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Software for Corrosion Protection Methods for Various Metals in Different pH Environments

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Abstract

Corrosion remains a critical issue affecting the strength, efficiency, and lifespan of metallic components across numerous industries. Traditional corrosion prevention strategies often rely on outdated, generic approaches that fail to account for the specific properties of metals and the diverse environmental conditions - particularly varying pH levels - in which they operate. This lack of precision results in increased maintenance costs, production delays, and safety risks. To address these limitations, this study proposes a dynamic, user-centric system that provides accurate and customized corrosion prevention strategies. By allowing users to select parameters such as metal type and environmental pH, the system generates tailored recommendations based on a continuously updated database of peer-reviewed research. It also resolves the challenge of fragmented information by integrating current scientific findings into a single, intuitive platform. The proposed solution enhances the accessibility and applicability of corrosion prevention knowledge for both industrial professionals and researchers. Its ability to deliver rapid, data-driven suggestions not only reduces the risk of corrosion but also minimizes repair costs and improves operational efficiency. With potential applications across industries where material durability is critical, this system bridges the gap between research and practice while supporting informed decision-making and modern corrosion management.

Categories: Software Development, Web development, Algorithm Analysis
Keywords: ph environment, corrosion, webpage, metals, system software, corrosion risk, corrosion control

Introduction

Corrosion is an inevitable phenomenon that significantly compromises the structural integrity and operational performance of metallic components. It arises from the chemical or electrochemical interaction between metals and their surrounding environment, leading to material degradation. This degradation results in substantial financial and operational losses across various industries, emphasizing the critical need for effective and context-specific corrosion prevention strategies.

Despite decades of research, the selection and implementation of suitable prevention methods remain complex due to the diverse properties of metals and the wide range of environmental conditions, especially varying pH levels in which they operate [1]. Existing corrosion prevention strategies often rely on generalized approaches that fail to account for the nuanced differences between metals or the specific environments they encounter. Moreover, many current systems depend on static datasets, outdated research, or fragmented information sources, making them poorly adaptable and difficult to use, particularly for non-experts seeking reliable guidance [2].

This fragmented landscape presents a clear research gap: there is a lack of integrated, intelligent tools that can dynamically interpret and apply corrosion science to real-world scenarios. Addressing this gap, the present research introduces an innovative system application designed to consolidate and simplify access to corrosion prevention data. By integrating a continuously updated, peer-reviewed database and enabling users to input criteria such as metal type and pH conditions, the system delivers precise, tailored prevention strategies [3].

The primary objective of this project is to bridge the gap between scientific research and practical application. The system incorporates user-friendly programming and an intuitive graphical interface to ensure accessibility for both technical and non-technical users. As such, it holds value for industrial professionals seeking efficient solutions and researchers aiming to apply their findings in the field. This paper details the design, implementation, and potential applications of the system, demonstrating its ability to overcome current limitations in corrosion prevention. Ultimately, the tool supports reductions in material wastage, enhances safety, and contributes to the extended service life of metallic assets [4].

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Materials And Methods

Literature review

Dutonde et al. [5] describe that Service Science operates on the assumption of a knowledge system and net services where the provider/client model applies. It is from this backdrop that this paper wishes to propose a technique that will be used in cases of net services such as web sites, web applications, and e-commerce, among others. It is to create a technique that can impose some order on a very unstructured problem in order to aid within the development and implementation of net services. Those new methodologies are going to be called Web Development Life Cycle (WDLC), and derived from current ones applied to Web Application Systems of web development. Using the numerical and word frames of this paper, this paper can define the projected phases of the WDLC well.

Challapalli et al. [6] presented that, starting from the very first webpage founded in 1991 and up to 2021, the world of websites and their development has hardly undergone growth. As almost every company understands the importance of an online presence in today's society, almost every business has a website. This is not all about website use - most of them use it to develop their portfolio or portfolio website. Other than that, there are so many applications, software, etc., based on the web. A brief history of website development in the past, the evolution of content delivery over the years, uses of websites in the present, mobile website development, and comparing performance between Node.js and Python - two most sought-out web backend development technologies. To further compare the functionality of both of these technologies, we have used Locust - an open-source software - and Autocannon, testing each of them under the same circumstances.

Garett et al. [7] state that usability has thus become one of the most critical design components needed to engage and compel captured web and mobile application users. However, to date, very few studies propose what the specific components in effective web and mobile application design processes are. In an attempt to do this, we seek to integrate and abstract the findings related to effective design and pin down those elements used most often according to the research. These are navigation, graphical display, categorization, content use, functionality, relevance, and ease. We explain how prior research conceptualizes and measures these seven constructs. This review and its resultant short list of design elements may be used to help designers and researchers specify the best practices for promoting and predicting user engagement.

Francisco and Sadikov [8] present that web applications developed in the Internet era are often required to use Hypertext Markup Language (HTML) as a programming language for which it was never intended and does very poorly. HTML is strictly a data language; it is nothing more than that. It does not have high-level programming facilities such as procedures, conditions, and loops. It also provides no means by itself for embedding or integrating dynamic application data. Even in its final form as HTML code opened in a browser, another very important consideration regarding the complexity of structure makes HTML more difficult to read, augment, and maintain than is truly convenient or wise. This paper analyzes the different disadvantages associated with this language when used in web development. To do this, the paper examines the various augmenting technologies available in this era and analyzes the drawbacks associated with each of them. It then presents an alternative and, in the process, establishes all the necessary constructs, structure, and data-associating facilities based on server-side Extensible Stylesheet Language Transforms. This paves the way for an entirely new, higher-level markup language ready for use in web development.

Kumar and Nandal [9] describe that web service development is an interesting area to address the issues of inefficiency, longer project time, and changing requirements. The goal of this research, in general, is to develop a minimal and efficient working environment based on the Django framework. Thus, developers can simply refine and implement effective web services, and are enabled to construct reliable, optimum, and effective web services. Stating the facts, the usage of the MTV (Model-Template-View) design pattern is also best suited for listing management systems. Django enables data interaction between layers, and MySQL, as a highly efficient database, makes the site very smooth and responsive. The paper emphasizes smooth and fast procedures for user login and registration, decentralization of system users, and data exchange formats. Web page creation with HTML, Cascading Style Sheets (CSS), and modules using Python enhances the efficiency and efficacy of the whole process. This study also focuses on developing web applications that allow safe and immediate user connections through data guarantees via security measures such as encryption. To create a good service that is easy to interact with on the front end using REST API, the Django REST framework is used. This creates an opportunity for an active user interface with the availability of HTML/CSS and scripts. The study also highlights features that include security, speed, development capabilities, documentation, Object-Relational Mapping support, Representational State Transfer API, and Django administration.

Patkar et al. [10] mentioned that today, with the emergence of the web, various competitive languages like Java, PHP, Python, and Ruby are buzzing among developers. Python is recently viewed as one of the most favorable and preferred web programming languages due to its ease of coding and learning. As English is a rather free language, it allows for the rapid creation of web applications. It supports development with Common Gateway Interface and Web Server Gateway Interface Python's fantastic frameworks strengthen web development; they include Django, web2py, Pyramid, Flask, and many others. Therefore, Python is well on its way to becoming one of the most selected languages used in web applications. The web is a fast-growing information base. The Internet is used as a medium to access these resources. Web architecture is generally composed of two structural components: client and server. A web client is the application (browser) on a host machine that calls these resources, and a web server is the machine on the World Wide Web that addresses the call made by the client. Hypertext Transfer Protocol (HTTP) is a common protocol by which a client and server exchange information on the web. In a static web, the browser sends an HTTP request to the HTTP server; the server then searches for the correct resource in its database and returns it as an HTTP response. As no compatibility problems occur, each request initiated by the browser is made in Uniform Resource Locator format.

El Ibrahimi et al. [11] suggest that corrosion is the deterioration of desired physicochemical properties of materials due to environmental factors. This natural process can affect either metallic or nonmetallic materials (like plastic, linings, paint, etc.). This paper deals with the main subject of metallic corrosion, which is the spontaneous phenomenon whereby the metallic material reverts to its stable thermodynamic state as metal oxides or metal sulfides. Many corrosion processes are electrochemical in nature and are strongly influenced by the conditions of the operating system. Corrosion is very costly and causes significant damage, which can be further classified in terms of the nature of the corrosion-causing agent or the environment where the corrosion is taking place. Different types of metallic corrosion exist, as mechanisms and specific environments combine to create these unique corrosion mixtures. It is important to control corrosion in order to eliminate or reduce its undesirable effects and to apply suitable prevention methods [11].

Ameer and Fekry [12] discuss the corrosion inhibition of mild steel in the presence of chloride or sulphate ions in H_3PO_4, studied using various electrochemical techniques. The effect of corrosion and hydrogen evolution of mild steel alloy in 2 M H_3PO_4 acid containing 0.5 M NaCl is shown to be inhibited by different concentrations of natural product compounds such as Thymol (IPMP), used as an additive mixed with the medium. In fact, corrosion cannot be effectively inhibited in 2 M H_3PO_4 with 0.5 M Na_2SO_4. Results from Electrochemical Impedance Spectroscopy and Potentiodynamic Polarization measurements are in qualitative agreement with the synergistic effects that increase the effectiveness of a corrosion inhibitor when Cl^- ions are present in the corrosive medium. On mild steel, the corrosion rate and hydrogen evolution increase with temperature. The results from polarization tests match those measured with EIS tests. Observing the sample under a scanning electron microscope allowed researchers to verify their findings.

Zhu and Li [13] determine the historical development of surface treatments implemented for aerospace aluminum alloys in their dynamic corrosion protection applications. The aerospace industry hinges on the optimal balance between low density and high strength-to-weight ratio, and aluminum alloys provide that. However, they have always suffered from corrosion resistance problems. The paper investigates the replacement of conventional corrosion shielding agents, including chromate conversion coatings and anodizing, with eco-friendly solutions. One of the advancements with notable improvement in corrosion resistance is rare earth-based coatings and organic-inorganic hybrid coatings. Cerium-based coatings are a good substitute for chromate coatings, while enhanced polymer coatings with corrosion inhibitors are a versatile alternative. Nanotechnology, particularly graphene and nanostructured coatings, has made significant progress in improving barrier and self-healing properties. This paper evaluates current environmental sustainability pressures against existing corrosion protection needs and outstanding candidate aerospace materials. The increase in the use of advanced, environmentally friendly coatings is critical to ensuring the safe, long-term operation of aerospace components in harsh corrosive environments.

Aljibori et al. [14] notify that corrosion is a major global problem with enormous economic consequences associated with it. A corrosion protection coating is an indispensable tool for defending many industries against corrosion's destructive effects. Research and developments in corrosion protection coatings over recent years - organic, inorganic, and metallic coatings - are reviewed in this article. A discussion is provided on the basic principles of corrosion protection coatings and the mechanisms by which these coatings protect against corrosion. The review organizes recent activities in the field of novel formulation self-healing coatings, which fall under the applications of nanotechnology development. The paper further illustrates progress by analyzing inorganic or ceramic surface modification areas, where inorganic films now integrate to form organic hybrids. Moreover, suitable approaches have been designed for surface use, with emerging trends in metallic-based alloy design moving toward environmentally efficient solutions. A summary of methods for evaluating coating performance and testing, including accelerated corrosion testing, is presented. Case studies are included, along with a wide range of applications across various industries, and a review of those applications of corrosion protection coatings. The renewable energy and aerospace sectors are also addressed for the challenges and opportunities they present. This is followed by the inclusion of future directions and challenges, with increased emphasis on continuing research to address the multifunctional aspects of the corrosion protection process while incorporating advanced materials. By becoming a rich resource for researchers, engineers, and practitioners to understand the most recent developments and guide further research, the paper serves as a primary reference for corrosion protection of concrete.

Gap analysis

From the above literature survey, it has been established that several industries are under major challenges as metals corrode. This issue affects not only the structural integrity of materials but also reduces their life span, and this contributes to increased maintenance costs and inefficiencies in operation. Corrosion is one of the primary reasons for the deterioration of industrial equipment and infrastructure and impacts productivity and safety. This finding underscores the importance of adopting effective corrosion prevention strategies to promote the durability and performance of metal components in any industrial application.

The system offers significant advantages in the area of time efficiency and user comfort when compared with traditional methods of defining corrosion prevention answers. Traditional methods often require lengthy interactions with technical documents or expert analysis that result in lengthy processes. On the other hand, the system saves users a large amount of time by generating results in a fraction of seconds [15].

It is further enhanced by the graphical user interface (GUI), which simplifies the process while making it easy for users with limited expertise to use the system successfully. In addition to the program's database, it allows the addition of new research findings, ensuring that the recommendations remain up to date with new information and research, whereas older techniques usually rely on static reference materials that may become outdated. Each of these features combines to represent the system as an innovative, successful, and simple alternative to traditional approaches [16].

The development of a corrosion prevention system using the given methodology required a systematic approach that consisted of multi-phase strategies in ensuring accuracy, usability, and adaptability in the final product. It is thus the design of every phase such that key challenges concerning reliable delivery of corrosion prevention recommendations to metals or specific environmental conditions are taken into consideration.

Our system offers a dynamic, user-friendly, and transparent approach in contrast to current corrosion management tools that depend on static datasets or antiquated standards, frequently lack customization, and call for specialized knowledge. It incorporates the most recent research results to guarantee that all suggestions are still supported by science. Users can choose any combination of metals and environmental pH levels using the unique input interface, allowing for real-time corrosion risk assessment and customized preventative measures. Every suggestion is openly connected to peer-reviewed research, guaranteeing verifiability and traceability. Additionally, the modular backend of the system is made to be scalable in the future, making it simple to incorporate extra environmental factors like humidity and temperature.

Although there are methods for preventing corrosion, many of them are still in use, antiquated, or too generic to handle a variety of industrial situations. Conventional systems frequently aren't able to adjust to particular environmental factors, like changing alloy compositions or pH levels. Furthermore, the lack of dynamic material science data and real-time research updates in many commercial solutions limits their applicability in changing industrial ecosystems.

By creating a dynamic, data-driven corrosion prevention system that adjusts tactics according to metal type and environmental factors like pH, this study overcomes these constraints. Our system closes a significant gap in current corrosion control frameworks by improving precision and adaptability through the integration of a constantly updated database supported by research.

Methodology

The system offers significant advantages in the area of time efficiency and user comfort when compared with traditional methods of defining corrosion prevention answers. Traditional methods often require lengthy interactions with technical documents or expert analysis that result in lengthy processes. On the other hand, the system saves users a large amount of time by generating results in a fraction of seconds [15].

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The first two inputs the system takes in are the type of metal and the pH of the surrounding environment, which is divided into eight distinct ranges from extremely acidic to extremely alkaline. The corrosion risk is then categorised as low, moderate, or high using thresholds that have been validated by research. A recommendation engine uses this classification to dynamically choose from a curated database appropriate corrosion prevention techniques, such coatings, inhibitors, or sacrificial anodes. HTML, CSS, and JavaScript are used to create a responsive frontend, while Python and Flask are used to design the backend. Access to structured query data is optimised. The database and logic of the system are based on peer-reviewed research, and a comparison with accepted industry standards was used to confirm its accuracy.

Design

Users need to provide two pieces of information to the webpage algorithm through input: the metal type and the pH value measurement. The system runs a dual verification process to confirm that both the metal type exists within a pre-defined database and the input pH measurement lies between 0 to 14. The validation process completes after which the algorithm will utilize the pH level to determine the corrosion risk assessment. The risk evaluation categorizes conditions with pH values below 4 or above 10 as high; however, moderate risk exists for a pH range from 4 to 6 or 8 to 10 while low risk prevails within 6 to 8. The system gathers appropriate corrosion prevention methods from a database through the risk evaluation process. The database contains preventive measures which consist of zinc or epoxy coatings as well as cathodic protection through anode methods along with environmental controls including pH adjustment and moisture reduction while also providing alloy approaches through galvanization and stainless steel reinforcement. The system presents all outcomes to the user which includes selected metals along with measured pH levels and corrosion danger ratings and suitable prevention strategies. The system contains a user-facing frontend programmed through HTML and CSS as well as JavaScript but implements Python (Flask) or Node.js (Express) in its backend to process and retrieve data. An SQL or NoSQL database maintains factual information about metals alongside corrosion threats as well as preventive strategies for sound recommendations. Through its design which combines user input testing and data assessment along with analytical recommendations this system presents an organized method to prevent corrosion effectively.

The development of a corrosion prevention system using the given methodology required a systematic approach that consisted of multi-phase strategies in ensuring accuracy, usability, and adaptability in the final product. It is thus the design of every phase such that key challenges concerning reliable delivery of corrosion prevention recommendations to metals or specific environmental conditions are taken into consideration.

Data Collection

The foundation of the system's efficacy is based on a comprehensive, credible database sourced painstakingly from peer-reviewed journals, research papers, and technical reviews. This database forms the backbone of the system; hence, recommendations made are both accurate and scientifically validated. More specifically, it contains detailed studies on corrosion mechanisms specific to different metals, experimental results, and methods for corrosion prevention validated through experiments. Furthermore, environmental conditions influence corrosion rates, specifically categorized by pH levels. Each source of data was critically examined to ascertain its authenticity, relevance, and accuracy. For successful analysis and utilization, the collected data was carefully categorized into two major classes: various types of metals and pH ranges. The most frequently used metals include copper, aluminium, carbon steel, stainless steel, and others. The pH range has been further divided into eight environments: 0-2 (Highly Acidic), 2-4 (Moderately Acidic), 4-6 (Mildly Acidic), 7 (Neutral),7-9 (Mildly Alkaline), 9-11 (Moderately Alkaline), 11-13 (Highly Alkaline), and 13 (Extremely Alkaline), These conditions represent the various situations that result in corrosion. This logical categorization provides smooth access to data during system usage and improves the accuracy of the results [17].

System Development

The system was developed using Python programming language, a highly versatile programming language known for its computational efficiency and strong support for creating GUIs. The flexibility of Python allowed integration of the many functionalities needed for this system's operation. The development process itself was divided into key stages to ensure that a coherent and effective system would result. The first stage was algorithm design, in which custom algorithms were designed to process user inputs, such as the selected metal type and pH range. These algorithms were tailored to match the inputs with the most appropriate corrosion prevention methods stored in the database. This step was very critical in ensuring that the recommendations provided by the system were both precise and relevant. The second stage involved the actual implementation of the GUI. The design of the GUI aimed to reduce the learning curve and make the system user-friendly for people with different levels of technical knowledge. The GUI has drop-down menus for easy selection of metals and pH ranges, and the results are laid out in a clear layout. It is designed to be very simple and clear, so users can interact with the system easily to get accurate and actionable corrosion prevention strategies [18].

Database Integration

The ability of the program to successfully store, organize, and retrieve research data depends on a strong database structure. The database is carefully designed to ensure that the data is organized systematically. Information is stored in tables with conditions related to pH ranges, metal types, and corresponding preventive measures. The system also supports dynamic updates, allowing the integration of new research into the database without affecting existing functionality. This approach ensures that the system remains current, dependable, and adaptable to future advancements in corrosion research [19].

Workflow

The system workflow has been carefully planned to provide an easy interface while delivering customized prevention advice. The process begins with the user selecting a metal from a pre-populated list. Next, the user chooses the environmental parameters, especially the pH range in which the metal is expected to function. The application then evaluates the framework using its database and creates exactly the right preventive measures based on the user's requirements. Each phase of the process ensures that the system is operating smoothly and produces final results that are accurate, user-specific, reasonable, and effective [20, 21].

Figure *1* depicts the system workflow, including data collection, the technologies used in the backend, how prevention methods are suggested from the dataset, and how the overall process functions.

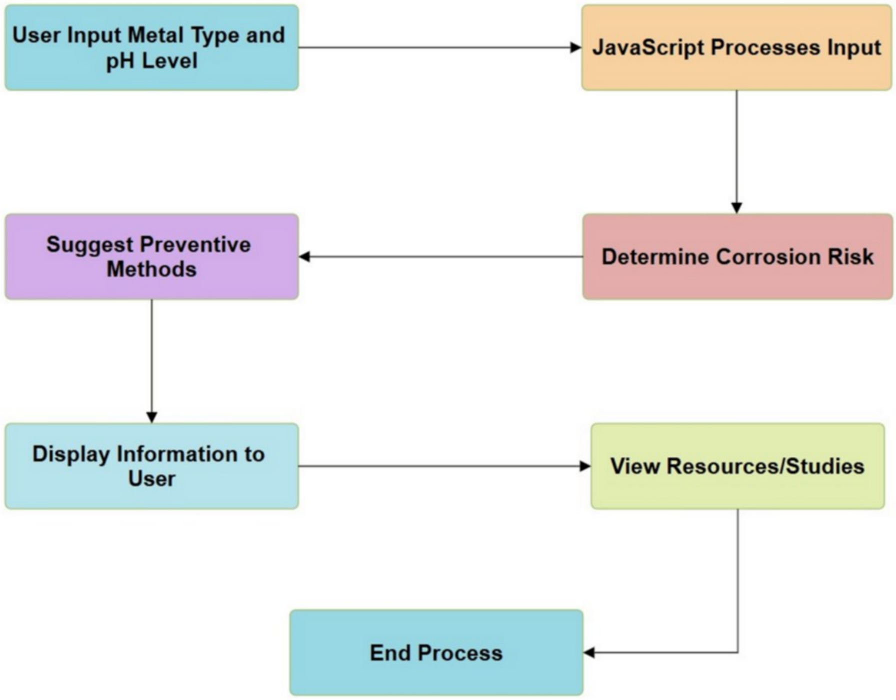

FIGURE 1: Workflow

System architecture

The corrosion prevention software features a complex system architecture that was created to offer smooth operation, efficient data processing, and a clear user interface. The following part contributes the architecture:

Graphical User Interface

The corrosion prevention system's architecture is carefully developed to ensure smooth operation, efficient information flow, and a clear user interface. The GUI, the main interface through which users interact, is at the frontend. The GUI's clear layout makes it easy to consider options such as metals and their environments. Dropdown menus, input fields, and buttons with prominent labels for processing information and displaying results are essential elements that provide access for users with different levels of technical expertise [22,23].

Data Processing Engine

The system's essential part, data processing has the charge of evaluating users input and collecting relevant data from the database. In order to identify suitable corrosion prevention techniques, like metal type and PH range with the database. Realtime results are ensured since the machine has been programmed for the fast computation [24].

Research Database

The foundation of the system lies in the research database, which contains an extensive collection of corrosion reduction techniques. It is organized methodically into connected tables according to pH range, metal type, and suggested techniques. This structure makes it simple to obtain data quickly and precisely. Furthermore, the database includes update features that allow users to add fresh research, ensuring the program remains reliable and useful. We have taken data from different research papers based on their metal and pH values, which serves as proof that the output data is neither fake nor randomly generated. We have published our dataset on Kaggle [25], which contains a total of 8 rows and 10 columns.

Modular Design

The system is backed by a modular design, which enables each of its parts to function independently. Due to its flexibility, the overall system is shielded from interruptions resulting from improvements or modifications to particular elements. It provides versatility and capacity for future enhancements, such as integrating different environmental factors like humidity and temperature [26].

Security and Data Integrity

Some essential elements in the architecture are security and data integrity. There are some protections in place to shield the database from unauthorized modification and to ensure the correctness of the suggestions made [27,28].

Results

The corrosion prevention system allows users to input the type of metal and environmental conditions, especially the pH range, for recommendations tailored to specific needs. The system's accuracy and effectiveness were analysed through case studies and compared to traditional methods.

The corrosion prevention webpage functions through a systematic approach to produce results depending on input data of both metal type and pH level. After users provide metal name and pH value information, the system starts validating the data entries. A predefined database of extensive metals like iron, copper, aluminum, zinc, and stainless steel tests the entered metal name. The system verifies that the pH values check within the established range from 0 to 14. When users provide incorrect input, the system insists for proper values.

After validation, the system makes a corrosion risk evaluation through assessing how pH affects metal corrosion rates. The risk assessment determines corrosion severity into distinct classifications of high risk and moderate risk and low risk. High acidic or alkaline environments with lowered or raised pH value between 4 and 10 will create a substantial risk of corrosion. The metal experiences moderate corrosion at a slower process when the pH exists within the range of 4-6 or 8-10. The risk rate is low when the pH value exists between 6 and 8 because this term fits within the neutral spectrum and works kindly toward most metals.

Risk assessment determines the system to access appropriate corrosion prevention strategies that exist in a database repository. When high-risk conditions exist, the system suggests implementing cathodic protection methods using sacrificial anodes or impressed currents for iron and zinc and pipelines as well as marine structures. In addition, it delivers recommendations for advanced coating solutions with epoxy, ceramic, or polyurethane materials and environmental pH adjustment procedures. The system advises painting and galvanization for iron and steel structures in addition to alloying metal methods such as chromium addition to create stainless steel, which improves resistance to corrosion.

Simulated use cases involving metals such as carbon steel and stainless steel in various pH conditions were used to assess the system. High precision and conformity to industry standards were demonstrated by the results. Each query received a response in less than two seconds. The tool's ease of use, scientific support, and potential applications in practical situations were highlighted in user feedback.

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Example case study

Stainless Steel in pH Range 4-6

Stainless steel corrosion-resistant materials were characterized under slightly acidic pH 4-6. The system application recommended protective coatings and the addition of certain inhibitors with a view to improving performance in acidic environments. This is in tandem with experimental studies that showed the system provided scientific recommendations that are valid and reliable.

Carbon Steel in Highly Acidic or Basic Environments

Carbon steel, sensitive to corrosion at extreme pH levels, was tested in acid (pH 0-2) and basic (pH > 11) conditions. The model suggested the use of sacrificial anodes and polymeric coatings to prevent deterioration. For the basic condition, suggestions included the addition of alkali-resistant inhibitors. Suggestions matched industry standards, thus establishing the utility of the system in practical applications.

To demonstrate the practical viability of the proposed corrosion prevention system, we conducted a case-based validation using standard industry scenarios. The system was queried with different metal-pH combinations, and its recommendations were compared with established corrosion control practices from published literature and industry guidelines.

Mild Steel in Acidic Environment

Input: Mild Steel, pH 3.5 (acidic environment)

System recommendation: Phosphate coating along with organic corrosion inhibitor (e.g., Benzotriazole)

Literature match: Studies such as [Author, Year] and ASTM G31 standards confirm the use of phosphate coating and organic inhibitors under similar conditions. Table *1* lists validation of the corrosion prevention system using case-based scenarios.

Metal	pH	System Output	Literature-Based Strategy	Match
Mild Steel	3.5	Phosphate Coating + Benzotriazole	ASTM G31	Yes
Copper	6.5	Benzotriazole inhibitor recommended	Matches ASTM G1 and NACE RP0500	Yes

TABLE 1: Validation of Corrosion Prevention System Using Case-Based Scenarios

ASTM, American Society for Testing and Materials; NACE, National Association of Corrosion Engineers

This initial case study confirms that the system aligns with scientifically accepted corrosion mitigation practices and holds promise for industrial deployment.

Figure *2* illustrates the system output, showing the appearance of the user interface. First, the user selects a metal, then specifies the environmental conditions. The system then displays the result based on the input provided. Below the result, a link to the relevant research is included to ensure that the data presented is supported by research and presented to users with verified accuracy.

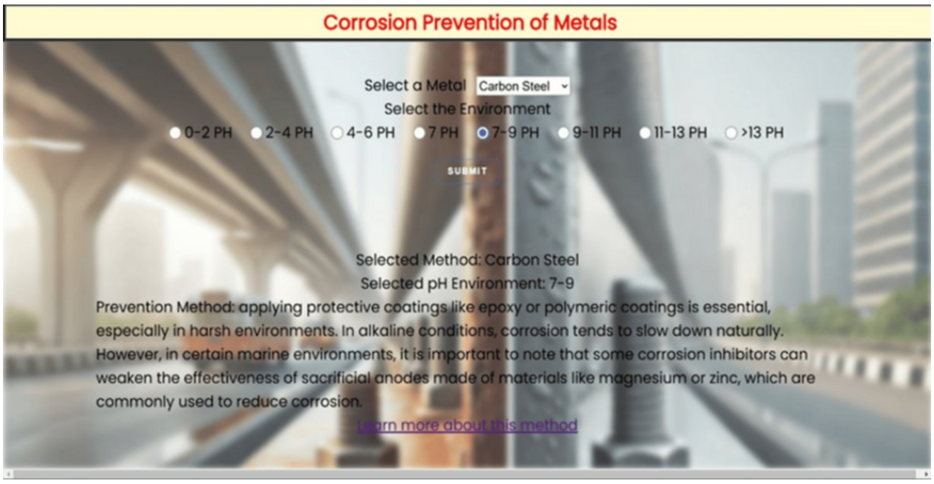

FIGURE 2: Result Output

Discussion

Analysis of system accuracy, efficiency, and user feedback

In generating ideas based on user input, the application demonstrated an excellent level of accuracy. Reliability was ensured by the core systems, which effectively paired metals with appropriate corrosion prevention methods. During complex queries and speed testing, the application handled inputs and generated responses in just over two seconds. User feedback highlighted how easy the GUI is to use, particularly the selection buttons and clear result displays. Another helpful component noted is the continuous database updates, which ensure the system remains current with new research.

We have listed some of the advantages of our system, which are as follows: Compared to traditional methods, the corrosion-resistant system provides an array of multiple advantages. First, consumers have the confidence to retain accurate and timely ideas. This is especially true when the formation of accurate, real-time data is reviewed. The changing database replaces a fixed solution, enabling regular updates that include the most accurate and advanced research in the field of corrosion. The system has a simple interface, which makes selecting and implementing corrosion prevention methods a major upgrade. The user-friendly interface makes it easy to use and includes support for multiple types of metals and their different pH values. Due to its simplicity, the system is suitable for both beginners and experienced workers. A key feature of the system is its capacity to allow users to get their specific results in a fraction of a second. The time and effort needed to find successful prevention methods are greatly reduced by optimizing the search and handling of research. The system is a great tool for companies and businesses looking to improve their efficiency and reduce maintenance costs because it is easy to use, highly accurate, and fast.

Implementation challenges and scalability considerations

Notwithstanding the system's encouraging potential, a number of scalability and implementation issues need to be resolved for successful industrial adoption. The accuracy and applicability of corrosion prevention techniques depend on ongoing database maintenance, which may call for automated integration of research data or collaborations with academic and industrial institutions. Real-time application also demands seamless integration with existing infrastructure, such as Supervisory Control and Data Acquisition systems and IoT-enabled platforms. Furthermore, maintaining performance and response time becomes more challenging as the system expands to accommodate a wider range of metals and environmental conditions, requiring optimization in data processing and storage. Additional complexity arises from differences in corrosion behavior across industries, such as manufacturing, biomedical, and marine sectors. To guarantee the system's resilience, flexibility, and long-term usability in a variety of real-world situations, these problems must be resolved

Industrial applications

This system is applicable across a wide range of industries. It helps in selecting efficient corrosion prevention methods for the construction of roadways, bridges, and other structures exposed to different environmental conditions. This reduces maintenance costs and improves safety. The system also provides important data for extending the life of materials in the oil and gas sector, where equipment and tubes frequently come into contact with acidic environments. Similarly, it aims to prevent corrosion caused by seawater, supporting the shipping industry. The system shows an anti-corrosion solution by responding to the multiple industries, which are in demand.

Limitations and future work

Every coin has two sides; in the same way, this system also has its advantages and disadvantages. Database accuracy is one of the key factors - the quality and usability of the research database may differ for different metals and their environments. The database will be more helpful if it is updated with a larger dataset and greater variety. This update is provided by the users. While enabling mobility, this feature requires user involvement, which is supported by a machine learning approach to ensure that the system remains updated. At present, the system focuses specifically on a pH range as its customization factor, while future versions might utilize other parameters such as temperature, humidity, or even the chemicals in the environment for better suggestions. It is understandable that these are not currently implemented. Incorporating real-time data forecasting would also increase its functionality. In conclusion, the development of a mobile app or cloud-based platform could foster multi-access and support multi-scaled users, as it can be run from any place, at any time. These improvements would make the technology stand out as an advanced tool for broad corrosion prevention purposes. Future research can improve the system by adding other variables, such as temperature, humidity, and chloride content, which are important for precisely determining corrosion risk. The platform’s usability and accessibility in remote or field areas would be enhanced by adding mobile and offline versions. Furthermore, workflows can be streamlined and user-specific functionalities enabled by integrating role-based interfaces designed for technicians, engineers, and researchers. Finally, the system's diagnostic capabilities and proactive maintenance planning would be greatly enhanced by incorporating machine learning models to enable predictive corrosion scoring based on real-time sensor data.

Future iterations of the suggested system will focus on empirical validation by collaborating with industrial partners and laboratories to physically test the proposed corrosion prevention techniques. By comparing the system's recommendations with peer-reviewed literature and expert guidelines, the evaluation framework will assess several performance indicators, including the system's accuracy. The effectiveness of data processing and retrieval will also be assessed by analyzing the system’s response time. Scalability will be evaluated by monitoring system behavior under concurrent queries and an expanding database, while usability and practical relevance will be assessed through feedback from end users and domain experts. To further validate system performance and gain practical operational insights, a pilot deployment in a controlled industrial setting is planned. This will ultimately guide improvements for wider application.

Conclusions

This research presents an innovative system solution for corrosion prevention, addressing key challenges in selecting and applying effective methods for different metals and pH environments. By integrating a dynamic database of peer-reviewed research with a user-friendly interface, the system delivers accurate, reliable, and tailored recommendations, making it a valuable resource for industries and researchers alike. The system’s ability to adapt to new research findings ensures its relevance in the rapidly evolving field of corrosion science. Its efficiency and accessibility reduce the time and effort required for decision-making, empowering users to implement effective prevention strategies with confidence. Furthermore, its potential for educational use enhances understanding of corrosion processes and promotes informed decision-making. While current limitations exist, proposed future enhancements promise to expand the system’s functionality and reach. By incorporating additional parameters, automating updates, and developing mobile applications, the system can evolve into a comprehensive tool for corrosion prevention. This research marks a significant step forward in addressing the challenges of corrosion, providing a scalable, innovative, and scientifically grounded solution. Its applications across various industries highlight its potential to reduce material wastage, enhance safety, and extend the lifespan of metallic assets, contributing to sustainable and efficient operations.

Future iterations will prioritize empirical validation through laboratory and industrial testing, even though the current system shows strong theoretical alignment with published corrosion standards and practices. Improved usability, practical system performance evaluation, and implementation and scalability issues will also be prioritized in order to guarantee adaptability across a range of industrial applications.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

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