

# Experimental study on vibration and noise of the ROEWE electric vehicle

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**Abstract.** In order to control the vibration and noise of the ROEWE electric vehicle, it is necessary to carry out the experimental study on the vibration and noise of the electric motor. Firstly, two acoustic sensors are arranged on both sides of the road to measure the pass-by noise of the electric vehicle and to analyze the influence of motor noise on the passing noise. Then, several acoustic sensors are arranged in the vehicle to measure the noise signal in the vehicle, and to analyze the characteristics of interior noise. At the same time, one acoustic sensor and three vibration acceleration sensors are arranged in the vehicle power cabin to measure the vibration signal, and measure the signals of the upper and lower vibration acceleration sensors of the powertrain mount, and analyze the vibration and noise characteristics of the motor and the vibration isolation rate of the powertrain mount. The experimental results show that the vibration of the ROEWE motor has obvious order characteristics, which is mainly composed of order components of order 8, order 16, order 24, order 40, order 48 and order 72 based on the motor output shaft speed and frequency converter switching frequency components concentrating on 10000Hz and 20000Hz. Therefore, to reduce vehicle vibration and noise from the perspective of optimizing motor vibration, the impact of cogging torque on motor vibration should be mainly considered.

**Keywords:** Electric vehicle, Vibration, noise, Order analysis.

## 1 Introduction

In order to find the law of the vibration and noise of the electric vehicle, and to improve the NVH characteristics of electric vehicles, it is necessary to carry out the bench vibration and noise experiment of electric vehicle motor and electric drive system, as well as the vibration and noise test of vehicle driving on the road [1-6]. In this paper, a ROEWE electric vehicle produced by SAIC Group is selected as the experimental object, and its parameters

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was listed in Table 1. The list of the test equipment is shown in Table 2. The following vibration and noise tests are carried out, including:

- (1) Pass-by noise tests at constant speed and acceleration speed outside the vehicle.
- (2) Interior noise test at constant speed and acceleration speed.
- (3) Vibration test of power cabin at acceleration speed and constant speed.

**Table 1.** Test vehicle parameters

|                                |                                 |           |                           |
|--------------------------------|---------------------------------|-----------|---------------------------|
| Motorcycle type                | ROEWE ERX5-EV400                |           |                           |
| Level                          | Compact SUV                     |           |                           |
| Motor Rated power / Peak power | 40KW/85KW                       |           |                           |
| Gearbox                        | Single-speed transmission, 9.35 | Body type | Five-door, five-seat, SUV |
| Length × width × height (mm)   | 4554×1855×1716                  |           |                           |
| The wheelbase (mm)             | 2700                            |           |                           |
| Drive motor/motor type         | Single motor/synchronous motor  |           |                           |
| Motor layout                   | Front                           |           |                           |

**Table 2.** List of the test equipment

| Number | Equipment Name    | Type     | Quantity | Manufacturer                                            |
|--------|-------------------|----------|----------|---------------------------------------------------------|
| 1      | DASP              | INV360N  | 1        | Beijing Dongfang vibration and Noise Research Institute |
| 2      | Preamplifier      | AWA14425 | 10       | Hangzhou Aihua Instrument Co., Ltd                      |
| 3      | Vibration sensor  | BZ1102   | 10       | Beidaihe Practical Electronic Instrument Co., Ltd       |
| 4      | Sound Level Meter | ISV1101  | 2        | Hangzhou Aihua Instrument Co., Ltd                      |

## 2 Pass-by noise tests outside the vehicle

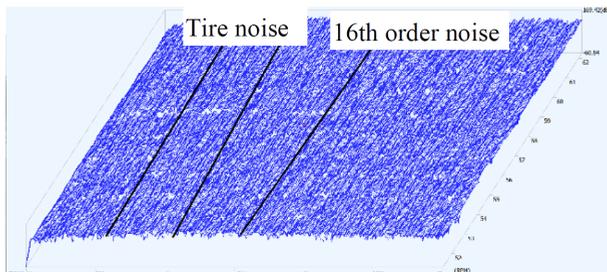
Test conditions is as following:

- a) 50km/h full throttle acceleration;
- b) Driving at constant speed 40, 50, 60, 70, 80, 90 and 100km/h.

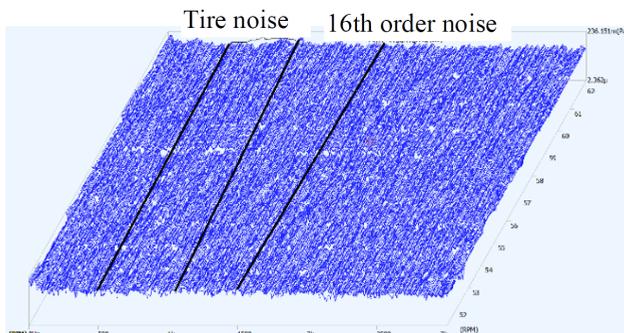
It can be found from Figure 2 and Figure 3 that the external acceleration noise of the test vehicle is the tire noise and the noise related to the 16th order of the motor mainly. It can be seen from Figure 4 and Figure 5 that at constant speed driving the noise outside the test vehicle is mainly caused by motor torque pulsation and cogging torque vibration, with order 8, 16, 24, 48 and 72 components based on the motor output shaft speed.



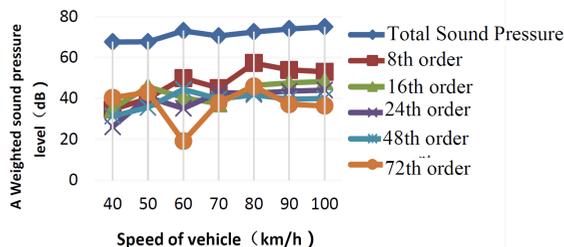
**Fig. 1.** Site photo of pass-by noise test.



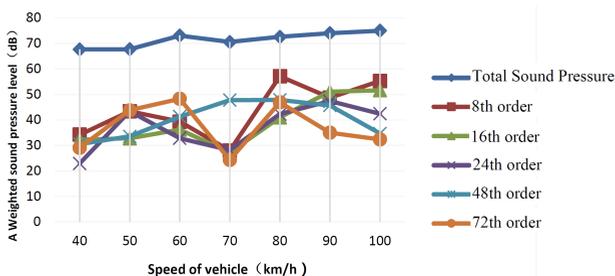
**Fig. 2.** Noise waterfall array analysis on the left side of Road (Acceleration condition).



**Fig. 3.** Noise waterfall array analysis on the right side of Road (Acceleration condition).



**Fig. 4.** Noise order analysis on the left side of Road (Constant driving speed condition).



**Fig. 5.** Noise order analysis on the right side of Road (Constant driving speed condition).

### 3 Interior noise test

It is the same as the external noise test condition, the conditions of interior noise test are as following:

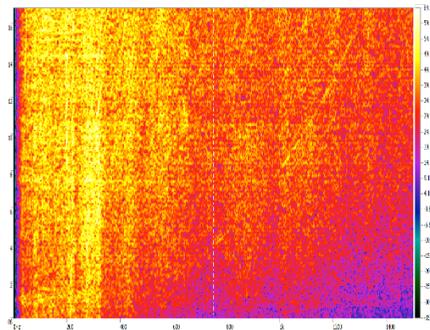
- a) 50km/h full throttle acceleration;

b) Driving at constant speed 40, 50, 60, 70, 80, 90 and 100km/h.

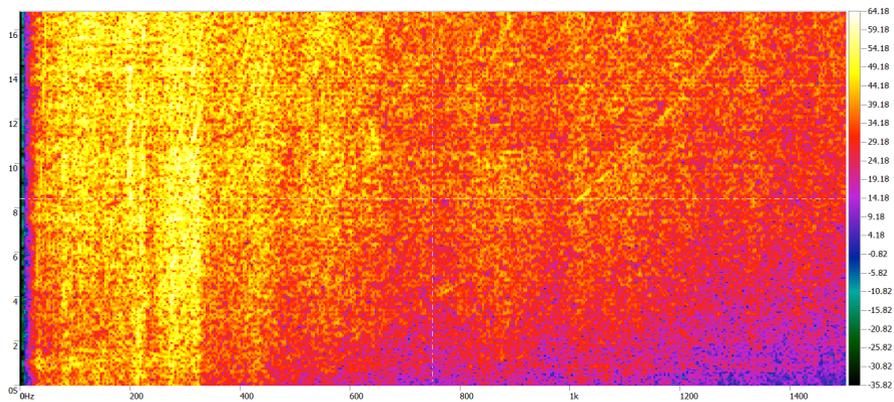
In Figure 6, the Acoustic sensors are arranged near driver's ear. It can be seen from Figure 7 and Figure 8 that the main noise components of driver and right rear seat passenger under the driving acceleration conditions are resonance band noise less than 500Hz and the 16th order component based on motor output shaft speed. It can be noticed from Figure 9 and Figure 10 that the order component of noise in the vehicle under the constant driving speeds is mainly the 8-order component based on the speed of motor output shaft caused by motor torque pulsation.



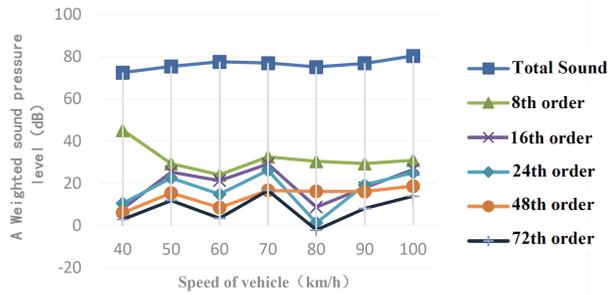
**Fig. 6.** The Acoustic sensors near driver's ear.



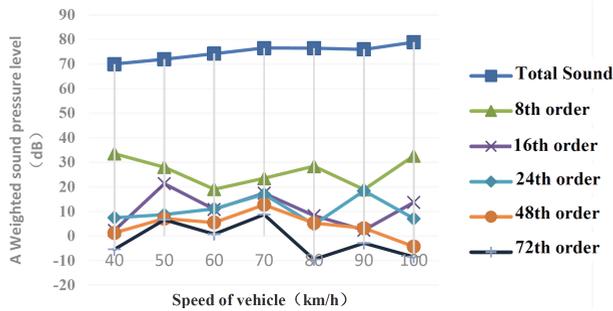
**Fig. 7.** Driver's external ear noise order analysis (acceleration condition).



**Fig. 8.** Noise order analysis of right rear seat passenger's external ear (acceleration condition).



**Fig. 9.** Noise order analysis of driver's external ear (constant driving speed condition).



**Fig. 10.** Noise order analysis of right rear seat passenger's external ear (constant driving speed).

## 4 Vibration and noise test of the power cabin

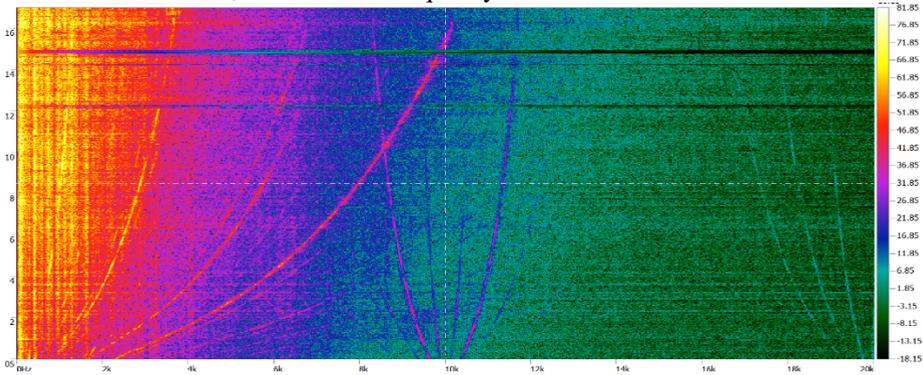


**Fig. 11.** The Acoustic sensors at power cabin.

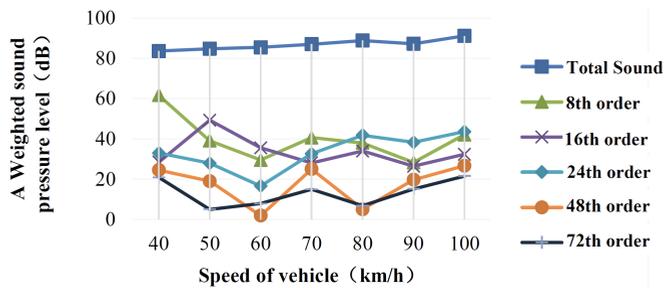


**Fig. 12.** Vibration acceleration sensor of upper and lower measuring points of motor mount.

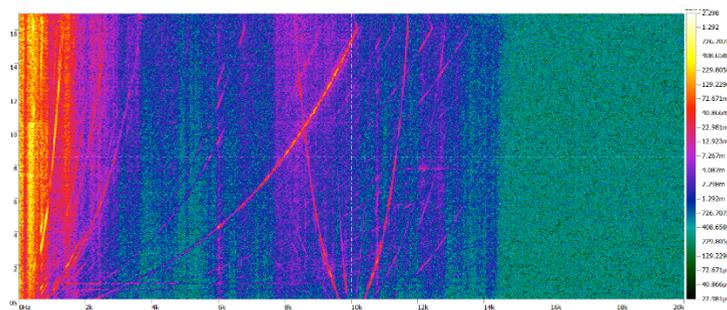
In Figure 11, the acoustic sensor is arranged at power cabin and in Figure 12, the Vibration acceleration sensor is arranged at upper and lower measuring points of motor mount respectively. As can be seen from Figure 13, based on the motor output shaft speed, the main noise order components of the front power cabin are order 24, order 48 and order 72, which are caused by torque ripple and cogging torque vibration. The noise of the front power cabin includes the noise caused by the frequency converter switch with the central frequency of 10000Hz and the resonance band noise below 500Hz, of which the resonance band noise below 500Hz plays a major role. It can be observed from Figure 14 that the power cabin noise order component under constant driving speed conditions includes order 8, order 16 and order 24 components based on the motor output shaft speed caused by motor torque pulsation, and the interior noise order component is mainly order 8 components based on the motor output shaft speed caused by motor torque pulsation. It can be noticed from Figure 15 that under the acceleration condition, the motor vibration has obvious order characteristics, which is mainly composed of order components of order 8, order 16, order 24, order 40, order 48 and order 72 based on the motor output shaft speed and frequency converter switching frequency components concentrating on 10000Hz and 20000Hz. It can be seen from Table 3 that under the constant driving speed condition, the motor mount has a good vibration isolation effect on the motor vibration, completely isolated the components above 5000Hz, attenuated the vibration below 5000Hz, and the main frequency transmitted to the frame is below 300Hz.



**Fig. 13.** Noise Order analysis of power cabin (acceleration condition).



**Fig. 14.** Noise order analysis of power cabin (constant driving speed condition).



**Fig. 15.** Order analysis of motor mount vibration (at frame) along z direction of vehicle coordinate system (Acceleration condition).

**Table 3.** Vibration isolation rate of motor mount(Isolation rate =1- Effective value of vibration acceleration of body / Effective value of motor vibration acceleration)

|                                                                |       |       |       |       |       |       |       |
|----------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| The vehicle speed displayed with the instrument cluster (km/h) | 40    | 50    | 60    | 70    | 80    | 90    | 100   |
| The vehicle speed measured with GPS(km/h)                      | 38.51 | 47.82 | 58.06 | 68.27 | 78.91 | 86.43 | 96.19 |
| Vibration isolation rate of motor mount in X-direction (%)     | 76.07 | 82.23 | 72.36 | 78.98 | 89.53 | 88.98 | 87.51 |
| Vibration isolation rate of motor mount in Y-direction (%)     | 78.35 | 83.49 | 74.27 | 82.61 | 79.57 | 79.67 | 78.91 |
| Vibration isolation rate of motor mount in Z-direction (%)     | 60.16 | 70.44 | 55.30 | 73.33 | 82.95 | 86.10 | 70.50 |

## 5 Conclusion

In this paper, in order to control the vibration and noise of the ROEWE electric vehicle, the experimental study on the vibration and noise of the electric motor was carried out. The main conclusions are as follows:

- (1) The Pass-by noise of SAIC ROEWE ERX5 is distributed at all frequencies, and the amplitude of low-frequency component is greater than that of high-frequency component. The low-frequency component is mainly the vibration noise of sidewall and tread, and includes the harmonic component caused by the 16<sup>th</sup> order of the motor.
- (2) The interior noise test results show that the noise of the driver's outer ear and the right rear seat passenger's outer ear of SAIC ROEWE ERX5 exceeds 70dBA at a constant speed of 100km / h or acceleration, and the noise needs to be reduced. The main noise components of driver and right rear seat passenger under driving acceleration conditions are resonance band noise less than 500Hz and the 16th order component based on motor output shaft speed.
- (3) The vibration of ROEWE ERX5 motor has obvious order characteristics, which is mainly composed of order components of order 8, order 16, order 24, order 40, order 48 and order 72 based on the motor output shaft speed and frequency converter switching frequency components centered on 10000Hz and 20000Hz. Cogging torque plays a major role in motor vibration, and motor torque ripple plays a great role in vehicle vibration. Therefore, to optimize vehicle vibration from the perspective of optimizing motor vibration, the impact of cogging torque on motor vibration should be mainly considered, and optimizing motor torque ripple will also improve the vibration response of vehicle.

The authors express their gratitude to the SAIC Industrial Foundation Fund (1729) for the financial support of the study.

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