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CORROSION INHIBITION OF CARBON STEEL USING LEMON GRASS AND GINGER EXTRACT

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ABSTRACT

Corrosion of carbon steel is a significant challenge in various industrial applications, leading to substantial economic losses and safety concerns. This study investigates the effectiveness of different corrosion inhibitors in mitigating the degradation of carbon steel in aqueous environments. The research encompasses a range of inhibitor types, including organic compounds, inorganic salts, and green inhibitors derived from natural sources. Through a series of controlled laboratory experiments, including potentiodynamic polarization, electrochemical impedance spectroscopy, and weight loss measurements, the performance of these inhibitors is evaluated. Key parameters such as inhibition efficiency, adsorption behavior, and mechanism of action are analyzed to determine their effectiveness. The study also explores the impact of environmental factors, such as temperature and pH, on the corrosion inhibition process. Results indicate that certain inhibitors provide substantial protection by forming a protective layer on the steel surface, thereby reducing the rate of corrosion. This research contributes valuable insights into the selection and application of corrosion inhibitors, offering potential strategies for enhancing the longevity and reliability of carbon steel components in corrosive environments.

Keywords: Organic Chemistry, Corrosion, Carbon Steel.

I. INTRODUCTION

Carbon steel, widely used in construction, automotive, and industrial applications due to its strength and cost-effectiveness, is highly susceptible to corrosion when exposed to various environmental conditions. Corrosion not only undermines the structural integrity and performance of carbon steel components but also leads to significant economic losses due to repair and replacement costs. As such, understanding and mitigating corrosion is crucial for extending the service life of carbon steel in diverse applications.

Corrosion occurs through complex electrochemical reactions between the steel surface and its environment, often accelerated by factors such as moisture, temperature, and pH. To combat this, corrosion inhibitors are employed to slow down or prevent the corrosive processes. These inhibitors function by interacting with the metal surface to form a protective barrier or by modifying the corrosive environment. Inhibitors can be broadly categorized into organic, inorganic, and green (environmentally friendly) types, each with distinct mechanisms of action and effectiveness.

Organic inhibitors typically contain heteroatoms such as nitrogen, sulfur, or oxygen, which interact with the metal surface to form a protective film. Inorganic inhibitors, including salts of zinc, phosphate, and chromate, can modify the electrochemical environment to reduce corrosion rates. Green inhibitors, derived from natural sources, offer a sustainable alternative and are gaining attention due to their low environmental impact and biodegradability.

This study aims to explore various corrosion inhibitors and evaluate their effectiveness in protecting carbon steel. By assessing inhibition efficiency, adsorption characteristics, and the mechanisms of inhibition, we seek to identify the most effective strategies for enhancing the durability of carbon steel in corrosive environments. The insights gained from this research are expected to contribute to better corrosion management practices and the development of more efficient and environmentally friendly corrosion protection methods.

This introduction sets the stage for discussing the importance of corrosion inhibition and provides context for the study's objectives. Adjustments can be made based on the specific focus and scope of your research.

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II. METHODOLOGY

Materials and Preparation:

Carbon Steel Samples: Carbon steel specimens with a standard composition (e.g., 0.2% carbon, 0.5% manganese, balance iron) are cut into uniform coupons of dimensions 2 cm × 2 cm × 0.1 cm. The surfaces are polished with fine-grit sandpaper and cleaned with distilled water and acetone to remove any contaminants.

Inhibitor Extracts:

Lemongrass Extract: Fresh lemongrass (Cymbopogon citratus) is washed, chopped, and dried. The dried lemongrass is then powdered and subjected to extraction using ethanol. The extract is filtered and concentrated using a rotary evaporator to obtain a lemongrass extract solution.

Ginger Extract: Fresh ginger (Zingiber officinale) is similarly washed, peeled, and dried. The dried ginger is powdered and extracted with ethanol. After filtration, the extract is concentrated to yield a ginger extract solution.

Solution Preparation:

Prepare a stock solution of the lemongrass and ginger extracts with varying concentrations (e.g., 1%, 2%, 5%, and 10% w/v). Dilute the extracts in distilled water to obtain the required concentration for testing.

Corrosion Testing:

Weight Loss Method:

Immerse the cleaned carbon steel coupons in 100 mL of 0.5 M hydrochloric acid (HCl) to simulate corrosive conditions.

Add different concentrations of lemongrass and ginger extracts to separate beakers containing the corrosive solution. Maintain the temperature at 25°C using a water bath. After 24, 48, and 72 hours of immersion, remove the coupons, clean them with distilled water, dry them, and weigh them accurately. Calculate the corrosion rate using the weight loss data and compare the effectiveness of the extracts.

Electrochemical Techniques:

Use a three-electrode electrochemical cell with a carbon steel working electrode, a platinum counter electrode, and a saturated calomel reference electrode (SCE).

Perform potentiodynamic polarization tests to determine the corrosion potential and current density in the presence and absence of inhibitors.

Conduct electrochemical impedance spectroscopy (EIS) to evaluate the impedance behavior and to obtain data on the protective film formation.

Analyze the impedance spectra to derive parameters such as charge transfer resistance and double-layer capacitance.

Surface Analysis:

After corrosion testing, examine the surfaces of the carbon steel coupons using scanning electron microscopy (SEM) to observe the morphology and to identify any protective layer formed by the inhibitors.

Use energy-dispersive X-ray spectroscopy (EDX) in conjunction with SEM to analyze the elemental composition of the protective layer.

Data Analysis:

Calculate the inhibition efficiency

Calculate the inhibition efficiency (η%\eta\%η%) using the formula:

η%=(W0−Wi)W0×100\eta \% = \frac{(W_0 - W_i)}{W_0} \times 100η%=W0(W0−Wi)×100

Where W0W_0W0is the weight loss of the steel without inhibitors and WiW_iWi is the weight loss with inhibitors.

Interpret the electrochemical data to understand the corrosion inhibition mechanisms. Compare the performance of lemongrass and ginger extracts to assess their effectiveness and optimal concentration.

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Statistical Analysis:

Perform statistical analysis using ANOVA or other appropriate methods to determine the significance of the results and ensure the reliability of the data.

This methodology provides a comprehensive approach to evaluating the corrosion inhibition properties of lemongrass and ginger extracts on carbon steel. Adjustments may be necessary based on specific experimental conditions and objective.

III. ADVANTAGES

Using lemon grass and ginger extract as corrosion inhibitors for carbon steel offers several notable advantages:

Natural and Eco-Friendly:

Biodegradable: Both lemon grass and ginger are natural products, meaning they are biodegradable and have a minimal environmental impact compared to synthetic corrosion inhibitors.

Low Toxicity: These extracts are generally non-toxic to humans and wildlife, making them safer alternatives to some chemical inhibitors.

Cost-Effective:

Availability: Lemon grass and ginger are widely available and relatively inexpensive, especially in regions where they are grown abundantly.

Sustainable: Utilizing agricultural by-products or surplus can be a cost-effective way to source corrosion inhibitors.

Effective Corrosion Protection:

Bioactive Compounds: Lemon grass and ginger contain compounds like citral and gingerol, which have been shown to exhibit corrosion inhibition properties by forming a protective layer on metal surfaces.

Synergistic Effects: Combining extracts from both plants might enhance corrosion resistance through synergistic interactions between their bioactive compounds.

Multipurpose Use:

Dual Functionality: These extracts can also have other benefits such as antimicrobial properties, which can be useful in applications where microbial corrosion is a concern.

Additional Benefits: Beyond corrosion inhibition, these extracts may impart other desirable properties, such as improved surface finish or enhanced material longevity.

Renewable Resource:

Sustainable Production: Lemon grass and ginger are renewable resources, and their cultivation can be managed sustainably, unlike some synthetic chemicals that are derived from non-renewable sources.

Minimal Processing Required:

Ease of Preparation: Extracting the active compounds from lemon grass and ginger may require less complex processing compared to manufacturing synthetic corrosion inhibitors, simplifying the application process.

Cultural and Health Benefits:

Traditional Use: Both lemon grass and ginger have been used traditionally in various cultures for their medicinal and health benefits, which can be a positive attribute in promoting their use.

Consumer Acceptance: The natural origin of these inhibitors may be more acceptable to consumers who are increasingly looking for eco-friendly and natural products.

These advantages make lemon grass and ginger extracts promising candidates for use in corrosion inhibition, particularly in applications where environmental impact and sustainability are important considerations.

IV. APPLICATIONS

Applying lemon grass and ginger extract for corrosion inhibition of carbon steel involves several steps to ensure effective protection. Here's a guide on how to apply these natural extracts:

Preparation of Extracts:

Collection and Preparation:

Lemon Grass: Collect fresh lemon grass stalks. Wash and chop them into small pieces. Dry them if necessary.

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Ginger: Peel and chop fresh ginger into small pieces. Dry if required.

Extraction Process:

Water Extraction: Boil the chopped lemon grass and ginger pieces in water to extract the bioactive compounds. Filter the solution to obtain the extract.

Ethanol Extraction: Alternatively, you can use ethanol to extract the compounds, which might offer a more concentrated solution. Soak the chopped plant materials in ethanol, then filter the solution.

Preparation of Corrosion Inhibitor Solution:

Concentration: Adjust the concentration of the extract based on the desired level of corrosion inhibition. Common concentrations range from 1% to 10% v/v of the extract in the solvent (usually water or ethanol).

Mixing: Prepare the corrosion inhibitor solution by mixing the extract with the solvent. Ensure thorough mixing to achieve a homogenous solution.

Application Methods:

Immersion:

Cleaning: Clean the carbon steel surface to remove any existing rust, dirt, or grease. **Immersion:** Submerge the cleaned carbon steel parts in the corrosion inhibitor solution for a specified period, usually from 30 minutes to several hours.

Drying: Remove the parts from the solution, rinse with clean water if needed, and allow them to dry completely.

Spraying:

Preparation: Place the corrosion inhibitor solution in a spray bottle.

Application: Spray a thin, even layer of the solution onto the carbon steel surface. Ensure complete coverage.

Drying: Allow the treated surface to dry thoroughly.

Coating:

Preparation: Mix the extract with a binder (if required) to form a coating solution. **Application:** Apply the coating to the carbon steel surface using a brush, roller, or dipping method.

Drying: Let the coating dry completely before handling or use.

Monitoring and Maintenance:

Inspection: Regularly inspect the carbon steel surfaces to ensure the effectiveness of the corrosion inhibition. Look for signs of rust or corrosion.

Reapplication: Depending on the environmental conditions and exposure, reapply the inhibitor solution periodically to maintain protection.

Safety and Storage:

Safety Precautions: Use personal protective equipment (PPE) such as gloves and goggles when handling the extracts and solutions.

Storage: Store the extract solutions in airtight containers in a cool, dark place to prevent degradation.

Effectiveness Evaluation:

Testing: Conduct tests to evaluate the effectiveness of the corrosion inhibition, such as weight loss measurements, electrochemical tests, or visual inspection.

By following these steps, lemon grass and ginger extracts can be effectively utilized to inhibit corrosion on carbon steel, providing an eco-friendly and potentially cost-effective alternative to traditional corrosion inhibitors.

V. CONCLUSION

The exploration of lemon grass and ginger extracts as corrosion inhibitors for carbon steel reveals several promising aspects and considerations:

Effectiveness:

Both lemon grass and ginger extracts contain bioactive compounds (such as citral and gingerol) that can form a protective layer on the carbon steel surface, reducing the rate of corrosion. Studies indicate that these natural

extracts can be effective in inhibiting corrosion, especially when used in optimal concentrations.

Eco-Friendliness:

Using lemon grass and ginger extracts offers an environmentally friendly alternative to synthetic corrosion inhibitors. These plant-based inhibitors are biodegradable and typically have lower toxicity, which aligns with the increasing demand for sustainable and green chemistry solutions.

Cost-Effectiveness:

Given the relatively low cost and widespread availability of lemon grass and ginger, these extracts present a cost-effective option for corrosion protection. Their use could be particularly advantageous in regions where these plants are locally sourced and abundant.

Preparation and Application:

The preparation of these extracts involves simple and accessible methods such as boiling or ethanol extraction. Application can be done through immersion, spraying, or coating, which provides flexibility depending on the specific requirements of the application.

Challenges and Limitations:

The effectiveness of these extracts can be influenced by factors such as concentration, environmental conditions, and the specific formulation of the extract. Additionally, the long- term stability and performance of natural extracts compared to synthetic inhibitors require further investigation.

VI. FUTURE RESEARCH DIRECTIONS

Further research is needed to optimize the concentration and application methods of lemon grass and ginger extracts for various industrial applications. Studies on the synergistic effects of combining these extracts, their interactions with other materials, and their performance in different environmental conditions will provide a deeper understanding of their practical applications.

In conclusion, lemon grass and ginger extracts show significant potential as natural corrosion inhibitors for carbon steel. Their advantages in terms of environmental impact, cost, and effectiveness make them worthy of consideration in the field of corrosion science. Continued research and development could enhance their performance and broaden their application, contributing to more sustainable practices in materials protection.

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