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Effect of Hexagonal Boron Nitride Nanoparticles Additions on Corrosion Resistance for Zinc Coatings of Weathering Steel in Rainwater

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Abstract

Zinc and its alloy coatings are commonly used to provide cathodic protection for weathering steel. However, the steel substrate corrodes faster than the Zinc coating because of the coating's negative corrosion potential. Many studies have examined Zinc and alloy coatings' resistance to corrosion. Hot-dip galvanizing, Electrodeposition, and Zinc-rich coat (ZRC) spray are just some of the methods that can be used to deposit such coatings. Commercially available 99.95 % pure Zinc oxide was used in the electroplating process in this investigation. Steel samples were plated in Zinc sulphate and Zinc oxide solutions and were controlled by different bath parameters such as voltage, current, pH, temperature, and coating time. The addition of hexagonal Boron Nitride (h-BN) nanoparticles has also shown significant improvements in corrosion resistance. However, Zinc-based coating techniques reinforced with h-BN incorporation show the best corrosion current density (I_{corr}) of Hot dip 2 % wt. (2.1 µA/cm^2), ZRC 2.5 % wt., (4.4 µA/cm^2), and electroplating 15.75 g/L (0.081 µA/cm^2), which is an order of magnitude lower than coatings without h-BNs. The corrosion rates and current densities of Zn/h-BN coated layers were investigated in a controlled laboratory environment that mimicked natural conditions (Rainwater solution) by extrapolating polarization curves.

Keywords: Zinc, Boron Nitride (h-BN) nanoparticle, Corrosion resistance, Cold dip, Hot dip, Electroplating.

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1. Introduction

Zinc galvanization has been used extensively in the construction industry, particularly in the weathering steel used in the creation of bridges, buildings, and pipelines due to its exceptional resistance to corrosion.

Cold dip, hot dip, and electro-galvanizing are the three most common methods for producing Zinc-based galvanized steel sheets. There is a close relationship between the coating's microstructure and surface characteristics and its performance [1]. High-temperature oxidation of Zinc-electroplated grey cast iron produced a sub-surface layer with ideal defect distribution and compressibility stresses, greatly improving the material's fatigue and corrosion resistance [2]. Surfaces electroplated with Zinc have microstructural features indicative of a successful deposition process.

Electrodeposition additives (thiourea and dextrin on Zinc electroplating on mild steel in Acid Chloride solution) had a significant impact on the final product, and the plated samples proved more resistant to corrosion in salt water than the uncoated ones [3]. Because of differences in grain size and the incorporation of inert particles, Zinc composites exhibit a slightly more positive corrosion potential and lower corrosion current densities than pure Zinc coatings. Diamond or alumina particle addition to coatings slightly improved their corrosion resistance [4]. As the current density is increased, the weight of all Zinc deposition layers, regardless of their thickness or composition, will increase. Corrosion resistance performance of Zinc coatings produced by cold spraying versus other processes. Corrosion resistance is enhanced by the corrosion current density (I_{corr} of 28.24 A/cm^2) and corrosion potential (Ecorr of -0.1 mV) values calculated from polarization data for up to 72 hours of exposure to a NaCl solution with a pH of 7. An anti-corrosion barrier of at least 72 hours can be maintained by a Zinc cold dip coating applied to a mild steel base. The increased thickness made possible by cold spray makes it a viable option for extending the useful life of sacrificial Zinc coatings [5]. A metallic coating is highly advantageous in situations where preventing corrosion and abrasion is of paramount importance. In addition, electrochemical studies proved that ZRC's corrosion behavior was enhanced by the addition of nanoparticles. Adding nickel-20 chromium nanoparticles to ZRC increased corrosion resistance by 88.7 percentage points, while adding both TiO2 and nickel-20 chromium nanoparticles increased it by 99.8 percentage points [6]. Both calcium-free alkaline solutions and model pore solutions, (containing $Ca2^{+}$) influenced the corrosion characteristics of hot-dip galvanized steel by varying the pH and the severity of the resulting corrosion attack on the coating. Changes in air pH have a major impact on Zinc corrosion. Zinc corrosion rates were found to be unacceptable in both very alkaline (high pH) and very acidic (low pH) environments. Buildings with galvanized reinforcement last much longer than those without. This coating's benefits include improved resilience in the face of carbonation [7]. Composite coatings that contain h-BN are superior to those