Determining the Railway Track Condition using the INS / GPS System

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Abstract. The paper discusses the development of the "test vehicle" system for preliminary test of the railroad. The test is accomplished on the basis of the own developed systems for data storage based on the GPS receiver and inertial sensors. All data are stored in the external energy independent memory (FLASH) while the navigation data are sent to the navigation server via GPRS network. The quality of the railway is determined according to the three axis acceleration analysis while the GPS receiver defines the event position. The experimental data are recorded on the selected part of the railroad and furthermore are analyzed.

Keywords: Railway faults, GPS receiver, Accelerometer.

1 Introduction

Nowadays the railway geometry is measured by the high speed wagon measurement tools like EM120 or EM250 [1]. These tools control the railway condition and parameters, which are compared with the regulation technical data. The control is performed according to the preliminary elaborated schedule while the time period between two consecutive tests is defined as one year or higher. During this period it is possible to emerge a digression at the railway geometry, which is a potential source of an accident. This is the reason to develop a system, which may register the railway places with increased risk to avoid the accidents during the exploitation time. This system does not require any additional high – qualified personal or railway equipment.

The "test vehicle" system is developed at [2]. The dangerous railway places are recognized according to the effective values of the vehicle accelerations. Another method is discussed at [3], where the proposed method for defect recognition is based on wavelet transformations of the acceleration signals. This method requires a perfect suspension state to guarantee the correct results. Another method for determination of the railway deflection in the longitudinal direction is proposed at [4], which is based on the acceleration of the vehicle terminal junction. Such type of test systems are also proposed at [5] and [6] but their high cost limited their application in the railway systems.

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2 "Test Vehicle" System Description

The "test vehicle" system is realized with the measuring system, described at our previous work [7] (Fig.1), which is installed on a locomotive traveled regularly on the selected route. The measuring system is mounted on the locomotive reduction gear to ensure the system will measure only accelerations originated from the rails.

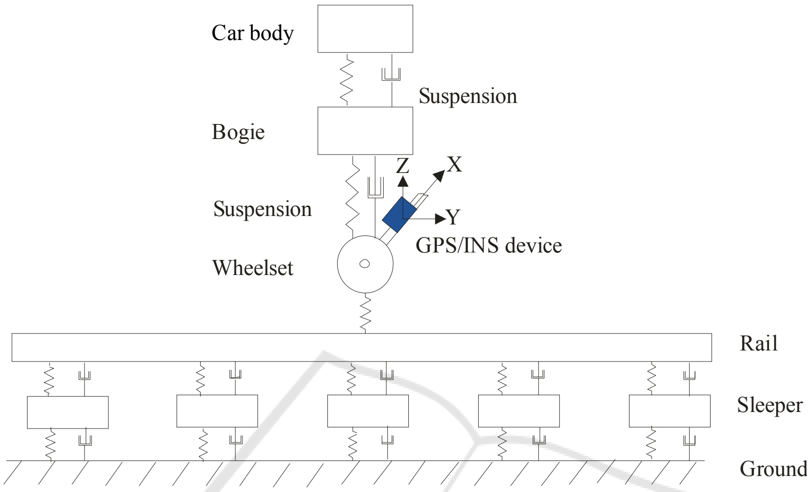

Fig. 1. Measuring system details.

The dynamics of the railway – locomotive interaction in the vertical direction may be explained with the mathematical model shown at Fig.1. The frequency distribution of the acceleration data vary from one axis to another. The maximum frequency of the vertical and lateral fluctuations is limited from 0.5 to 1Hz. In the same time the railway faults generate vibrations with a maximum frequency up to 2000Hz.

The force/translation (F/y) relation is described according to the equation:

$$F = c_h . y^{\frac{3}{2}} \quad (1)$$

The connection between the wheel and the railroad is very tight, so the wheel translation repeats the railway faults. If the railway quality is very good, the system vibrations are provoked by the non – parallel rail position or rail defects.

The proposed system measures the accelerations of all three axes. The acceleration data are recorded with the GPS navigation data as a data block per 1 second. One data block contains 40 inertial data and 1 GPS message, so the time distance between the inertial samples are defined as 0.025s. The traveled distance for each data block is defined as follows:

$$\Delta\lambda_{мин} \geq 2.\Delta t.v \quad (2)$$

where $\Delta\lambda_{мин}$ - traveled distance, Δt – time interval and v - vehicle speed. If the maximum speed is limited to 60km/h, the traveled distance is equal to $\Delta\lambda_{мин}$ = 0.833m.

The normative standards define the lateral acceleration maximum value. For Bulgarian railway this value is set to 0.85m/s^2. The maximum longitudinal acceleration varies according to the vehicle speed, but its maximum value is set to 0.6m/s^2. Esveld [8] defines the safety maximum accelerations of the French railway company SNCF. These values are summarized at Table 1.

Table 1.

Transverse cart acceleration	6 m/s^2	Vehicle speed V<350 km/h
Transverse crate acceleration	2.5 m/s^2	
Vertical crate acceleration	3 m/s^2	

These values may be used as recommended maximum values for inertial data analysis.

3 Experimentation Results

The experiment is implemented for ten days while the test vehicle is driven on the same route. The navigation and inertial data are recorded on MMC/SD memory card and are simultaneously transmitted to the map server via GPRS network. Furthermore the data are analyzed using MATLAB software tools.

The developed software tool allows to select the desired maximum acceleration limit and to find the places where the previously defined limit is overcome. This choice is made through GUI (Graphic User Interface) menu (Fig.2).

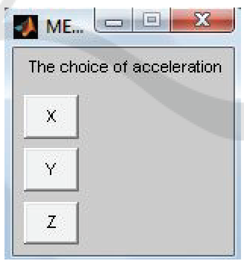

Fig. 2. Graphic User Interface menu.

The MATLAB tool also allows to select one or more days using alternative menu (Fig.3).

Fig. 3. Alternative menu.

The basic criterion of the railway faults is based on the number of acceleration values which overcome the selected maximum value. The analyzed railway length is set to 80m. The distribution of the number of points where the acceleration exceeds the limit is shown at Fig.4 (analyzed acceleration – X axis, maximum acceleration - 0.4m/s^2).

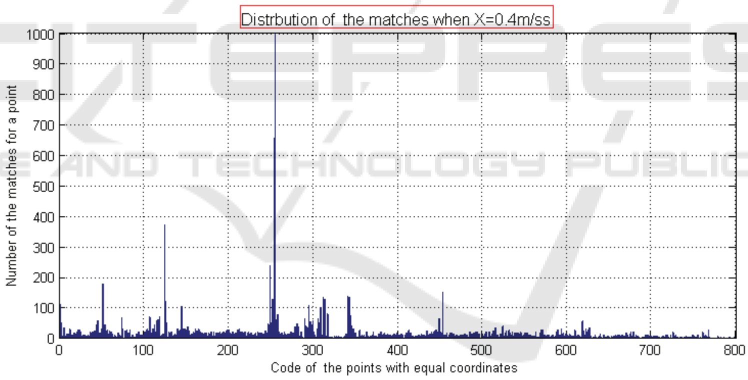

Fig. 4.

Figure 5 also represents the number of points with exceeded acceleration on 3D map. At this figure the latitude and longitude regions are divided to 100 bars to create 3D map.

When the points of interest are determined the tool may print that points which acceleration exceeds a given number. Figure 6 represents such distribution when the number of points of interest for some region exceeds the limit of 110 coincidences.

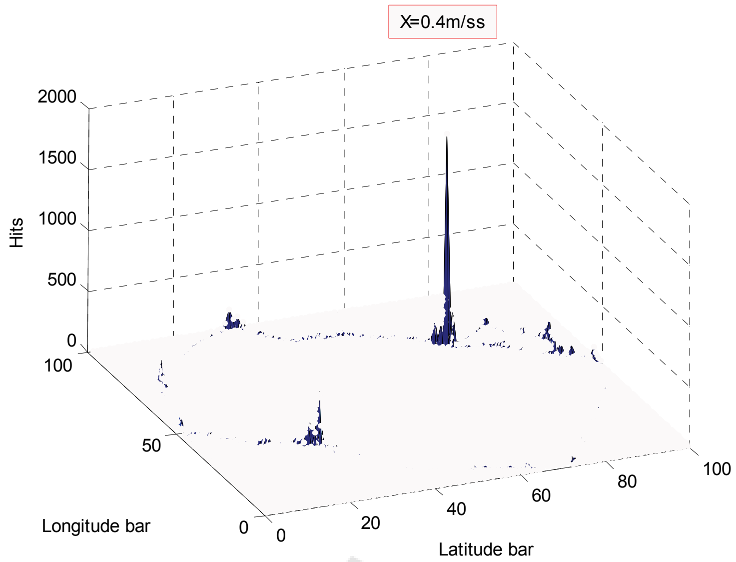

Fig. 5.

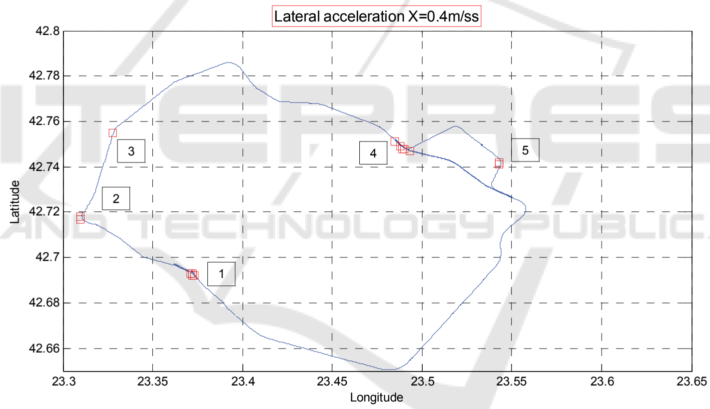

Fig. 6.

The Z axis is also analyzed to specify the railroad condition. The limitation value is set to $4m/s^2$ and the obtained distribution of Z accelerations which exceed the selected limit is shown at Figure 7.

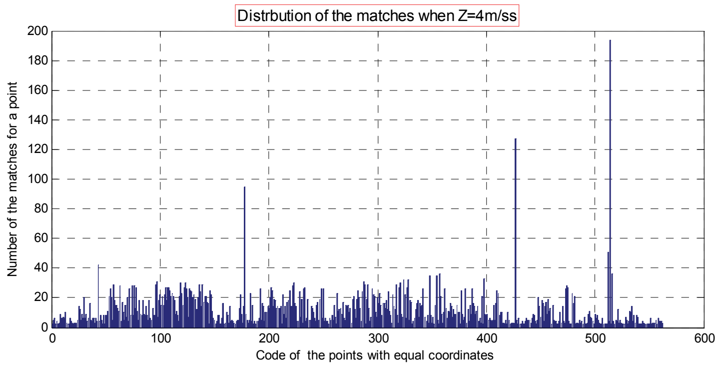

Fig. 7.

The same distribution with shown latitude and longitude bars in 3D graphic is shown at Figure 8. At this figure the longitude and latitude regions are also divided to 100 bars.

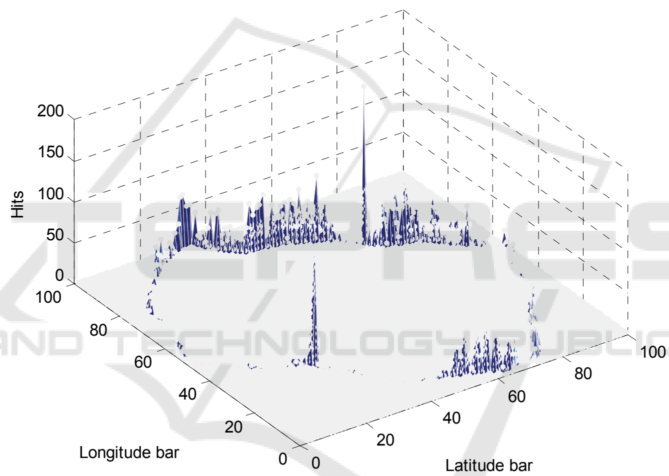

Fig. 8.

The limit number of matched points is set to 45 and the number of points of interest are estimated from Figure 7 and their position are shown at Figure 9.

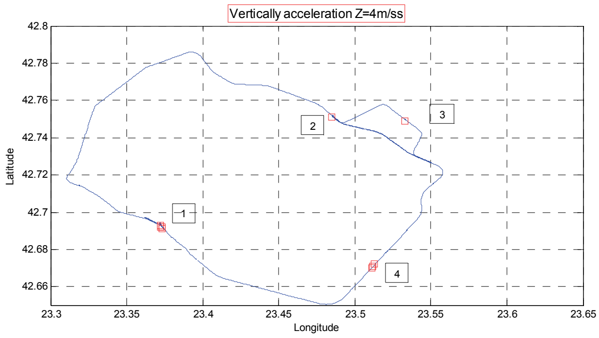

Fig. 9.

4 Conclusions

The proposed “test vehicle” system may be used for preliminary test of the railroad state to increase the safety level of the railways. As the system is permanently installed on the locomotive, it constantly gives the actual information and may warning for railway problems in a real time via GPRS network. When such condition is found, the railway company may use standard measurement tools to establish the real railroad state to increase the safety level.

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