THE EXPERIMENTAL ANALYSIS OF THE MEANDERING PHENOMENON GENERATED AT A RAILWAY WAGON

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Abstract: *During running, the railway vehicles are subjected to external excitation generating vibrations. These vibrations have a negative impact on the quality of travel, can endanger road safety. Vertical and transverse unevenness of the track and its discontinuities are the main source of vibration from railway vehicles. Another source of vibration is the rolling stock defects such as eccentricity and flatness tread. At the above are added increased speed of movement and increased payload, elements which have imposed the need to describe in a more rigorous way the complex phenomena that occur at the interaction vehicle-runway, vehicle response to irregularities path, implications in improving vehicle stability and comfort.*

Mathematical modeling by random processes of the excitation induced by the path irregularities and dynamic response generated by the vehicle in motion, allows a more accurate description of the interdependence between vehicle vibration and statistical, also spectral properties of path irregularities. This method was used in the dynamics of railway vehicles in the last period, being facilitated by the expansion theory of random vibration and the continuous improvement of equipment, methods of measurement and analysis vibrating mesh that occur in the process of rolling. In the present study we analyzed the phenomenon experimentally. The experimental analysis is based on measuring and machining vibrations measured on a railway wagon by a research team from the Institute of Solid Mechanics.

Keywords: *vibration, railway vehicle, meandering movement, numerical processing*

1. INTRODUCTION

Currently still a significant part of goods and passengers traffic from Europe is carried by rail. The rail system already provides solutions for the transport all over the world, in terms of safety, environment, total journey time, low emissions and low energy. It has the potential to offer attractive urban, regional and long distance mobility [8].

Innovation resulting from technology added value is steadily contributing to strengthen all market segments and their seamless connections, as well as contributes to environmental efficiency, security and safety, and intelligent mobility. The impact of today's rail technology in high-speed is outpacing the increase in aviation for journeys; high-speed trains are therefore the preferred passenger choice for journeys of this distance [8,9]. Intensive development of modern technology and increase goods traffic and speed of travel, the increased noise and vibration level and specific rail transport while traveling. Noise generated during train movements acting adversely on passengers, service personnel and the population in areas crossed by rail.

In addition, intense noise makes it hard to distinguish the sound signals and verbal commands and thereby worsening security conditions rail transport. Railway equipment presents a number of specific issues in terms of shock and vibration, as few vehicles that run on a runway apparently so smooth [9].

Shocks and vibrations from vehicles by rail can occur due to variable speed drive, the game at the ends of the rails, bumps, curves and elasticity ways, taper, eccentricity and deviations from appropriate form of bandages guidance rock rolling on the rail by wheel flange, jerk during braking maneuver and wantonness. The suspension system rolling stock is intended to cushion the shock and vibration, reducing them to acceptable levels [1-3]. Sources of noise and vibration from railway vehicles can be external or internal. The most important sources of noise and vibration are running outside wheel itself, suspension systems and coupling elements, the action of air on the outer walls wagon braking action etc [7]. Rolling noise is produced by all elements in direct contact when running the rails and metal wheels with their bandages [3].

If the suspension chassis is not effective enough, it is possible that the entire steel structure of the wagon to come into vibration. Stoppages and changes speed, the various couplings can become new sources of noise and vibration. Air action against the walls of the wagon produces aerodynamic noise, particularly those giving birth at the front walls and protruding parts of the wagon. Sources of noise and vibrations occur particularly inside the railcars. These sources are the main internal combustion engines, power generators, air compressor and transmission systems (FIG. 1).

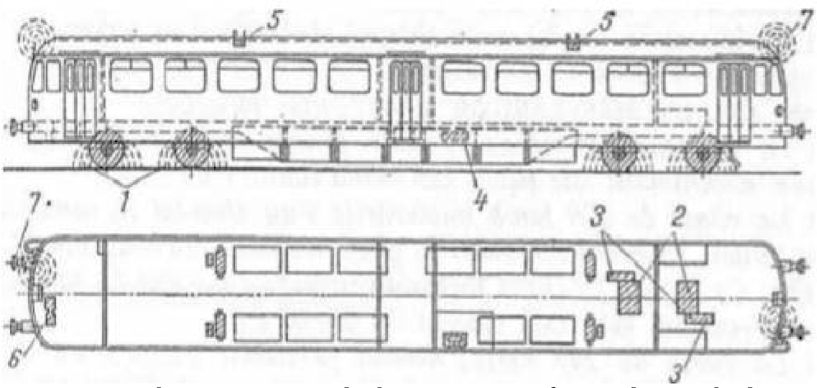

FIG. 1. The main noise and vibration sources for a railway vehicle
1 - rolling and suspension systems; 2 - driving motors; 3 - reducers; 4 - transformator; 5 - exhaust; 6 - air compressor; 7 - horn.
(source: documents.tips/zgomotul-si-vibratiile-la-mijloacele-de-transport-rutier.html)

Noise transmission outside to the inside of the wagon is done in three ways: by air - ventilation channels or other holes and leaks (air noise); the wagon structure as vibration (sound structure of the wagon) and acoustic waves by the action on the dividers exterior of the wagon. Railway wagons required as the noise level in compartments to be as small and yet not be an adjacent track, to avoid disturbing residents concerned. The first problem could be solved largely in the last 15 years, based on systematic research, the constructive nature in various parts of wagons as floors, walls and windows. As normative for new wagons at average speeds of 80 km/h are taken into consideration following noise levels: fast trains 55 dB(A), fast trains 60 dB(A), and 75 dB(A) in tunnels. To double the speed of movement, the noise level increases inside the wagons around 6 dB(A), so the cars fast trains that develops a speed of 200 km/h consider a noise level of 62 dB(A) [10]. On the other hand vertical and transverse unevenness of the track and its discontinuities are the main source of vibration from railway vehicles. Another source of vibration is the rolling stock defects such as eccentricity and flatness tread [11].

Also, due to constructive peculiarities of railway vehicles can generate and support vibrations on the vehicle. The increase in velocity and increased payload imposed also need to describe in a more rigorous way of complex phenomena that occur at the interaction vehicle-runway, vehicle response to irregularities path, with implications for improving vehicle stability and hence the comfort of passengers [5,6].

Modeling processes induced irregularities random excitation path and the vehicle dynamic response allows a more precise description of the interdependence between vehicle vibration and statistical and spectral properties of irregularity path [2].

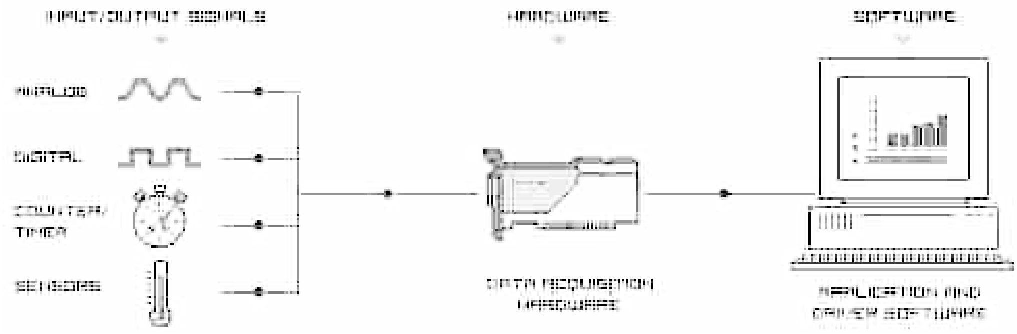

FIG. 2. A system of measurement, acquisition and processing of vibration signals (source: home.hit.no/~hansha/documents/industrial_it_automation.htm)

This method has been increasingly used in vehicle dynamics railway last time, being facilitated by the expansion theory of random vibration and the continuous improvement of equipment, methods of measurement and vibration analysis of low frequency (as presented in FIG. 2) that appear in the tread [4].

2. EXPERIMENTAL ANALYSIS FOR THE MEANDERING MOVEMENT

2.1 Issues concerning realization of vibration records. For experimental analysis of the vibrations have been recorded simultaneously on the magnetic tape acceleration of vibration to the different components of the vehicle at the three levels of interest, the container, bogie and axle of the vehicle in three orthogonal directions. On an additional channel were recorded simultaneously throughout the record, comments on the specific conditions of their time, and details regarding the parameters used.

In FIG. 3 transducer arrangement can be distinguished on the three masses vibrant and measuring system components consisting of transducers T, preamplifiers load and visualization devices and data storage, a tape recorder and a digital oscilloscope.

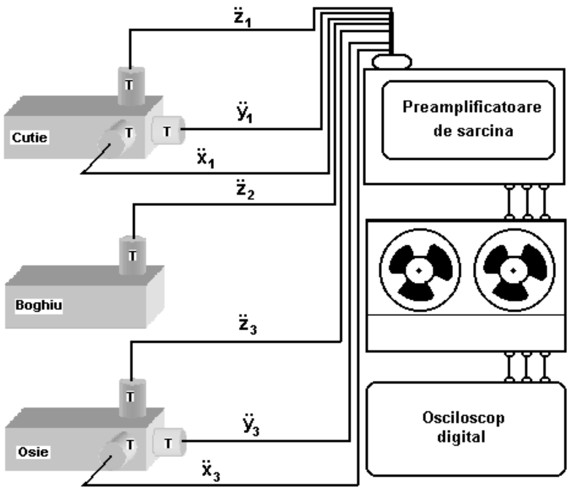

FIG. 3. Measurement scheme of vibration records

The transducers "T" are the type piezoelectric vibrating elements are mounted properly. Before recording, signals were amplified, thus achieving a coarse filter. As I stated earlier, to record and store data has been used a tape Bruel & Kjaer, every time there were three parallel acceleration, one of the channels recording was used for additional comments on rates and the areas where measurements were made. Fluke digital oscilloscope type of measurements used to monitor and ensure their accuracy. For further study in specialized programs is necessary analog-digital conversion of these accelerations. Either $t_1 = 0,\ t_2, ...,\ t_N = T,\ \ t_k = (k-1)h;\ \ k = 1,\ 2, ...,\ N$ set of digitized data that are obtained by analog-digital conversion and established a sampling step h. This raises problems because too small a sampling step involves a heavy workload both for data collection and numerical processing them.

On the other hand, a step too large sampling results in an interference between low frequency components and high frequency in the analyzed signal which is a great source of errors in determining the spectral densities of data studied. Since at least two samples are needed in order to define a cycle frequency component of signal analysis that the highest frequency that can be highlighted using the sampling step h is called the Nyquist frequency associated sampling step considered $f_N = \dfrac{1}{2h} = \dfrac{N-1}{2T}$. The f_N components of frequencies higher than the analyzed signal will interfere with the frequencies below this frequency. To avoid interference errors there are two methods. The first method is to choose a step sampling small enough so that it is physically impossible analyzed signals contain frequencies higher than the Nyquist frequency associated and it is recommended that this frequency to choose one and a half to two times higher than the frequency of the anticipated maximum, and the second method is the use of low pass filters before they are sampled so that frequencies beyond the range of interest should not be included in the analyzed signal in this case can be chosen f_N equal to the maximum frequency interest.

Whether $u(t)$ a signal measured under the conditions above. Since the frequency range of interest is up to 100 Hz, then consider imposing a sufficient $f = 200\,\text{Hz}$ sampling frequency resulting in a $\Delta t = 0{,}005\,\text{s}$ sampling time to provision and this frequency. And the sampling period $T = 60\,\text{s}$ meaning that the average speed of the train $V = 138\,\text{km/h}$ is the length of the sampling $L = 2{,}3\,\text{km}$. The signals were converted into numerical data using a data acquisition boards National Instruments BNC-2120 and stored in the computer.

2.2 Rail vehicle dynamics problems analyzed the records of vibration at high speeds. Based on measurements of vibration described above can be highlighted a number of important issues for railway vehicle dynamics. The expressions presented below summarizes the main problems that can be studied by processing of vibration measurements performed:

- $\ddot{z}_1, \ddot{z}_2, \ddot{z}_3 \Rightarrow$ Estimating the dynamic forces of the wheel-rail contact
- $\ddot{z}_1, \ddot{x}_1, \ddot{y}_1 \Rightarrow$ Estimating passenger comfort
- $\ddot{x}_3, \ddot{y}_3 \Rightarrow$ Highlighting the movement flexuosity
- $\ddot{z}_3 \Rightarrow$ Tread spectral density estimation (Spectral analysis)

Physical phenomena encountered in the operation are generally characterized by representing the amplitudes while quantities. In this way can be represented sizes and displacements, velocities, accelerations, forces, moments, pressures, temperatures, by varying amplitudes over time.

Much of the physical phenomena can be characterized by temporary diagrams showing a signal a fraction repeatability. In this case the phenomenon is called deterministic and knowing the initial parameters of the signal characterizing the phenomenon investigated, can accurately predict the size desired amplitude at one time located a temporary baseline. Through such simple graphical representation can monitor any deterministic phenomenon, knowing all the data needed to fully characterize the phenomenon studied. Also it can be said that an important part of engineering the physical phenomena of wide interest, not deterministic, ie each graphical representation of the phenomenon considered is unique, unlike any other. In this case it is impossible to say exactly where the amplitude magnitude followed at some point of time. However in this case we can say with sufficient precision, after studying the phenomenon closely, the signal sought does not exceed a certain amplitude but is found behind many records that are within this range, but it is impossible to specify where does to the time it is within that range limitation. Going a little further, you can even make laws which bind the membership and the recorded signal distribution within the range of amplitude. This seemingly illogical expounds allure of a random signal and sets a number of parameters and signal characteristics. For statistical analysis of these signals characterizing the accelerations measured on a railway vehicle that random processes, it took several simplifying assumptions. Thus to reduce the volume of records for characterization widest possible these random processes and thus to reduce the workload required of this operation, it was considered that these signals are of ergodic which had to be shown to reinforce the correctness work on these records that were put under analysis. Data from the measurements are processed in the original program and provides statistical information on the characteristics of these signals, and actual calculations were made in Excel. The repetition of these measurements may also provide statistical information time course of any type of new or existing rail vehicle in operation. One can appreciate the degradation of structures such as vehicles, finding and how it degrades by discovering the causes that produce degradation.

3. NUMERICAL PROCESSING OF RECORDS. RESULTS AND DISCUTIONS

This section illustrates methods of numerical processing carried out simultaneously records of vibration in the vertical direction, the transverse and longitudinal with a triaxial accelerometer mounted on the outer axle grease. By processing these records can reveal flexuosity movement characterized both time domain and frequency. Figures 4, 5 and 6 contains samples of acceleration records made on 3 directions.

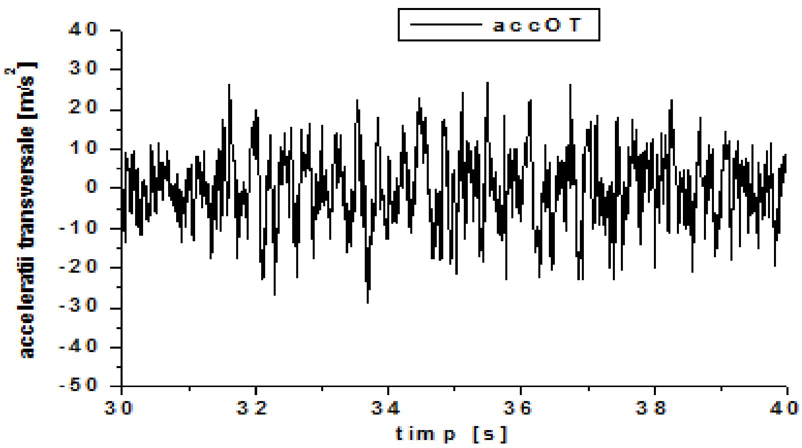

FIG. 4. Samples of records accelerations measured in the transverse direction

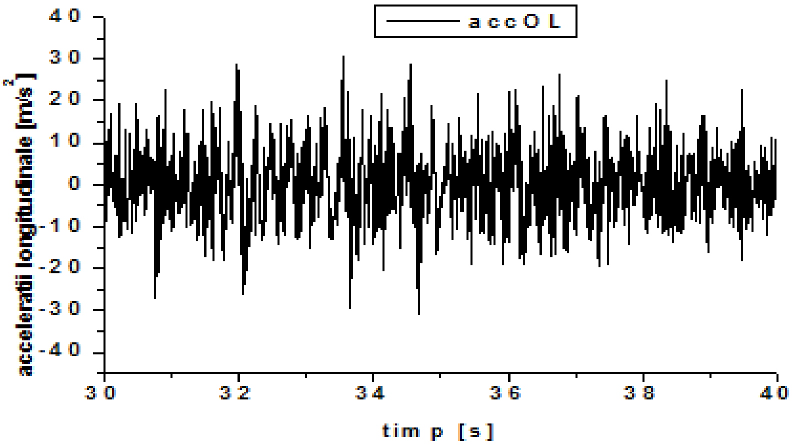

FIG. 5. Samples of records accelerations measured in the longitudinal direction

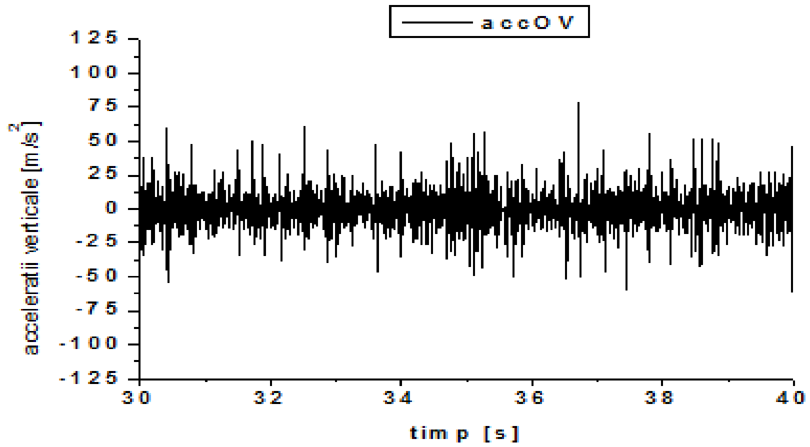

FIG. 6. Samples of records accelerations measured in the vertical direction

Following the calculations were obtained the following correlation coefficients r_{TL} =0.3, r_{TV} = -0.014 and r_{VL} = -0.033. It is noted transverse and longitudinal accelerations That is correlated in a statistically much better than in the horizontal direction Those recorded vertical to the recorded ones.

The F = 3.2Hz frequency is found in the transverse accelerations amplitude spectra (FIG. 7) and longitudinal filtered (FIG. 8), which does not happen if the amplitude spectrum of vertical accelerations filtered (FIG. 9).

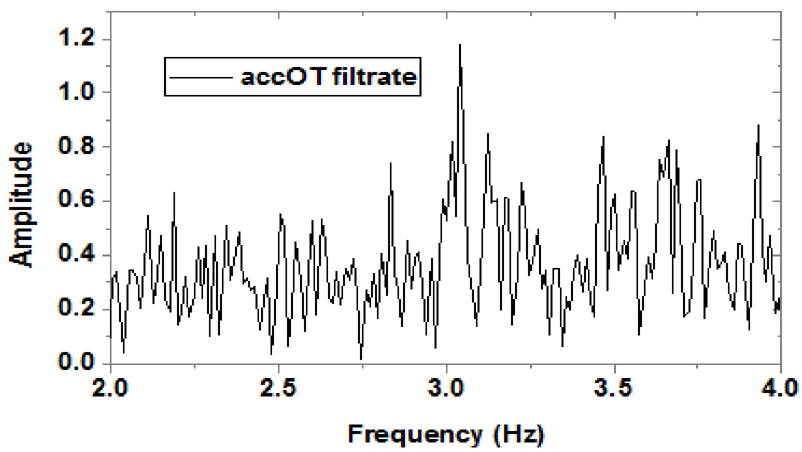

FIG. 7. The spectrum of amplitude transverse accelerations filtered

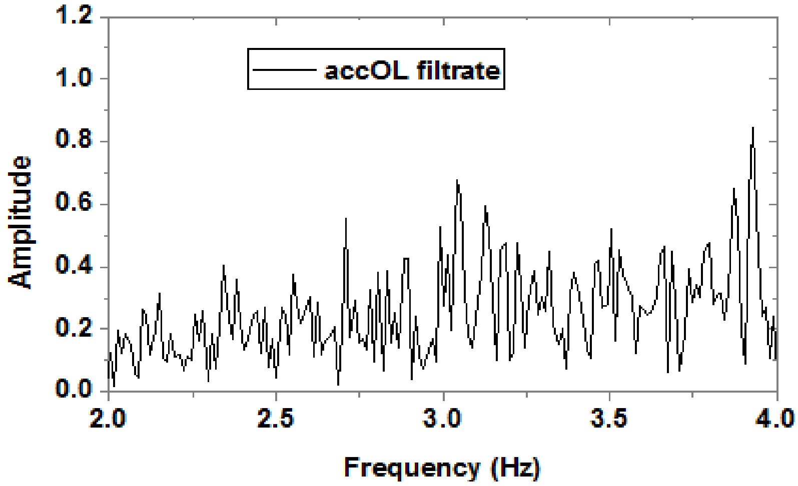

FIG. 8. The spectrum of amplitude longitudinal accelerations filtered

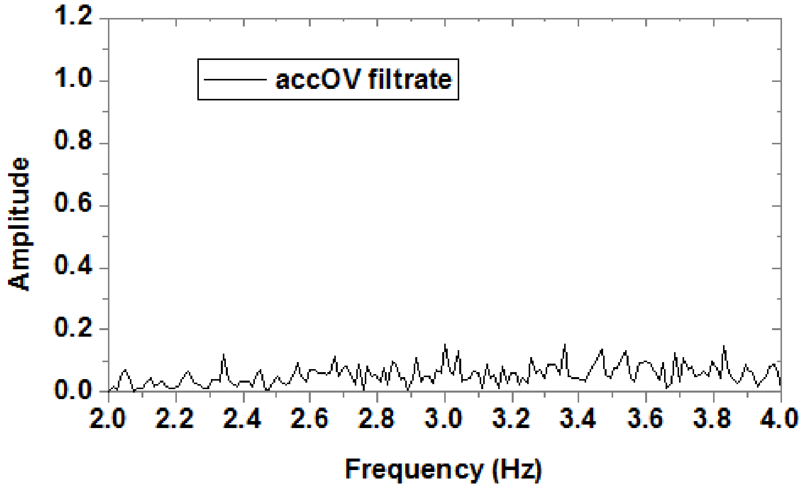

FIG. 9. The spectrum of amplitude vertical accelerations filtered

The values of these correlation coefficients show that transverse and longitudinal accelerations are strongly correlated filtered, while their correlation with vertical accelerations filtered is much weaker, what underlines once again that the movement analyzed in the frequency range 2-4 Hz is movement corresponds flat as meandering phenomenon.

CONCLUSIONS

Simultaneous measurement in three directions (x-longitudinal, y-transversal and z-vertical) of the accelerations at the box axle grease, can provide useful information for highlighting the phenomenon presented. This type of measurement is virtually the only possible real operating conditions since the use of other types of sensors such as travel or gear is not feasible. It is recommended piezoelectric acceleration transducer given that are robust and have a reduced size.

Methods of processing acceleration signals recorded and processed in this paper can reveal flexuosity movement. By determining the amplitude of signals recorded spectra can specify the frequency of occurrence as hunting movement.

By filtering signals in this frequency range it appears clearly as hunting movement, one can determine the dominant frequency sufficiently precise as hunting movement velocity corresponding to the entries that were made. Method correlation coefficients between measured accelerations in three directions applied for both signals unfiltered and filtered signals especially highlights the strong correlation of acceleration horizontally and poor correlation between them and vertical.

Numerical processing of experimental data is very necessary because the study is done on real situations, that vehicle is studied under realistic conditions, and the results easily contain useful information about both the vehicle studied and about raceway on moving such a vehicle. In case if instead of using a tape recorder and oscilloscope measurement laptop scheme is greatly reduced, the data are digital data processing can be instantaneous. In this way the measurement results can be obtained quickly, reducing working time user. So someday you can check a large number of vehicles and can count the integrity of any vehicle or track on which it runs. The statistical data in a database, obtained by successive measurements over time may provide important information about the sub-assemblies to the vehicle.

For a larger number of vehicles can see which parts fail in a shorter time and the causes of their deterioration, upgrades subsequent vehicle may consist of simple replacement of subassemblies old with new, redesigned that appropriate conduct all claims arising in operation.

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