MINISTRY OF EDUCATION

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Doctoral School of Mechanics and Mechatronics

Contributions regarding the analysis of the dynamic behavior of wagons intended for rail freight transport

SUMMARY

THESIS

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Content

Introduction

The importance of studying the dynamic behavior of a wagon in a curve

Give the current context regarding global warming, the creation of non-polluting modes of transport and rail traffic has regained the attention of local and international authorities. The rail transport can present advantages. Low energy consumption, transportation of large volumes, and low "CO2" emissions place this transport option at the top of the list when it comes to long-distance road transport.

In order for rail transport to be cost-effective, it must provide safety and commercial speed. In the case of a railway incident, the material damages are much higher than in the case of a car incident. Consequently, research and studies on traffic safety provide very important data and solutions from an economic point of view.

Thus, before the railway vehicles are put into circulation, they must go through a process of carefully studied tests and simulations in order to receive the approval of the characteristics of dynamic behavior and static tests [1].

The goal of these tests is to quantify vehicle performance under known representative operating and infrastructure conditions.

Vibrations influence passenger comfort, cargo integrity, and traffic safety. The ride quality of railway vehicles is influenced by the vibrations that occur in all freight or passenger cars [2, 3].

Irregularities in the running surfaces of rails and wheels are the main factors that cause vibrations to occur [4, 5].

When it comes to rails, there are deviations from the geometric shape of the track, irregularities on the running surface and discontinuities of the rail. The items mentioned above are the main causes that generate vibrations [6].

In order to study the vibrations, the theoretical version and the experimental version are adopted. Upon completion, the results obtained by the two methods are compared [7].

The complex oscillating system has specific vibration characteristics to the railway vehicle [8].

For the experimental version, in this case a tank wagon, the railway vehicle is equipped with sensors connected to a locomotive and tested on a railway ring under operating conditions. The data obtained has been processed and analyzed.

For the theoretical version, there are several programs ("Matlab", "Simulyng", "Ansys") that, based on the numerical model created, develop theoretical graphs for the vibration values. In order for the simulation to be as close as possible to reality, an equivalent mechanical model made up of rigid masses must be created and linked together by massless elastic and damping elements. The reality will be closer to the results if the mechanical model is more complex. The more complex the mechanical model, the more difficult it is to formulate general conclusions.

In order to obtain useful information, it is advisable to adopt a less complex model. For efficiency in railway vehicles, a mechanical model includes the suspended mass of the bogie and the mass of the vehicle box linked together by elastic and damping elements. Although numerical simulations are important, they cannot be considered without experimentally obtained data [9, 10].

Studies based on numerical simulations or measured data have shown that the vehicle's dynamic response is correlated with path irregularities [4, 5], which creates the premises to develop certain methods for monitoring the path quality or the condition of the vehicle [1, 12]. Was used the correlation method to highlight the connection between the vertical and lateral axle box acceleration and the track geometry parameters processed differently based on a measurement run on a curve line [4]. The correlation between the rail weld geometry and high-frequency vibrations of the axle box acceleration and was used to develop an approach for real-time health detection of rail. Based on the Pearson correlation coefficient, the results of the numerical simulations were used for an analysis regarding the correlation between the vertical irregular track and the dynamic response of a two-axle bogie [5].

This paper presents an analysis of the vertical vibration of two bogies in a railway freight vehicle both empty and loaded based on the experimental results obtained through measurements made while in motion on an experimental track in a curve. In fact, the RMS (root mean square) acceleration is looked at and measured on the two bogies frame above the axles for several measurement sequences at constant speed. In addition, the spectral analysis of the measured acceleration helps to identify a series of defects in the running surfaces of the wheels and rail.

In the case of putting into production a new wagon, it must be tried and tested from all points of view. The wagon is subjected to static tests and dynamic tests.

The tests are established by the SR EN 14363-A1:2019 standard [1].

Chapter 1

The current state of research on rolling stock ride quality

The interaction wheel-to-rail is a specific issue for railway transportation means, regarding wear, fault anticipation, comfort, and safety. All of them are highly documented in the literature [1, 11, 12], more often after the speed was increased on the railway.

The wheel-to-rail interaction is the subject of [13], where an investigation of the dynamic effects of a wheel running on a discretely supported rail was investigated [14]. The suspension of the wagon is analyzed and optimized using dedicated models [15] and implementing the simulations [16-19] for the optimization of the bogie frames and suspension, as testing them must be performed after the results of the calculations are validated at safe speeds. Measuring the vibrations induced in the car body by the track unevenness [21] is performed using accelerometers mounted on the car body, analyzing the amplitude of the acceleration and the frequency of the signal. In [14] is presented a numerical analysis re- garding the correlation between the dynamic response of a bogie and the displacements of the axles during circulation on a track with vertical irregularities, in a harmonic behav- ior of vibration, a method which can be used to diagnose the faulty dumpers of the sus- pension. The higher levels of acceleration can be measured by placing an acceleration sensor on the axle box [21], the operation is intended to measure the efforts on the axle and bearings. The paper [4] is analyzing the correlation between axle box accelerations in lateral and vertical directions, and differently processed track geometry parameters based on an accurate measurement run on a straight track. The electronic sensors used for acceleration measuring can be of the piezoelectric Mechanical (MEMs) technology, a sensor that eliminates the need for selection, qualifica- tion, and system-level integration of discrete devices. The study [15] investigates the development of a nanocomposite that can exhibit both piezoelectric and magnetic effects in terms of sensing and actuation, respectively. The application of acceleration sensors in the measurement of the track irregularities is presented in [16], focused on an irregularity probabilistic model that lays the foundation for stochastic and probabilistic analysis of vehicle/track systems. A similar approach of using acceleration sensors on axle boxes is presented in [17], where there is a comparison between irregularities provided by rail joints and welded rail. A similar method was used in [18], regarding the correlation between vehicle responses and track irregularities using dynamic simulations and measurements. The localization of the track irregularities is presented in [19], by using the time and distance measurements. Some works [20] are focused on the modeling of the railway vehicle suspension components, which are key components for the passenger's comfort. In [21] there are measurements of track irregularities presented in graphs related to distance, with a precision of 3-25m, for a locomotive and a passenger coach, aiming to use the same data recorded for all the vehicles, as being correlated. The development of a numerical model for railway vehicle's comfort assessment through comparison with experimental measurements [22] is presenting a solution in which they compare the measurements alongside the car body and states that the values read near the bogies are close to the real ones, while the sensors placed in the middle of the vehicle are subject to noise by adding the influences of both bogies. An interesting article [23] is presenting an experiment with some low-cost sensors placed alongside a train and which we're collecting data from 9 sensors to calibrate the information they provided, and to evaluate the comfort of the passengers using the RMS average value for the acceleration. The present paper will present in subchapter 2 the experimental setup for collecting acceleration information from one tank wagon, unloaded and loaded, performed on an ellipsoid track, part of the test facility located at Faurei, Romania. Data collected were presented in subchapter 3, and analyzed to detect that the values are correct and to decide whether the acceleration measured on the car body is clear and how relevant the values are for characterizing the comfort of the passengers. The last part of the paper is dedicated to the discussions and conclusion section regarding the comfort estimation using onboard acceleration sensors.

Prior to the entry into service of rolling stock, it shall undergo a process of testing and simulation for the type-approval of dynamic performance and static testing. [1]

The aim is to quantify the vehicle's performance under known representative operating and infrastructure conditions. All new or modified vehicles must be checked for their dynamic characteristics to assess the driving safety, the on-line load and the driving quality of the vehicle. An assessment may be made for the initial approval of the vehicle type or for an extension of the approval [1].

The quality of travel in railway vehicles is influenced by the vibrations that occur in all freight or passenger cars. Vibrations affect passenger comfort, cargo integrity and traffic safety [2].

The main factors that cause the vibrations are the irregularities of the running surfaces of the rails and wheels. Relative to rails we have deviations from the geometric shape of the track, irregularities of the tread and the discontinuities of the rail. The listed problems are the most important causes of vibration.

In case of irregularities in the tread, we have wheel defects: flat wheel, oval, eccentricities, flat wheel, polygonal profile [22].

In order to study the vibrations, the theoretical version and the experimental version are adopted. Upon completion, the results obtained by the two methods are compared. [21]

For the experimental version, in this case a tank wagon, the railway vehicle is equipped with sensors connected to a locomotive and tested on a railway ring under operating conditions. The data obtained has been analyzed put in correlation and processed.

For the theoretical version, there are several programs ("Matlab", "Simulyng", "Ansys") that, based on the numerical model created, develop theoretical graphs for the vibration values. In order for the simulation to be as close as possible to reality, an equivalent mechanical model made up of rigid masses must be created and linked together by massless elastic and damping elements. The reality will be closer to the results if the mechanical model is more complex. The more complex the mechanical model, the more difficult it is to formulate general conclusions. [22 –24]

In order to obtain useful information, it is advisable to adopt a less complex model. For efficiency in railway vehicles, a mechanical model includes the suspended mass of the bogie and the mass of the vehicle box linked together by elastic and damping elements. Although numerical simulations are important, they cannot be considered without experimentally obtained data. [11, 12]

The wagon is subjected to static and dynamic tests.

The standard SR EN 14363-A1: 2019 establishes the tests and simulations for the approval of the wagon.

This article presents the study of vibrations on the y-axis, in the curve, measured on a tank car.

This paper presents the analysis of transverse vibrations (on the y-axis) of a tank car, based on the recorded results, on a curved railway, at variable speeds, loaded and empty. In fact, the RMS (root mean square) acceleration is recorded on the axles of the first bogie and on the 2 bogies of the wagon, in the case of the empty and loaded wagon, for several measurement sequences at a constant speed. The spectral analysis of the RMS leads to the identification of the constructive defects of the wagon as well as the ability of the wagon to pass over the defects of the road.

Chapter 2

Directions, objectives and research - development methods of the doctoral thesis

2.1. The actuality of the doctoral thesis

The actuality of the doctoral thesis results from the conditions imposed by the safety of traffic in the railway system and the ride quality of railway vehicles.

Traffic safety and ride quality are closely related to the dynamic behavior of wagons, whether they are freight or passenger.

From the perspective of increasing traffic speeds in the single European railway space, both for freight and passenger traffic, the real-time analysis and continuous evaluation of the dynamic behavior of the wagons acquires particular importance from the point of view of the technical evaluation of the wagons , as well as from the point of view of the technical evaluation of the running infrastructure.

The policy of the European Union for the development of railway transport provides for the achievement of speeds of 140 km/h - 160 km/h, in alignment and landing for freight traffic, 160 km/h - 180 km/h for regional passenger traffic and 250 km/h – 260 km/h for interregional passenger traffic.

The present work aims to show that there is a close correlation between the dynamic behavior of the wagon and its technical condition, respectively the technical condition of the running infrastructure, being able to follow the evolution of defects over time and even pinpoint non-conformities/defects in the running track .

The further development of universal devices, which can be mounted on any wagon and which will allow the technical evaluation of the wagon-track assembly, will ensure the efficiency of the preventive maintenance process, with effects in reducing operating costs and increasing traffic safety by eliminating events railway determined by this type of non-conformities.

2.2. Research - development directions

Since rail transport is the most optimal and efficient land transport alternative, following the increase in the volume of rail transport, the aim is to increase the safety, security and comfort of passengers, respectively the safety and integrity of goods. From this perspective, the research and development directions identified are:

D1: Increasing traffic safety.

D2: Reducing maintenance costs of rolling stock and rolling stock infrastructure, by applying preventive maintenance.

D3: Efficient railway maintenance by identifying critical points in real time and not according to a set/periodic maintenance plan.

D4: Increase running speed/maintain design speed by effectively managing the causes of speed restrictions from both a wagon and track perspective.

D5: Development of a concept that links the vibrations occurring in the running system to the critical points, so as to identify track defects without additional costs.

2.3. Research - development objectives

The main objective of the thesis (Op), which derives from the research-development topic proposed for the doctoral program, is formulated as follows:

Op: Analysis of the dynamic behavior of freight wagons and the establishment of criteria / solutions / methods for observing and tracking its evolution in real time, both from the point of view of the vehicle and of the influence of the railway running infrastructure on it, to ensure safety circulation, through a process of continuous preventive evaluation.

To fulfill the main objective, the following secondary objectives (Os) were identified:

Os1: Analysis of the necessary equipment that allows the study of dynamic behavior

Os2: Analysis of optimal methods of measurement and recording of experimental data

Os3: Analysis and selection of the optimal measurement points and the type of railway vehicle intended for the experimental study.

Os4: Analysis of the characteristics of the line on which the experimental measurements are carried out

Os5: Analysis and processing of experimental data

Os6: Statistical analysis using the RMS (root mean square) method

Os7: Realization of the theoretical simulation program of the dynamic behavior of the wagon and its validation based on experimental determinations

2.4. Research - development methodology

In order to achieve the main and secondary objectives mentioned above, a research-development methodology was developed which includes the following stages:

M1: Selection and presentation of the freight car intended for the study / analysis of dynamic behavior

M2: Establishing the place chosen for carrying out the experimental measurements intended for the analysis of the dynamic behavior

M3: Analysis of the characteristics of the line on which the tests and measurements were carried out

M4: The choice of the decoding and analysis system of experimentally obtained data and their centralization

M5: Analysis of rolling dynamics of experimentally measured transverse vibrations

M6: Analysis of rolling dynamics of vertical vibrations mes

CHAPTER 3

Presentation of tank wagons for the transport of liquid products, with a metal tank,

The characteristics of the tank car analyzed in the paperThe tank wagon has 4 axles, type Zacs (with discharge under pressure) and a total capacity of 85 m^3. The construction data highlighted in fig. 2 manufactured by REVA Simeria is intended for the rail transport of light petroleum products, class 3 RID (gasoline, diesel, mineral oil), as well as other products corresponding to the tank code L4 BH

Figure 3.7 shows the tank car that is the object of the analysis of this work.

The wagon is intended for use in an outdoor temperature range between -20°C and +50°C.

Loading / filling of the tank can be done, depending on the characteristics of the transported material, through the dome (equipped with a hinged cover closed with 4 tightening screws), or through the bottom of the tank, through the drain pipe.

The cistern is emptied from the lower part through the DN 100 emptying pipe, with mechanical bilateral actuation located at the lower central part of the cistern, with the dome cover closed.

The wagon is a construction with a completely new superstructure according to EN, RID, CUU, UIC, STI 321 standards. The resulting wagon will be a wagon intended for international traffic.

The wagon's equipment, such as: complete bogie, automatic brake, buffers, traction, binding, are in accordance with EN and UIC norms.

Fig.3.7. The tank wagon with measure

Main features

the length of the wagon over the buffers – 14940 mm
chassis length – 13700 +12/0 mm
wagon wheelbase – 9400 mm
the distance over the extreme axles – 11200 mm

total capacity of the tank – 85 m3
useful capacity of the tank (according to RID) – approx. 85 m3
external diameter of the tank – 2950 mm
external length of the tank over the bottoms – 13000 +30/-30 mm
inclination of the tank towards the middle of the tank 10
calculation pressure (according to RID; for a temperature of 20oC) – 4 bar
maximum working pressure – 3 bar
hydraulic test pressure – 4 bar
calculation depression of the tank – 0.4 bar
explosion pressure check (according to TRT 006 and RID 2017) – 8.7 bar
calculation temperature according to RID +20oC
height of the axis of the pads at the level of the rail (new wagon, empty) – 1060 +5/-10 mm
height of the traction axis from the level of the rail (new wagon, empty) – 1040 +5/-10 mm
traveling speed of the wagon: loaded wagon 110 km/h empty wagon 130 km/h
the minimum radii for entering the curve: – on main lines 150 m – on garage lines

CHAPTER 4

Făurei Railway Testing Center

In the south-east of Europe, the only railway training ground is at the Făurei Railway Testing Center and belongs to the Romanian Railway Authority - AFER.
The increase in transport requirements in the last century in Romania led to the need to build a railway testing center in Romania. Against the background of the increase in towing speed, the development of transports, of tonnages towed, was made in conditions of traffic safety.
The Făurei Railway Testing Center (CTFF) is a testing ground that allows test trains to run at a speed of 200 km/h.
The CTFF was opened in 1978 and since then, almost all prototype vehicles produced in Romania have been tested there.4. Presentation of the conditions in which the experiment was done.

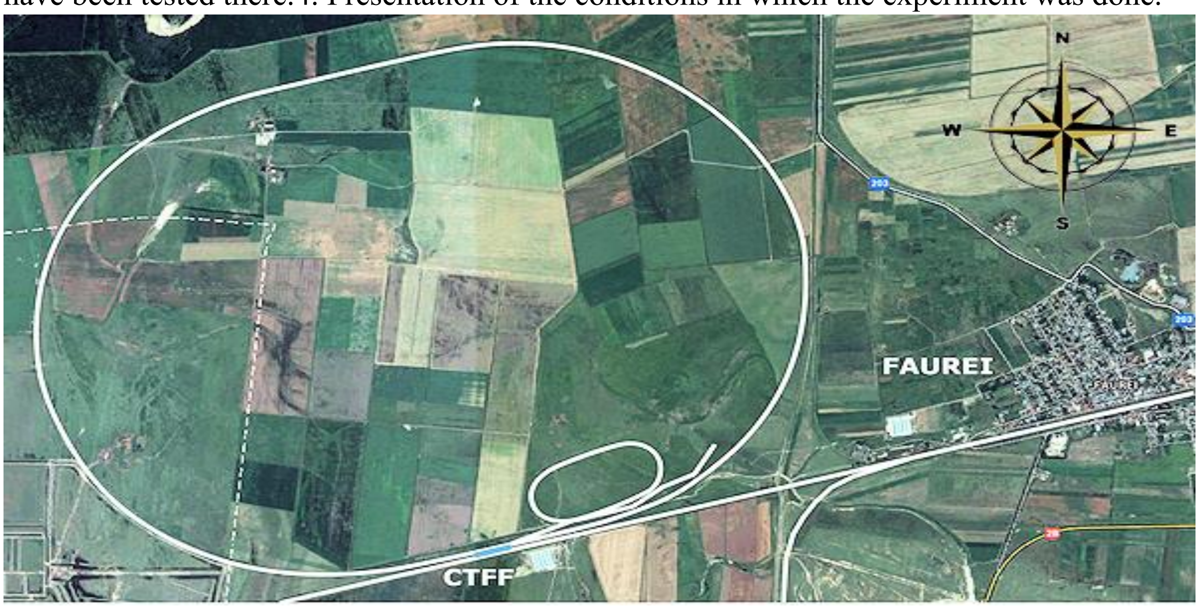


Fig.4.1. Localizarea Centrului de Testări Feroviare Făurei (imagine din Google Earth)

The technical characteristics of the line on which the measurements were made

AFER's Făurei railway testing center has a total length of 20.2 km of lines, of which:

The big ring has the following characteristics:

-length 13.709 km with 6 bridges and 4 level crossings;
-two curves with radii of 1800 m and elevations of 150 mm;
- single-phase alternating current supply of 25 kV, 50 Hz.
- the length of the alignments 1000 m and 950 m,
- maximum speed 200 km/h
- the level of the chain at 5.5 m

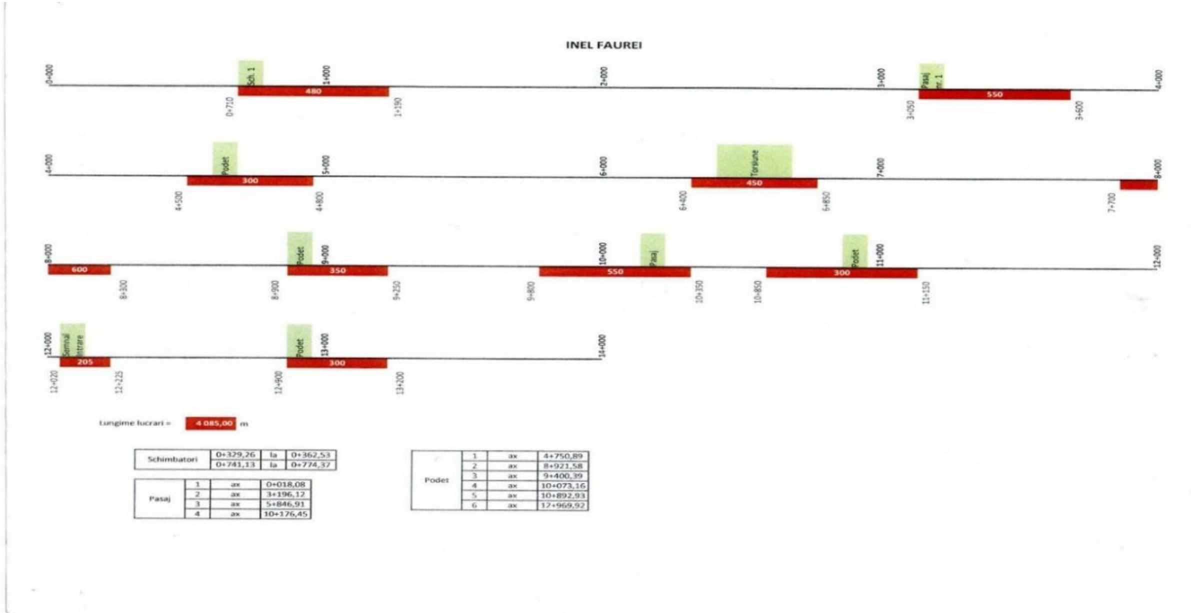
Chapter 5

Characteristics of the railway line on which the tests were carried out

5.1. General presentation of the characteristics of the line on which the records were made

The total length of the test ring at the Făurei Railway Testing Center is 13,712 km.
The rail type is 60 (kg/ml)

Fig. 5.1. General presentation of the configuration of the line from the Great Ring at CTF Făurei An overview of the configuration is in figure 5.1.



5.1. General presentation of the characteristics of the line on which the records were

Made Showing a section of the line plotting report.

Raport trasare

Interval; Inel Mare Faurei De la km: 0+000 pana la km: 13+712 Data: 04-11-2020

Racord in existent la P1-2.30m

Numar punct	Pozitie kilometrica	Geometrie proiect	Supra inaltare	Dist pichet ax (proiect)	Valori ripare(mm)	Dif. nivel proiect	Valori ridicare(mm)	Cota proiectata	Aliniam. si curbe stanga	dreapta	Declivitate de la-pana la	decliv./dist.
494	11+922.75		150		4		3	201.482				
495	11+947.63		150		7		1	201.482				
496	11+972.02		150		2		4	201.482	r=1800.055			
497	11+997.54		150		-1		6	201.482	lc=2391.694			

Fig. 5.3. The measurement report of the line from km 2 to km 5.

The above tables have the following columns:

Column 1 numbering of the points where the measurement was made

Column 2, the kilometer distance corresponding to the point where the measurement was made

Column 3 line configuration (bridge, passage...)

Column 4 overhang (being in the curve, the measured area has an overhang of 150 mm, on the outer thread)

Column 6 the value of the horizontal deviation from the projected route.

Column 8 the value of the vertical deviation from the projected route.

Column 9 projected value

Columns 10 and 11 are the graphic representation of horizontal deviations

Column 12 and 13 the graphic representation of vertical deviations

After studying the variations, a correlation is made between the time when acceleration peaks were recorded, the traffic speed and the place where the high values appear can be determined. In this way, the measures to be taken to remove the defects can be determined.

Chapter 6

Analysis of the running dynamics of the four-axle tank car

The dynamic running behavior of the tank wagon on four axles is determined and verified by obtaining some numerical values of the evaluation variables of the technical characteristics of the study wagon such as: accelerations, displacements and forces.

The dynamic running behavior of the four-axle tank car strictly refers to the interaction of the vehicle with the roadway, necessarily determining the running safety or ride quality. The determination of the aforementioned dynamic rolling behavior characteristics is done using, depending on the application procedure (partial or complete), the following quantities:

- accelerations;
- wheel-rail interaction forces;
- transverse forces between axle box and axle.

Depending on the road test conditions, the usage procedure will be:

- partial – where only certain parts of the traffic conditions and vehicle states are taken into account.
- complete – in which all traffic conditions and vehicle conditions are taken into account.

The measurement methods used are normal and simplified. In the normal method, the evaluation checks the track load, the running safety and the running quality by directly measuring the wheel-rail interaction parameters and forces (Y/Q), or the accelerations occurring at the level of the vehicle box and running gear.

In the framework of the simplified method, for the purpose of evaluation, only the quality and safety of running is checked by measuring the transverse forces in the head of the axle boxes and the accelerations occurring at the level of the vehicle chassis.

Description of measuring devices and their installation

6.1. Overview

The dynamic running characteristics of the tank car, on two axles intended for the transportation of petroleum products, were evaluated by adopting the partial procedure and the simplified measurement method in the tests. The measured parameters were:

- the vertical, respectively horizontal-transverse accelerations at the axle box of the leading wheel on the outer line of the curve

- the vertical, respectively horizontal-transverse accelerations on the wagon chassis in the axis of the wheel on the outer thread and respectively in the axis of the leading axle.

6.2. Measuring devices Placement and installation of measuring devices

"The measurement and analysis equipment for determining dynamic performances and analysis of walking quality is made up of: the system of measuring devices; software for data acquisition and experimental analysis in the frequency and time domains; analytical model with 17 degrees of freedom showing the movement of the railway vehicle."

For the thorough analysis of the dynamic interaction between the main components of the vehicle, information on the response of the mounted axle to the excitations induced by the roadway is useful. In the functional model, 6 acceleration transducers will be inserted to acquire signals from the axle and the wagon box next to the bogie. 1 and 2.

"The system for evaluating the structural strength and impact response of railway vehicles is composed of: the system of measuring devices; software for data acquisition and experimental analysis in the time and frequency domains; calibrated analytical model of a railway vehicle."

The measurement system was developed on analog input channels, which can be configured for CCLD (Constant Current Line Drive) type transducers or for direct voltage inputs.

Name	Type / Manufacturer / Characteristics	Series	Certificate
Equipment for vibration control and structural analysis composed of:	MCG Plus mechanical vibration measurement system, manufacturer Hottinger Germany, transducer type B12/200, electronic strain gauge AB – 22,	801063892	Quality Certificate EC133769 / 11.06.2017
Accelerometru	Hottinger Bruel Mecanic 1-B12/500	08521015	CE 34992/06.01.2018
Accelerometru	Hottinger Bruel Mecanic 1-B12/500	08521019	CE 35205/06.01.2018
Accelerometru	Hottinger Bruel Mecanic 1-B12/500	08521026	CE 35206/06.01.2018
Accelerometru	Hottinger Bruel Mecanic 1-B12/500	090510387	CE 35207/06.01.2018
Accelerometru	Hottinger Bruel Mecanic 1-B12/500	090510394	CE 35208/06.01.2018
Accelerometru	Hottinger Bruel Mecanic 1-B12/500	090510419	CE 35209/06.01.2018
Laptop	Toshiba08521026		

Table 6.1. The measuring devices used in the tests

Fig.6.3.The accelerator mounted on the first axle of the first Fig.6.4.The accelerator mounted on two axles of the first

bogey

6.3. Data acquisition module

"The MCG Plus mechanical vibration measurement system, manufactured by Hottinger Germany, presents an efficient solution for applications with a large number of acquisition channels and individual control of each channel. Main features are: 12 analog input channels, frequency range: DC to 25.6KHz, 65.5 kHz maximum sampling frequency, REq-X (response equalization) technology, supports TEDS transducers, interchangeable front panel.

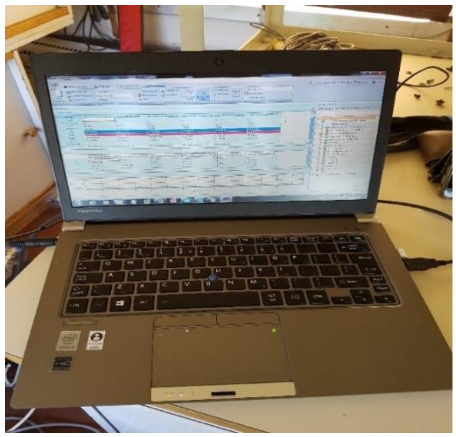


Fig. 6.1. Data acquisition mode Fig.6.2. The terminal on which it registers

"The LAN-XI 3160 A-042 generator is produced by the Bruel&Kjaer company and is a combination of a 4 analog channel acquisition module and a 2 analog channel signal generator. Main features are: 4 analog input channels, frequency range: DC to 51.2 KHz, 131 kHz maximum sampling frequency, 2 analog output channels, Dyn-X technology, REq-X technology (response equalization), supports TEDS translators."

Fig.6.3.The accelerator mounted on the first axle of the first

Fig.6.4.The accelerator mounted on two axles of the first

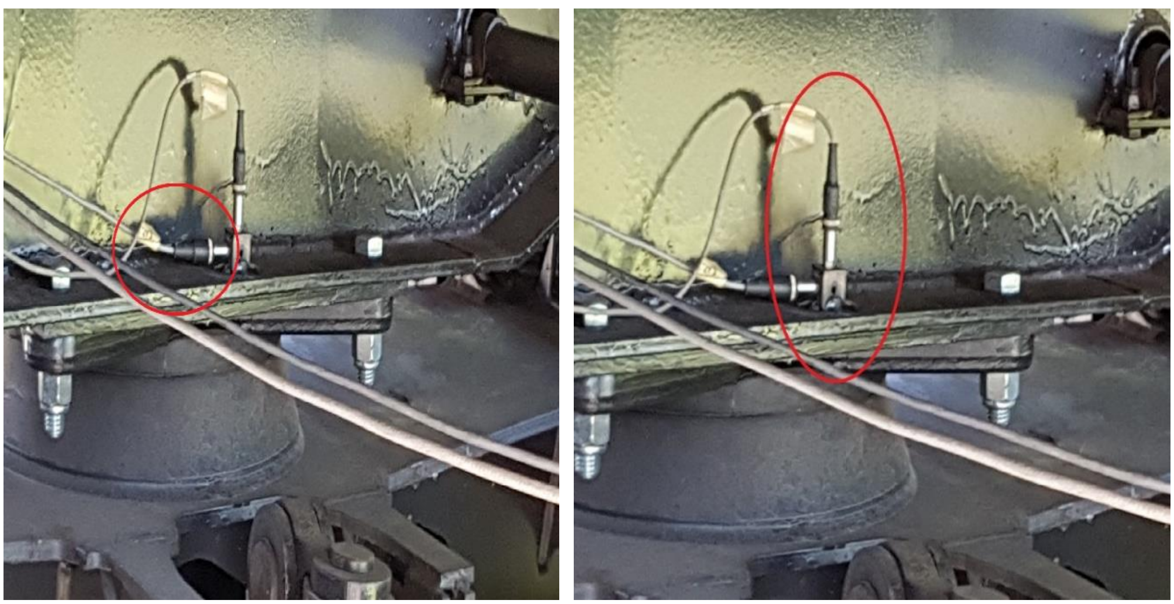


Fig.6.5 accelerometers mounted on the carbody

Accelerometer 08521019: ICP; Sensitivity: 1.02 mV/(m/s²); measuring range: ±4900 m/s² pk; frequency range (±5 %): 1 to 10000 Hz; frequency range (±5 %): 0.6 to 12000 Hz; frequency range (±ddB): 0.3 to 17000 Hz; resonance frequency: ≥35 kHz; resolution: 0.005 m/s² rms; non-linearity; ≤1%; meal: 10 gm.

Hereinafter referred to as accelerometer number 2, it was mounted on the second axle of the first bogie in the direction of travel of the tank car, figure 7.4.

Accelerometer 08521026: ICP; Sensitivity: 5.10 mV/(m/s²); measuring range: ±981 m/s² pk; frequency range (±5 %): 1 to 5000 Hz; frequency range (±5 %): 0.7 to 8000 Hz; frequency range (±ddB): 0.35 to 15000 Hz; resonance frequency: ≥28 kHz; resolution: 0.01 m/s² rms; non-linearity; ≤1%; meal: 20 gm.

Accelerometer number 3, hereafter named, was mounted on the box of the wagon, above the first bogie in the direction of travel of the tank wagon, figure 6.5.

The total length of the test ring at the Făurei Railway Testing Center is 13,712 km.

The rail type is 60 (kg/ml)ig. 5.1. General presentation of the configuration of the line from the Great Ring at CTF Făurei

An overview of the configuration is in figure 5.1.

The measurements were carried out on the curved portions of the terminal,

- Between km 2 and km 5

- Between km 9 and km 12

- empty tank wagon at the nominal load, having a total mass of 23200 kg;

- tank wagon loaded at normal load, having a total mass of 90,000 kg.

The speed average with which the wagon traveled was between 105 km/h - 135 km/h.

Six accelerometers were mounted on the wagon, four of them measured the Y-axis accelerations:

1. on the leading axle, (fig. 3)
2. on the second axle of the bogie (fig.4)
3. on the carbody in the middle of the bogie 1, (fig.3)
4. on the carbody in the middle of the bogie 2,

Presentation of experimentally obtain data

Recording of acceleration was made at constant velocity. Results of tests are presented in the chart in the following figures. Figure 7 contains the vibration values recorded by the accelerometer mounted on the axle 1, axle 2 of the bogie and carbody 1 and carbody 2, in the case of the empty wagon and 125 km/h speed. Figure 8 contains the vibration values recorded by the accelerometer mounted on the axle 1, axle 2 of the bogie and carbody 1 and carbody 2, in the case of the empty wagon and 130 km/h speed. Figure 9 contains the vibration values recorded by the accelerometer mounted on the axle 1, axle 2 of the bogie and carbody 1 and carbody 2, in the case of the empty wagon and 135 km/h speed.

The vibration of the wagon is random, to describe such a vibration the RMS is used.

Chapter 7

Conducting experimental tests and recording measured data

The experiments were carried out on the railway line at the Railway Testing Center of the big ring. The ring has 2 curves located between km 2 and km 5 and between km 9 and km 12, (figure 7.1.)

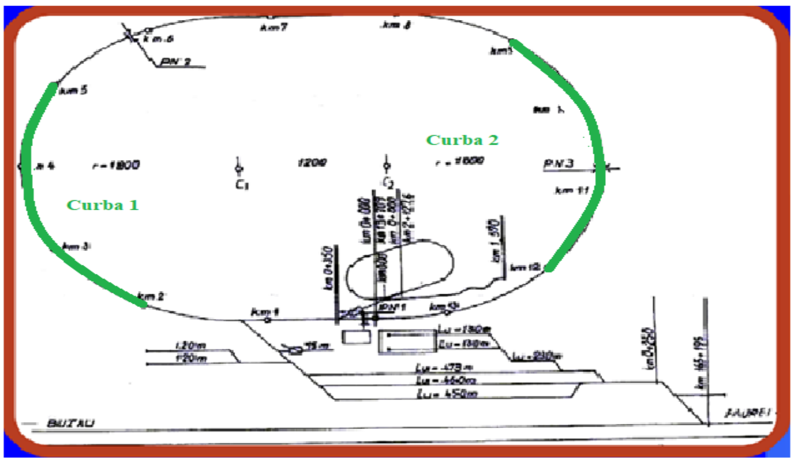


Fig. 7.1. The large test ring, curves 1 and 2, on which the recordings were made (green segments)
The tank car was coupled to the laboratory car, both being hauled by the LDH 1250 series 283 locomotive.

Fig.7.2. The train with which the measurements were made All 6 accelerometers are connected to the data acquisition system in the laboratory wagon.

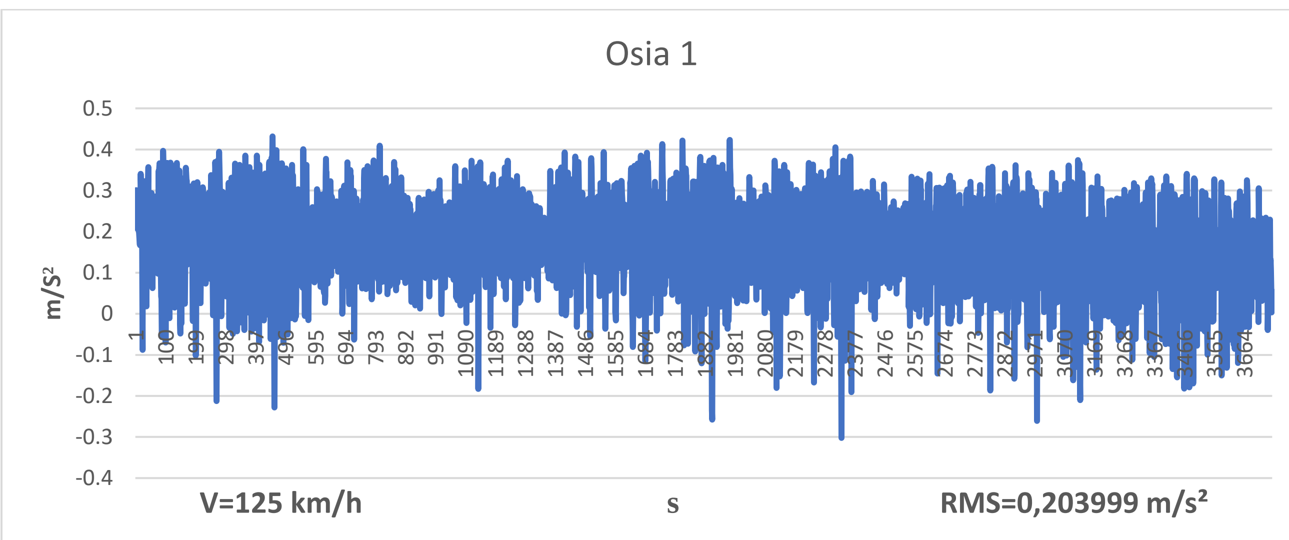
The locomotive tracks the two wagons, the tank wagon and the laboratory wagon, at speeds of 125 km/h, 130 km/hr and 135 km/hour when the wagon is empty and at speeding speeds 105 km/ha, 110 km/he and 115 km/her when the vagon is loaded.
The direction of the ring is clockwise.
The locomotive starts, after the first round, the reconnaissance round, reaches the proposed speed.
When it reaches the 2 km border, the recording starts. When the laboratory wagon reaches the border at km 5 the recording stops.
The process is resumed when the laboratory wagon reaches the borne at kilometre 9.

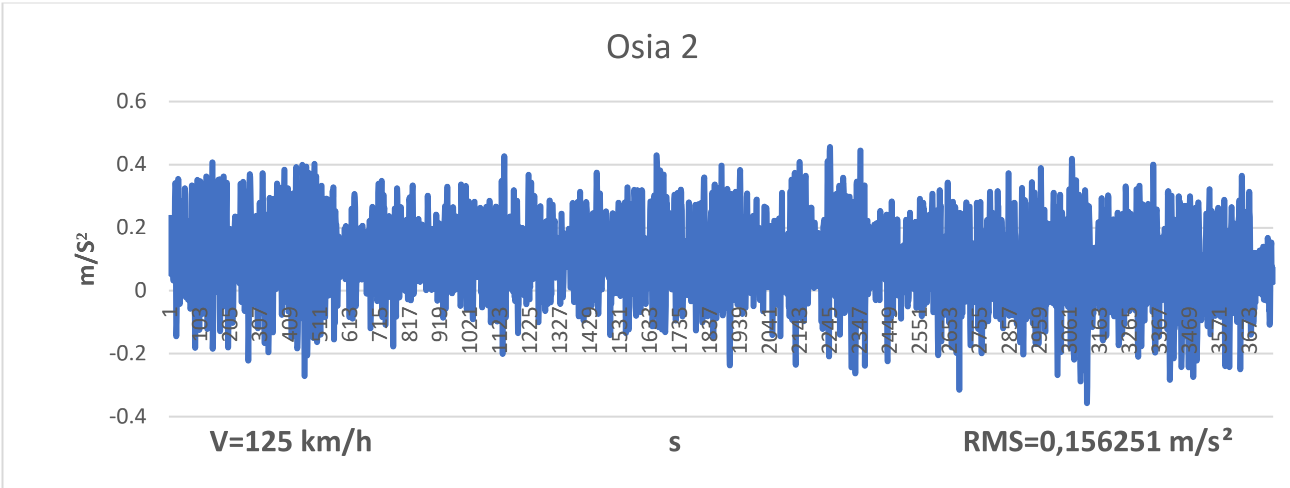
7. Experimental data

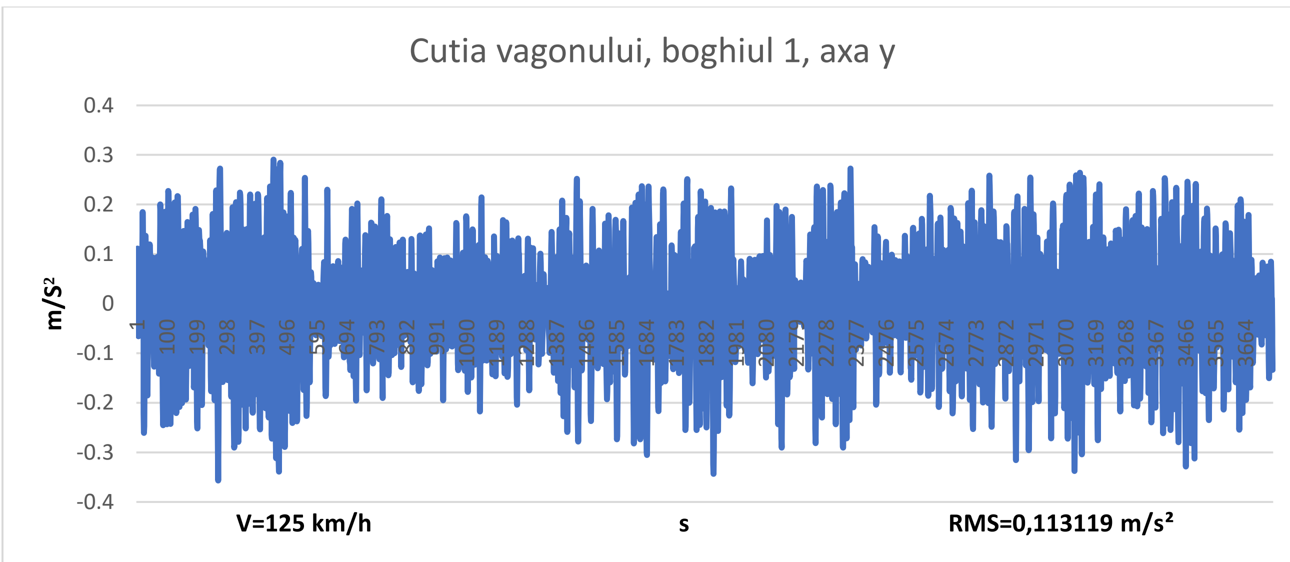
The experimental measurements were made while the locomotive treated the tank wagon and the laboratory wagon. At the start of recording, the accelerometers transmit the vibration values measured in m/s2 from 0.02 in 0.02 seconds, until the recording is stopped. A table of primary data recorded during measurements is contained, for example, in Annex 1. The other tables are on the stick and can be made available for consultation. At one record there are between 4,000 and 5,000 data for each channel accelerometer, and at each pass the data is recorded on 6 channels. The tables obtained are transformed into graphics for better visualization and interpretation.

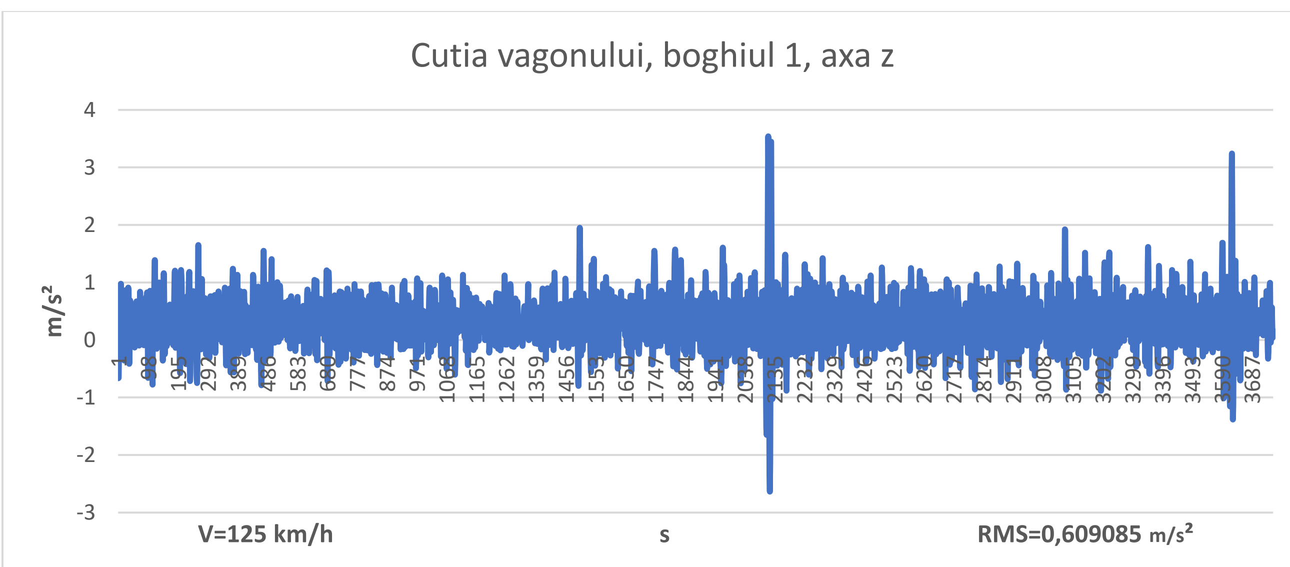
7.1. Graphs for the study of vibrations at the empty tank wagon, at passing over the curve 1

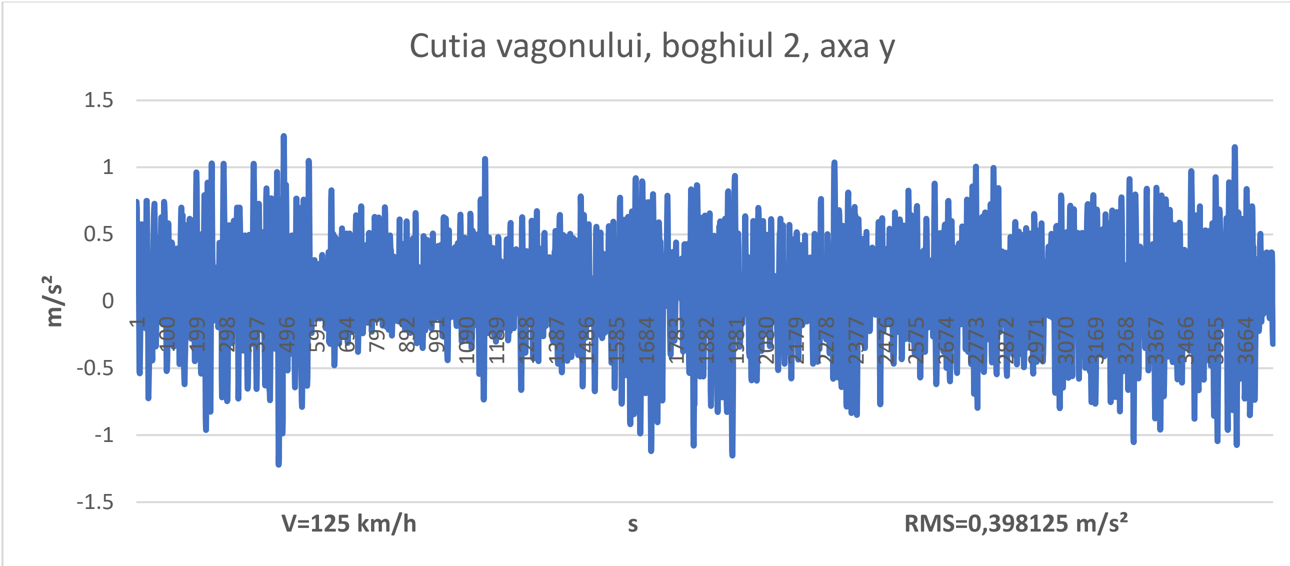
7.1.1. Vibrations recorded at passing 1 over curve 1, empty wagon.




Osia 2
m/s²
V=125 km/h
s
RMS=0,156251 m/s²


Cutia vagonului, boghiul 1, axa y
m/s²
V=125 km/h
s
RMS=0,113119 m/s²


Cutia vagonului, boghiul 1, axa z
m/s²
V=125 km/h
s
RMS=0,609085 m/s²



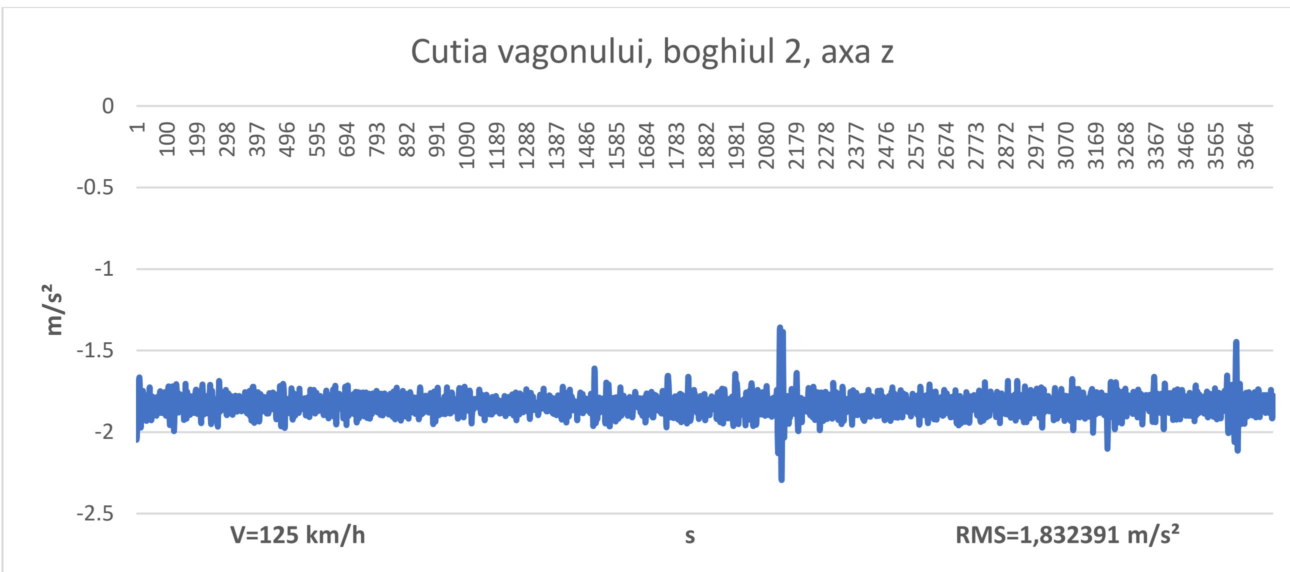
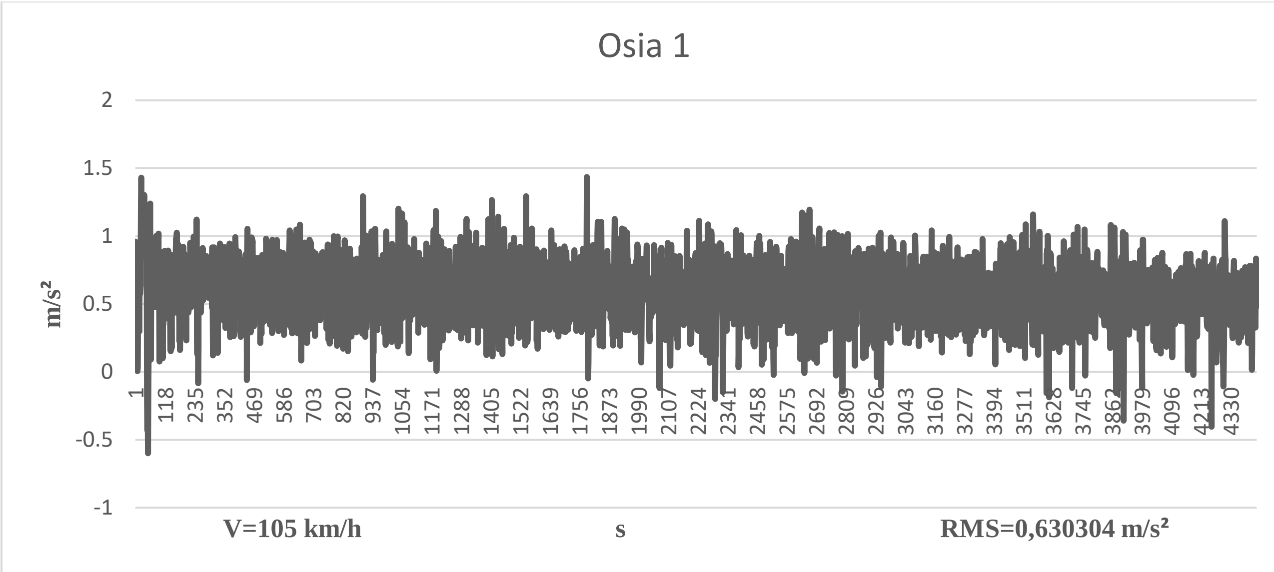
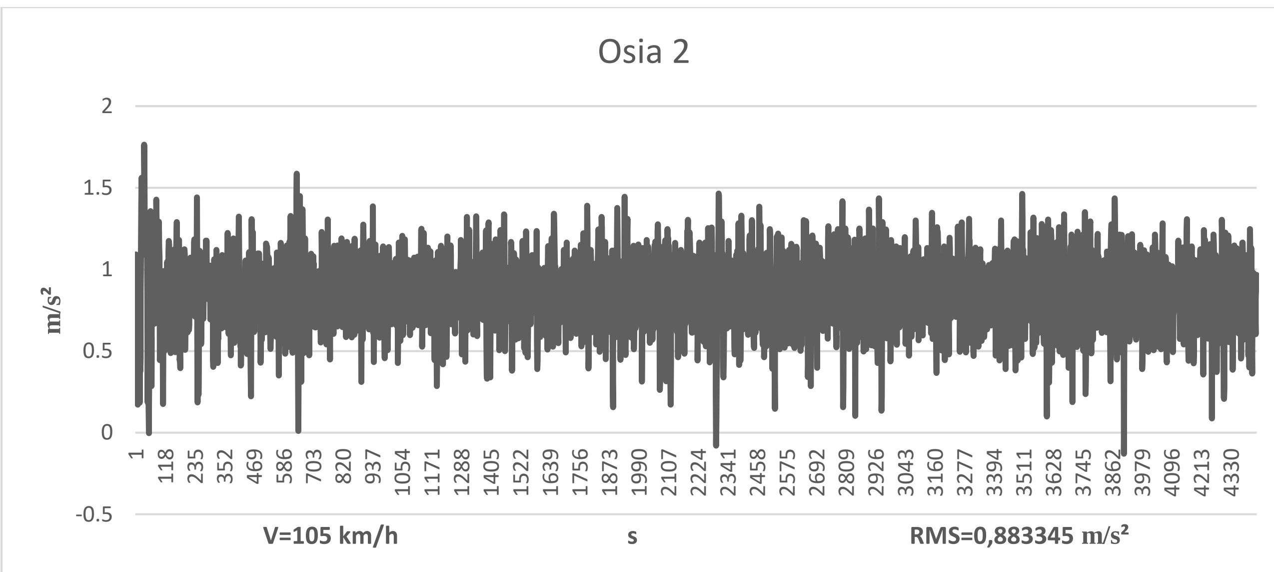


Fig. 7.1.1. Graphs with the vibration values recorded by the 6 accelerometers at the first cross over curve 1, from km 2 to km 5.In the case of the empty wagon the measurements were made through 9 passes with the Empty Wagon, over curve 1 at relatively close speeds of 125 km/h, 130 Km/h and 135 km/hr.

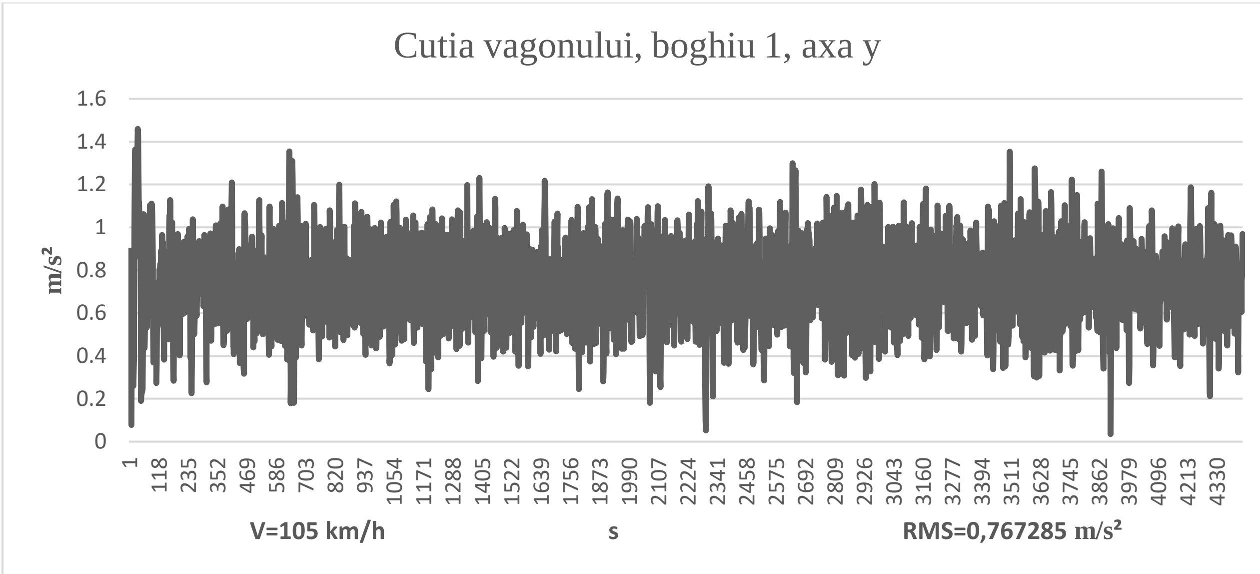
7.2.1. Vibrations recorded at passage 1 over curve 1 with the wagon loaded

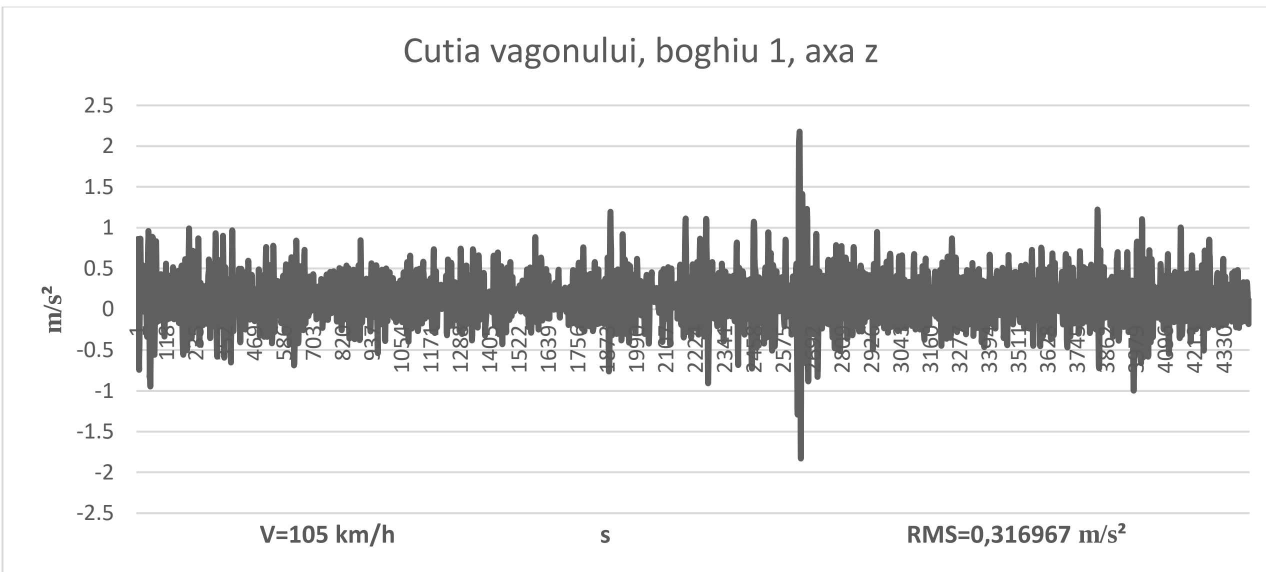


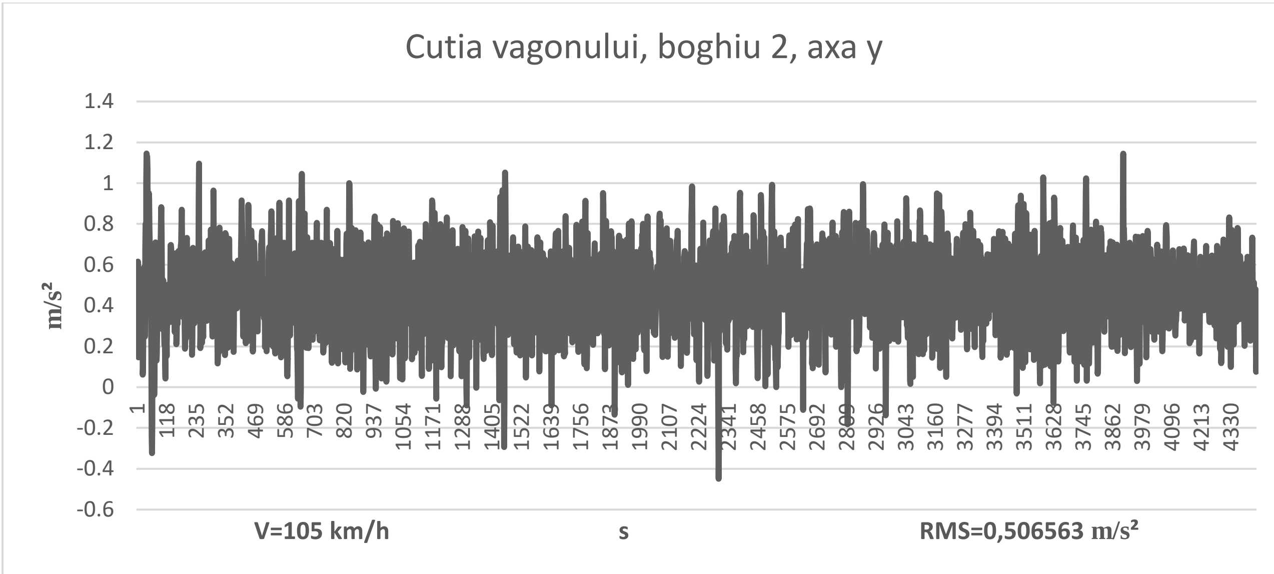
Osia 1
m/s²
V=105 km/h
s
RMS=0,630304 m/s²



Osia 2
m/s²
V=105 km/h
s
RMS=0,883345 m/s²


Cutia vagonului, boghiu 1, axa y
m/s²
V=105 km/h
s
RMS=0,767285 m/s²


Cutia vagonului, boghiu 1, axa z
m/s²
V=105 km/h
s
RMS=0,316967 m/s²



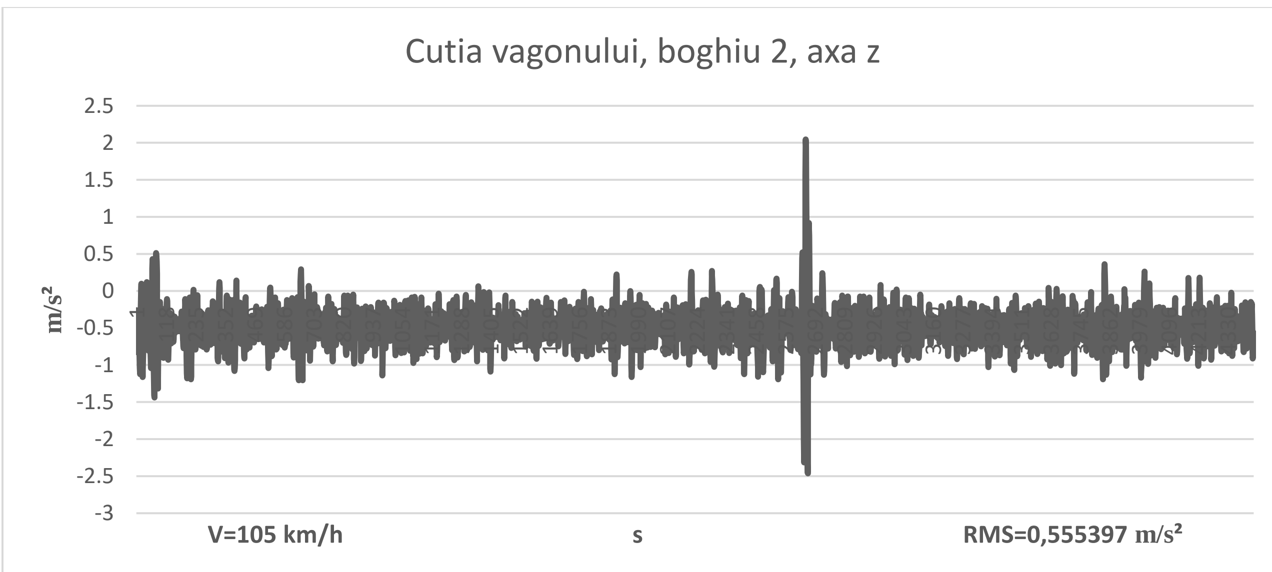
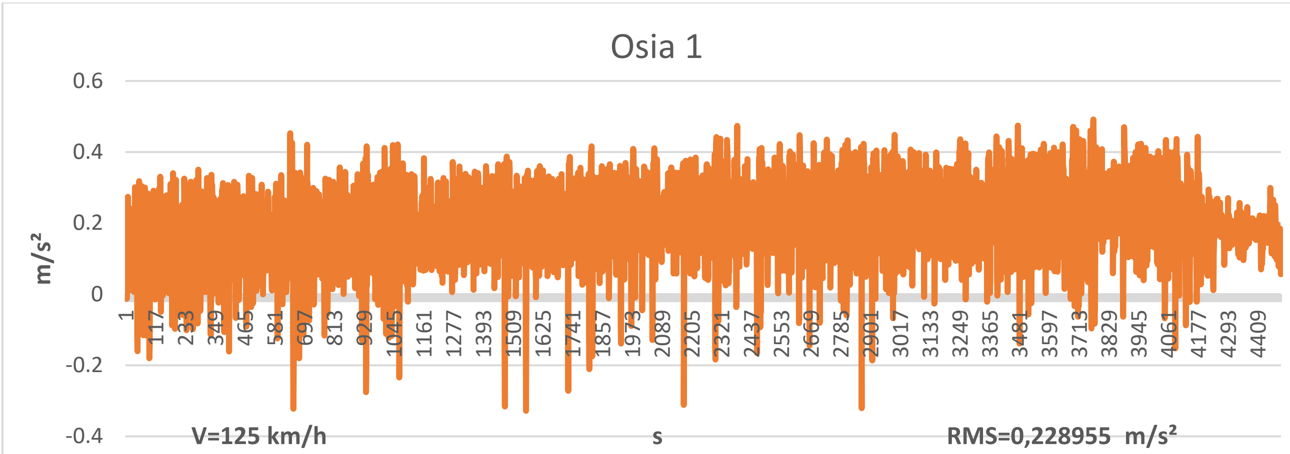
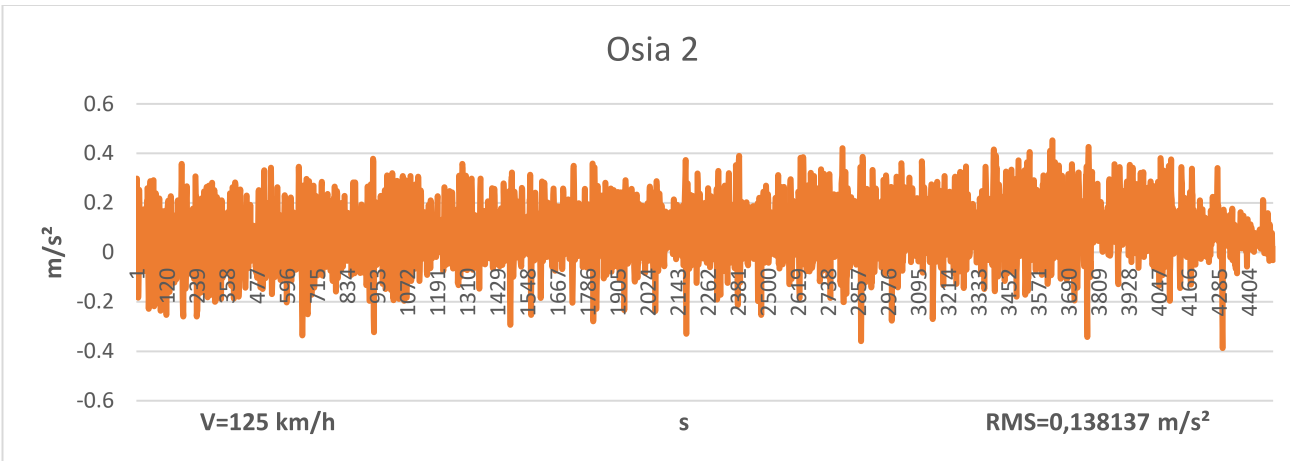
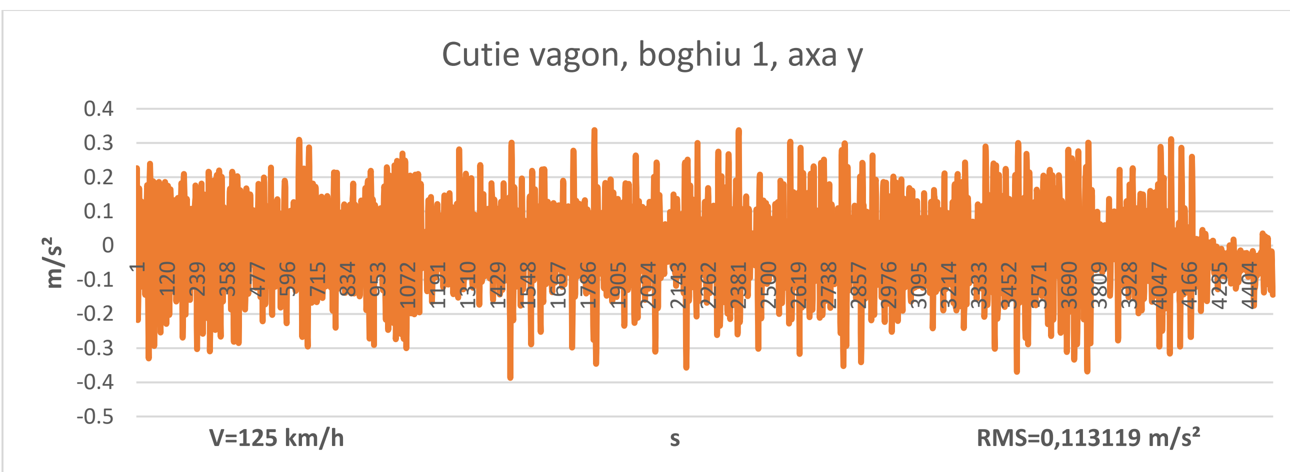


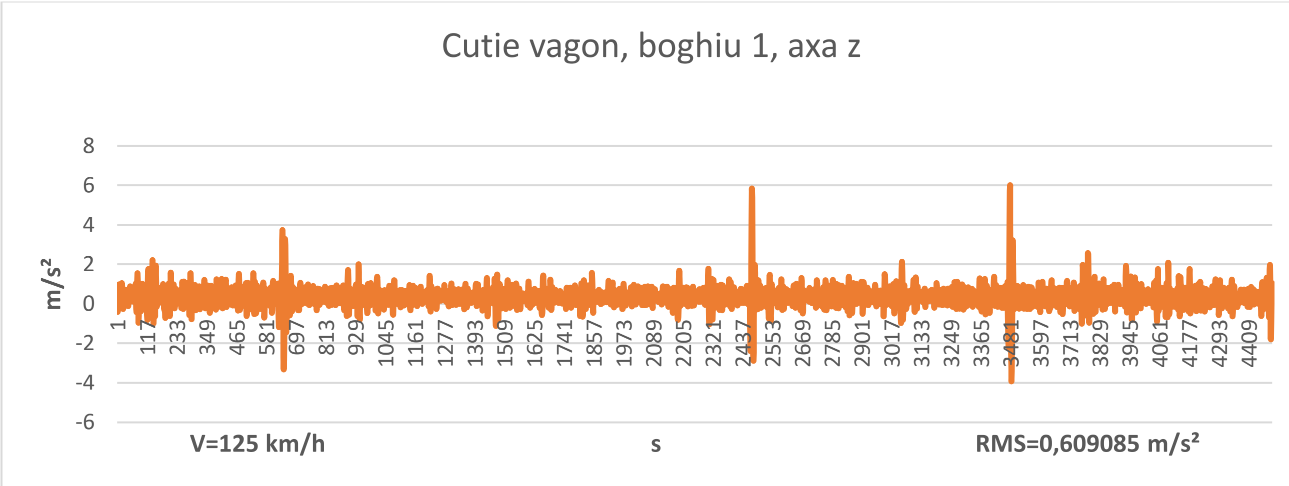
Fig.7.2.1. Graphs with the vibration values recorded by the 6 accelerometers at the first passage over the first curve, from km 2 to km 5 with the empty wagon In the case of the blank wagon the measurements were made through 9 passes with the loaded wagon, over the curve 1 at relatively close speeds 105 km/h, 110 km / h and 115 km / hr.

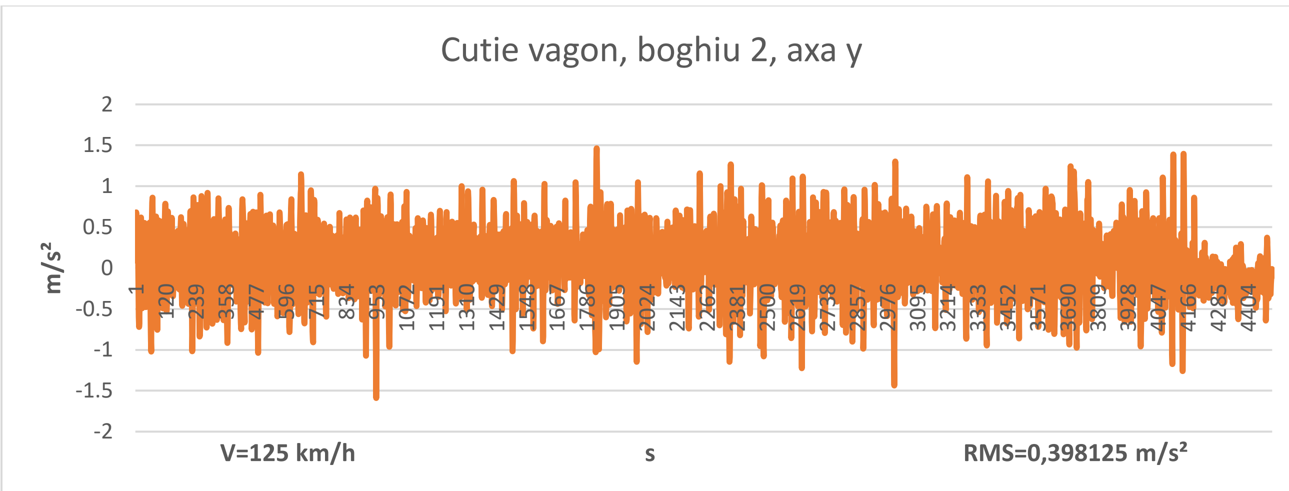
7.3.1. Vibrations recorded at passage 1 over curve 2, empty wagon.


Osia 1
m/s²
V=125 km/h
s
RMS=0,228955 m/s²


Osia 2
m/s²
V=125 km/h
s
RMS=0,138137 m/s²


Cutie vagon, boghiu 1, axa y
m/s²
V=125 km/h
s
RMS=0,113119 m/s²





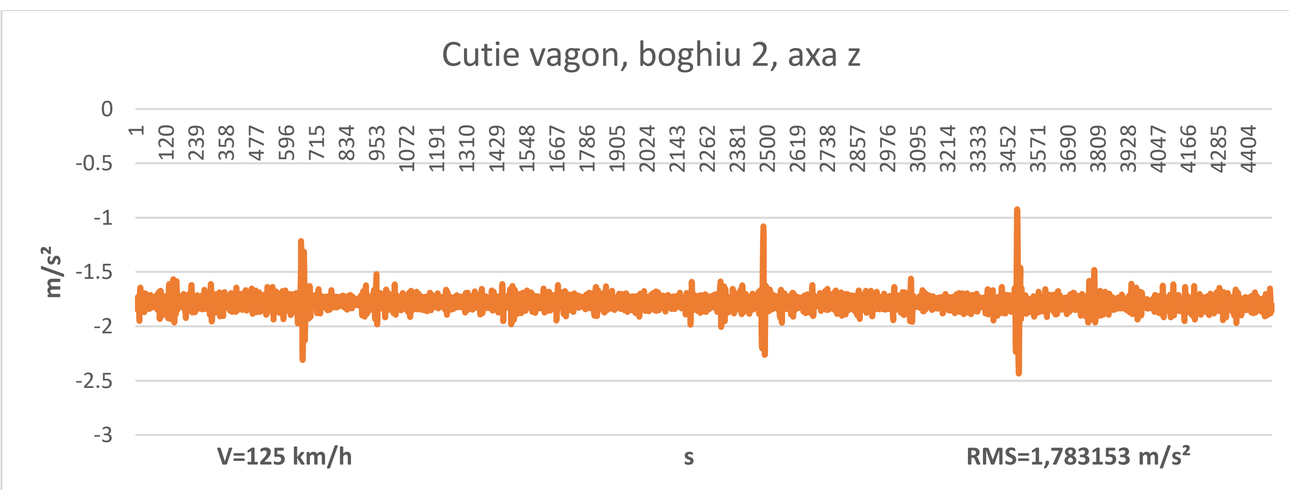
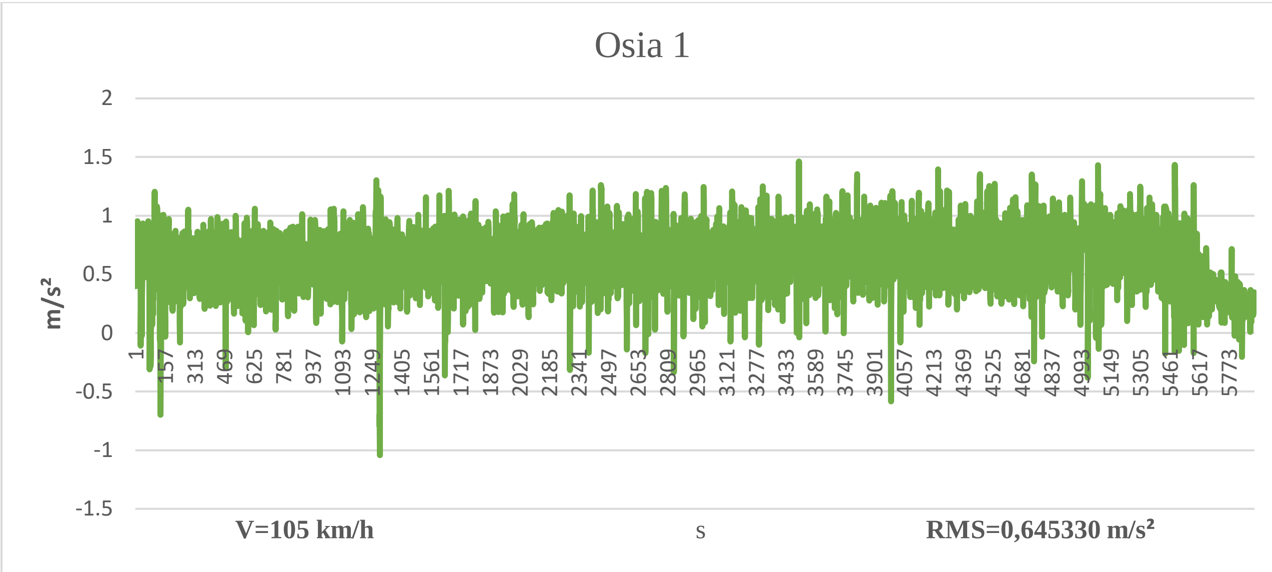
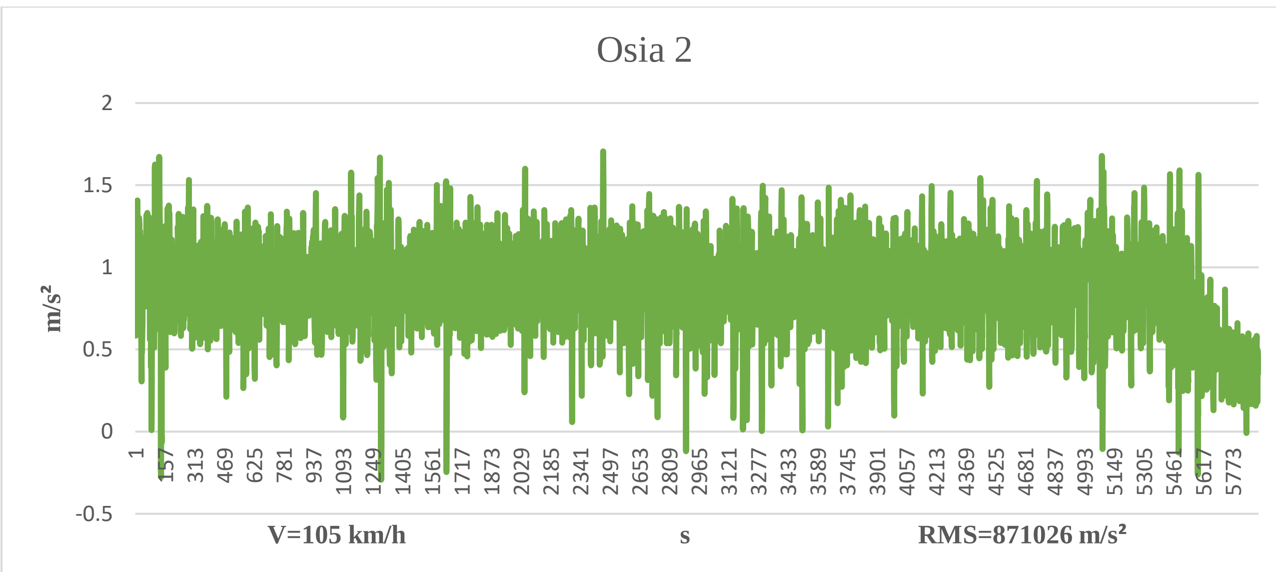
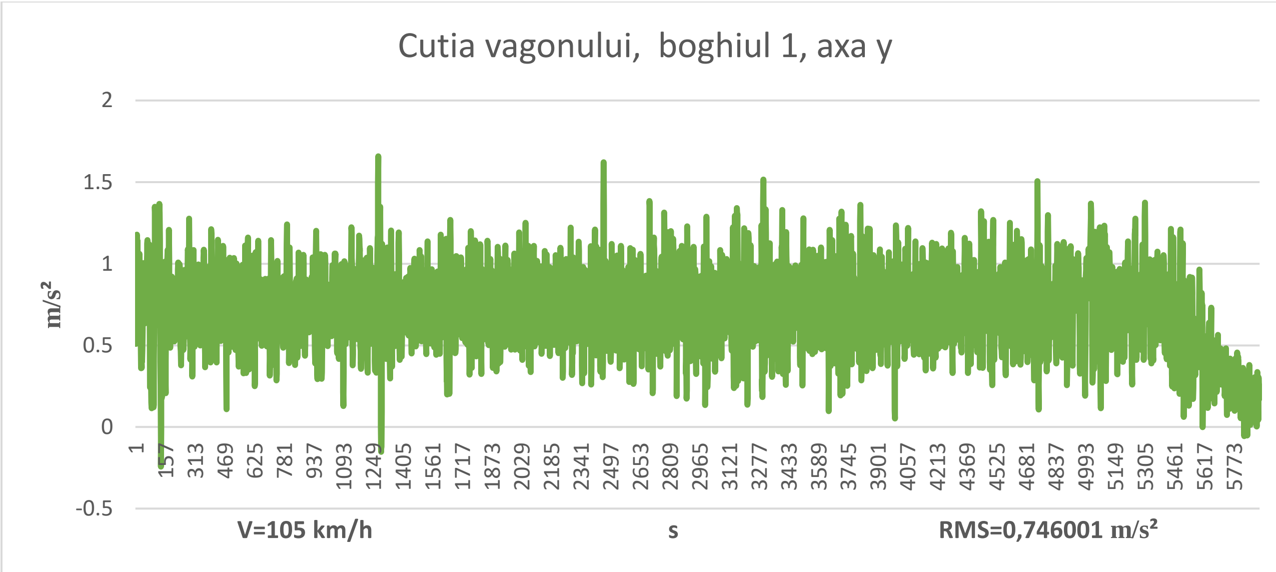


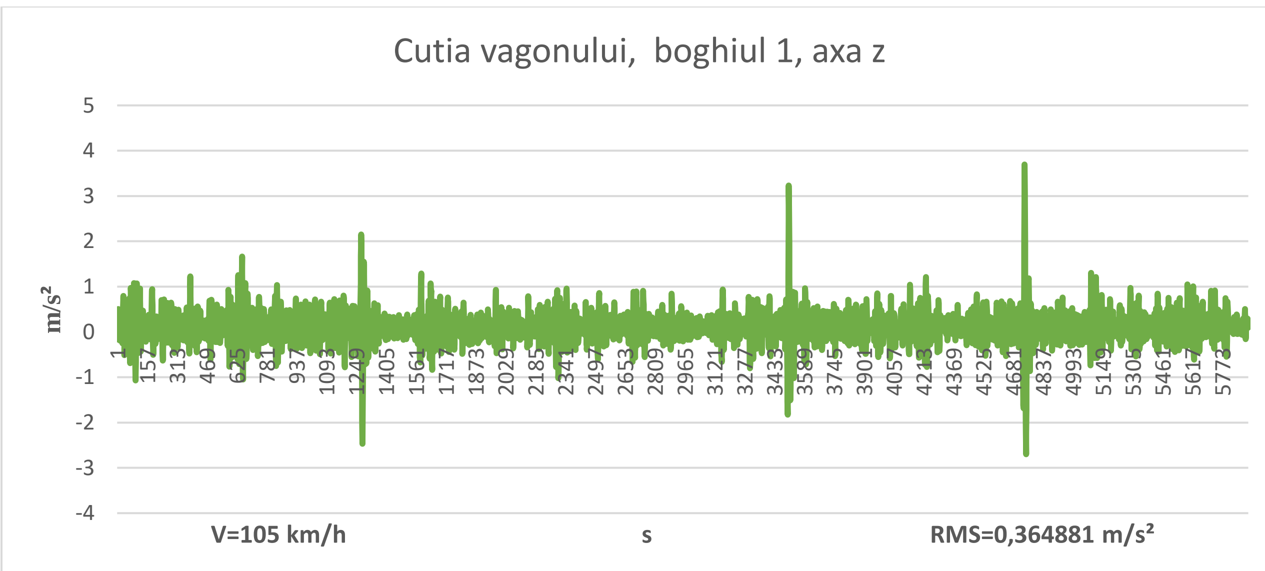
Fig.7.3.1. Graphs with the vibration values recorded by the 6 accelerometers at the first passage over the second curve, from km 9 to km 12.In the case of the empty wagon, the measurements were made during the 9 runs on the ring, over curve 1 and over Curve 2 at relatively close speeds of 125 km/h, 130 km/hour and 135 km/hr.

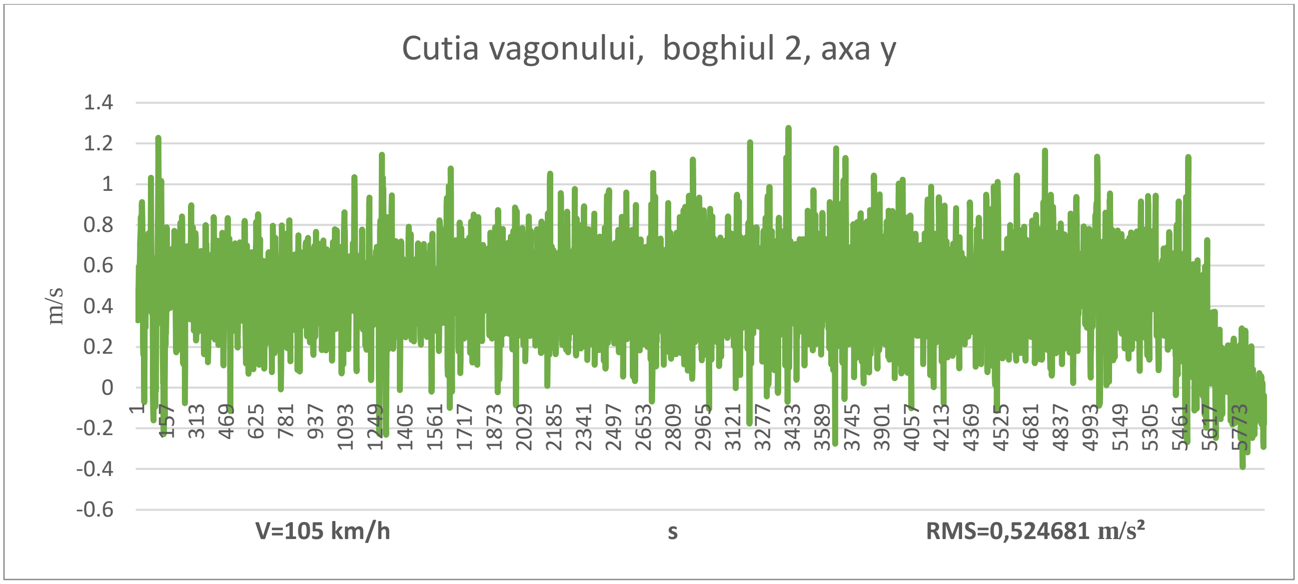
7.4.1. Vibrations recorded at passage 1 over curve 2, loaded wagon






Cutia vagonului, boghiul 1, axa y
m/s²
V=105 km/h
s
RMS=0,746001 m/s²


Cutia vagonului, boghiul 1, axa z
m/s²
V=105 km/h
s
RMS=0,364881 m/s²



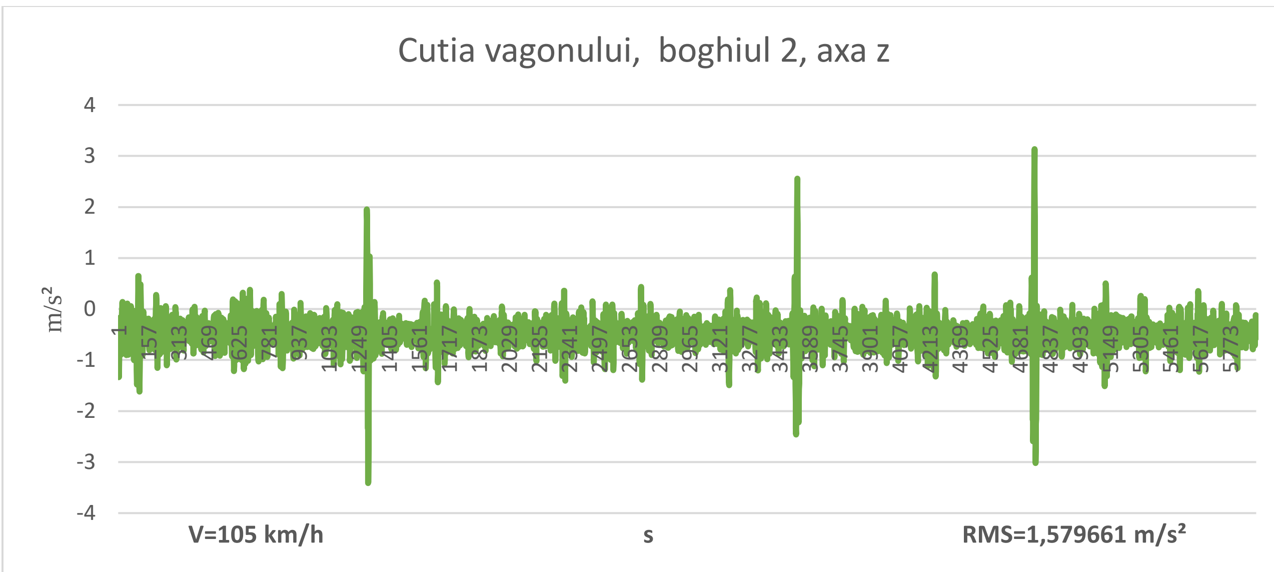


Fig.7.4.1. Graphs with the vibration values recorded by the 6 accelerometers at the first passage over the second curve, from km 9 to km 12.In the case of the loaded wagon, the measurements were made during the 5 runs on the ring, over curve 1 and over Curve 2 at relatively close speeds of 105 km/h, 110 km/hour and 115 km/hr.

Deterministic disturbances were recorded at the joints and along the rail on the vertical direction and on the cross direction on the track.

The suspended masses of the vehicle, when moving on the track, produce vibrations which areined by axle movements.

Knowing the disruptive effect that expresses the shift in time of the axle, one can theoretically assess the quality of a vehicle's driving and, at the same time, determine how the main constructive parameters of the vibrant system can be changed to increase the dynamic performance of the vehicle.

The wave of the rails between the crosses and the rolling of the wheels over the irregularities and discontinuities of the path generally produce vibrations of the track and at the same time vertical vibration of the axles. Analysing the quality of the ride it is necessary to know whether how the vibrations of the superstructure of the path influence the vibration of the suspended masses of the vehicle.

The rigidity of the path is, as a rule, very high in comparison with the rigidities of the suspension and, accordingly, the frequencies of the vehicles (in the order of hertz) are much lower than those of the superstructure (in order of tens of hertzies), the vibrations of the surstructure are a supracritical disturbance for the vehicle vibration system (over resonance), the radius where the small amplitudes of the vibrations of the superstructure can be reduced almost completely by the vehicle suspension.

For this reason, in almost all theoretical works studying the vibration system of vehicles, the vertical elasticity of the path is not taken into account in relation to the elasticities of the suspension. That is why there is also the simplification of the theoretical study of vibrations in railway vehicles, which in this way considered the maximum with two vibrating masses - the suspended mass of the boghi and the mass of a box, instead of three masses, where the third would be the unsuspended mass supplemented with the reduced load of the superstructure of the path (that part of the body mass that is considered to participate in the vibratory movement).

CHAPTER 8

Analysis of experimentally obtained data

The behavior of a tank wagon in a curve can be affected by a number of factors, including the speed of the wagon, the radius of the curve, the weight and distribution of the load, and the status of the rail. One of the potential consequences of a tank wagon negotiating a curve is the appearance of vibrations.

Vibrations can occur when the forces acting on the wagon, including the centrifugal forces and gravity, cause the vagon to move or swing in a certain way. The shape and distribution of the tank's weight, as well as the presence of any liquid or gas inside, can also affect how the wagon behaves in a curve.

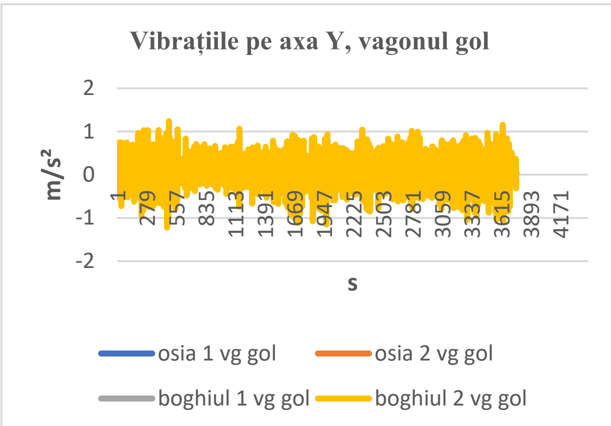
If the vibrations are severe, they can cause damage to the wagon, rail or other equipment. In some cases, they can even lead to a drift. It is therefore important for railway operators to take measures to minimize the occurrence of vibrations and to ensure that the tank wagons operate safely and smoothly in curves. This may include measures such as reducing speed, improving track maintenance or changing the tank wagon design.

As a result, the comparative study of vibrations recorded on accelerometers mounted on the wagon boxes and on the axles leads to practical verification of the vagon's behavior in situations encountered in operation.

Study of data obtained experimentally at crossing curve 1,

8.1. Vibrations recorded on the Y axis at the passage of the curve 1

Vibration recorded at the cistern passing, empty, at a speed of 125 km/h and the loaded wagon at a velocity of 105 km/hr at the passing of curve 1.



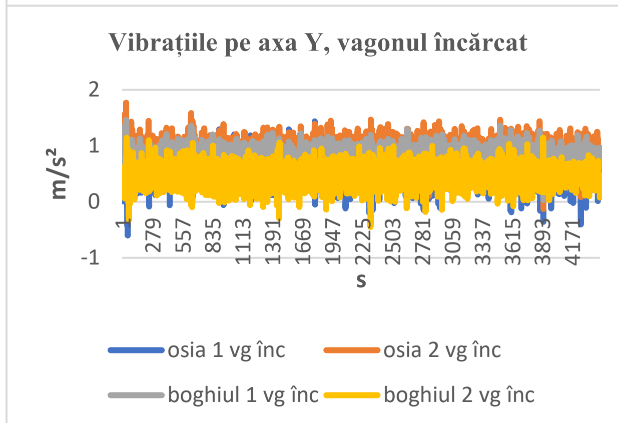


Fig. 8.1.1. The vibration chart recorded on Y-axis at the first passage, over the curve 1, of 125 km/h, with the empty wagon,

Fig.8.1.2. The vibrations chart on the axis, the at first passage over the 1 curve, at a speed 105 km/hour, the wagon loaded,

In the case of the empty wagon, the vibrations recorded on the y axis, by the accelerometer mounted in the middle of the wagon's thigh in the right of the second boghiu, recorded the highest values, regardless of speed. The other values, recorded on the Y axis, of the other 3 accelerometers are smaller, both positive and negative values.

In the case of the loaded wagon, the vibrations recorded on the y axis, by the accelerometer mounted on axis 2 of the first boghiu, recorded the highest positive values, regardless of speed.

8.2. Vibrations recorded on the Z axis when crossing the curve 1

Vibration recorded when crawling the tank wagon, empty at speeds of 125 km/h and the loaded wagon at velocities of 105 km/hour when passing the Curve 1.

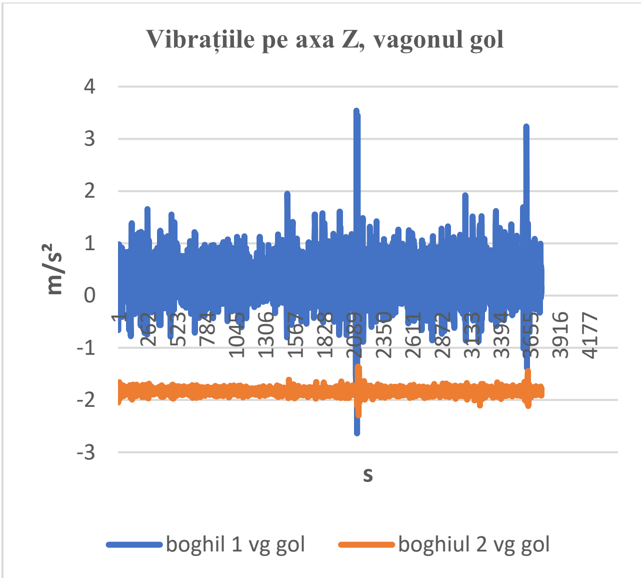


Fig. 8.2.1. The vibration chart recorded on the Z axis, passage, over the curve 1, at speed, at first passage with the empty wagon, at 105 km/hour,

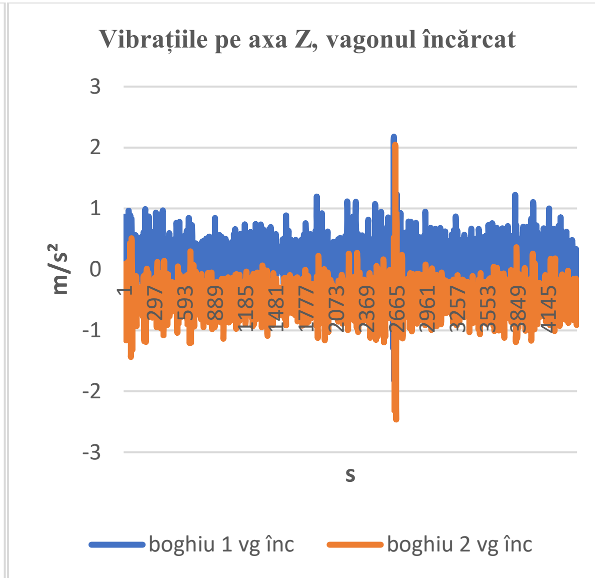


Fig.8.2.2. The vibrations chart, at the first over the 1 curve, at a speed of 125 km/h, and with the loaded wagon.

In the case of the empty wagon, the vibrations recorded on the Z axis, by the accelerometer mounted in the middle of the wagon's thigh in the right of the first boghiu, recorded the highest values, regardless of speed.

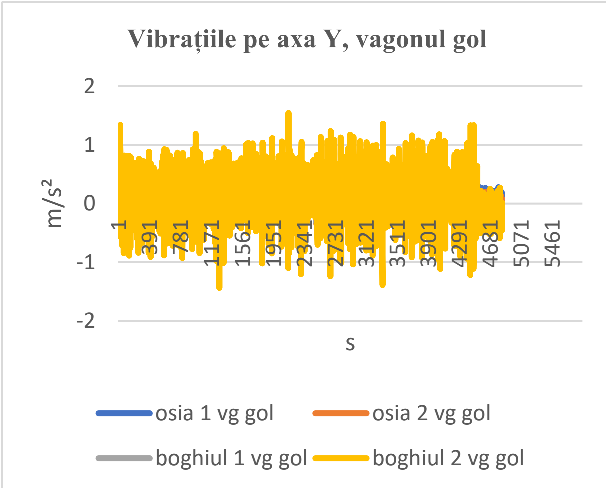
The other values, recorded on the Z axis, of the other accelerometer are smaller, and have only negative values.

In the case of the loaded wagon, the vibrations recorded on the axis,Z by the accelerometer mounted to the box of the wagon in the direction of boghi 1, recorded the highest positive values, regardless of speed.

The values recorded on boghiul 2 are smaller, having both positive and negative values.

8.3. Vibrations recorded on the Y axis when crossing the curve 2

Vibration recorded when cutting the cistern wagon, empty at a speed of 125 km/h and the loaded wagon at a velocity of 105 km/hr, when crawling over curve 2.



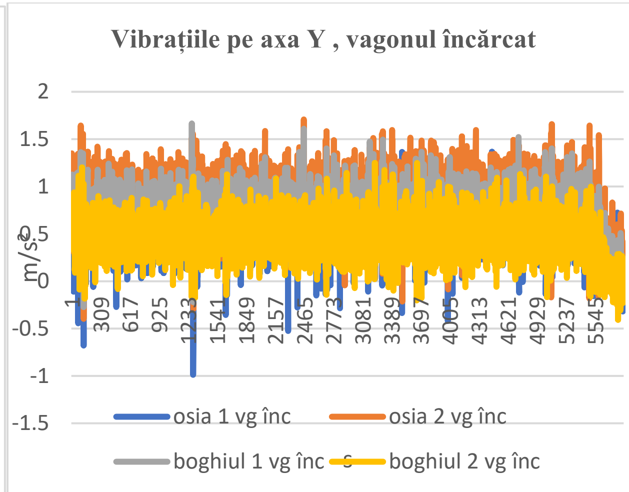


Fig. 8.3.1. Vibration chart recorded on the Y axis, the first pass, over curve 2, at first pass over the curve wagon, at the speed of 105 km/hour,

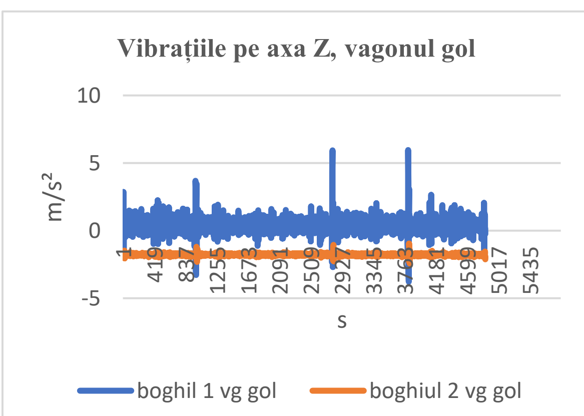
Fig.8.3.2. The chart of vibrations recorded at at a speed of 125 km/h, with the empty the loaded wagon

In the case of the empty wagon, the vibrations recorded on the y axis, by the accelerometer mounted in the middle of the wagon's thigh in the right of the second boghiu, recorded the highest values, regardless of speed. The other values, recorded on the Y axis, of the other 3 accelerometers are smaller, both positive and negative values.

In the case of the loaded wagon, the vibrations recorded on the y axis, by the accelerometer mounted on axis 2 of the first boghiu, recorded the highest positive values, regardless of speed.

8.4. Vibrations recorded on the Z axis, when crossing the curve 2

Vibration recorded when crawling the tank wagon, empty at a speed of 125 km/h and the loaded wagon at a velocity of 105 km/hour, when passing over curve 2.



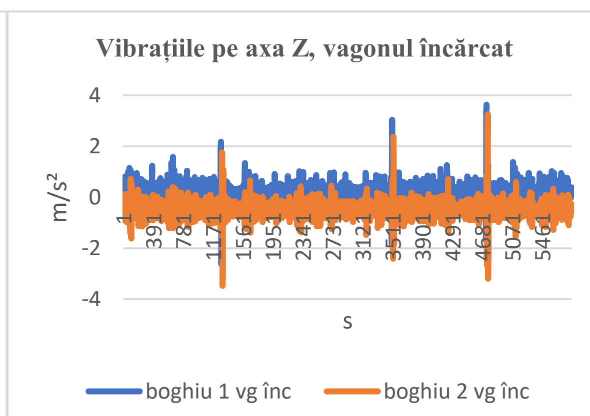


Fig. 8.4.1. Graph of vibrations recorded on the Z axis, Fig. The graph of the vibrations recorded on the Z axis, at the first passage, over the curve 2, on the first pass over the Curve 2, at the speed of 125 km/h, with the empty wagon, at a speed of 105 km/hour, the wagon loaded

Conclusions From the analysis of the graphs showing the data obtained experimentally, when passing over curve 1, as well as at the passage over thecurve 2, it turns out that vibrations on the Y axis are approximately the same regardless of the variation of the speed or curve on which the recordings were made.

In the case of an empty wagon the values recorded by the accelerometer mounted on the box of the wagon in the right of the second boghi are the highest, practically on the graph that illustrates all values measured on the Y axis, the other values registered are no longer visible, here the phenomenon of scurvy intervenes, at the second Boghi all accelerations increase. In the case of the loaded wagon, the scraping phenomenon is mitigated. The mass of the cargo presses the wagon onto the rail and the snake is no longer determining. The highest vibration values were recorded at the second axis of the first boghi. In the case of the loaded wagon, the measurement interval was several seconds longer, and the exit from the curve was also recorded. Thus, the values of accelerations on the y axis decrease with the centrifugal force.

In the case of the empty wagon, the vibrations recorded on the Z axis, by the accelerometer mounted in the middle of the wagon's thigh in the right of the first boghiu, recorded the highest values, regardless of speed.

The other values, recorded by the accelerometer mounted on the second boghi, on the Z axis, are smaller, and have only negative values.

In the case of the loaded wagon, the vibrations recorded on the Z axis by the accelerometer mounted onto the wagon's box in the direction of boghi 1, recorded the highest positive values, regardless of speed.

The values recorded on boghiul 2 are smaller, having both positive and negative values.

In the case of the values recorded on the Z axis, all graphs show large leaps of values in the same places. When crossing the curve 1 is a single place where the values record a doubling of values, both in the positive and negative spectrum, at passing over curve 2 are 3 segments in which triplets of values were measured.

The peak values illustrate the need to eliminate level passes and joints due to the critical points they generate on the runway.

Chapter 9

Statistical analysis - Average square root RMS

All time intervals during which measurements were made were divided into intervals of 3 seconds and for each interval RMS was calculated. The tables in which the square roots averages were calculated are in Appendix 3 The data obtained experimentally were processed, square root averages have been calculated for all the situations studied.

We have four cases:

Empty wagon when crossing the curve 1, are given for 9 passes, 3 at a speed of 125 km/h 3 at the speed of 130 km / h 3 at an speed of 135 Km/h Emptying wagon at the passage of curve 2, is given for 8 passes 3, at a velocity of 125km/h 3, at the speeds of 130km / h 2, at the velocities of 135 km/hour Cargo loaded at the passing of the Curve 1, 5 passes are given 2 at the Speed of 105 km /h 1 at the Speeds of 110 km / hour 2 at a Speed of 115 km / hr Cargo charged at passing the Curva 2, is provided for 5 passages 2 at The speed of 105 Km/hr 1 At the speed Of 110 km/ h 2 At the Speed Of 115 km/hr

9.1. The case of the empty wagon when crossing curve 1.

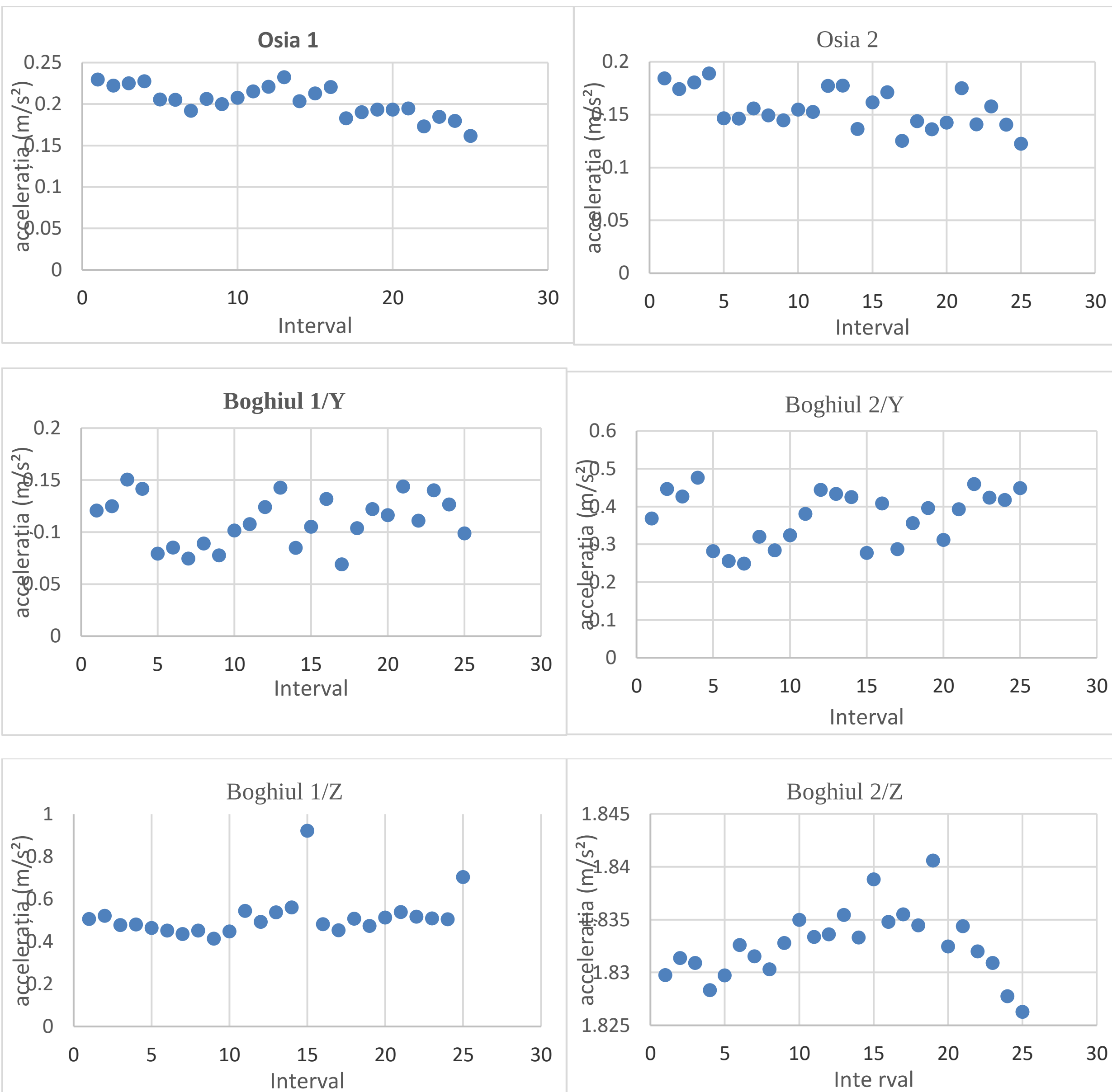
Crossing 1, empty wagon, curve 1, speed = 125 km/h

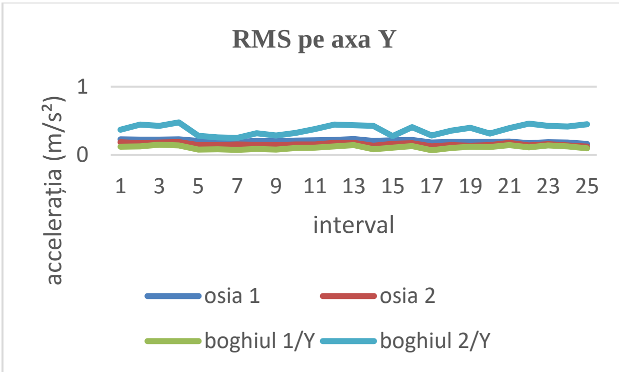
	osia 1	osia 2	boghiul 1/Y	boghiul 1/Z	boghiul 2/Y	boghiul 2/Z
1	0.229740	0.184362	0.120849	0.505864	0.368157	1.829743
2	0.222349	0.174237	0.124946	0.520500	0.446528	1.831361
3	0.225210	0.180642	0.150652	0.476515	0.426598	1.830891
4	0.227803	0.188997	0.141765	0.479264	0.476463	1.828306
5	0.205804	0.146719	0.079591	0.463869	0.282354	1.829721
6	0.205333	0.146374	0.085183	0.451486	0.255659	1.832572
7	0.192087	0.155917	0.074842	0.434883	0.249099	1.831526
8	0.206276	0.149501	0.089122	0.450587	0.320087	1.830292
9	0.200034	0.144849	0.077921	0.412519	0.284283	1.832762
10	0.207848	0.154888	0.101782	0.447162	0.324171	1.834967
11	0.215290	0.152593	0.107946	0.543529	0.380849	1.833339
12	0.221104	0.177453	0.124148	0.492166	0.443959	1.833599
13	0.232693	0.177567	0.142754	0.536342	0.433583	1.835420
14	0.203504	0.136644	0.084955	0.559418	0.425258	1.833283
15	0.212846	0.161813	0.105282	0.921277	0.277327	1.838806
16	0.220806	0.171376	0.131972	0.480852	0.407921	1.834769
17	0.183093	0.125379	0.069054	0.452997	0.287215	1.835480
18	0.190215	0.143943	0.103865	0.507286	0.356472	1.834441
19	0.193485	0.136237	0.122359	0.472501	0.395933	1.840582
20	0.193560	0.142527	0.116339	0.512885	0.311491	1.832447

21	0.194703	0.175159	0.144086	0.537740	0.392871	1.834368
22	0.173304	0.140863	0.111192	0.516500	0.459494	1.831981
23	0.184814	0.157782	0.140443	0.508469	0.423569	1.830896
24	0.179739	0.140556	0.126675	0.503785	0.417707	1.827743
25	0.161633	0.122557	0.098915	0.703053	0.449033	1.826263

Table 9.1.1. The RMS values calculated for the vibrations recorded during the first passage of the empty wagon, at a speed of 125 km/h, over the first curve, from km 2 to km 5,

Graphic representation of the data in table 9.1.1.





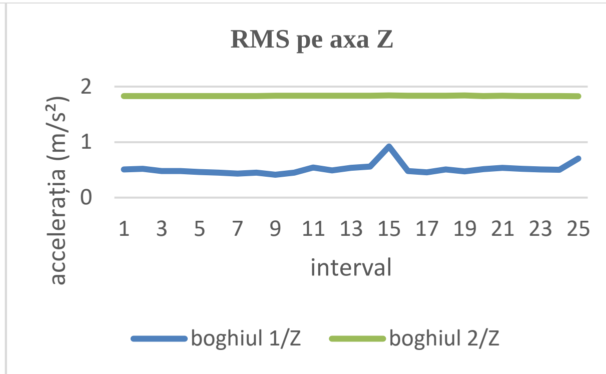


Fig.9.1.1. Graphs with RMS values for empty carriage at passage 1, over curve 1, at speed of 125 km/h

9.2. Empty car case when crossing curve 2

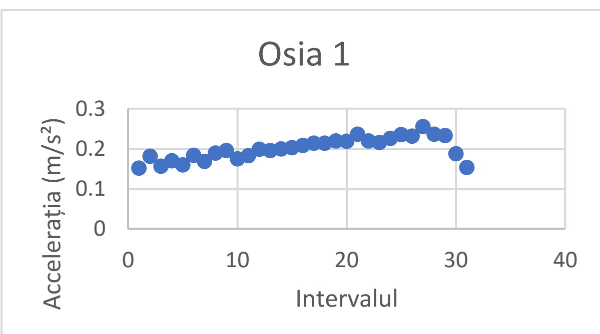
Trecerea 1, vagonul gol, curba 2, viteza = 125 km/h

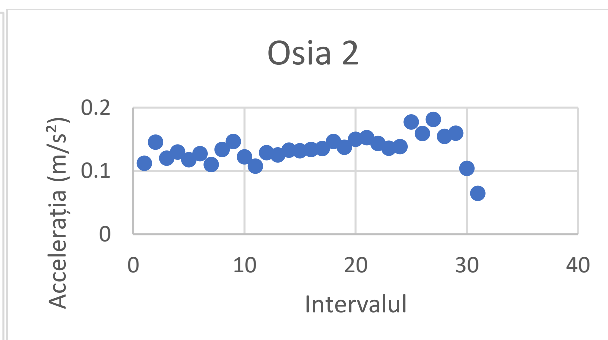
	osia 1	osia 2	bohiu 1/Y	boghiu 1/Z	boghiu 2/Y	boghiu 2/Z
1	0.182701	0.136217	0.132819	0.632907	0.424285	1.779465
2	0.187698	0.138601	0.124163	0.592723	0.426582	1.775321
3	0.188412	0.125195	0.125169	0.514522	0.413317	1.779793
4	0.180712	0.116298	0.102411	0.561961	0.400758	1.775743
5	0.205449	0.134708	0.123827	0.969544	0.448818	1.779613
6	0.191138	0.106372	0.094717	0.493442	0.288353	1.775935
7	0.223370	0.150420	0.138350	0.560458	0.463669	1.778042
8	0.211786	0.128506	0.122388	0.458920	0.327629	1.776008
9	0.201931	0.114446	0.088915	0.460325	0.342642	1.775794
10	0.221519	0.122024	0.108922	0.567072	0.350410	1.776120
11	0.220889	0.118142	0.101147	0.475093	0.354124	1.773722
12	0.222876	0.113535	0.092604	0.479046	0.297176	1.777578
13	0.236593	0.142612	0.116540	0.500436	0.463123	1.779011
14	0.233178	0.125869	0.105737	0.445584	0.397731	1.779657
15	0.236135	0.124881	0.104983	0.491339	0.326668	1.778657
16	0.246259	0.150594	0.129681	0.546989	0.469487	1.780491
17	0.240451	0.120563	0.088854	1.080633	0.383749	1.784955

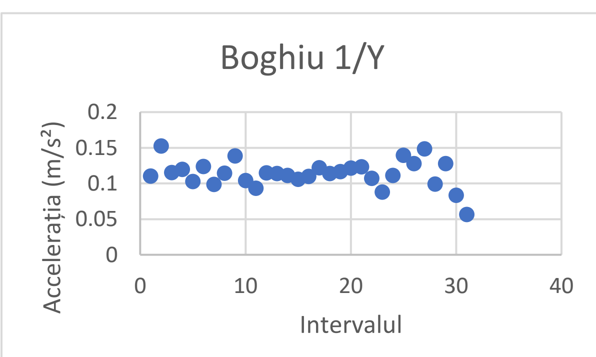
18	0.240517	0.144483	0.119673	0.500130	0.449279	1.782105
19	0.252065	0.157342	0.132624	0.495654	0.438685	1.782122
20	0.261842	0.158634	0.119798	0.521349	0.412828	1.785711
21	0.242446	0.135147	0.090411	0.567734	0.387072	1.783003
22	0.247994	0.155505	0.113747	0.469299	0.368865	1.785282
23	0.250724	0.154624	0.118238	0.514428	0.403657	1.787587
24	0.258617	0.165589	0.125792	1.194383	0.391620	1.797593
25	0.271272	0.189040	0.152144	0.519437	0.542589	1.789149
26	0.267634	0.165451	0.111071	0.667308	0.322397	1.791902
27	0.265680	0.159490	0.101336	0.569245	0.422454	1.791197
28	0.249371	0.150875	0.125975	0.588947	0.422973	1.795916
29	0.197749	0.109687	0.059165	0.500318	0.181208	1.797873
30	0.180927	0.072608	0.069472	0.550078	0.241824	1.798386

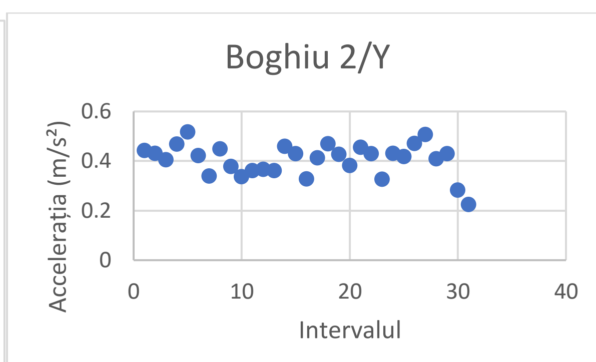
Tabelul 9.2.1. Valorile RMS calculate pentru prima trecere a vagonului gol, cu viteza 125 km/h peste a doua curba de la km 9 la km 12

Reprezentarea grafică a datelor din tabel 9.2.1.









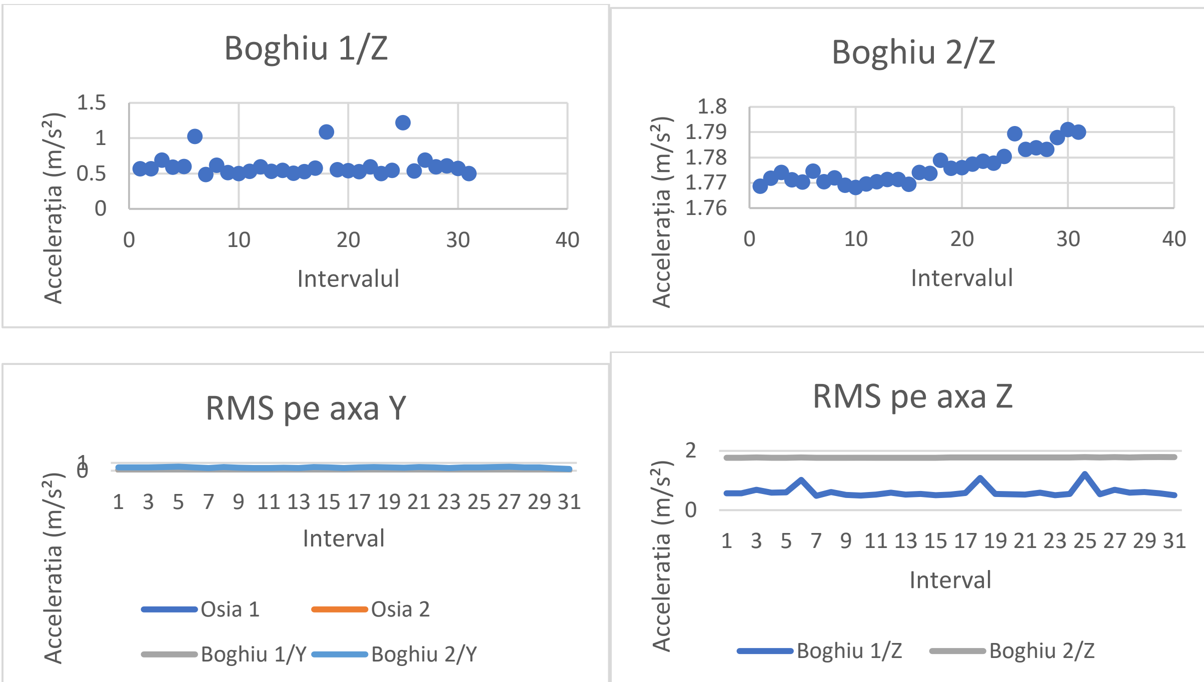


Fig. 9.2.1.Graphs with RMS values for empty wagon, at the first crossing, over curve 2, at a speed of 125 km/h

Conclusions

The Quadratic Average root calculated for experimentally measured values follows the same trend as the charts in Chapter 8, except that the values peaks are attenuated.

From the analysis of the graphs showing the RMS values, at passing over curve 1, as well as passing above curve 2, it turns out that the values calculated for the Y axis are approximately the same regardless of the variation of the speed or curve on which the recordings were made.

In the case of the discharged wagon RMS on the y axis with the highest values are the values calculated for the second boghi of the wagon.

In the case of the unloaded wagon, the RMS on the Z axis with the highest values shall be the values calculated for the second boghi of the wagon.

When the wagon is empty the highest demands are on the second boghi both for the vibrations recorded on the axis Y and on the Z axis.

In the case of the loaded wagon the calculated values for the accelerometer mounted on the second axis of the first boghiu of the wagon are the highest, practically in all the graphs the line that illustrates the values calculated for the vibrations on the Y axis, is first, has the greatest value.

In the case of the loaded wagon, the vibrations recorded on the Z axis by the accelerometer mounted onto the wagon box in the direction of boghi 2, recorded the highest positive values, regardless of speed. In the case of the values recorded on the Z axis, all graphs show large leaps of values in the same places. When passing over curve 1 there is only one place where the values record a doubling of values, both in the positive and negative spectrum, when passing across the curve 2 there are 3 places where tripling of the value has been recorded.

Chapter 10

Analysis of calculated values for Average Square Root of vibrations measured on the Y axis

In the case of the discharged wagon, the analysis of the values obtained shows that the highest values of vibrations were recorded on the wagon box in the right second boghi on the Y axis, and in the event of the loaded vagon the greatest value was recorded by the accelerometer to be mounted on axis 2

This section presents an analysis of the RMS characteristics calculated for vibration values on the Y axis, on axis 1, axis 2, wagon box at boghi 1 and 2 based on the processing of recorded experimental data.

10.1. Analysis of the values calculated for the Medium Square Root in the case empty wagon, at passing over curve 1

Figures 9.1.1.–9.1.9 illustrate the variations in the values of the average square roots recorded on curve 1, at speeds of 125 km/h, 130 km/hr, 135 km/hour, right at axis 1, axis 2, wagon box in the middle of boghi 1 and 2 for the empty wagon.

In all charts, RMS accelerations, measured on the axis and body, decrease with speed.

The RMS values calculated for boghi 2 is in all cases higher compared to the other values recorded on the Y axis.

The RMS values calculated for boghiul 1 is in all cases lower compared to the other values recorded on the Y axis
In the case of calculated values for vibrations recorded on axis 1

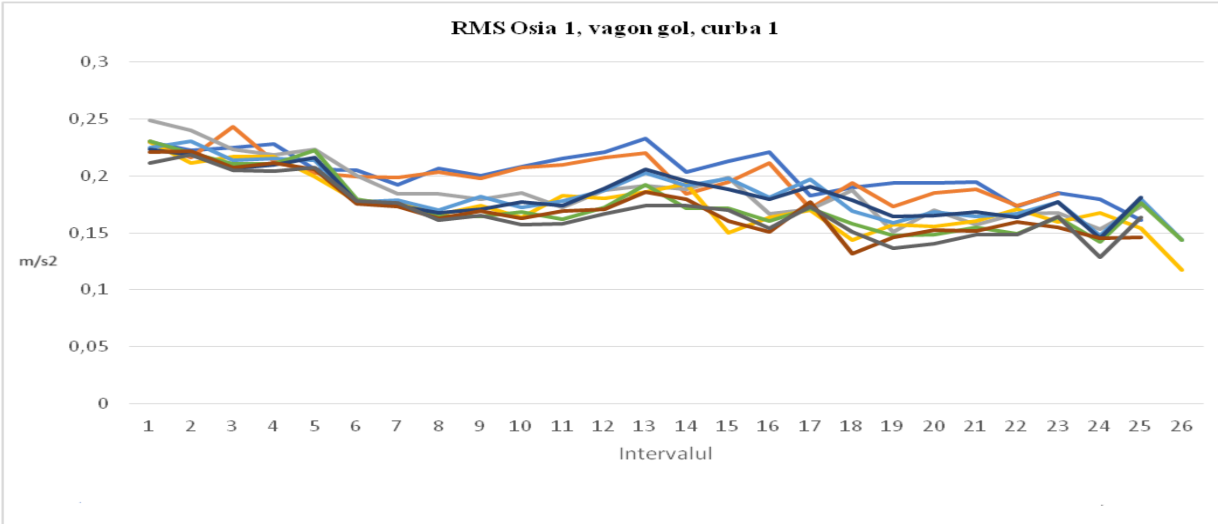
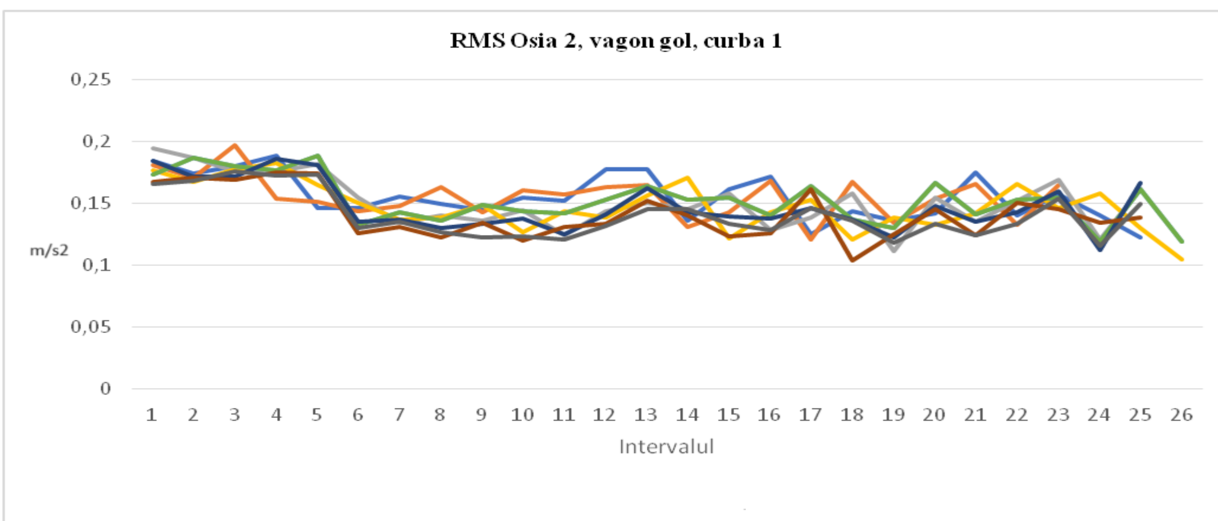


Fig. 10.1.1. RMS values recorded by the accelerometer mounted on the first axis, with the empty wagon, on the curve 1, at all 9 successive passes.

For the first 5 points the RMS values are within the range of 0,248480 – 0,204432, in the next 6 points the values fall abruptly and fall between the value 0,197461 – 0,157699, in point 12 and 13 the valutes increase and are no longer close, as value, at all passes, having the range between 0,232692 – 0,174134, followed by a decrease to point 16 at values between 0,220806 - 0,153835, in point 17 values group in the range 0,197093 - 0,173319, in point 18 values drop, reach in the interval 0,193946 – 0,13270, between point 19 and 22 values linearly vary reaching the range 0.170736 – 0,148781, in point 23 values increase at the interval 0.184537 – 0.15850, in point 24 drop to values 0,167 – 0,1288370.
In the case of calculated values for vibrations recorded on axis 2



„ Fig. 10.1.2. RMS values recorded by the accelerometer mounted on the second axis, with the empty wagon, on the curve 1, at all 9 successive passes.

For the first 5 points the RMS values are approximately linear, within the range of 0.194650 – 0.173658, in the next 6 points the values drop abruptly, evolving linearly, and fall between values 0.177452 – 0.131655, in point 12 and the 13 values increase, having the range between 0.177566 – 0.145342, followed by a change in zigzag up to point 26, the maximum values calculated in point 21, with the value range 0.175159 – 0.124782.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

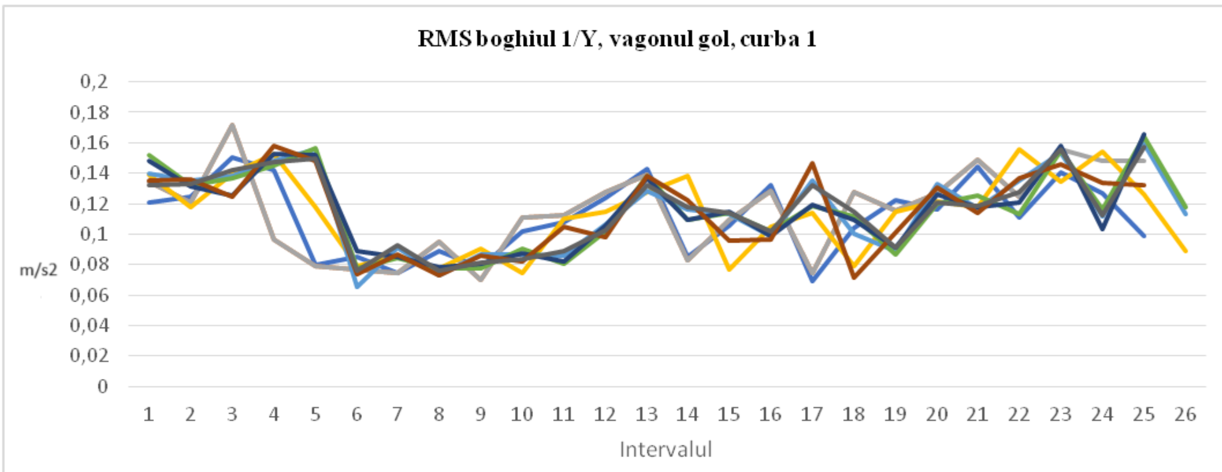


Fig. 10.1.3. RMS values recorded by the accelerometer mounted on boghiul 1, with the empty wagon, on the curve 1, at all 9 successive passes.

For the first 4 points the RMS values are linear within the range of 0,171452 – 0,124848, in the next 2 points the values drop abruptly and reach values in the range 0,07621 – 0,065196, until point 11 have a variation on the same layer of values, in point 11, 12 and 13 values increase at all passes, leaving at the range 0.142754 – 0,132443, until point 24 is a zig-zag increase. The highest value is in point 25, with 0.165872.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 2

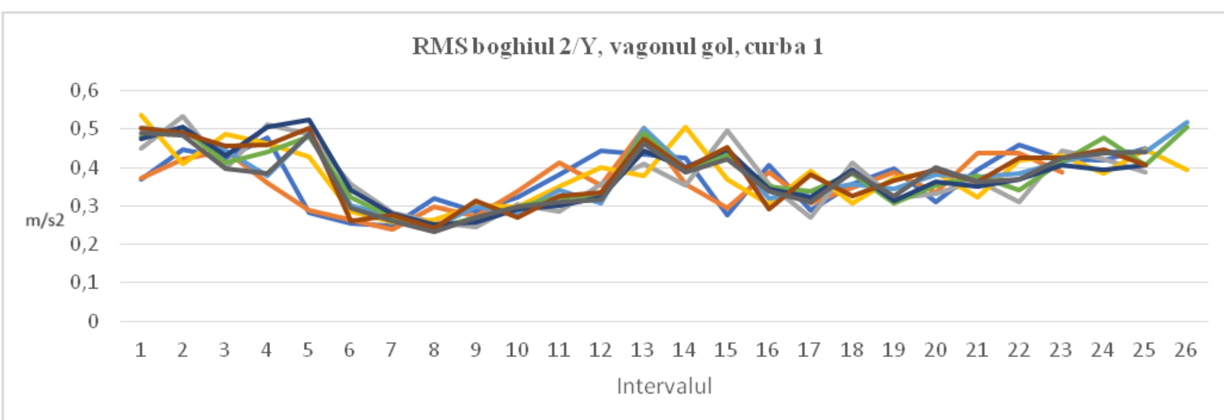


Fig. 10.1.4. RMS values recorded by the accelerometer mounted on boghiul 2, with the empty wagon, on curve 1, at all 9 successive passes

For the first 4 points the RMS values are linear within the range of 0.505346 – 0.384466, in the next 2 points the values drop abruptly and reach values in the range 0.279730 – 0.26174, until the point 11 have a variation on the same layer of values, in the point 12, 13 and 14 values increase at all passes, leaving at the interval 0.502476 – 0.420932, until the item 24 is a zig-zag increase. The highest value is in point 25, with 0.505571.

10.2. Analysis of calculated values for the Medium Square Root in the case of empty wagon, when crossing curve 2

Figures 9.2.1.–9.2.8 illustrate the variations of the mean square roots recorded on curve 2, at speeds of 125 km/h, 130 km/hr, 135 km/hour, right on axis 1, axis 2, the wagon box in the middle of boghi 1 and 2 for the empty wagon. In all charts, RMS accelerations, measured on the axis and body, decrease with speed.

The RMS values calculated for boghi 2 is in all cases higher compared to the other values recorded on the Y axis, in the case of empty wagon.

In the case of the values calculated for the vibrations recorded on axis 1 when crossing curve 2

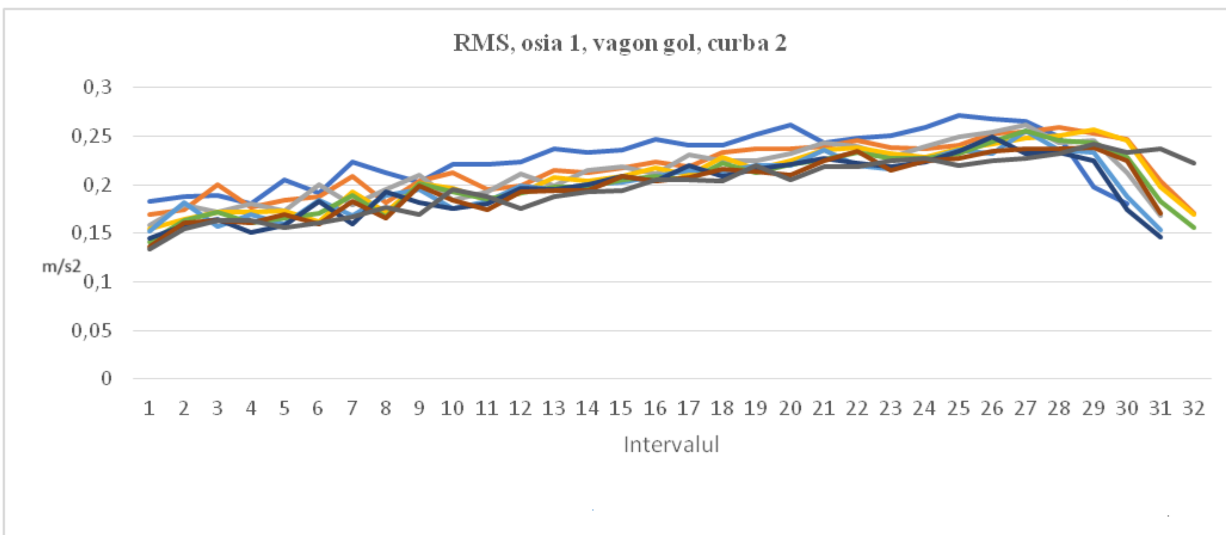


Fig. 10.2.1. RMS values recorded by the accelerometer mounted on the first axis, with the empty wagon, on the curve 1, at all 8 successive passes

When entering the curve in point 1, the RMS values are in the range of 0.133626 – 0.1827 and up to point 26 there is a zigzag increase up to the values of 0.242023 – 0.271271.

The following values up to point 32 are decreasing, eventually reaching the values 0.146559 – 0.222386

In the case of calculated values for vibrations recorded on axis 2

Fig. 10.2.2. RMS values recorded by the accelerometer mounted on the second axis, with the empty wagon, on the curve 2, at all 8 successive passes.

The first 3.4 points have increasing values reaching the values of 0.132397 – 0.155390, in points 8.9 is recorded and a peak of the RMS within the range of 0.11121 – 0,15901. Then the RMS values increase approximately linearly to point 23, 24 when a peak of values was recorded in the range of 0.142555 – 0.189196. By the end of the chart, point 32, is a sharp drop to the values of 0,143294 – 0,036465.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

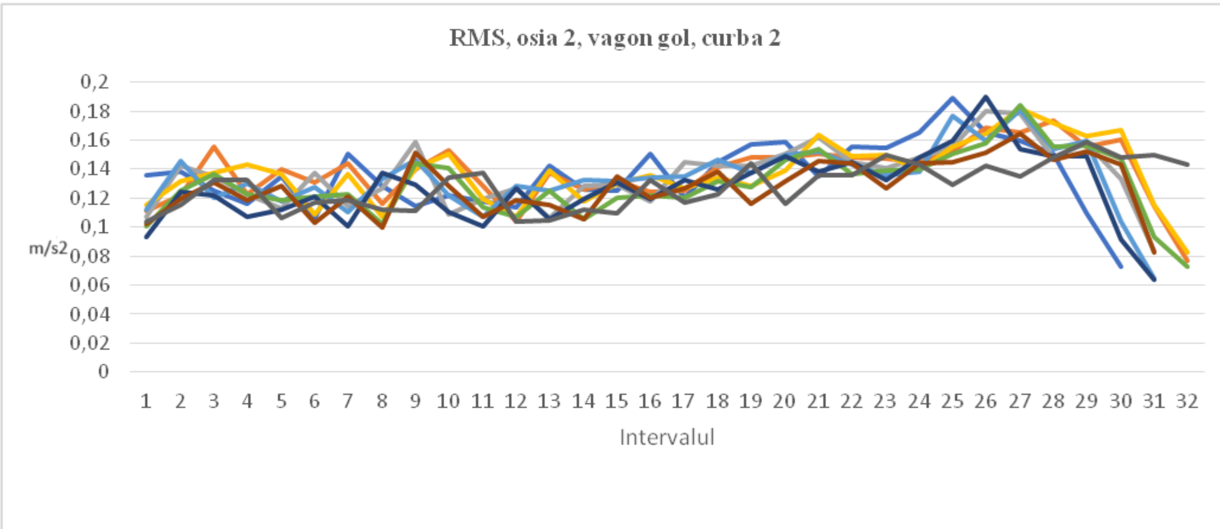


Fig. 10.2.2. RMS values recorded by the accelerometer mounted on the second axis, with the empty wagon, on the curve 2, at all 8 successive passes.

The first 3.4 points have increasing values reaching the values of 0.132397 – 0.155390, in points 8.9 is recorded and a peak of the RMS within the range of 0.11121 – 0,15901. Then the RMS values increase approximately linearly to point 23, 24 when a peak of values was recorded in the range of 0.142555 – 0.189196. By the end of the chart, point 32, is a sharp drop to the values of 0,143294 – 0,036465.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

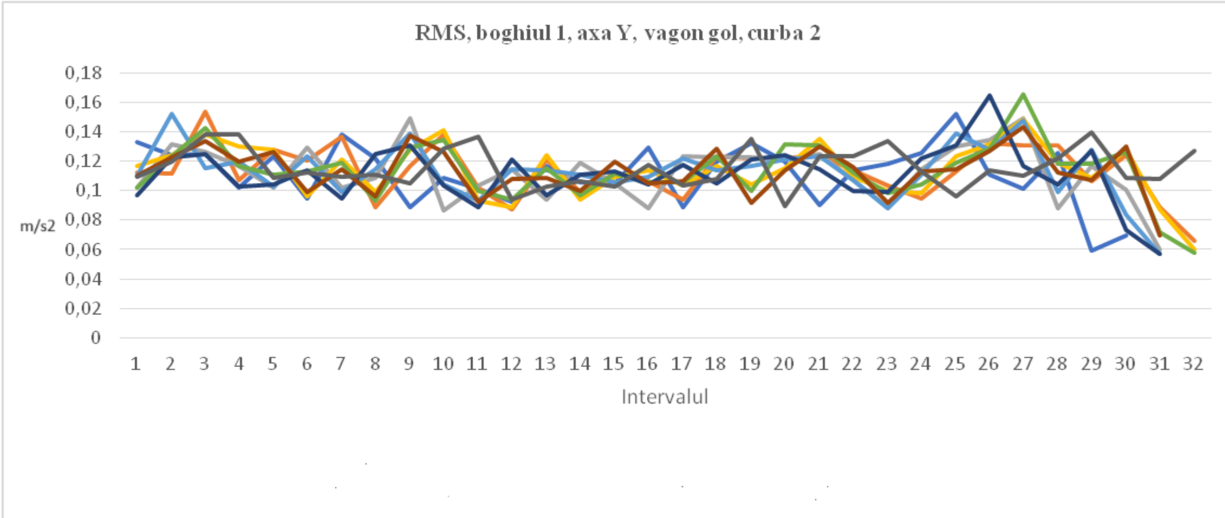


Fig. 10.2.3. RMS values recorded by the accelerometer mounted on boghiul 1, with the empty wagon, on the curve 1, at all 9 successive passes.

The RMS values calculated for the empty wagon, on the box of the wagon in the right of the boghi 1, at passing over the curve 2, have 3 peaks, the first at point 2.3 and reaches the values of 0,134015 – 0,154112, the second sharp increase was recorded at point 9-11, with values ranging between 0,086247 – 0,149737, the last peak of the RMS value is at points 25-27, with value ranging from 0,11361 – 0,165566.

After these increases there is a decrease to the values of 0,108103 – 0,057972.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 2

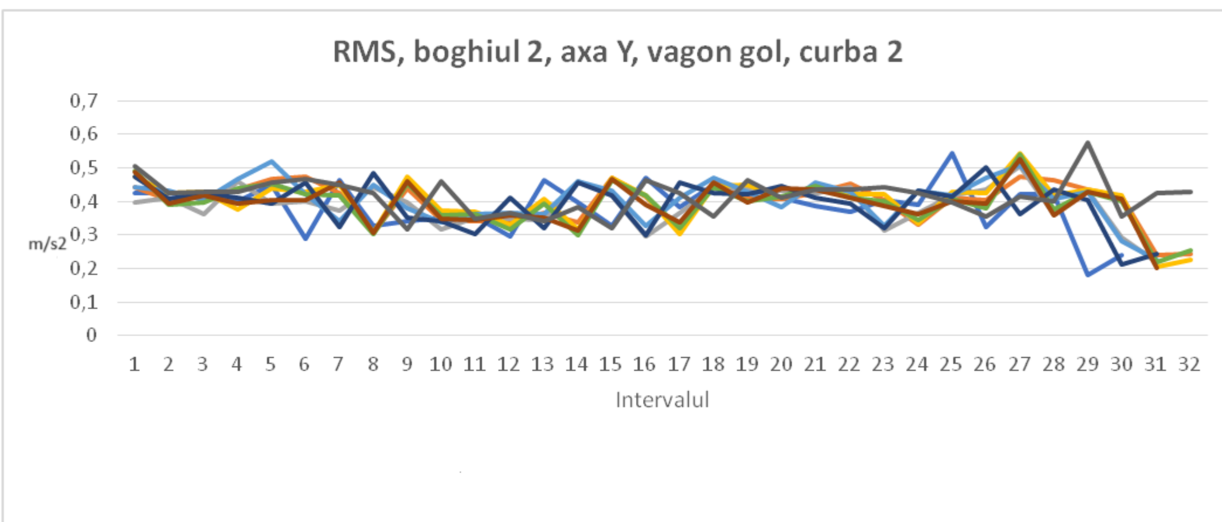


Fig. 10.2.4. RMS values recorded by the accelerometer mounted on boghiul 2, with the empty wagon, on curve 1, at all 8 successive passes

The RMS values calculated for the empty wagon, in the right of boghi 2, are approximately linear up to point 3, 4. The values in point 4, for all 8 passes, are in the range of 0.430237 – 0.394639. In the range of points 4-20 RMS has values with great variations, in the range 0.288351 – 0.469162. From point 24 to point 30 are values that vary sharply in the range of 0.321755 – 0.574726. The values of the last points drop abruptly to the value of 0.181207.

10.3. Analysis of the values calculated for the Medium Square Root in the case loaded wagon, at crossing curve 1.

Figures 9.3.1.–9.3.5. illustrate the variations of the mean square roots recorded on curve 1, at speeds of 105 km/h, 110 km/hour, 115 km/hr, right at axis 1, axis 2, the wagon box in the middle of boghi 1 and 2 for the loaded wagon. In all charts, RMS accelerations, measured on the axis and body, decrease with speed.

The RMS values calculated for axis 2 is in all cases higher compared to the other values recorded on the Y axis, in the case of the loaded wagon.

In the case of calculated values for vibrations recorded on axis 1

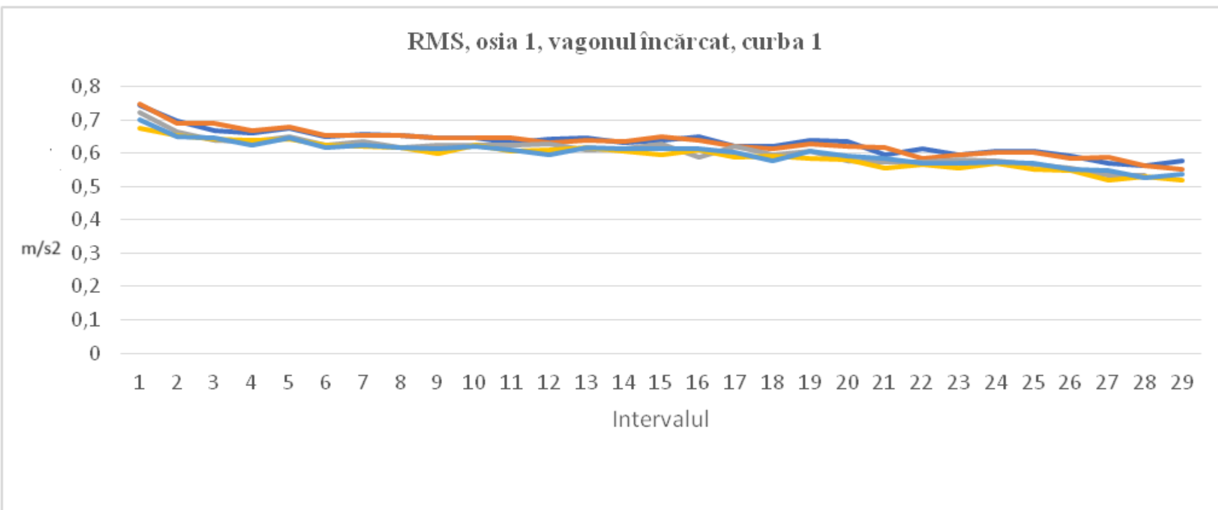


Fig. 10.3.1. RMS values recorded by the accelerometer mounted on the first axis, with the wagon loaded, on the curve 1, at all 5 successive passes.

The RMS value for the loaded wagon, at axis 1, on curve 1, decreases without major variations from the values of 0,700202 – 0,720639 in point 1 to 0,536079 – 0,57564 in point 29.

In the case of calculated values for vibrations recorded on axis 2

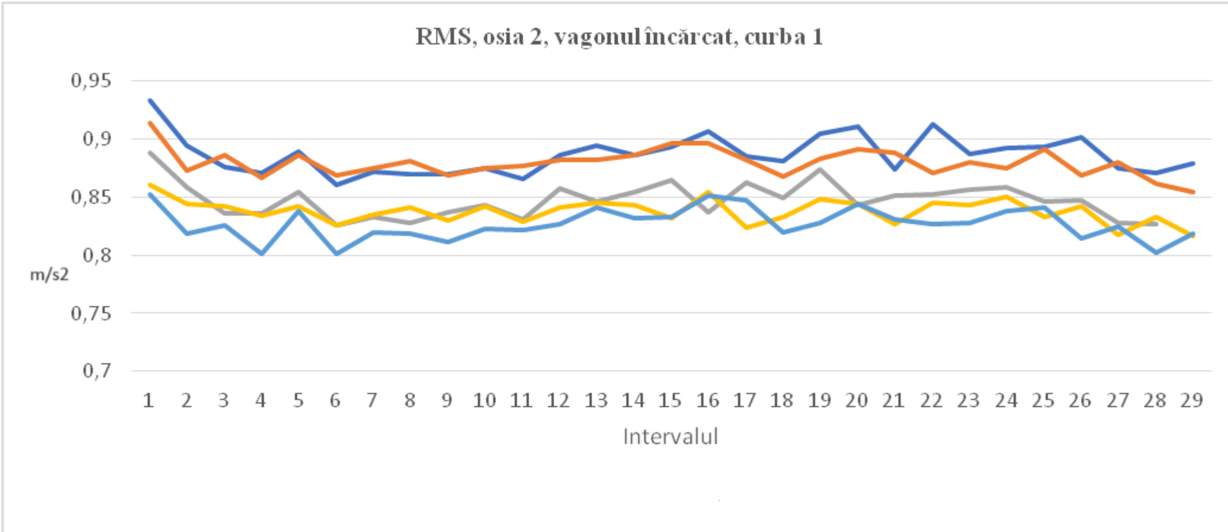


Fig. 10.3.2. RMS values recorded by the accelerometer mounted on the second axis, with the wagon loaded, on the curve 1, at all 5 successive passes.

In the case of the loaded wagon, the RMS values, calculated for the vibrations recorded on axis 2, in the first 2 points decrease from the values of 0.852322 – 0.933535, to the value of 0.873121 – 0.818554, then the rms values vary in the range of 0.801009 – 0.913149 without major variations.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

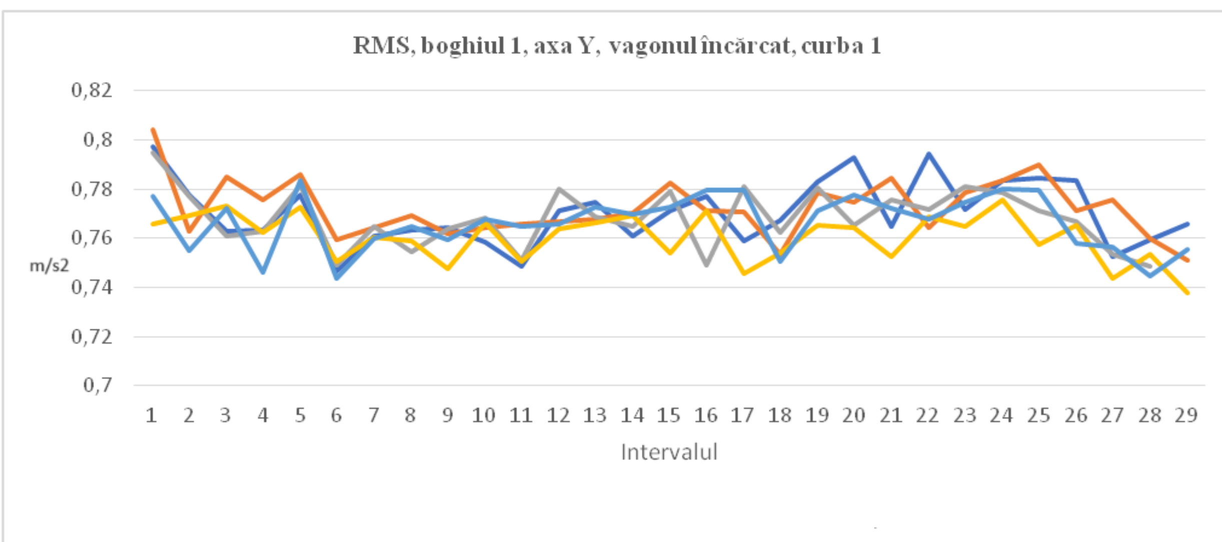


Fig. 10.3.3. RMS values recorded by the accelerometer mounted on the box of the wagon, in the right of the boghi 1, with the car loaded, on the curve 1, at all 5 successive passes.

In the case of RMS values calculated for the loaded wagon, in the right of boghi 1, recorded at all 5 passages, have a variation in the range of 0.804203 – 0.737512 for the whole measure.

Cannot set a line to illustrate the variation of values.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 2

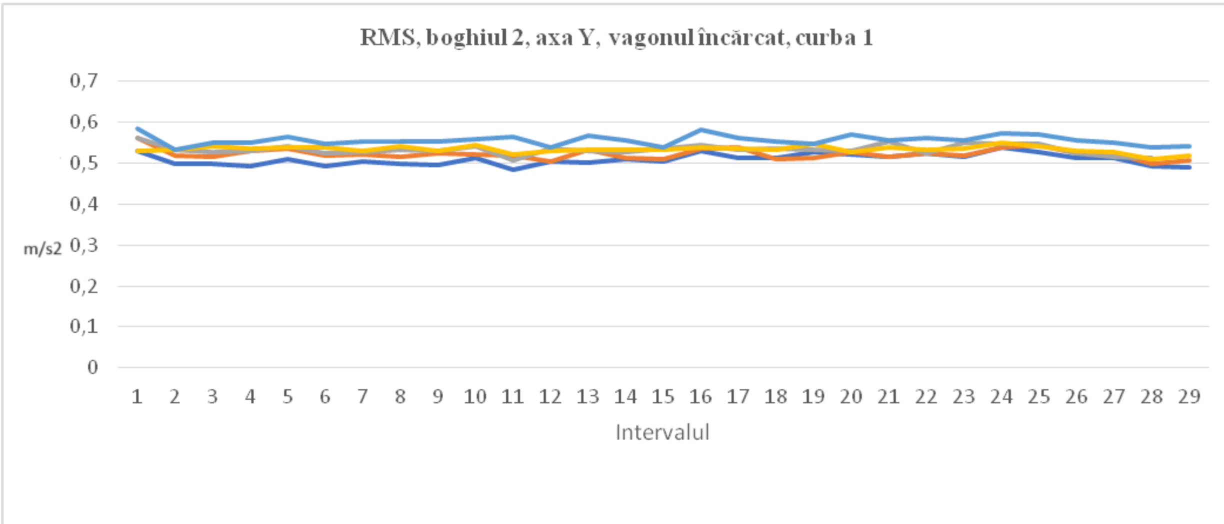


Fig. 10.3.4. RMS values recorded by the accelerometer mounted on the box of the wagon, in the right of the boghi 2, with the car loaded, on the curve 1, at all 5 successive passes.

The RMS value in the case of the wagon loaded, in the right of boghi 2, at a speed of 105 km/h, on the curve 1, decreases without major variations from the values 0,585382 – 0,528824 in point 1, to 0,536079 – 0,57564 in point 29.

10.4. Analysis of the values calculated for the Medium Square Root in the case loaded wagon, when crossing curve 2

Figures 9.4.1.–9.4.5. illustrate the variations of the mean square roots recorded on curve 2, with speeds of 105 km/h, 110 km/hour, 115 km/hr, right on axis 1, axis 2, the wagon box in the middle of boghi 1 and 2 for the loaded wagon. In all charts, RMS accelerations, measured on the axis and body, decrease with speed.

The RMS values calculated for axis 2 is in all cases higher compared to the other values recorded on the Y axis, in the case of the loaded wagon.

In the case of calculated values for vibrations recorded on axis 1

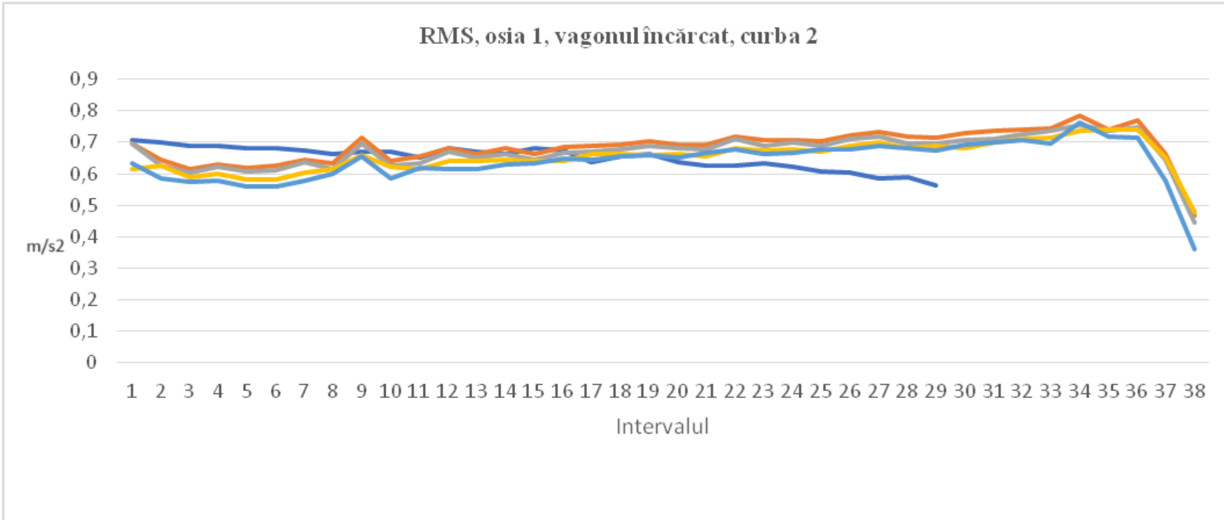


Fig. 10.4.1. RMS values recorded by the accelerometer mounted on axis 1, with the wagon loaded, on curve 2, at all 5 successive passes

In the case of the loaded wagon, the RMS values for axis 1 are almost linear for points 1 to 34 and are in the range of 0.783933 – 0.559169 from point 34 to point 37, the value drops abruptly to 0.359528.

In the case of calculated values for vibrations recorded on axis 2

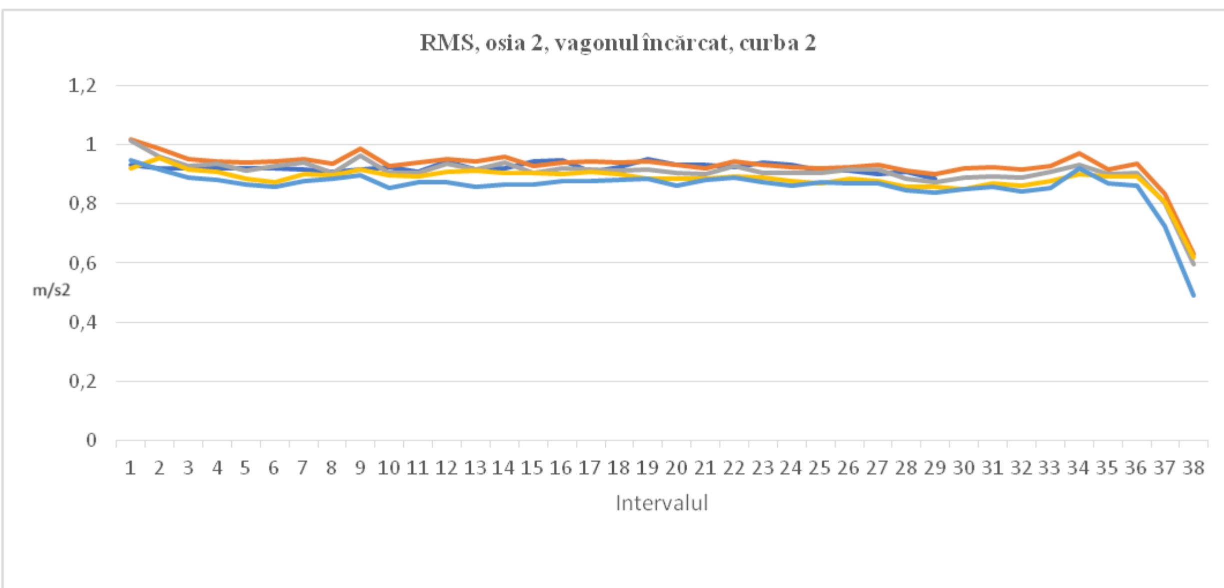


Fig. 10.4.2. RMS values recorded by the accelerometer mounted on axis 2, with the wagon loaded, on curve 2, at all 5 successive passages In the case of the wagons loaded the RMS value for axis 2 is almost linear for points from 1 to point 34 and is in the range of 1,015442 – 0,855355 from point 34 to point 37, the value drops abruptly to 0,491002.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

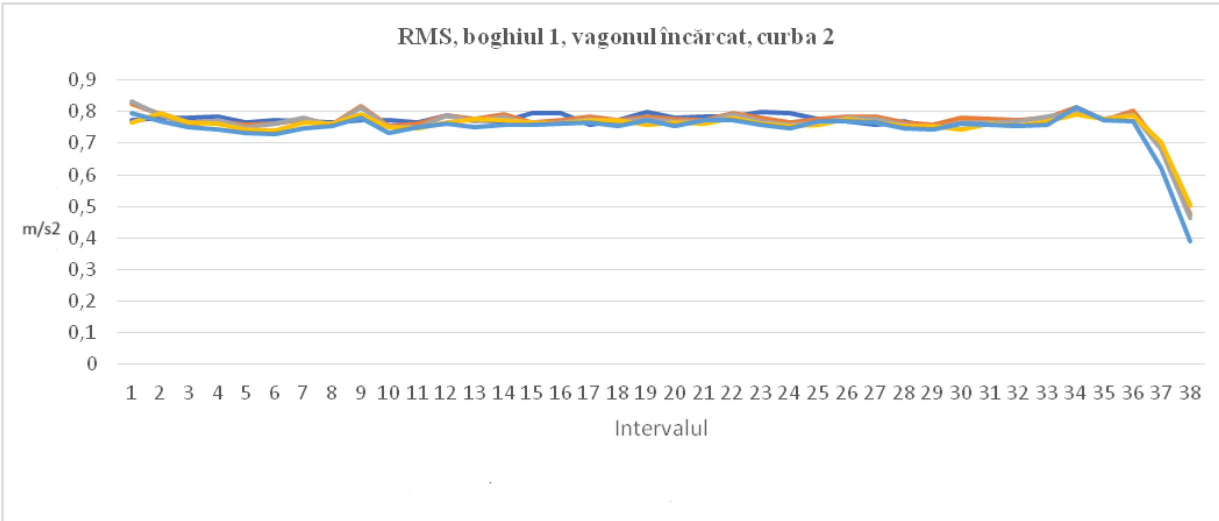


Fig. 10.4.3. RMS values recorded by the accelerometer mounted on the box of the wagon, in the right of boghi 1, with the car loaded, on the curve 2, at all 5 successive passes.

In the case of the loaded wagon the RMS values, for the accelerometer mounted on the wagon's box, at boghiul 1, are almost linear for points from 1 to point 34 and are within the range of 0,83321 – 0,732474 from point 34 to point 37, the value drops abruptly to 0,390711.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 2

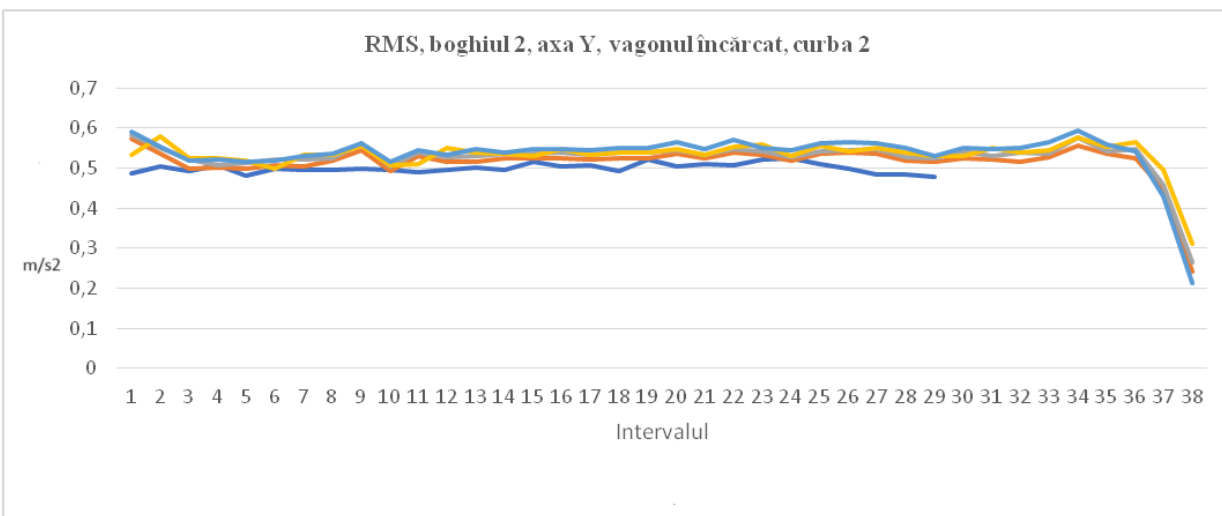


Fig. 10.4.4. RMS values recorded by the accelerometer mounted on the box of the wagon, in the right of boghiu 2, with the car loaded, on the curve 2, at all 5 successive passes.

In the case of the loaded wagon the RMS values, for the accelerometer mounted on the wagon box, at bogue 1, are almost linear for points from 1 to point 34 and are within the range of 0,590369 – 0,540111 from point 34 to point 37, the value drops abruptly to 0,213145.

In the case of the loaded wagon, the time interval while the measurements were recorded was longer than the time period for the empty wagon case, so the vibrations were measured when the wagon comes out of the curve, the values recorded on the Y axis in the last 9 seconds drop sharply, as a result of the decrease in the centrifugal force that occurs when crossing the curves.

Chapter 11

Analysis of calculated values for Average Square Root of vibrations measured on the Z axis

In the case of the unloaded and loaded carriage, the analysis of the values obtained shows that the highest values of vibrations were recorded on the carriage box in the second boghium measured on the Z axis.

This section presents the analysis of the characteristics of vibrations, measured on the Z axis, on the wagon box at boghi 1 and 2 based on the processing of recorded experimental data.

11.1. Analysis of calculated values for the Medium Square Root in the case of an empty wagon, when crossing curve 1

Figures 9.1.1.–9.1.9. illustrate the variations in the mean square roots values recorded on curve 1, at speeds of 125 km/h, 130 km/hr, 135 km/hour, right in the box of the wagon in the middle of boghi 1 and 2 for the empty wagon.

In all charts, RMS accelerations, measured on the body, decrease with speed.

The RMS values calculated for boghi 2 are in all cases significantly higher than the other values recorded on the Z axis.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

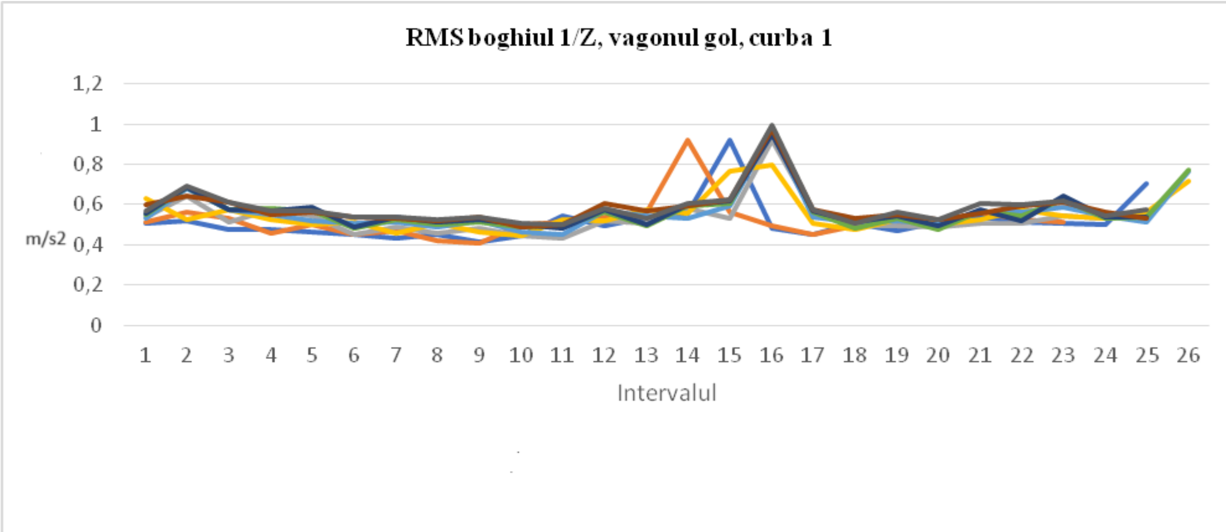


Fig. 11.1.1. RMS values recorded by the accelerometer mounted on boghiul 1, with the empty wagon, on the curve 1, at all 9 successive passes.

In the case of an empty carriage, when crossing curve 1, the RMS values recorded on the carriage box at boghi 1, are linear, with values ranging from 0.410781 to 0.574441, with one exception, in points 14, 15, 16 is a peak that reaches the value of 0.993823. The peak value is delayed, it is not at the same point for each pass, because the start of records is not done exactly from the same spot every time.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 2

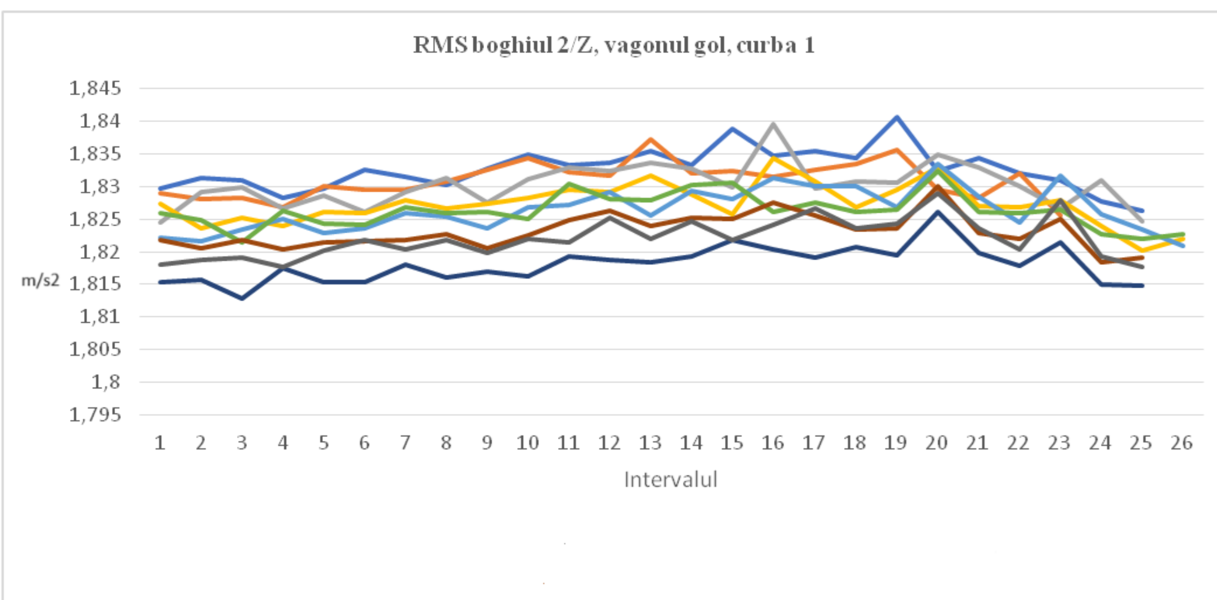


Fig. 11.1.2. RMS values recorded by the accelerometer mounted on boghiul 2, with the empty wagon, on the curve 1, at all 9 successive passes In the case of the Empty Wagon, at the passing

over the Curve 1, the RMS value recorded on the box of the wagon at the boghul 2, are linear, with values ranging from 1,812836 – 1,840583.

11.2. Analysis of the values calculated for the Medium Square Root in the case of an empty wagon, when crossing curve 2

Figure 9.2.1.–9.2.8 illustrates the variations in the mean square roots values recorded on curve 2, at speeds of 125 km/h, 130 km/hour, 135 km/hr, in the box of the wagon in the middle of boghi 1 and 2 for the empty wagon. In all graphs, the RMS accelerations measured on boghiu 2 are higher.

The RMS values calculated for boghi 2 are in all cases higher than the other values recorded on the Z axis in the case of an empty wagon.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

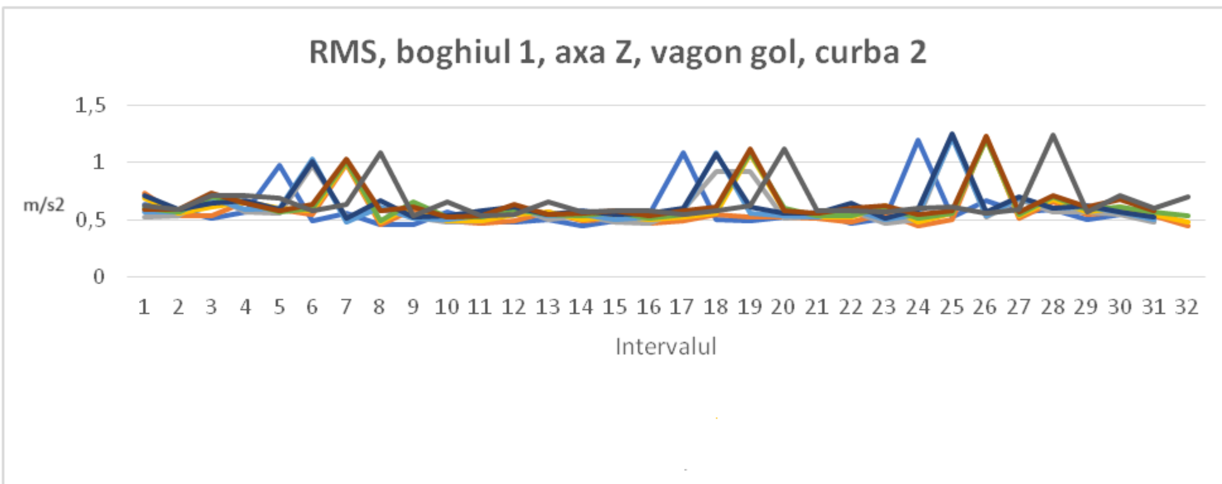


Fig. 11.2.1. RMS values recorded by the accelerometer mounted on boghiul 1, with the empty wagon, on the curve 2, at all 9 successive passes.

In the situation when the measurements were made with the empty wagon at crossing the curve 2, the RMS for the vibrations recorded on the Z axis, at boghiul 2, have 3 peaks. The values for linear segments are in the range of 0.709542 – 0.568399. The peaks are recorded in paragraphs 7, 19, 26. The values are within the value range of 0.969841 – 1.238311.

Peak values are deferred, because at each pass the start of records

is not made from exactly the same point.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 2

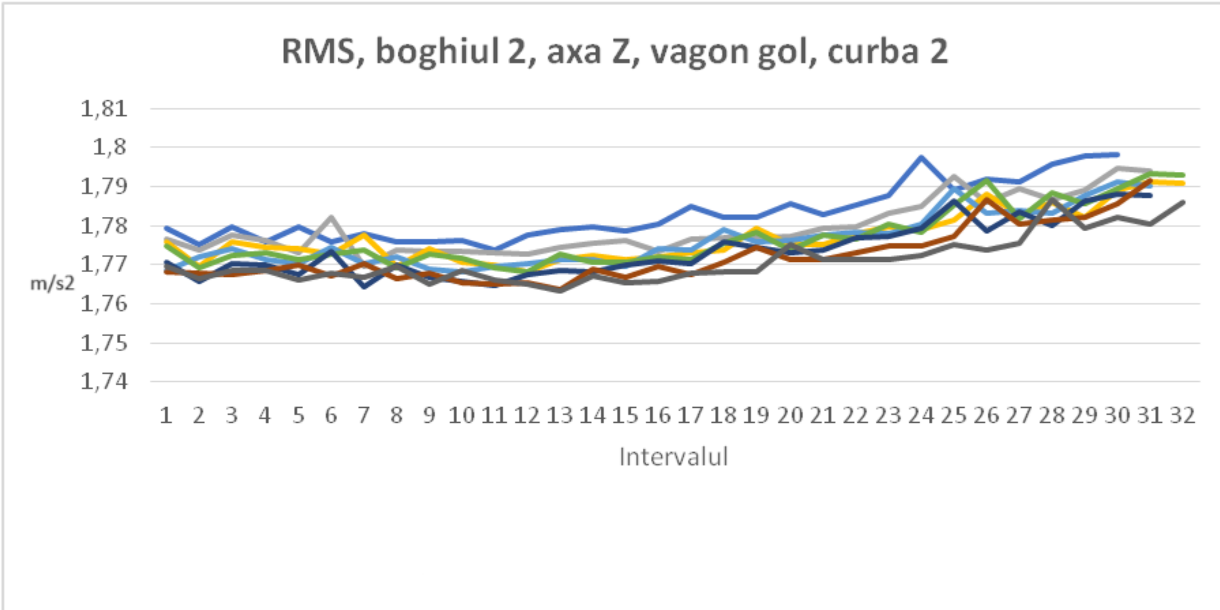


Fig. 11.1.4. RMS values recorded by the accelerometer mounted on boghiul 2, with the empty wagon, on the curve 2, at all 8 successive passes.

In the case of an empty carriage, when crossing curve 2, the RMS values recorded on the carriage box at boghiu 2 are linear, slightly increasing, with values ranging from 1,76645 to 1,797593.

11.3. Analysis of calculated values for the Medium Square Root in the case of the loaded wagon, when crossing the curve 1.

Figures 9.3.1.–9.3.5. illustrate the variations in the mean square roots values recorded on curve 1, at speeds of 105 km/h, 110 km/hour, 115 km/hr, right in the wagon box at the middle of boghi 1 and 2 for the loaded wagon.

The RMS values calculated for boghi 2 are in all cases higher than the other values recorded on the Z axis, in the case of the loaded wagon. In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

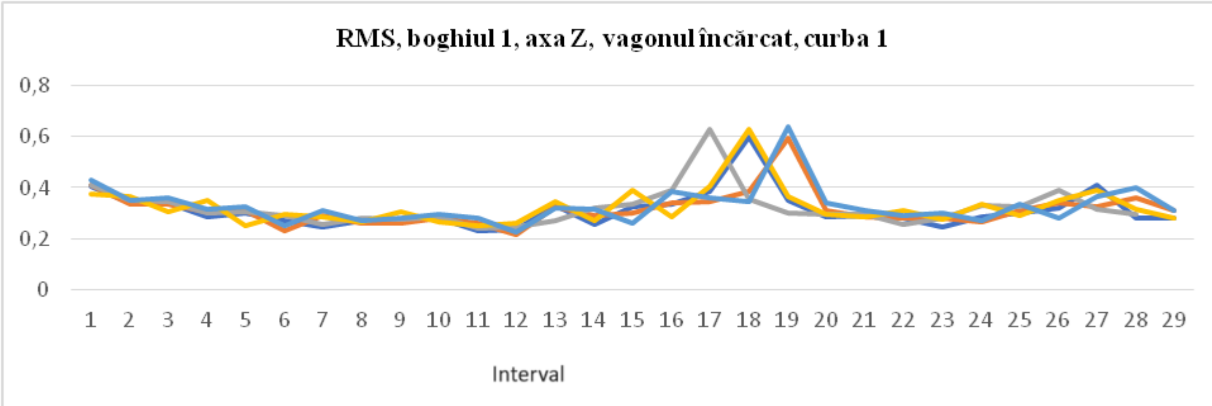


Fig. 11.3.2. RMS values recorded by the accelerometer mounted on boghiul 1, with the empty wagon, on the curve 1, at all 9 successive passes.

In the case of a loaded carriage, when crossing the curve 1, the RMS values recorded on the carriage box at boghi 2, in the direction Z, are linear, with values ranging from 0.642984 to 0.519626, with one exception, in paragraphs 17, 18, 19 is a peak that reaches the value of 0.83044.

The peak value is delayed, it is not at the same point for each pass, because the start of records is not done exactly from the same spot every time.

11.4. Analysis of the calculated values for the Medium Square Root in the case of the loaded wagon, when crossing the curve 2

Figures 9.4.1.–9.4.5 illustrate the variations of the values of the medium square roots recorded on the curva 2, at speeds of 105 km/h, 110 km/hr, 115 km/hour, right in the box of the wagon in the middle of the boghi 1 and 2 for the charged vagon.

The RMS values calculated for boghi 2 are in all cases higher than the other values recorded on the Z axis, in the case of the loaded wagon.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 1

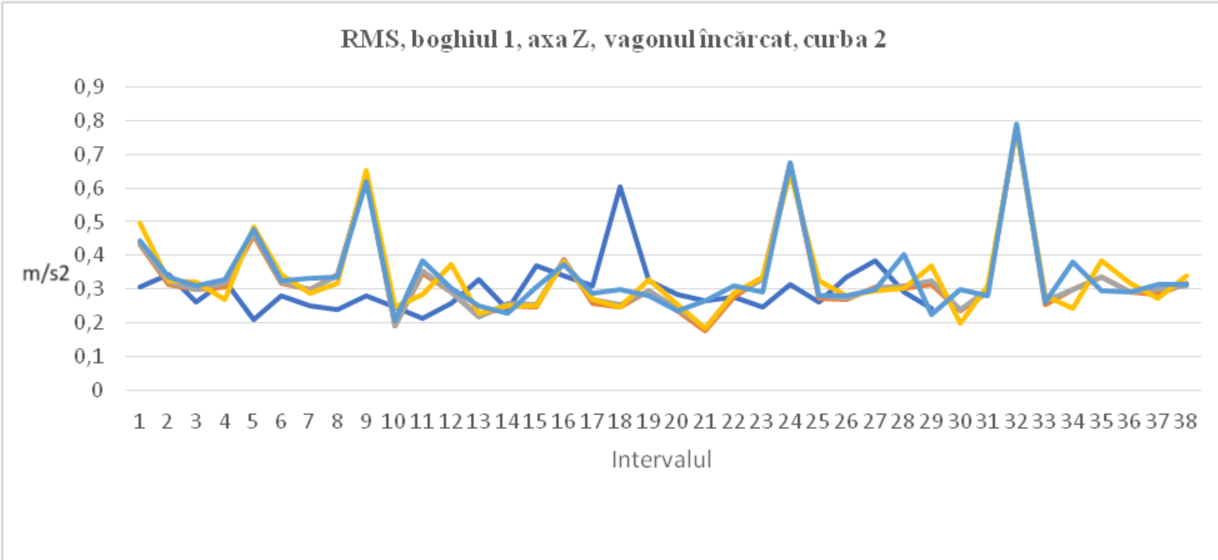


Fig. 11.4.1. RMS values recorded by the accelerometer mounted on boghiu 1, with the wagon loaded, on curve 2, at all 5 successive passes.

The values calculated for the RMS in the case of vibrations, measured on the Z-axis, recorded on the wagon box in the middle of boghi 1, when the vagon was loaded and crossed the curve 2, have several leaps of values.

Item 5 9 18 24 32 RMS value 0.479230 0.620311 0.602998 0.674525 0.789077 The values calculated for the intermediate points of these peaks are in the range 0.443319 – 0.186427.

In the case of the values calculated for the vibrations recorded on the wagon box at boghi 2

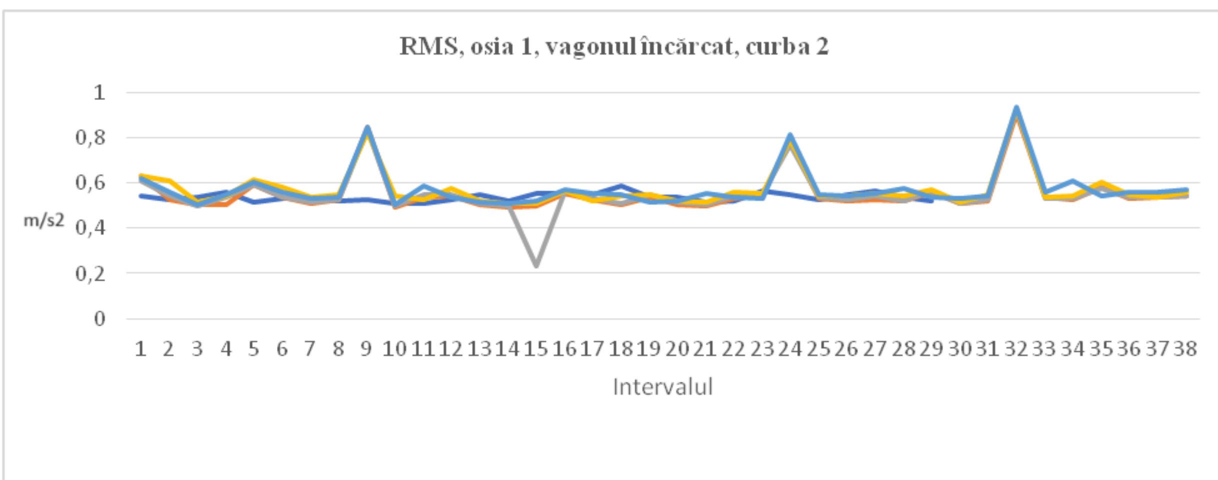


Fig. 11.4.2. RMS values recorded by the accelerometer mounted on boghiul 1, with the empty wagon, on curve 1, at all 9 successive passes.

The values calculated for the RMS in the case of vibrations, measured on the Z-axis, recorded on the wagon box in the middle of boghi 2, when the vagon was loaded and crossed the curve 2, have several leaps of values.

Item 5 9 15 24 32 RMS value 0.606324 0.847702 0.230913 0.817474 0.938078 The values calculated for the intermediate points of these peaks are in the range 0,504703 – 0,0,585451.

The RMS values for vibrations measured on the Z axis have a large range of values, due to the critical points in the runway that cause the vibrations to occur at the Z-axis.

Chapter 12

Theoretical simulation of wagon behavior and comparison data

Matlab simulation refers to the process of using the MATLAB software environment to model and analyze the behavior of a system or process. MATLAB offers a comprehensive set of tools and functions that enable the creation of simulations for various fields, such as engineering, physics, finance, and more.

An overview of the steps involved in configuring and running a MATLAB simulation.

Model Creation: The first step is to define the mathematical model that represents the system or process that you want to simulate. This involves formulating the governing equations, the initial conditions and any relevant parameters. MATLAB provides a convenient platform for defining these equations using symbolic mathematical tools or by writing functions. In the case of the thesis we used the model presented Dynamics of railway vehicles by Ioan Sebeşan Discretization: In many cases, continuous mathematical models have to be discretized to perform numerical calculations. Discretion involves dividing the system into smaller time or spatial steps, usually using methods such as finite difference, finite elements, or finite volume techniques. MATLAB provides built-in functions and tools to facilitate the discretionization process.

Simulation configuration: Once the pattern is defined and discretized, you need to configure

simulation parameters. This includes specifying the simulation time interval, the time step size and any other relevant settings. MATLAB provides functions to configure your simulation environment, allowing you to customize the simulation according to your requirements.

Simulation execution: After configuring the simulation, you can run it by calling the corresponding MATLAB functions. The simulation will progress iteratively, advancing the state of the system in each step of time according to the defined equations and integration method. MATLAB provides tools for monitoring and visualizing simulation results in real time or in post-simulation analysis.

FINAL CONCLUSIONS

C.1. GENERAL CONCLUSIONS All efforts must be directed towards ensuring the safety of the movement of railway vehicles, including the evaluation of dynamic driving behaviour, which is an important factor, especially in newly built vehicles, in which the ability to ensure stability and safety on the railroad has not yet been demonstrated.

Improving the dynamic performance of freight wagons is important given that they do not operate on special lines, but are operated in mixed traffic.

Mixed traffic should not affect the driving regime of passenger cars, which is why improving dynamic performance is essential.

During the movement of freight wagons there may be significant rail wear and damage, which can affect both the quality of movement, but above all the safety of movement.

In overhanging curves, freight wagons generally travel below the nominal speed of the curve, which leads to an inclination of the body towards the inside of the Curve with a greater load effect of the inner thread than the outer one.

Also, in curves, at joint lines, the runway may present so-called discontinuous turns, with the appearance of shock angles. When driving over these curves, dynamic shock forces will appear, which in addition to damaging the profile of the wheel and rail, can even cause the vehicle to deviate.

It must be borne in mind that freight wagons travel in international traffic, and in Western European countries, the conditions related to the protection of the runway are much more restrictive.

In this respect, the determination, study and evaluation of the dynamic driving behaviour of freight wagons becomes a necessity. Dynamic behavior is assessed on the basis of two well-defined parameters, namely, determining traffic safety and determining the driving behaviour of the vehicle. These two assessments are considered comprehensive in terms of determining the dynamic driving behaviour of a railway vehicle.

However, this demonstration of the safety capability of a wagon is not easy to in practice, as many railway administrations do not have the technical means to demonstrate the safety capacity of the rolling stock. This relates to the adaptations of the railway lines of national rail infrastructure companies or the existence of test railroad fields, suitable for the conditions of validation of rail technical designs for the various types of newly constructed vehicles or performing upgrades and technical renovations.

At the same time, for the demonstration and validation of new railway technical projects on the newly constructed rolling stock, it is necessary to have specialized staff with high professional training, with expertise in the field of rolling material, to ensure a certification and attestation as close as possible to the required technical conditions and with the minimization of technical errors. This can only be achieved by ensuring a high qualification of technical staff, by participating in training courses, symposia and conferences, exchanging experiences with specialists from other countries, and by engaging in European multidisciplinary projects in the field of rolling stock with development within a certain time frame.

Also, for a proper validation of new rolling stock projects, in addition to technical capabilities (e.g.: test lines, railway test polygons, etc...) and technical personnel must be highly qualified. Calibration is absolutely necessary

devices, appliances and stands, as often as possible from a technological point of view, for the verification of the characteristics of railway vehicles and the evaluation of the results. This ability to analyze and certify the results obtained must be validated by calibration of the devices and demonstrated by their periodic verification and annual evaluation of technical personnel serving these devices by a national accreditation body.

C2 ORIGINAL CONTRIBUTIONS

We have chosen to study the dynamic behavior of rolling stock when driving in the curve because in these areas the centrifugal force appears and the danger of drifting is greater. If in the curve the wagon meets all the safety conditions, as a rule, in the alignment, no more deviation conditions occur.

The rolling stock that was planned to be studied was a boghiuri wagon, a tank wagon was chosen because for this type of wagon the approval was obtained from the Romanian Railway Authority – AFER, the owner of the Făurei Railroad Testing Centre.

The results obtained can be generalised to all cargo wagons on boghiers and to passenger wagons, the principles are the same.

We validated the theoretical results through tests and tests, carried out personally at the Railway Testing Centre, for the tank wagon. At the same time, following the analysis of the results obtained, with the help of the MATLAB program we simulated the conditions of the trials, and the theoretical results we compared with the practical results.

By placing the acceleration transducers in the horizontal plane at the level of the boghiu frames, above the axles from the outer thread of the runway of the test polygon line at Făurei, the safety of the movement of the tank wagon was assessed.

Measures for assessing the quality of driving were the maximum values of the vertical and transverse accelerations obtained, as well as the RMS values on vertical (Z axis) and horizontal directions (axa Y).

The results obtained generated an extensive analysis of them, on the basis of which it was possible to carry out an adequate evaluation of the tank wagon in terms of dynamic driving behavior. Following the evaluation, it was established that in terms of rolling safety and walking quality, the rolling stock meets very well the requirements imposed with regard to dynamic rolling behavior. In addition, the safety against drainage is ensured, and there is no danger in terms of draining it under normal operating conditions and operation.

The evaluation of the data processed constituted an essential basis in the analysis and assessment of the safety of movement and the quality of running of the tank wagon, and it was found that the technical design of them was within the limits imposed.

From the study of the vibrations measured by the accelerometers mounted on the box of the wagon in the right of the boghi 1 and 2, on the Z axis, it turns out that in some places are values much higher than the mean values.

Depending on the speed of movement and the time when the peaks of values were recorded, the place where they were registered was determined.

Chapter 6 presents the characteristics of the line on the large test ring at Făurei, the place where the tests were carried out. Theoretically obtained data and field checks established the areas that determined the maximum values of vibrations.

When driving on the first curve from km 2 to km 5 there was only one peak of values, in the direction of a level passage between km 3+050 to 3+650, shown in figure 1.

Fig. 1. Passage over the railway from km 3+050 to km 3 +650

On the second curve from km 9 to km 12 there were 3 peaks of values.

The first peak was measured at passing over the passage between the kilometre positions 9+800 and 10+350 illustrated in Fig.2.

Fig.2. Passage from km 9+800 to km 10+350 The second peak was recorded when crossing the pond between the kilometre positions 10+850 and 11+180, shown in figure 3.

Fig.3. The bottom from km 10+850 to position 11+180 The third peak was recorded at the bottom from the input signal on the large ring, figure 4.

Fig.4. The highest value of vibrations was recorded when crossing the line of the Great Ring at the Făurei Railway Test Center. The interruption of the railway wire generates the highest vibrations.

In the center of the test ring was a oil mine (a probe), which leads to the passing of heavy cars over the studied passage. The high values of vibrations measured on the Z axis illustrate the negative effects on the railway status of the level pass.

For effective monitoring at minimum cost, I propose a method of detecting railway defects in real time, without additional costs generated by the movement of a track measuring motor or the pulling of a railroad measuring wagon.

Currently, there are data acquisition systems that operate wirelessly.

Presentation of a universal data procurement system The Data Procurement System is the perfect tool for all test and measurement situations. It has the unique ability to record any signal or information received from terminals.

Each module is an autonomous mobile data procurement unit for vehicle testing, integrated in real time, for bench or portable testing, for service work, or for continuous monitoring activities.

The system has high measurement accuracy thanks to patented technology, long-term stability along with an integrated calibration certificate.

Easy to use, small and portable, intuitive operation through HBM's Catman software.

Open to different software platforms: LabView, Visual Studio.NET, DIAdem, CANape, DASYlab and more!

A reliable measuring chain, extremely precise data acquisition system, can be perfectly combined with sensors to have a complete measurement and testing solution. From sensor to software: simply "connect and measure". Versatile applications, can be used for monitoring the health of the infrastructure.

Fig. 1 presentation of the measurement chain of the data procurement system Installation of this data acquisition system in the locomotive and receptors that measure the vibrations on the Z axis, on the wagon box, in the direction of the boghi 1 and 2, makes it possible at the end of a race, after examining the data recorded by the system, to tell with accuracy where are critical points to the infrastructure travelled.

The proposed method leads to preventive or predictive maintenance of bridges, tunnels, and railways.

It is a modular solution for the effective monitoring of tracks, but also of trains subject to various internal and external factors that can cause wear or failure.

This can happen, for example, due to damage, an incorrect construction process or an extreme situation resulting from an accident or an environmental load. In order to be able to notice these material changes and react properly before serious damage occurs, the implementation of a damage identification system is crucial.

Monitoring structural behavior can detect anomalies over time, thus enabling more efficient implementation of maintenance and repair actions, with a direct impact on the reduction of operating costs.

Replacing program based maintenance with condition based maintenance is the primary objective of infrastructure monitoring, providing the following benefits:

 Increases traffic safety.

 Continuous observation Maintenance automation Early detection of damage enables immediate response, extending the major review cycle, saving cost and time.

Structural Health Monitoring System for Railway The railway industry has undergone long historical developments and operations. In recent centuries, people have relied on the industry's secure transport services, both inside and between cities.

Railways also play an important role in modern logistics and freight distribution.

Solutions for reliable and robust railway measurement, testing and analysis results

Whether physical testing of individual components or whole vehicles is carried out in the laboratory, on development test benches or on the track, under realistic conditions, it is necessary to examine: safe and reliable operations structural durability, fatigue, robustness and reliability propulsion performance and efficiency compliance with legal requirements and international standards (e.g., EN 15227, EN 14363) effective data testing and analysis The flexible integration of measurements of all types in a single configuration, increases the efficiency of development, making the development and testing process easier and less risky, enabling manufacturers to develop efficient vehicles and designed for maximum safety.

Analysis and diagnosis, maintenance and repairs: measurements in and for the railway.

Predictive and condition-based monitoring is important to ensure safety, cost efficiency and smooth and easy operation of the railway.

Regular inspections and railway maintenance are mandatory in order to avoid conditions causing defects to the vehicle or infrastructure.

Highly accurate measurements of trains with on-board monitoring systems, which capture either the vehicle itself or the status of the track, provide important data and insights for modern maintenance solutions.

Previous measurement methods, diagnosis or monitoring, usually only provide reports of shutdown time or inaccurate measuring data. Usually, such data do not provide an overview and cannot be used for reliable forecasting processes. Equipping the vehicle and infrastructure with dedicated measurement technology is therefore indispensable [140-143].

Monitoring of tunnels, bridges and trains along the road in rail infrastructure and civil engineering The load and voltage measurements applied are necessary to observe material changes and react in time. A reliable monitoring system can detect anomalies over time, thus allowing for more efficient implementation of maintenance and repairs, which immediately leads to reduced operating costs.

Replacing program-based maintenance with conditional maintenance is the primary objective of infrastructure monitoring.

I am currently involved in the proposal for a project to produce a prototype that will detect the critical points of the railway infrastructure, which is to be mounted on all types of wagons.

The project is being carried out with the collaboration of the Polytechnic University of Bucharest, the Faculty of Transport, the Department of Rolling Material, the National Institute of Research and Development for Electrical Engineering ICPE-CA bucharest and TEHMIN Brasov.

4. CONCLUSIONS

The vertical vibrations of the bogie frame of a tank wagon both empty and loaded were analyzed, in this paper.

The analysis was based on RMS acceleration for several measurement sequences of empty and loaded situations. The results showed that the RMS acceleration is about two times higher in the second bogie frame than in the first bogie frame. Additionally, RMS has shown to increase acceleration with speed. The RMS acceleration analysis for several measurement sequences at the same speed has made visible the influence of track defects on the bogie vibrations. Due to the variability of amplitude defects along the track, the RMS acceleration is not equal to the same speed. They are dispersed over the range of approximately 0.03g to 0.9g. Based on the spectral analysis of the measured accelerations, rail defects have been identified. The highest values were recorded when passing over a joint rail.

Moving over a passage and a footbridge did not generate such high values. Future research may aim to analyze the correlation between the vibrations of the 2 bogies based on the measured acceleration. The correlation between the accelerations measured on the bogie frames can be the basis for the development of a method for monitoring the state of the vehicle's primary suspension.

Fig. 13. The joint

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