SELECTED ABSTRACTS OF D.SC. AND PH.D. THESES SUBMITTED AT RUSSIAN TRANSPORT UNIVERSITIES

Selected abstracts of D.Sc. and Ph.D. theses submitted at Russian transport universities

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Batraev, V. V. Improving the efficiency of using the transit capacity of railways. Abstract of Ph.D. (Eng) thesis [*Povyshenie effektivnosti ispolzovaniya propusknoi sposobnosti zheleznodorozhnykh linii. Avteref. dis… kand. tekh. nauk*]. Moscow, RUT (MIIT) publ., 2022, 24 p.

The issues of increasing the efficiency of the use of capacity, ensuring traffic safety, and improving reliability of functioning of technical means have been and remain the most important for railways. The safe functioning of railway transport, as a complex technical and technological system, requires provision of a coordinated policy in the field of operation, the development of new construction principles, improvement of existing locomotives and stationary technical means of ensuring train traffic safety, as well as development of new regulatory technical documents, considering minimisation of human factor impact on the process of organising train traffic. Failures of technical means and imperfection of the processing algorithms in the on-board systems of automatic locomotive signalling (ALS), their insufficient functionality, are a significant constraint for the effective use of the transit capacity of railways. In this regard, it is especially important to form a new set of scientific and practical methods for the organisation of traffic and the functioning of technical means of ensuring safety, which will qualitatively increase the use of line capacity while minimising infrastructure costs.

The objects of research are automated systems of control and train traffic safety, methods for organising train traffic using technical means with extended functionality.

The subject of research englobes infrastructure and locomotive technical means for ensuring train traffic safety, methods, algorithms and risk assessment models, methods, and tools for the efficient use of the capacity of railway lines.

The purpose of the work is to ensure reliable functioning of the control and safety system based on technical and technological solutions in the field of efficient use of the capacity of railways.

The analysis of the existing technical means of control and train traffic safety was carried out, which showed the possibility of increasing the efficiency of the use of capacity and made it possible to use the results obtained in development of technical requirements and technical solutions for newly created control and safety systems.

A technique has been developed for the efficient use of throughput capacity in the case of functional redundancy of train traffic safety systems, which made it possible to increase the efficiency of throughput use with the use of modern technical means for ensuring train traffic safety.

The analysis of the efficiency of capacity use in emergency situations was carried out. The results allow us to formulate new principles for operating modes of the «virtual coupling» technology without changing the structure of the existing auto-lock.

A technique is proposed for improving reliability of information reception in the complex interaction of on-board and stationary safety devices, which makes it possible to improve the algorithms for processing signals from track circuits by locomotive safety systems, considering changes in the phase of the received signal of a multi-valued signalling and to reduce the decision-making time by up to 3 times. The principle of determining the boundaries of track circuits has been developed and experimentally confirmed, which provides more accurate positioning of the rolling stock on the railway track, including the Moscow Central Circle.

An algorithm has been developed for the rolling stock to follow ground signals at an increased speed. The use of the algorithm allows locomotive safety devices to allow the movement of rolling stock at a higher permissible speed at the «yellow» light signal and reduce the distance between the subsequent trains along the track.

The analysis of the possibility of using the domestic element base in on-board safety devices and interval control systems is carried out. An evidence base was obtained and introduction of the domestic element base into the complex of technical means developed by JSC NIIAS on the instructions of JSC Russian Railways was ensured.

It is recommended to use the developed methods and techniques as a permanent functionality of on-board and infrastructure control and safety systems. Due to modularity, the described technologies can be implemented independently and in the shortest possible time.

The prospect for further development of the research topic is development of technologies for

automatic control of the integrity of the train by on-board means and the development of ALS systems, considering interference from asynchronous motors, as well as safety control of locomotive signalling for high-speed trains.

2.9.4 – Transportation processes management.

The work was performed and defended at Russian University of Transport.

Krasnov, O. G. Prediction of wear and contact fatigue damage of rails for the conditions of intensification of cargo traffic. Abstract of D.Sc. (Eng) thesis [*Prognozirovanie iznosa i kontaktno-ustalostnoi povrezhdaemosti relsov dlya uslovii intensifikatsii gruzovogo dvizheniya. Dis… dok. tekh. nauk*]. Moscow, RUT (MIIT) publ., 2022, 40 p.

Increasing axle loads is recognised throughout the world as one of the main directions that can dramatically increase the carrying capacity of lines by increasing productivity of cars. The United States, Canada, Australia, South Africa, and Sweden followed this path. The introduction of rolling stock with increased axle loads is taking place on Russian railways. To increase the resource of rails, in 2012–2013 the reconstruction of technological lines at JSC EVRAZ ZSMK, the construction of a new production facility at PJSC ChMK were carried out. The reconstruction of production allowed organising the production of differentially heat-strengthened rails from furnace heating of various quality categories in accordance with GOST R [State standard] 51685–2013. In accordance with the «Strategy for development of railway transport in the Russian Federation until 2030» the task was set to bring the technical and technological level of infrastructure, the scope of its maintenance and repair to the best world standards.

The problem of establishing scientifically substantiated factors that determine the intensity of rail wear and formation of contact fatigue defects on their surface, the development of methods for predicting rail wear and their contact fatigue life, taking into account quality categories, train flow structure and axial loads, levels of unsuppressed accelerations, rail lubrication, longitudinal slopes within track profile and mass of trains, types of intermediate rail fastenings used, as well as more accurate ways to take into account the force impact on the track from rolling stock with increased axial loads and the state of the track is relevant.

The objective of the work is to develop scientifically based methods for predicting wear of rails of different quality categories and their contact fatigue damage for the conditions of intensification of cargo traffic.

A block diagram and analytical expressions have been developed for predicting the quantitative values of lateral and vertical wear of rails using the first introduced concept of «basic wear rate».

It has been established that distributions of vertical forces from interaction of wheels of rolling stock and the track in the trains composed with the cars with close axial loads, are stationary, ergodic processes with insignificant asymmetries (no more than 3 … 3,5 % of the average values) and are well approximated with normal law according to the Kolmogorov–Smirnov agreement criterion.

A method has been developed for determining integral distribution of vertical forces, which makes it possible to take into account the impact of different types of rolling stock, considering the designs of running gears and the values of axial loads, the speed of movement, the dependence of the stiffness of the under-rail base on seasonality (summer, winter), the cross profile of the track, the state of the track (presence of wet or dry splashes), the share of each type of rolling stock in the total impact on the track.

Based on the complex theoretical and experimental studies carried out, new scientifically substantiated technical and technological solutions have been obtained to reduce wear and contact fatigue damage of rails for the conditions of intensification of cargo traffic.

A block diagram and analytical expressions have been developed for calculating the lateral and vertical wear of rails using the concept of basic wear intensity introduced for the first time. On the basis of complex experimental and theoretical studies, quantitative values and patterns of changes in intensity of wear were established depending on the quality categories of rails, the radius of curved sections of the track, the levels of outstanding accelerations, the frequency of lubrication, the longitudinal profile of the track and the mass of trains, the design of the rolling stock undercarriage and the values of axial loads, the type of intermediate rail fastenings used. This made it possible to develop a scientifically based method for predicting wear of rails of various quality categories to determine the quantitative values of lateral and vertical wear under different operating conditions.

According to the results of multivariate calculations of rail wear using the Rail Profile Wear Evolution software tool as part of the Universal Mechanism software package, according to the criterion of maximum

convergence of experimental and calculated data in the experimental curved sections of the track, the parameters of the Specht wear model were established: wear coefficient $k_v = 2{,}57 \cdot 10^{-13}$, jump coefficient $k_y = 12$ and critical power density $P_{cr} = 30$ W/mm² for DT350 rails. A method is proposed for estimating the intensity of wear of rails of different quality categories by determining their wear coefficients.

The factors are ranked according to the share of their contribution to the intensity of rail wear. The factors that make it possible to control rail wear are identified: the quality category of rails, the type of lubrication and the frequency of lubrication, the levels of outstanding accelerations, the stability of the rail inclination. A rational choice of control factors using a forecasting technique will make it possible to minimise the intensity of rail wear under various operating conditions.

To automate the calculation of rail wear, a computer program was developed in the graphical programming environment Lab View 2011. Using the example of 36 curves, the lateral wear of rails was simulated using the developed program and a comparative analysis of the calculated and experimental data on rail wear presented by the technical department of the Slyudyanskaya track distance of the East Siberian Infrastructure Directorate was carried out. The difference between the calculated and experimental data did not exceed 15 %.

An algorithm has been developed for predicting the contact fatigue damage of rails before formation of cracks on the tread surface. The stress-strain state of the contact zone was studied on the developed finite element model of rolling of a car wheel along a rail. Based on the simulation results, it was found that the components of the stress tensor on the rail surface are in a disproportionate multiaxial stress state. This made it possible to justify the use of the Brown-Miller deformation model for predicting the contact fatigue damage of rails on the tread surface before cracking.

The parameters of deformation curves of elastic, plastic and total fatigue of rail steel were determined using the modified Rusl – Fatemi hardness method. A polynomial dependence of the relative damage of the rail rolling surface on the vertical force F_i was established by performing calculations in the MSC.Fatigue software package using the average characteristics of the indicators of the degree of fatigue strength and ductility of rail steel and the calculated stresses in the contact zone of the wheel and rail.

A device based on a vision system has been developed, a video signal processing algorithm has been proposed to determine the distributions of wheel-rail contact points along the cross section. By testing a loaded cargo car equipped with the developed device, it was found that the main share of contact points falls on the longitudinal strips of the rail surface located at a distance of 20 … 25 mm from the inner side face (26,4 %), and on the longitudinal strips of the rails' surface, rails' surface, located at a distance of 25 … 30 mm (22 %).

A method has been developed for determining the integral distributions of vertical forces, which makes it possible to take into account the impact of different types of rolling stock, taking into account the design of the running gear and the values of axial loads, the speed of movement, dependence of the rigidity of the undersleeper base on seasonality (summer, winter), the transverse profile of the track, as well as the condition of the track in the form of wet and dry splashes.

A technique has been developed for predicting the contact fatigue damage of the rail rolling surface before cracking, taking into account degradation of the mechanical properties of rail steel depending on the tonnage processed. It has been calculated by calculation that an increase in the proportion of cargo cars with axle loads of 245 kN from 9 to 64 % for the conditions of the Trans-Baikal DI will lead to a decrease in the time before the initiation of contact fatigue cracks on the rail surface by 11,3 %.

For the first time for Russian railways, the patterns of formation of a worn cross section of the rail head in straight and curved sections of the track and the efficiency of removing contact fatigue damage extending to a depth of 2,5 mm using a rail-cutting train were established. A technique has been developed for determining the geometric parameters of the cutting tool of milling wheels with the transformation of a cloud of points by the method of singular value decomposition and the use of Delaunay algorithms, which made it possible to choose a rational profile of the cutting tool for high-quality reprofiling of a worn rail head.

The prospects for further development of the thesis topic are:

– research on the rational choice of control factors to reduce the intensity of rail wear;

– studies of contact-fatigue damage of rails in curved sections of the track of small and medium radii.

2.9.2. – Railway track, survey and design of railways.

The work was performed and defended at Russian University of Transport.

Malyshev, N. V. Models and methods of container flow dispatching at terminals. Abstract of Ph.D. (Eng) thesis [*Modeli i metody dispetcherizatsii konteineropotoka na terminalakh. Avteref. dis… kand. tekh. nauk*]. St.Petersburg, Emperor Alexander I St. Petersburg State Transport University, 2022, 16 p.

Reducing the time of transportation of containers by rail and increasing the volume of transit transportation of containers by four times are the priority tasks noted in the Decree of the President of the Russian Federation «On the National Development Goals of the Russian Federation until 2030». In order to achieve the tasks set, JSC Russian Railways has been implementing the concepts of container business development and creation of logistics centers in the Russian Federation in the last decade, moving to the policy of building new facilities and introducing information technologies in the terminal and warehouse complex. The basis of the policy refers to the railway terminals, which connect different types of transport in international traffic and allow to increase the volume of processing, creating the necessary conditions for further development of container traffic. A number of foreign container terminals in terms of the level of technical development, the number of technological operations, the speed and reliability of their execution are approaching automated high-tech industries, becoming the basis for intensive development of the transport complex. The current system for organising container transportation in the Russian Federation is far from the use of integrated automation in transport, storage and loading and unloading operations, while dispatching can be considered as the main stage for combining the processes and objects of the terminal within the framework of an automated control system for introduction of advanced technologies, including robotics. The analysis of domestic and foreign theoretical studies has shown that the theoretical and practical aspects of scheduling have not been studied enough. The combination of these facts determines the practical and theoretical relevance of scheduling issues in the processing of container traffic at terminals, as a research topic.

The objective of the thesis is to improve the efficiency of the terminal through development of new models and methods of interaction between railway and other modes of transport in the system of container terminals. The subject of research refers to models and methods of container flow dispatching at railway transport terminals. The object of study is the railway container terminal.

The analysis of the state and growth trends of cargo transportation in containers showed insufficient implementation of the transit potential of international transport corridors with Asia due to the lack of processing capacity of terminals. Trends in reducing the cost of automation, increasing costs per employee and an increase in the number of complexly automated enterprises in related areas of the economy in the last decade justify introduction of unmanned technologies in the near future at points of concentration of cargo flows, such as container terminals.

It has been determined that container traffic dispatching is able to solve the problems of reducing operating costs and increasing the processing capacity of the terminal.

The approach proposed in the developed methodology to determine the required amount of equipment for intra-terminal movements based on the probability distributions of the number of arriving and departing containers, as well as the storage strategy, made it possible to:

– Consider the specialisation of equipment for intra-terminal movements. The value obtained in the simulation in 92 % of the terminal operation time is 3 PTM less than as a result of the calculation according to the existing methodology when calculating the required number of PTM for the entire terminal;

– Consider the likelihood of queues when performing tasks. Based on the simulation results presented in the histogram, it can be concluded that queues appear when performing tasks by 6 PTM in more than 30 % of the terminal's operation time.

It has been determined that an increase in the number of cranes from one to two reduces the cycle time of operations from a stack to a car by 38 %, which exceeds the reduction in the time of other types of operations from 14 % to 31 %. Also, increasing the number of taps from one to two leads to a decrease in dispersion from 47 % to 88 %, however, a further increase in the number of taps has an effect on dispersion of less than 31 %.

The obtained dependencies showed that the operational capabilities for direct reloading increase by 61 % with an increase in the number of cranes from one to two. While the wait time for vehicle-to-stack operations is less than 5 minutes, the wait time for stack-to-vehicle operations increases to 30 minutes when the cargo front is fully loaded.

The developed scheduling method takes into account the scheduling models proposed in the thesis, aimed at minimising the empty run of PTM, increasing the productivity of the crane and meeting the deadline for completing the task.

Dependences of the average cost of the idle time of two car deliveries under cargo operations on the moment of switching between deliveries with the Erlang distribution of the k-th order of the execution time of the cargo operation and its special case – exponential distribution with a mixed priority of servicing car deliveries are determined.

The dependencies of the total time of execution of tasks of PTM were determined using the current technology and the strategy for completing tasks when calculating Pareto optimality in relation to six criteria aimed at increasing the productivity of the crane and minimising the empty run of PTM. Based on modelling the distribution of tasks between PTM during the month, it is shown that a strategy aimed at reducing mileage can reduce the time to complete tasks by 9,6 %.

The expected economic effect from introduction of dispatching models and methods is achieved by reducing operating costs when choosing the switching point between supply of cars and reducing the time to complete the tasks of PTM during intra-terminal movements and amounts to more than 9,5 million rubles.

2.9.4 – Transportation processes management.

The work was performed and defended at Emperor Alexander I St.Petersburg State Transport University.

Polyakov, B. O. Determination of aerodynamic resistance of cargo trains with innovative cars with increased carrying capacity. Abstract of Ph.D. (Eng) thesis [*Opredelenie aerodinamicheskogo soprotivleniya gruzovykh poezdov s innovasionnymi vagonami uvelichennoi gruzopodemnosti. Avtoref. dis… kand. tekh. nauk*]. St.Petresburg, Emperor Alexander I St. Petersburg State Transport University, 2022, 16 p.

Currently, Russia is actively developing and building a new generation of rolling stock for railways. One of the main tasks in development of innovative railway technology is to increase efficiency. It is known that the resistance to movement is the factor that affects the economic performance. Taking into account the value of resistance to movement allows effectively using energy resources in transportation of goods and passengers. In scientific works devoted to resistance of trains, attention is more often paid to clarifying the general calculation methodology, studying the processes of energy dissipation into the environment and energy losses in bearings, less attention is paid to the study of aerodynamic resistance, especially for cargo trains.

The objective of the work is to develop a methodology for determining the aerodynamic resistance of a cargo train with traditional and innovative gondola cars on digital models.

A technique has been developed for determining the aerodynamic component of the main resistance to cargo train movement, including:

– development of solid models of the studied rolling stock units, on the basis of which calculation models are created that take into account the characteristics of the environment and railway infrastructure;

– study on digital models of various options for cargo train movement with determination of the dependence of the aerodynamic component of the main resistance to movement when changing the number of cars in the train and models of cars;

– extrapolation of the obtained data to a train of any length, composition and load.

A classification of various components of the total aerodynamic resistance is proposed according to the signs of dependence on speed, load and number of cars.

A computational-empirical method for determining the main resistance to movement of rolling stock has been created, which consists in using the obtained dependences of aerodynamic resistance on digital models together with experimental data to determine the mechanical resistance to determine the resistance for various options for cargo rolling stock.

The values of aerodynamic resistance for different parts of the train are determined depending on the speed, the number of cars and the level of their loading, and the qualitative and quantitative characteristics of the interaction of the train with the air are obtained.

The calculation results are compared with the data of full-scale experiments, as well as with the results of the analytical determination of the aerodynamic component of the main resistance to train movement.

When comparing the specific values of the aerodynamic resistance of cars of various models, it was established that:

– articulated cars create the least specific aerodynamic resistance per unit weight (reduction up to 42 %) and unit length (reduction up to 32 %) of the train, but the greatest when considering the resistance per unit of the rolling stock (increase up to 7 %);

– innovative gondola cars with increased body volume due to elongation in loaded mode create less (down to 30 %) specific resistance per unit of weight, unit of train length and unit of rolling stock compared to a traditional gondola car;

– innovative gondola cars with increased body volume due to broadening in laden mode create less (up to 18 %) specific resistance per unit of weight, unit of train length and unit of rolling stock compared to a traditional gondola car.

05.22.07 – Railway rolling stock, train traction and electrification.

The work was performed and defended at Emperor Alexander I St. Petersburg State Transport University.

Shinkaruk, A. S. Increasing the duration of the life cycle of a passenger car based on increasing durability of its center beam. Abstract of Ph.D. (Eng) thesis [*Povyshenie prodolzhitelnosti zhiznennogo tsikla passazhirskogo vagona na osnove uvelicheniya dolgovechnosti ego khrebtovoi balki. Avtoref. dis… kand. tekh. nauk*]. Moscow, RUT (MIIT) publ., 2022, 20 p.

In accordance with the strategy of the Russian Railways holding company, it is planned to optimise the route network and train schedules, increase speeds, increase cargo traffic and passenger traffic. The requirements for ensuring safety during operation of passenger rolling stock are determined as a matter of priority by ensuring reliability and strength of the supporting elements of the car. Despite the constant improvement of methods for repairing both components and parts, and passenger cars as a whole, when calculating the strength of car elements, there are areas that are still difficult to be assessed, including due to the presence of a technological factor. Thus, the experimental assessment of the rolling stock remains the only and rather costly method that establishes the conformity of the car design with regulatory safety requirements.

To ensure and implement the objectives of the strategy, more than 18,5 thousand passenger cars are currently used to transport passengers in long-distance traffic, however, the actual demand for passenger rolling stock, especially during summer and holiday transportation, is only increasing. Despite the fact that in the last 5 years the purchase of rolling stock has been growing in general, over the past decade the rate of replenishment of the passenger car fleet has been reduced by more than 35 %, and it is not possible to fully meet the demand for transportation during peak periods.

In addition to the problems that arise with compensation for rolling stock that is retired due to its service life, owners face questions about the optimality of carrying out scheduled preventive maintenance and transferring the car to a non-working fleet for this period. So, when a car is sent for a scheduled repair, physical wear and tear, depending on the ranges of plying and the intensity of operation, is not the same, which leads to placement of cars with varying degrees of wear, from minimal to excess, into repair positions. Therefore, depending on the actual volume of repair, the cost of restoring the resource, as well as downtime directly in repair, will be different.

The objective of research is to increase the life cycle of a passenger car, the frame design of which includes a center beam, by increasing its durability.

The object of research are passenger cars of models 61–828,61–425 and 61–4186.

Based on the complex theoretical and experimental studies performed, new technical and technological solutions have been obtained to increase durability of the center beam and increase the life cycle of a passenger car.

Based on the analysis of the structure of the passenger car fleet, it was found that the models of cars used in transportation activities on the territory of the Russian Federation, the design of which includes the presence of a center beam, is increasing and, as of December 31, 2020, is 86 % of the total fleet.

As a result of the study of the newly manufactured main beam, it was proved that after welding of the I-beam of the pivot beam to the channel of the main beam, alternating residual stresses from –415 MPa to 354 MPa are formed.

Based on the results of experimental studies, sections of the main beam were identified that are subject to the greatest corrosion effect (metal in the area of welded seams adjoining the pivot, end and intermediate beams).

The study of the elements of the main beams, which have developed a standard service life (40 years), found that the metal basically meets all the standard strength characteristics.

Studies of the elements of the center beam that have reached their standard service life have shown that the corrosion failure of the centre sill is largely affected by the formation in the metal structure of a significant spread of residual stresses arising during the manufacture and operation of the car.

As a result of the experimental paint coating on the car centre beam, it was proved that shot blasting, including in welding places, stabilises the residual stress fields, thereby increasing the corrosion resistance of the metal surface layer.

The use of advanced paint coatings effectively reduces corrosion and external effects on the metal structure of the passenger car frame.

It is recommended to use the developed technology for preparation and painting of the passenger car centre beam with integration into the preventive maintenance system, which can be implemented in the shortest possible time in all shot-blasting and painting complexes of passenger car depots and at car repair plants without significant operating and investment costs.

The prospect of further development of the topic is evaluation of new paint coatings to protect the undercarriage of the rolling stock from the effects of external factors and corrosive effects on the load-bearing frame of the passenger car frame.

2.9.3. – Railway rolling stock, train traction and electrification.

The work was performed and defended at Russian University of Transport.