Research on Failure Modes of Defective Gasoline Engine Products Based on Pareto Diagram

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Abstract. The failure of gasoline engines seriously affects the safety of drivers and passengers. It is one of the main reasons for the recall of defective automobile products. In order to study the failure regularity of defective gasoline engine products and obtain the product failure mode, the data of the recall of automobile products caused by the defects of gasoline engine in the past five years were studied by using the Pareto Diagram. The research results show that the key factors for the sub-assembly of gasoline engine defects that lead to the recall of automotive products are fuel supply system, lubrication system and cooling system. The key factors of the failure mode are degradation or loss of function failure modes, blockage and leakage failure modes.

1. Introduction

The study found that engine failure or defect is the main cause of vehicle failure[1]. Studying engine failure or defect will not only improve the technical level of engine manufacturing, but also improve the emission quality of vehicle exhaust and reduce traffic accidents. At present, the research on engine faults or defects mainly focuses on the optimization of defects in the engine manufacturing process[2], the detection and isolation of engine faults by closed-loop system under simulated conditions[3], the method using neural network engine fault detection[4], using the Fourier algorithm and L-M algorithm to optimize BP neural network to detect the fault of the car engine[5]. The above studies on engine faults and defects are based on the detection and determination of faults when the engine is known to have failed, without prejudging and studying the faults and defects that may occur in the engine. A series of studies have been carried out based on the recall data of defective automobile products at home and abroad. Luo Yaling et al. analyzed and designed the defective automobile recall information management system based on the characteristics of defective automobile product recall[6], Yan Yin et al. analyzed the data of defective automobile recall products in automotive product manufacturing defects and safety technologies[7]. Lian Lanxiang et al. predicted the recall probability of defective automotive products and established an effective mathematical model[8].

This paper analyzes the failure modes and failure regularity of gasoline engine defective products in the past five years by statistical methods of the Pareto Diagram, extracts the key sub-assembly and key failure modes of defect occurrence, and the failure mode is further analyzed.

2. Pareto Diagram statistical method
Statistical analysis of sample data is an important means to obtain the law of development of things. Common statistical methods of data are permutation, causal, scatter, histogram, and stratification. The causal map helps to explain how the various causes interact with each other, but the quality or quality characteristics determined by the causal map are not specific and not targeted; A scatter plot is a graph used to investigate whether there is a correlation between two variables, but the scatter plot reflects only a trend, and a qualitative analysis requires a specific analysis. The histogram is represented by a series of longitudinal stripes or line segments of varying heights, but when the number of samples extracted is too small, the histogram statistics will produce large errors with low confidence. The stratification method divides the whole into several levels and studies them separately. However, because there are many factors affecting the quality change in the actual production process, it is difficult to draw the law of change if these factors are not distinguished. The Pareto Diagram is a histogram drawn in order of frequency of occurrence, indicating how many results are caused by the type or category of the confirmed type. By observing and analyzing the Pareto Diagram, the main factors affecting the development of the object can be grasped. In this paper, after considering the advantages and disadvantages of various data statistical methods, the statistical method of the Pareto Diagram is selected as the data statistical method.

The Pareto Diagram, named after the Italian economist V. Pareto, is a chart of the quality issues and quality improvement projects that appear in order of importance. The basic principles for project or factor classification are as follows: the influencing factors are divided into three categories: A, B, and C. Factor A refers to the cumulative frequency interval [0-80%); factor B refers to the factor in which the cumulative frequency is in the range of [80%-90%); factor C refers to the cumulative frequency at [90%-100%]. Factor A is the factor with higher frequency, so it is the main factor (key factor); factor B is the second key factor; factor C is the secondary factor.

3. Gasoline engine defect type analysis

According to the research and analysis of the 2015-2017 defective vehicle product recall data, engine defects are the most important factors causing defects and recalls of automotive products, as shown in Figure 1. This paper explores the engine defect mode of recalled cars.

![Figure 1. The number of recalls of defective automobile products in 2015, 2016 and 2017 related to the assembly](image)

According to the relevant data of the SAMR Defective Product Administrative Center (hereinafter referred to as “Defective Product Center”), using the Pareto Diagram method to study the partial recall of gasoline engines in China's defective automobile products in 2017, the Pareto Diagram is shown in Figure 2.
Figure 2. Pareto diagram for defective gasoline engine products recalls in 2017 related to sub-assembly

From the statistical analysis, it can be seen that the sub-assembly with the most recalls in the engine assembly is the fuel supply system, followed by the lubrication system and the cooling system. It can be seen that the key factors affecting the recall of engine defects are fuel supply system, lubrication system and cooling system; the second key factor is the starting system and the engine harmful substance purification system; the secondary factors are the valve operation, the block, the ignition system, crank-connecting rod mechanism and intake and exhaust system. As shown in Figure 3, it is a detailed analysis of the development trend of key factors for gasoline engine defects in 2013-2017.

Figure 3. Scatter diagram for recalls percentage of defective gasoline engine products in 2013-2017 related to sub-assembly

As can be seen from Figure 3, the percentage of defect recalls in the fuel supply system has remained at around 50% for five years, and is much higher than the number of defect recalls in the lubrication system and cooling system, and continues to rise in 2014-2017; the number of defect recalls in the lubrication system continued to decline in 2014-2017 after reaching the maximum in 2014; the number of defect recalls in the cooling system fluctuated within five years, but remained generally around 8%.
The following is a detailed analysis of the types of failures of the factors with the most cumulative recalls of the key factors of gasoline engine defects. Using the statistical data from the SAMR Defective Product Administrative Center, the statistical analysis of the defect types of the fuel supply system is performed, as shown in Table 1, according to the high to low number of failures.

| Failure label                                      | Frequency |
|---------------------------------------------------|-----------|
| Stalling during driving                           | 51        |
| Abnormal noise                                     | 51        |
| Engine vibration                                   | 39        |
| Short-term power shortage                         | 27        |
| Fault light is on                                 | 26        |
| High-speed sudden flame out                       | 14        |
| Gasoline leakage                                   | 14        |
| Self-ignition                                     | 10        |
| Cylinder shortage                                  | 10        |
| Abnormal noise in the fuel tank                    | 10        |
| Damage to the gasoline pump                        | 9         |
| Tingle                                            | 7         |
| High fuel consumption                              | 7         |
| Cruising range unable to reach rated value         | 7         |
| Loss of power during driving                       | 6         |
| ……                                                | 126       |

“...” represents all other fault labels with less than 6 fault declarations, and the subsequent digits are the sum of all such fault reports.

Among the fault labels involved in the recall of the fuel supply system, the faults involving the engine's own performance are abnormal noise, engine vibration, cylinder shortage, tingle, blasting, knocking, vibration and lack of fire, accounting for 30.43% of the total number of recalls of the fuel supply system; faults involving engine power include stalling during driving, short-term power shortage, high-speed sudden flame out, cruising range unable to reach rated value, loss of power during driving, flame out and accidental acceleration, accounting for 27.78% of total recalls of fuel supply system; the faults involving engine fuel include gasoline leakage, spontaneous combustion, abnormal noise in the fuel tank, damage to the gasoline pump, high fuel consumption, fuel leakage and fuel gauge display, which are too large compared to the actual residual amount, accounting for 14.25% of the total recall of the fuel supply system; involving the fault light failure, the fault light occupies 6.28% of the total recall of the fuel supply system; 21.26% of the total recalls of fuel supply systems involving other failures. It can be seen that the automobile engine defect products which are recalled due to the failure of the engine's own working performance account for the majority, the second is the product recalled due to the engine power, and finally the product recalled due to the engine fuel and the fault light failure.

4. Research on failure mode of defective gasoline engine products

The failure mode is the manifestation of the fault. In general, the failure mode refers to a fault phenomenon that has occurred in the product and can be observed or measured. Common product failure modes are classified into damage failure mode, loose failure mode, offset failure mode, blockage and leakage failure mode, degradation or loss of function failure modes, and other failure modes. The following is a study on the failure mode of gasoline engine for defective automotive products based on data from the SAMR Defective Product Administrative Center.

The number of recalls of defective gasoline engine products in China in 2017 is shown in Figure 4.
As can be seen from Figure 4, the main factors affecting the recall of gasoline engine defects are degradation or loss of function failure modes, blockage and leakage failure modes; the second key factor is the offset failure mode; the secondary factors are damage failure mode, other failure mode and loose failure mode. As shown in Figure 5, the following is a detailed analysis of the development trend of key factors for gasoline engine defects in 2013-2017.

Figure 5. Scatter diagram for recalls percentage of defective gasoline engine products in 2013-2017 related to failure mode

It can be seen from Figure 5 that the number of defective gasoline engine product recalls due to degradation or loss of function failure modes has generally increased in the past four years, reaching a minimum in 2014 and much higher than the blockage and leakage failure modes. The number of recalls is about 50% of the total number of recalls. The number of recalls of defective gasoline engine products recalled due to blockage and leakage failure modes reached a maximum in 2014, and the...
overall downward trend in 2014-2017. Taking the degradation or loss of function failure modes as an example, the layout Pareto Diagram method is used to further study as shown in Figure 6.

Figure 6. Pareto diagram for the number of recalls of defective gasoline engine products in 2017 related to degradation or loss of function failure modes

According to Figure 6, the key factors are functional failure and abnormal noise; the second key factor is performance degradation; the secondary factor is over heating and pollution hazard limits. As shown in Figure 7, the development trend of the key factors of gasoline engine failure mode in 2013-2017 is analyzed in detail.

Figure 7. Scatter diagram for recalls percentage of defective gasoline engine products in 2013-2017 related to failure causes

It can be seen from Figure 7 that the defective gasoline engine products recalled due to functional failure have a continuous upward trend in 2014-2017, except for the high percentage of total recalls in 2013, and account for about 50% of the total recalls of performance degradation or failure modes, which is much higher than the number of defective gasoline engine recalls due to abnormal sounds. Defective gasoline engine products that were recalled due to abnormal noise have a small number of recalls in 2013 and 2017, however, in 2014-2016, it remained relatively stable at around 30%.
5. Conclusion
Using the Pareto Diagram method to analyze the specific recall times of each sub-assembly in the engine assembly, the key factors affecting the engine defect recall are the gasoline engine fuel supply system, lubrication system and cooling system failure. After counting the types of defects in the fuel supply system, it is known that the fault labels that involve the most recalls are stalling during driving, abnormal noise, engine vibration, short-term power shortage, and fault light.

The key factors affecting the recall of automobile defects through the Pareto Diagram method are performance degradation or failure mode, blockage and leakage failure modes. The second key factor is the offset failure mode. A detailed analysis of the specific failure causes of performance degradation or failure modes can be seen, the key factors are functional failure and abnormal noise; the second key factor is performance degradation.

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