PSD analyzing for complicated shock signal

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Abstract: This paper presents a new idea for analyzing the complicated shock signal. Based on this kind of analysis, an equivalent power spectral density(PSD) chart is drawn for vibration environmental test, which is carried to test the vehicle loading instrument's vibration behavior. The environment test is equivalent to the condition under which the vehicle and the instrument is experiencing a firing period. Exactly speaking, the short time vibration during the firing period is a complicated shock event. The paper points out the deficiency of the commonly used half sine equivalence for the shock and vibration environment test and gives the procedure of how to draw the PSD chart through the actual acceleration data.

Key words: environment test; waveform equivalence; complicated shock; power spectral density(PSD)

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In order to ensure the reliability of the instrument installed in vehicle, or to examine its performance, it is required to do the shock and vibration environmental test for the instrument. So it is essential to make the appropriate shock and vibration standard for the environmental test. If the standard is much harder as compared to the actual case, it may increase the cost to reinforce the instrument. On the other hand, if the vibration or shock level is lower than the actual case, there may be little meaning for the test. Theoretically speaking, it is required to make the test waveform and amplitude be equivalent to the actual acceleration environment. But the waveform equivalence is a rather difficult task because the shock acceleration pulse generated by the vibrator or impact device is rather simple and regulate, such as half sine, rectangle, or trapezoid. Suppose the actual impact is a simple shock, it can be easily transformed into a standard half sine wave. Fig.1 shows a simple shock signal and its corresponding equivalent half sine impulse.

As usual, the real acceleration signal collected during the driving process is random signal and can be treated through power spectral density (PSD) analyzing. Based on this analyzing result, the corresponding PSD chart can be drawn by he maximum peak envelope method, which uses the estimation of the overall spectrum's amplitude envelope. In another case, when the vehicle is not running on the road but has parked and starts to fire, it is commonly considered that the firing process can be regarded as one shock, as the whole process is less than 1 s. Based on this point of view, usually a half sine waveform pulse is got through shock response spectrum[1]. But in actual cases, the acceleration signal during the short firing period is very complicated[2], when such short period signal is regarded as simple shock signal and is simulated as a half sine pulse shock, it has little practical use in actual condition. This paper presents a new idea for acceleration waveform equivalence. It treats this vehicle firing period of shock as a type of wide brand random vibration, thus an equivalent random PSD chart is drawn for vibration environment test. It points out the deficiency of the usual half sine equivalence and gives the procedure of how to draw the PSD chart thorough the actual acceleration data.

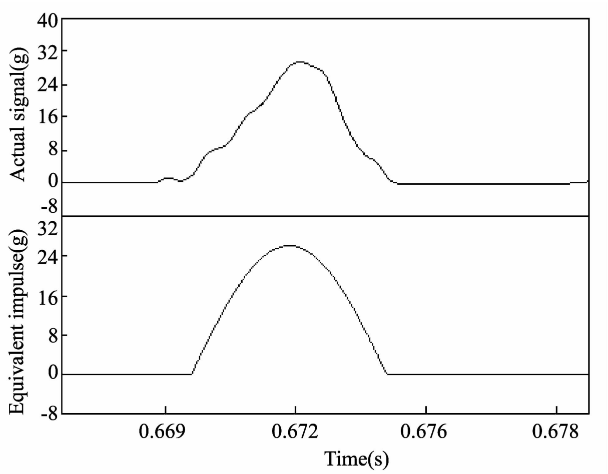

Fig.1 Simple shock acceleration signal

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1 Deficiency of half sine equivalence for complicated shock acceleration signal

The half sine equivalence for simple shock acceleration signal is customarily accepted for environment test. The equivalence is based on the shock response spectrum analysis. With this method, the shock response spectrum of simple shock acceleration signal is compared with a half sine acceleration signal, if these two spectrum are approximately the same, then the maximum acceleration on full frequency range are almost the same[3], and this is the basis for such equivalence. As an example, Fig. 2 shows the two shock response spectrum for the corresponding signals in Fig. 1.

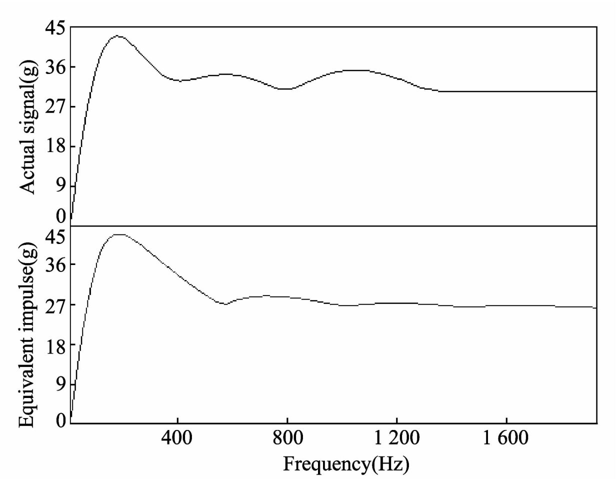

Fig. 2 Shock spectrum for signals in Fig. 1

But for complicated shock acceleration, as shown in Fig. 3, its frequency components are rich and generous, especially the main components are focused in high frequency brand. With such a signal, the waveform equivalence stated above encounters a difficult: the equivalent half sine pulse's peak amplitude and pulse width change with the cutoff frequency of the low pass filter (LPF) for the complicated signal. The influence of the cutoff frequency on the peak amplitude and width of the equivalent half sine signal is shown in Table 1.

Table 1 Cutoff frequency and half sine waveform

	Cutoff frequency (Hz)	Pulse width (ms)	Peak amplitude (g)
1	nun	0.25	398
2	2 000	0.26	147
3	1 000	0.35	37
4	500	1.5	20
5	200	4.4	19
6	100	8	12

For the signal in Fig. 3, its duration time is almost 100 ms, and its equivalent pulse width is changed from 0.25 to 8 ms as shown in Table 1. Especially for the equivalence time width less than 1 ms, even if its distribution over the frequency span are approximately the same as the complicated shock acceleration, their duration time makes a great difference, thus this kind of equivalence is unpractical.

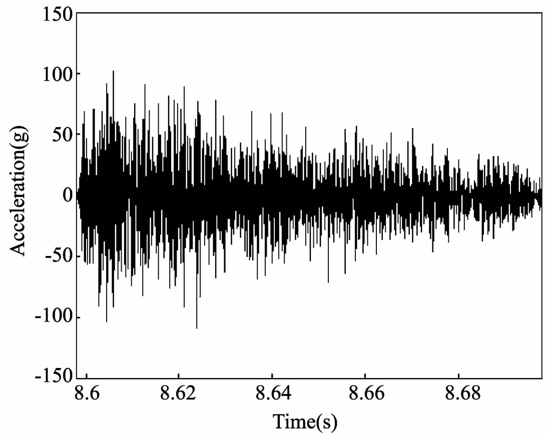

Fig. 3 Complicated shock acceleration signal

2 PSD equivalence for complicated shock signal

In order to simulate the actual vibration environment, it is practical to treat the complicated shock acceleration process as a short time random vibration, thus by PSD analysis instead of shock response spectrum analysis, the environment test for vehicle loading instrument during firing period is made as random wide band vibration. The analysis is carried out by the definition of PSD[4], and the main procedure is shown in Fig. 4.

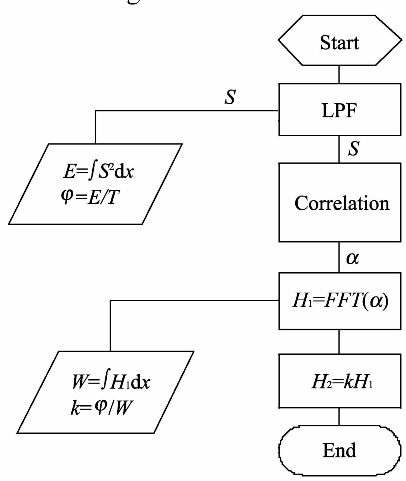

Fig. 4 Analyzing procedure of PSD

The software Flexpro7.0 is used for above analysis. The "LPF" step is to cutoff the high frequency component which is upper than 3 kHz. These higher frequency components usually have little influence on the tested instrument. It is recommended to remove the offset of the original acceleration signal in this step. E is the energy of the LPF signal S, and T is the elapsing time of the signal (100 ms). K is the correction factor, which is used to compensate the additional energy caused by noise signal[5].

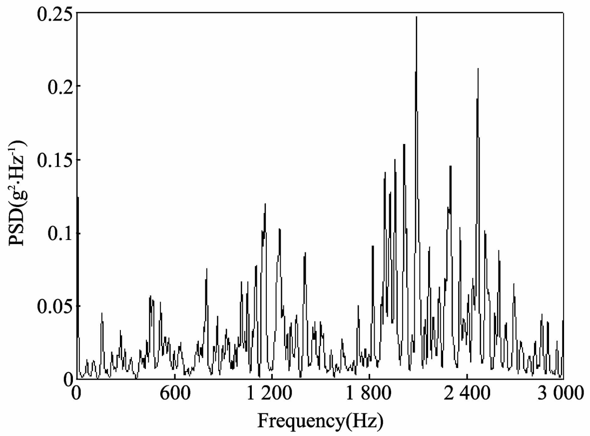

Fig. 5 PSD analyzing result

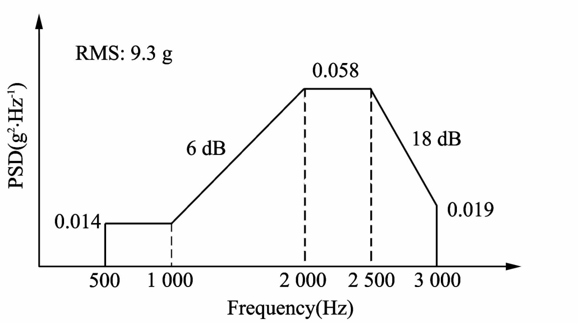

Fig. 6 Vibration test spectrum chart

Fig. 5 shows the analyzing result for the complicated signal of Fig. 3, and Fig. 6 is the corresponding PSD vibration chart which is derived from Fig. 5 according to the maximum amplitude envelope principle.

3 Conclusion

The analysis and the equivalence stated above is of engineering applying value, especially for the environmental vibration test aiming at the examination of the running behavior of vehicle loading instrument. The environmental vibration test may last 5 min or more for the examination. It is needed to point out that sometimes the firing of the vehicle is accompanied by huge energy release and the high energy impact may generate a high magnitude complicated shock acceleration signal. In such a case, even though the complicated shock signal can not be directly simulated through shock response spectrum method, it really needs to be equaled to a half sine pulse by some special data processing, so as to simulate the velocity change during the firing period. Thus it is needed to use wide brand random vibsation test as well as half sine pulse shock test to examine the comprehensive behavior of the vehicle loading instrument.

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