# Investigation of the Some Problems of Running Safety of Rolling Stock on the Ukrainian Railways

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**Summary**
The results of the evaluation of the running safety conditions of railway vehicles are presented by means of computer simulation. The localization of possible damages of bearing structures of high-speed train is determined with the help of calculation of the strength characteristics and the method of non-destructive metallography. There is the information about the development of software and hardware complexes providing an instrumental assessment of the technical condition of railway vehicles.

**Keywords:** rolling stock, derailment, computer simulation, strength characteristics, testing

## 1. Introduction

Ukrainian school of mechanics of the railway transport, which was set up in the middle of the last century by academician V. Lazaryan, laid the foundations of the dynamics and strength of the rolling stock of 1520 mm gauge. Then were first used mathematical modeling techniques to the study of the stability of the unperturbed motion of railway vehicles, forced vibrations of locomotives and wagons, as well as stationary and transient motions of trains.

Theory of rolling stock vibrations has become practically suitable largely through the efforts of many prominent scientists. The landmark in the development of methods for solving the problems of the dynamics of the rolling stock has become research work on the stability of high-speed jet-propelled car-lab [5]. Through this work, in addition to establishment of a record at the time speed on the track with gauge of 1520 mm, it has been validated mathematical model of the dynamics of high-speed rolling stock.

Over the past decades there was a rapid development of technical solutions to improve means of railway transport. It was promoted by a qualitatively new methods and means of scientific research of vehicles mechanics, in particular, particularly in the areas of computational mechanics and experiment.

## 2. Assessment of running safety of the railway vehicles

Train accidents that happen on the railways, as a rule, are causing significant material damage and, what is especially unacceptable, sometimes are associated with the risk to human life. Substantial part of traffic accidents are caused by poor dynamics of the train as a whole and of its individual vehicles. The reasons may lie in the deviations from the norms of the maintenance of rolling stock and track, as well as in non-standard modes of motion of the train. After analyzing of the derailment situation it is not always possible to identify and explain the reason for derailment due to the combined effect of many factors, some of which are not fixed by objective means of control on a moving train.

### 2.1. Determination of the probable causes of derailment of freight wagons

Determination of the causes of derailment of freight wagons is crucial for the development and implementation of measures to prevent accidents on the railways. Mechanical causes of derailment of rolling stock usually associated with an unfavorable combination of power interaction factors of wheel sets and track. Characteristics of the dynamic interaction of the rolling stock and track structure depends on a large number of factors that are associated with

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structural features of wagons, technical condition of their trucks, scheme of forming and modes of running of the train, and with the design and indicators of track maintenance.

Research and analysis of the possible reasons for derailment by means of performance evaluation of rolling stock and track interaction requires the construction of a generalized computer model of the dynamics of the system «train-wagon-track». Phased study of the longitudinal dynamics of the train, and then of the spatial oscillations of the wagon or group of wagons with the use of traditional approaches does not provide a complete solution of tasks related to the problems of derailment of certain units of rolling stock.

With the help of models of train longitudinal dynamics forces of intercar connections at a given mode of running and scheme of its forming are assessed [3]. However, these models do not allow assessing the impact of design features and technical condition of locomotives and wagons on running safety parameters taking into account the actual state of the track on the derailment section. According to the models of another type, which describe the spatial oscillations of wagons, forces of interaction with neighboring vehicles are treated as quasi-static. Such an approach can be considered acceptable for estimating parameters of running safety in the free-running mode but during the analysis of circumstances and determination of factors which mostly influencing vehicle stability against derailment it is insufficient.

For investigation of causes of derailment of freight wagons in the train the combined computer model of the dynamics of the train is offered (see Fig.1). This model which describes the longitudinal dynamics of the train on the traditional pattern includes a group of three or five wagons, each of which is represented by a spatial system of 19 solid bodies with 114 degrees of freedom. The location of listed model of three wagons unit in the train model as a subsystem of the whole system determined by the serial number of the wagon, which was the first derailed. In the scheme of tractive connection this wagon is located centrally. The parameters of three wagons unit, which are necessary for computer simulation, including wagon that derailed first, as well as the other vehicles in the train are determined according to actual data of official investigation.

In the case of derailment during the traction mode the relevant tractive characteristic of the train locomotive is formed in the model. If, however, derailment occurred during braking then the appropriate braking characteristics are formed. According to the given plan and profile of the track characteristics of the primary and secondary resistances to motion for each locomotive and wagon of the train are appointed on the section of derailment.

At creation of computer model designed for the prompt investigation of mechanical causes of derailment of rolling stock the following should be taken into account:

- characteristics of the interaction between all the vehicles of the train by the real scheme forming with the actual loading of wagons, types of draft gear of the automatic couplers,
- the mode of train running (traction, idle running, braking) and running speed at the section of derailment,
- plan and profile of the track on the section of derailment,
- design features and technical condition of wagons of the group,
- technical characteristics and track condition on the section of derailment.

Combined computer model of the train is formed on the basis of materials of an official investigation of the derailment on the principle of subsystems by the „folding" of the finished basic dynamics models of wagons [8]. Parameters necessary for the calculation are specified by the information corresponding to the actual derailment. The model of the dynamics of freight wagons is stored in a computer database and represents the most common types of railway freight wagons with trucks of model 18–100, for example, gondola, boxcar, hopper and tankcar [4].

For displaying the technical condition of the wagon trucks at the moment of derailment in the basic models there were introduced 112 special parameters with a total number of basic parameters of about 500. Special parameters characterize: the actual sizes of the center plate in the longitudinal and lateral directions, height of the cylindrical part of the body center plate and depth of the truck center plate, clearances be-

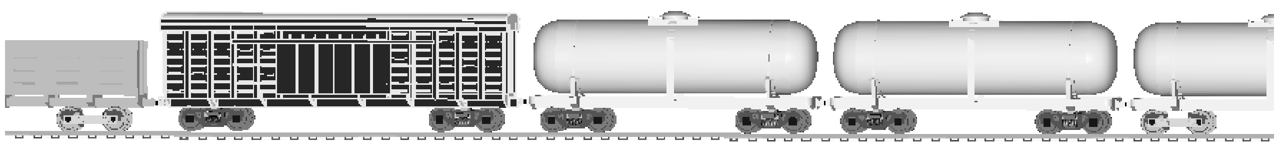

Fig. 1. Fragment of a computer model of train

tween side bearings of body and trucks, overstating of friction wedges relative to the reference surface of the bolster, wear of the friction plates and the box guides of the side frames, the height of springs of the spring group, and the wheel diameters (see Fig. 2).

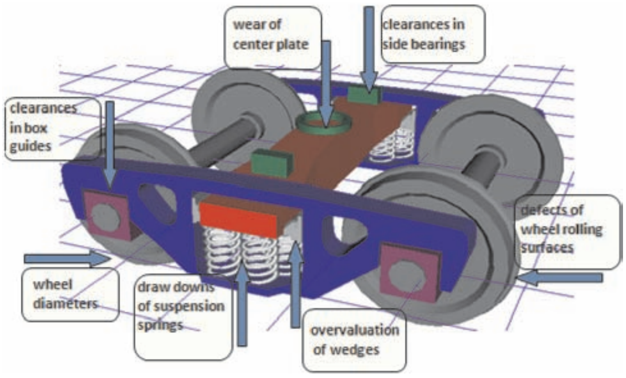


Fig. 2. The factors of the technical conditions of the trucks (model 18–100) in special model of freight car dynamics

The values of these parameters, which are established on materials of official investigation of the derailment, are the input information for the specification of the basic models. After their assuming there is an automatic recalculation of related quantities in the model, which is to perform the setting up of the model according to the actual technical condition of the trucks. The data obtained by reading of the wheel profilograms and processed by a special algorithm are entered into the computer model. Also, in the models of wagon group detected defects on the wheel threads are taken into consideration. In particular, this applies to flat spots that can have a significant impact on the interaction forces of the wheels and rails.

The equations of the train motion are automatically generated on the basis of the Newton-Euler formalism in the form of a system of differential-algebraic equations.

In the simulation of the dynamics of the rolling stock derailment special intention is required for setting the parameters of plan and profile of the track as well as for its characteristics at the section of derailment. To display the actual condition of the track it is advisable to use the files of measurements of the track-measuring car by which with the help of the developed algorithm irregularities in the horizontal and vertical directions are calculated.

By means of the developed model of the train dynamics through a computer experiment one can study the power interaction of the wagons and track with the definition of all dynamic parameters. In each simulation case the results obtained by integrating by the method of the Park with the automatic control of precision. Calculated values are the displacements, speeds and accelerations of all elements of the wagon which derailed first. According to the calculation the following parameters of running safety are identified:

- vertical and horizontal lateral forces of wheels and rails interaction – $Q$ and $Y$,
- lateral forces $H_l$ from each wheelset and the sum of lateral forces $H_{sl}$ from the wheelsets of one bogie,
- wheels safety factor $k_s$ against derailment according to the condition of rolling in of the wheel flange on the rail head,
- safety factor of lateral stability of the wagon against overturning $k_o$,
- the ratio $Y/Q$ of lateral and vertical forces of interaction between wheel and rail,
- lift of the wheel over the rail head.

In order to determine the situation of derailment according to the results of simulation output values are analyzed on the track sections $\Delta s_1$ and $\Delta s_2$ before and after the section of derailment.

The main difficulties in the use of computer simulation concerning the identification of possible causes of derailment lie in the fact, that, firstly, preconditions of the process of derailment is not defined formally enough, secondly, the computer model of the dynamics of the train includes a plurality of elements and connections with stochastic characteristics, and thirdly, obtaining a significant number of dynamic parameters as a result of experiments required to produce a certain approach to the analysis of the data obtained.

With the availability of prior information about the mechanism of derailment recognition of characteristics of the emergency situation under investigation is set by the criteria applicable to the mechanism concerned. Thus, in the case of the wagon derailment as a consequence of rolling of the wheel through the railhead occurrence of an event of derailment according with the results of the simulation is based on the basis of an analysis of the safety factor $k_s$, ratio $Y/Q$ and the check of duration $\Delta t$ of exceeding of the regulated limit values by the values abovementioned.

At the next stage the weighting coefficients of factors influence on the implementation of derailment are determined. For this purpose, according to the analysis two sets of variants H0 and H1, those at which the derailment may occur, and those at which the derailment will not occur are formed. The calculation of the weight of the factor A influence on the occurrence of derailment is carried out by calculating the conditional probability of occurrence of the derailment $H_0$ by Bayes formula [13]:

$$\lambda_i = P(H_0|A) = \frac{P(H_0)P(A|H_0)}{P(H_0)P(A|H_0) + P(H_1)P(A|H_1)}, \quad (1)$$

where the values of probability $P(H_0)$, $P(H_1)$, $P(A|H_0)$, $P(A|H_1)$ are calculated based on computer simulation. The results of calculations by formula (1) are represented as a list of factors $A_i$, which accompanied a certain derailment with the values of weighting coefficients $\lambda_i$ of their impact on the occurrence of the derailment.

## 2.2. Assessing of the impact of the technical condition of the dampers on the running safety of passenger wagons

Hydraulic dampers in the passenger rolling stock of the track of 1520 mm are often in fault condition. The main reasons for the poor state of dampers are the design defects, manufacturing technology and repairing of used dampers. Therefore, the actual problem is assessing the impact of the technical condition of the dampers on the safety parameters of passenger cars. To solve this problem the means of experimental studies and computer simulations were used.

In the experimental part of the work the wagon testing on dropping from the wedges was conducted. This is a standard procedure used at stationary test of rolling stock of 1520 mm gauge. It consists of natural oscillation excitation of a vehicle by rolling it through the wedges placed under the wheels in a specific pattern to induce the desired types of oscillations – bouncing, pitching, or sway. Tests were conducted with both the switched and switched off dampers.

Before the tests accelerometers for measuring the accelerations on the body and bogie frames in vertical and transverse directions were installed. Fig. 3 shows examples of oscillograms of the vertical accelerations of the body.

According to obtained records of dynamic processes the main natural frequency $f$, values of the logarithmic decrements of oscillations $\delta$ and the calculated damping parameters $\beta = 2 \cdot m \cdot f \cdot \delta$ ($m$ – mass of a body) were determined. These data are presented in Table 1.

Table 1

**Data on the results of dropping of the passenger car from the wedges**

| Parameters | Types of oscillations | | | | | |
|---|---|---|---|---|---|---|
| | bouncing | | pitching | | sway | |
| | with dampers | without dampers | with dampers | without dampers | with dampers | without dampers |
| ***f*, Hz** | 1,30 | 1,25 | 1,38 | 1,25 | 1,48 | 1,43 |
| ***δ*** | 2,17 | 0,31 | 2,25 | 0,52 | 0,94 | 0,34 |
| ***β*, kN·s/m** | 234,9 | 32,7 | 257,9 | 53,8 | 116,0 | 40,2 |

From the table data it follows that the frequency of natural oscillations is slightly reduced in the absence of hydraulic dampers, while the decrements of oscillations are significantly reduced. Thus, for oscillations of bouncing in case of hydraulic dampers switch off the value of δ is reduced by 7 times, for pitching oscillations – 4,3 times, for sway oscillations – 2,8 times. The values of the damping coefficient β calculated from the experimental data are also significantly reduced: for oscillations of bouncing the values are reduced by 7,2 times, for pitching oscillations – 4,8 times, for sway oscillations – 2,9 times.

Test results provide a basis for conclusions about the possibility of using the procedure of dropping from the wedges to assess the damping ability of their spring suspension.

The experimental data are used to verify computer model of the dynamics of a passenger car as spatial

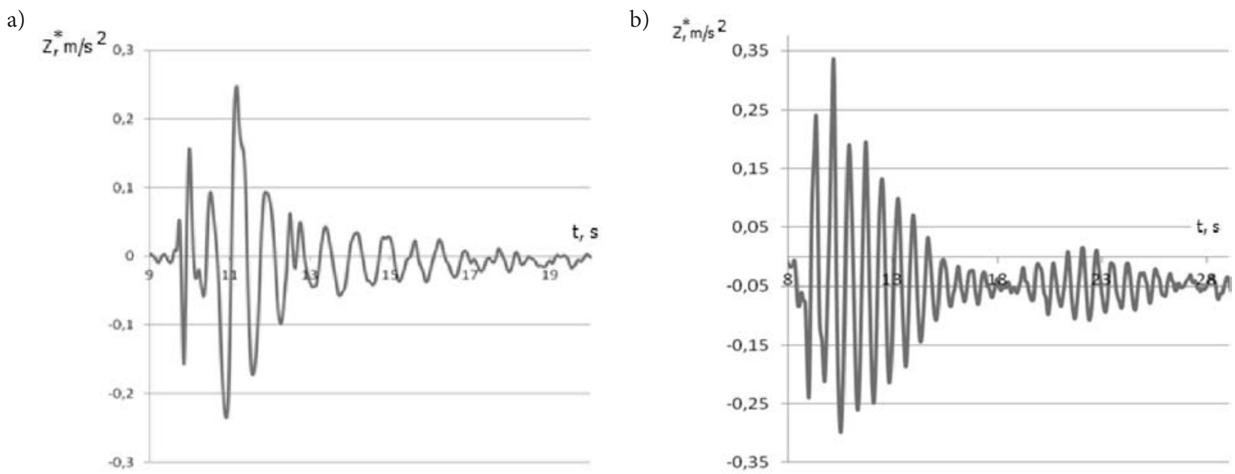


Fig. 3. Oscillograms of vertical body accelerations: a) with the switched dampers, b) with switched off dampers

system with 41 solid bodies with 64 degrees of freedom. Assessment of the adequacy of the model carried out using the divergence factor ε (or coefficient of discrepancy) of H. Theil [10]. This value is determined by the formula:

$$\varepsilon = \frac{\sqrt{\sum_{i=1}^{n}\left(x_i^e - x_i^M\right)^2}}{\sqrt{\sum_{i=1}^{n}\left(x_i^i\right)^2}}, \qquad (2)$$

where $x_i^M$ and $x_i^e$ – predicted and experimental values; $n$ – number of values that are checked.

The assessment of influence of failure of the hydraulic dampers on the dynamics of a passenger car was carried out on straight track at speed ranging from 50 km/h to 160 km/h with the step of 10 km/h. Simulation was carried out with moderately worn wheel profiles and satisfactory condition of the track. The first calculation case corresponds to the case when all the dampers are in good condition. Other variants related to the failure of the dampers as follows: 2 – damper switched off on the left side of the first bogie; 3 – damper switched off on the left side of the second bogie; 4 – both dampers are switched off on the left side of the car; 5 – dampers of the first bogie are switched off; 6 – left damper of the first bogie and right damper of the second bogie are switched off; 7 – right damper of the second bogie is in working condition; 8 – left damper of the second bogie is in working condition; 9 – all the dampers are faulty.

The safety factor against derailment of the wheelsets from the rails $k_s$ was accepted as the main indicator of the dynamic running safety of the wagons on the track of 1520 mm gauge [7]. Fig. 4 shows graphs of the dependences of the minimum value of the $k_s$ on the speed. Here the numbers of graphs are corresponding to the numbers of calculated cases.

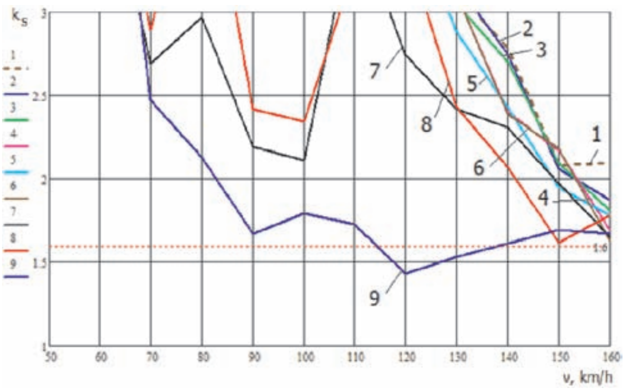


Fig. 4. The minimum value of the coefficient $k_s$

As can be seen from Fig. 4, the lowest value of the coefficient $k_s$ in case of working condition of all the dampers is 2,09 at a speed of the wagon motion $v$ = 160 km/h. Since the maximum permissible value of this index for passenger cars is $[k_s]$ = 1,6, in this case (first variant) the conditions of running safety in a predetermined speed range are satisfied. For variants 2–7 there is a significant decrease in the values of $k_s$ at $v$ = 160 km/h. In variant 8 the smallest value of $k_s$ approaches the limiting value at $v$ = 150 km/h. In the case when all the dampers of the car are faulty running safety conditions are violated at the speed $v$ = 120 km/h.

## 3. Prediction and monitoring of strength characteristics of the traction rolling stock bearing structures

Fatigue destructions of underframe parts of railway rolling stock usually occur in highly-stressed points of supporting structures with existing stress concentrators. Due to large surface stress there are fatigue cracks which are converted further to the macroscopic cracks [12]. That is why the prediction of possible location of damages in rolling stock supporting structures by means of timely held technical diagnostics in order to detect fatigue cracks allows to eliminate the causes that threaten traffic safety at the early stages of operation.

Diagnostics of technical condition of the rolling stock metal structures in order to detect cracks in load-bearing elements is usually carried out by using non-destructive test methods, such as ultrasonic, eddy current, capillary, magnetic, and acoustic emission. Such test method as non-destructive metallography is also widely used but mainly in order to investigate the structural condition of metal structures of pipelines, vessels, reservoirs, bridges, aircraft cabins, etc. [2, 6]. The introduction of metallography methods in railways is currently important. The car body frame of an electric multi-unit operated with a maximum speed of 160 km/h was chosen as an object of research in order to examine the effectiveness of non-destructive test methods for detection the cracks of rolling stock load-bearing structures.

### 3.1. Diagnostics results and strength calculations

During visual examination of car body frame of the high-speed electric multi-unit there was revealed a spreading of cracks in bolsters in the mounting area of jaw damper brackets (Fig. 5).

In order to evaluate the stress-strain state of the jaw damper attachment point there were conducted strength calculations in the computer package Solid Works Simulation [1]. According to the calculations the greatest stress in the area of gussets weld was 115.5 MPa (Fig. 6). The obtained stress values exceeded the fatigue limit of $\sigma_{-1}$ = 87 MPa. Thus there was a possibility of destruction of the investigated attachment point.

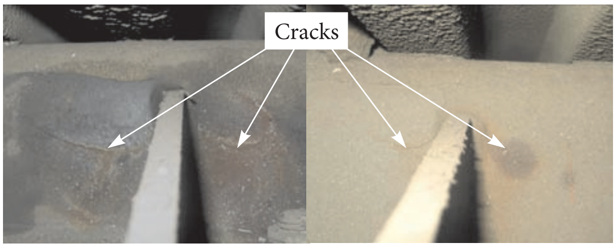


Fig. 5. Revealed cracks in the bolster

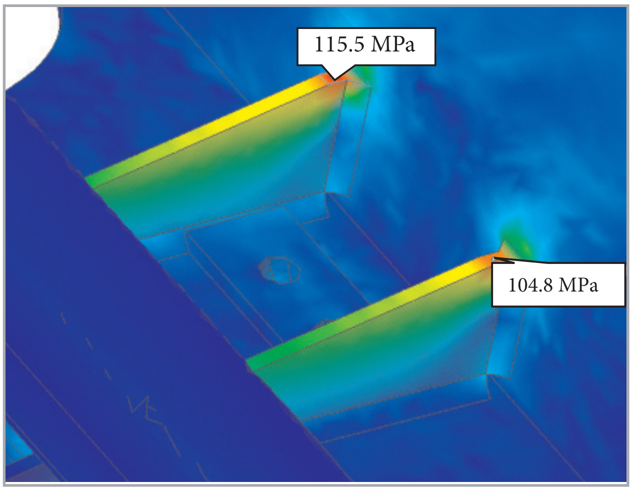


Fig. 6. The largest estimated stresses in the bolster

According to the calculations it turned out that in addition to the identified macro-cracks in the bolster in the mounting area of the damper brackets (Fig. 5) there was probable presence of micro-cracks that could develop to macro-size along the entire length of the bolster.

### 3.2. Non-destructive control of the bearing structures

In order to detect invisible surface defects (cracks) with the size of 1 micron there was conducted the non-destructive control of the investigated attachment point by using liquid penetration examination of the body frame. The analysis determined that this method of non-destructive control failed to reveal surface cracks of the body frame that is why the method of non-destructive metallography was applied.

By means of non-destructive metallography one can directly study the microstructure of metal, identify surface and internal defects such as cracks and pores, or investigate corrosive damage, conduct an incoming control of metals, etc., without cutting samples of structural elements, by using a portable microscope or replicas (prints of patterns).

The method of non-destructive metallography was applied to control bearing structures of the body frame (bolster and center sill). There was used a set of equipment (Fig. 7) that included: angle grinder, portable grinding-and-polishing machine Akkupol (Ibendorf, Germany), set of abrasive grinding and polishing attachments, replicas – acetylcellulose films (Buehler, Germany), stationary optical microscope Axiovert 25 CA (Carl Zeiss, Germany), etc.

The method of non-destructive metallography made it possible to study in details the areas of bolster cracks (Fig. 5) in order to detect micro-cracks that could have led to macro-cracks further. The surface treatment in selected areas of control consisted of two phases: grinding with discs of different granularity and polishing with diamond paste.

Polished surface was then moistened by solvent in order to obtain viscous surface layer on which a rep-

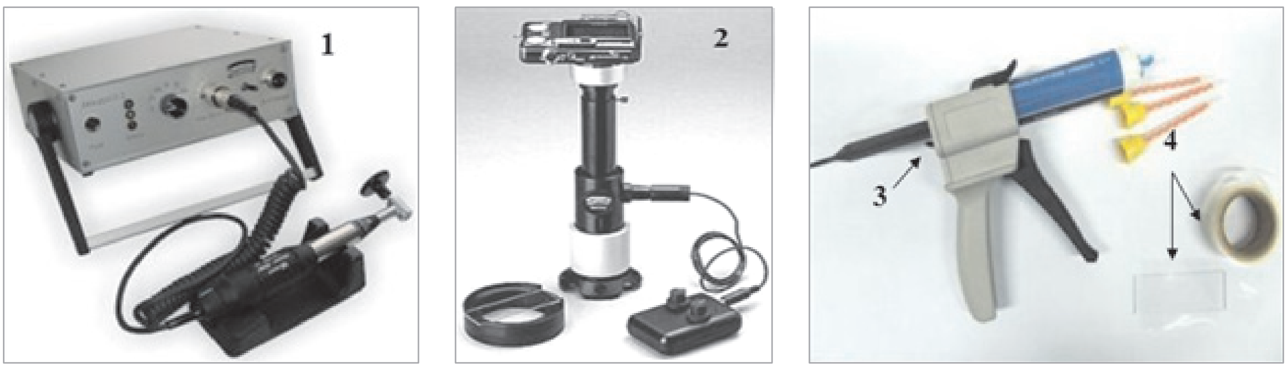


Fig. 7. Equipment for non-destructive metallography: 1) grinding-and-polishing machine Akkupol, 2) portable light field microscope TCM, 3) press for «liquid» replicas, 4) replicas

lica later was laid. Exposure time of replicas lasted for 3–5 minutes. Replicas analysis was performed by using optical microscope Axiovert 25 CA at magnifications of × 200 and × 500.

Under laboratory conditions it was defined that frame micro-cracks detected on approximately 50 mm distance from macro-cracks in the elements of bolster ranged in size from 50 to 300 microns (Fig. 8). There were both isolated cracks (bolster №1) and their accumulation and branching (bolster №2). From the microscope examination of replicas it was found that cracks arising in areas of welding points of damper bracket with the bolster mainly spread along the bolster.

Besides there was carried out the study of body frame center sill for the presence of fatigue micro-cracks because the center sill usually sustains intense longitudinal loads in modes of traction and braking. During the analysis of replicas there were defined cracks up to 200 microns that spread both along and across the central sill.

Taking into account that there were found spreading micro-cracks in supporting structures of the body frame (bolster and center sill) it is necessary to study the staging of defects accumulation and to determine criteria characterizing the resistance to the emergence and accumulation of additional micro-defects in metal structures. It is also important to establish a resource of structural elements of micro-cracks.

## 4. Current monitoring and diagnostics of technical condition of rolling stock

In order to implement modern approaches to monitoring and diagnosis of technical condition of

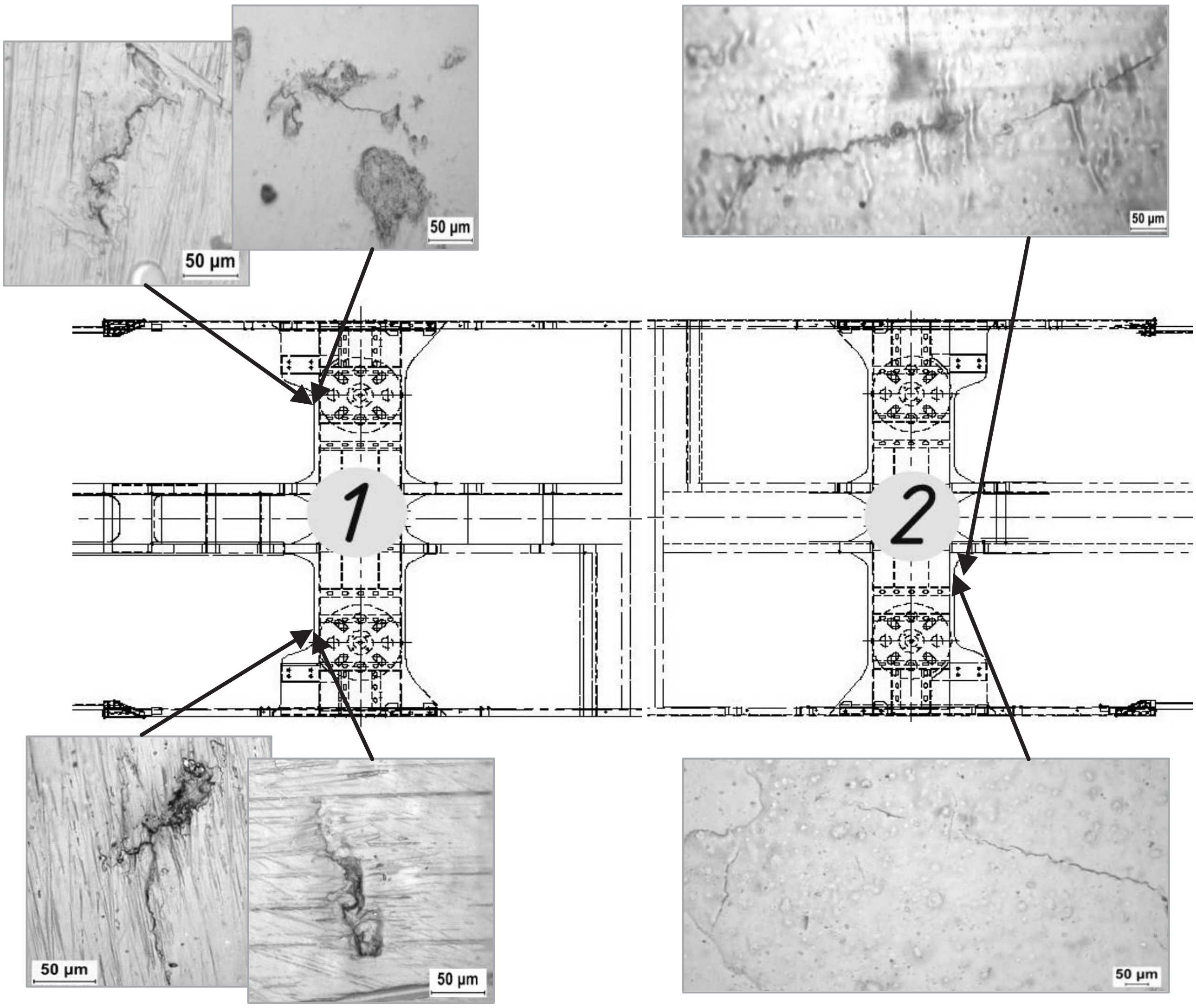


Fig. 8. Micro-cracks at designated areas of bolsters

the rolling stock DNDC UZ develops software and hardware complexes that provide instrumental assessment of technical condition of the rolling stock both after the repairs, and in operating conditions.

### 4.1. Portable device for weighing by wheels

While using of all kinds and series of traction rolling stock an important factor in their effective use is the realization of maximum traction through the full use of trailing weight. This can be achieved by ensuring equal distribution of weight on the axles and wheels. For this purpose after repairing or replacement of spring suspension and after the current repairs there is the necessary condition to carry out the work of the control of weighing parameters.

The portable device is proposed for measuring the static load of the wheels of the rolling stock units on the track (Fig. 9).

The software for weighing device, which was designed in complex software LabVIEW, tuned to different types of rolling stock with the ability to make alternate or simultaneous measurement of static load on each wheel, with automated calculation, recording and editing of control cards. Thus, the following parameters are determined for locomotive:

- the load on each wheel,
- divergence of loads on the wheels of each wheelset,
- divergence of loads on the side of the locomotive section,
- divergence of loads on each bogie of the locomotive section,
- divergence of loads on the wheels along the diagonal of the locomotive,
- the total weight of the section.

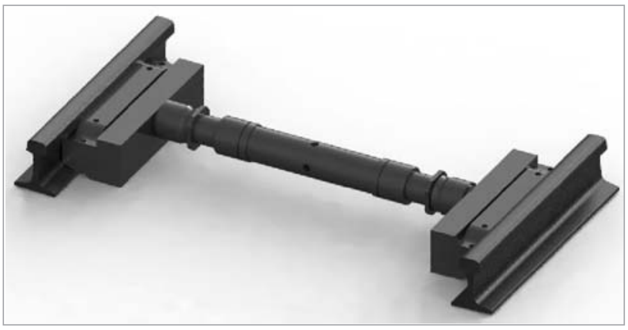

Fig. 9. Device for weighing of the rail vehicles by wheels

### 4.2. Stationary device for automatic wheels fault detection

The important component of the safety running is to provide early detection of faults of the rolling stock bogies. There was conducted the work on creation of stationary devices for automatic wheels fault detection (AWFD) in order to reduce the time period from the appearance of the defect to its detection.

AWFD device should provide continuous technical control and identification of units of the rolling stock with abnormal dynamic effects on the track. This device consists of hardware and software.

The hardware part of the complex based on a platform National Instruments CompactRIO, which allows solving a wide range of tasks related to the control of the condition of the rolling stock bogies. The system performs the collection, storage, visualization and processing of information signals from the sensors of vibrational accelerations, with which track section is equipped (Fig. 10). CompactRIO includes controller with the real-time operating system PharLab, chassis and input/output modules. Chassis carry the core programmable logic integrated circuit (FPGAs) which directly connects to the universal and specialized input / output modules with integrated tools for negotiation and processing of information signals.

The statistical processing subsystem of measurement results of the impact of rolling stock bogies, which was developed in software complex LabVIEW, is based on the determination of an abnormally high level of impact of the wheels on the rails, which can be regarded as abnormal values of normally distributed sample. These anomalous values are determined using the following statistical criteria as a Chauvenet criterion and 3σ (three standard criteria).

Fig. 10. Measured track section

Criterion 3σ is also used to identify the wheel that causes abnormal impact on the rail. Peaks that exceed a specified level are counted in the recorded signal. In this case, the serial number of the peak corresponds to the wheelset. Using the floating range of points hitting to the range allows searching for specific wheelsets without a priori information about the weight of freight cars. An example of displaying the identification of peaks in a particular implementation is shown in Fig. 11.

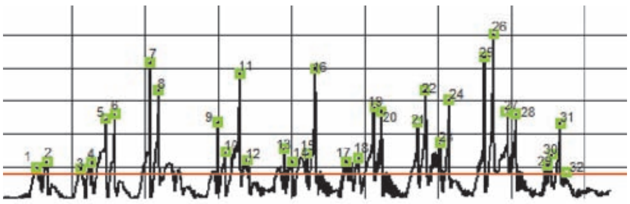

Fig. 11. Identification of peaks that correspond to a particular wheelsets

AWFD device allows detecting the faults of rolling stock bogies that have passed the measuring area with identification of the car and rapid transmission of information to the nearest station in order to perform technical diagnosis.

### 4.3. Mobile system for controlling running test of the rolling stock

During the operation rolling stock as any complex technical system is prone to failure that can be due to: violation of manufacturing techniques of individual elements; severe operating conditions; noncompliance with form of technological processes of loading; unloading and transportation of cargoes; aging and wear of units. This is precisely why the important and urgent task is to implement the controlling periodic testing and dynamic diagnostics of the rolling stock units during the whole life cycle in the Ukrainian railways. For this purpose the development studies of the mobile system of controlling running tests and dynamic diagnostics of rolling stock were held.

The mobile system of controlling running tests and dynamic diagnostics of the rolling stock units (MSCT) designed on the basis of the platform National Instruments CompactRIO allows to solve a wide range of tasks related to the control of the vehicles state both in test on track and in normal operation. The system includes two functional options: evaluation of the strength parameters, dynamics and safety parameters in real-time mode and the performance of tests in «black box» standalone mode. MSCT of open type is used in the tests of passenger rolling stock (Fig. 12a) and MSCT of closed type is used in the tests of freight cars (see Fig. 12b).

MSCT consists of measuring data acquisition subsystem and subsystem of express processing. Acquisition subsystem of measuring data performs collection, storage and visualization of changes in information signals from the sensors of displacement, acceleration and mechanical strain. Furthermore, data of the GPS receiver is used for analyzing the impact on the speed, change in the monitored parameters, obtaining of precise time signals and determination of current coordinates. Since this receiver produced by third parties LabView Real Time Module has no standard tools for obtaining of GPS data, so the set of closed virtual devices that installed separately is used for interaction with it.

Express processing subsystem is a complex of software installed on a PC that implements the determination and recognition of safety performance in real-time with the results updating interval of once every two seconds or once at 100 meters of distance traveled. For each of the parameters it is set the defined by standard filtering parameters, that is: for lateral acceleration of a bogie frame ($y^+$) it is used a low pass filter with cutoff frequency of 10 Hz; for lateral body acceleration ($y^*$) it is used a low-pass filter with cutoff frequency of 6 Hz; for vertical body acceleration ($z^*$) it is used a band pass filter with a range of 0.4–4 Hz. After the performing of filtering the expectation value and standard deviation are calculated for the further determination of maximum possible values of the accelerations in accordance with regulatory requirements [9, 11]. Values defined in this way are compared with the limit values.

a)

b)

Fig. 12. Mobile system for controlling tests

## 5. Conclusions

1. To investigate the influence of such factors as the mode of running of the train, technical condition vehicle and track on the derailment section the generalized computer model of the train dynamics was developed as a one-dimensional system of rigid bodies with the inclusion of a module that simulates the spatial oscillations of three-car unit. The location of the specified module in the model of train is determined by the serial number of the car, which was the first that derailed.
2. According to the results of simulation of the passenger car dynamics, in order to estimate the impact of technical condition of hydraulic damper on dynamic parameters of carriage it was found that in accordance with the indicators of car stability on railway track with the working condition of all of the dampers safety requirements are satisfied in the considered speed range, including 160 km/h. In the case of incapacity for work of all hydraulic dampers stability margin of carriage against derailment is exhausted at a speed of 115 km/h. In other cases, damper failures conditions of safety are not violated.
3. The places of visually detected fatigue cracks in the body bolsters of the electric multi-unit cars at the attachment points of jaw dampers confirmed by calculation of the stress-strain state of the body frame. According to the analysis, micro-cracks in certain areas in bolsters and center sills which in further operation may lead to macro-crack were found by method of non-destructive metallography of the structure of the metal in the bearing structures of the electric multi-unit body frame. It is recommended studying the staging of accumulation of micro-cracks in supporting elements of the rolling stock frame structures.
4. The performed development of hardware and software complexes is oriented to implementation of instrumented assessment of technical condition of rolling stock and the quality of its interaction with the infrastructure by evaluating weighing parameters, the impact on the track, dynamics and running safety. In particular, the proposed information-measuring system provides an opportunity for testing of rolling stock through its whole lifetime without testing cars. This system will improve the quality and speed of diagnostic operations and, as a result, significantly improve the running safety of passenger and freight transportation.

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## Badanie wybranych problemów bezpieczeństwa ruchu taboru na kolejach ukraińskich

**Streszczenie**
Artykuł przedstawia wyniki oceny warunków bezpieczeństwa ruchu pojazdów kolejowych przeprowadzonej metodami symulacji komputerowej. Umiejscowienie ewentualnych uszkodzeń w strukturach łożysk pociągów dużych prędkości określono obliczeniami wytrzymałości i metodą nieniszczącej metalografii. W artykule zamieszczono informację o stanie rozwoju oprogramowania i sprzętu do oceny stanu technicznego pojazdów kolejowych.

**Słowa kluczowe:** tabor, wykolejenie, symulacja komputerowa, właściwości wytrzymałościowe, badania i testy

## Исследования по избранным вопросам безопасности движения подвижного состава украинской железной дороги

**Резюме**
В статье представлены результаты оценки условий безопасности движения единиц подвижного состава при использовании компьютерного моделирования. Размешение возможных повреждений в структурах подшинников поездов высоких скоростей определяется при помощи вычисления свойств прочности и метода неразрушающей металлографии. В статье размещена информация о состоянии развития программного обеспечения и оборудования для оценки технического состояния единиц подвижного состава.

**Ключевые слова**: подвижной состав, сход с рельсов, компьютерное моделирование, свойство прочности, исследования и тесты