ISSN 2706-655X Vol.6, Issue 5: 59-66, DOI: 10.25236/IJFET.2024.060509

Test and analysis of reverse braking abnormal sound condition of a pure electric passenger car

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Abstract: *In order to solve the abnormal noise caused by the left front wheel of a pure electric SUV in the process of reversing braking, the objective test method was adopted and the LMS vibration and noise test equipment was used to test. By sampling and analyzing the vibration frequency of each component of the brake assembly, the results show that the vibration amplitude of the front subframe bracket, brake and caliper bracket is the most obvious. Based on the vibration frequency sampling analysis of the brake assembly and other components, the problem location is locked, and the cause is further analyzed, which provides ways and thinking for the solution of such abnormal working conditions.*

Keywords: *Acoustics, Astern brake abnormal sound, Calipers, Front subframe, Vibration frequency*

1. Introduction

In the process of driving, the normal operation of the braking system is very important for driving safety. In the car driving, parking brake or reverse brake will appear abnormal sound. Especially when reversing braking, abnormal noise will cause concern for the driver, and have a certain impact on the performance and reliability of the vehicle[1]. It is very important to analyze the cause of abnormal brake noise for solving the problem, ensuring driving safety and improving driving comfort. Based on the engineering experience of Oems at home and abroad, and combined with the engineering problems to be solved by the author, this paper uses the objective reproduction method to analyze and improve the research[2].

2. Cause analysis of abnormal brake sound

There may be many reasons for abnormal brake noise. The following are common reasons summarized according to engineering experience: (1) Brake disc wear: brake disc wear may lead to abnormal brake noise. When the brake disc is worn to a certain extent, it may produce friction noise between the metals, resulting in abnormal noise. (2) Uneven brake disc surface: The uneven surface of the brake disc may lead to uneven contact between the brake disc and the brake disc, producing scratching noise and causing abnormal noise. (3) Foreign matter between the brake disc and the brake disc: Foreign matter between the brake disc and the brake disc, such as sand, iron filings or brake ash, may dry interfere with the normal contact between the brake disc and the brake disc, resulting in scratching or sharp noise. (4) Brake system components loose: some parts of the brake system, such as brake calipers, steering gear, shock absorbers, brake disc shields, etc., if loose or incorrectly installed, may produce abnormal sound. (5) Brake fluid problems: pollution or bubbles of brake fluid may lead to abnormalities in the brake system, such as abnormal noise. (6) Overheating of the brake system: Prolonged braking or rapid braking may lead to overheating of the brake system, which may affect the contact between the brake disc and the brake disc, resulting in abnormal sound. (7) Design or manufacturing defects of the brake system: defects in the design or manufacturing of the brake system may lead to abnormal sound[3]. For example, improper design or quality problems cause uneven friction between the brake disc and the brake disc.

To determine the exact cause, systematic inspections and tests may be required. This may involve checking the degree of wear of the brake pads and discs, the loosening of the brake system and foreign objects, etc., to determine the specific cause of the abnormal sound. According to the actual driving

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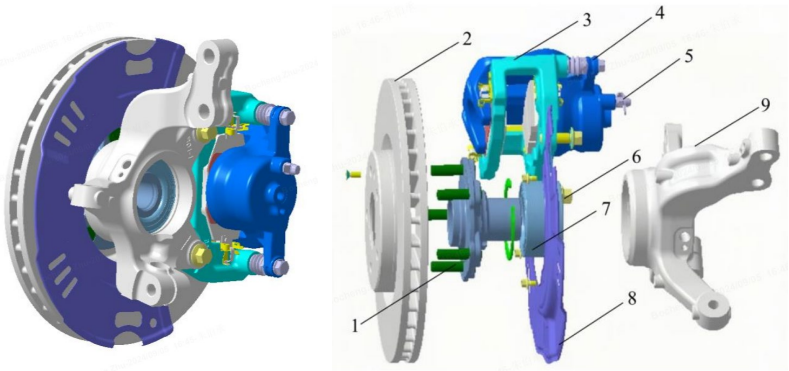
situation and the preliminary test results, the cause of the body may be generated within the brake assembly components. Therefore, in order to solve this problem, the author uses LMS test equipment to sample and analyze each component that can produce abnormal noise, so as to determine the abnormal noise source[4].

2.1. Front brake with steering knuckle assembly introduction

The front brake belt steering knuckle assembly is one of the core components of the automobile front wheel brake system. It consists of two parts: brake and steering knuckle. The brake part is a device used to realize the braking function, which is usually composed of a brake caliper, a brake disc and a brake disc. Brake calipers apply pressure to the brake disc through the brake disc, and friction generates braking force, thereby slowing down the rotation speed of the wheel. The brake can be controlled by brake pedal or brake hydraulic system. The steering knuckle is the device responsible for the steering function. It includes components such as steering knuckle housing, steering shaft, bearing and transmission gear[5]. The knuckle is connected to the wheel by the steering shaft, allowing the wheel to turn left and right. At the same time, the steering gear is connected with the steering mechanism through the transmission gear, which converts the rotation of the driver's steering wheel into the steering of the wheel. Because the most important source of abnormal braking noise in this working condition is still the brake assembly, including but not limited to the brake assembly. Figure 1 below shows its main parts.



1. Wheel bolt 2. Brake disc 3. Caliper bracket 4. Caliper caliper body 5. Bleed screw 6. Screws 7. Front hub assembly 8. Dust cover 9. Steering knuckle

Figure 1: Front brake belt steering knuckle assembly parts drawing.

2.2. Dynamic model of low frequency vibration of front brake

The low frequency vibration dynamics model of the front brake can be expressed using the following main equations:

(1) Rotation equation:

The rotation equation of the brake disc can be expressed as:

$$I * \alpha + d * \omega + C * \theta = T \tag{1}$$

Where, I is the moment of inertia of the brake disc, α is the angular acceleration of the brake disc, d is the damping coefficient of the brake disc, ω is the angular velocity of the brake disc, C is the friction coefficient of the brake disc, θ is the displacement of the brake disc, and T is the braking torque.

Its rotational differential equation can be expressed as:

$$\frac{d_\omega}{d_t} = \frac{-FD}{I} \tag{2}$$

Where D is the distance between the brake disc and the axis.

(2) Braking force equation:

The friction force between the brake disc and the brake disc can be expressed as:

$$F = \mu * N \tag{3}$$

Where, F is the braking force, μ is the friction coefficient, and N is the contact force between the

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brake disc and the brake disc.

(3) Braking torque equation:

Braking torque can be expressed as:

$$T = R * F \tag{4}$$

Where T is the braking torque and R is the radius of the brake disc.

The relationship between braking force and braking noise frequency can be described using the following simplified general equation:

$$f_{braking} = C_2 * F \tag{5}$$

Where, f_{brake} is the brake noise frequency, C_2 is the proportional coefficient, representing the proportional relationship between the brake noise frequency and braking force. In addition, the equation is a simplified model, assuming a linear relationship between braking noise frequency and braking force, and ignoring other possible factors. In the real world, the brake noise frequency may be affected by a number of factors, such as the contact between the brake and the brake disc (or drum), the vibration characteristics of the brake, the friction characteristics of the brake material, and so on. Through the above dynamic equation, it can be seen that the most direct connection component of abnormal braking noise is the brake part. In order to avoid the effect of resonance excitation, the following objective test part will carry out the corresponding sample analysis of its connecting parts[6]. The low-frequency vibration dynamic characteristic equation of the front brake can be obtained through experimental testing and data analysis, involving geometric structure parameters, friction characteristics and braking force, etc., which can be used to optimize the design and performance of the front brake, improve the braking effect and reduce vibration and noise.

3. Condition recurrence

3.1. Subjective evaluation and analysis

This working condition can be specifically described as the process of reversing at low speed, when the brake pedal is often pressed, the left front wheel position makes an abnormal sound. The working background is: a pure electric rear-drive passenger car, the vehicle brakes once in a straight line forward, and when the backward straight line lightly brakes, there is an abnormal sound in the front, which basically occurs every time the car reverses[7]. The preliminary analysis results are as follows:

(1) The gap exists because the chassis structural components are not assembled in place.

(2) The current vehicle is configured with One-Box, One-Box priority check.

(3) Chassis parts themselves caused by problems. Therefore. based on this, the author tests and analyzes the problem parts one by one.

3.2. LMS noise and vibration test equipment introduction

LMS noise and vibration test equipment is a professional equipment, used to measure and analyze the characteristics of mechanical vibration and noise, LMS noise and vibration test equipment mainly includes vibration sensor, sound sensor, data acquisition system and analysis software and other components. The vibration and noise signals of the target object are measured by installing vibration sensors and sound sensors, and then the collected signals are converted into digital signals by the data acquisition system, and signal processing and analysis are carried out by the analysis software. The characteristics of LMS noise and vibration test equipment include the following aspects: 1、versatility, 2、high precision, 3、high efficiency, 4、visual display. In short, LMS noise and vibration test equipment is a kind of advanced tool, widely used in machinery, automotive, aerospace, electronic equipment and other fields, for vibration and noise testing and analysis to improve product quality and performance[8]. To this end, the author reproduced the test equipment according to the actual situation, as shown in the following figure2:

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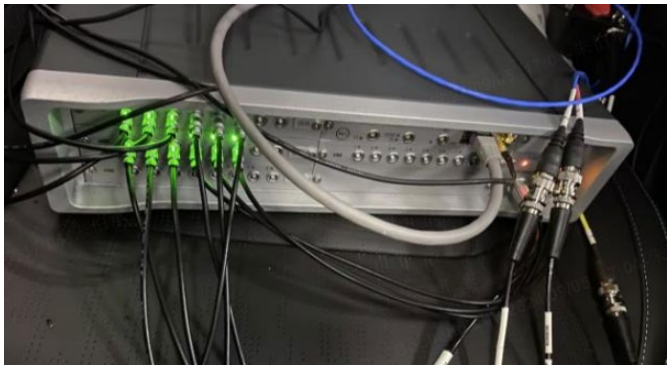

Figure 2: LMS test device connection diagram.

The installation position of each sensor is shown in Figure 3:

Figure 3: Field layout of some sensors in the vehicle.

Because the sensor interface position is fixed, the X, Y and Z directions need to be re-matched when installed at the test position due to component interference.

4. Test result

4.1. Vibration spectrum analysis of brake abnormal sound

Objective tests are divided into two types before and after calibration, calibration is to avoid the impact of gaps between components and resonance effects. According to the data collected by LMS equipment, the vibration frequency spectrum of abnormal braking noise is analyzed first, and then the time spectrum of abnormal braking noise is analyzed according to the vibration characteristics. According to the test data results, the vibration amplitude of the front subframe bracket, the brake and the caliper bracket is the most obvious. Because the sound is generated by the vibration of the object, it indicates that the possibility of abnormal sound is the greatest.

Vibration spectrum of each component is shown in figure 4 to figure 7:

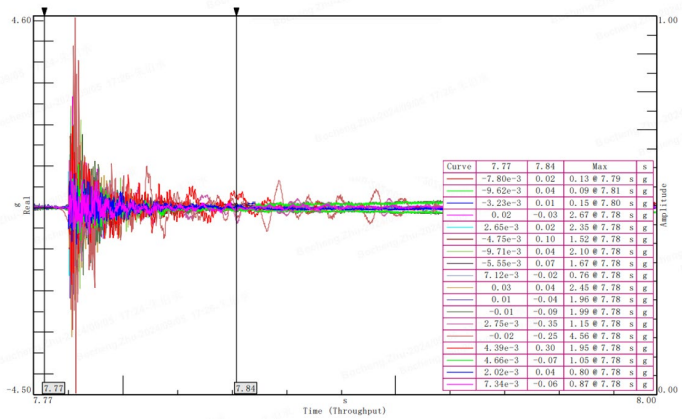

Figure 4: Test results when each component is not calibrated.

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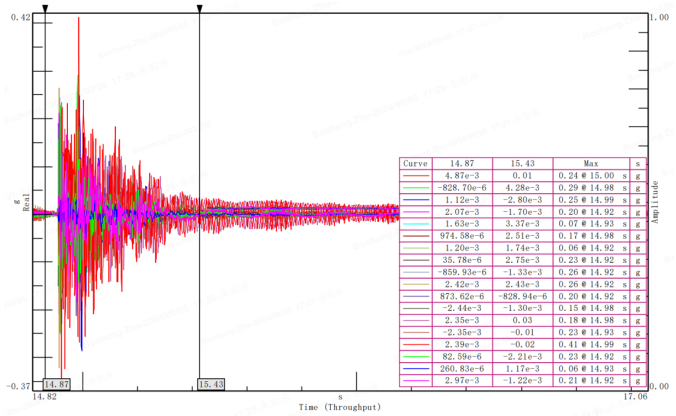

Figure 5: Test results after the first calibration.

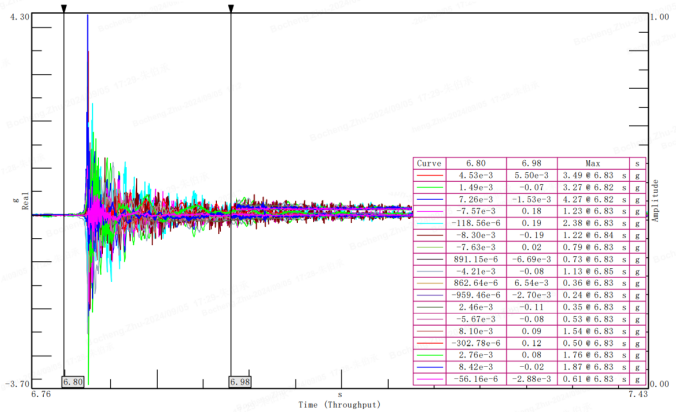

Figure 6: Test results after the second calibration.

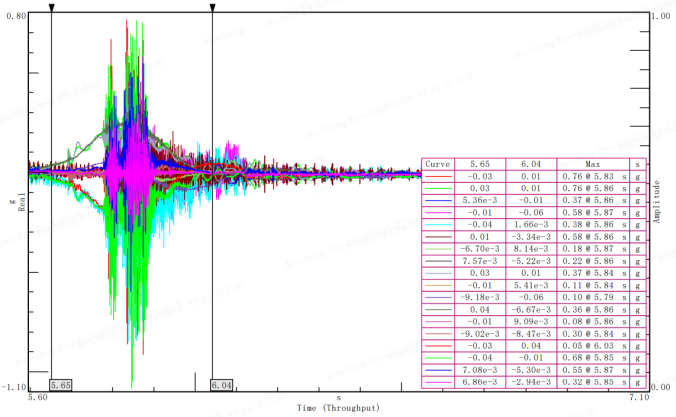

Figure 7: Test results after the third calibration.

4.2. Time spectrum analysis of abnormal braking sound

In the test, the key parts need to be sampled and analyzed, and the data modes before and after calibration are compared to analyze the root cause of abnormal brake noise. The test plan is divided into pre-calibration and post-calibration. The impact of component calibration on the test is mainly reflected in improving the accuracy, consistency, repeatability and efficiency of the test. These effects can improve the credibility and reliability of test results and help analyze and evaluate vehicle performance and functionality.

Uncalibrated test results, as shown in Figure 8 below:

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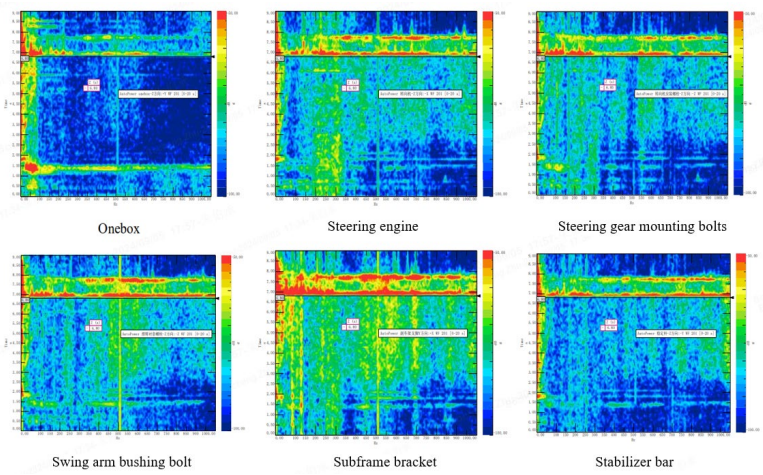

Figure 8: Test results when each component is not calibrated.

Conclusion: Through the comparison of vibration spectrum, the vibration at the foot of subframe is the most obvious when the backward braking time is 6.08s.

Test results of calibrated subframe bolts, as shown in Figure 9 below:

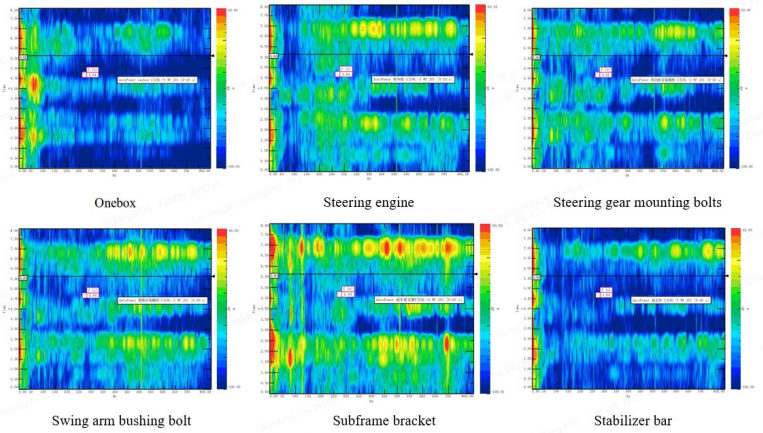

Figure 9: Test results after the first calibration.

Conclusion: Through the comparison of vibration spectrum, the vibration at the foot of subframe is the most obvious when the backward braking time is 5.64s.

Test results after calibration of subframe + swing arm bushing bolt, as shown in Figure 10 below:

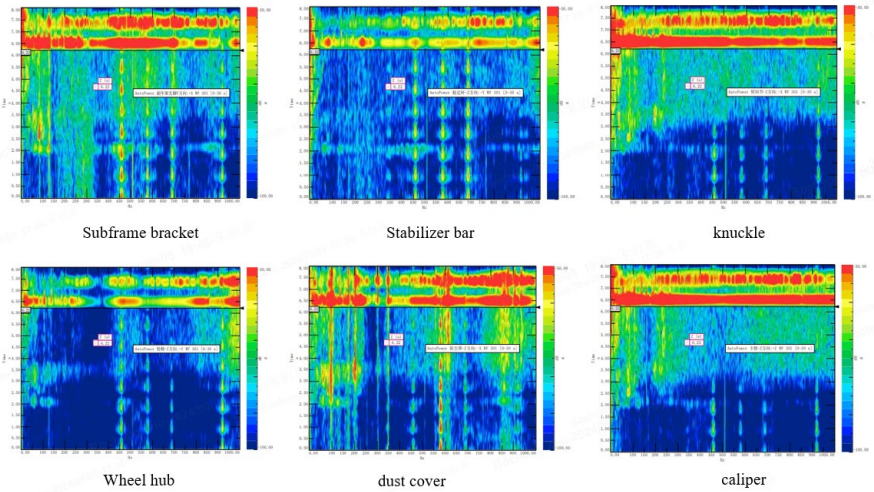

Figure 10: Test results after the second calibration.

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Conclusion: According to the comparison of vibration spectrum, the brake position vibration is the most obvious when the braking time is 6.22s.

Subframe bolt + swing arm bushing bolt + steering knuckle bolt + caliper guide pin bolt after calibration state test results, As shown in Figure 11 below:

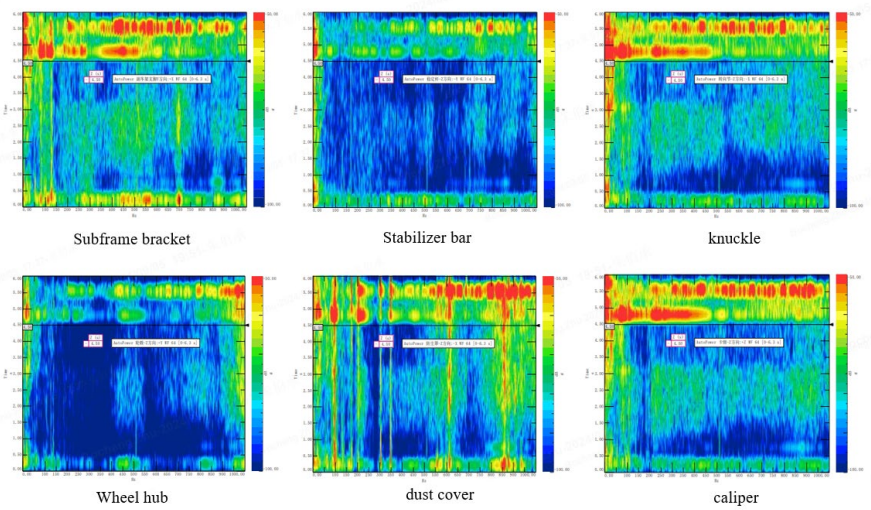

Figure 11: Test results after the third calibration.

Conclusion: Through the comparison of vibration spectrum, the vibration at the caliper bracket is the most obvious when the backward braking time is 4.5s.

Through the vibration frequency domain analysis of the above parts, the sound source can be identified. On the One hand, it can exclude the influence of one-box, steering machine, steering machine mounting bolts, swing arm bushing bolts, stabilizer bar sub-frame support foot, stabilizer rod, steering knuckle, wheel hub and dust cover; At the same time, the front subframe bracket, brake and caliper bracket are basically locked, and it is found that the spectrum at the caliper bracket is most obvious by comparison. To solve the noise problem generated by the caliper bracket, the following five ways can be used as a reference:

(1) Cleaning and lubrication: First, clean the surface of the caliper bracket and brake disc to ensure that there is no oil or debris. Then, the appropriate lubricant is used in the appropriate position, such as high temperature burn resistant lubricant, to reduce friction and vibration.

(2) Replace the brake disc: If the material of the brake disc is inappropriate or the quality is problematic, you can consider replacing the appropriate brake disc. Selecting suitable brake material can reduce noise and improve braking performance.

(3) Check and repair brake disc problems: If there are problems with the brake disc, such as uneven wear or uneven surface, you can try to grind or replace the brake disc. Ensure the flatness and surface quality of the brake disc to reduce noise generation.

(4) Adjust and tighten the support structure: check whether the connection between the caliper bracket and the support structure is tight, and make appropriate adjustments. If the support structure is found to be loose, damaged or problematic, it needs to be repaired or replaced in time.

(5) Repair or replace the damaged caliper bracket: If the caliper bracket itself is damaged, such as deformation or wear, it may need to be repaired or replaced. Ensure that the structure of the caliper bracket is complete and meets the normal working requirements to reduce the occurrence of abnormal sound.

5. Conclusions

(1) Through the comparison of vibration frequency collected by vibration acceleration sensors arranged in One-Box+ steering gear + steering gear mounting bolt + swing arm bushing bolt + subframe support foot + stabilizer bar and other parts, it is found that the vibration at the subframe support foot is the most obvious, followed by the steering gear. After the bolt torque at the foot of the subframe is

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calibrated, the abnormal brake noise is improved, but it can still be heard in the car.

(2) Through the comparison of the vibration frequency collected by the vibration acceleration sensor arranged in the sub-frame support foot + stabilizer bar + steering knuckle + wheel hub + steering knuckle + caliper bracket and other parts, it is found that the vibration at the caliper bracket is the most obvious, and the abnormal brake noise disappears after the torque of the guide pin bolt is calibrated. The initial judgment is that the abnormal sound is related to temperature and humidity. Due to the complexity of the engineering project, it is recommended to replace the caliper (friction plate) for the problem valve.

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