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An Experimental Study of Train Approach Detection by Vibration Analysis

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Abstract For safety and security for both the workers around the railway tracks and railroad operators, early identification and warning of an approaching train is most important to give workers time to get off the track and remove tools from the track. Experiments have been conducted at a seamless steel railway to spot vibration symptoms of approaching freight trains and passenger trains. Various vibration sensors and frequency ranges are used. As a result, an approaching train can be reliably detected by vibration at a specific frequency with a lead time of about 30 seconds.

Keywords: *Experiment Study, Rail Train, Approach Detection, Vibration Analysis*

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1. Introduction

Safety is of the utmost importance to workers around railroad tracks, as well as to rail operators and companies. Statistics by the railroad industry and the U.S. Federal Railroad Administration (FRA) indicate that 65 worker casualties (5 per year on average) have occurred between 2000 and 2012 resulting from the maintenance of ways and corresponding structures [1]. For this safety, early identification and warning of an approaching train are most important to let workers have time to leave the track and remove tools off the track.

There are some available solutions and technologies employed for the train approaching detection such as Treadle Mechanisms, Inductive Sensors, Infrared (IR) Beam Sensors, Radar Technologies, Acoustic Detection, Time-Domain Reflectometry, Anisotropic Magneto-Resistive Magnetometers, and Detection through Rail Vibrations with Accelerometers. A survey may be found in [2].

As for the vibration-based method, J. J. Genova [3] verified that significant and useful information could be extracted via analysis of train-induced rail vibrations and suggested that railroad companies and manufacturers of railroad devices assess the potential marketability of the flagman assistance device.

In this experimental study, we hope to determine what vibration sensors are needed for a practical train approaching detection instrument, the frequency range of the detection, and the design route of an instrument.

2. Accelerometers and Test Systems

We considered different kinds of accelerometers for this study:

-General-purpose accelerometer for industrial use
-High-sensitivity accelerometer for low-frequency testing
-Ultrasonic accelerometer

General purpose accelerometers, model SENDIG L14, have a sensitivity of about 25pc/m/s^2 and a frequency range 10Hz to 10 kHz. They are piezoelectric shear mode base-isolated and reliable for field use.

High-sensitivity accelerometers for low-frequency testing have a sensitivity of about 500-1000 pc/m/s^2 and a frequency range of 0.5 Hz to 1000 Hz and a bigger size.

An ultrasonic accelerometer was also tried for a frequency range of 7 kHz to 61 kHz analysis.

Figure 1. Vibration analyzer

As for data collecting and analysis instrument, we used the SENDIG S966 analyzer which can do long-time seamless recording and has an analysis frequency range 0.5Hz~62kHz.

3. Experiment Field

Experiments have been conducted at Huzhou, Zhejiang, P.R. China. It is a seamless steel rail that runs both freight trains and passenger trains.

Figure 2. Experiment field

Accelerometers are attached below the rail by magnet bases. We have tried the accelerometer installed in 3-D directions but found that the position perpendicular to the steel rail can output a much stronger signal than others so we used that for the entire following tests.

Figure 3. Accelerometer installation

During the everyday operation, both freight trains and passenger trains passed. Their running speed range from 30 to 120 km/hour. During the test, we have persons at 1km and 2km away who worked as signal men.

4. Measurement Data Analysis

A. When a passenger train with a speed of 120km/h approached at 2km away to the sensor, no obvious new spectrum peak can be observed besides the 2 very small noises at 2025Hz and 4075Hz with amplitude less than 0.003m/s^2 as in Figure 4.

B. When this passenger train with a speed of 120km/h approached from 1.3km away, a new spectrum peak at frequency 1300Hz can be observed although its amplitude was still smaller than noise as in Figure 5.

C. When this passenger train with the same speed approached 1.0km away, the new spectrum peak amplitude at frequency 1300Hz doubled with some sideband peak as in Figure 6.

D. When this train with the same speed approached 500m away, this spectrum peak amplitude at frequency 1300Hz is about 85 times higher than that at 1km as in Figure 7.

E. When this train arrived at the sensor location, this spectrum peak amplitude at frequency 1300Hz is about 543 times higher than that at 1km as in Figure 8.

F. When a freight train with a speed of 60km/h approached about 1km away from the sensor, a 1.2-1.3kHz new spectrum appeared. When it approached at a little bit more than 500m away, we can find a 1200-1275Hz spectrum peak very obviously as in Figure 9. Considering a freight train with a speed of 60km/h uses the same time of 30 seconds to pass 500m as a passenger train with speed 120km/h to pass 1000m, they will give same alarming time.

G. We have tried the high-sensitivity (500pc/m/s^2) accelerometers with a low-frequency range 0.5-200Hz analysis. No obvious train approaching signal was observed. Another issue with this measurement scheme is it is easy to be affected by various noises like people walking around, using tools, blowing whistles, and speaking.

H. Ultrasonic accelerometer was also tried but a very weak signal was observed.

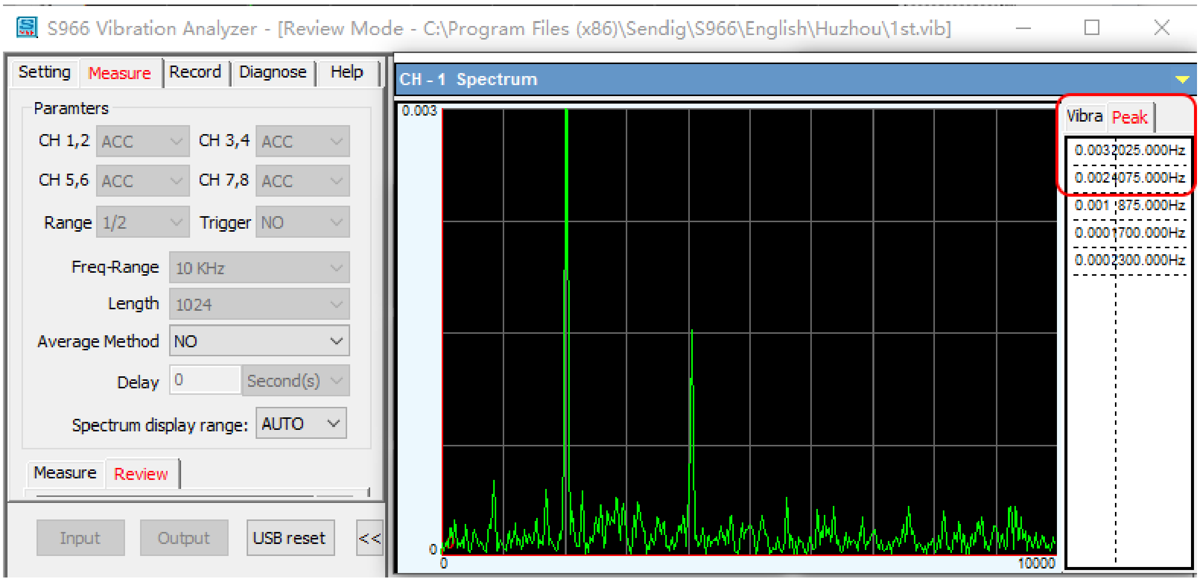

Figure 4. Spectrum peak of noise when the train at 2km away

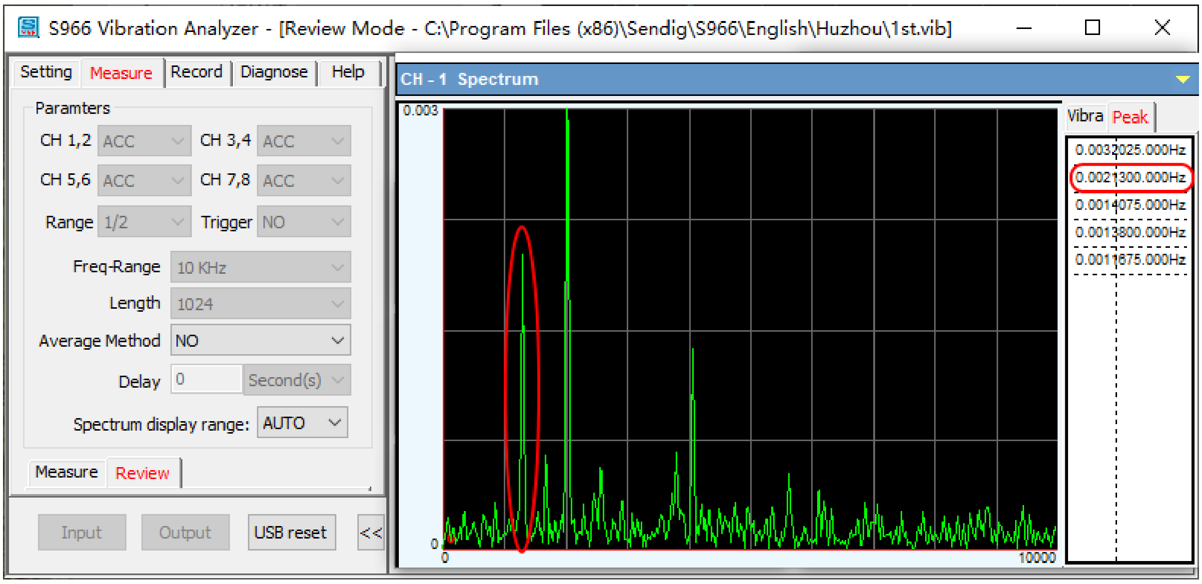

Figure 5. Spectrum peak appears when the train at 1.3km away

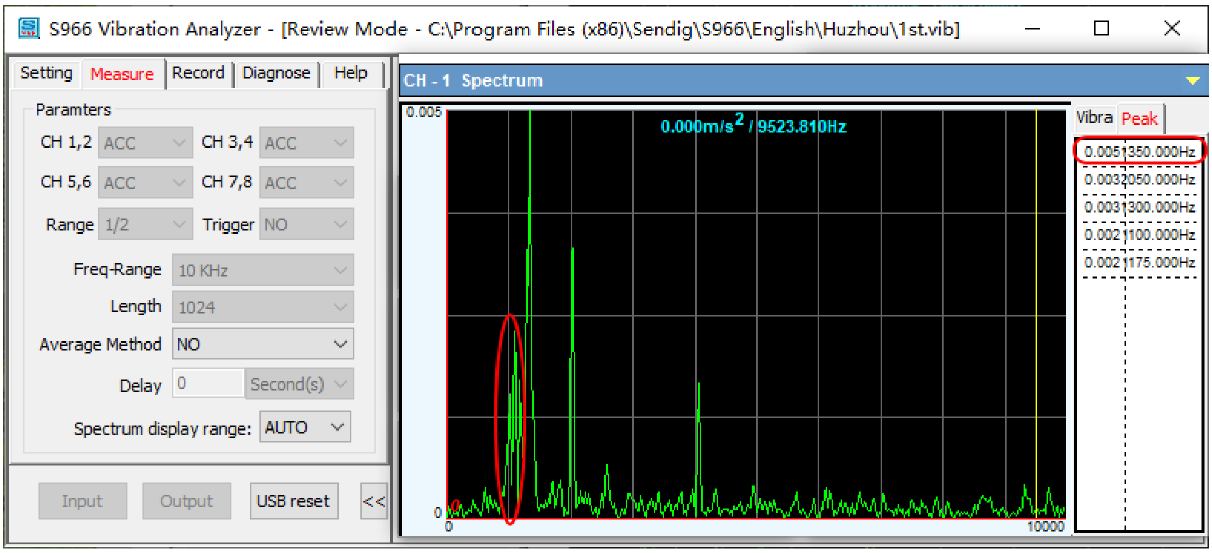

Figure 6. Spectrum peak amplitude at frequency 1300Hz doubled when the train at 1km away

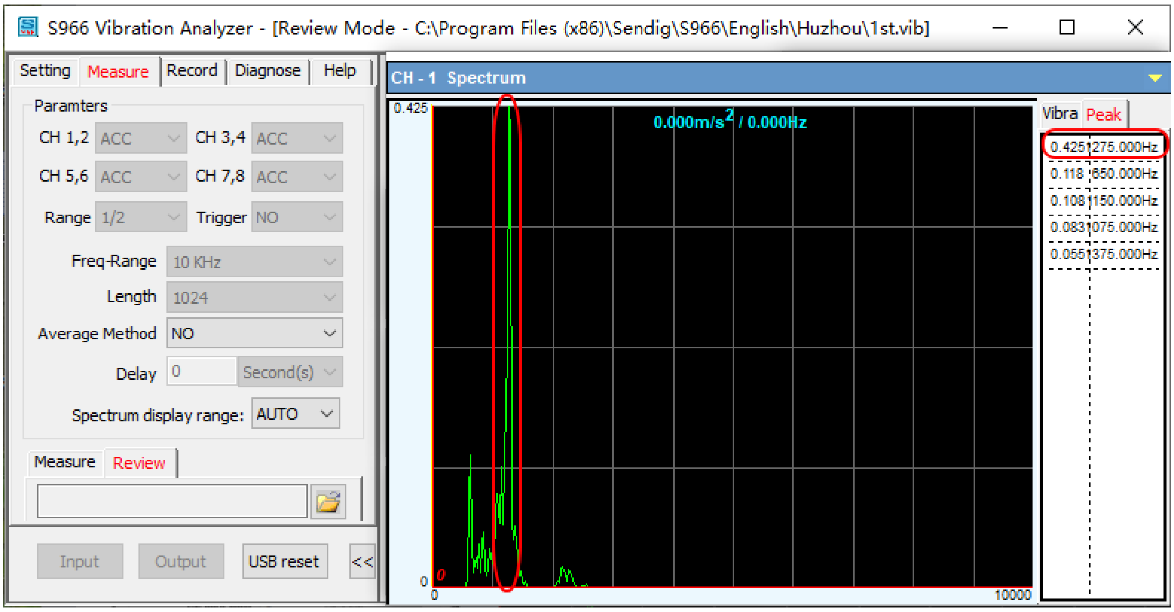

Figure 7. Spectrum peak when the train at 500m is about 85 times high than that at 1km away

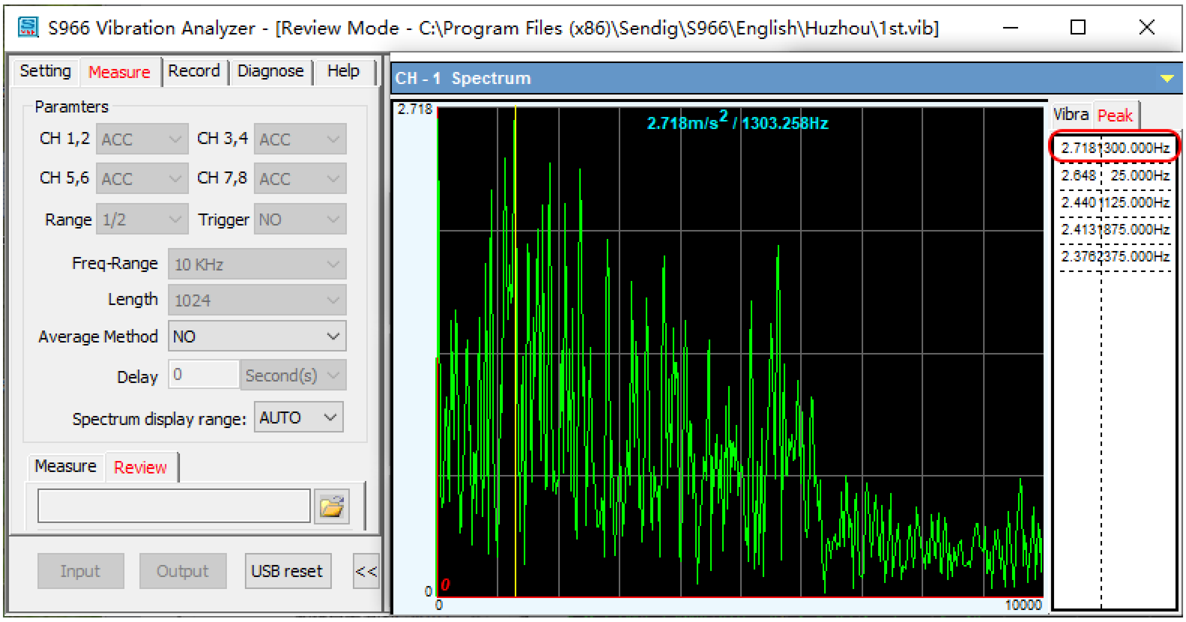

Figure 8. Spectrum when the train arrived at the sensor location is about 543 times higher

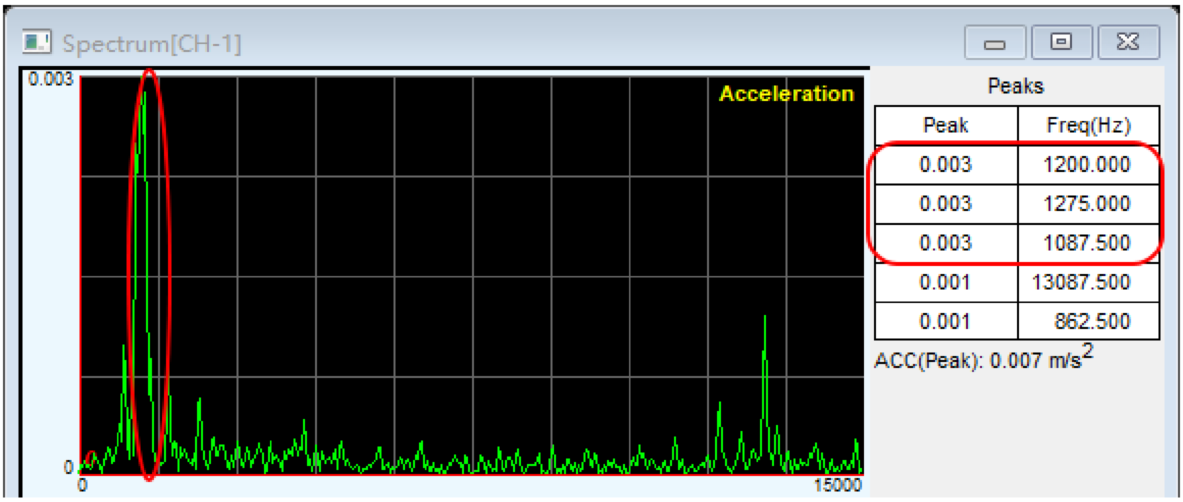

Figure 9. Spectrum when a freight train with a speed of 60km/h approached at about 500m away

5. Conclusion

An approaching train can be detected by a general-purpose accelerometer with high sensitivity installed perpendicular to the steel rail with a spectrum analysis frequency of around 1.3 kHz. Both freight trains and passenger trains can be alarmed with a lead time of about 30 seconds.

Accelerometer installed in the direction perpendicular to the steel rail can output a much stronger signal than in other directions.

High-sensitivity accelerometers with low-frequency range analysis and ultrasonic accelerometers with very high-frequency range analysis are not helpful.

More confirmation experiments may be conducted on various rail materials, rail type and train type, and train speed. A prototype device should be designed for further testing and application.

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