

Design and Experimental Research on Vertical Vibration of Wheel Vehicle Seat

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Abstract: Seat comfort design is one of the research focuses in the user experience design for vehicles. In this paper, we take the common wheel tractor as the design object. Based on the Fast Fourier Transform analysis method, we analyze the vertical vibration characteristics of the seat under different speed and different vehicle conditions. The results show that when the driving speed increases, the impact of empty car on seat vibration is more obvious than that when the load is loaded. Beside, when the test speed is the highest, the seat vibration is the most severe. The seat vibration is a low-frequency vibration with the natural frequency less than 2 Hz, which avoids the sensitive frequency range of human body and makes the seat comfortable. The test results provide theoretical support for the damping user experience design of the seat.

Keywords: Comfort, Seat, Vertical vibration, FFT, Natural frequency, User experience.

1. Introduction

Modern transportation vehicles put forward higher and higher requirements for the bearing comfort of drivers and passengers. In order to improve the user experience of drivers and passengers, reduce the fatigue in the process of transportation, and then avoid traffic accidents, it is the key research field of vehicle design. In this paper, the tractor, which is the most widely used modern agricultural vehicle, is studied as the design object. Tractors play an important role in agricultural production, but the working environment of tractors is poor, and tractor vibration has a significant impact on user experience factors such as driving stability and ride comfort [1, 2]. During the operation, the driver bears the high-intensity low-frequency vibration of the seat for a long time. Because different parts of the human body have different resonance frequencies, such as the human

body trunk is 3-6 Hz, the spine is 3-5 Hz, and the internal organs are 4-8 Hz. The long-term seat vibration has a serious impact on the driver's work efficiency and physical and mental health, and even causes permanent back pain and other occupational diseases [3-5]. Vehicle seat is an important part of vehicle damping system [6, 7]. Therefore, it is of great significance to study the vibration characteristics of the wheel tractor seat, improve the vibration characteristics of the seat, design a reasonable, comfortable and safe seat, and improve the comfort of the driver [8, 9].

In this paper, the vibration test system is composed of tractor John Deer 1204, vibration signal acquisition system and vibration signal analysis system. The vertical vibration characteristics of the tractor seat under different speeds and different vehicle conditions are analyzed and studied, so as to provide theoretical support for the research of seat vibration reduction.

2. Tractor Vibration Signal Acquisition System

2.1. Composition of Vibration Signal Acquisition System

The data acquisition system of vibration test in this paper consists of LC0803 series strain acceleration sensor, four channel dynamic and static data collector,

wireless network adapter, computer, etc. During data acquisition, the sampling frequency and sampling time can be set according to the actual requirements, and the collected vibration signal can be transmitted to the computer through the network port for storage. In the process of signal acquisition, the collected signal can also be monitored in real time. The schematic diagram of vibration signal acquisition is shown in Fig. 1.

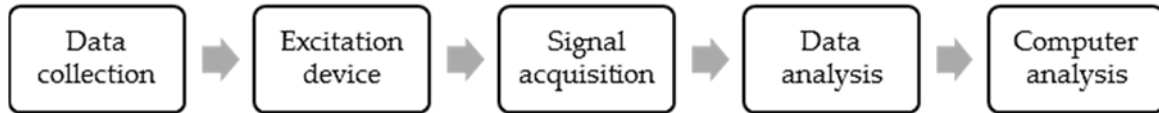


Fig. 1. Schematic diagram of vibration signal acquisition.

2.2. Tractor Parameters and Sensor Arrangement

2.2.1. Tractor Parameters

In this paper, John Deer 1204 tractor is taken as the research object, and its parameters are shown in Table 1.

Table 1. Tractor parameters.

Tractor parameters	
Engine model	LR6A3Z-21
Engine displacement	6.49
Number of engine cylinders	6, in-line
Engine power (kW)	91.875
Tractor minimum mass (kg)	4570
Front tire size (inches)	14.9-24
Front tire pressure (MPa)	180
Rear tire size (inches)	18.4-38
Rear tire pressure (MPa)	180

2.2.2. Acceleration Sensor

In this paper, LC0803 series strain type acceleration sensor is used, which has the characteristics of stable performance, light weight, small volume and high sensitivity, especially the zero frequency response. It is suitable for low frequency vibration measurement. When in use, the direction of the test acceleration is consistent with the sensitive direction of the acceleration sensor.

The vibration signal acquisition schematic diagram of the experimental system is shown in Figure 1. Four channel dynamic and static data collector is used, LC0803 series is used as the sensor end of strain type acceleration sensor, Wi-Fi wireless network card is used as the transmission part, and the server for data transmission analysis is used. Therefore, in the data acquisition experiment, different sampling frequency and sampling time are designed according to different application scenarios. The collected data is transmitted to the server in real time by IPv4 wireless for analysis. In the experiment process, we can monitor all kinds of signals collected in different scenes in real time.

2.2.3. Excitation Device

The driving surface of the tractor is as shown in Fig. 2 for manual road paving [10]. The tractor drives on the exciting road at different driving speeds, and the exciting frequency $f_e = v/d$ is changed by changing the driving speed of the tractor.

- d : spacing between adjacent angles, 1 m;
- l : angle steel length and exciting road width, 2 m;
- L : length of exciting pavement, 20 m;
- h : angle steel height, 0.06 m.

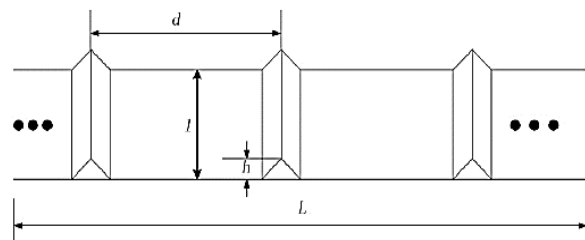
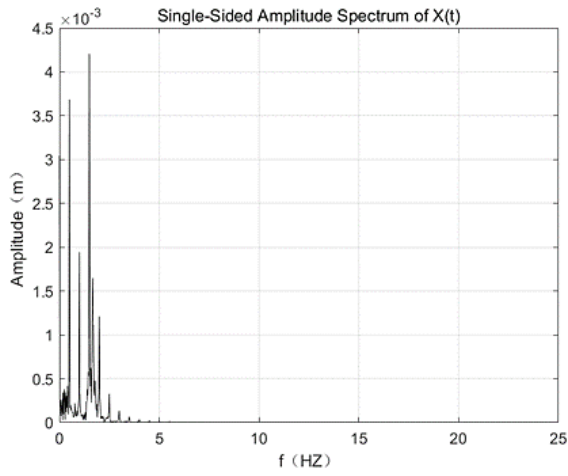
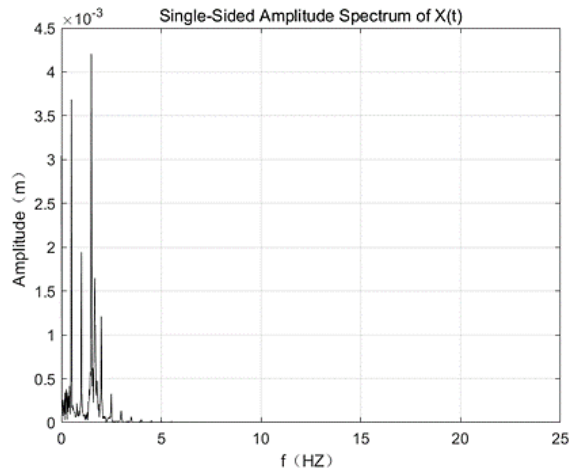


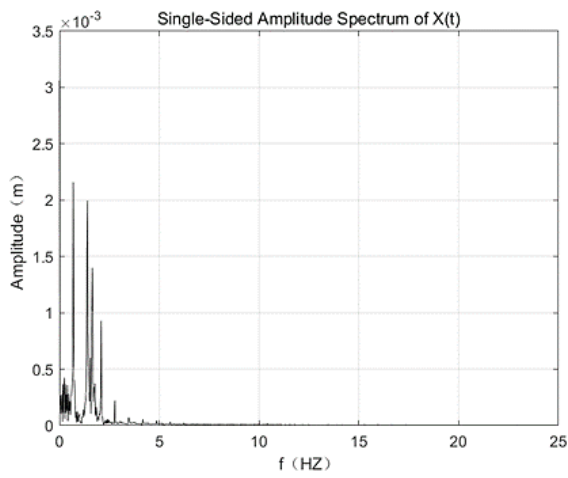
Fig. 2. Excitation device.



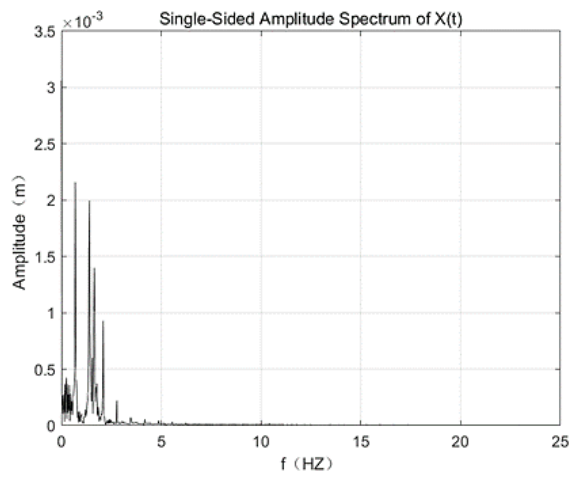
(a) $v = 0.97$ m/s



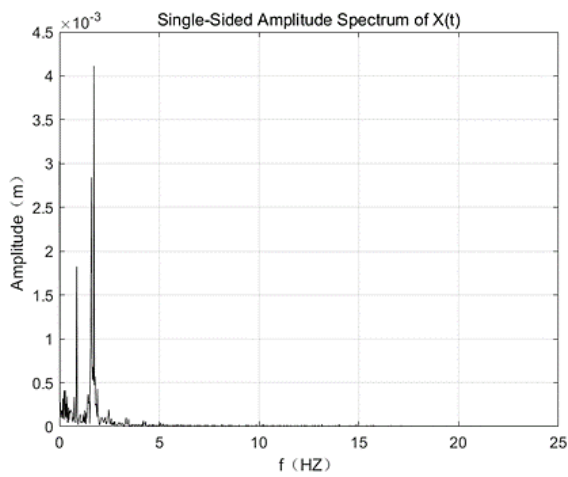
(b) $v = 1.20$ m/s



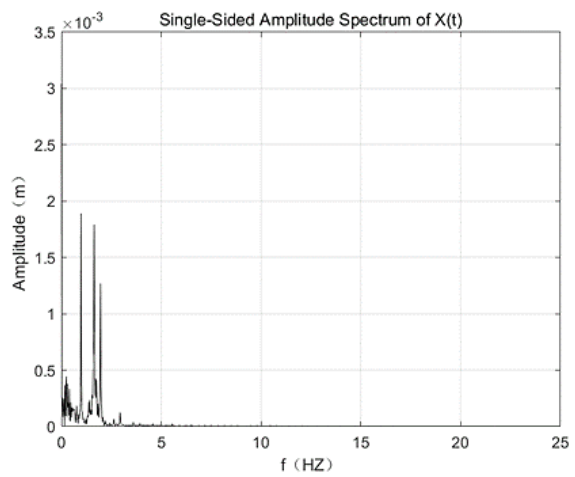
(c) $v = 1.41$ m/s



(d) $v = 1.58$ m/s

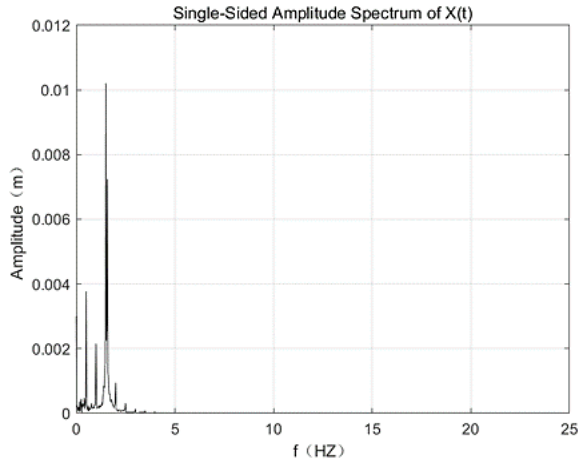


(e) $v = 1.79$ m/s

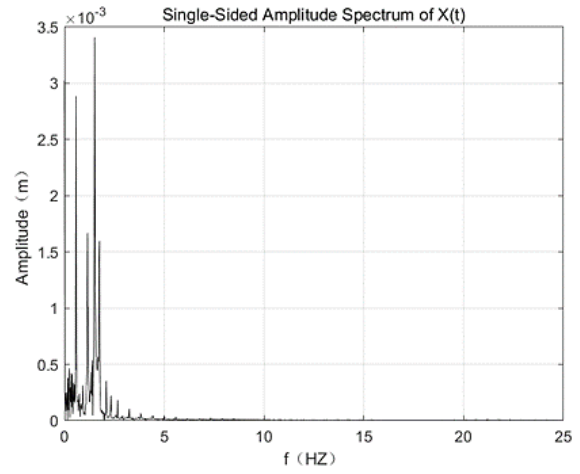


(f) $v = 2.01$ m/s

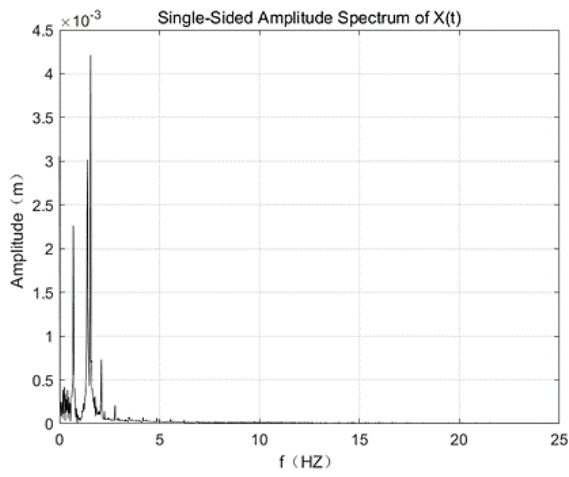
Fig. 4. Spectrum diagram of different speed in empty car state: (a) $v = 0.97$ m/s; (b) $v = 1.20$ m/s; (c) $v = 1.41$ m/s; (d) $v = 1.58$ m/s; (e) $v = 1.79$ m/s; (f) $v = 2.01$ m/s.



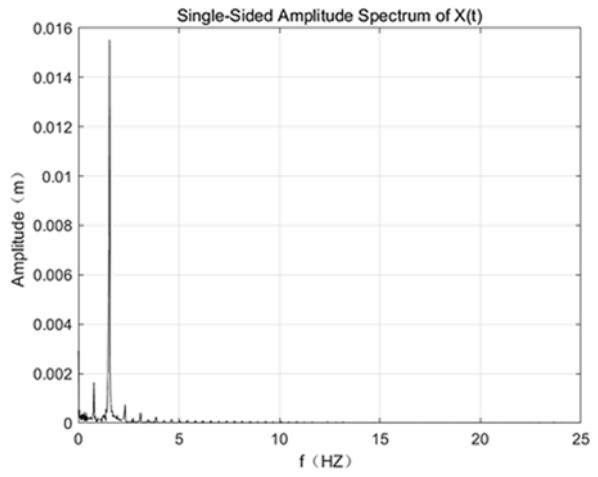
(a) $v = 0.99\text{m/s}$



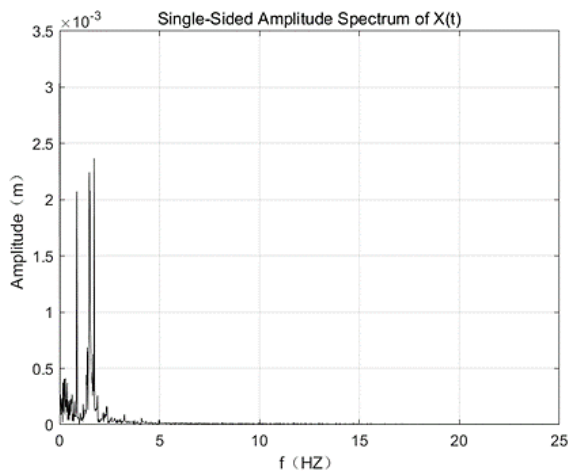
(b) $v = 1.23\text{m/s}$



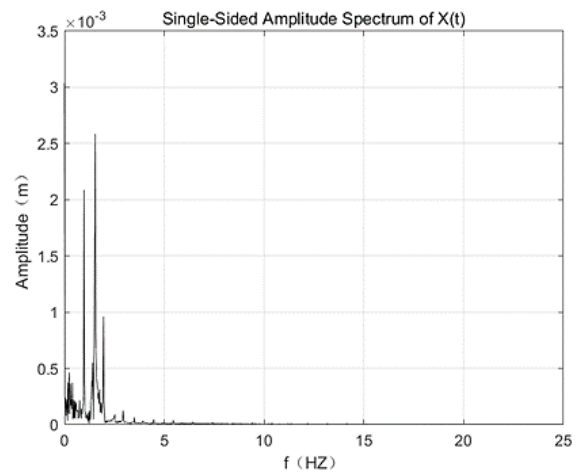
(c) $v = 1.40\text{m/s}$



(d) $v = 1.59\text{m/s}$



(e) $v = 1.82\text{m/s}$



(f) $v = 2.02\text{m/s}$

Fig. 5. Spectrum of seat response at different speeds under load: (a) $v = 0.99\text{m/s}$; (b) $v = 1.23\text{m/s}$; (c) $v = 1.40\text{m/s}$; (d) $v = 1.59\text{m/s}$; (e) $v = 1.82\text{m/s}$; (f) $v = 2.02\text{m/s}$.



Fig. 5. Tractor four round block test.

3. Road Test Results and Analysis

3.1. Vibration Signal Acquisition and Analysis Method

Under the condition that the tractor carries a rotary cultivator and an empty vehicle, the vibration signals of the seats at different speeds of the tractor are collected, and the classical FFT is used for spectrum analysis [5, 11, 12].

It can be seen from literature [5] that 4 Hz – 8 Hz is the sensitive vibration frequency range of human body. The spectrum of tractor vertical vibration in the range of 0-25 Hz is analyzed by using low-pass filter. In order to reduce the main lobe width, improve the frequency resolution and suppress the signal energy leakage, Hanning window is used in this paper.

3.2. Results and Discussion

Fig. 3 and Fig. 4 are the spectrum of seat response at different speeds when the tractor is empty and loaded, respectively.

According to Table 2 and Table 3, the load and empty speed amplitude diagram of tractor seat at different speeds can be obtained, as shown in Fig. 6.

It can be seen from Fig. 6 that under the condition of load and empty vehicle, the vibration rule trend of tractor is the same: when $v = 1.60 \text{ m/s}$, namely, excitation frequency $f_e = 1.6 \text{ Hz}$, the seat vibration is severe, which has a significant impact on the driver's driving. The driver must hold the steering wheel tightly in case of severe turbulence, which is caused by the excitation frequency close to the natural frequency of the seat [13, 14]. According to Fig. 3 (a-f), Table 2 and Table 3, the natural frequency range of the seat is less than 2 Hz, avoiding the sensitive frequency range of the human body, and the seat has good damping performance.

7. Conclusions

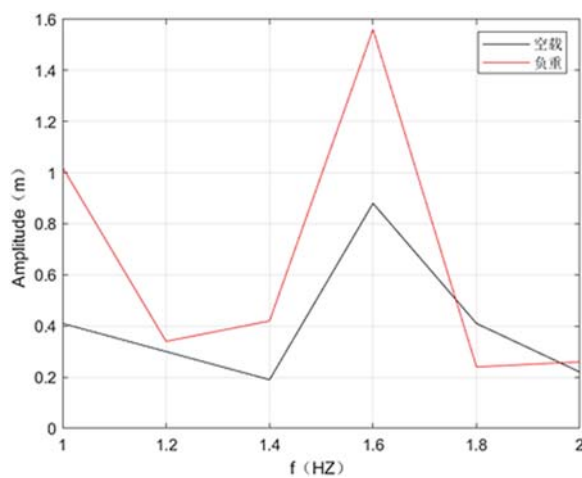
Based on the fast Fourier transform analysis method, this paper discusses the vibration characteristics of the seat at different speeds and different vehicle conditions. The results show that the factors affecting the vibration of tractor seat are terrain condition, speed and vehicle condition. The seat vibration is a low-frequency vibration, the natural frequency range is less than 2 Hz, avoiding the sensitive frequency range of human body, improving the comfort of the seat. We can make design of new seat avoid the sensitive frequency by accurate data. Next time we will do some research of driver weight influence to the seat vibration. The test results have theoretical significance for the design of seat vibration reduction.

Table 2. Vibration data when empty.

Speed	Excitation frequency	Maximum amplitude	Corresponding frequency of maximum amplitude
(m/s)	Hz	cm	
0.97	0.97	0.41	1.49
1.20	1.20	0.30	1.61
1.41	1.41	0.19	0.69
1.58	1.58	0.88	1.55
1.79	1.79	0.41	1.73
2.01	2.01	0.22	0.98
0.97	0.97	0.41	1.49
1.20	1.20	0.30	1.61

Table 3. Vibration data when load.

Speed	Excitation frequency	Maximum amplitude	Corresponding frequency of maximum amplitude
(m/s)	Hz	cm	
0.99	0.99	1.02	1.50
1.23	1.23	0.34	1.51
1.40	1.40	0.42	1.55
1.59	1.59	1.56	1.55
1.82	1.82	0.24	1.73
2.02	2.02	0.26	1.54
0.99	0.99	1.02	1.50
1.23	1.23	0.34	1.51

**Fig. 6.** Velocity vs. amplitude.

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