Study on the Frequency Range Law of Pavement Vibration Caused by Double-lane Car Rendezvous

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Abstract: Through field testing and MATLAB programming, the frequency range law of road surface vibration caused by the rendezvous of double-lane car can be achieved. The results show that the spectrum curve is dense within the range of 40Hz, and the main frequency of pavement vibration is located at the low frequency of about 20Hz, and is not affected by the size of the rendezvous load of cars applied to the pavement. With the increase of vehicle speed, the peak acceleration value in the frequency domain of road vibration also increases gradually. When the car intersects at a speed of 20km/h, 30km/h and 40km/h, the corresponding frequency of the peak acceleration in the road vibration frequency domain is about 84.7Hz, and the frequency decreases to 83.32Hz when the car intersection speed is increased to 50km/h.
***Keywords*:** on-site testing; MATLAB programming; car rendezvous; pavement vibration; Acceleration spectrum

1. Introduction

In recent years, with the gradual growth of China's cities and the rapid development of highway transportation, the problem of road vibration caused by this has become increasingly serious. Regarding the problem of pavement vibration caused by automobile operation, most scholars study the time-history effect of pavement[1], but when considering the frequency range, it is limited to the single-lane moving load[2], and the load case of double-lane automobile intersection is rarely reported. In this paper, the method of combining field test and MATLAB programming is used to study the frequency range law of road surface vibration caused by the intersection of double lane cars by placing a collector and an accelerometer on the road surface, and the collected time-history information is processed by 1/3 octave of the frequency range.

2. Testing Overview

The items shown in Table 1 were all in place prior to field testing. The test time is scheduled for 23:00-24:00 on the evening of January 28, 2024, and the test site is Shagang Road in the Economic and Technological Development Zone, Nanchang City, Jiangxi Province. After investigation, it can be seen that Shagang Road is a north-south direction, with a length of about 500m, good road smoothness, less surrounding traffic flow, and an asphalt concrete surface layer on a single-layer cement concrete pavement, which is more suitable as a site for this test. The brands of the small cars used in this test are the 2008 commemorative COROLLA and the 2013 classic SYLPHY, and some of the configuration parameters are detailed in Table 2.

Table 1. List of test items

Name	Type	Quantity
Accelerometers	KD-YZ-ST10K□KD15000L	1
Cable	Aviation plugs-BNC(5m)□TNC/BNC(10m)	1
Collector	KD-MINIV16	1
Toolbox	Conventional test kits	1
Notebook	Xiaomi portable laptop	1
Annex	Screws, magnetic seats, certificates, test reports	

Table 2. Configuration parameters of small cars

Vehicle brand	COROLLA 2008 commemorative model	SYLPHY 2013 Classic
Weight (t)	1.28	1.25
Wheelbase (m)	2.6	2.7
Size(m)	4.540×1.760×1.490	4.625×1.760×1.505
Top speed (km/h)	195	198
Acceleration time per 100 km/h (s)	11.8	11.9

Figure 1 shows the actual picture of the field test. The tester assembles the test supplies shown in Figure 1 (a) and places them in the middle of the length direction of Shagang Road, and the distance from the west curb and the white solid line is 257.6cm and 47.8cm respectively, and the sampling frequency is 400Hz, and the debugging work is completed before the formal measurement. When the tester issues the “start” command, the driver starts the vehicle, and the car accelerates briefly and then drives in a straight line towards the vibration testing point.

(a) Testng supplies (b) The car passed by the vibration testing point

Figure 1. On-site testing image

3. Data processing

As a result of this on-site testing, the time-history data of the acceleration of the road surface vibration caused by the double-lane intersection is available on a laptop computer that connects the sensor and collector via a cable. In order to further analyze the frequency development law, the full frequency range can be converted into a 1/3 octave spectrogram by 1/3 octave filtering, which is programmed by MATLAB software. In the 1/3 octave process, the fast Fourier transform (FFT) is performed on the sampled signal to calculate the amplitude spectrum in the frequency domain response[3], and then the data of the amplitude spectrum is used to calculate the average value in the bandwidth of each center frequency. The calculation formula used for this data processing is as follows.

According to the definition of root mean square value (RMS) and discretization, we can get:

$$RMS = \sqrt{\frac{1}{T}\int_0^T x^2(t)\,\mathrm{d}t} = \sqrt{\frac{1}{N\Delta}\sum_{n=0}^{N-1} x^2(n\Delta)\cdot\Delta} = \sqrt{\frac{1}{N}\sum_{n=0}^{N-1} x^2(n)} \tag{1}$$

In Eq. (1), is the sampling time interval, and , and is the continuous and discrete signal time history, respectively.

Convert Eq. (1) into a frequency-domain expression, and the Parseval equation of continuous form is obtained:

$$\int_{-\infty}^{+\infty} \left|x(t)\right|^2 \mathrm{d}t = \int_{-\infty}^{+\infty} \left|X(f)\right|^2 \mathrm{d}f \tag{2}$$

Discretize the above equation and notice that the continuous spectrum differs by one from the discrete spectrum definition, and the discrete form of the Parseval equation is obtained:

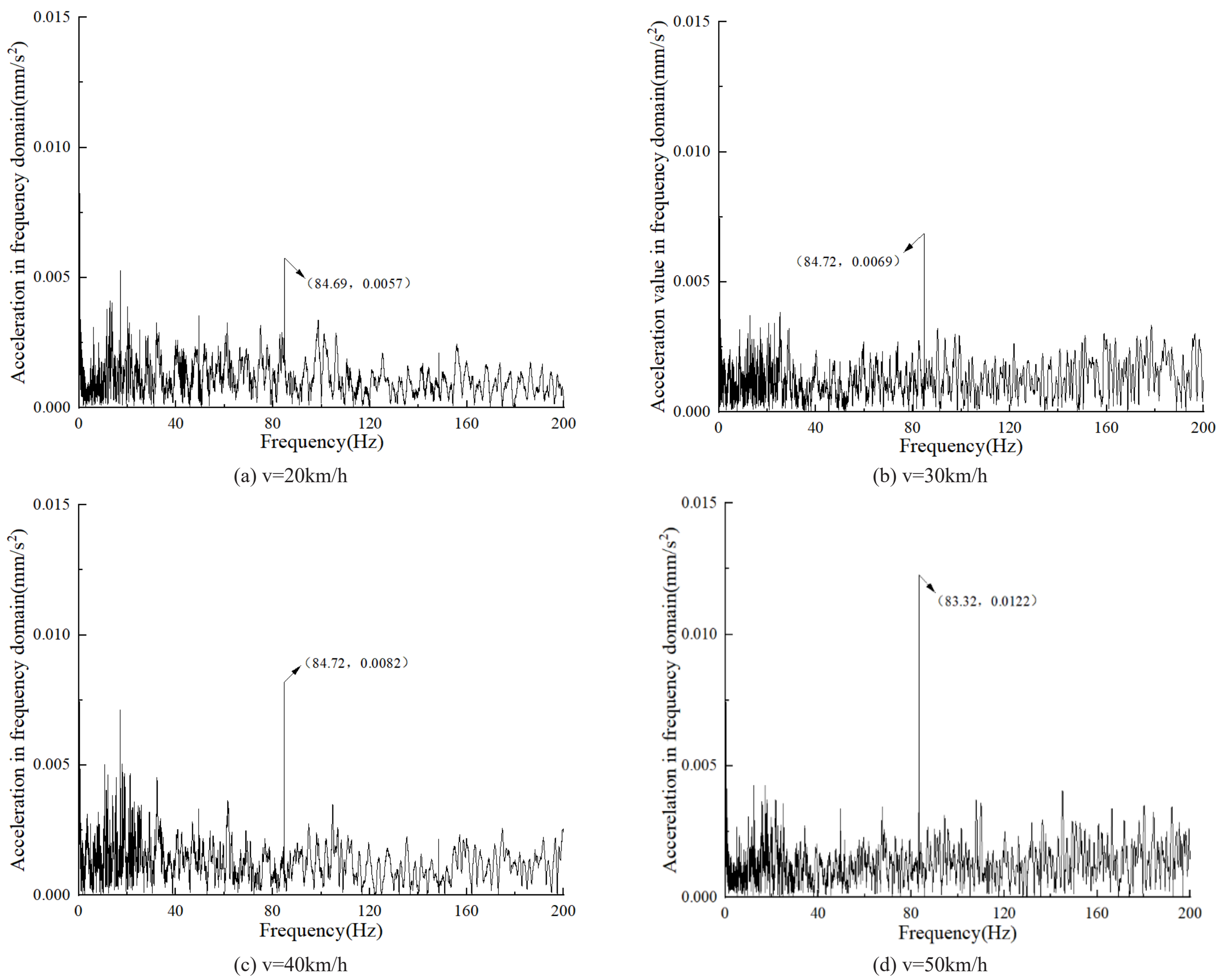
$$\sum_{n=0}^{N-1} x^2(n)\cdot\Delta = \sum_{m=0}^{N-1}\left(X(f_m)\cdot\Delta\right)^2\cdot\frac{1}{N\Delta} \tag{3}$$

Namely

$$\sum_{n=0}^{N-1} x^2(n) = \frac{1}{N}\sum_{m=0}^{N-1} X_m^2 \tag{4}$$

4. Spectrum analysis

As shown in Figure 2, the road surface vibration acceleration spectrum curve caused by the intersection of double-lane vehicles is presented. Table 3 shows the peak acceleration value in the frequency domain of pavement vibration under different working conditions. From the chart, it can be found that the areas with dense spectral curves are all within the range of 40Hz, which indicates that the main frequency of road vibration is located at a low frequency of about 20Hz, and is not affected by the size of the intersection load of the car applied to the road surface. With the increase of vehicle speed, the peak acceleration value in the frequency domain of road vibration also increases gradually. This is because the higher the vehicle speed, the closer it is to the shear wave velocity of the road structure, and the vibration waves generated by the two different vibration sources of the vehicle and the road surface are more likely to interfere with each other. In addition, when the automobile rendezvous speed is 20 km/h, 30 km/h and 40 km/h, the corresponding frequency of the acceleration peak in the road vibration frequency domain is about 84.7 Hz, and the frequency decreases to 83.32 Hz when the automobile rendezvous speed is increased to 50 km/h.



(a) v=20km/h (b) v=30km/h

(c) v=40km/h (d) v=50km/h

Figure 2. Spectral curve of road vibration acceleration at the intersection of double-lane vehicles

Table 3. Peak acceleration in the frequency domain of pavement vibration under different vehicle intersection conditions

Operating conditions	One	Two	Three	Four
Vehicle speed (km/h)	20	30	40	50
Peak acceleration in the frequency domain (mm/s2)	0.0057	0.0069	0.0082	0.0122

5. Conclusion

Through field testing and MATLAB programming, the frequency range law of road surface vibration caused by the intersection of doube-lane cars can be obtained. The results show that the spectrum curve is dense within the range of 40Hz, and the main frequency of pavement vibration is located at the low frequency of about 20Hz, and is not affected by the size of the intersection load of cars applied to the pavement. With the increase of vehicle speed, the peak acceleration value in the frequency domain of road vibration also increases gradually. In addition, when the automobile rendezvous speed is 20 km/h, 30 km/h, and 40 km/h, the corresponding frequency of the acceleration peak in the road vibration frequency domain is about 84.7 Hz, and the frequency decreases to 83.32 Hz when the automobile intersection speed is increased to 50 km/h.

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