ISSN: 2664-9640

Research on Road Simulation Test Method for Suspension System with BIW

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Abstract

Based on the 6-DOF spindle-coupled road simulation test bench, a road simulation test method for suspension system with BIW is introduced. The fixed mode and the iteration strategy of suspension system are emphasized. By comparing the results of road simulate durability test and road durability test, the validity of the test method is proved.

Keywords

Suspension, Road Simulate, Iteration, Durability test.

1. Introduction

The durability and reliability of a vehicle represent its ability to operate reliably over long periods of time without wear and fatigue cracking of components or systems during passenger or freight transport. Durability and reliability are important indicators to measure the performance of vehicle, which is directly related to the life and property safety of consumers[1]。

In the process of driving, the vehicle bears dynamic random load. The load is transferred to the body through the suspension. Suspension system also supports important components such as the engine or electric motor and gearbox. Under the action of dynamic random load for a long time, fatigue damage is easy to occur in the high stress area, welding area and the connecting area of each component of the suspension system, which leads to fatigue failure and ultimately threatens the driving safety. So it is very important to reasearch the durability reliability of suspension system.

At present, there are several commonly methods for durability and reliability test of suspension systems: public road test, enhanced road test, and laboratory road simulation test. Public road test and enhanced road test are closer to the actual driving state of vehicles, making important contributions in previous vehicle research and development. However, with the decrease in research and development costs for automobile enterprise and the compression of development cycles, more and more mature laboratory road simulation test is increasingly recognized in the industry due to its advantages such as good testing consistency, no interference from environmental factors and uninterrupted operation. It is often used in the early stages of vehicle development and component update verification.

This paper introduces a road simulation test method for suspension system with BIW based on 6-DOF spindle-coupled road simulation test bench. The following will introduce and analyze the road simulation test technology, road spectrum acquisition, test bench construction, iteration and durability test in turn.

2. Road simulation test technology

Road simulation test[2] is a technology that accurately replicates the force state and motion posture of suspention system driving on different road surfaces through iterative methods on a laboratory road simulation test bench. Targeted durability tests are conducted on the entire vehicle and various subsystems to ensure that the cumulative damage amount on the vehicle or components in a few days or weeks is equal to the cumulative damage amount generated in several years under actual road conditions. So the defects in the entire vehicle system and components can be identified, optimized and improved in the early design stage. Road simulation test technology can be roughly divided into two different directions: wheel coupling and spindle coupling.

Spincle coupling road simulation test technology is the most accurate and widely used road simulation test technology for durability reliability test of suspension system at present. The test bench as shown in Figure 1, consists of four subsystems. Each subsystem connects with the wheel hub and can provide vertical, horizontal, lateral, outward, steering and braking inputs at the same time to reproduce the vehicle or subsystems's stress state and movement posture. The bench can be configured flexibly so the front and rear suspension systems can be tested simultaneously saving test time.

Figure 1: 6-DOF spindle-coupled road simulation test bench

3. Road spectrum acquistion

In order to conduct road simulation test on a laboratory bench, firstly it is necessary to determine the force and motion attitude data of the suspention system while driving on the road which is the input target signal of the test bench. The testing vehicle will be equipped with sensors such as strain gauges, acceleration sensors, wire displacement sensors, and six axis wheel force transducer. The sensor data collection for typical road conditions such as Belgian road, gravel road, and washboard road,etc will be carried out on the enhanced road test site. The collected data is collectively referred to as the road spectrum.

3.1. Sensor selection

In this paper, two sets of data were collected based on an SUV model in the enhanced road test site. Each set of data included four kinds of enhanced road. The sensor selection is shown in Table 1:

Table 1: Sensor selection

Sensor name	Measuring position	Notes
Six axis wheel force transducer	Wheel	Measure wheel center load
Wire displacement sensor	Absorber	Measure the change in the motion stroke of the shock absorber
Strain gauge	Front stabilizer bar	1/4 bridge circuit

Strain gauge	Front spring	1/4 bridge circuit.One on the lateral side and one on the lateral side
Strain gauge	Rear stabilizer bar	1/4 bridge circuit
Strain gauge	Rear spring	1/4 bridge circuit.One on the lateral side and one on the lateral side

3.2. Road spectrum processing

After the road spectrum data collection was completed, the damage of different roads to vehicles was calculated. Finally, one kind of enhanced road surface data was selected as the iterative target signal in each group of data. In order to save iteration time, the two roads were joined together and some transition road signals were deleted. The final target signal was obtained after mean removal, resampling and unit conversion. Taking the left front wheel vertical load Fz as an example, the processing method is shown in Figure 2 below:

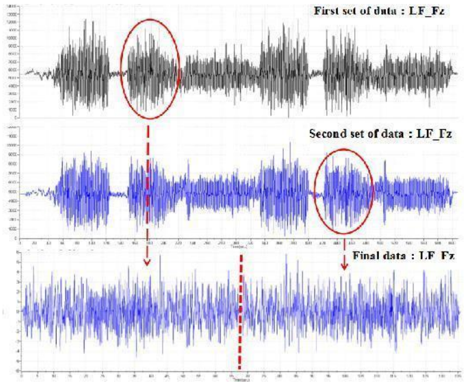

Figure 2: Road spectrum processing

4. Test bench construction

4.1. Suspension system fixed method

In suspension road simulation test, the suspension is usually fixed on the restrained reaction fixtures[3], as shown in Figure 3. The advantage is that the suspension system is easy to replace, and more suspension components can be exposed to the visual range, which is more conducive to observing the suspension failure position during the test. The disadvantage is that the rigid constraint stiffness of the suspension is too large, which is deviated from the actual situation.

The method proposed in this paper is that install the suspension to the BIW and fixed constraints are applied to the BIW, as shown in Figure 4. This method more truly retains the connection stiffness between suspension system and BIW, which is closer to the actual situation. At the same time, the area on the BIW that are prone to crack failure such as the shock absorber tower package can also be assessed.

Figure 3: Restrained reaction fixtures

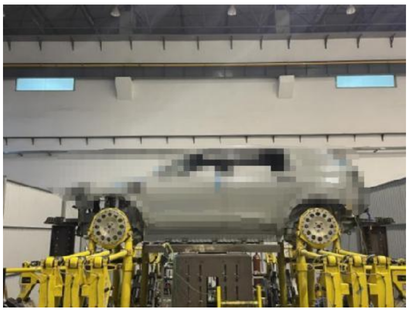

Figure 4: BIW fixtures

4.2. BIW fixtures introduction

The BIW fixtures are composed of the main base fixtures, the side beam fixtures and the front and rear longitudinal beam fixtures:

The main base fixtures are internal and external nested structure. The internal substructure can slide up and down, as shown in Figure 5. After determining the relative distance between the wheel center and the side beam according to the state of the vehicle's counterweight, the height of the internal substructure of the base can be adjusted. After the height adjustment is completed, the inner and outer substructure are fastened by bolts to form a whole fixture.

The side beam fixtures are composed of a base and several U-shaped clips, as shown in Figure 6. The base are fixed by bolts to the main base fixtures and the upper surface of the base has multiple rows of bolt holes, which can be arranged with multiple U-shaped clips. The side beams of the vehicle are clamped in the U-shaped clips by bolts, and the position of the BIW is initially fixed, as shown in Figure 7.

The front and rear longitudinal beam fixtures should firstly be reinforced by welding square tubes at the left and right longitudinal beams. The left and right square tubes are connected to a cross bar. The cross bar is fixed on a column fixture that can be moved up and down, as shown in Figure 8. After the BIW fixed, the wheel hub is connected with the test bench to complete the construction of the test bench.

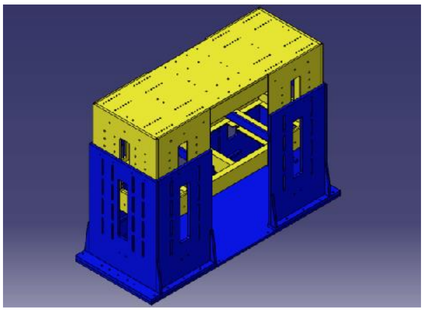

Figure 5: Main base fixtures

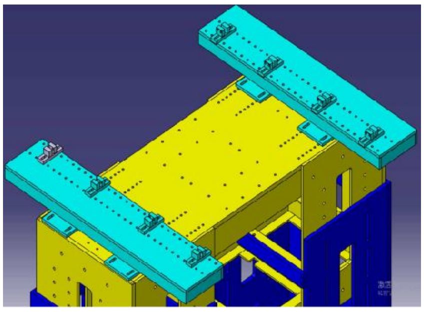

Figure 6: Side beam fixtures

Figure 7: Fixing method of side beam

Figure 8: longitudinal beam fixtures

5. Iteration

5.1. Iteration result evaluation

The iterative principle and process of road simulation test of suspension system are similar to that of vehicle road simulation test[4]. The iterative principle and theoretical formula will not be repeated here.

The relative error of the Root Mean Square (RMS) of the target signal and the response signal is usually used to evaluate the iterative accuracy. According to experience, it is considered that when RMS is less than 10%, the time domain curve of response signal and target signal has a high coincidence degree, and the iteration effect is good.In order to conduct in-depth research

ISSN: 2664-9640

on the iterative strategy, the iteration was terminated when the RMS of each channel was less than 5%.

5.2. Iteration strategy

According to the influence on iteration accuracy and iteration speed, the target signal channels are divided into control channels and monitoring channels. The control channel is used for iteration, and the monitoring channel is used to assist analysis and judgment. In the iteration, two iteration methods were selected.The first one: the six axis wheel force was the control channel, and the strain channel and the wire displacement channel (hereinafter referred to as the displacement channel) were the monitoring channel. The second: six axis wheel force, strain and displacement channels were all control channels. The iterative results showed that:

Only six axis wheel force channels were controlled and iterated 30 steps:

Based on the iterative data analysis of the right rear of the suspension, the six axis wheel force converged quickly, and the RMS was < 5%,as shown in Figure 9. However, after 22 steps iteration, with the increase of iteration steps, the lateral strain of right rear spring (RR_Spring_X) and right rear displacement (RR_Dis) gradually increased,as shown in Figure 10.

Compared with the iteration results of step 22 and step 30, it can be observed from the time curve that at some time points, there were obvious contradiction between the spring strain and displacement channel with the vertical Fz force channel. Fz was not consistent with the target signal, but the strain and displacement channel had been well consistent with the target signal. With the increase of the number of iteration steps, Fz gradually approached the target signal, but the strain and displacement channels had exceeded the target signal. The RMS error begun to increase and the suspension system attitude appeared abnormal,as shown in Figure 11.

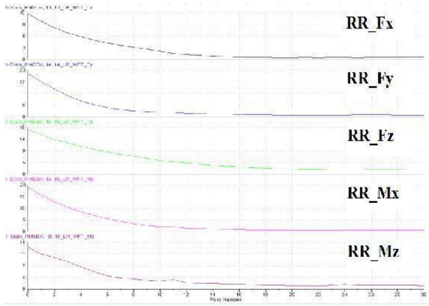

Figure 9: RR six axis wheel force RMS

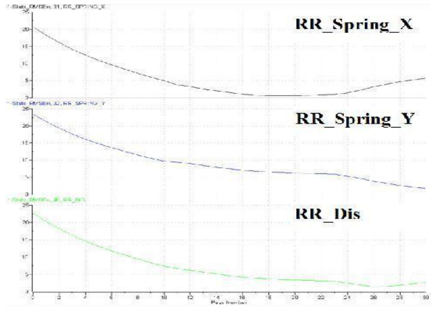

Figure 10: RR strain and displacement RMS

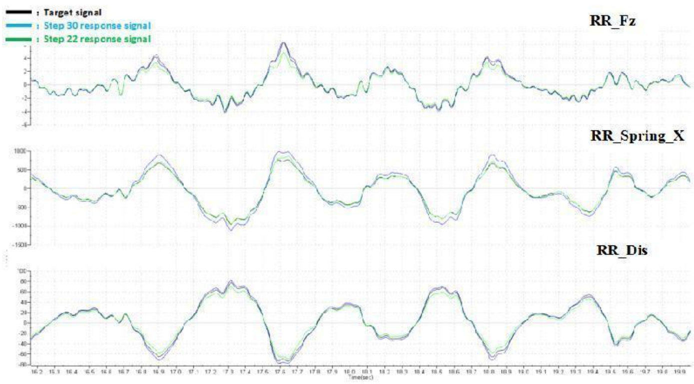

Figure 11: Comparison of time curve between response signal and target signal of different iteration steps

The six axis wheel force, strain and displacement channels were controlled at the same time, and iterated 26 steps:

The displacement channel was controlled in the initial steps of iteration,so the control of low frequency signal was increased. The motion attitude of the suspension system could be constrained quickly, as shown in Figure 12.

ISSN: 2664-9640

With the increase of iteration steps, gradually released the control of displacement, focus on the control of six axis wheel force and strain channels, and the RMS of all channels was gently decline, as shown in Figure 13.

At some time points, the six axis wheel force channel and the strain channel were also contradictory, but by adjusting the iterative gain value of the two kinds of channels, the response signal gradually approach the target signal. The final iteration was 26 steps and a better iteration result was obtained, as shown in Figure 14.

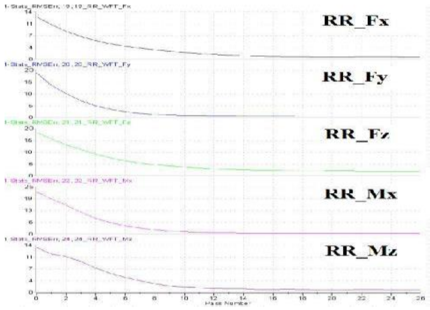

Figure: 12 RR six axis wheel force RMS

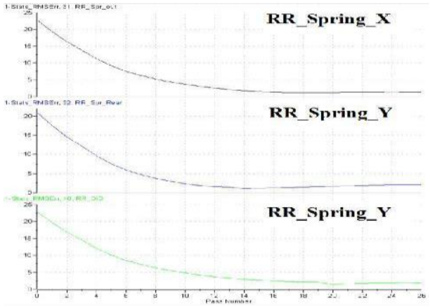

Figure 13: RR strain and displacement RMS

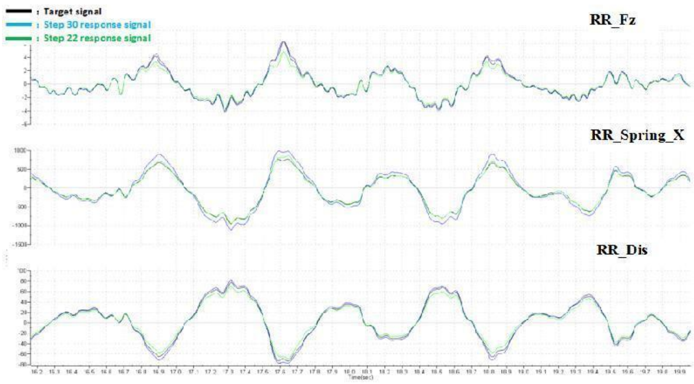

Figure 14: Comparison of time curve between response signal and target signal of different iteration steps

After the iteration result was confirmed, the damage amount of the single cycle was calculated. According to the damage equivalence principle, it was determined that a total of 6283 cycles need to be completed, which was equivalent to driving 30,000 kilometers on the enhanced road test site.

6. Durability test

Before the durability test, according to the previous test experience or CAE related calculation results, the developer was sprayed on the parts prone to stress concentration which could be convenient to check the crack at the small stage. In the process of durability test, cracks appeared in subframe stress concentration area and longitudinal arm mounting point in BIW, as shown in Figure 15-18. The fracture situation and crack location were consistent with the road test. The test results proved the effectiveness of the proposed road simulation test method for suspension system with BIW.

Figure 15: Subframe stress concentration area
(road simulation durability test)

Figure 16: Subframe stress concentration area
(enhanced road test site durability test)

Figure 17: longitudinal arm mounting point in BIW(road simulation durability test)

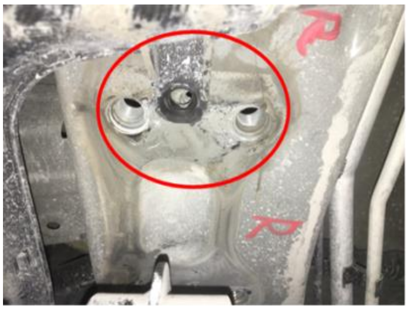

Figure 18: longitudinal arm mounting point in BIW(enhanced road test site durability test)

7. Conclusion

This paper proposes a road simulation test method for suspension system with BIW, and introduces the test method from the aspects of test bench construction, road spectrum acquisition, iteration and durability test. The results show that:

The suspension system fixing method introduced has good fixing effect in the test, and can be adjusted according to different vehicle parameters.The fixtures has strong practicability

By analyzing the iterative effects of different iterative strategies, it is shown that in suspension system iteration, in addition to control the six axis wheel force channel, control the strain of components and the wire displacement of shock absorber channel can obtain better iteration effects in low frequency band.The force and movement attitude are closer to the target signal.

By comparing the results of suspension road simulation test and the road test of the whole vehicle in the enhanced road test site, it is concluded that the test results of the suspension system are consistent, which proves the test method proposed in this paper can well complete the durability verification of the suspension system, thereby shortening the verification cycle of the suspension system and saving the test cost.

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