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code transmitter; microprocessor; train traffic control center; dispatcher

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NEW POSSIBILITIES OF RAILWAY TRAFFIC CONTROL SYSTEMS

Summary. This article analyses the train traffic control systems in 1435 mm and 1520 mm gauge railways. The article analyses the aspects of train traffic control and locomotive energy saving by using the coordinates of track profile change that have been received from GPS. In the article, achievements of Lithuanian railways (LG) in the area of train traffic control optimisation are presented.

НОВЫЕ ВОЗМОЖНОСТИ СИСТЕМ УПРАВЛЕНИЯ ЖЕЛЕЗНОДОРОЖНЫМ ДВИЖЕНИЕМ

Аннотация. В статье рассматриваются системы управления движением поездов, следующих по железнодорожным линиям, ширина колеи которых составляет 1435 мм и 1520 мм. В статье рассматриваются энергосберегающие аспекты использования систем управления движением поездов и локомотивов, при использовании координат профиля железнодорожного пути, полученных от GPS. В статье представлены достижения «Литовских железных дорог» (LG) в сфере оптимизации управления движением поездов.

1. INTRODUCTION

The railways of the Baltic states have inherited the railway infrastructure of 1520 mm railway gauge and a typical Russian Standard traffic control system. The railways of different railway gauge width in the Baltic states and the EU have been presented in Fig. 1. The Baltic states are constructing a 1435 mm Rail Baltica railway line in which contemporary traffic control systems will be used. Currently, the EU is implementing the installation of smart traffic control systems by using the opportunities of global navigation systems GPS, GALILEO, etc. It is essential to look for technical solutions for the coordination of different railway traffic control systems of 1435 mm and 1520 mm width. To master passenger train routes between the railways of 1435 mm and 1520 mm width, it will be essential to evaluate, not only the differences of the gauge and contact network standards, but also those of traffic control systems. The kinetic energy of trains is not fully used to reduce the locomotive fuel or electric energy consumption for traction. Production of hybrid locomotives with energy saving and accumulation systems is only being developed. Since the detachment of Lithuanian railways, UAB VLRD, along with Russian companies, has produced the first diesel-electric powered hybrid

locomotive with electric power TEM-35 for running on 1520 mm gauge, in which energy collection and saving systems are installed.

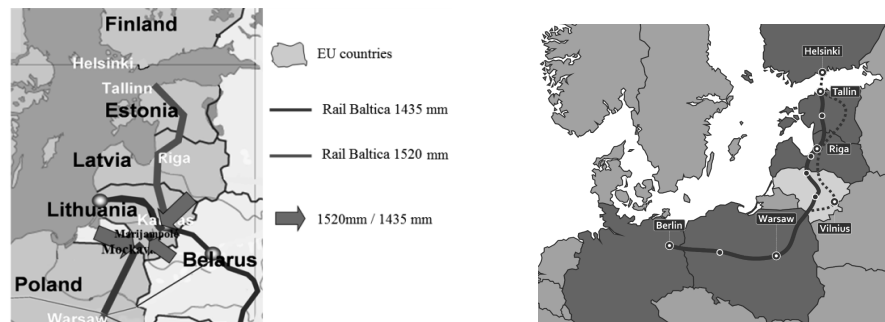


Fig. 1. Different width gauge railways in the Baltic states and EU countries

Рис. 1. Железные дороги государств Балтии и Европейского Союза с колеёй различной ширины

2. TRAFFIC CONTROL SYSTEM ANALYSIS

Railway automation and remote mechanics equipment increase the throughput of trains, simplify train traffic control, improve the overall quality of the entire railway services and increase their competitiveness. Currently, LG has installed the microprocessor traffic control systems of the companies Bombardier and Siemens. The main technical measure of interval train traffic control is an automatic track control AB. Where an automatic interlocking system AB is used for train track traffic control, the way-stations are divided into block zones, the length of which may be up to 1000-2600 m. Block zones are fenced off by light signals of way-stations. Electric track circuit, which is an information sensor certifying the presence or absence of a train, is installed in block zones. The role of conductors in the electric track circuit is taken by rails (Fig. 2a). Relay-based traffic control systems, where a chain of rails is used and there is a microprocessor control on the centralised information screen, are presented in Fig. 2.

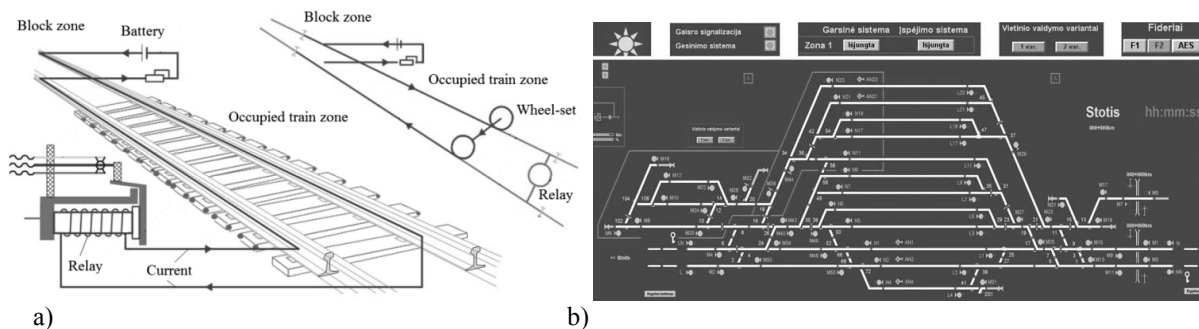


Fig. 2. A relay-based traffic control system, where a chain of rails is used, and (a) there is a microprocessor control on the centralised information screen (b)

Рис. 2. Релейная система управления движением с использованием рельсовой цепи (a), пример информации управления движением поездов на мониторе при микропроцессорной централизации (b)

A track circuit is the body of the railway section rail lines and the equipment attached to it that is meant for transmitting the signals. Should the train enter the block zone, it connects two opposite rail lines by its wheel sets [4]. Therefore, the track relay breaks the circuit of the permissible signal of the side track light, and it creates the power circuit of the red light signal. This way, a restrictive light signal is switched on.

The main interval train movement instruments at way-stations and stations are an automatic and a semi-automatic track block, an automatic locomotive signalisation, an automatic level crossing signalisation, an electric switch and a signal centralisation EC, a traffic control centralisation and a train traffic control in EC. To control the technical condition of the running train rolling stock, automatic control measures RAKP are used. For recording the intensity of the track section by train at interval traffic regulation systems, track circuits are used. Automatic track interlocking (AB) divides the way-station into interlocking zones by light signals of the way-stations. The light signals change automatically, depending on where the train is located.

Microprocessor centralised traffic control system. The microprocessor (Electronic CTC) centralised traffic control system has replaced the relay system (RCTC). Relays were replaced by contactless systems created in the microprocessor base [7, 9]. The CTC system consists of a centralised train dispatcher office that controls railroad interlockings and traffic flows in portions of the rail system designated as CTC territory. One hallmark of the CTC is a control panel with a graphical depiction of the railroad. On this panel the dispatcher can keep track of train locations across the territory that the dispatcher controls.

3. AUTOMATIC LOCOMOTIVE SIGNALIZATION (ALS)

ALS locomotive equipment. The signals of automatic locomotive signalisation light signal have to conform to the signals of track light that the train is approaching. The lights signals of the locomotive are installed in locomotive control cabins and signal to the engine driver and his assistant.

Control of locomotive driver's alertness. Alertness of locomotive driver is controlled as the train approaches a restrictive light signal, when the green light signal of the locomotive is changed to yellow. In this case, the locomotive driver must confirm his alertness once by pressing the alertness handle. Later on, KLUB-U carries out periodic checks (every 30-40 s) of the alertness of the locomotive driver. In all cases, if the locomotive driver does not press the alertness handle in time, the train is stopped automatically by an automatic brake.

4. AUTOMATIZATION SYSTEMS OF LOCOMOTIVE CONTROL

Signalisation equipment are used for transferring information both one way and both ways from the track to the locomotive and from the locomotive to the track equipment. To this end, along with the induced channels, radio and satellite communication channels are used. The information transferred from track equipment to the locomotive is used in the signalisation systems of the locomotive, in train automatic braking systems, in the safety complexes of the locomotive equipment, and also in various optimum control unified systems with different levels of locomotive control automatism – in this case, the locomotive is controlled by a board computer that receives relevant information.

Automatic rolling stock control system. Modern rolling stock axle box heating (temperature) control, blocked wheel and wheel geometry defect detection have been installed in running rolling stock systems. By installing these systems, the costs of rolling stock and infrastructure technical maintenance are reduced, and rolling stock accidents are easier to avoid.

ATLAS-LG systems control the trains running in both directions in the system installation zones. In the sections of a dual railway system, the systems for the control of trains running both ways are usually located in one control post, which controls the heating of the axle boxes and blocked wheel temperature and the surface defects of wheel rolling in the trains passing by, the dynamic wheel forces to the rail and the alternating forces (load). The structural scheme of the control of the wheel sets axle box heating (temperature) and dynamic wheel force to the rail has been submitted in Fig. 4.

The system of ATLAS-LG system moving rolling wheel, acting dynamic force Q change by electric signal system and a diagram of total dynamic force change: ΔQ – the change signal of dynamic force Q ; S – the distance travelled by a moving rolling stock wheel; A/D – analog/discrete signal converter.

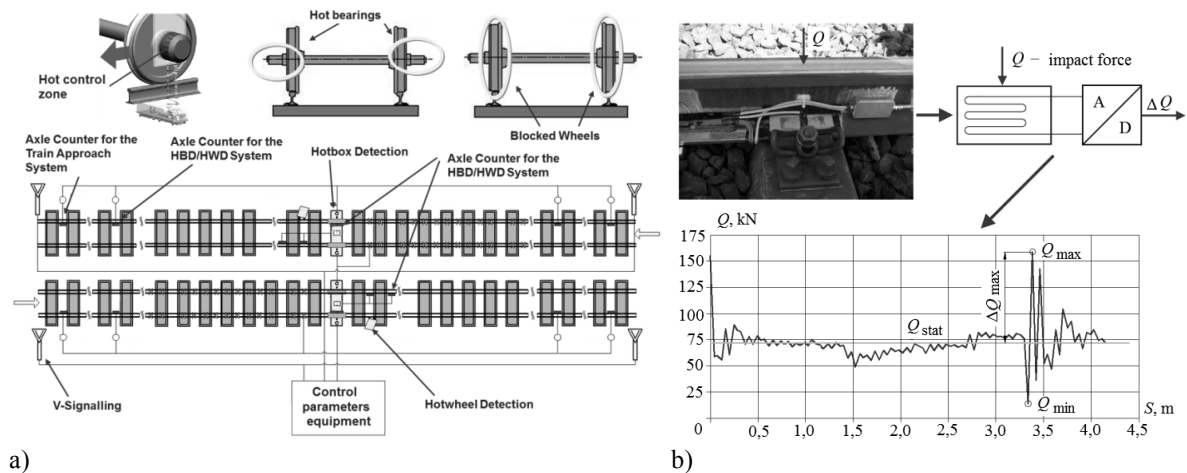


Fig. 3. The structural scheme of wheel set axle box heating (temperature) control and dynamic force to rail measurement

Рис. 3. Структурная схема измерения нагрева букс колёсных пар и динамической силы воздействия колеса на рельс

GSM-R radio communication system is based on a standard GSM but with different specific frequencies used in the railway system and some programmed functions. That is a radio communication system, which is meant for information to be transmitted and received between the rail tracks and the train (voice and data).

The levels of European train control system ETKS. By using the European Train Control System (ETKS) from the equipment in the rail track to the train, the information is transferred, according to which maximum permissible speed is constantly calculated. In the sections, a signalisation system is installed (traffic control light signals and information stands and displays, which are used to inform the locomotive driver of the permissible speed). Information is transmitted to the train from the standard electromagnetic inducers (the so-called Eurobalises) that are installed in the track. [2]. In the cases of all three levels, by using the train computer Eurocab, the speed of the train is comparable to the maximum permissible speed. The 4th ETKS level is a European train control system, by using which the locomotive driver of the train can not only transmit information about permissible speed but also constantly control how these instructions are followed.

Global navigation systems. Global Positioning System (hereinafter – GPS) is a universal positioning system comprising satellites of the Earth [5]. GPS is a US satellite radio navigation system. GLONASS (Russ. *Globalnaja navigacionaja sputnikovaja sistema – Global Navigation Satellite System*) is a Russian satellite radio navigation system. In the GPS system, the exact location of the train is established by a GPS receiver mounted on the train. The GPS receiver, by receiving signals from satellites, establishes geographic coordinates and the movement speed and transmits this information to the control and memory block [3, 6, 8, 9, 14]. In the GALILEO system, this service will be implemented on higher quality, preciseness, universality and reliability levels, as compared to GPS or GLONASS systems [16 - 18].

5. NEW LG TRAFFIC CONTROL SYSTEM OPPORTUNITIES

Once LG started planning the procurement of new generation Western locomotives to complete its locomotive modernisation, it had to decide what safety systems would be used in the locomotives. On the one hand, locomotive safety systems (LSS) have to operate with the technically outdated locomotives in the cabins of which the traffic control equipment for the 1520 mm gauge width railways traffic control equipment has been installed. These are different from the traffic control equipment used on 1435 mm gauge width tracks used in EU countries. On the other hand, the LSS

conception must allow movement on to the second and third ECTS level technical solutions. By creating the LSS structure while not reducing the system's interoperability with ETCS equipment, the national peculiarities of the railway infrastructure were taken into consideration. Therefore, the LSS of the Lithuanian railways has certain differences as compared to those of the second level ETCS requirements. First of all, the LSS is meant to work with railways with 1520 mm railway gauge. The LSS is meant for use in locomotives by operating them with 1520 mm railway gauge in which the train's location is not indicated by means of balises, which are widespread in EU railways. In railways of 1520 mm, the location of the train is by using track circuits and axial meters.

The interoperability of the locomotive equipment with the stationary track equipment of LSS and ETCS are slightly different. The LSS in its memory holds all the information about permissible speed, and also about objects that are in the direction the locomotive is heading to. In the ETCS system the equipment of the locomotive indicates the positioning of the train according to the signals of balise, the position (coordinate) of which is well-known, and the position of the LSS train is indicated according to the GPS coordinates and the track circuit (track sensor) data.

When creating the LSS structure, LG attributed special attention to the possibilities of using the GSM-R radio channel. LG was the first from the post-Soviet republics that installed the GSM-R radio communication network. Currently, LG has implemented the first stage of the project GSM-R radio channel use for the control of locomotives and data transmission [19].

A data transmission and control to the traffic control centre station GSM-R has an interface with the LSS via a systemic block. Train data is transferred to the traffic control centre (railway ordinate, the indication of the light signal, the level of the locomotive driver's alertness, the pressure of the brake bus, etc. – 21 information channels in total), and from the control centre to the locomotive – emergency and forced braking commands – a permission to drive through a restricting signal and temporary speed limits. The structural schemes of train positioning indication of 1520 and 1435 mm gauge railways are presented in Fig. 4. Fig. 4b illustrates the signal structures using Eurobalise of the 1520 and 1435 mm gauge trains. 1520 mm gauge train positioning control system structure: G – green, Y – yellow, R – red, W – white, YG – yellow green transmitter code signals; PR – track equipment code signal input equipment; TCS – track equipment code signals; EIE – Eurobalise signals input equipment.

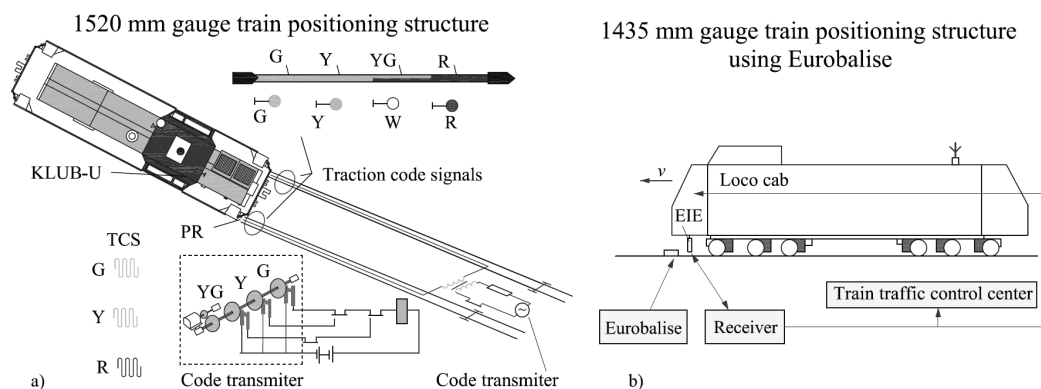


Fig. 4. 1520 mm and 1435 mm gauge train location indication structural schemes by using Eurobalise and track circuit signals

Рис. 4. Структурные схемы определения местонахождения поездов на железных дорогах с шириной колеи 1520 мм и 1435 мм с использованием сигналов Евробалис и рельсовой цепи

The authors suggest a structural scheme for 1520 mm railway gauge width train traffic control by using global positioning systems. This is presented in Figs. 5a and 7. The created traffic control structure would allow for controlling the coordinates of traffic control objects (A1-A3 track profile, A4-track light signals moving in one direction of trains, individual locomotives, etc.). By controlling the change of coordinates of the track profile, one can create locomotive control attachments

(modules) that will provide information directly to the locomotive control system (LCS) [14, 15]. In this way, by evaluating the change of the track profile coordinates independently from the position of the locomotive controller LD, the speed of the locomotive will be controlled and fuel consumption will be significantly reduced. Currently, locomotive drivers control the train manually and cannot fully evaluate the change of the track profile. For example, in the section Kaunas-Vilnius, there are over 160 rise and 140 slopes bigger than 2 parts per thousand. However, a locomotive driver can only memorise the greatest rise and slopes. In the structure of a typical AC/DC current system locomotive, there is a diesel engine (DM), the crankshaft of which is connected to the traction generation GS of alternating current (AC). The speed of a locomotive DC traction motor TM is changed by changing the output voltage of uncontrolled rectifier. Currently, locomotive drivers control trains manually and cannot fully evaluate the change of the track profile. For example, in the section N. Vilnia-Kaunas, there are over 126 rises and 177 slopes. [13]. However, a locomotive driver can only memorise the greatest rises and slopes and control the train by using the kinetic energy of the train, and he cannot save fuel in this way. In this way, fuel consumption can be used only partly. The structural scheme of traffic control by using global positioning systems (a) and the track profile in N. Vilnia-Kaunas section (b) is presented in Fig. 5. The authors have suggested the creation of a traffic control system in which the change of locomotive speed would be realised according to the coordinates of track profile change. The diagrams of electric train kinetic energy control in traction, braking cycles by evaluating the track profile in the section N. Vilnia-Kaunas are submitted in Fig. 6. The diagram of electric train kinetic energy control traction, braking by evaluating the track profile in the section Vilnius-Kaunas shows the amount of electric energy that we can save at the expense of kinetic energy.

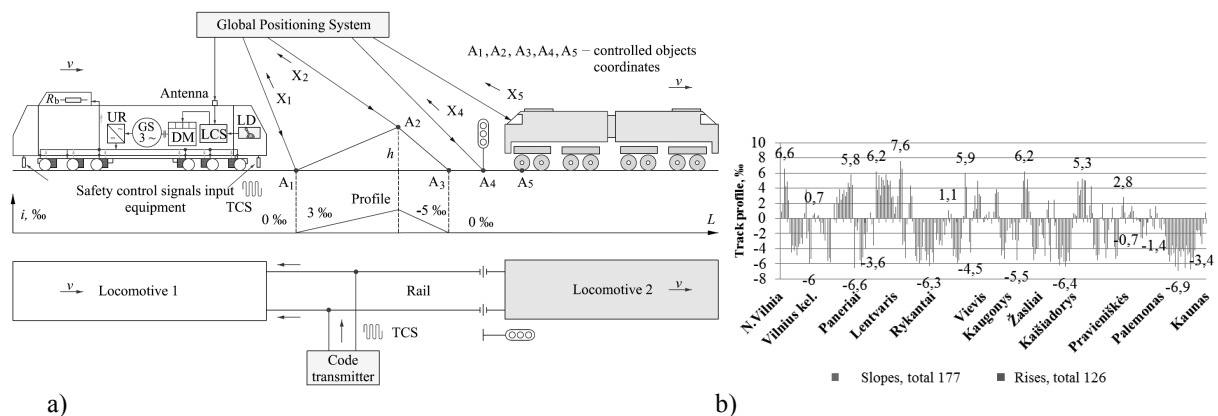


Fig. 5. The structural scheme of traffic control by using global positioning systems (a) and the track profile in Naujoji Vilnia-Kaunas section (b): R_b – braking resistor; L – distance; TCS – traction code signals

Рис. 5. Структурная схема управления движением поездов с использованием глобальной системы позиционирования (a) профиль пути на участке Новая Вильня – Каунас (b): R_b – тормозные резисторы; L – расстояние; TCS – кодовые сигналы пути

The diagram of an electric train kinetic energy control traction, braking by evaluating the track profile in the section Vilnius-Kaunas shows the amount of electric energy that we can save at the expense of kinetic energy. The aggregate amount of electric energy consumed for traction by using energy accumulation systems is expressed by the following dependence $P_{\Sigma}(t) = P_T(t) - P_B(t)$. Here: $P_T(t)$ – the amount of power consumed in traction cycles t_1-t_2 , t_3-t_4 , t_4-t_5 , t_7-t_8 ; $P_B(t)$ is the amount of power consumed that has been accumulated in the power accumulation batteries in the cycles of electro-dynamic braking t_4-t_5 , t_6-t_7 . $v(t)$ are the diagrams of electric train speed change: 1, 2 – in the parking cycle; 3, 4 – in the electro-dynamic braking cycle; 5 – in the traction cycle; (6 – speed limit diagram in the section). The amount of the power saved by an electric train is marked in Fig. 6.

The diagrams of electric train kinetic energy control traction in electro-dynamic braking cycles by evaluating in the track profile show that the aggregate amount of the power for traction consumer by using energy accumulation systems will be reduced since it is expressed by the following dependence: $P_{\Sigma}(t) = P_T(t) - P_B(t)$.

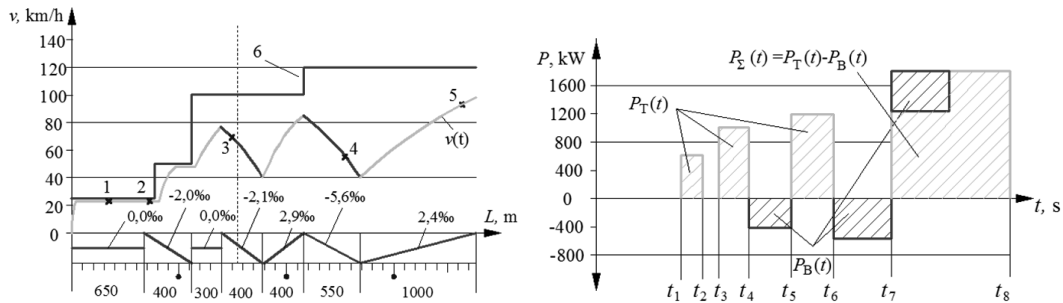


Fig. 6. The diagrams of electric train kinetic energy control traction in electro-dynamic braking cycles by evaluating the track profile

Рис. 6. Диаграммы управления кинетической энергией электропоезда в циклах тяги и электро-динамического торможения, с учётом оценки профиля пути

From the amount of power consumed in the traction cycles, the accumulated amount of energy consumed in the accumulation batteries will be deducted. The structural schemes of LG traffic control centre by using global positioning (a) and transmission data via GSM-R radio channel (b) for the locomotive systems is presented in Fig. 7 [1, 10, 11].

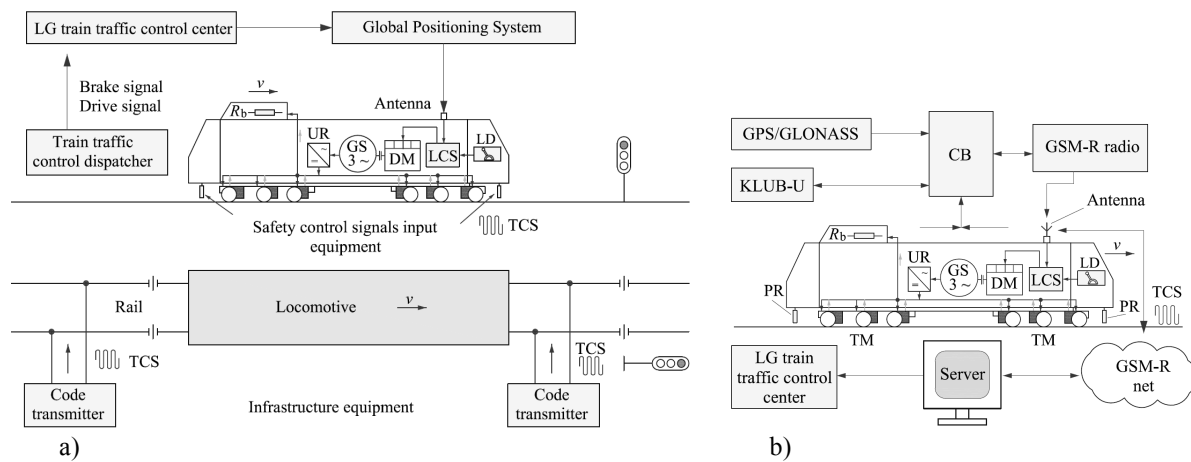


Fig. 7. The structural schemes of LG traffic control centre by using global positioning (a) and transmission data via GSM-R radio channel (b) for the locomotive systems: CB - commutation block

Рис. 7. Блок-схемы центра управления движением Литовских железных дорог с использованием систем глобального позиционирования (a) и передачи данных по радиоканалу GSM-R на локомотив (b): CB – блок коммутации

In 1520 mm gauge railways, the train traffic control systems are made of the stationary equipment in infrastructure and mobile equipment in locomotives (the locomotive signalisation ALS). The LSS completes information exchange with the track equipment, receives automatic locomotive signalisation (ALS) signals, receives information about speed limits and about the fact that employees are working on the track, etc. The equipment of the locomotive transmits information to the LSS about the traction switch on/off, controls re-switching from one cabin to another one, controls the position of the electric air valve (EAV), and controls the pressure of the supply and brake bus. Current time is corrected according to GPS signals [20]. The data of track electronic map and the train running

schedule are recorded into the LSS interior energy-wise independent memory. The permissible speed in the section and independent from the engine driver braking is completed according to the data of the electronic map and train parameters (train weight, wheel set number, etc.). The typical fragment of an electronic map with the data of locomotive running is depicted in Fig. 8. The train movement parameters (railway ordinate, the permissible speed) are established according to GPS/GLONASS satellite and electronic map data, and also according to the signals of locomotive track sensors. The factual locomotive speed is compared to the permissible one, and once it is exceeded, the supply of the EAV valve is broken and the train is stopped independently from the locomotive driver. In this way, the LSS realises its main safety functions.

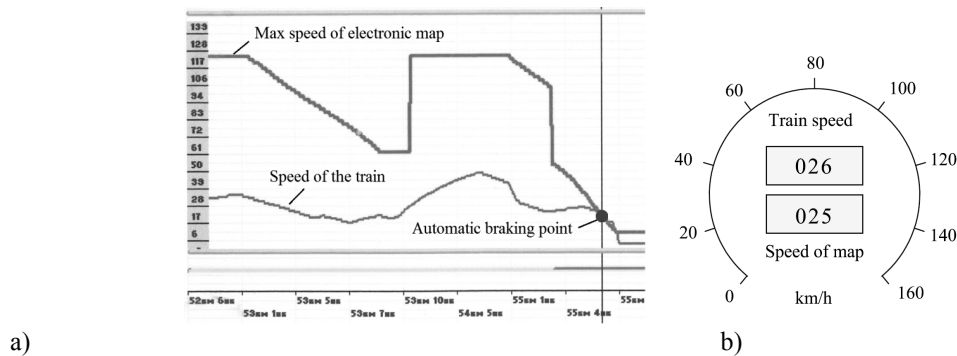


Fig. 8. A fragment of KULB-U electronic cassette of the permissible section speed according to an electronic map and a fragment of the train speed (a) and KLUB-U speed indications in the shield during the automatic braking

Рис. 8. Фрагмент разрешенной для данного участка электронной кассетой КЛУБ-У допустимой скорости в соответствии с электронной картой и скоростью поезда во время автоматического торможения

A locomotive receives ALS signals via GSM-R radio channel and from the track equipment. By organising freight train traffic, it is very important to reduce the time of the attempts to brake the train before a trip. A practical attempt of train a braking system that was formed in traditional systems is completed by the locomotive driver and station employees. The locomotive driver indicated the necessary pressure in braking cylinders through the braking controller. To make sure that all the front wagons are being stopped, the locomotive driver completes a visual check of them. Where the weight of the train is around 6000 t, the number of wagons is more than 100 units. Such a train is a very long one and the time for the practical inspection of its braking system’s functionality is very long. The structural schemes of freight train set braking attempt automatisaton and the integrity control of the train by using GPS and GSM-R is provided in Fig. 9.

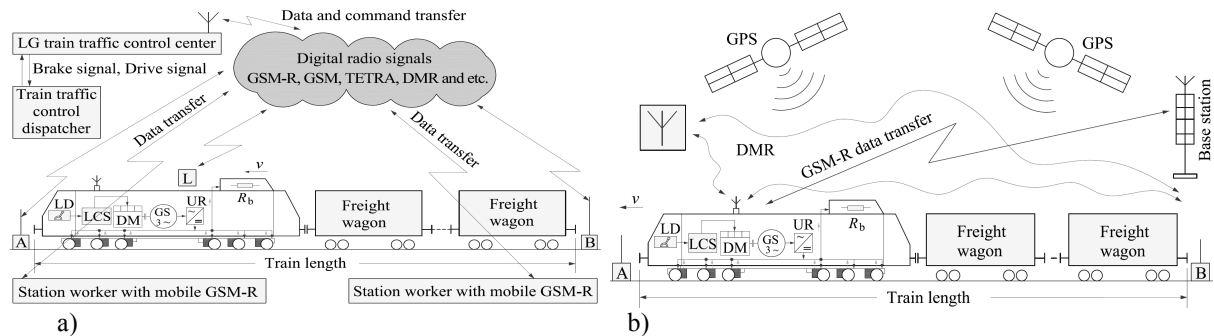


Fig. 9. The automatic control schemes of the LG train braking (a) and integrity (b) systems test using GPS and GSM-R

Рис. 9. Структурные схемы Литовских железных дорог автоматизации тестирования торможения (a) и целостности поезда при помощи GPS и GSM-R (b)

By using the system provided for freight train braking attempts, one can significantly reduce the time of the tests, the test results may be transferred by radio communication channel to the locomotive driver, the station employees who prepare the documentation of the train, and the LG train traffic control dispatcher. Fig. 9 marking: A – train front coordinate; B – train end coordinate; L – locomotive coordinate.

Train set braking system test automatization allows the following: reducing the costs by 25%, the time of the train set braking system test, the archiving of the test parameters, and the sending of the parameters in an electronic form (reduces the documentation preparation time).

Train integrity control. The integrity of the freight train is checked by controlling the speed of the last wagon, the route of the last wagon, the pressure of the braking bus of the last wagon, and the changes in the pressure of the braking bus of the last wagon braking. A photo of LG contact network equipment remote control is presented in Fig. 10.



Fig. 10. A photo of LG contact network equipment remote control

Рис. 10. Снимок устройств дистанционного управления контактной сети Литовских железных дорог

Before the launch of the “Da Vinci” system, there were 33 stations in LG, which could have been controlled from an old traffic control centre EVC. Out of them, 21 stations was constantly controlled. In the new traffic control centre, the control of 91 stations is completed: out of them, control of 7 border station traffic is carried out; control of 13 distribution, freight, passenger station traffic is carried out; 11 stations (5 of them are included into the Rail Baltica project) have no traffic centralisation EC.

6. CONCLUSIONS

By using global navigation systems and radio communication systems, one can basically change the quality of train traffic control:

- For the control of train integrity, GPS and GSM-R radio communication systems are used.
- For the freight train braking tests before the trips, the system suggested by the authors is to be used.
- For the reduction of locomotive fuel and power consumption, locomotive attachments (modules) are to be created that could correct the locomotive speed according to the coordinates of the GPS track profile change.

New train traffic control systems improve only the work of the operators who observe the interval movement of trains. It is essential to look for technical solutions for the matching of the different 1435 mm and 1520 mm width railway traffic control systems. By using global navigation systems and GSM-R radio communication systems, the train may be stopped from the traffic control centre if there is a failure in the train traffic system or the alertness of the engine driver is confused. Even though the

railway traffic control system gauge of the EU (1435 mm) and that of the Baltic states (1520 mm) differ, one has to expand the GSM-R radio communication data transmission and global navigation systems in them. Equipping threat control and traffic consequence liquidation division in train traffic control centres is suggested.

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