# Vehicle durability test based on user survey

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**Abstract**

The vehicle durability test is an important means of assessing and verifying the vehicle reliability. At present, the domestic automobile enterprises generally have some problems such as nonstandard test methods, the test mode insufficiently associating to the users in the vehicle durability test. It proposes a method for establishing the vehicle durability test mode in the paper, based on the theory of fatigue damage. Through the users' survey, the load acquisition and data analysis are carried out from the testing ground and the social roads by using of six-component force tester. It is proved, that the vehicle durability test method can not only shorten the test cycle, but also increase the appearance and countermeasures of adverse conditions. Meanwhile, it can reduce many kinds of adverse problems occur after the new vehicle coming into the market, and improve the quality of vehicle reliability.

*Keywords:* user survey, durability test, load collection, damage value

## 1 Introduction

The automobile durability is one of the quality problems which the users are most concerned about. The durability as an important indicator to measure the automobile quality has long been attached great importance by the automobile production enterprises. Because of only those automotive products with good reliability can be durable and popular with users. The vehicle durability test is the most direct and effective evaluation of automotive reliability and durability. The automobile enterprises should carry out the vehicle durability test during the new vehicle design and trial production phase, in order to verify the automobile reliability, and reduce the adverse problem after production [1].

At present, the advanced automobile enterprises in American, in Europe and in other countries have paid more and more attention to the automobile durability. A complete set of durability management system from the design to the service has been established, in order to improve the reliability of the automobile. The automobile durability has become the main factors of its products to win in the market competition. John Hollenbeck took the application of automobile electronic control modules in the vehicle as an example, to discuss the preparation and the implementation method of the durability technology during automobile product development [2]. Early durability tests in China are most to ensure the vehicle component does not break, damage, and can meet certain

quality requirements, during the most extreme conditions. The test mode mainly depends on the experience value. It results in the insufficient association with the users.

In the paper through the investigation on the user's habits and the road environments, combing with the test road conditions in a proving ground, getting the load acquisition and data analysis from the testing ground and the social road by using of six-component force tester, one vehicle durability test mode has been proposed and improved. It can improve the reliability and users' satisfaction, provide the basis for reducing the cost, simplifying the design.

## 2 Vehicle durability test mode set-up process

The establishment of automobile durability mode derives from the surveys of users' habits, the environment and the real test field conditions. The automobile durability mode will be built on the basis of achieving the endurance test goal, by contrasting the test mode with the social roads intensity. Please see Figure 1.

## 3 Fatigue damage theory

### 3.1 S-N CURVE

The cycle of stress or strain before material fatigue failure is called fatigue life. The curve expressing the relationship between the stress (strain) level S and the standard sample fatigue life N is known as the material S-N curve [3].

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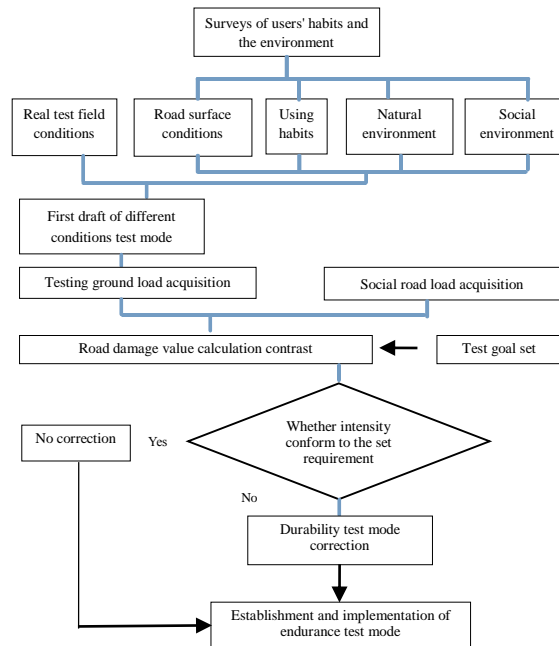*Corresponding author* e-mail: fuhudai@126.com

FIGURE 1 The overall set-up process

## 3.2 CUMULATIVE FATIGUE DAMAGE THEORY

Fatigue fracture is a process of cumulative damage. At present, there are many kinds of theories and methods for calculating the fatigue life of parts under random load [4]. Miner linear cumulative fatigue damage theory has simple expression, and a considerable degree of agreement between its life estimation and the test results in most cases. So it is currently the most common method for fatigue life prediction. The total damage by Miner cumulative fatigue damage theory is shown in Equation (1).

$$D = \sum_{i=1}^{n} di = \sum_{i=1}^{n} \frac{ni}{Ni} . \qquad (1)$$

In Equation (1), $Ni \rightarrow$ the damage cycles on $\sigma - n$ curve corresponding to the stress level $\sigma i$;
$ni \rightarrow$ the actual work cycles under the action of the stress level $\sigma i$;
Let $N_0$ be the limit life corresponding to the fatigue limit $\sigma_{-1}$, according to the Basquin relationship, there is:

$$Ni = \left( \frac{\sigma_{-1}}{\sigma_i} \right)^m N_0 . \qquad (2)$$

In Equation (2), $\sigma_{-1} \rightarrow$ fatigue limit; $N_0 \rightarrow$ fatigue life corresponding to the fatigue limit;

Taking Equation (2) into Equation (1) can get calculation formula of the cumulative damage. See Equation (3).

$$D = \sum_{i=1}^{n} \frac{ni}{N_i} = \sum_{i=1}^{n} \frac{ni}{\left( \sigma_{-1}/\sigma i \right)^m N_0} = \sum_{i=1}^{n} \frac{ni\sigma_i^m}{N_0 \sigma_{-1}^m} . \qquad (3)$$

According to Miner theory, the fatigue damage will happen when the whole material damage finishing.

## 4 User habits survey

The use habits and the road environment information include four aspects, which are the road surface conditions, users using vehicle habits, natural environment and social environment. According to the investigation information of these four aspects, the statistics for the users actually driving habits and the road surface features will be obtained. The establishment of durability test mode is based on these features.

1) Road environment, the road conditions and proportion of mountain road, freeway, city road and so on;

2) Use habit, intensity and frequency of braking, use frequency of hand brake, window, CD and so on;

3) Natural environment, maximum and minimum air temperature, sunshine, humidity and other natural factors when using vehicle;

4) Social environment, the quality of fuel, emission standards and other social environmental factors;

## 5 Road load collection and calculation method of fatigue damage

### 5.1 ROAD LOAD COLLECTION

The input force to the vehicle from the road is transferred through the tire suspension, shock absorbers and so forth. The sensors for the road load collection are arranged on the

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vehicle input force transmission path. According to the principle, tire six-component force tester, strain gauges and acceleration sensors are arranged on the tire, the suspension upper and lower arms, damping spring and the spring seat. Please see Table 1.

TABLE 1 Road load collection illustration

| CH | Position | | Sensor | Unit |
|----|----------|----|--------|------|
| 1 | | | six-component force tester | N |
| 2 | | | six-component force tester | N |
| 3 | | | six-component force tester | N |
| 4 | FR | L | strain gauges | mm |
| 5 | | | acceleration sensor | G |
| 6 | | | acceleration sensor | G |
| 7 | | | six-component force tester | N |
| 8 | | | six-component force tester | N |
| 9 | | | six-component force tester | N |
| 10 | FR | R | strain gauges | mm |
| 11 | | | acceleration sensor | G |
| 12 | | | acceleration sensor | G |
| 13 | | | strain gauges | mm |
| 14 | RR | L | acceleration sensor | G |
| 15 | | | acceleration sensor | G |
| 16 | | | strain gauges | mm |
| 17 | RR | R | acceleration sensor | G |
| 18 | | | acceleration sensor | G |

## 5.2 ROAD LOAD DATA PROCESSING METHOD

### 5.2.1 Load data pre-processing

Please see Figure 2. The original data collected from the load are acceleration, force, torque, and the curve when micro strain changes along with the time domain. The disturbed data on the curve should be removed. For example, the unexpected "cusp" on the acceleration curve is generally judged to be disturbed location, and the data corresponding to all channels at this time should be removed.
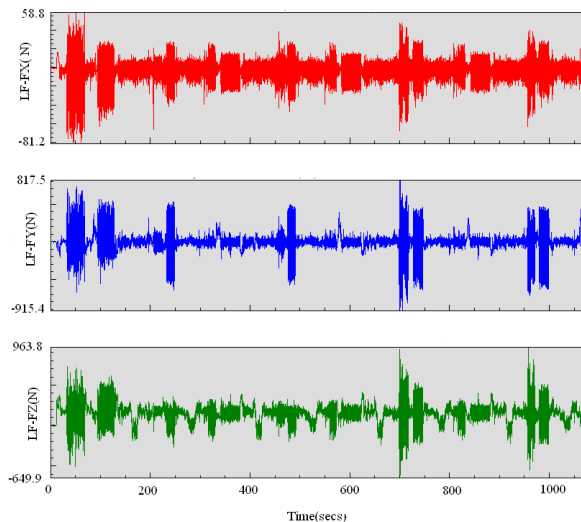


FIGURE 2 The original data collected from the load

The loads collected directly when the car in motion is continuous data changed over time, namely load-time, strain-time data. The load spectrum cannot be used directly for fatigue life estimation, because of the uncertainty of

random load. It must be for statistically processed. The load-time processed is called load spectrum. The load spectrum which is the graph with statistical properties can essentially reflect the load changes of parts. For random load, the statistical analysis method widely used is mainly counting method. The load-time processed into a series of complete cycle or half cycle is called counting method. The counting methods proposed from abroad have more than a dozen kinds. The two-parameter counting method now mostly used is rain-flow counting method. The method considers that the presence of plastic is a necessary condition of fatigue damage, and its plastic property must be the hysteresis loop of stress-strain [5].

The road load data collected are processed by rain-flow counting method. The continuous data changing over time are assigned into 100 intervals, and the output unit is times. Please see Table 2.

TABLE 2 Road load data collected by rain-flow counting method

| Interval Position | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|-------------------|--------|-------|-------|-------|------|------|------|
| LF-FX | 258026 | 63524 | 47322 | 28346 | 6035 | 2382 | 1160 |
| LF-FY | 125407 | 59336 | 22858 | 5172 | 1546 | 562 | 276 |
| LF-FZ | 48924 | 36955 | 11204 | 4326 | 1614 | 764 | 463 |
| Interval Position | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| LF-FX | 724 | 462 | 289 | 254 | 148 | 92 | 114 |
| LF-FY | 117 | 73 | 45 | 20 | 21 | 15 | 13 |
| LF-FZ | 291 | 129 | 86 | 55 | 52 | 27 | 21 |

### 5.2.2 Calculation of fatigue damage value

The data processed by rain-flow counting method are fed into the material S-N curve. It will calculate the fatigue damage value Dm, which is the absolute value. Although the vehicle chassis and body are composed of a variety of materials, each material has its own S-N curve. So they cannot be simply fed to calculate the absolute damage value. Introducing the concept of relative damage value is needed here. The ideal S-N curve will be constructed. The input values of reference road are fed into S-N curve, and the Dm value is exactly 1. Then the road input values from the testing ground are fed into the ideal S-N curve. The damage value calculated can reflect the contrast between the pavement strength in testing ground and the reference road [6].

## 6 Establishment and improvement of durability test mode

### 6.1 TEST GOAL SET

In order to shorten the test cycle, the road durability test is generally conducted on the testing ground with various features, such as twisted road, stone road and long road etc. The enhancement coefficient that of the various strengthened roads relative to the ordinary roads must be confirmed, in order to make the results comparable. The enhancement coefficient is the ratio of mileage that of the

car running on the social roads and on the strengthened test roads under the same failure mode.

$$K = \frac{L_1}{L_0}.$$  (4)

In Equation (4), $L_1 \rightarrow$ mileages running on the social roads; $L_0 \rightarrow$ mileages running on durability test roads of the testing ground.

## 6.2 USER HABITS SURVEY

According to the method of user habits survey, many owners use habits, road environments and other data have been collected in a period of time. The user operation class and running class data which provide the basis for establishing the durability test mode have been extracted by analysing.

## 6.3 PRELIMINARY ESTABLISHMENT OF ENDURANCE RUNNING MODE

Based on user habits survey and one testing ground conditions, the vehicle durability test running mode for highway, city road, mountain road, bad road, traffic jam and other conditions has been preliminarily set up. According to the anchor point on the running track of the testing ground, the operation specification for the velocity, acceleration and braking in each interval is confirmed.

## 6.4 LOAD DATA ACQUISITION AND ANALYSIS ON TESTING GROUND AND SOCIAL ROAD

### 6.4.1 Load acquisition on testing ground

According to 5.1 road load data acquisition methods, three loading modes such as no-load, half load, full load are used after the six-component force tester, strain gauges and acceleration sensors are arranged on the experimental car. In accordance with the preliminary testing ground durability test mode driving, 10 groups of the original load data are collected. The data processed by a certain proportion will be added.

### 6.4.2 Social road load acquisition

Through the surveys of the user habits and the road environment, the users' driving road surface and speed constitution have been gotten. According to this information, the social characteristics roads are selected. The social road load data are collected in accordance with 6.4.1 loading mode. It will be used as the reference road to

generate S-N curve, and to compare with the testing ground durability test mode.

### 6.4.3 Load intensity contrast between the testing ground and social road

The damage value ratio of the testing ground relative to the social road is calculated, according to the methods described in 5.2. The items in each channel are not the same during collecting the road load in testing. So the calculation of damage value should be separately carried out. Please see Table 3.

TABLE 3 Road load comparison

| Channel No. | Data type | Enhancement coefficient | Damage value comparison |
|---|---|---|---|
| 1 | LF-FX | 3 | 3.26 |
| 2 | LF-FY | 3 | 4.21 |
| 3 | LF-FZ | 3 | 2.73 |

The enhancement coefficient is assumed to 3 in Table 3. By comparing the damage value in the testing ground and in the social road, the values of some channels are below or above the standard value. So we should adjust the proportion of some conditions in the durability mode. For example, the proportion of bad road conditions should be increased when the vertical damage value is relatively low.

## 6.5 ESTABLISHMENT AND IMPLEMENTATION OF ENDURANCE RUNNING MODE

The established and improved vehicle durability test mode based on the above method has been used into the reliability test of new vehicle developing. It is proved that the mode can effectively find the adverse conditions and propose the countermeasures in advance during the trial stage. It also can reduce the occurrence of the adverse conditions after new vehicle quantity production into the market.

## 7 Conclusions

With the rapid development of automobile industry in China, how to correctly, quickly and effectively carry out the vehicle reliability test is the research for the domestic automobile enterprises to do. A process and method for establishing the vehicle durability test mode and putting it into practical application have been proposed in the paper, based on the theory of fatigue damage. The results showed that the method cannot only effectively improve the vehicle durability design quality, but also enhance the users' recognition to the automobile products.

## References

[1] Bertodo R 1987Reliability and durability of automotive prime movers. *Int J of Vehicle Design* **8**(2) 145-8

[2] Ensor D F 1999 Customer Usage Profiling and Accelerated Development *Journal of the Engineering Integrity Society* **6**(6) 892-8

[3] Bannantine J A, Comer J J, Handrock J L 2004 Fundamentals of metal fatigue analysis *New Jersey Prentice Hall Englewood Cliffs* 168-83

[4] Svensson T 1996 Fatigue damage calculations on block load sequences *Fatigue Fract.Engng Mater Struct* **19**(3) 251-64

[5] Khosrovanch A K, Dowling N E 1990 Fatigue loading history reconstruction based on the rainflow technique *International Journal of Fatigue* **16**(2) 20-4

[6] Lalanne C 2002 Fatigue damage *Mechanical Vibration and Shock* **4**(6) 157-61

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