65	-0,700	231,6
Nitriding	-0,138	9,44 x 10^6
Oxidation	-0,524	7,02 x 10^3
Ar/H_2	-0,518	1,80 x 10^3

Conclusions

A significant increase in the charge transfer resistance (Rct) was observed for all treatments, compared to the pure steel. This increase indicates an improvement in corrosion protection provided by the surface treatments. However, among the different treatments evaluated, the best results were achieved with the nitriding process, which showed the highest charge transfer resistance, suggesting a superior corrosion protection capability compared to the oxidation and Ar/H_2 treatments.

Acknowledgments

FAPEMIG, Processo n° APQ-01451-22; Relam-UFU; Capes, CNPq

References

1. I. S. Bhat *et al. Surface & Coatings Technology*. **2024**, 480 (130596).
2. S. Yu *et al*. *Materials Chemistry and Physics*. **2023**, v. 305 (128002).
3. S. Shi e C. Su. *Materials Chemistry and Physics*. **2020**, v. 248 (122929), p. 1-6.