Mining and Analysis of In-use Vehicle Corrosion Data Based on Typical Environmental Conditions in China

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Abstract. As an important performance indicator for measuring product quality and safety, vehicle corrosion resistance has always been of great concern to industry enterprises and consumers. In this paper, we collect, processed and analysed exterior corrosion data from a total of 54 in-use vehicles (the vehicle that has been licensed and put into service) of nine models with high ownership in the coastal region of North China. Through the evaluation model of automobile corrosion resistance performance, data mining analysis was conducted on five key areas and the whole vehicle with different brands and ages (3-year and 6-year vehicles), key areas including exterior body, passenger compartment, luggage compartment, engine compartment, and chassis. It was found that the chassis and engine compartment of each vehicle model were severely corroded, with the corrosion surface of some chassis parts reaching 100%. The luggage compartment and exterior body were slightly corroded, and the luggage compartment parts of 8 models have not corroded after 3 years of use.

Keywords: Environment of China; Corrosion; Corrosion resistance; Evaluation models.

1. Introduction

By the end of 2022, it has been 319 million vehicles in China, making China the world's largest automotive market. Since China started to implement the automotive recall system, there have been 154 cases of automotive recalls due to corrosion defects, involving 57 automotive brands and more than 9 million vehicles. In recent years, consumers have been increasingly concerned about the corrosion of automobiles [1], and during the period from 2012 to 2022, the number of complaints involving corrosion of automobiles has been rising year by year, with a cumulative total of more than 23,000 cases. At present, the automobile enterprise mainly uses accelerated corrosion tests to quickly verify the corrosion resistance of prototype vehicles at the development stage [2]. However, the correlation between the enhanced corrosion in the current test standards and the environmental corrosion in the real market service conditions is poor, i.e., the results of the test do not fully reflect the actual performance of the market, which leads to serious corrosion problems in the market for the vehicle models that have been verified by the vehicle accelerated corrosion tests. By building a set of corrosion resistance evaluation model that can analyse the normal service vehicles (in-use vehicles) in the market [3], and by optimising the evaluation model, the corrosion status and problems in the in-use vehicle market can be accurately analysed, so as to solve the limitation problem of the test guiding automobile anti-corrosion quality control.

In this paper, the passenger vehicle corrosion resistance evaluation model was used to analyse the corrosion status of each area and the whole vehicle appearance of 54 different in-use vehicles in 9 models driving in the coastal area of North China, aiming to explore the Chinese automotive corrosion data and provide data support for accurately improving the corrosion resistance of vehicles.

2. Sample and research methodology

2.1 Sample Selection

In the process of automobile service, the corrosion severity of each component varies greatly [4], and the corrosion degree of components is higher in poor microenvironments. By exploring solutions for surface rusting of parts with automobile manufacturers and combining the sensitivity of consumers to corrosion of parts, the whole vehicle is divided into 5 major areas from the perspective of visibility, namely, the exterior body, the passenger compartment, the luggage compartment, the engine compartment and the chassis. In order to circumvent the corrosion differences brought about by environmental factors, the nine vehicle models involved, with a total of 54 vehicle samples, are all in the North China coastal region (Table 1). There are four distinct seasons in the North China coastal region, and a small amount of snow-melting salt is used in winter. Meanwhile, there are developed urban industries, and a high percentage of user complaints about vehicle corrosion, which can be considered as one of the typical environmental conditions in China.

In order to ensure that the research samples are more in line with the vehicle using habits of Chinese comsumers, the samples in this paper are 3 and 6 years old respectively, with an average annual mileage of 10,000 to 20,000 kilometers. The manufacturer's guide price of the nine models studied in this paper ranges from ¥59,000 to ¥120,000 yuan, which can be considered that all models are in the same grade. To ensure the reliability of the data, the samples of each vehicle age are 3, i.e., a total of 6 sample vehicles for each model. In addition, for the purpose of further ensuring the validity of the research sample, combining with user questionnaire research, maintenance records inquiry and appraisal assessment, extreme working conditions, accidents, modifications, maintenance and other situations are excluded.

Table 1. Study sample vehicles

Vehicle Model	Age and number of vehicles	Average annual mileage	Brand classification
Model 1	3 years (3 vehicles) & 6 years (3 vehicles)	17040 Km	Chinese joint venture brand
Model 2	3 years (3 vehicles) & 6 years (3 vehicles)	13311 Km	Chinese joint venture brand
Model 3	3 years (3 vehicles) & 6 years (3 vehicles)	15306 Km	Chinese joint venture brand
Model 4	3 years (3 vehicles) & 6 years (3 vehicles)	13679 Km	Chinese joint venture brand
Model 5	3 years (3 vehicles) & 6 years (3 vehicles)	14065 Km	Chinese independent brand
Model 6	3 years (3 vehicles) & 6 years (3 vehicles)	13318 Km	Chinese joint venture brand
Model 7	3 years (3 vehicles) & 6 years (3 vehicles)	15145 Km	Chinese independent brand
Model 8	3 years (3 vehicles) & 6 years (3 vehicles)	11953 Km	Chinese independent brand
Model 9	3 years (3 vehicles) & 6 years (3 vehicles)	14770 Km	Chinese independent brand

2.2 Research methodology

The corrosion data of about 350 parts in 5 areas were collected, and the corrosion grade of each part was evaluated according to the standard [5], the corrosion research method including part evaluation and vehicle evaluation. Corrosion grade in accordance with the severity of the classification from 0 to 9, grade 0 for no corrosion phenomenon, the larger value indicates more serious corrosion, the most serious grade 9 corrosion can reach the degree of corrosion perforation or corrosion fracture, etc. Different corrosion grades have the corresponding deduction conversion (Table 2).

Table 2. Corrosion rating sheet

Corrosion grade	Corrosion grade	Corrosion description	Corrosion rating and demerit point conversion
0	No corrosion	No corrosion of any kind	0 points
1	Minimal corrosion	1 to 5 small rust spots	1 point
2	Minor corrosion	More small rust spots; the corrosion area accounts for <10% of the total area of the parts	3 points
3	Slight corrosion	Medium-sized rust spots; 10% ≤ corroded area <40% of the total area of the component	

4	Moderate corrosion	A lot of medium-sized rust spots; 40%≤the corrosion area of the total area of the parts < 60%.	6 points
5	Large Corrosion	Large size rust spots; 60%≤corrosion area of total area of parts ＜100%.	
6	Total corrosion	Large corrosion area or very large rust spots; the corrosion area accounts for 100% of the total area of the parts.	8 points
7	Severe corrosion	A small amount of rust scale accumulation, not easy to fall off	
8	Very severe corrosion	A large amount of rust scale accumulation, cracking or flaky off	
9	Perforation	Perforation, fracture, extension holes	10 points

In this paper, the data is analysed in the dimensions of average corrosion rating and corrosion resistance of each region and the corrosion evaluation score of the whole vehicle appearance for 54 sample vehicles. Among them, the average corrosion rating (r_{ave}) refers to the average corrosion ratings of all the parts in an area or the whole vehicle, as follows:

$$r_{ave} = \frac{\sum_1^3 \sum_1^n r_{ij}}{3n}$$

Where: n is the number of all parts in an area of a vehicle or the vehicle as a whole that are involved in benchmarking, and rij is the corrosion grade of the i part of the j vehicle in an area or the whole vehicle.

Corrosion resistance (p) refers to the percentage of corroded parts in an area or the whole vehicle in the number of all parts in that area or the whole vehicle, calculated as follows:

$$p = \frac{\sum_1^3 c_j}{3n} \cdot 100\%$$

Where: cj is the number of parts corroded in an area or the whole vehicle of the j vehicle.

The whole vehicle evaluation uses the passenger vehicle appearance corrosion resistance evaluation model to calculate the corrosion status of each part of the study sample and analyze the corrosion resistance of different areas of the vehicle, and the statistical model is as follows:

$$W = 10 - \sum_{i=1}^{2} \left\{ \sum_{j=1}^{3} \left[\left(\frac{1}{N_{ij}} \times \sum_{k=1}^{N_{ij}} R_{ijk} \right) \times \theta_j \right] \times \delta_i \right\}$$

Where: W is the appearance evaluation score (the higher the score, the better the corrosion resistance of the model). δ_i is the weight of the appearance evaluation node indicator. θ_j is the weight of the parts category indicator. N_{ij} is the number of parts in each parts category. R_{ijk} is the corrosion deduction value of individual parts.

3. Vehicle corrosion data analysis

3.1 Corrosion data analysis of the exterior body

The exterior body is a relatively high visibility area and users are very sensitive to the

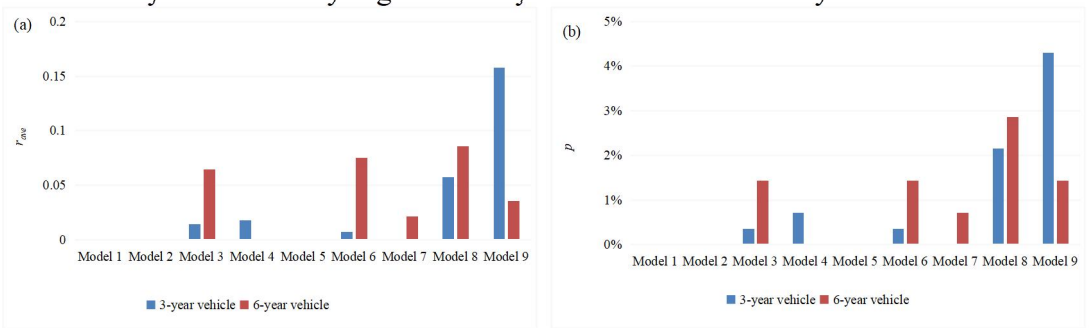


Fig. 1 Corrosion data analysis of the exterior body

(a) Average corrosion grade; (b) Corrosion resistance.

component corrosion in this area. The vehicle corrosion complaints are also mainly focused on this. Each enterprise attaches great importance to the corrosion protection of the exterior body, and has taken a lot of effective measures [6, 7]. The exterior body of Model 1, Model 2 and Model 5 have no corrosion, while the exterior body of Model 9 has been severely corroded.

3.2 Corrosion data analysis of the passenger compartment

The passenger compartment is highly visible, and users are very sensitive to the corrosion of components in this area. It is found that the steering column in the passenger compartment has the most serious corrosion, with some models showing grade 6 corrosion in the steering column and 100% corrosion in the area. No corrosion occures in the passenger compartment of Model 2 and Model 4, whereas Model 7 and Model 9 have more serious corrosion in the passenger compartment after 6 years of use.

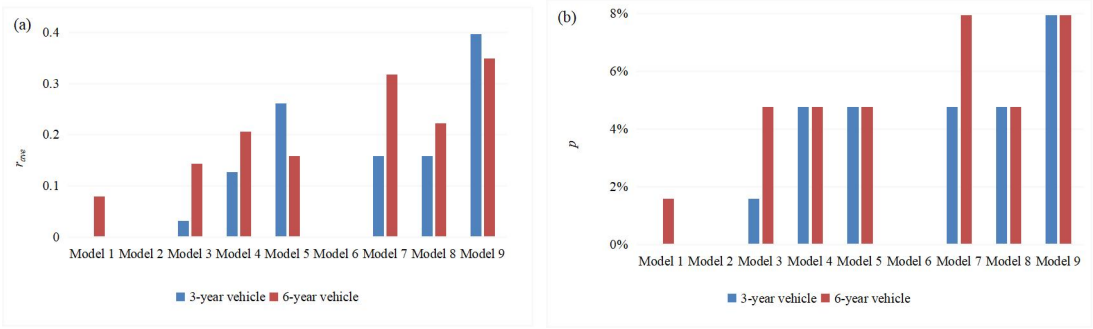


Fig. 2 Corrosion data analysis of the passenger compartment
(a) Average corrosion grade; (b) Corrosion resistance.

3.3 Corrosion data analysis of the luggage compartment

The luggage compartment is highly visible and corrosion conditions in this area are mild, which makes corrosion problems relatively rare. No corrosion occurres in the luggage compartment of Model 1, Model 3 and Model 5, while Model 2 has more serious luggage compartment corrosion after 6 years of use.

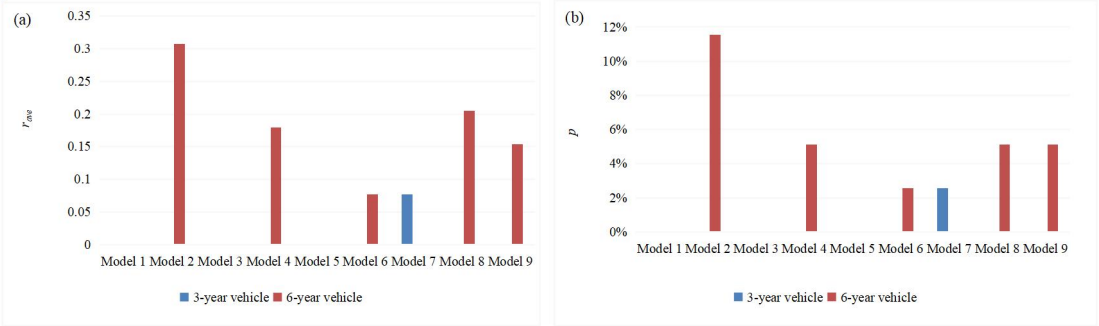


Fig. 3 Corrosion data analysis of the luggage compartment
(a) Average corrosion grade; (b) Corrosion resistance.

3.4 Corrosion data analysis of the engine compartment

The engine compartment belongs to the area of medium visibility. This area is often in a high-temperature environment, corrosion conditions are relatively harsh [8], resulting in more corrosion problems and even the risk of functional failure and safety hazards. The engine compartments of Model 2 and Model 3 have no corrosion after 3 years of use, while minor corrosion occures after 6 years of use. Model 8 has a small number of parts corroded after 3 years of use, but a large number of corrosion problems after 6 years of use.

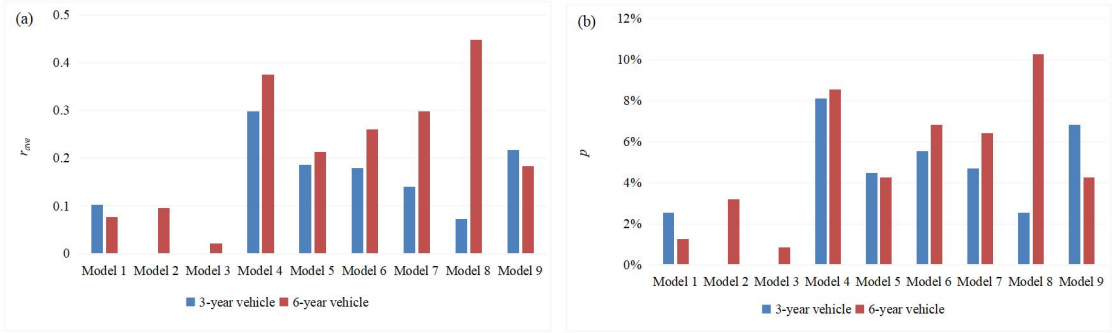


Fig. 4 Corrosion data analysis of the engine compartment
(a) Average corrosion grade; (b) Corrosion resistance.

3.5 Corrosion data analysis of the chassis

The chassis is a relatively low visibility area, the user will generally notice the corrosion phenomenon in this area during maintenance. The corrosion conditions in this area are very harsh, and it is very susceptible to mud and water splash, stone impact, snow-melting salt erosion, etc., which is the hardest-hit area of the vehicle corrosion problem [9, 10]. More corrosion problems occur in the chassis area of each model. Model 1 and Model 2 chassis average corrosion grade is low, with less number of parts that corrosion occurs, while Model 9 chassis average corrosion grade is high.

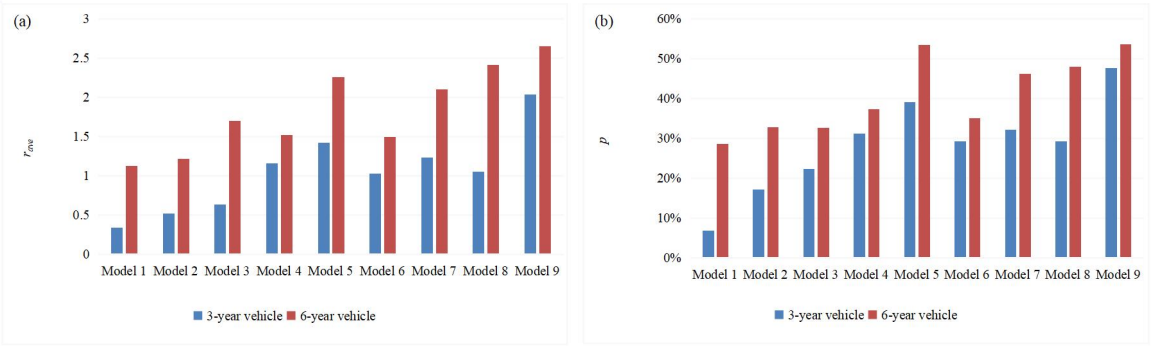
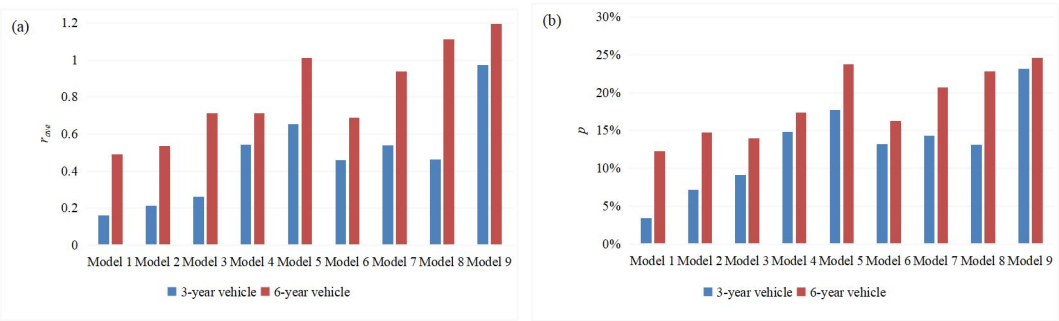


Fig. 5 chassis corrosion status analysis
(a) Average corrosion grade; (b) Corrosion resistance.

3.6 Corrosion data analysis of whole-vehicle

By comprehensively analysing a total of five areas, namely the appearance corrosion resistance performance in the whole-vehicle dimension, including the exterior body, the passenger compartment, the luggage compartment, the engine compartment and the chassis, it is found that Model 1 has the lowest average corrosion grade and corrosion resistance, and the highest evaluation score for the the whole vehicle appearance, which indicates that the corrosion quality of Model 1 is the best. Model 9 has a higher average corrosion rating and corrosion resistance, and the lowest evaluation score for the whole vehicle appearance, which illustrates that the corrosion quality of Model 9 is the worst.



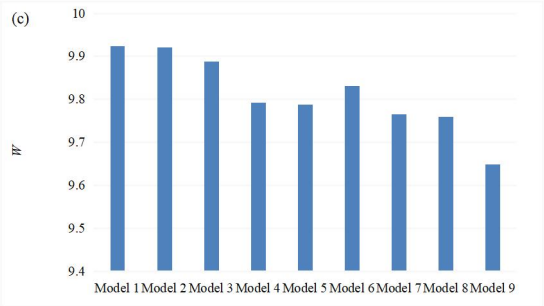


Fig. 6 Corrosion data analysis of whole-vehicle
(a) Average corrosion grade; (b) Corrosion resistance; (c) Evaluation score.

4. Summary

In this paper, 9 models corrosion data of high-ownership vehicles in the typical environment of China are deeply excavated and quantitatively analyzed. Conclusions are reached as follow: (1) The overall corrosion resistance of various vehicle brands in the Chinese market is good. The corrosion phenomenon occurs less and the corrosion resistance is good in luggage compartment and exterior body. The corrosion problem of the vehicle is less after 3 years of service. (2) Passenger compartment corrosion is mainly concentrated in the steering column, and the corrosion area of some steering column reaches 100%. (3) The working conditions of the engine compartment and chassis are relatively poor, especially the chassis where more parts have higher corrosion grades. Although the 9 vehicle models involved in this paper all have corrosion problems to varying degrees, they generally perform well. At this stage, with the rapid development of China's automotive industry, major automobile enterprises still need to be committed to the manufacture of excellent quality automotive products, to meet the needs of users of automotive sensory quality.

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