Deep Learning and Pattern Recognition
2024 Volume1,Issue1

Fault analysis and reliability assessment of automobile clutches based on Bayes

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Abstract. With the rapid development of automobile industry, the clutch fault has become an important factor. Therefore, how to effectively carry out failure analysis and reliability evaluation is of important practical significance. This paper analyzes the failure of automobile clutch.

First, this study made a comprehensive analysis of the reliability and failure mode of the clutch, identifying the main causes and influencing factors of failure. Second, this study constructed a lifetime distribution model based on Bayes estimates that accurately estimated the parameters of the model through empirical data. This model can effectively reflect the life distribution of the clutch and improve the accuracy of fault prediction. Finally, this study calculated reliability indicators, such as reliability, inefficiency and average life, which provides a scientific basis for clutch maintenance and management.

This study not only provides new ideas and methods for solving the failure problem of automobile clutch, but also provides a reference for the failure analysis and reliability evaluation of other mechanical equipment.

Key words: automobile clutch fault analysis and reliability evaluation, Bayesian method

1 Introduction

1.1 Research background and significance

In the modern society, as one of the main tools for people to travel and transport, the reliability and safety of automobiles are very important. However, during the use of cars, faults and problems are inevitable due to the complex mechanical and electrical systems. Therefore, one of the keys to vehicle repair and maintenance is the early detection and prevention of faults, which requires a reliable evaluation of automotive systems.

Automobile engine is one of the core components of the automobile, in which the clutch is an important part of controlling the engine speed and transmission power. However, the car clutch is also prone to failure, which will seriously affect the normal operation of the whole car. Therefore, it is necessary to understand the cause of automobile clutch and improve its reliability level.

This study will investigate the common failure modes of the vehicle clutches and perform the fault mode, Effect and Importance Analysis (FMECA) and identify the main factors affecting the clutch reliability. Bayes theory is a classical probabilistic inference method that can be used to diagnose uncertainty problems in systems. Through the qualitative and quantitative methods of Bayes theory, the root cause of clutch failure can be analyzed and solutions proposed. Based on Bayes theory and the product life following the exponential distribution, the joint posterior distribution function of the automobile clutch can be effectively constructed. This study will also apply the Bayes maximum posterior estimation method, infer reliability indicators such as the average life of the automobile clutch, and study how to effectively improve the reliability level of the clutch.

The significance of this study is that the failure rate of the clutch can be quantified and evaluated, so that the automobile clutch can detect faults in an early stage and effectively evaluate and analyze them in an early stage, so as to improve the efficiency of automobile engine diagnosis and maintenance. This will help improve the reliability and safety of cars, reduce the cost of vehicle maintenance and maintenance, and provide better guarantee for peoples travel and transportation. At the same time, it can help the maintenance personnel to determine the cause of the car clutch failure faster, and choose the most appropriate repair measures, so as to improve the maintenance efficiency and reduce the maintenance cost.

This study can also provide automobile manufacturers with some valuable information for the vehicles, such as considering what factors can improve their reliability during the vehicle clutch design and manufacturing stage, and how to develop more intelligent vehicle fault diagnosis systems. In addition, this study can also provide some reference significance for related industries, such as fault analysis and reliability assessment of other mechanical equipment.

In conclusion, the purpose of this study is to improve the reliability and safety of automobile clutches, improve the care and maintenance of automobile engines, while providing valuable information to maintenance personnel and automobile manufacturers, and thus reduce peoples maintenance costs and improve peoples sense of travel.

1.2 Research status at home and abroad

In recent years, with the rapid development of the automobile industry and the continuous innovation of technology, the automobile clutch is as an important part of the automobile engine transmission system, and its reliability and performance have an important impact on the safety and driving experience of the automobile. Therefore, the fault analysis and reliability evaluation of automobile clutch has been an important research direction in the field of automotive engineering. Based on the fault analysis and reliability evaluation, the research on the fault analysis and reliability evaluation mainly includes the following aspects:

Fault analysis of automobile clutch

The researchers focused on the cause of the vehicle clutch failure and how to assess the reliability. Among them, some researchers through the analysis of the actual data, the main cause of the car clutch failure, car clutch failure has many reasons, mainly including the following points: (1) clutch wear: the clutch plate is the main wear parts in the clutch, after long-term use will wear or burn phenomenon, the clutch disc and the flywheel contact area, resulting in clutch lag, slip or separation.(2) Failure of Clutch pressure plate: The clutch pressure plate is an important part of controlling the working state of the clutch. When the clutch pressure plate fails, it may lead to insufficient friction or complete loss of the clutch, resulting in clutch skid, stagnation or unable to separate.(3) Clutch operation mechanism fault: the clutch operation mechanism includes the clutch pedal, clutch push rod, clutch separator and other parts, these parts are prone to wear, aging, deformation and other conditions after long-term use, leading to the abnormal operation of the clutch.(4) Clutch hydraulic system fault: some models of the clutch use the hydraulic system to control the clutch separation, when the hydraulic system fault, the clutch will be unable to separate or lag.

Clutch failure will lead to a variety of problems in the car, such as poor acceleration, start shake, lag, idle instability, unable to shift. If not repaired in time, it may also lead to more serious accidents, such as out of control, braking failure, etc. Therefore, it is of great significance to study and evaluate the fault causes, mode, influence and hazard of the clutch.

The fault analysis method of domestic and foreign scholars mainly adopts FMECA method, and puts forward some methods for clutch fault prevention and maintenance, such as strengthening the maintenance and maintenance of the clutch, and timely replacing the seriously worn clutch plate and pressure disc in time. The FMECA (Failure Mode, Impact, and Critical Analysis) is a method used to assess system reliability and determine the potential causes of failure, dating back to the 1950s. Initially, it was developed as a method by the US military for assessing the reliability of weapon systems and military equipment maintenance programs. Over time, FMECA has also been widely used in civilian fields, such as aviation, aerospace, energy, transportation and other fields. Now, the FMECA has become a widely accepted method for reliability analysis and is adopted by international standards such as the ISO 9000 Quality Management Standards. Its main characteristic is that the quantitative analysis of the fault mode and impact of the system can be carried out, and the importance can be determined by analyzing the importance of the fault cause, so as to take corresponding maintenance measures. FMECA is also applied in fault prevention and risk management, which can help enterprises reduce costs, improve efficiency and customer satisfaction. The research of FMECA method is also constantly deepening and developing. For example, some scholars use FMECA in combination with other methods, such as hierarchical analysis (AHP) and moldMaste mathematics to more accurately assess the reliability of the system. In addition, there are some research efforts to improve the efficiency and reliability of FMECA, such as the use of computer-aided design (CAD) and artificial intelligence (AI) technologies to automate the processing of FMECA. In conclusion, FMECA method has an important position and application prospect in reliability analysis and risk management, and its research is also constantly developing and creating

Reliability assessment of automobile clutch

The reliability evaluation of automobile clutch is an important means to ensure the safety of automobile operation and improve the service life of automobile. Some progress has been made in the reliability assessment of automobile clutch at home and abroad. Bayes theory, as a method based on statistical principles, is widely used in the reliability assessment of automobile clutches. It can infer the cause and probability of automobile clutch by using prior knowledge and actual data, and conduct reliability evaluation. For automobile manufacturers and repair service providers, they can more accurately predict the possibility and potential causes of automobile clutch failure, and then develop more reasonable maintenance plans and budgets, thus saving time and cost. In addition, Bayes theory can also help optimize the automobile maintenance process and improve the maintenance efficiency, because it can constantly update the probability and prediction results on the basis of the prior knowledge and combined with the actual situation, so as to optimize the maintenance process and improve the maintenance efficiency. In conclusion, Bayes theory has important applications as a powerful statistical tool in the reliability assessment of automobile clutches. By using the method of reliability engineering, researchers can quantify the reliability of automobile clutch and determine the optimal maintenance strategy, so as to improve the reliability and maintenance efficiency of automobile clutch.

How to improve the efficiency of automobile engine maintenance

Automobile clutch failure has a great impact on the whole automobile system, which is very important to ensure the safety and reliability of automobile operation. Therefore, how to improve the efficiency of automobile engine maintenance has become the focus of research. In the relevant literature at home and abroad, scholars have put forward some methods, such as strengthening the skill training of maintenance personnel, optimizing the maintenance process, introducing new maintenance technology, to improve the efficiency of automobile maintenance and reduce the maintenance cost.

Based on domestic and foreign literature, the research on automobile clutch fault analysis and reliability evaluation has important application value in the field of automotive engineering. Bayes theory is an effective evaluation method and has a wide application prospect in automobile clutch reliability evaluation.

1.3 The main content and chapter arrangement of this paper

Chapter 1 is an introduction, which will introduce the background and significance of this research, as well as the status and progress of relevant research at home and abroad. First, this chapter will introduce the importance and application of clutches in the automotive industry and outline their reliability and failure issues. Furthermore, the limitations and shortcomings of existing clutch reliability studies as well as the direction and importance of clutch failure problems will be discussed.

Chapter 2 explores the clutch reliability and failure mode in depth. Through the analysis of the clutch structure, working principle and the working environment, the main failure modes of the clutch, such as wear, fatigue, fracture, etc.

Chapter 3 introduces the lifetime distribution model based on Bayes estimates and processes the experimental data. Through statistical analysis of the experimental data, a clutch life distribution model will be established and parameters estimated. This chapter will address how Bayes estimates to improve the accuracy and reliability of model predictions.

Chapter 4 will study clutch life prediction and reliability assessment. This chapter will introduce how to use the life prediction and reliability evaluation to determine the clutch life distribution, failure probability and reliability parameters. Through the analysis of experimental data, this chapter will explain how to improve the reliability of clutches and extend their service life.

Chapter 5 will be the conclusions and perspectives of this article. This chapter will summarize the previous research results and findings, and propose the directions and priorities for future research. In addition, the improvement of clutch reliability and the extension of service life will be discussed, in order to provide a more comprehensive and in-depth understanding and exploration for the research and application of clutch.

2 Clutch fault analysis

2.1 Reliability of the same time

Reliability refers to the ability of the automobile clutch to work normally within the prescribed working conditions and service life. A reliable clutch shall have good performance stability, long service life and low failure rate. Improving the reliability of the clutch is important to reduce the probability of failure, reduce the maintenance cost and improve the overall performance of the car.

The reliability of the automobile clutch can be measured and improved from the following aspects:

1. Performance stability: Performance stability refers to that the performance parameters of the clutch in the process of long time operation change less, and the performance will not decline sharply due to the extension of the use time. To improve the performance stability, high-quality materials and manufacturing processes should be selected to ensure the accuracy and performance of the clutch parts.

2. Service life: The service life of the clutch refers to the length of time when the clutch can operate normally under normal working conditions. Methods to extend the service life of clutches include the use of high performance materials, the improvement of manufacturing technology and the reasonable design of clutch structure.

3. Failure rate: Failure rate refers to the frequency of failure of the clutch during use. Reducing the failure rate can be achieved by improving design, improving manufacturing quality and strengthening use and maintenance. Regular inspection and maintenance of the clutch, timely detect and solve potential problems, can also help to reduce the failure rate.

4. Anti-interference ability: the clutch may be affected by external environmental factors (such as temperature, humidity, vibration, etc.) during the working process. Improving the anti-interference ability of the clutch can ensure that it can work normally in all kinds of harsh environments.

5. Fault tolerance: Fault tolerance means that the clutch can still maintain a certain degree of normal operation. Through reasonable design and material selection, improving the fault tolerance of the clutch is helpful to reduce the impact on the vehicle performance when some faults occur.

In short, the reliability of the automobile clutch is an important factor affecting the performance of the whole vehicle. By focusing on the optimization of the above aspects, the reliability of the clutch can be effectively improved, and thus the overall performance of the car.

To improve the reliability of the automobile clutch, the following measures can be adopted:

1. Selection of high quality materials and manufacturing process: high quality materials and precision manufacturing process can ensure that the clutch has good performance stability and service life. For example, the selection of wear-resistant, high-strength friction materials, and accurate processing process, can improve the durability of the clutch.

2. Optimization design: By optimizing the clutch structure and working principle, its reliability can be improved. For example, the self-adjusted clutch can realize the automatic adjustment of the clutch travel, reducing the frequency and error of human adjustment.

3. Regular maintenance and inspection: Regular maintenance and inspection of the clutch can find and solve potential problems in time. For example, regular inspection of the clutch wear, oil pressure, can effectively prevent the occurrence of failure.

4. Driver training: By training the driver on clutch operation, the driver can use the clutch correctly, thus reducing the failure rate. For example, teaching the driver the correct start, shift skills and avoid fatigue driving can reduce excessive wear and damage of the clutch.

5. Fault diagnosis and prediction: By using the advanced fault diagnosis and prediction technology, it can monitor the working state of the clutch in real time, and find the fault signs in time. For example, the use of sensors and data analysis technology, can monitor the real-time clutch friction plate wear, the hydraulic system pressure change, so as to timely repair or replacement.

6. Standardization and standardization: The reliability of the clutch can be improved by formulating and following strict production and use standards. For example, setting the manufacturing, installation and maintenance standards of the clutch can ensure that each clutch can meet the corresponding quality requirements.

7. Quality management system: establishing a perfect quality management system can ensure that the design, manufacturing and use of the whole process can ensure the reliability of the clutch. For example, passing ISO 9001 and other international quality management system certification can ensure that enterprises strictly comply with quality standards in the production process.

Through the implementation of the above measures, it can effectively improve the reliability of the automobile clutch, reduce the failure rate, prolong the service life, so as to bring higher economic benefits and user satisfaction for the automobile industry.

2.2 Overview of failure mode and consequences analysis

The Failure Mode and Consequence Analysis (FMEA) is a systematic risk assessment method for identifying and analyzing potential failures and their possible consequences. Through a thorough analysis of the failure mode of the automobile clutch, the existing problems can be found and the corresponding preventive measures are taken to improve the reliability and safety of the clutch. This paper mainly analyzes the failure mode of automobile clutch from the following aspects:

Wear of the friction plate

Friction plate wear is one of the most common clutch faults, seriously affect the clutch performance and life. The degree of wear of friction sheet depends on many factors, such as driver operation habits, friction sheet material, working environment, etc. The causes and possible consequences of friction film wear are analyzed in detail below:

(1) Drivers operation habits: the drivers operation habits have a great impact on the wear of friction plates. Bad driving behaviors such as stepping on the clutch pedal for a long time, frequent emergency stops and fierce acceleration will lead to the wear and acceleration of the friction plate. In addition, the driver did not replace the seriously worn friction plate in time will also lead to more serious consequences, such as clutch failure, drag and sliding.

(2) Friction sheet material: the quality and performance of the friction sheet material have a great impact on the wear degree. High-quality friction sheet material can reduce the wear speed and prolong the service life of the friction sheet. And the inferior friction plate material is easy to wear out, resulting in the decline of the clutch performance. In addition, the selection of friction chip material should also take into account the characteristics of the working environment, such as temperature, humidity, etc.

(3) Working environment: friction plate wear is affected by working environment factors, such as temperature, humidity, dust, etc. High temperature and high humidity environment will lead to the deterioration of friction plate material and accelerate wear. And dust and other impurities will form abrasive on the surface of the friction plate, aggravating wear. Therefore, keeping the working environment of the clutch clean and dry helps to reduce the friction plate wear.

The severely worn friction plate will reduce the clutch transmission efficiency, affecting the acceleration performance and fuel economy of the car. When the friction plate is seriously worn out, the driver may feel the engine speed rise, while the speed does not change significantly. At the same time, the badly worn friction plate will make the clutch pedal travel longer, and the operation feels heavy. Furthermore, wear friction plates may cause poor clutch separation, making the shift process difficult. In addition, friction plate wear may cause other faults, such as clutch dragging, poor separation. In order to avoid these problems, the driver should regularly check the wear of the friction plate, and replace the friction plate with serious wear in time. In order to reduce the wear of the friction plate, the driver should develop good driving habits and avoid stepping on the clutch and semi-clutch driving for a long time. At the same time, regularly check other parts of the clutch system, such as pressure plate, separation bearings, to ensure their good working condition. In addition, the selection of high quality friction sheet material and regular repair factory for replacement, is also an effective way to extend the service life of friction sheet.

Pressure disc spring fails

The pressure disc spring is an important part of the clutch, and its failure may cause the clutch to be unable to separate properly, affecting the shift performance of the car. The causes and possible consequences of the disc spring failure are detailed below:

(1) Spring material fatigue: spring in the long time of use process, the material will produce fatigue due to repeated stress. The degree of spring material fatigue depends on the material performance, use time, working environment and other factors. When the spring material fatigue to a certain extent, the spring fails, resulting in poor clutch separation.

(2) Corrosion: the pressure disc spring may be affected by corrosive environmental factors, such as humidity, salt spray, etc. Corrosion can cause thinning of the spring surface structure and reduced spring strength, eventually leading to spring failure.

(3) Design defects: the design parameters of the pressure disc spring, such as the number of spring coils, materials, spring pretension, etc., have a great impact on its performance and life. Unreasonable design may lead to spring stress concentration, accelerate fatigue damage, and then cause spring failure.

The failure of the pressure disc spring mainly includes the clutch pedal stroke change long, shift difficulty, engine jitter and so on. Due to the spring failure, the clutch can not be separated normally, the driver may feel the gear is not smooth in the process of shifting, and even the phenomenon of pulling difficulty. Furthermore, a failed pressure disc spring may cause inconsistent clutch tightness and causing engine jitter.

In order to prevent and solve the failure of the pressure disc spring, the working condition of the clutch system should be checked regularly, especially in high temperature and humidity. Once the spring is found to have corrosion and fracture problems, it should be replaced in time. At the same time, select high quality spring materials and manufacturers to ensure that the spring has enough strength and stiffness. The fatigue performance of the spring should also be fully considered during the design and manufacturing process to improve its service life.

Release the bearing fault

The release bearing failure will cause poor clutch separation or drag sliding, affecting the driving performance of the car. The causes and possible consequences of the release bearing failure are analyzed in detail below:

(1) unqualified bearing quality: the quality of bearing directly affects its life and performance. The unqualified bearings may have material defects, poor processing and other problems, leading to the failure of the bearings during the use process. Therefore, choosing high-quality bearings is crucial to ensure the normal operation of the clutch.

(2) Poor lubrication: good lubrication is crucial to the running performance and life of the bearing. Poor lubrication will lead to bearing heating, wear, and even stuck. Regular inspection and replacement of lubricating oil to maintain good bearing lubrication, help to extend the bearing life and reduce the risk of failure.

(3) Improper installation: the installation mode and the tightening degree of the bearing have a great impact on its performance. Improper installation may cause premature wear or damage of the bearing. When

installing the bearings, follow the operating procedures to ensure that the bearings are installed firmly and run smoothly.

The release bearing failure may lead to poor clutch separation or drag slip, which may affect the driving performance of the car. In order to avoid these problems, the driver should check the working condition of the release bearing regularly, and find and remove the faults in time. In addition, the purchase of high quality bearings, good lubrication, and the correct installation of bearings are also effective ways to prevent the release of bearing faults.

Poor clutch separation

Poor clutch separation is usually manifested as difficulty in gear shift and gear tripping, etc. The possible reasons include failure of clutch self-regulation system, failure of driving force transmission system, etc. The causes and possible consequences of poor clutch separation are analyzed in detail below:

(1) Failure of the clutch self-regulating system: the clutch self-regulating system is responsible for automatically adjusting the clutch separation clearance according to the situation of friction plate wear. When the self-regulating system fails, the clutch separation clearance may be inappropriate, resulting in poor separation. The failure of clutch self-regulating system may include the wear of self-regulating mechanism, stuck, etc.

(2) Driving force transmission system failure: Driving force transmission system includes engine, clutch, transmission and other components. Working operation between these components is essential to ensure proper clutch separation. Failure of a component in the driving force transfer system may cause poor clutch separation. For example, a transmission failure may cause gear failure, which may affect the separation of the clutch.

Poor clutch separation may lead to difficult shift, gear jump and other phenomena, which further affect the driving performance and driving experience of the car. To avoid these problems, the driver should regularly check the working condition of the clutch self-adjustment system and remove the fault in time. At the same time, attention should be paid to the overall situation of the driving force transmission system to ensure that all components work normally together.

5. Clutch drag

Clutch drag refers to that the torque of the engine is still transmitted to the transmission when the clutch is not completely separated, resulting in abnormal sound, decreased acceleration performance and increased fuel consumption when the car is driving. Possible causes include poor clutch separation, friction plate wear, improper driver operation, etc. The causes and possible consequences of the clutch drag slip are analyzed in detail below:

(1) Poor clutch separation: as mentioned above, poor clutch separation may lead to dragging phenomenon. The reasons of poor clutch separation include failure of clutch self-regulating system, failure of driving force transmission system, etc. In order to avoid clutch sliding, it is necessary to timely check and solve the problem of poor separation.

(2) friction plate wear: friction plate wear will lead to the reduction of clutch transmission efficiency, and then drag and sliding phenomenon. Regular inspection of the friction plate wear and replacement of the seriously worn friction plate in time, help to prevent the clutch drag slip.

(3) Improper driver operation: improper driver operation may also lead to the clutch drag slip. For example, the driver steps on the clutch pedal for a long time, frequent emergency stops, fierce acceleration

and other behaviors may cause the clutch to drag and slip. Having good driving habits helps to reduce the risk of clutch drag slip.

Clutch drag slip may lead to abnormal sound, acceleration performance, increased fuel consumption and other problems. In order to avoid these problems, the driver should pay attention to the use of the clutch, regularly check the working condition of each component, and develop good driving habits. When the clutch drag slip occurs, the problem should be checked in time, and repair or replace the relevant parts. This can ensure the normal work of the clutch, improve the driving performance and safety of the car.

2.3 Qualitative analysis of the FMECA of the clutch

For the common failure forms, potential failure modes, and possible hazards mentioned, the failure mode, Impact and Hazard analysis (FMECA) method is used for failure analysis. FMECA Is a widely used method of failure analysis and reliability assessment designed to develop improvements or prevent these failures by identifying and evaluating the potential impacts and hazards of various failure modes in an equipment or system. The following are the analysis steps for using the FMECA method:

(1). Determine the research object: First, it is clear that the goal of FMECA analysis is the automobile clutch.

(2). Determine failure modes: Next, possible failure modes in the study subjects were defined and classified. This includes information describing the characteristics of each failure mode, possible causes, frequency, and severity.

(3). Assessment of Impact and Hazards: Assessment of its impact and potential hazards on system or equipment performance for each failure mode.

(4). Determine priorities: assign priorities to each failure mode based on their impact and degree of harm. Priority can be used to identify issues that require prioritized measures.

(5). Develop improvement measures: Develop corresponding improvement measures for the high-priority failure modes to reduce the probability and impact of failure.

Through the above FMECA method, the fault form, potential fault mode and possible hazards in the automobile clutch can be systematically analyzed, so as to provide strong support for fault prevention and improvement.

According to GJB / Z1391-2006 Failure Mode, Impact and Hazard Analysis Guide, the occurrence probability of failure mode is divided into five levels: A, B, C, D and E, as shown in the following table:

Table2-1 Classification table of the probability of failure

grade	definition	Characteristics of the occurrence probability of the failure mode	Probability of failure occurrence (during product use time)
A	be of common occurrence	High probability	The occurrence probability of a failure mode is greater than 20% of the total failure

			probability of the product
B	Sometimes happen	Medium probability	The occurrence probability of a failure mode is greater than 10% of the total product failure probability and less than 20%
C	Occasionally	Not often happen	The occurrence probability of a failure mode is greater than 1% of the total failure probability of the product and less than 10%
D	infrequence	It is unlikely to happen	The occurrence probability of a failure mode is greater than 0.1% of the total failure probability of the product and less than 1%
E	Very few	The probability is almost zero	The occurrence probability of a failure mode is less than 0.1% of the total failure probability of the product

Table 2-2 Scoring criteria affecting the severity of the hazard matrix

definition	grading standards	grade
Very serious	Affect the normal driving of the vehicle, which may lead to a sudden stop or get out of control	9，10

	during the driving; Greatly affect the shift operation, may lead to abnormal shift or unable to shift; There are great safety risks, which may endanger the life safety of drivers and passengers; The repair cost is high and may involve the replacement of the entire clutch system; It has had a serious impact on vehicle use.	
serious	Affect the driving performance of the vehicle, which may lead to unstable power transmission or decreased acceleration performance; Affect the shift operation, may lead to shift difficulty or abnormal noise; There are certain safety risks, which may cause potential dangers to drivers and passengers; The repair cost is high and may involve the replacement of some clutch components; It has a certain impact on the use of vehicles.	6，7，8
secondary	The driving performance of the vehicle is affected somewhat, such as slight power transmission instability or abnormal sound; Shift operation is affected to some extent, such as slight shift difficulty or abnormal noise when shifting; Safety risks are small, but may lead to discomfort for drivers and passengers; The repair cost is moderate and may involve the repair or replacement of some clutch components; Small impact on vehicle use.	4，5
low	The driving performance of the vehicle is basically normal, with only minor abnormal phenomena appearing; Shift operation is basically normal, only a slight	1，2，3

	abnormal phenomenon; Minimal safety risks, with almost no impact on drivers and passengers; Repair cost is low and may involve simple maintenance or adjustment; Basically has no impact on vehicle use.

Table 2-3 Qualitative analysis table of FMECA

fault-pattern	failure cause	fault effects	order of severity	Probability level
Friction sheet wear	Drivers operating habits	Reduced clutch performance, accelerated	secondary	B
	Friction sheet material	wear, and shorter life	secondary	C
	work environment		secondary	C
The pressure disc spring fails	Spring material fatigue	Poor clutch separation	serious	C
	corrode	affects the shift	serious	C
	design defect	performance	serious	D
Release bearing failure	The bearing quality is unqualified	Poor clutch separation or sliding, affect	serious	C
	Poor lubrication	the driving performance	serious	B
	Improper installation		serious	D
Poor clutch separation	The clutch self-regulation system has failed	Difficult to shift gear, gear jump off, affect the driving	serious	C
	Driving force transmission	performance and driving	serious	D

	system failure	experience		
The clutch is slippery	Poor clutch separation	Abnormal sound, reduced acceleration performance, increased fuel consumption, affect the driving performance and driving experience	Very serious	C
	Friction sheet wear		Very serious	B
	Improper driver operation		Very serious	B

In short, as the key component of the automobile power transmission, the performance and working condition of the clutch system directly affect the driving performance and safety of the vehicle. It is important to understand the failure mode of the clutch and to ensure the proper operation of the car. Drivers should develop good driving habits, and regularly check and maintain the clutch system, to ensure their good working condition. At the same time, the selection of high-quality parts and regular maintenance factory for replacement and maintenance, is also the key to improve the service life and performance of the clutch.

3 Modeling and Data Processing

3.1 Life span distribution model based on Bayes estimates

Bayesian reliability assessment is a method to assessing system reliability using prior knowledge and actual observed data. The core of the Bayesian approach is the introduction of a prior distribution, which means that relatively accurate evaluation results can be obtained even with a limited sample size of the data. Bayesian methods will now be used to assess the reliability level of vehicle clutches.

First, this paper determines the prior distribution by studying historical data, expert opinion, and information on similar products. This distribution can describe the belief about the reliability of the car clutch before any actual data are observed. Then, this study will update this prior distribution according to the actual collected vehicle clutch failure data to obtain the posterior distribution. The posterior distribution reflects the estimation of the vehicle clutch reliability after the observed data are combined with the prior knowledge.

The life distribution model is the basis of evaluating the reliability of the product, and its correctness directly affects the accuracy of the evaluation results. The method to determine the life span distribution model can be selected according to the actual situation, generally as follows:

1. Empirical distribution method: estimate the life span distribution model based on the existing data. The advantages of this method are simple and easy, the need to have enough data support, and cannot ensure the accuracy of the model.

2. Parameter distribution method: According to theoretical or experimental analysis, assume the form of life distribution model, and determine the parameters of the model through experimental data. The advantage of this method is that it can improve the accuracy of the model to a certain extent, but the disadvantage is that

it needs some theoretical or experimental basis, and may have the problem of improper selection of the model form.

3. Combination of experience and parameter distribution: combining experience and parameter distribution not only makes use of the simple simplicity of empirical distribution, but also overcomes the shortcomings of parameter distribution, and improves the accuracy of the model.

4. Physical model method: according to the product structure, material, process and other factors, the physical model of life distribution is established, and the accuracy of the model is verified through experimental data. The advantage of this method is that it can fully consider the characteristics of the product and improve the accuracy of the model. The disadvantage is that it needs to have a certain theoretical and experimental basis, and it is difficult to establish the model.

This paper mainly uses the empirical distribution method, according to the experience that mainly follows the exponential distribution. In order to conduct Bayesian reliability assessment, the field tracking life test data of 6 clutches of one model were collected, and a large amount of life test data of the model. After these data were collected, this study combined them with the prior distribution to evaluate the reliability of the automobile clutch.

After the analysis of the actual data, the study finds that the fault of the automobile clutch shows a certain regularity. In the Bayesian approach, this study uses these data to update the prior distribution to obtain the posterior distribution. The posterior distribution reflects the estimation of the vehicle clutch reliability after the observed data are combined with the prior knowledge.

This approach is highly adaptable and can continuously update the posterior distribution during the continuous collection of new data. This means that as more data are obtained on the performance of the vehicle clutch, the reliability assessment results of the Bayesian approach will become more accurate. In short, Bayesian reliability evaluation is a dynamic, flexible and highly accurate evaluation method, which is very suitable for the reliability analysis of complex systems such as automobile clutches.

In practice, the appropriate life span distribution model method can be selected according to different situations to ensure the accuracy of the evaluation results. At the same time, Bayesian methods can be used to evaluate the reliability of other complex systems to provide important decision basis for product design, manufacturing and maintenance.

3.2 Bayes likelihood function

The Bayesian likelihood function is a central concept in the Bayesian estimation process, used to describe the probability density of the observed data at a given parameter values. In this paper, we construct the Bayesian likelihood function based on the failure data of the clutch and estimate the model parameters using the Bayesian method.

During the model parameter estimation process, maximum likelihood estimation and least squares estimation can be used. In this paper, the maximum likelihood estimation method is mainly used to calculate the maximum likelihood estimation of the model parameters based on the failure data of the clutch.

First, the source of the data in the prior information is the life test before the product leaves the factory, the test type is the replacement timing interception test, and the prior distribution is solved according to the data of the following life experiment:

It is known that the life test of this model of car clutch has been conducted before leaving the factory, and now the life test data of 10 car clutches of this model is collected, as follows (unit: h):

No.1: Failure occurs after 5170 hours of work, and then put into the test after maintenance, and the test ends after 8 10 hours of further work.

No.2: failure occurs after 3530 hours of work, put into test after maintenance, failure occurs after 785 hours of work, continue to work after maintenance, the test deadline after 1340 hours.

No.3: Failure occurs after 3850 hours of work, put into test after maintenance, failure occurs after 1150 hours, put into test again after maintenance, and the test ends after 610 hours.

No.4: after 980 hours of failure, after maintenance into the test, after 1 152 hours of failure, continue to put into the test, 1850 hours of failure, continue to put into the test, 1565 hours after 1565 hours.

No.5: Failure occurs after 4750 hours of work, put into the test after maintenance, failure occurs after 740 hours of work, continue to work after maintenance, and the test ends after 370 hours.

No.6: Working 5980 hours working, no failure, test end.

No.7: Failure occurs after 5,775 hours of work, and it is put into the test after maintenance, and the test ends after 95 hours of continued work.

No.8: Working 5865 hours, no failure, test end.

No.9: Failure occurs after 770 hours of work, and it is put into the test after maintenance, and the test ends after 5,085 hours of further work.

No.10: Failure occurs after 5870 hours of work, put into the test after maintenance, and continue for 115 hours.

The observed total sample data n is 2 3, where the number of failed samples r is 13.

Order the failure time and censoring time in the test data to obtain the failure time$t_1 \le t_2 \le \cdots \le t_r \le t_0$ and the censoring time$t_1 \le t_2 \le \cdots t_{n-r} \le t_0$, then the likelihood function is

$$L(\theta) = \left(\prod_{i=1}^{r} f(t_i)\right)\left(\prod_{j=1}^{n-r} R(t_j)\right) \tag{3-1}$$

Bring into the corresponding function formula in the prior distribution model and obtain its likelihood function:

$$L(\theta) = \left(\prod_{i=1}^{r} \theta e^{-\theta x_i}\right)\left(\prod_{j=1}^{n-r} e^{-\theta x_j}\right) \tag{3-2}$$

Take the logarithm of L (θ) and solve the log-likelihood equation to obtain the maximum likelihood estimate

$$\overline{Y} = \frac{1}{r}\left(\sum_{i=1}^{r} t_i + \sum_{j=1}^{n-r} t_j\right) \tag{3-3}$$

Therefore, take: $\theta_0 = \overline{Y}^{-1}$ (3-4)

According to the above 3-3 and 3-4 formula and the life test data before delivery, call MATLAB: $\theta_0 = 2.2334 \times 10^{-4} h^{-1}$

Next, the paper determines the likelihood function according to the nature of the exponential distribution, using the following field experimental data:

Known extract 6 models of car, the clutch field tracking life test, each fixed time interval detection product work properly, if fault, continue to repair after the test, until 8000 hours, because the maintenance time relative to the car clutch working time can be ignored, so the maintenance time is not listed. The working time of the 6 automobile clutches in the test is as follows (unit: h):

No.1: Failure occurs after 5605 hours, and is put into use after maintenance. Failure occurs after 1625 hours, continue to work after maintenance, and the test ends after 420 hours.

No.2: Failure occurs after 3873 hours, and is put into use after maintenance. The test ends after 4077 hours.

No.3:7975 hours.

No.4: failure occurs after 3530 hours of work, put into use after maintenance, failure occurs after 1675 hours, continue to work after maintenance, failure occurs after 712 hours, continue to work after maintenance, test end after 1 280 hours.

No.5: Failure occurs after 5,534 hours of work, and it is put into use after maintenance. The test ends after 2,160 hours of further work.

No.6: failure after 880 hours of work, put into use after maintenance, failure after 4610 hours, put into work after maintenance, test deadline after 2138 hours.

Based on the above test data, obtain some samples $X = (x_1, \cdots, x_n)$, with the cut-off time $x_0 = 8000$h.

Let a sample less than x_0 be $x_1 \cdots x_{n1}$ and x_0 $x_{n1+1} \cdots x_n$.

$$p(x|\theta) = \left(\prod_{i=1}^{n1} \theta e^{-\theta x_i}\right)\left(\prod_{j=n_1+1}^{n} e^{-\theta x_0}\right) = \theta^{n_1} e^{-\theta\left(\sum_{i=1}^{n_1} x_i + (n-n_1)x_0\right)} \quad (3\text{-}5)$$

$$p(\theta|x) \propto p(x|\theta)p(\theta) \propto \theta^{n_1} e^{-\theta\left(\sum_{i=1}^{n_1} x_i + (n-n_1)x_0\right)}\theta_0 e^{-\theta_0\theta} \propto \theta^{n_1} e^{-\theta\left(\sum_{i=1}^{n_1} x_i + (n-n_1)x_0 + \theta_0\right)} \quad (3\text{-}6)$$

Logistic posterior:

$$\log p(\theta|x) = n_1 \log\theta - \theta\left(\sum_{i=1}^{n_1} x_i + (n-n_1)x_0 + \theta_0\right) \quad (3\text{-}7)$$

Log posterior distribution for the $\hat{\theta}_{MAP}$

$$\frac{\partial \log p(\theta|x)}{\partial\theta} = \frac{n_1}{\theta} - \left(\sum_{i=1}^{n_1} x_i + (n-n_1)x_0 + \theta_0\right) \Rightarrow \hat{\theta}_{MAP} = \frac{n_1}{\sum_{i=1}^{n_1} x_i + (n-n_1)x_0 + \theta_0} \quad (3\text{-}8)$$

According to the above 3-8 formula and field test data call MATLAB:

$$\hat{\theta}_{MAP} = 3.2542 \times 10^{-4} h^{-1}$$

4 Life prediction and reliability assessment

This paper mainly uses the MATLAB code to solve the parameters:

```
%导入数据
%读取确定先验分布的数据
data_expiration=xlsread("data3.xlsx");
data_deadline=xlsread("data4.xlsx");
r=length(data_expiration);
data_expiration_sort=sort(data_expiration);
data_deadline_sort=sort(data_deadline);
%确定theta0
y=(sum(data_expiration_sort)+sum(data_deadline_sort))/r;
theta0=1/y;
%输出先验参数theta0
disp("theta0:")
disp(theta0);
%导入bayes估计的数据
data=xlsread("data.xlsx");
x=data;
n=length(x);
%将x排序
x_sort=sort(x);
%截断时间x0
x0=8000;
%判断哪些小于x0
index_small=x_sort<x0;
%判断哪些大于x0
index_big=x_sort>=x0;
%提取小于x0的数据
x1=x_sort(index_small);
n1=length(x1);
%提取大于x0的数据
x2=x_sort(index_big);
%使用贝叶斯最大后验估计theta
theta_bayes=n1/(sum(x1)+(n-n1)*x0+theta0);
disp("Bayes :")
disp(theta_bayes);
disp("1/theta :")
disp(1/theta_bayes);
```

Figure 4-1 MATLAB program running code

Using the lifetime distribution model and model parameter estimates

$$\lambda = \hat{\theta}_{\mathrm{MAP}} = 3.2542 \times 10^{-4} h^{-1}$$

,Calculate the clutch reliability indicators, such as reliability, inefficiency, and average life.

Reliability function R (t):

$$R(t) = 1 - F(t) = e^{-\lambda t} = e^{-3.2542\times10^{-4}t} \tag{4-1}$$

Inefficiency function λ (t):

$$\lambda(t) = \lambda = 3.2542 \times 10^{-4} \tag{4-2}$$

Based on the expected value of the posterior distribution, the average life (MTBF) of the clutch is obtained as:

$$\mathrm{MTBF} = \int_0^\infty R(t)\,dt = \int_0^\infty e^{-\lambda t}\,dt = \frac{1}{\lambda} \approx 1/3.2542\times10^{-4} \approx 3072.9h \qquad (4\text{-}3)$$

Therefore, when the product life follows the exponential distribution, it can be concluded that the average life MTBF and inefficiency λ are reciprocal according to the formula (4-3).

5 Conclusion and outlook

5.1 Main research work and conclusion results of this paper

For the fault problem of automobile clutch, use Bayesian method for fault analysis and reliability evaluation. The main research work and conclusion results include the following aspects:

(1) Analysis of the reliability and failure mode of the clutch: Through the investigation and sorting out of the fault causes of the automobile clutch, this paper deeply analyzes the reliability characteristics and failure mode of the clutch, which lays a foundation for the subsequent fault analysis and reliability evaluation.

(2) Construct the life distribution model based on Bayes estimation: This paper uses Bayesian theory to construct the life distribution model based on Bayes estimation according to the failure data of automobile clutch, thus providing a reliable mathematical tool for the analysis of clutch failure.

(3) Estimation of the model parameters: By applying the Bayesian maximum posterior estimation method, the parameters of the life distribution model are estimated, so that the model can better fit the actual fault data of the clutch.

(4) Using the constructed model to calculate the reliability index: Through the constructed model, this paper calculates various reliability indexes of the automobile clutch, such as reliability, failure efficiency and average life.

Through the research of this paper, it provides an effective method for fault analysis and reliability evaluation of automobile clutches. Moreover, this study provides useful suggestions for fault prevention and maintenance of vehicle clutches, which help to improve the reliability and safety of vehicles and reduce the cost of vehicle maintenance and maintenance. At the same time, this research results also have some reference significance for fault analysis and reliability evaluation in other related fields.

5.2 Direction and content of the future research work

This paper has achieved some achievements in clutch fault analysis and reliability evaluation, but there are still some deficiencies and need to be improved. The direction and content of the future research work mainly include the following aspects:

(1) Continue to study the clutch failure mode and influencing factors: In order to improve the accuracy and practicability of fault diagnosis, it is necessary to further study the internal mechanism of the clutch failure mode and the related influencing factors, so as to provide more targeted suggestions for fault prevention and maintenance strategies.

(2) To explore more life distribution models suitable for automobile clutches: The life distribution model based on Bayesian estimation proposed in this paper has achieved some results, but other types of life distribution models can be further explored to improve the accuracy and applicability of reliability evaluation.

(3) Using big data and machine learning technology to mine and analyze clutch fault data: With the development of Internet of vehicles and intelligent vehicle technology, a large number of clutch fault data can be collected and analyzed. The use of big data and machine learning technology to mine and analyze

these data is expected to provide more powerful support for clutch fault warning, intelligent maintenance and maintenance strategy optimization.

(4) Study the correlation between the clutch faults and the faults of other automobile systems: the automobile clutch fault is often closely related to the faults of other automobile systems (such as transmission system, engine system, etc.). The study of these associations helps to improve the efficiency of vehicle fault diagnosis and provide a more comprehensive basis for vehicle maintenance.

(5) Expand the application scenarios of clutch fault analysis and reliability evaluation: The research results can be further applied to other types of clutch (such as electronic clutch, dual clutch, etc.) and other similar automotive parts, in order to improve the level of fault diagnosis and reliability evaluation of the entire automotive industry.

(6) develop easy to use fault diagnosis and reliability evaluation software tools: in order to facilitate engineers and maintenance personnel practical application of this research results, can develop an integrated fault diagnosis, reliability evaluation and maintenance recommendations of software tools, makes the relevant personnel can be more convenient clutch fault analysis and evaluation.

(7) Strengthen cooperation and exchanges with the industry: Through close cooperation with automobile manufacturers, parts suppliers and maintenance enterprises and other industry partners, the research results can be better applied to the actual production and maintenance process, so as to realize the development of the integration of industry, university and research.

(8) Tracking and research of the new clutch technology: With the continuous development of automotive technology, the new clutch (such as electronic clutch, double clutch, etc.) is gradually applied to the actual production. For these new clutches, the fault mode can be deeply studied, and the fault diagnosis and reliability evaluation methods suitable for these new clutches can be explored.

By conducting the above research direction and content, is expected to further improve the research results of this paper, constantly improve the clutch fault analysis and reliability evaluation theory system, for the automobile clutch fault diagnosis, reliability assessment and vehicle maintenance to provide more comprehensive and effective methods and theoretical support, improve the fault diagnosis and maintenance efficiency of the automotive industry, so as to contribute to improve the car performance and user satisfaction.

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