The reliability acceleration test method of special vehicle transfer box

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Abstract: This paper introduces the principle of the simulation load acceleration test system, the principle of accelerating test, and discusses the technology and method of the reliability acceleration test of the box.The accelerated test results show that the simulation load acceleration test can meet the reliability test of the unit, which can shorten the development cycle and have important production practical value for research and new product development.

1 Introduction

In addition to the performance indexes of the vehicle, the transmission system must meet strict reliability indicators. As an important part of the wheeled vehicle transmission system, the unit is based on its durability and reliability test [1-2]. However, the workload of the gearbox vehicle drive system is large, the workload is complex, the influence of the environment and the condition is large, the random factors are many, and it is not easy to control, so it is long and time-consuming and expensive [3]. According to the current actual car test mileage, the test of the box is completed for nearly two years. We use the platform test, through the control test condition, the experimental environment stability, the test time concentration, easy to obtain the experimental results [4-5]. Therefore, it is necessary to study the method of accelerating test of the reliability platform of the equivalent relationship with the real car experiment, to improve the efficiency of product development, eliminate the weak link of design, reduce the defect, and it is of great significance to the reliability of the product [6-7].

2 The composition of the test system and the loading basis of the system

2.1 Test system composition

The test system set machine, electric and liquid integration are composed of simulated loading system, electro-hydraulic and pneumatic control system, data detection processing system, cooling system and so on. The structure of the system is shown in figure 1.

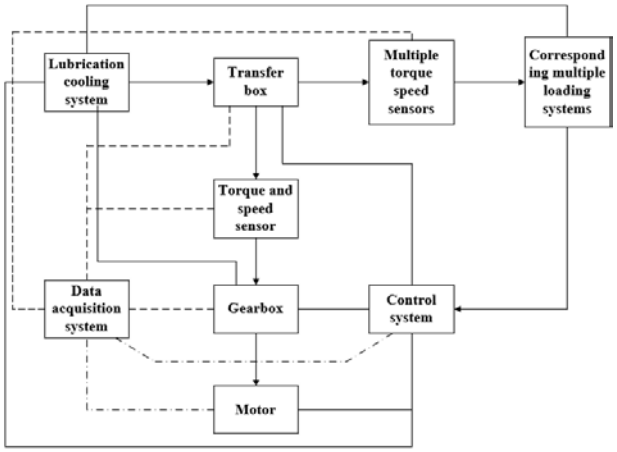

Fig. 1. diagram of the system structure of the system

1.2 The loading basis of the test system

The box is an important part of the special vehicle transmission system, which has the characteristics of "one input and more output". The function of the box is transferred to the bridge drive box and the wheel side reducer, and eventually the wheel turns. Among them, inter-wheel differential is used to realize the difference between left and right wheels of the vehicle, inter-axle differential is used to realize the difference between front and rear axles of the vehicle bridge. In addition, the inter-axle pneumatic combined relief mechanism is set in the sub-box to realize the conversion of the difference between axles and wheels of the vehicle.

Transmission system torque is transferred to the engine -- transmission box -- transmission box -- (each) transmission box -- wheel side, and the maximum torque of the engine is transferred to the torque load of the transmission box. In this case, the calculation formula of torque M acting on the transmission box is shown in Formula (1).

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$$M=M_{e,max} \times i_q \quad (1)$$

The maximum torque of the engine is converted to the torque load of the transmission box. In this case, the calculation formula of torque M_z acting on the side transmission box is shown in Formula (2).

$$M_Z=M_{e,max} \times i_q \times i_b \quad (2)$$

M--moment at the input end of the transfer box, unit (N.m);

$M_{e,max}$--The maximum torque of the engine on the sexual curve, unit (N.m);

i_q--transmission ratio of the gearbox;

i_b--Transmission ratio from transfer box to transmission $_{box}$;

3 Analysis of the accelerated test method of the transfer box

The purpose of the reliability acceleration test is to quickly effectively stimulate fault, analyze fault and improve the design and prove the effectiveness of the improvement by using the actual sensitive stress condition of the unit, by testing the design defect of the product, and improve the reliability of the product by correcting the measures, and evaluate the reliability level of the product in a short time.

3.1 Principles of accelerated test

The accelerated test is to improve the test stress, strengthen the test conditions and accelerate the failure of the prototype under the premise of not changing the failure mechanism of the original prototype and not adding new failure factors, so as to predict the product reliability under normal load in a relatively short time.

In order to simulate the actual operating conditions of the transfer box as accurately as possible, the following principles should be considered when accelerating the test prototype on the bench:

(1) The failure factor of the accelerated test should be consistent with the actual operating condition of the box, which is not to increase the new failure factor.

(2) The failure mechanism, failure mode, fault distribution and sequence should be similar to that of the real truck test.

(3) Shortening the test time should be reasonable.

3.2 Failure mechanism analysis

The failure mechanism of the parts is determined by the stress condition. Different stress types have different failure mechanisms, and different stress levels will encourage the development of different failure mechanisms. The stress level is high, and its corresponding failure mechanism develops fast. Therefore, in the accelerated experiment, the simulation load must choose the stress condition that has the promotion effect on the failure mechanism, and the stress condition of the failure mechanism has important influence and must be strictly controlled.

3.3 Reliability analysis of the transfer box

The transfer box is a complex component system, which is composed of the box assembly, gear assembly, lubrication system assembly, wheel (shaft) differential assembly, shaft assembly, etc. Therefore, the failure factors and mechanisms of different parts in the box are different, and the simulation load reinforcement should be different.

First, the reliability analysis of the transfer box is analyzed, including the failure mode, the failure form analysis, the failure impact, the severity analysis, the harm effective analysis and the and the FMECA.Also identify key components and key weaknesses in the data and information collected from the box test.

After the mechanical analysis of key parts in operation, the gear or bearing parts are mainly contact fatigue failure, and the simulation load factor should be related to the average of the load, and the main factor affecting the fatigue life is the amplitude and the number of cycles of the alternating load. The above factors are considered in the process of accelerating the experiment.

According to the data and information collected from the real car test of a particular box, and the reliability analysis of the case, we can know due to the failure mode of the gear, differential shaft and box body assembly, the performance of the vehicle is directly affected, and the vehicle is not completed. Therefore, the shaft of the idle wheel, the differential shaft and the box body complement are the key parts of the reliability of the box. We analyze the failure phenomenon and mechanism, and the main driving force of the box is the idle gear, which is the weakest link in the box. Therefore, the idle gear is focused on the acceleration test.

3.4 Reliability acceleration time determination

According to the results of the reliability analysis of the initial case, we know that the wheel differential in the compartment is a key component of dynamic shunt and transmission. The box assembly and the wheel and the idle gear are the three key points of the box, and the weakest three parts of the many structural parts. However, based on the actual failure and fracture mechanism analysis, the idle gear is weaker than the wheel differential and the box. Therefore, the experimental method can be obtained according to the S-N curve and linear fatigue damage theory of the idle gear.

a) Determine the fatigue damage of the idle gear

According to the input torque of the previous input load test, the input torque is shown in figure 2.

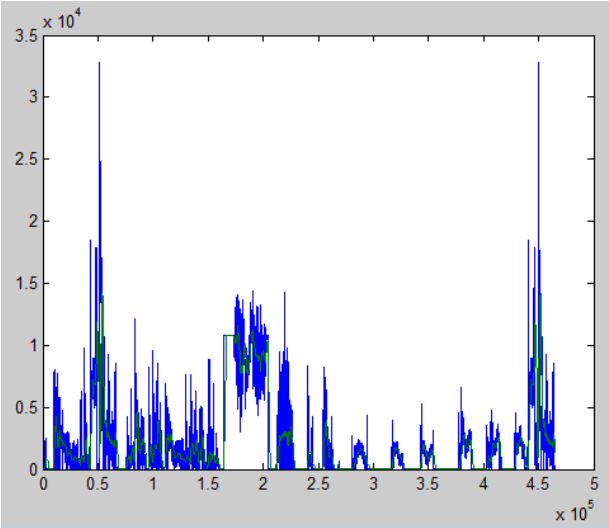

Fig. 2. Input shaft torque value in input load test

According to the measurement torque spectrum of the input load test and the corresponding idler, the stress distribution status of the root position of the idle wheel is shown in table 1.

Table 1. Distribution of stress distribution of idle wheel root

Maximum stress(Mpa)	32	76	118	162	198
Input torque	0 ～ 1100	1100 ～ 2200	2200 ～ 3250	3250 ～ 4350	4350 ～ 5400
Input mean torque	550	1650	2725	3800	4895
probability	0.4732	0.2938	0.0689	0.0148	0.0165
Stress number	30841168	12856680	8583506	3238942	5759495
Maximum stress(Mpa)	225	297	350	426	526
Input torque	5400 ～ 6500	6500 ～ 7600	7600 ～ 8700	8700 ～ 9800	9800 ～ 10850
Input mean torque	5950	7050	8150	9250	10325
probability	0.2609	0.0154	0.0273	0.0482	0.0157
Stress number	154825	86702	173404	198176	37158

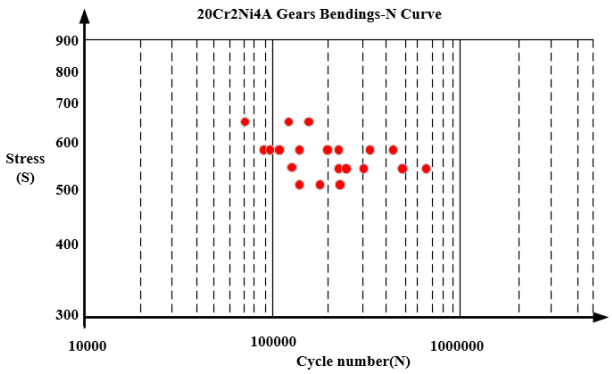

Fig. 3. Idle wheel bending fatigue S-N curve

1) Determine the fatigue strength limit of the idle wheel

The material is 20Cr2Ni4A, according to the measured idle wheel S-N curve, the fatigue strength limit of the idle wheel r is: σ_{-1c}=419.360Mpa.

2) Determine the damage of the reliable index

According to cumulative theory of linear fatigue damage, when the stress of idle wheel is bigger than σ_{-1c}, accrue damage. In light of this, running 48000kmas (reliability index), the idling gear has a 61930057 stress cycle, idling gear damage:

$$S = \frac{\Sigma_{i=s}^{i0} n_i \sigma^m{}_i}{n_0 \sigma^m_{-1c}} \quad (3)$$

In the form:

m—idling gear s-n curve constant;

σ_i—The levels of stress at all levels are shown in table 1;

n_i—The number of cycles of stress levels at all levels is shown in table 1;

n_0—The cycle base,n_0=25×107;

Calculate:

$$S = \frac{n_5\sigma_5^m + n_6\sigma_6^m + n_7\sigma_7^m + n_8\sigma_8^m + n_9\sigma_9^m + n_{10}\sigma_{10}^m}{n_0\sigma_{-1c}^m} \approx 0.3622$$

b) Determine the number of fatigue cycles N

In order to shorten the test time and simulate the actual conditions more realistically, the fatigue cycle number is determined according to the damage theory and the approximate proportion of each gear of the gearbox.as shown in table 2:

Table 2. Parameters under load stress

Step stress σ_i(MPa)	426	526
Input torque under different stresses Mi	9250	10325
Damage under different stresses Si	0.1195	0.2427
Rotation number under different damage	2454119	797529
Speed of revolution r/min	210	180

According to the table 2, when the cumulative damage of the idle wheel in different echelon stress is 0.3622, total fatigue damage cycle number N is 3251648 times.

c) Determine the reliability of the load time

According to the theory of injury, it can be obtained:

T=S • N/(60 • n)= 0.3622 • 3251648/(60 • n)=100.7h

3.5 Accelerated test section

In order to shorten the test time and the more actual simulation of the actual condition, according to the S-N curve of the idler and the linear fatigue damage theory, the time t of the reliability acceleration is determined. According to the statistics of the actual sports car pavement distribution and the proportion of use, the

actual gear of the gearbox is roughly proportional, the maximum torque operating condition of the engine, We have proposed the relevant test plan.

Figure 4 shows the transfer box test section.

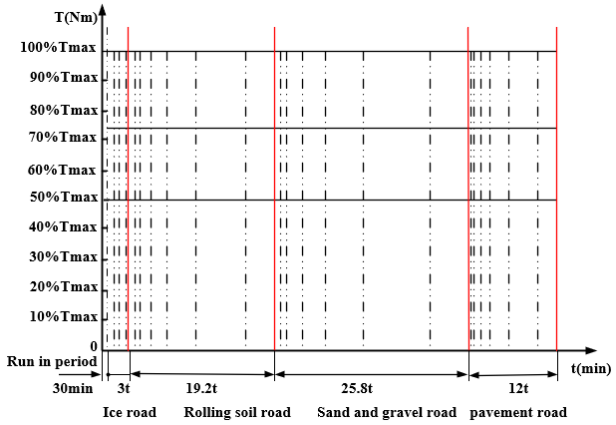

Fig. 4. Acceleration test section of the transfer box

Comments: a） $T_{max}=M_{max} \cdot i_{variation} \cdot i_{Torque\ ratio}$； （T is the torque, Nm; M_{max} is the maximum torque）

The key mechanical parts which have the S-N fatigue curve can be evaluated by improving the test stress and strengthening the workload. The higher the stress level, the more obvious the reinforcement effect. Therefore, we use the maximum torque condition of the vehicle engine with the transfer box.

a) The gearbox grinding period 30 min is carried out without load

b) We determine the test time t in the following ways：

1) Through the load spectrum of the system , the S-N curve of the key weak parts and the linear fatigue damage theory， We calculated t.

2) We can refer to similar systems according to the complexity, importance, technical characteristics and reliability requirements to determine t.

c) The proportion of each road surface is distributed in accordance with the actual field test road : pavement road 20 %， sand and gravel road 43 %，rolling soil road 32 %，ice road5 %.

d) Each road is divided according to the number of gearbox forward gear and each gear proportion of the time.

e) The above is the partition of the loading section, take 8 forward gear MT gearbox for example. The double dash line in the diagram is each gear segment in gearbox.1, 2gear is load of 75 percent T_{max}, 3 to 8 gear is load of 50 percent T_{max}, 75 percent T_{max}, 100 percent T_{max}.

f) Each gear speed chooses the engine's three typical speed. Maximum torque point speed, maximum power point speed and most common working speed.

The transfer box reliability acceleration test is distributed according to figure 4， in 10 cycles to complete reliability acceleration test with time t.

4 Conclusions

After the bench acceleration test system passes through the transfer box prototype simulates load strengthening test 100.7 hours,

We have carried on the decomposition appraisal to the box to comprehensive appraise the damage situation of transfer box body, the gear, the bearing and the shaft kind of parts and so on. And compare and analyze with the real vehicle reliability evaluation record of 880 hours, we find that the zero fault mode and fault mechanism of the prototype after simulated acceleration test are basically consistent with those of the real vehicle reliability production test, but the time was cut eight times.

The test verification of the simulated accelerated test system on the bench shows that:

(1) The theoretical basis and method of simulated loading intensification and acceleration test are reasonable.

(2) The bench accelerated test technology has the advantages of improving the test efficiency, shortening the test cycle, saving manpower, material resources and financial resources, and wide application prospect and so on. It also has important practical value for scientific research and new product development.

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