MONITORING AND EMERGENCY PREVENTION IN AREAS WITH INCREASED AXIAL LOAD

Zheleznov, Maxim M., *Russian University of Transport (MIIT), Moscow, Russia.*
Pevzner, Viktor O., *JSC VNIIZhT, Moscow, Russia.*
Ponomarev, Valentine M., *Russian University of Transport (MIIT), Moscow, Russia.*

ABSTRACT

The article describes the essence of the problem of emergencies in areas with increased intensity of the transportation process. Methods and technical solutions in the field of rail track monitoring based on aerospace technologies are shown. The results of the experimental operation of cars with an axial load of 27 tf / axis are presented, which included tracking the dynamics of the geometric parameters of the track and adjacent territories using tele-shooting using a drone (quadrocopter-drone).

<u>Keywords:</u> *railway, increased axial load, aerial survey, monitoring, emergency situations, impact on the track.*

Background. *For more than 150 years, Russia's railways have functioned as a single centralized mechanism aimed at the economic efficiency of the entire complex in the interests of the state.*

During the formation of JSC Russian Railways and its subsequent reforming, there have been significant changes in the economic model of functioning. Now it is an infrastructure company, interested primarily in obtaining the maximum revenue for the use of its infrastructure by carriers – owners and tenants of cars. Also, JSC Russian Railways is interested in a maximal reduction of the cost of maintaining the infrastructure with an increase in the level of safety and efficiency of its use [1].

Objective. *The objective of the authors is to consider the issues of monitoring and emergency prevention in areas with increased axial load.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, graph construction, evaluation approach.*

Results. *At the same time, the industry is on the verge of another increase in carload load up to 27 tons per axle. Special railcar structures designed for operation with such a load are created. Experimental polygons have been determined on which the experimental operation of trains consisting of cars with increased axial load will be carried out (Pic. 1).*

In the solution of the problem, an important place is occupied by technologies for monitoring the geometric parameters of the railway track as a key infrastructure component, which accounts for the main impact. In this context, it is proposed to complement the existing system of such monitoring with global space monitoring methods (GLONASS / GPS and remote sensing data processing systems) that allow to [2, 3]:

– cover the entire experimental polygon in a single coordinate system by measuring the geometric parameters of the track;

– promptly monitor the status not only at selected control points, but also throughout the section;

– to track volumetric deformations, which have an extended character and actually change the geometry of the track of the entire polygon.

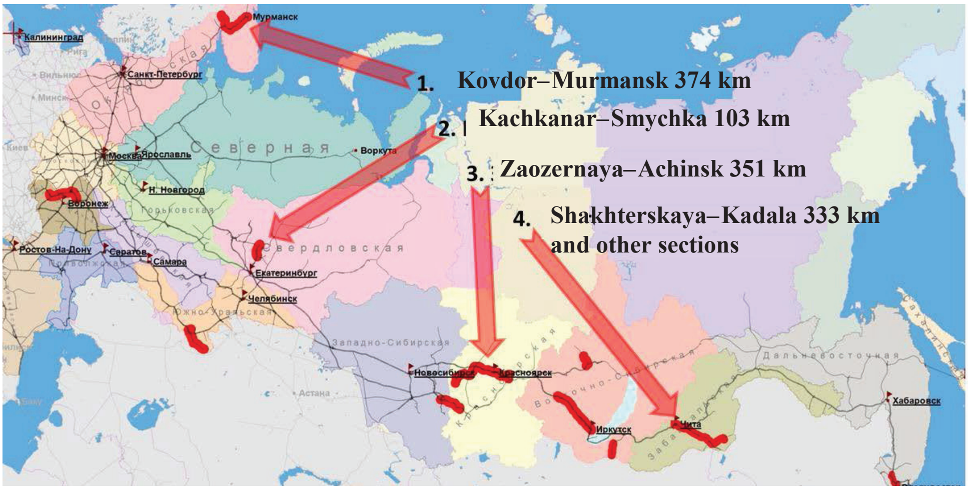
Taking into account the fact that experimental polygons of trains consisting of cars with increased axial loads are closed routes, the most automated measuring methods should be used [4–9], which form three technological levels:

1. Control areas for measuring geometric parameters by high-precision geodetic equipment.

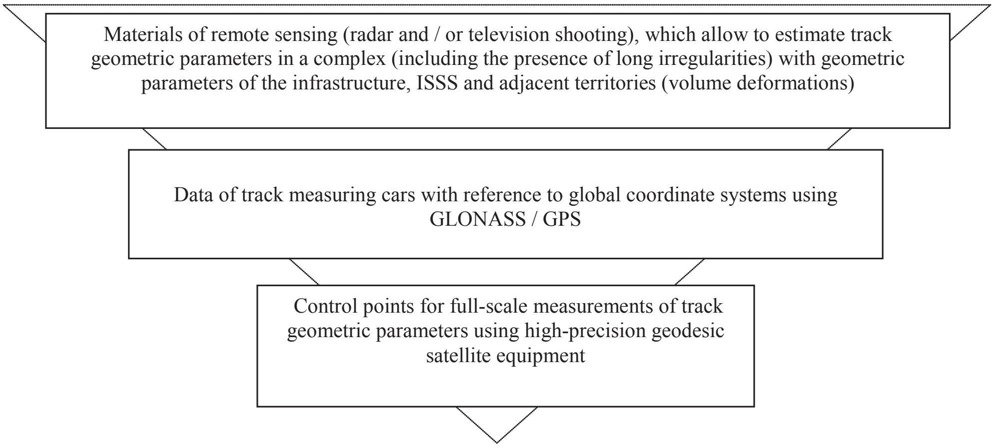
2. Data of track measuring cars with reference to global coordinate systems with the help of GLONASS / GPS equipment.

3. Materials of aerospace remote sensing (radar and / or television shooting), which allow to evaluate the geometric parameters of the track in the complex (including the presence of long irregularities) with the geometric parameters of the infrastructure objects, ISSS and adjacent areas (volumetric deformations).

The proposed technological scheme of monitoring (Pic. 2) will allow covering the whole experimental



Pic. 1. Promising polygons of heavy traffic.



Pic. 2. Technological scheme of monitoring.

Pic. 3. An image from space of Kovdor Mining and Processing Combine.

Table 1

The shooting parameters for the UAV of the Chinese company DJI Phantom 3

Height of survey (m)	Length of measured long irregularities (m)	Spatial resolution (mm)	Accuracy of measurement of geometric parameters of track in plan (mm)
5	10,7	2,6	0,3
10	21,4	5,2	0,5
25	53,6	13,1	1,3
50	107,2	26,2	2,6
100	214,4	52,4	5,2
250	536,1	130,9	13,1
500	1072,3	261,8	26,2
1000	2144,7	523,6	52,4

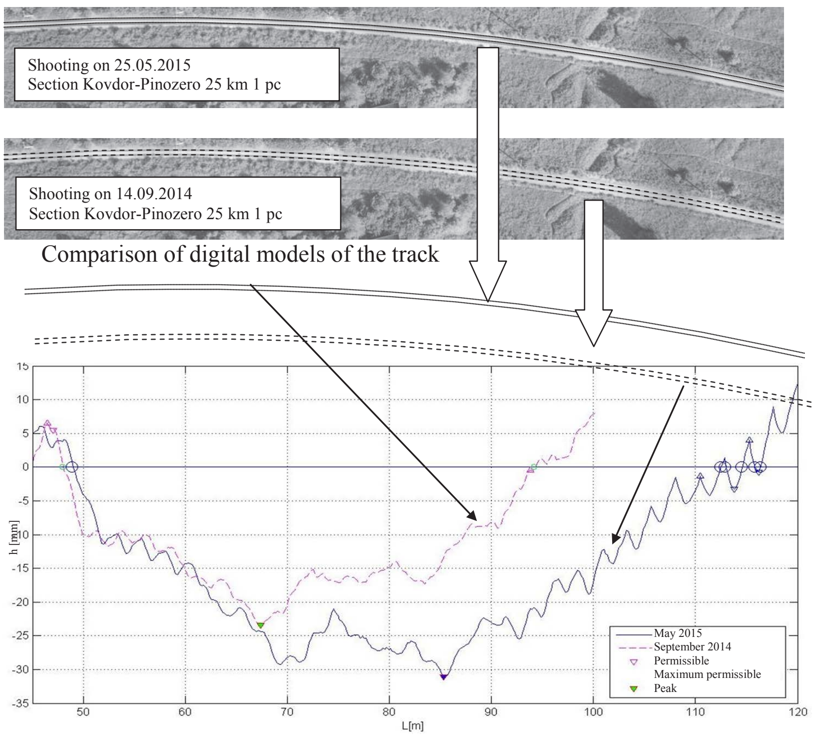
range of heavy traffic with measurements. As an example, Pic. 3 shows a fragment of the space image of the Kovdor Mining and Processing Combine with access roads.

In 2014–2016 on Kovdor-Murmansk section of the October Railway, the experimental operation of cars with an axial load of 27 tf / axle was carried out. Experiments of this kind were not performed on the Russian rail network before, the impact of such loads on the track superstructure and the roadbed was not studied. It was necessary to determine how the cars with increased axial load will influence the accumulation of deformations and the stress-strain state of the track, to test the developed technologies of global monitoring and mathematical modeling.

As an operational and low-cost way to monitor the geometric parameters of the railway track in areas of heavy traffic, surveys were taken from an unmanned aerial vehicle (UAV) – a quadrocopter-drone (Pic. 4).

TV pictures with UAV allow to detect the change in geometric parameters of the track with a high accuracy and speed at a point to several hundred meters. Including the dynamics of long irregularities based on the materials of periodic survey.

Pic. 4. Quadrocopter with a television camera.



Pic. 5. The growth of the natural unevenness for the period from September 2014 to May 2015 at the 25th km of the Kovdor–Pinozero section.

The technology for determining long irregularities in the plan is as follows:

1. The operator directs the UAV to the center of the studied section of the railway track and sets the survey, depending on the required measurement accuracy and the length of the measured long irregularities (Table 1).

2. After the survey, the UAV transmits a snapshot to the operator's console, which is then processed to recognize the railway track and determine its geometric parameters in the plan.

Based on the parameters given in the table, for modern serial devices, the optimal survey heights when detecting long irregularities of the track are 25–100 meters, at which their determination in the plan is possible with an accuracy of 1–5 mm.

To detect changes in the geometric parameters of the track in time, it is advisable to periodically survey potentially hazardous areas. After the images are linked to each other by contour points and the object is recognized, it is possible to fix the changes in geometric parameters of the track in plan with millimeter accuracy [11, 12].

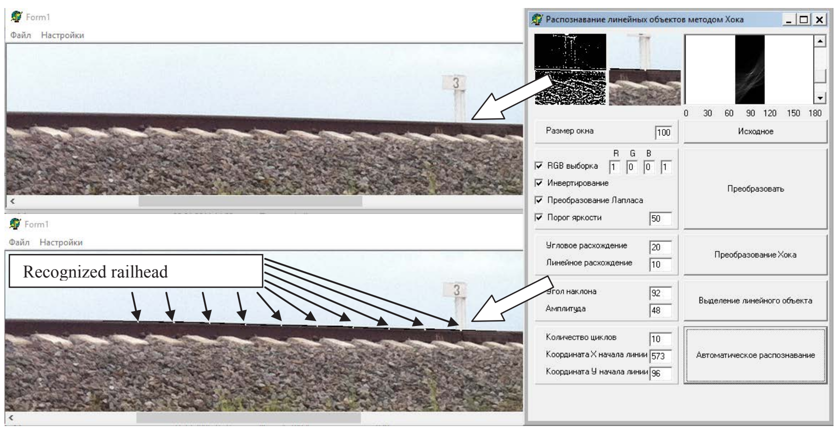
In the course of research based on the materials of television shooting with the verification of high-precision geodetic measurements and binding to a single coordinate system, the numerical parameters of long irregularities of the track (volume deformations) were first obtained – see Pic. 5.

The aerial shooting equipment of the UAV makes it possible to survey parallel to the railway track at the height of the railhead, which allows us to detect relative depressions of the track (Pic. 6).

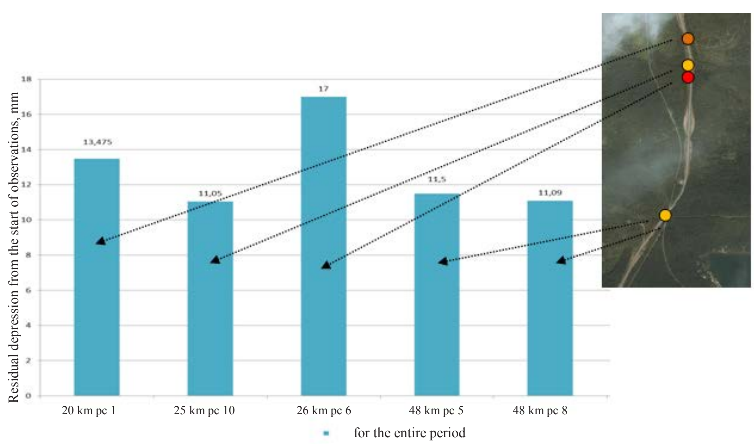
The technology of determining vertical irregularities repeats the technology of determining the unevenness in the plan. The survey is conducted parallel to the railway track at the height of the railhead. Then the line of the rail head is recognized [11] by the Hock method (Pic. 7).

The application of global aerospace monitoring methods allows not only to track the geometric parameters of the track in the entire section Kovdor-Murmansk, but also to identify objects posing a potential threat to the railway [13, 14] (water bodies, emerging dams, reclamation and construction works,, gully-forming processes, etc.), thereby showing the

Pic. 6. Relative depressions of the track at the 25th km of the Kovdor–Pinozero section.



Pic. 7. Recognition of the railhead by the Hock method.



Pic. 8. Refinement of control points by leveling for remote sensing.

dependence of the state of the track on the state of the adjacent territory.

Volume deformations can be associated with deformations of the roadbed, the parameters of the irregularities changing with the growth of the handled tonnage. Obviously, monitoring the parameters of long irregularities can serve as an important means of diagnosing the state of the roadbed when it is under the influence of cars with increased axial load and heavy trains.

Remote sensing technology helps to identify the depressions of the railway track with the subsequent refinement of control points by leveling (Pic. 8). At the same time, it becomes possible to construct the dependence of the entire section's depression on the handled tonnage and reach the economic parameters of operation.

Conclusions. *The conducted observations and the results of research of the state of the railway track under increased axial loads using global satellite monitoring methods made it possible to make the following generalizations:*

1. When introducing a new rolling stock with increased axial loads, it is necessary to evaluate it not only by the strength indicators of the track superstructure elements, but also by the deformability of the track as a whole.

2. The increase in axial loads leads to an increase in the deformations of the track, especially on humid soils (revealed by the analysis of space monitoring data of adjacent territories and depressions of the track).

3. It is advisable to use cars with increased axial loads on closed routes in specialized turntables for the possibility of periodic analysis of the state of the track and adjacent territories based on remote sensing data.

4. The developed monitoring systems for potentially hazardous sections of the railway track using the UAV (quadrocopter-drones) are effective and low-cost means of detecting volumetric deformations. Aerial photography from low altitudes provides operational data on the state of the track and the dynamics of changes in its geometric parameters both in the horizontal plane and in the vertical plane.

REFERENCES

1. Pevzner, V.O., Nadezhin, S.S., Anisin, A.V., Tretyakov, V. V. Evaluation of the deformability of the track in places of disorders and possible changes in the timing of straightening with increasing axial load of freight cars [*Ocenka deformativnosti puti v mestah rasstrojstv i vozmozhnyh izmenenij v srokah vypravki pri povyshenii osevoj nagruzki gruzovyh vagonov*]. *Vestnik VNIIZhT*, 2013, Iss. 4, pp. 44–48.

2. Zheleznov, M. M. About the concept of information and technological improvement of the track maintenance system based on innovative technologies, including satellite ones [*O koncepcii informacionno-tehnologicheskogo sovershenstvovanija sistemy vedenija putevogo hozjajstva na osnove innovacionnyh tehnologij, v tom chisle sputnikovyh*]. *Bjulleten' Ob'edinennogo uchenogo soveta OAO «RZD»,* 2012, Iss. 5, pp. 1–7.

3. Zheleznov, M. M. The main directions of research in the field of monitoring and maintenance of the railway track on the basis of satellite technologies [*Osnovnye napravlenija issledovanij v oblasti monitoringa i tehnicheskogo obsluzhivanija zheleznodorozhnogo puti na osnove sputnikovyh tehnologij*]. *Vestnik transporta Povolzh'ja*, 2011, Iss. 6, pp. 59–64.

4. Constantini, M., Trillo, F., Vechiolli, F., Vasileisky, A. Ground deformation monitoring by persistent scatterer pairs (PSP) SAR interferjmetry. *Proceedings of the 8th All-Russian Open Conference «Earth from Space – the Most Effective Solutions»*. Moscow, IKI RAS publ., 2010, pp. 243–244.

5. Roghaei, M., Zabiholah, A. An Efficient and Reliable Structural Heath Monitoring System for Buildings after Earthquake. *APCBEE Rrocedia*,2014, Vol. 9, pp. 309–316.

6. Shariff, F., Rahim, N. A., Hew, W. P. Zigbee-based data acquisition system for online monitoring of grid-connected photovoltaic system. *Expert System with Application*, 2015, Vol. 42, Iss. 3, pp. 1730–1742.

7. Samadi, A., Amiri-Tolkadany, E., Davoudi, M.H., Darby, S. E. Experimental and numerical investigation of stability of overhanging riverbanks. *Geomorfology,* 2013, Vol. 184, pp. 1–19.

8. Wang, M. L., Lynch, J. P., Sohn, H. Sensor Technologies for Civil Infrastructures. *Woodhead Publishing Series in Electronic and Optical Materials*, 2014, Vol. 55, pp. 159–178.

9. Shen, H., Klapperich, H., Abbas, S. M., Ibrahim, A. Slope stability analysis based on the integration of GIS and numerical simulation. *Automation in Construction*, 2012, Vol. 26, pp. 46–53.

10. Zheleznov, M. M., Pevzner, V. O., Vasilevsky, A. S. [*et al*]. The concept of monitoring macroterritorial deformations of the railway track using space technologies [*Koncepcija monitoringa makroterritorial'nyh deformacij zheleznodorozhnogo puti s ispol'zovaniem kosmicheskih tehnologij*]. *Scientific support of innovative development and increasing the efficiency of railway transport: Collective monograph of members and scientific partners of the Joint Scientific Council of JSC Russian Railways*. Ed. by B. M. Lapidus. Moscow, Mittel Press publ., 2014, pp. 97–111.

11. Zheleznov, M. M. Aerospace remote sensing based determination of track geometry characteristics. *Vniizht Bulletin*, 2012, Iss. 5, pp. 1–7.

12. Zheleznov, M. M. Developing innovative technologies to be implemented with the track maintenance IT system. *Vniizht Bulletin*, 2013, Iss. 1, pp. 15–18.

13. Vasileysky, A. S., Zheleznov, M. M., Makarov, A. Yu. Monitoring of potentially dangerous effects on the railway infrastructure using space RS systems [*Monitoring potencial'no opasnyh vozdejstvij na zheleznodorozhnuju infrastrukturu s ispol'zovaniem kosmicheskih sistem DZZ*]. *Vestnik VNIIZhT*, 2010, Iss. 6, pp. 16–19.

14. Ponomarev, V. M., Shevchenko, A. I. Improvement of the system for preventing and eliminating emergencies on railway transport [*Sovershenstvovanie sistemy preduprezhdenija i likvidacii chrezvychajnyh situacij na zheleznodorozhnom transporte*]. *Nauka i tehnika transporta*, 2005, Iss. 3, pp. 8–15.

15. Zheleznov, M. M., Ponomarev, V. M. Aerospace emergency monitoring methods. *World of Transport and Transportation*, Vol. 15, 2017, Iss. 4, pp. 214–227. ●

Information about the authors:

Zheleznov, Maxim M. – Ph.D. (Eng), associate professor, deputy head of the department of scientific work of Russian University of Transport (MIIT), Moscow, Russia, m.zheleznov@mail.ru.

Pevzner, Viktor O. – D.Sc. (Eng), professor, senior researcher of JSC VNIIZhT, Moscow, Russia, vpevzner@list.ru.

Ponomarev, Valentine M. – D.Sc. (Eng), professor, head of the department of MIIT, Moscow, Russia, ponomarev.valentin@inbox.ru.

Article received 10.11.2017, accepted 24.12.2017.

The work was carried out within the framework of the grant of JSC Russian Railways for the development of scientific and pedagogical schools in the field of railway transport.