

# EXPERIMENTAL STUDY ON VIBRATION AND NOISE OF MINIBUS REAR DRIVING AXLE

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**Abstract.** Test of interior and external noise and vibration signals of Minibus were conducted in accelerating and constant velocity driving conditions. By using time domain, frequency domain and 3D spectral array methods, the exterior noise, interior noise, the vibration acceleration of driver's seat and driving axle, the NVH characteristics of the Minibus were analyzed. On the one hand, we find that the interior noise is larger than exterior noise under accelerating state, due to the cabin poorly sealing. On the other hand, because of the poor isolation rate of the suspension and the huge noise and vibration of driving axle and power train, the interior noise is very great and affecting the driver's comfort. The experimental results show that the main frequency components of interior noise consist of two parts, one is the low frequency which originates from vibration exciting of the power train, and the other is the middle and high frequencies which originate from vibration exciting of the driving axle and transmission system. These experimental results will give help to further study of the NVH characteristic of the Minibus.

## 1 Introduction

The NVH problem of the automotive is one of the most important factors affecting the ride comfort and customer's acceptance. The NVH engineer and researchers have done a lot of job to study the interior noise, external noise and vibration, and have achieved great successes for the vehicle with the traditional combustion engine and pure electric motor [1-3]. Experimental methods are the basic way to analyze the interior, exterior acoustic characteristic and vibration of the automobile [4-10]. HANG Chunxiang (2009) tested the noise spectrum of pure EV motor system. HE Luchang (2010) tested the sound and vibration characteristic of a new electrical vehicle in the four-wheel tumbler test bench of semi-free noise elimination chamber, and analyzed the distribution of internal noise and main frequency ingredients at different speeds. The authors (2010, 2011, 2012) have carried out a series of bench tests and road tests on the driving axle of minibus, identified the sound sources and vibration sources of the driving axle and revealed the relationship among the discomfort, vibration and noise of the driving axle.

This paper introduces a NVH test on Minibus and analyzes the interior sound field characteristic, external accelerating noise and the vibration signals at driver's seat, the bottom of driver's seat and driving axle.

## 2 Measurement of noise and vibration under accelerating state

The accelerating noise test was carried out on the National standard noise test road, by using no-load test method. Fig.1 is the layout of road accelerating NVH test. Fig.2 is the picture of Foton minibus.

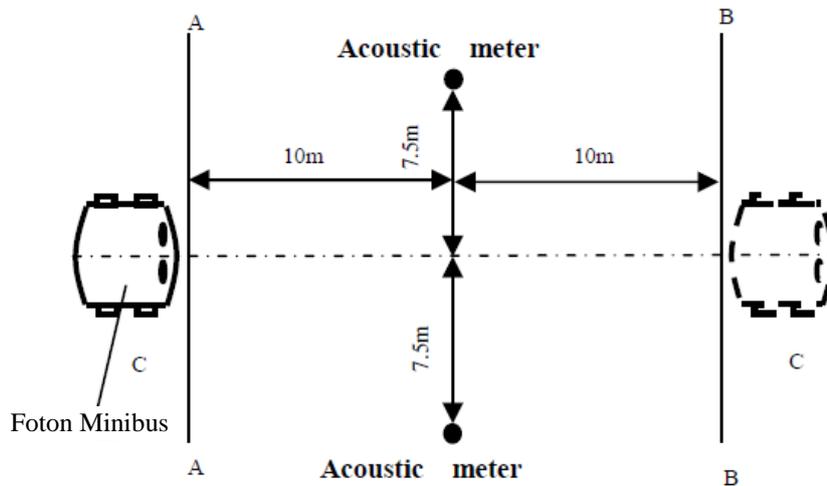


Fig.1 Layout of road accelerating noise testing



Fig.2 The picture of FOTON Minibus

During the test, when the minibus driven to the line C-C, throttle fully opened and the minibus was accelerated and passed through the 20m long test track. The initial velocities for accelerating were 40, 50, 60 km/h, respectively. As the main frequencies of vibration and noise were less than 2000Hz, so the sampling rate was set as 5120Hz. The data acquisition system was DASP 306. The noise signal at both driver's ear side in cab and road side were measured synchronously.

### 2.1 Measurement of interior noise and main reducer's noise

Fig.3 shows the interior noise and the main reducer's noise with different gear stalls under accelerating state. From this figure, we can find out that the interior noise level during accelerating is obvious, as high as 77.3dBA at driver's ear. The first noise source for causing interior noise larger may be from power train's noise and vibration, and the second noise source may be from driving axle.

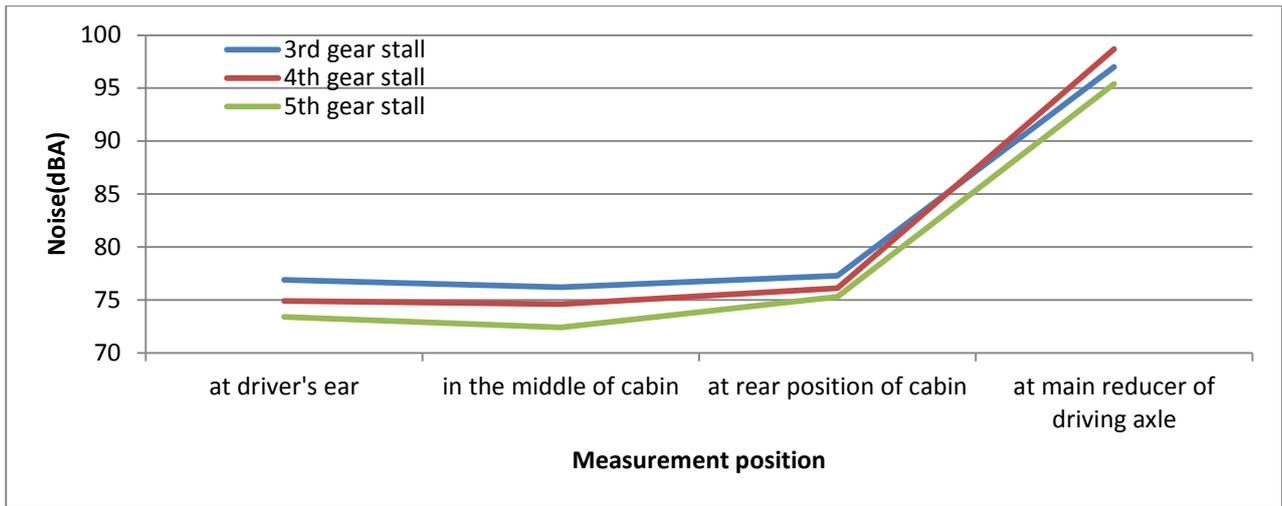


Fig.3 Interior noise and the main reducer's noise under accelerating state

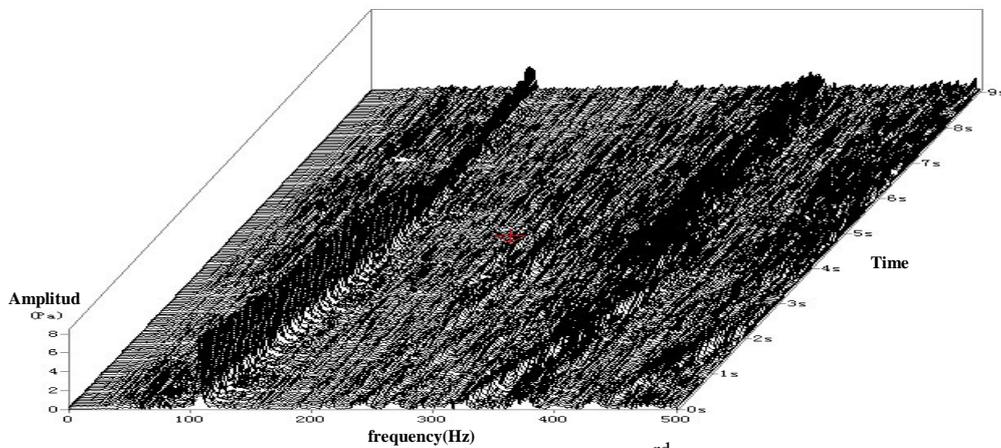


Fig.4 Spectrum array of the main reducer's noise with the 3<sup>rd</sup> gear stall under accelerating state (0-500Hz)

## 2.2 Measurement of external noise

Fig.5 shows the changes of external noise on both sides of the road under different gear stalls. From this figure, we can find out that the noise level decreases with gear stalls, and the noise level on both sides of the road are slightly different. According to Fig.6(a) and Fig.6(b), we could discover that the external noise on both sides of the road is narrow band noise, concentrating at 106Hz and its harmonic components, mainly from power train noise and partly from transmission system noise.

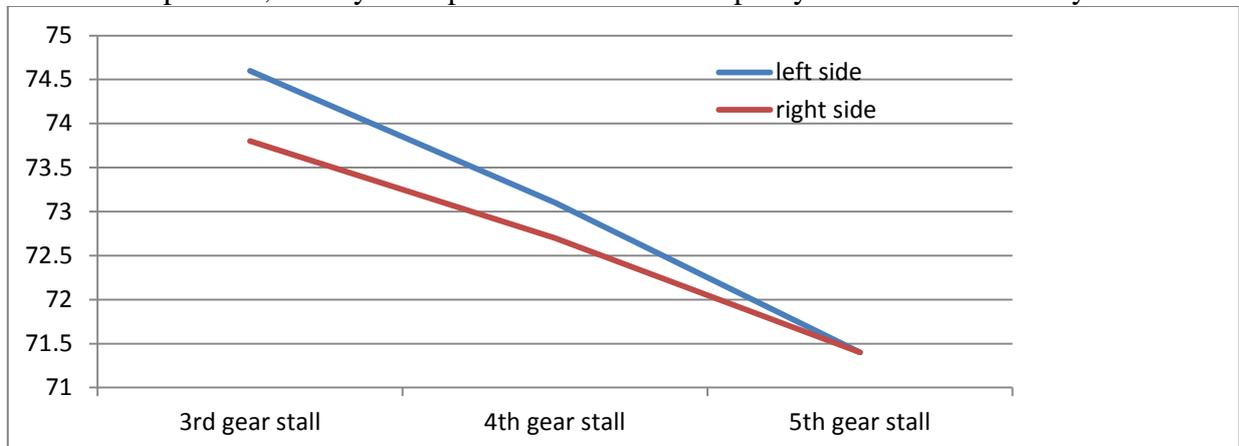
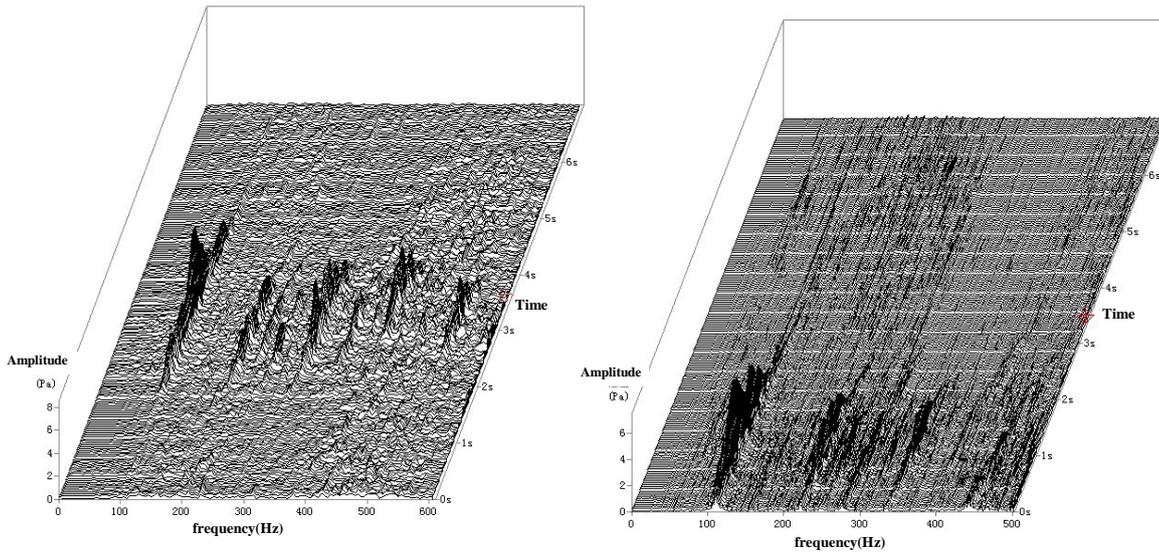


Fig.5 External noise on both sides of the road under acceleration state



(a) left side (b) right side

Fig.6 Spectrum of external noise under acceleration from 50km/h with 3<sup>rd</sup> gear stall

### 2.3 Test on vibration under accelerating state

Fig.7 shows vibration measurement results at main reducer, at seat base and at seat under different gear stalls. From this figure, we can find out that the vibration level at main reducer is very high, but the vibration isolation rate of seats is good.

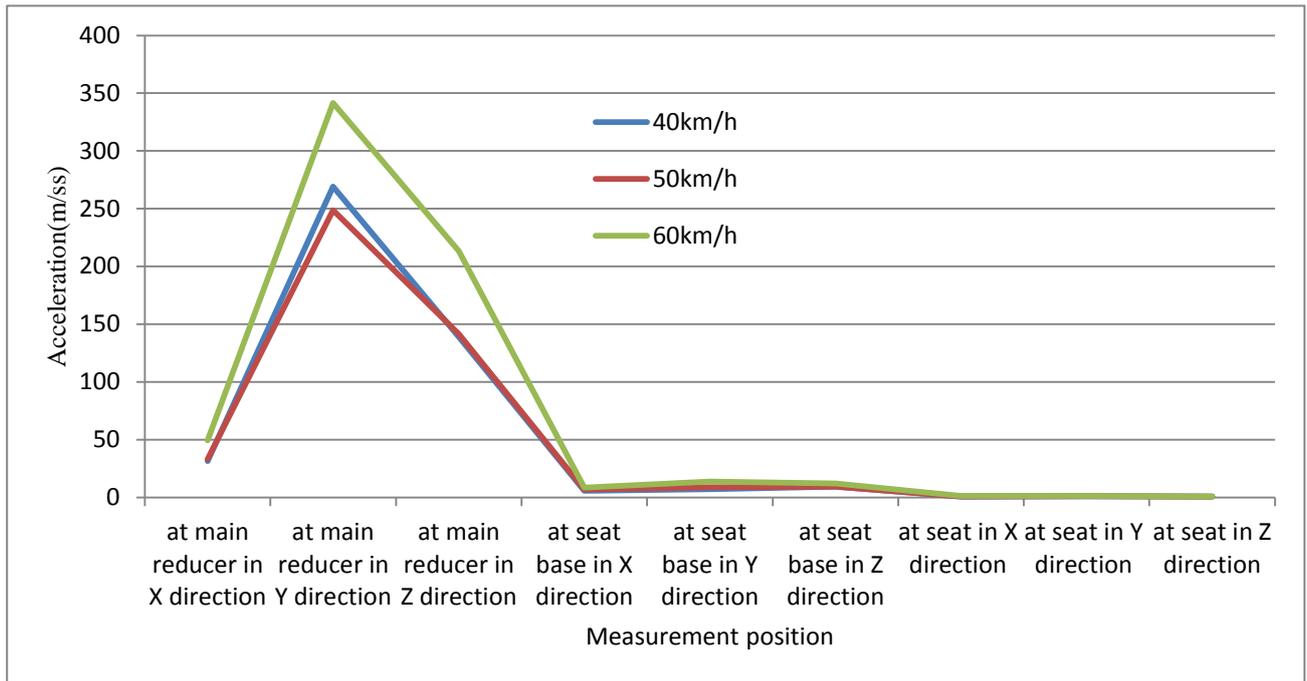


Fig.7 Vibration measurement under accelerating state from 50km/h

## 3 Noise and vibration testing under constant driving velocity

In order to obtain the actual noise level and vibration level under constant velocities, the driving velocities of 40, 50 and 60km/h were taken respectively.

### 3.1 Noise tests

Under constant driving velocities of 40, 50 and 60 km/h, interior noise changes with the velocities and gear stalls and reaches as high as 74.7dBA at the rear part of the cabin, shown in Fig.8. At the speed of 40km/h, the coherent coefficient between noise at driver's ear and noise at main reducer reaches the maximal value of 0.88 at the frequency of 1124Hz, and at the speed of

50km/h, the coherent coefficient between noise at driver's ear and noise at main reducer reaches 0.57 at the frequency of 814Hz. According to Fig.9, the coherent coefficient between noise at driver's ear and noise at main reducer reaches 0.73 at the frequency of 819Hz. So to a large extent, the noise at driver's ear comes from the main reducer's noise.

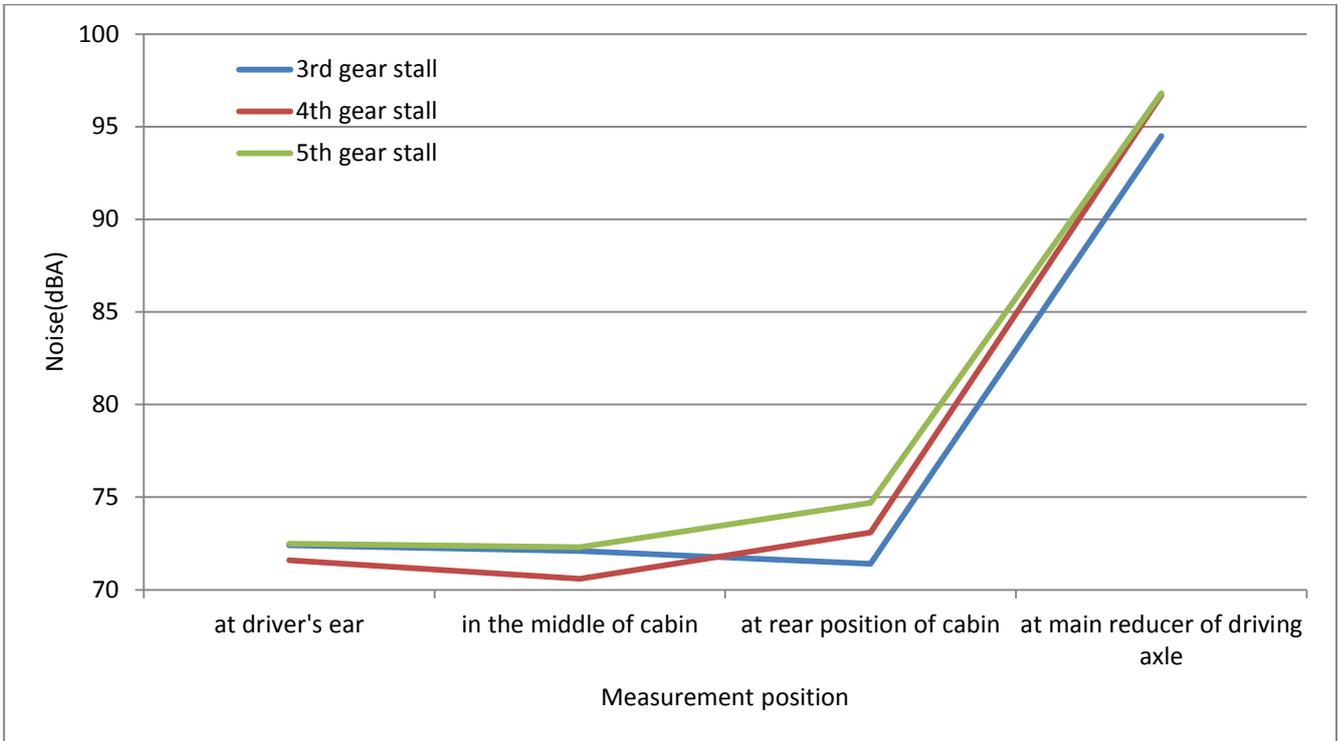


Fig.8 Interior noise under constant driving velocity

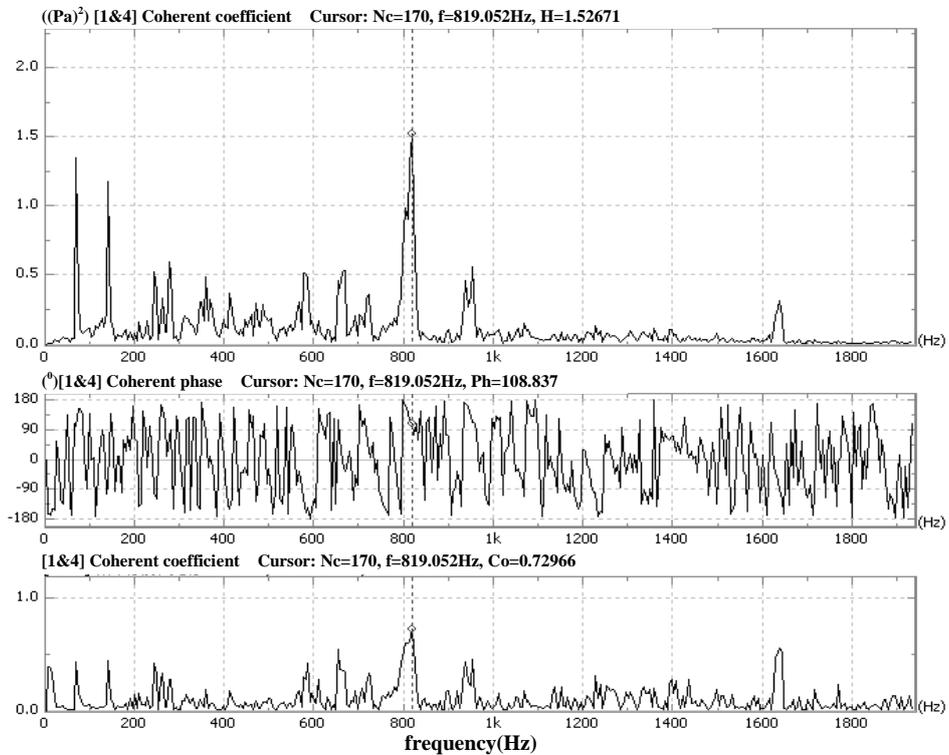


Fig.9 Coherent analysis between noise at driver's ear and noise at main reducer under speed of 60km/h

### 3.2 Vibration tests

Under constant driving velocities of 40, 50 and 60 km/h with three gear stalls, the vibration acceleration at three positions on minibus are shown in Fig.10, Fig.11 and Fig.12, and Fig.13 is spectrum of vibration at main reducer with 3<sup>rd</sup> gear stall. The vibration acceleration at main reducer roughly increases with the velocities at three gear stalls. From the three figures, we also find that the isolation rate of the driver's seat is good. So the vibration of main reducer must be improved.

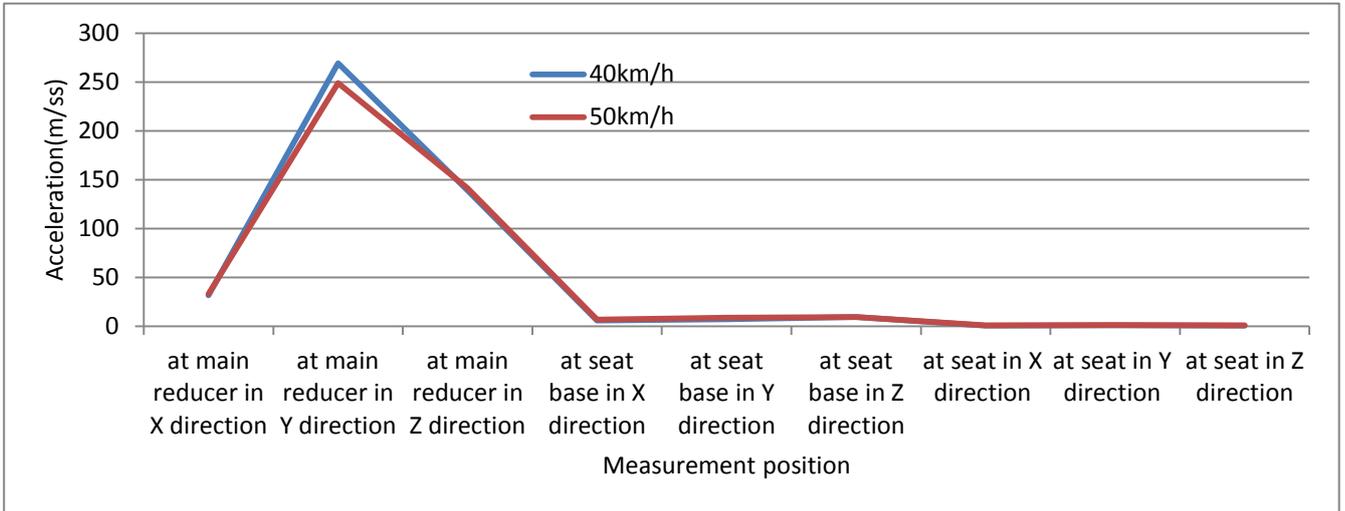


Fig.10 Vibration measurement with 3<sup>rd</sup> gear stall

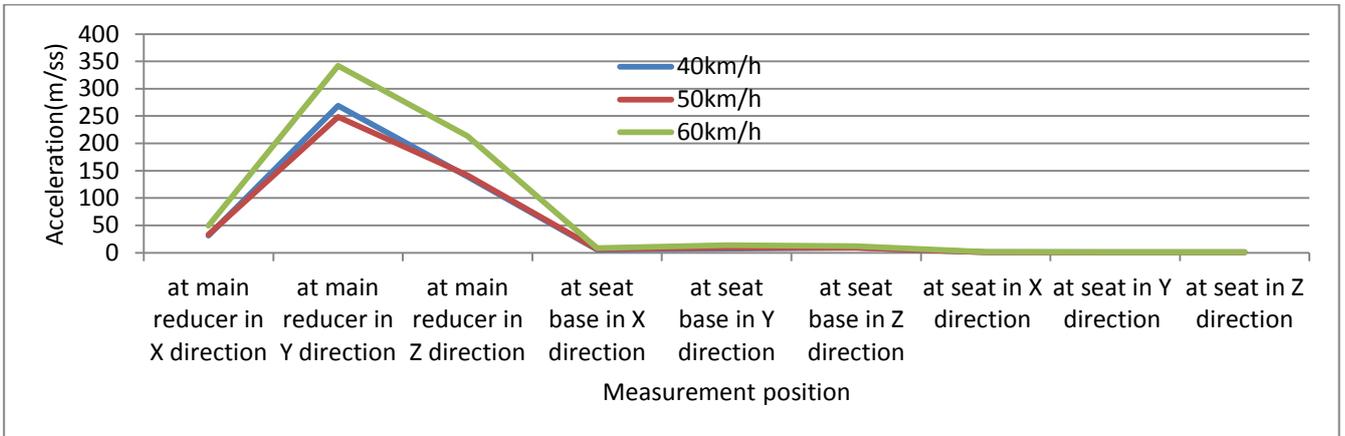


Fig.11 Vibration measurement with 4<sup>th</sup> gear stall

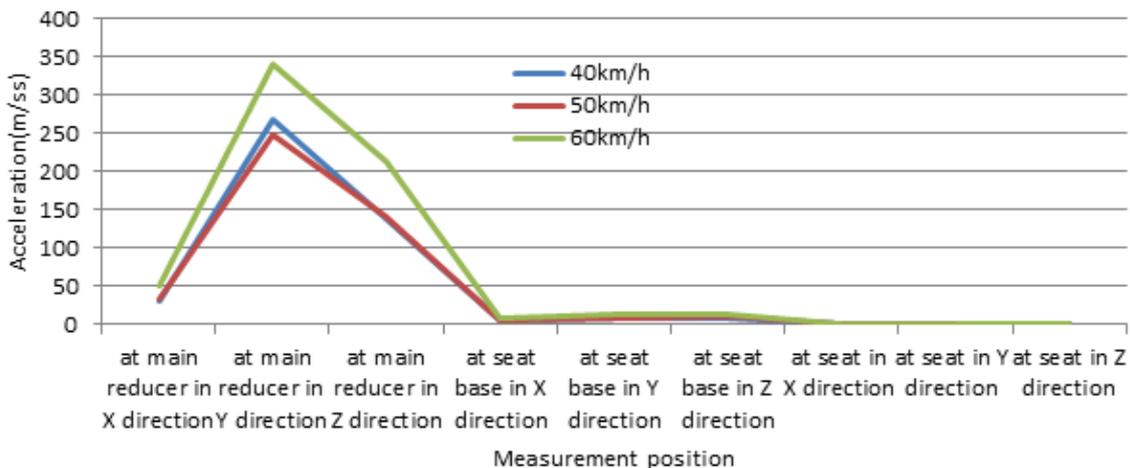


Fig.12 Vibration measurement with 5<sup>th</sup> gear stall

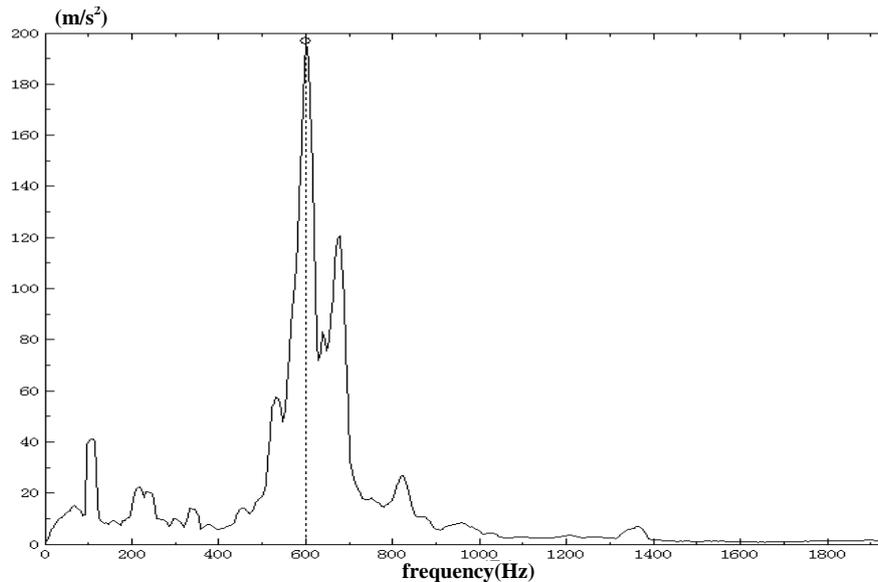


Fig.13 Spectrum of vibration at main reducer with 3<sup>rd</sup> gear stall

#### 4 Conclusion

This paper introduces a NVH test on minibus, and analyzes the interior sound field characteristic, external accelerating noise and the main vibration signals at different positions of minibus. The conclusions are reached as following:

- (1) The main reasons for causing interior noise largely is from power train and main reducer of driving axle. If the cabin is sealed well, then this kind of noise will be reduced.
- (2) The exterior noise on both sides of the road is narrow band noise, concentrating at 106 Hz and its harmonic components, mainly from power train noise and partly from transmission system noise.
- (3) Under constant driving velocities of 40, 50 and 60 km/h with three different gear stalls, the vibration acceleration at main reducer roughly increases with the velocities at three gear stalls. The coherent coefficient between noise at driver's ear and noise at main reducer reaches high at the main noise frequencies. So to a large extent, the noise at driver's ear comes from the main reducer's noise and the vibration of main reducer must be improved.
- (4) These results will give help to further study of the NVH characteristic of the minibus.

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