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Intelligent Algorithms for Air Pollution Corrosion Risk Assessment and Management of Automotive Materials

Xin Wang[1,a,*], Kaixu Ren[1,b], Mengmeng Zhuang[1,c], Xiuxu Wang[1,d], Jiayu Wang[1,e], Peng Liu[1,f], Jiawei Zhao[1,g]

[1]Automotive Data of China Co., Ltd, Beijing, China
[a]wang_xin@catarc.ac.cn, [b]renkaixu@catarc.ac.cn, [c]zhuangmengmeng@catarc.ac.cn, [d]wangxiuxu@catarc.ac.cn, [e]wangjiayu@catarc.ac.cn, [f]liupeng2021@catarc.ac.cn, [g]zhaojiawei@catarc.ac.cn
[*]Corresponding author

Abstract: *The evaluation of corrosion risk of automotive materials refers to the assessment of the potential risk of corrosion of automotive materials during use, in order to determine their impact on automotive performance and safety. At present, the methods for assessing and managing the corrosion risk of automotive materials are mainly based on expert experience and manual measurement. These methods have problems such as inaccurate evaluation results and low efficiency. With the development of artificial intelligence technology, intelligent algorithms are gradually being applied in the automotive field. Therefore, this article proposed a risk assessment model for automotive material corrosion based on intelligent algorithms, aiming to predict risks in advance and reduce unnecessary losses. This article mainly applied experimental analysis and algorithm comparison to analyze the influencing factors of automotive material corrosion, and compared the performance of different intelligent algorithms. The experimental results showed that the minimum error rate of the support vector machine algorithm was 9.8%, and further improvement of the intelligent algorithm was needed.*

Keywords: *Intelligent Algorithms, Automotive Materials, Corrosion Risk, Assessment and Management*

1. Introduction

As an important means of transportation, automobiles have become an indispensable part of people's daily lives. However, automobiles are susceptible to various factors during use, among which corrosion is an important issue. Corrosion can lead to problems such as shortened service life, reduced safety, increased maintenance costs, and in severe cases, may even lead to traffic accidents. Therefore, it is necessary to conduct risk assessment and management of corrosion of automotive materials.

With the development of automobiles, the requirements for materials and functions are also increasing. Many scholars have conducted research on intelligent algorithms. Oswald C studied a new data compression method from the perspective of data mining, with a focus on sequence pattern mining methods commonly used in text compression. He attempted to utilize the deep correlation between words in language to achieve better text compression. He proposed a new effective method called universal Huffman tree encoding, which allows for universal compression of any text at the word level through a corpus [1]. Musaed Alrashidi compared the most common traditional numerical estimation methods with current intelligent optimization algorithms to demonstrate how to accurately estimate the impact of size and shape on wind resource assessment. He used intelligent optimization algorithms and numerical methods to evaluate wind energy resources [2]. Trust Tawanda proposed a network-based intelligent node size algorithm for the maximum traffic problem in directed networks. The intelligent node symbol algorithm is intelligent because it does not use the incremental path method to calculate the maximum market value. The principle of intelligent node labeling algorithm is to balance the total input and output values of all intermediate nodes, which can avoid excessive or stagnant traffic and reduce underutilized output arcs, thus designing the optimal network [3]. Few people have conducted risk assessment and management research on corrosion of automotive materials, so the topic proposed in this article has contemporary value and practical significance.

In this article, the hazards and causes of corrosion of automotive materials were introduced, and the

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shortcomings of existing evaluation methods were analyzed. A corrosion risk assessment model for automotive materials based on intelligent algorithms was proposed. The model was trained using machine learning algorithms and could automatically identify and evaluate the corrosion risk of automotive materials. Using a grey prediction model, the most reasonable parameters were selected based on the grey values for risk assessment. The advantages, disadvantages, and future development directions of this model were also discussed.

2. Risk of Corrosion of Automotive Materials

2.1 Types of Automobile Corrosion

The acidic substances in rainwater can corrode the metals on the surface of automobiles, leading to corrosion [4-5]. At the seaside or on winter roads, chemicals used can corrode the metal on the surface of automobiles. Rust is produced by the reaction of iron and oxides on the metal surface, which can cause corrosion on the surface of automobiles. Other materials on the surface of automobiles may react chemically with metals. When different metals come into contact, such as metal connectors or bolts, electrical corrosion may occur. When current passes through an electrolyte (such as water or salt water), electrical corrosion would accelerate. When oxidants are injected into the interior of an automobile, they may cause corrosion. The humidity in the environment where automobiles are used is relatively high. In winter road use, salt or other chemicals may be used to prevent icing, which may cause corrosion.

General corrosion refers to the oxidation of raw materials present on the surface of an object, resulting in local or overall corrosion of the metal on the surface of the object [6]. In general corrosion, corrosive substances often directly attack the surface of the square. The mechanism mainly includes adsorption of substances, diffusion of controlled reaction rate, and electrochemical action. Galvanic corrosion refers to the corrosion that occurs when two different metals come into contact in an electrolyte medium due to differences in their surface potential. A small electric stack is formed at the contact point, where one metal object is corroded and the other metal object becomes an electron acceptor. Current corrosion refers to the corrosion phenomenon that occurs under the action of current. The reason for its occurrence is that when the electrolyte flows through the metal surface, new ions replace the already oxidized ions and enter the reaction. Due to this reason, the concentration of metal ions in the electrolyte does not decrease, but instead increases, thus accelerating the corrosion process. Due to the difference between the local chemical environment within the gaps on the metal surface and the external chemical environment of the metal, dissolution corrosion, also known as crevice corrosion, often occurs. This type of corrosion can in some cases worsen the metal shape and even lead to serious damage to metal parts. The mechanism of crevice corrosion is due to the different local structures on the surface, which form different local potentials. In addition, the accumulation of internal moisture generates heterogeneous batteries, causing corrosion.

Spot corrosion is manifested as localized corrosion, often occurring in small protrusions or depressions on the metal surface of automobiles. Porous corrosion is a localized deep hole that affects the integrity and mechanical properties of automotive metals. Uniform corrosion is the corrosion of the entire metal surface of an automobile, often occurring on vehicles exposed to harsh environments or wading roads. Crystal corrosion may cause brittle cracking of automotive metal materials.

2.2 Corrosion Prevention and Risks

For automotive metal surfaces, anti-corrosion coatings can be used for protection to reduce the impact of external corrosion factors. Coating the surface of automotive metal parts with a protective layer using electrophoretic coating technology can improve the corrosion resistance of automotive parts. By spraying or applying anti-corrosion grease or oil on automobile metal parts, it is possible to properly isolate contact with chemicals such as air. It is necessary to clean the surface of the automobile in a timely manner to avoid corrosion factors staying on the surface for too long, which can lead to rust. The use of corrosion-resistant metal products with high strength and corrosion resistance, such as stainless steel, aluminum alloy, etc., can greatly improve the corrosion resistance of automotive metal parts [7-8]. Regular inspections are required to promptly address any signs of corrosion. Regular vehicle cleaning and maintenance can maintain the cleanliness and maintenance of the vehicle body and components. When repairing automobiles and replacing parts, selecting appropriate materials and adopting electrochemical anti-corrosion measures such as anode protection or cathodic protection can

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effectively prevent corrosion of the automobile body and parts. Maintaining a dry environment inside the automobile can avoid the impact of moisture on automobile components. It should be avoided to park the automobile for a long time as much as possible to prevent corrosion caused by factors such as air humidity.

The impact of corrosion: it can lead to a decrease in the material strength and performance of automotive components, thereby affecting the safety and reliability of vehicles; it can cause damage to the automobile's coating and appearance, affecting the aesthetics and value of the vehicle. It can lead to circuit faults or short circuits, increasing the risk of vehicle accidents; it would lead to an increase in the maintenance cost of automotive components, as corroded components need to be replaced or repaired. For the detection of automobile corrosion, the following methods can be adopted: it is necessary to regularly inspect the appearance of the automobile, including paint, body, chassis, and other parts, as well as the status of components, such as whether there is rust, peeling, and other phenomena. By touching the surface and components of the automobile with hand, people can check for any bumps, blisters, or other signs of corrosion. It can be determined by listening to the sound of the automobile running, and if there is any abnormal noise or friction sound, it may be caused by corrosion. Using professional testing equipment for comprehensive testing of automobiles, such as infrared scanning, X-ray testing, etc., can detect corrosion that is difficult to detect with the naked eye.

3. Experimental Conditions and Plan

3.1 Experimental Materials and Methods

The materials used in the experiment are two-phase high-strength steel and galvanized steel, with the galvanized steel base material being cold-rolled steel plate. This project used CO_2 (carbon dioxide) gas shielded solder to weld two phases of high-strength steel and galvanized steel respectively, and took local welding as the experimental object. Before conducting welding tests, the oxide film at the interface of the specimen should be polished with fine sandpaper, and the oil stains on the surface of the specimen should be removed with acetone to avoid contamination of the steel surface by penetrating welding metal, which can lead to welding errors. When welding, it is necessary to first turn on the power switch and turn the air supply switch to the "check" position. After opening the cylinder head, it is necessary to slowly turn the adjustment knob to adjust the airflow. In order to ensure stable welding process and beautiful weld formation, it is particularly important to select appropriate welding parameters, as shown in Table 1.

Table 1: Process parameters of carbon dioxide gas protective welding

Plate thickness (mm)	0.801~1.001	1.001~2.001
Spacing (mm)	0~0.501	0.801
Welding wire diameter (mm)	0.501~0.801	0.801~1.001
Current (V)	50~100	70~110
Welding speed (cm/min)	45	50
Gas flow rate (L/min)	6	11
Extension length (mm)	9	13

Before spot welding, the oil and impurities on the surface of the sample are usually cleaned with acetone to reduce the impact of dirt and impurities on the welding quality. This article mainly used a single pulse spot welding process that contacts both sides of the electrode for spot welding experiments, and the workpiece leaved visible electrode marks on both sides. The welding parameters in the experiment, such as welding current, insulation time, and electrode pressure, can all affect the microstructure, core size, and mechanical properties of spot welded joints. After welding was completed, the wire cutting method in the vertical direction of the carbon protected weld seam was used to obtain metallographic samples of two types of welds. A 4% ammonia solution was used to corrode metal samples, and the corrosion resistance of the samples was compared and analyzed. When measuring bias, the control voltage is an independent variable. By comparing the magnitude of self-corrosion current, the severity of the sample corrosion process during corrosion can be determined.

3.2 Experimental Plan

This article mainly studied the corrosion problem of body welds in the automotive industry. The corrosion test in acid rain environment was selected, and CO_2 protected solder and spot welding were used as the test units based on the range of solder and base metal. The corrosion effect of simulated

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acid rain solution with pH (public health)=3 and pH=4 on vehicle body welds was studied. The samples were immersed in two simulated acid rain solutions with different pH values, with a daily cycle of one month. The corrosion resistance of two-phase high-strength steel parts and galvanized steel based metal parts was evaluated using the weightlessness method. The immersion test adopted the sample complete immersion method, and the experimental temperature was room temperature.

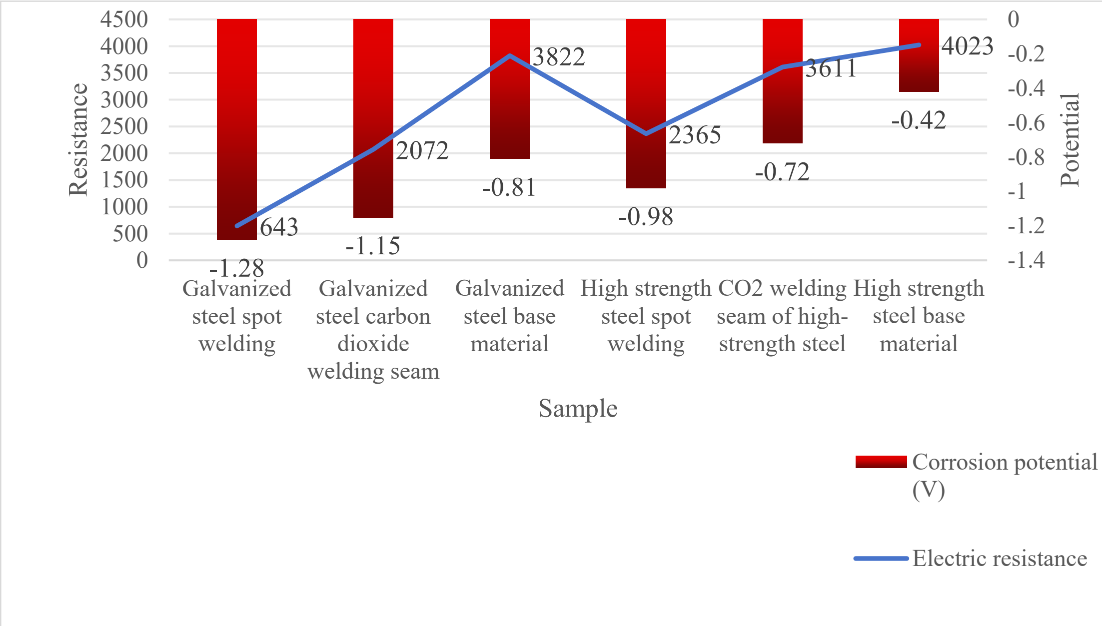

Figure 1: Data on anodes of welds and base metals in acid rain solution at a acid-base of 3

In the immersion test, CO_2 protected solder itself has many micro corrosion pools. At the macro level, it also forms corrosion pairs with adjacent areas of the base metal. The larger the potential difference between metal electrodes, the more severe the local galvanic corrosion. Therefore, the macroscopic manifestation is that the corrosion resistance of CO_2 protected welds is lower than that of spot welding. The solder itself is also more corrosive than the base metal.

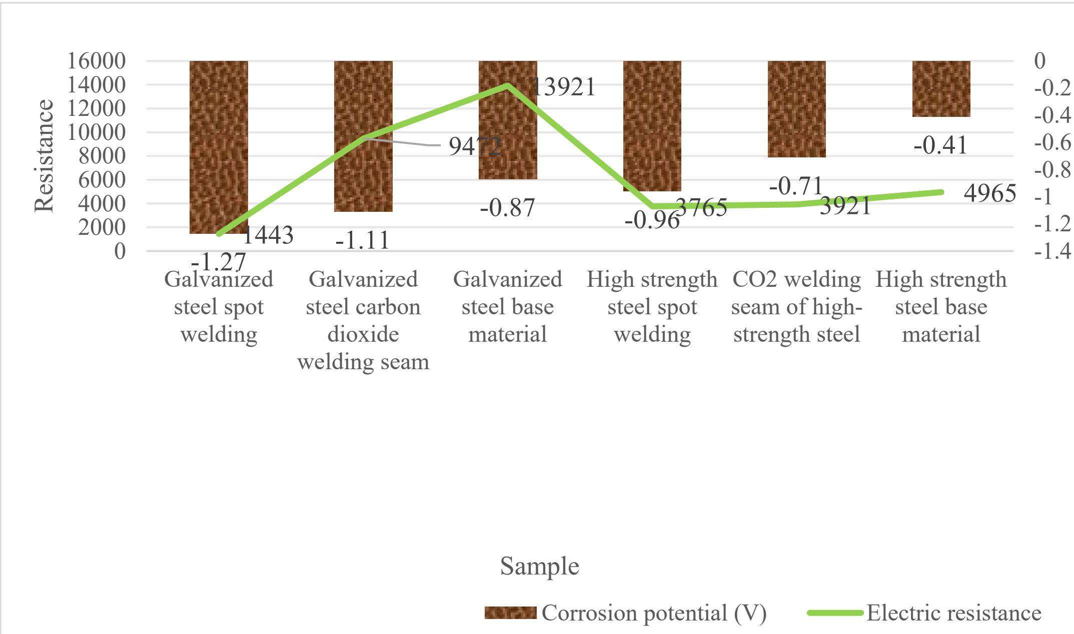

Figure 2: Data on anodes of welds and base metals in acid rain solution at a acid-base of 4

In Figures 1 and 2, in the same corrosive medium, there were significant differences in the corrosion potential of galvanized steel, two high-strength steel base materials, and corresponding spot welding and CO_2 welding, with spot welding galvanized steel having the smallest corrosion potential. Two high-strength steel matrix materials had the highest corrosion potential. The corrosion resistance

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of the weld seam was worse than that of the base metal.

Simulated acid rain solutions with different pH values are used as corrosion media, showing acidity. For dual phase high-strength steel, the anodic metal is discharged and dissolved to form ferrous ions, and the anodic reaction formula is:

$$Fe - 2e \rightarrow Fe^{2+} \tag{1}$$

Due to the sample being in an acidic solution, hydrogen ions undergo a reduction reaction at the cathode. The cathode reaction formula is:

$$2H^{+} + 2e \rightarrow H_2 \tag{2}$$

Due to the presence of a large number of hydrogen ions in the solution itself, when the hydrogen ions in the cathode surface solution layer undergo electron reduction to produce hydrogen, the used hydrogen ions can be rapidly reconstructed through diffusion. The lower the pH value, the more significant the corrosion effect. Zinc has high activity and reactivity. In an acidic solution, galvanized steel first reacts between the zinc layer and the corrosive solution. Zinc ions and hydrogen ions undergo displacement reactions, producing hydrogen, which corrodes and gradually destroys the zinc layer. During the welding process, the metal undergoes changes from melting to cooling and solidification. During the solidification process, shrinkage occurs, forcing the metal to deform on both sides of the weld. Compared to the base metal, welding corrosion is more severe.

3.3 Risk Assessment Model Design

The quantitative evaluation method uses quantifiable indicators for risk assessment, and evaluates risks objectively based on scientific data [9-10]. The advantage of qualitative risk assessment is that it is easy to use and in line with human understanding of things. Fuzzy comprehensive evaluation is an evaluation method based on fuzzy set theory, which solves uncertainty and converts fuzzy evaluation indicators into specific evaluation results [11-12]. The size, similarity, etc. of two or more fuzzy sentences are compared, and the comparison results are used for weight distribution in fuzzy comprehensive evaluation. The comprehensive calculation of these standards provides the final evaluation result. According to the principles of flexibility and dynamism, the structure of comprehensive evaluation decision indicators should be modifiable and scalable. When synthesizing fuzzy matrices, this article used a relatively mature weighted average operator:

$$I_a = W_a \circ J_a \tag{3}$$

Among them, J_a is the fuzzy evaluation matrix; W_a is the corresponding weight vector; $\circ$ represents the weighted average operator.

This article proposed a corrosion risk assessment model for automotive materials based on intelligent algorithms. This model is trained using machine learning algorithms and can automatically identify and evaluate the corrosion risk of automotive materials [13-14]. Firstly, a large amount of corrosion data was collected, including information on corrosion types, degrees, and locations. Then, these data were input into the model to automatically learn and identify different types and degrees of corrosion. Finally, based on the evaluation results of the model, the risk of corrosion of automotive materials was managed and controlled. The specific details are as follows: the data collection and preprocessing module is responsible for collecting relevant data on the automotive usage environment, body and components, and preprocessing these data to provide a reliable data foundation for subsequent modules [15-16]. The feature extraction and selection module utilizes data mining technology to extract corrosion related features through data analysis and modeling, and screens these features to select the features that have the greatest impact on corrosion as model inputs [17-18]. The intelligent algorithm module uses neural networks, genetic algorithms, support vector machines, etc., to evaluate and predict the corrosion risk of vehicle bodies and components [19-20]. The risk management module is based on the previous corrosion risk assessment results and the inspection status of the vehicle body and components, and carries out risk management and control for high-risk areas. By using anti-corrosion coatings, regular cleaning, and replacing dangerous components, the service life of automobiles can be extended and driving safety can be ensured.

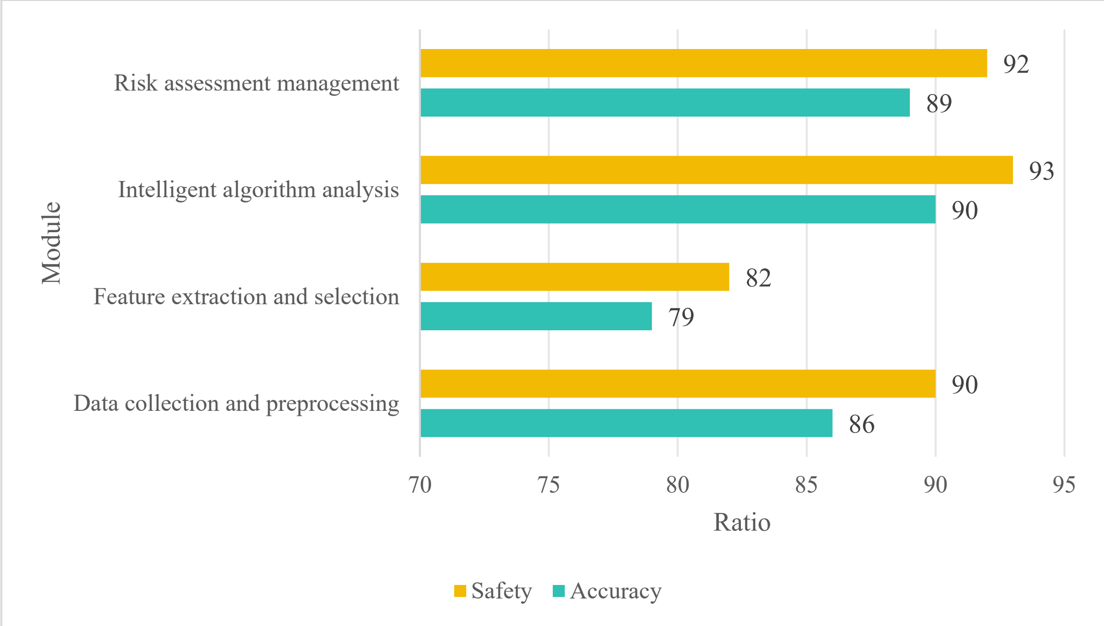

Figure 3: Performance analysis of the different modules

In Figure 3, the security of the data collection and preprocessing module was 90%, and the security of the feature extraction and selection module was only 82%; the security of the intelligent algorithm analysis module was the highest at 93%, and the security of the risk assessment management module could also reach 92%. In terms of accuracy, the intelligent algorithm analysis module was the highest, while the feature extraction and selection module was the lowest.

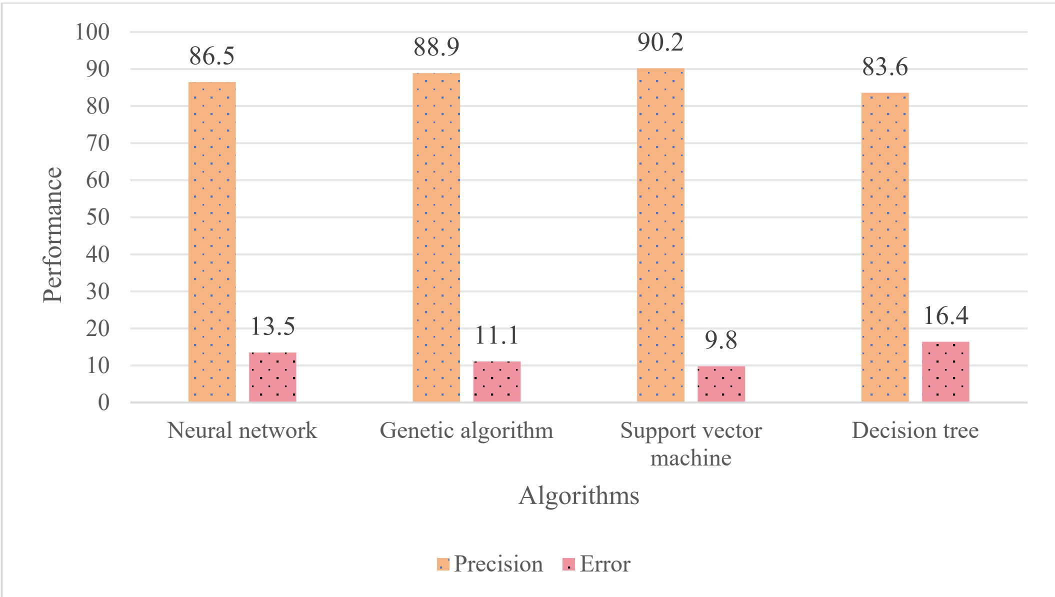

Figure 4: Performance analysis of the different intelligent algorithms

In Figure 4, the accuracy of the neural network algorithm was 86.5%, while the accuracy of the genetic algorithm was higher, at 88.9%. The support vector machine algorithm had the highest accuracy, reaching 90.2%, while the decision tree algorithm had the lowest accuracy, only 83.6%. Overall, there was still room for improvement in the accuracy of a single intelligent algorithm in the assessment and management of automotive corrosion risk. Neural network algorithms have strong generalization ability and adaptability, which can handle nonlinear relationships, but require a large amount of training data, and the model does not have interpretability. Genetic algorithm has global search ability and good processing performance for complex optimization problems, but its computational cost is high. The support vector machine algorithm is suitable for high-dimensional data and has good generalization performance and classification performance, but is sensitive to outliers. The decision tree algorithm has the characteristics of interpretability and ease of understanding, and is suitable for both discrete and continuous features, but it is prone to overfitting. Therefore, further research is needed on intelligent algorithms.

4. Discussion on Risk Assessment and Management Models

The risk assessment and management model proposed in this article is a model that utilizes intelligent algorithms and data analysis techniques to manage the corrosion risk of automotive materials. It can assess the corrosion risk of vehicles and provide effective management measures and recommendations by collecting and analyzing a large amount of data related to automotive material corrosion, as well as combining intelligent algorithms for pattern recognition and prediction. It can utilize big data for analysis and learning, thereby providing more accurate prediction results in corrosion risk assessment. This model provides real-time safety warnings and management recommendations by monitoring the status and environmental conditions of automotive materials in real-time, and updating corrosion risk assessment results in a timely manner. It can be applied to various types of automotive materials, including body sheet metal, engine components, exhaust systems, etc., in order to evaluate and manage the corrosion risk of different materials and environmental conditions. However, this model requires a large amount of data related to automotive material corrosion for training and analysis, and requires high quality and reliability of the data. There are currently many types of intelligent algorithms that require continuous optimization and optimization. Algorithm execution may have certain complexity and require professional personnel for operation and maintenance, which may increase manpower and cost investment.

By integrating and sharing data related to automotive material corrosion, a more comprehensive and high-quality dataset can be established, further improving the accuracy and reliability of the model. By continuously improving and innovating intelligent algorithms, the computational efficiency and prediction accuracy of the model can be improved to meet the needs of different materials and environmental conditions. By combining the Internet of Things and sensor technology, real-time monitoring and early warning of the corrosion status of automotive materials can be achieved, providing more timely management measures and suggestions. Combining multiple intelligent algorithms, corrosion risk assessment and prediction were conducted. By introducing professional knowledge in the field of automotive material corrosion and combining intelligent algorithms, modeling and optimization were carried out. The corrosion behavior of different materials and environmental conditions was simulated and predicted using virtual simulation technology, providing more training and validation data for the model.

5. Conclusion

Intelligent algorithms can monitor the metal surface in real-time during the corrosion protection process of automotive materials, and select corresponding strategies based on different working conditions and environments. This article mainly evaluated the corrosion of automotive metal surfaces through algorithms and proposed corresponding solutions. The risk assessment and management model for automotive material corrosion based on intelligent algorithms has the advantages of high accuracy and real-time performance, but it also needs to face challenges such as high data demand, algorithm selection and optimization, and model complexity. The future development direction includes data integration and sharing, algorithm optimization and innovation, as well as real-time monitoring and early warning. The improved algorithm can integrate multiple algorithms, introduce domain knowledge, and combine virtual simulation technology to improve the performance and predictive ability of the model.

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