TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2014, Vol. 14, No.1, 37-49

# Improving the means of experimental determination of dynamic loading of the rolling stock

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Received January 06.2014: accepted February 10.2014

Summary: The article presents the results of research on the mobile control system running tests and dynamic diagnostics of rolling stock.

Key words: Means of test controller, test control, technical diagnostics.

## INTRODUCTION

The rolling stock of railways, being in the process of production, exploitation or repair, is characterized by certain, apt to the changes technical properties on that it is possible to estimate the state of object by realization of warranty and control tests.

In the process of exploitation, a rolling stock, as well as any difficult technical system, is apt to the refuses reasons of that can be: violation of technology of making of separate elements, heavy external environments, and failure to observe of norms of technological processes of loading, unloading and transporting of loads, aging and wear of knots. For this reason important and an actual task is introduction on the railways of Ukraine of the periodic proof-testing and dynamic diagnostics of units of rolling stock during all life cycle [9].

To that end in SE "DNDC UZ" a study on development of the mobile system of the working proof-testing and dynamic diagnostics of units of rolling stock is undertaken.

## ANALYSIS OF PUBLICATIONS

Modern progress of measuring technique trends give wide market abilities of new instrumental approaches for the estimation of dynamic internals, terms of safety of motion of trains and operative acceptance of measures on warning of emergency situations [5, 16].

Taking into account successful experience of introduction of the systems of diagnostics of carriage part of passenger carriages and locomotives, there is a necessity of further perfection of facilities and methods of experimental estimation of working dynamic internals and indexes of safety during all life cycle of rolling stock [3, 4].

## AIM AND METHODS OF RESEARCHES

Creation of the mobile system of the working proof-testing and dynamic diagnostics of units of rolling stock with development of subsystem of express-treatment on determination of indexes of safety.

For the decision of the put tasks the methods of classic mechanics, object-oriented programming, digital treatment of signals, mathematical statistics were used.

## RESULTS OF RESEARCHES

The mobile system of the working proof-testing and dynamic diagnostics of units of rolling stock on the base of platform of National Instruments CompactRIO allows deciding the wide spectrum of the tasks related to control of the state of transport vehicles, both in the conditions of tests and in the regular modes of exploitation [14].

The system plugs in itself two functional options: estimation of indexes of durability, dynamics and safety of motion real-time (Fig. 1), and also implementation of tests in autonomous behavior of "black box" (Fig. 2, 3) [6].

**Fig. 1.** Tests with the use of the mobile system in real-time

**Fig. 2.** Tests with the use of the mobile system in autonomous behavior of "black box"

**Fig. 3.** A measuring equipment is in the protected corps

The created system consists of next subsystems: collection of measuring information, determination of level of comfort, determinations of smoothness of motion and determination of indexes of safety in the mode express of treatment.

Executes **the subsystems of collection of measuring information** collection, storage and visualization of change of informative signals of sensors of moving, vibroaccelerations and mechanical deformations. In addition, for the analysis of influence of rate of movement on the change of the controlled parameters, the receipts of time-signals and determination of current positions are used data of receiver of GPS [18].

The system consists of:

- comptroller of CompactRIO - 9104,
- an undercarriage on 8 modules with the built-in programmable logical integrated circuit (PLIS),
- two universal modules of Analog-to-digital converter 9205 with maximal frequency of discretisation 250 kHz [19],
- five modules of tensometry 9237 with maximal frequency 50 kHz on a channel [20],
- module-receiver of SEA with RIOGxxxMobile.

Due to built-in there PLIS, CompactRIO has the opportunity to realize the algorithms of processing of measuring data at vehicle level with the determined period of implementation of 25 nanoseconds without the transfer of loading on central processing unit of comptroller.

The typical device of CompactRIO is plugged in itself by a comptroller with the real-time executive of PharLab or VxWorks, undercarriage and modules of input-conclusion. An undercarriage is carried on itself by a PLIS kernel, directly unites with the universal or specialized modules of input-conclusion, having built-in facilities of concordance and treatment of informative signals. There are different models undercarriages having a different amount of slots for the modules, and differ on descriptions of microcircuits PLIS. Due to a noninteraction, vehicle descriptions, insignificant sizes, weight, and also to possibility of work in unfavorable terms, CompactRIO can be used for the decision of wide spectrum of tasks on collection of measuring information and management by technical processes.

Majority of software for CompactRIO is developed on a chart that envisages his conditional dividing into three levels: virtual device of HOST VI on the managing personal COMPUTER with Windows OS, RT VI on a comptroller with the real time OS and FPGA VI on PLIS, that does not have own OS, because logic of work of the program will be realized directly at vehicle level. Each of the presented levels has the specific functional and will realize the separate functions of the system on the whole [28].

Typical tasks executable by means of HOST VI on the computer with Windows:

- maintenance of data on a computer and access to the databases,
- integration with the external informative systems,
- organization of interface.

Typical tasks executable in RT VI on the comptroller of the real time:

- processing of data,
- management,
- maintenance of data in built-in memory of comptroller and on external carriers.

Typical tasks executable in FPGA VI on PLIS:

- input-conclusion,
- vehicle clocking and management by the process of co-operating with an equipment,
- low-level treatment of signals.

PLIS is a microcircuit functionality of that is determined at programming or "configuration", that is more widespread term during work with this class of the integrated circuits. A package of LabView FPGA Module is adding to the software environment of LabView, that allows to set to the logician of work PLIS as an ordinary virtual device instead of her programming with the use of the specialized language of VHDL. This package allows to create the programs with synchronous and asynchronous parallel cycles executable at vehicle level and provides the collection and analysis of data determined at times.

The programmatic package of LabVIEW FPGA Module fully undertakes the multi-stage process of transformation of virtual device in a binary PLIS code. On the first stage a virtual device is converted in a text code in language of VHDL, that after it is compiled by the standard industrial compiler of Xilinx ISE in a binary kind. In the process of compiling there is optimization of code on speed implementations and amounts of the involved logical valves.

The result of compiling is a binary file (bitstreamfile), fully PLIS determines configuration. At the start of the program a binary file is loaded on an undercarriage, it means a process of configuration PLIS. A binary file can be writtenin in a built-in flash drive and automatically loaded at including of the system. In case of setting off feed configuration is not saved, therefore, after the repeated including, a binary file must be high-usage again.

At the corresponding tuning configuration can be downloaded automatically from the flash drive of device PLIS or by the program, by means of comptroller.

The virtual devices of FPGA VI can be executed fully, regardless of other components of the system, and to save a capacity even at the failure of comptroller. Moreover, on PLIS can be organized a buffer that prevents the loss of data in a similar situation.

PLIS is intended foremost for clocking, synchronization, management, capture of data and digital rough-down of informative signals. For a management by every module of input-conclusion, supports of functional of tire of PCI the special code is generated, using resources of PLIS. All, that will stop behind after it, intended for realization of logic userdefined. Thus, amount of resources of PLIS, necessary for concrete application, depends on complication algorithms and involved facilities of input-conclusion.

A virtual device for the comptroller of CompactRIO usually includes two or more than cycles: cycle with critical priority, in that the algorithms of management and processing of data, and cycle, will be realized with normal priority, that is responsible for maintenance of data, remote web-interface and connection on the network of Ethernet or tire of RS - 232.

For raising on the level of comptroller of the real time of the data got from the modules platform of CompactRIO, three ways provide for: through the elements of front panel, by means of variable, and through DMA FIFO buffer. The first two approaches are comparatively simple, from the point of view of realization, however nonoptimal from the point of view of efficiency. But the method of DMA FIFO allows jam-free to accept data got on high-frequencies of discretisation from the great number of the modules.

One of advantages of the mode of DMA consists in that communication of data takes place regardless of processor of comptroller. Devices of PLIS, supporting buffer of DMA FIFO, have a direct access to memory, unlike another ways requiring obligatory participation of processor. Direct access to memory will be realized by means of capture of tire of PCI (busmastering) by a device of PLIS at that he gets access to the management by a tire and access to memory, passing a processor.

The buffer of DMA FIFO consists of two departments: one part is in memory of PLIS, other - in memory of comptroller. On PLIS can come true memberwise record or reading from a buffer by means of knots of methods of FIFO Read and FIFO Write, and on a comptroller a record or reading of selections of elements can be conducted. Connection of two parts of buffer comes true by means of hardware and software of comptroller of DMA. Thus, from the point of view of software, they look as a single buffer of FIFO.

The virtual device of FPGA VI, placed on PLIS, will realize the functional of initialising, clocking, questioning of the modules of capture of data and subsequent loading of the got counting out in the buffer of DMA FIFO. For providing of determined the structure of "FlatSequenceStructure", in that the elements of questioning of the modules and record are located in a buffer, is used the sequence of implementation of commands.

DMA FIFO a buffer is cyclic polled through the time domain set by a timer at the level of comptroller of the real time, whereupon counting out, got as integers in accordance with dynamic range and bit of the module of collection, is rationed to the values of acceleration and deformations. The obtained data are given on a virtual device, that provides their treatment and storage on the external store of USB connected by means of tire.

The comptrollers of CompactRIO have built-in USB 2.0 comptroller, however not all stores support this standard, can bring to the considerable delays records over, that, in turn, result in the repletion of DMA FIFO buffer and improper work of the system on the whole.

The virtual device of management is absent in the presented system, takes place on the personal computer, and instead of him a mechanism that is named LabViewRemotePanel is used. This function will realize the so-called model of Customer-Server, where by a server comptroller, and by a client is any computer with set LabView . CompactRIO is licensed by default on one external connecting, however their amount can be extended.

For activating of RemotePanel on a comptroller it is necessary in tuning of project to activate Web-server and to choose those virtual devices to that it is necessary to settle remote access. This function allows considerably to shorten the expenses of time, that is needed for development of HOST VI, however can create loading on the network of telecommunications [7].

Except the modules of capture of data, for synchronization of time and receipt of values of current speed and coordinates, to the comptroller connected also GPS-receiver set on an undercarriage the same as and standard modules. Because a receiver is produced by a strange company, LabViewRealTimeModule does not have standard facilities for the receipt of data of GPS, therefore for co-operating with him drawn on the set of the closed virtual devices, set separately. In addition, for providing of the correct functioning of the module in composition a project in FPGA VI it is necessary also to add SubVI, supplied together with the module. In case if initialising went well, data of GPS appear as a cluster or directly in a text format that can be used for debugging of software or another tasks [18].

**The subsystem of determination of level of comfort** is based on the requirements of standard of UIC 513 and advising DSTU UIC 513 [10, 29]. These documents envisage the estimation of comfort of passengers of carriages of main railways in that passengers regularly occupy positions "sitting" or "upright".

On the accepted methodology the index of comfort settles accounts on accelerations: a) baskets in middle part, above pivot knots in three directions (simplified method - *NMV*), b) on a pillow in vertical, transversal direction, on the back of arm-chair end-on and vertical accelerations of basket (complete method in position "sitting" − *NVA*), c) baskets are in middle part, above pivot knots in three directions (complete method in position "upright" − *NVD*).

For the exception of high-frequency constituents in the spectrum of output signal and choice for the analysis of stripe of frequencies, corresponding to the eigentones of carriage, in the process of rough-down of data digital filtration of signal is used. Depending on the axis of acceleration and site of accelerometer three types of filter are used with different gain-frequency characteristics.

For accelerations, measureable an accelerometer that takes place at the level of sex, filters the gain-frequency characteristic of that is described by a Equation 1.

$$H_A(s)=\frac{s^2\cdot 4\pi^2\cdot f_2^2}{\left(s^2+\frac{2\pi\cdot f_1}{Q_1}\cdot s+4\pi^2 f_1^2\right)\left(s^2+\frac{2\pi\cdot f_2}{Q_1}\cdot s+4\pi^2 f_2^2\right)}. \quad (1)$$

For the accelerations measured at the level of places for a seat, expression of frequency response function looks like Equation 2.

$$H_B(s)=\frac{(s+2\pi\cdot f_3)\left(s^2+\frac{2\pi\cdot f_5}{Q_3}\cdot s+4\pi^2 f_5^2\right)}{\left(s^2+\frac{2\pi\cdot f_4}{Q_2}\cdot s+4\pi^2 f_4^2\right)\left(s^2+\frac{2\pi\cdot f_6}{Q_4}\cdot s+4\pi^2 f_6^2\right)}\cdot\frac{2\pi\cdot Kf_4^2\cdot f_6^2}{f_3\cdot f_5^2}, \quad (2)$$

and for the accelerations measured on a pillow and back of places for a seat:

$$H_C(s),H_D(s)=\frac{(s+2\pi\cdot f_3)}{\left(s^2+\frac{2\pi\cdot f_4}{Q_2}\cdot s+4\pi^2 f_4^2\right)}\cdot\frac{2\pi\cdot Kf_4^2}{f_3}. \quad (3)$$

In Table 1 brought coefficients over of filters.

The gain-frequency characteristics of the used filters are presented on a Fig. 4.

**Table 1. Coefficients of filters in accordance with the requirements of standard of UIC 513**

| Band limits | | | Parameters of amplitude-frequencyfunction | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $f_1$ (Hz) | $f_2$ (Hz) | $Q_1$ | $f_3$ (Hz) | $f_4$ (Hz) | $f_5$ (Hz) | $f_6$ (Hz) | $Q_2$ | $Q_3$ | $Q_4$ | $K$ |
| 0,4 | 100 | 0,71 | - | - | - | - | - | - | - | - |
| 0,4 | 100 | 0,71 | 16 | 16 | 2,5 | 4 | 0,63 | 0,8 | 0,8 | 0,4 |
| 0,4 | 100 | 0,71 | 8 | 8 | - | - | 0,63 | - | - | 1,0 |
| *0,4* | 100 | 0,71 | 2 | 2 | - | - | 0,63 | - | - | 1,0 |

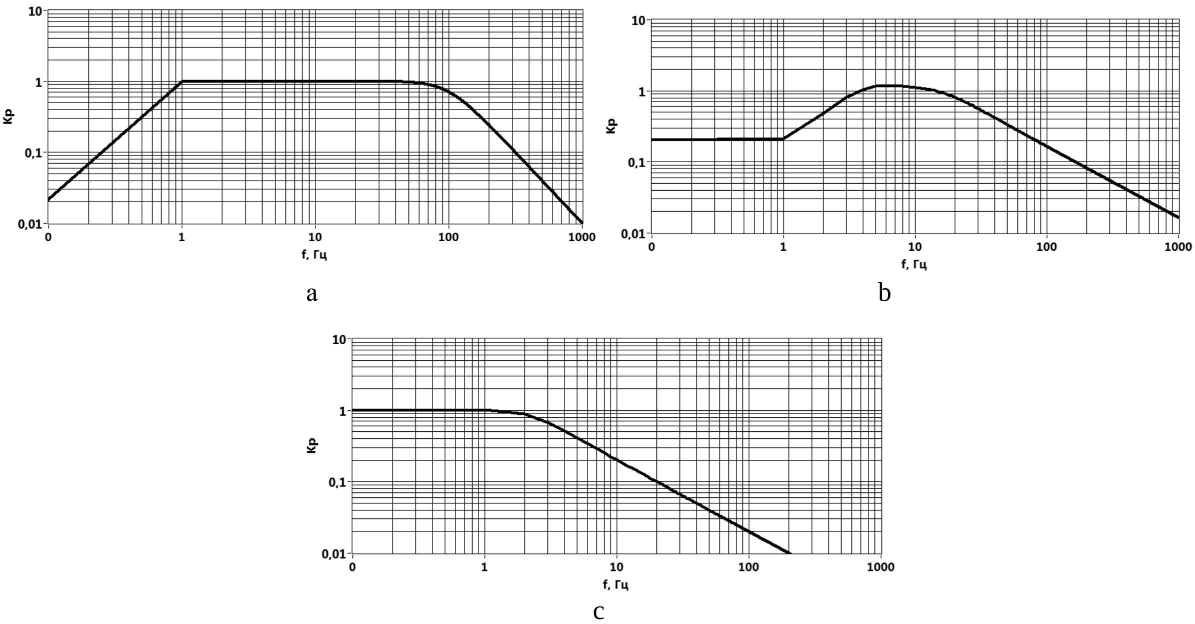



**Fig. 4.** Frequency response function of the used digital filters: a – $H_A(s)$, b – $H_B(s)$, c – $H_C(s)$, $H_D(s)$

In the process of treatment instead of formulas (1-3) without considerable influence on results it is possible to use the simplified presentation of Frequency response function [29]:

$$F_b(f)=\begin{cases} 0.4 & for \quad 0{,}4 \le f < 2 \\ 0.2\cdot f & for \quad 2 \le f < 5 \\ 1 & for \quad 5 \le f < 16 \\ 16/f & for \quad 16 \le f < f_{max} \end{cases} \qquad (4)$$

$$F_c^*(f)=\begin{cases} 1 & for \quad 0.4 \le f < 8 \\ 8/f & for \quad 8 \le f \le f_{max} \end{cases} \qquad (5)$$

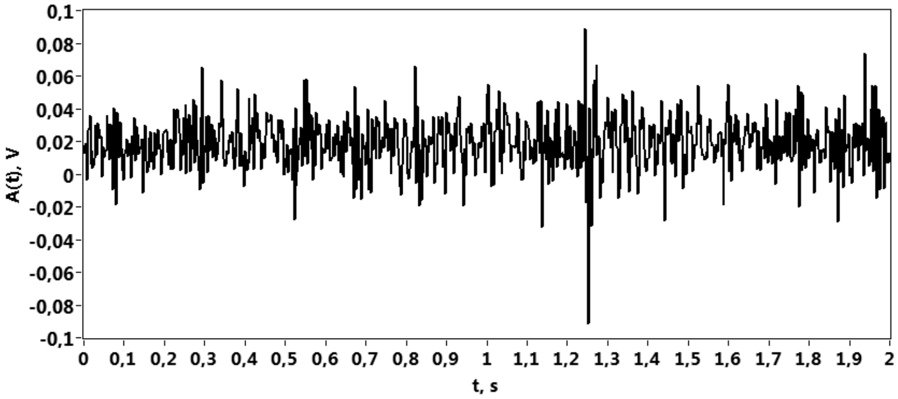
$$F_d^*(f)=\begin{cases} 1 & for \quad 0.4 \le f < 2 \\ 2/f & for \quad 2 \le f \le f_{max} \end{cases} \qquad (6),$$

where: $H_A(s)$ corresponds $F_b(f)$, $H_B(s)$ accordingly $F_c^*(f)$, and $H_C(s)$, $H_D(s)$ - $F_d^*(f)$.

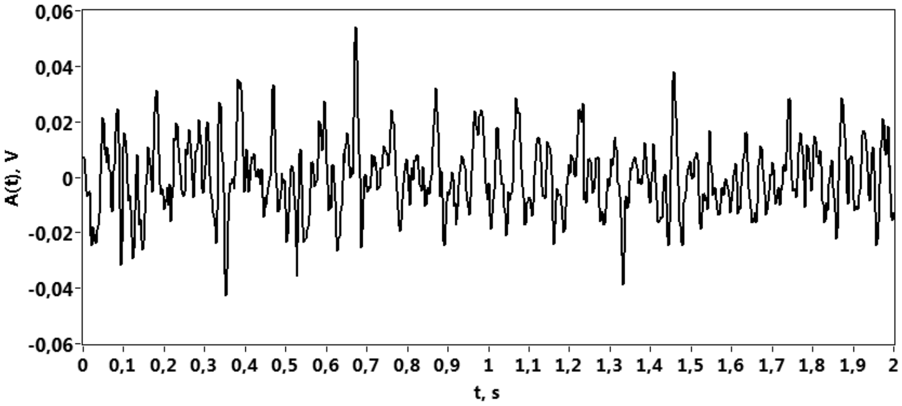
On a Fig. 5 results over of filtration of the signal, got from the accelerometer of the passenger carriage that moved at a speed of 70km/h (Fig. 5, a) located on the floor, are brought, before and after (Fig. 5, b) passing of filter.

In accordance with the requirements of standards [10, 29] the index of comfort, that is estimated on a next scale, settles accounts: N<1 − very good comfort, 1<N>2 − good comfort, 2<N>4 − middle comfort, 4<N>5 − bad comfort, N>5 − very bad comfort.

Technical implementation of subsystem is executed on the basis of results of working tests of model carriage 62-7067. The expected values of index of comfort of *NMV* are confronted with a border value *[N]=4,0.* The results of calculations are driven to the Table 2.




a




b

**Fig. 5.** Results of the filter

**Table 2.** Index of comfort of carriage № 8 models 62-7067 double-system electric train on a line Kyiv-Kharkiv

| Index | Speed, km/h | Mean | SCO | Percentage of the limit value,% |
|---|---|---|---|---|
| $N_{MVI}$ (index of comfort zone I, caster) | 61-70 | 2,6 | 0,3 | 65,4 |
| | 71-80 | 2,8 | 0,3 | 69,7 |
| | 81-90 | 3,2 | 0,1 | 80,4 |
| | 91-100 | 3,1 | 0,3 | 77,5 |
| | 101-110 | 3,7 | 0,1 | 92,4 |
| | 111-120 | 3,6 | 0,3 | 88,8 |
| | 121-130 | 3,9 | 0,2 | 98,0 |
| | 131-140 | 3,9 | 0,3 | 97,5 |
| | 141-150 | 3,6 | 0,2 | 90,2 |
| | 151-160 | 3,0 | 0,3 | 75,6 |
| $N_{MVm}$ (index of comfort in the middle of the body) | 61-70 | 2,2 | 0,3 | 55,9 |
| | 71-80 | 2,4 | 0,3 | 60,8 |
| | 81-90 | 2,6 | 0,6 | 66,0 |
| | 91-100 | 2,6 | 0,2 | 65,9 |
| | 101-110 | 3,1 | 0,1 | 77,1 |
| | 111-120 | 2,9 | 0,4 | 72,7 |
| | 121-130 | 3,1 | 0,1 | 77,0 |
| | 131-140 | 3,1 | 0,3 | 76,6 |
| | 141-150 | 3,0 | 0,1 | 75,5 |
| | 151-160 | 2,2 | 0,5 | 55,0 |
| $N_{MV1I}$ (index of comfort zone II caster) | 61-70 | 2,4 | 0,1 | 60,4 |
| | 71-80 | 2,6 | 0,3 | 64,0 |
| | 81-90 | 2,6 | 0,6 | 66,1 |
| | 91-100 | 2,6 | 0,3 | 65,3 |
| | 101-110 | 3,2 | 0,2 | 80,2 |

| | | | | |
|---|---|---|---|---|
| | 111-120 | 2,9 | 0,3 | 73,0 |
| | 121-130 | 3,2 | 0,1 | 79,1 |
| | 131-140 | 3,7 | 0,4 | 91,4 |
| | 141-150 | 3,0 | 0,1 | 75,5 |
| | 151-160 | 2,6 | 0,3 | 65,6 |

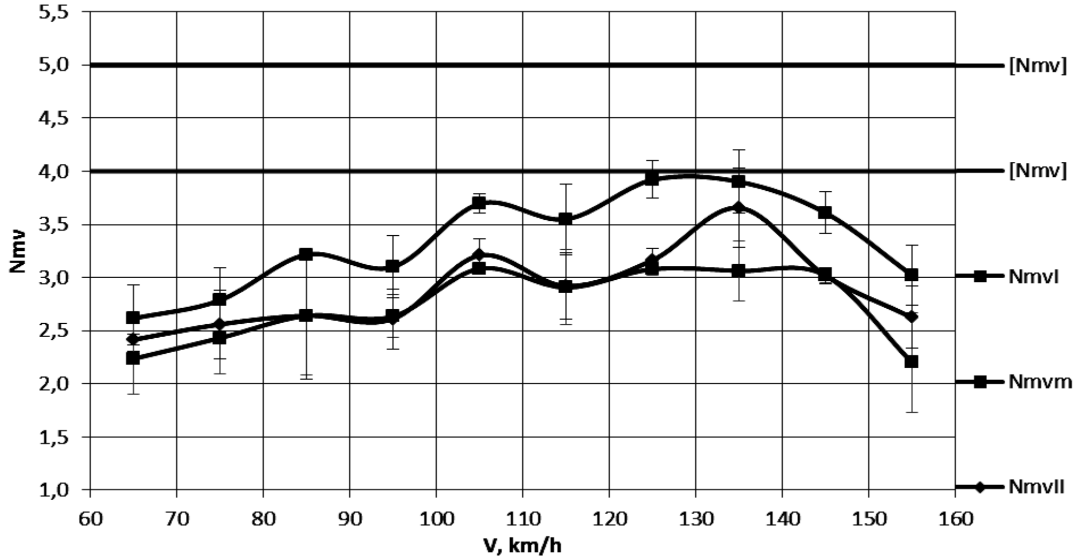



**Fig. 6.** Indexes of comfort for the carriage of model 62-7067 double-system electric train on a line Kyiv-Kharkiv (*NmvI*, *NmvII* - indexes of comfort in the zone of king-pin of I and II, *Nmvm* – index of comfort in the middle of basket)

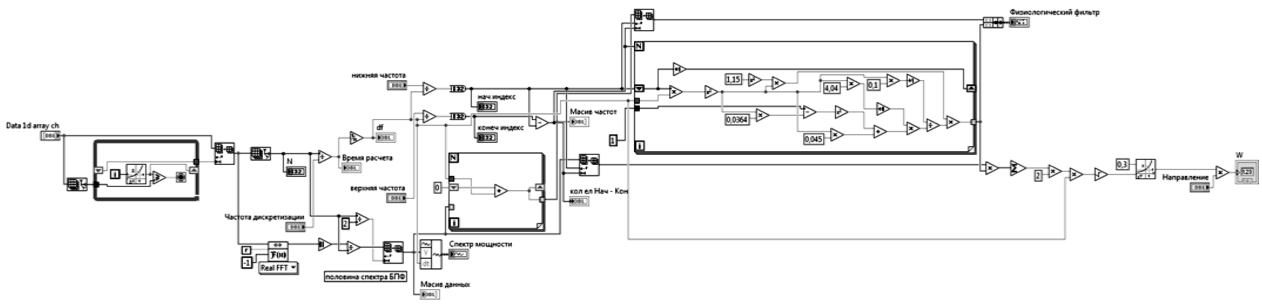


**Fig. 7.** General view of the block diagram

From tabular data the charts of dependences of indexes of comfort are built from the rate of movement (Fig. 6). Apparently, the terms of comfort perceptibly get worse in the range of rate of movement 120-140 km/h.

**The subsystem of determination of smoothness of motion** is based on the requirements of standard [10] by the c account of recommendations [1, 24]. These documents are intended for an estimation to the comfort of ride by verification of accordance of index to the smoothness of motion of carriage to the norms envisaged by technical documentation on carriages. The index of smoothness of motion depends on intensity and spectral composition of accelerations of basket of carriage.

On the accepted methodology the indexes of smoothness of motion of *Wz* settle accounts on the accelerations of basket above caster knots on the exit of "physiological filter". In accordance with it the indexes of smoothness of motion settle accounts in vertical (*Wzv*) and horizontal (*Wzh*) directions. The general view of Block Diagram is presented on a Fig. 7.

The data in Table 3 characterize the assessment of the indicators according to the smoothness of the recommendations [10, 21].

**Table 3.** Rating wagon ride quality index based on smoothness *Wz*

| Estimation of working internalss of carriage | *Wz* |
|---|---|
| Very good | 2 |
| Good | 2 – 2,5 |
| Sufficient for passenger carriages | 2,5 – 3 |
| Maximum for passenger carriages | 3 – 3,25 |
| Sufficient for a locomotive | 3,25 – 3,5 |
| Maximum for a locomotive | 3,5 – 3,75 |
| Sufficient for freight carriages | 3,6 – 4 |
| Maximum for freight carriages | 4 – 4,25 |
| Maximum for a man from the physiological point of view | 4,5 |
| Dangerous from the point of view of tails of rolling stock from rails | 5 |

The calculation of indexes of smoothness of motion is realized on a next algorithm: determined size of block for calculations, entry block determined size by an algorithm on founding 2, and by means of intrinsic function of LABVIEW transformation of Fourier is conducted for the construction of spectrum of power, on the basis of transformation of Fourier building arrays of frequencies and arrays of data in set range of frequencies from 0,5 Hz to 20 Hz, the value of the rationed gain-frequency characteristic of correcting filter settles accounts in obedience to expression (Equation 7), block diagram, that shown on a Fig. 8.

$$q_н(f) = 1.15 \cdot \sqrt{\frac{(1+0{,}1 \cdot f^2)}{(1+4{,}04 f^2)\cdot((1+0{,}0364 f^2)^2 + 0{,}045 f)}}, \quad (7)$$

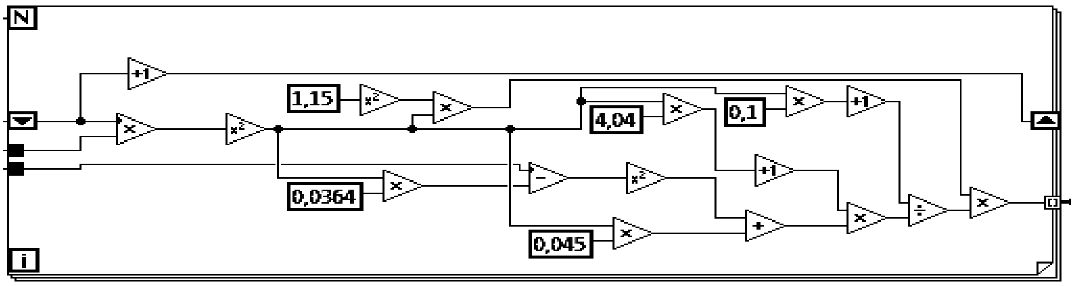



**Fig. 8.** Block diagram of the correction filter

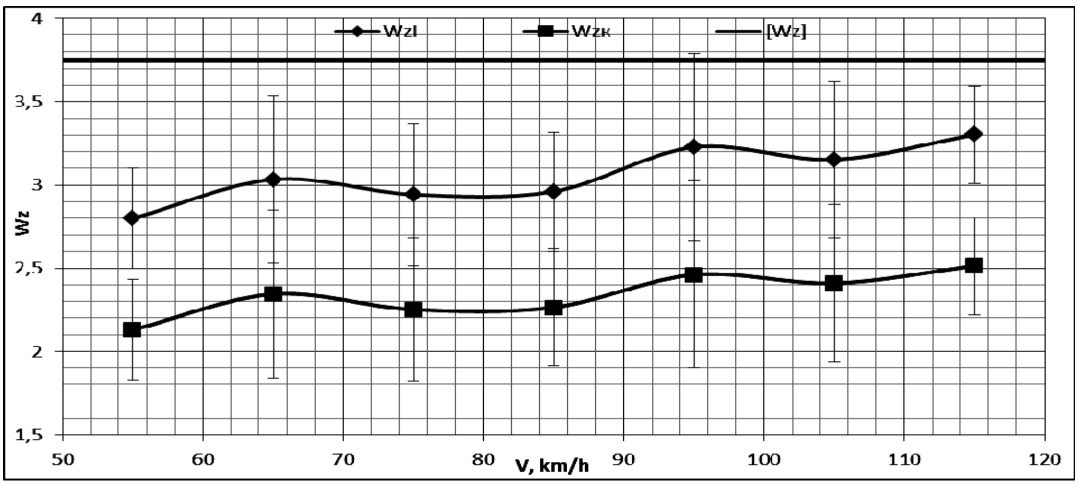



**Fig. 9.** Indexes of smoothness of motion of electric locomotive of CHS2 are in vertical direction (*WzI* – index of smoothness of motion in a caster section, *Wzk* – index of smoothness of motion in an operator's cab)

The eventual index of smoothness of motion of *Wz* for the array of data settles accounts on a formula:

$$W = a \cdot \tilde{a}_k^{0,3}, \qquad (8)$$

where: *α=4,346* − for vertical vibrations,

*α=4,676* − for horizontal (transversal) vibrations,

$\tilde{a}_k^{0,3}$ − mean quadratic value of vibroaccelerations on the exit of correcting filter.

Example of results of estimation of smoothness of motion for the electric locomotive of CHS2 is made an on Fig. 9.

The obtained values of smoothness on compare with the allowable limit for locomotives *[Wz]=3,75* [22].

**A subsystem of expresstreatment** is a complex of software set on the personal PC and will realize determinations and reflections of indexes of safety real-time with the interval of updating of result one time in two seconds or one time on 100 meters of the passed way.

According to operating methodologies of model tests on railways of track a 1520 mm is envisaged determination of indexes of safety of motion on basis so-called "frame forces" that operate from the side of frame constructions of working parts on wheel pairs [2]. However, because of that these descriptions do not give the direct picture of power cooperation of wheels with rails that results in the decline of authenticity of the results got in the process of working researches [12, 26, 23].

On the railways of countries EC the estimation of indexes of safety of motion of speed rolling stock is regulated by the standards, setting the next methods of tests [17, 15, 30]:

a) Normal method: measuring of forces of pin cooperation of *Y* (transversal) and *Q* (vertical),

b) Simplified method: measuring of lateral force (*H*) and accelerations of basket in transversal ($\ddot{y}^*$) and vertical ($\ddot{z}^*$) directions,

c) Simplified method: measuring of transversal acceleration of frame of light cart ($\ddot{y}^+$) and accelerations of basket in transversal ($\ddot{y}^*$) and vertical ($\ddot{z}^*$) directions.

With the purpose of introduction of the modern going near the estimation of indexes of safety of motion in DNDC UZ work on technical implementation of the simplified method of tests, was executed based on measuring of accelerations, ($\ddot{y}^+, \ddot{y}^*, \ddot{z}^*$) [11].

For each of indexes the certain a standard parameters of filtration are set, namely: for the transversal acceleration of frame of light cart($\ddot{y}^+$) the filter of LFS is used at frequency of shear 10 Hz, for the transversal acceleration of basket($\ddot{y}^*$) – is a filter of LFS at frequency of cut 6 Hz, for the vertical acceleration of basket ($\ddot{z}^*$) – band-pass filter is with range 0,4-4 Hz.

After implementation of filtration the expected value ($\bar{x}$) and standard deviation (*s*) settle accounts for further determination of maximally possible values of accelerations($X_{max}$) on a next formula:

$$X_{\max} = \bar{x} + k \cdot s, \qquad (9)$$

where: *k* – is a coefficient depending on the set level of authenticity (for determination of indexes of safety of *k* = 3).

The defined values are compared to the maximum values that is certain the standard of UIC 518 as follows: vertical acceleration of basket − $(\ddot{z}_s^*)_{\lim} = 3$ m/s², transversal acceleration of basket – $(\ddot{y}_s^*)_{\lim} = 3$ m/s² for direct areas and curves of large radius, $(\ddot{y}_s^*)_{\lim} = 2{,}8$ m/s² − for small curves by a radius 400≤R≤600, ($(\ddot{y}_s^*)_{\lim} = 2{,}6$ m/s² − for very small curves by a radius 250≤R≤400, transversal acceleration of frame of light cart determined on a next formula:

$$(\ddot{y}^+)_{\lim} = 12 - M_b/5, \qquad (10)$$

where: $M_b$ – is mass of light cart in tones.

The interface of the worked out programmatic complex of expresstreatment of indexes of safety of motion on the standard of UIC 518 is presented on a Fig. 10.

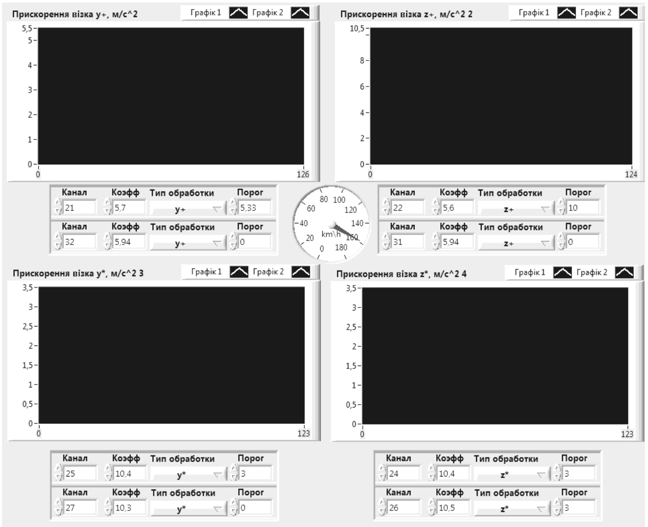


**Fig. 10.** Interface of subsystem of expresstreatment of indexes of safety

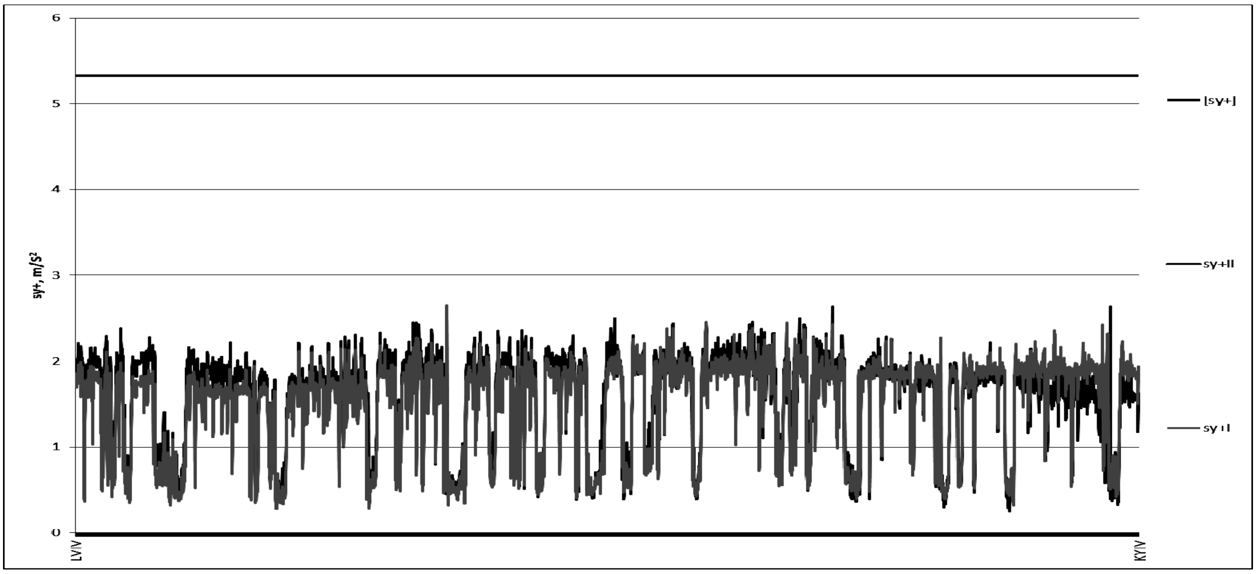



**Fig. 11.** Standart deviations of transversal accelerations of frame of the light carts measured in an experience journey en-route Lviv-Kyiv

An experience introduction of subsystem is carried out on the basis of results of working tests of model carriage 68-7041 on the routes of the following : Kharkiv-Kyiv, Kyiv-Donetsk and Lviv-Kyiv.

On a Fig. 11 standard deviations of horizontal transversal accelerations of frame of light cart are presented fixed during motion of research train en-route Lviv-Kyiv, Coming from that mass of light model cart 68-7041 makes 6,68 tons, $(s\ddot{y}_s^+)_{lim}$ =5,33m/s$^2$ [8, 25, 26]. As be obvious from the presented results, most standard deviations of accelerations no less what in two times below maximum legitimate value, that testifies to the considerable supply to stability of carriage from tails from rails.

## CONCLUSIONS

1. In DNDC UZ worked out informatively-measuring system, providing a testability rolling stock during all life cycle, and also executed technical implementation of the system at the working tests of locomotives, railcar of rolling stock, passenger and freight carriages. The created system will allow to improve quality and speed of diagnostic

operations and, as a result, considerably to promote safety of transportations.

2. Drawing on a similar hardwarily-programmatic complex allows to provide not only the accumulations of basic measuring data for further treatment but also real-time to watch appearance of dangerous office hours and correct motion of tests.

3. In future it is assumed to perfect the informatively-measuring system in part of increase of level of dust and water tight, and also by addition of the modules of Wi-Fi and 3G-link.

REFERENCES

1. **Dmitriev D., 2010.:** Generalization of experience with DSTU UIC 513:2004. Collection of scientific works DonIZT, № 23. – 182-187. (in Russian).
2. **Domin J., Chernyak A., 2003.:** Bases of dynamics of carriages : study guide. – К.: KUETT. – 270. (in Ukrainian).
3. **Domin R., Chernyak A., 2008.:** Vehicle-board diagnostics of the locomotive. Problems and prospect of development of transport systems minds reform of railway transport: management of economy and technology, Materials of IV international research and practice conference, Series of "Technician, technology". – К.: DETUT, – 43-44. (in Russian).
4. **Domin J., Dmitriev D., Domin R., 2005.:** Operating tests of CAS of current control of the technical state of working parts of passenger carriages and way. Railway transport of Ukraine, №3/1. –107-114. (in Russian).
5. **Domin J., Domin R., Dmitriev D., 2003.:** Computer checking of the state of working parts of passenger carriages. Railway transport of Ukraine, №5. – P. 4-6. (in Russian).
6. **Domin R., Mostovych A., Kolomiiets A., 2013.:** Facilities of instrumental estimation of the technical state of rolling stock. International information scientific and technological magazine "Wagon park", №6. – 10-15. (in Ukrainian).
7. **Domin R., Mostovych A., Kolomiiets A., Suslov E., Jerebko V., 2011.:** Modern tool for the tests of rolling stock. Railway transport of Ukraine, №6. – 16-18. (in Ukrainian).
8. **Domin R., Mostovych A., Kolomiiets A., 2013.:** Implementation of modern approaches in relation to the estimation of indexes of safety of motion. Materials of VI of the International research and practice conference of "Problem and prospect of development of transport systems in the conditions of reformation of railway transport: management, economy and technologies", - Series of "Technician, technology", К.: DETUT. – 45-47. (in Ukrainian).
9. **DSTU 2389:1994.:** Terms and determinations: Technical diagnostic and control of the technical state. - [Valid from 1995-01-01]. - К.: Ukrainian State Standard. – 24. (in Ukrainian).
10. **DSTU UIC 513:2004**, **2006.:** Mainline coaches. Discipline in relation to the evaluation of comfort of passenger’s dependently from vibration (UIC 513: 1994, IDT), Valid from 2006.01.01. - Kyiv: Dergspogivstandart of Ukraine. – 32. (in Ukrainian).
11. **EUROPEAN STANDARD EN 14363, 2010.:**, Railway of applications - Testing for the acceptance of running characteristics of railway vehicles - Testing of running behavior and stationary tests. – 120.
12. **Gorbunov N., Kostyukevich A., Kravchenko K., Kovtanets M., 2011.:** Influence of operatonal factors on redistribution of wheel pairs vertical loads upon rails / N. Gorbunov, // TEKA Commission of Motorization and Power Industry in Agriculture XIA. Poland. – 92-99.
13. **GOST 2860-94.:** Terms and Definitions: Reliability engineering. – К.: State Standard of Ukraine. – 90. (in Ukrainian).
14. **Instruction on exploitation and specification of CompactRIO 9012/9014, 2007.:** Built intellectual controller of the real time CompactRIO, - USA, Texas, Austin: National Instruments. – 19.
15. **Instruction RD 24.050.37.95., 1995.:** Freight coaches. Test methods for durability and drivability. – 102 p. (in Russian).
16. **Kirpa G., Domin J., Domin R., Dmitriev D., 2008.:** Patent of Ukraine 83459, MPK (2006) V61K 9/00. A device for continuous control of the mechanical rolling stock, - № u2003076579, claimed 14.07.03, publ. 25.07.08. Bull. № 14. (in Ukrainian).
17. **Norms for calculation and design of railway wagons MPS 1520 mm (non-self), 1996.:** - M,: GhosNIEV-VNIIZhT. – 352. (in Russian).
18. **Operation Instructions and Safety Guidelines cRIO Mobile Modules, 2011.:** Gxxx Series, − Germany, Troisdorf: Datentechnik GmbH. – 28.
19. **Operating instructions and specifications NI 9205, 2008.:** USA, Texas, Austin: National Instruments. – 36.
20. **Operating instructions and specifications NI 9237, 2009.:** − USA, Texas, Austin: National Instruments. – 40.
21. **OST 24.050.28-81, 1981.:** Coaches, Methods of measurement and evaluation of vibration, - Instead OST 24,050,28-74, - Enter, 01.01.83, - M,: Mintyazhtranspmash USSR. – 34. (in Russian).
22. **OST 24.050.16-85, 1985.:** Coaches, Methodology for determining smoothness, Introduced, 1.1.87, - M,: Mintyazhtranspmash USSR. – 16. (in Russian).

23. **Sapronova S., 2010.:** Modeling of locomotive wheel profile form. TEKA Commission of Motorization and Power Industry in Agriculture VX. Poland. – 270-278.
24. **SOU MPP 45.060-204: 2007, 2007.:** Coaches, Smoothness of motion, Methods of determination, Valid from 2008.04.01. – K.: Ministry of policy of Ukraine. – 15. (in Ukrainian).
25. **Specification 62.7066.TZ, 2010.:** "Electric two-system for interregional messages at the speed of 160 km/h", Kremenchuk: KVBZ. 79.
26. **Standards for calculating and assessing the strength of load-bearing elements, dynamic qualities and impact on the path of the vehicle-locomotives Railway MPS RF 1520 mm, 1998.: -** M,: VNIIZhT. – 145. (in Russian).
27. **TSI, 2011.:** Technical specification for interoperability relating to the rolling stock subsystem 'Locomotives and passenger rolling stock' of the trans-European conventional rail system, – [Valid from 2011-05-26]. – Brussels, 148.
28. **Fedosov V., Nesterenko A., 2007.:** Digital treatment of signals is in LabVIEW – M.: DMK Press. – 427 p. (in Russian).
**29.** **UIC Code 513 OR, 1994.:** Guidelines for evaluating passenger comfort in relation to vibration in railway vehicles, – 1st edition, 01.07.94, – International Union of Railways.
30. **UIC Code 518, 2009.:** Testing of and approval of railway vehicles from the point of view of their dynamic behavior - Safety - Track of fatigue - Ride of quality, 4-th ed, (September 2009), Paris: International Union of Railways.

## СОВЕРШЕНСТВОВАНИЕ СРЕДСТВ ЭКСПЕРИМЕНТАЛЬНОГО ОПРЕДЕЛЕНИЯ ДИНАМИЧЕСКОЙ НАГРУЖЕННОСТИ ХОДОВЫХ ЧАСТЕЙ ПОДВИЖНОГО СОСТАВА

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Александр Коломиец

Аннотация. В статье приведены результаты исследований по созданию мобильной системы контрольных ходовых испытаний и динамической диагностики подвижного состава.

Ключевые слова: средство испытаний, контролер, испытания контрольные, диагностика техническая.