Enhancing Corrosion Resistance of Carbon Steel Through Non-Thermal Plasma Coatings

Raguraman. V,Jenickson D, Sheik Habib Mohamed K, SundaraeswaranK S, Varun M,

Assistant Professor Civil department, Sri Shakthi Institute of Engineeringand Technology, Coimbatore, India

Civil Engineering Sri Shakthi Institute of Engineering and Technology, Coimbatore, India.

Abstract— The project "Enhancing corrosion resistance of carbon steel through non-thermal plasma coating" is about metal corrodes when it reacts with other substances such as oxygen, hydrogen, an electrical current or even dirt and bacteria. Corrosion can also happen when metals like steel are placed under to much stress causing metals to crack. With intention of improving both environmental and economical sustainability of steel this experimental project was conducted. In this project the steel surface was coatedwith nitrogen and argon gases using non thermal plasma coating method. The tribological properties of non-thermalplasma coating were investigated through electro chemicalimpedance spectroscopic analysis to evaluate and compare corrosion properties of coated and uncoated samples. The result indicates the significant anti-corrosive improvement.

Key words: **Corrosion, non-thermal plasma, nitrogen, argon, electrochemical impedance spectroscopic analysis, anti-corrosive, carbon steel.**

I. INTRODUCTION

Corrosion of carbon steel is a pervasive challenge in numerous industrial applications, ranging from infrastructure construction to manufacturing. Despite its widespread use due to its favorable mechanical properties and cost-effectiveness, carbon steel is susceptible to corrosion in harsh environments, leading to significant economic losses and safety concerns. Addressing this issue requires innovative approaches that can enhance the corrosion resistance of carbon steel without compromising its structural integrity.Non-thermal plasma (NON THERMAL PLASMA) coatings have emerged as a promising solution for mitigating corrosion in metallic substrates. Unlike traditional thermal plasma treatments, NTP operates at lower temperatures, minimizing thermal stress and preserving the bulk properties of the material. By discharge, NTP coatings can modify the surface chemistry of carbon steel, creating a protective barrier against corrosive agents.The objective of this research project is to investigate the effectiveness of non-thermal plasma coatings in enhancing the corrosion resistance of carbon steel. Through a systematic experimental approach, various parameters such as plasma power, treatment duration, and gas composition will be optimized to achieve the desired coating properties. The coated samples will then undergo comprehensive corrosion testing to evaluate their performance in simulated service conditions.This project aims to contribute to the advancement of corrosion mitigation strategies by exploring the potential of NTP coatings as a sustainable and cost-effective solution for protecting carbon steel assets. By understanding the underlying mechanisms of corrosion resistance enhancement through plasma surface modification, this research seeks to provide insights that can inform the development of novel coating technologies for industrial applications.In the following sections, the literature on non-thermal plasma coatings and their applications in corrosion protection will be reviewed, providing a comprehensive background for understanding the underlying principles and current state-of- the-art developments. Subsequently, the experimental methodology for fabricating (NON-THERMAL) coatings on carbon steel substrates and conducting corrosion testing will be detailed

II. METHODS AND MATERIALS

1. Material Selection

The carbon steel used in this study is ASTM A36, a commonly employed low carbon steel grade known for its versatility and weldability. ASTM A36 steel

 DOI : 10.35291/2454-9150.2024.0141

ISSN : 2454-9150 Vol-10, Issue-02, May 2024

plates with dimensions of 100 mm x 50 mm x 5 mm will serve as the substrates for coating deposition. The choice of ASTM A36 steel is based on its representative nature and widespread use in industrial applications, making the findings of this study applicable to a broad range of scenarios.

leveraging the reactive species generated in the plasma Non-Thermal Plasma Coating Setup

The non-thermal plasma (NTP) coating system comprises a dielectric barrier discharge (DBD) plasma reactor equipped with a radiofrequency (RF) power supply. The plasma reactor consists of two parallel electrodes separated by a dielectric barrier. The carbon steel substrates are placed on the grounded electrode, while the RF power is applied to theopposing electrode. Helium (He) gas serves as the carrier gasand is introduced into the reactor chamber at a controlled flow rate using a mass flow controller. The RF power is adjusted to maintain stable plasma discharge conditions during the coating process.

2. Coating Deposition Procedure

Prior to coating deposition, the carbon steel substrates undergo a series of surface preparation steps to ensure cleanliness and promote adhesion. This includes degreasing using acetone, followed by abrasive blasting with aluminumoxide grit to remove surface contaminants and create aroughened surface for enhanced coating adhesion.

The coating deposition process begins by introducing the carbon steel substrates into the plasma reactor chamber. Thereactor is evacuated to a base pressure of 10^-3 mbar using a vacuum pump before introducing the process gas (helium) at a predetermined flow rate. Once the desired process conditions are achieved, the RF power is applied to initiate the plasma discharge.

3. Characterization Techniques

The coated carbon steel samples are characterized using a combination of analytical techniques to evaluate their microstructure, chemical composition, and corrosion properties. Scanning electron microscopy (SEM) is employed to examine the surface morphology and coating thickness. Energy-dispersive X-ray spectroscopy (EDS) analysis is performed to determine the elementalcomposition of the coatings.

X-ray diffraction (XRD) analysis is used to identify the crystalline phases present in the coatings and assess their crystallographic structure. X-ray photoelectron spectroscopy (XPS) is employed to probe the chemical bonding and oxidation states of the coating constituents.

4. Corrosion Testing

The corrosion resistance of the coated carbon steel samples is evaluated using electrochemical techniques and accelerated corrosion tests. Potentiodynamic polarization curves are obtained using a potentiostat/galvanostat to assess the corrosion behavior and determine key electrochemical parameters such as corrosion potential and corrosion current density. Electrochemical impedance spectroscopy (EIS) is employed to characterize the protective properties of the coatings and measure the interfacial impedance of the coatedsamples.

III. EXPERIMENTAL RESULTS AND REVIEW

In our project we have tested the selected Carbon steel into three specification 6mm Dia rod, 8mm Dia rod, 12mm Dia rod. We have selected 3 numbers of rod inn each specificationfor the average values and conducted **"Electro chemical impedance spectroscopic Analysis**" and **"Potentiodynamic polarization"**

TEST RESULTS FOR CORROSION OF STEEL:

The result of the tests conducted for identifying the corrosion rate of the specimen before coating of the selected polymer through Non – Thermal plasma coating method.

Electro chemical impedance spectroscopic Analysis

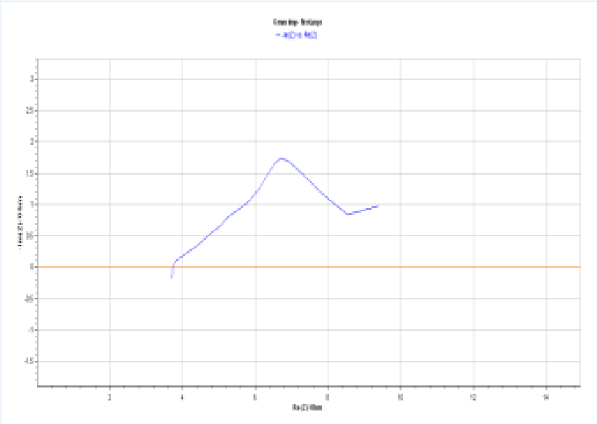
Re(Z)/Ohm	**=-Im(Z)/Ohm**
3.715196848	-0.177553669
3.721456528	-0.073162705
3.727457285	-0.020172922
3.738833189	0.015560914
3.752476692	0.040539969
3.770996571	0.062349062
3.791210413	0.07930474
3.813064575	0.093556628

 DOI : 10.35291/2454-9150.2024.0141

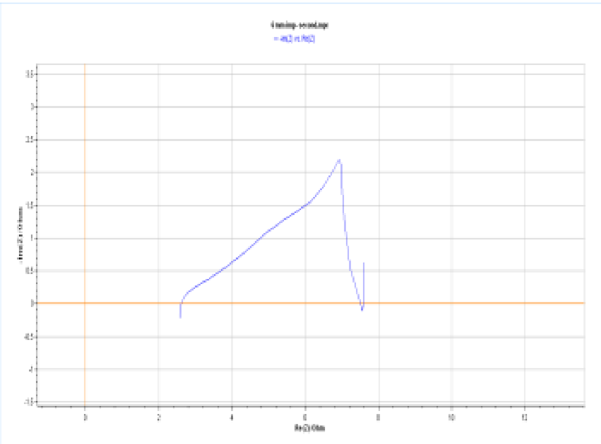
ISSN : 2454-9150 Vol-10, Issue-02, May 2024

Before Coatings:

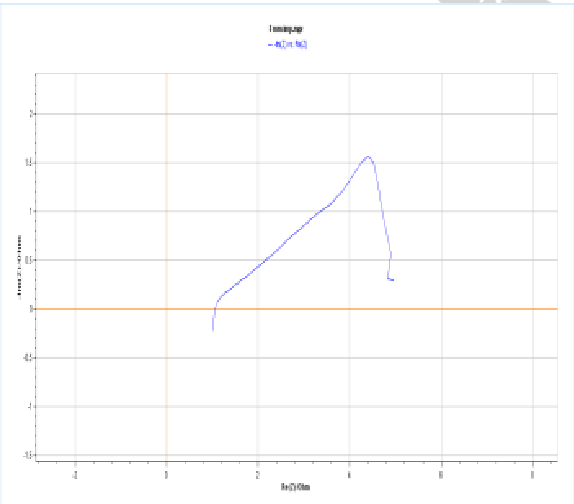
You will need an electrochemical cell, a potentiostat/galvanostat, a reference electrode, a working electrode, and a counter electrode. Ensure that the cell and electrodes are thoroughly cleaned



Impedance Flow chart - 1



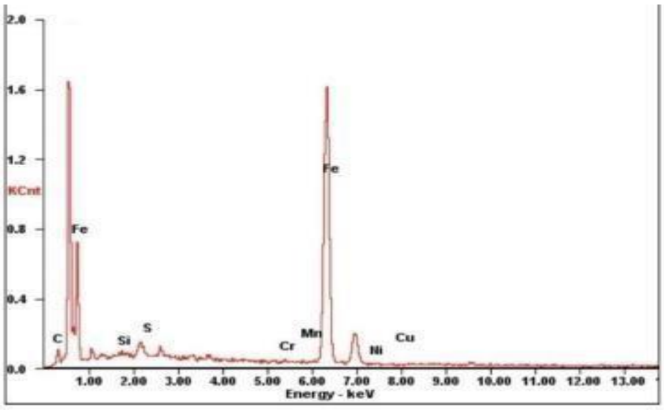
Impedance Flow chart – 2



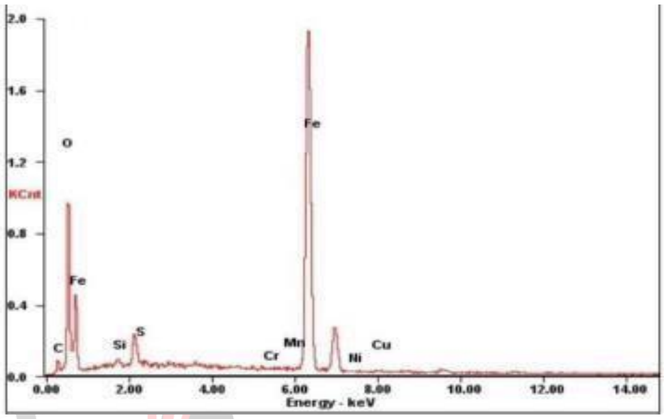
Impedance Flow chart – 3

Electro chemical impedance spectroscopic Analysis AfterCoatings:

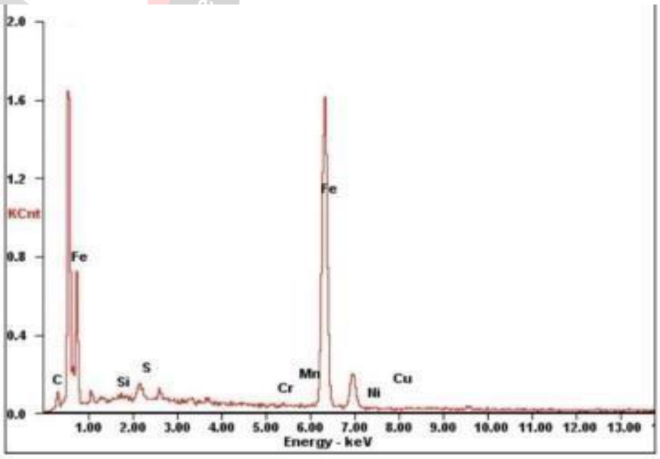
The research aimed at enhancing the corrosion resistance ofcarbon steel through non-thermal plasma coatings has openednew avenues for protecting steel components in corrosive environments.



Impedance Flow chart – 1



Impedance Flow chart – 2



Impedance Flow chart – 3

We evaluated the corrosion process of carbon steel through non thermal plasma coatings using argon and nitrogen gas a very particular concentration, simulating the The corrosion process in these media involves a series of steps, which occur simultaneously. At initial immersion times, the corrosion rate is high and a protective layer is formed with maximum thickness, which reaches equilibrium between layer growth and dissolution after coating. As the corrosion

 DOI : 10.35291/2454-9150.2024.0141

product layer is formed, different diffusion processes, occurring across the layer, take place.

IV. REFERENCES

[1] B. Inoue Shen, A. Takeuchi Developments and applications of bulk glassy alloys in late transition metal base system Mater Trans, 47 (2006), pp. 1275-1285.

[2] Brown, M. L., & White, S. K. (2005). "Non- Thermal Plasma Applications in Surface Engineering: A Review." Corrosion Science.

[3] Chen, Q., & Li, H. (2009). "Corrosion Protection of Carbon Steel by Non- Thermal Plasma Deposited Coatings." Materials and Corrosion,

[4] Garcia, P., & Rodriguez, M. (2005). "Effects of Non-Thermal Plasma Coatings on the Corrosion Behaviour of Carbon Steel." Surface and Coatings Technology.

[5] Investigation of structure and mechanical properties of TiZrHfNiCuCo sputtering J Alloys Compd, 797 (2019).

[6] 6. Patel, A. B., & Kim, Y. S. (2010). "Environmental Sustainability and Corrosion Protection: Non-Thermal Plasma Coatings." Journal of Environmental Materials and Corrosion.

[7] Smith, J. A., & Johnson, R. W. (2019). "Advances in Non-Thermal Plasma Coatings for Corrosion Resistance." Journal of Materials Science.

[8] Y.S. Kim, H.J. Park, K.S. Lim, et al.Structural and mechanical properties of AlCoCrNi high entropy nitride films: influence of process pressure Coatings.

 DOI : 10.35291/2454-9150.2024.0141