ABSTRACTS of D.Sc. and Ph.D. THESES

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

For the original Russian text please see p. 242.

DOI: DOI: https://doi.org/10.30932/1992-3252-2020-18-242-254

Bugreev, N. V. Improving the efficiency of planning and production activities of centralised signalling and block section unit. Abstract of Ph.D. (Eng) thesis [*Povyshenie effektivnosti planirovaniya i proizvodstvennoi deyatelnosti distantsii signalizatsii, tsentralizatsii i blokirovki. Avtoref. dis... kand. tekh. nauk*]. Moscow, RUT publ., 2020, 24 p.

Based on the research carried out, new scientifically grounded methodological, technological, organizational and managerial solutions for improving planning of production activities of railway transport enterprises, which are essential for development of the country, are presented.

The following theoretical and practical results are obtained:

• The necessity of developing new methods and technologies for production planning of the activities of structural subdivisions of the infrastructure complex of JSC Russian Railways was substantiated. It is shown that digital transformation of production processes in railway transport makes it possible to increase the planning efficiency of labour and material resources due to availability of new, previously unavailable capabilities for automated collection and analysis of large volumes of various statistical information, and the use of more advanced technological algorithms.

• A new method has been developed for statistical assessment of the necessary and sufficient time that should be reserved to perform a complex of additional work by centralised signalling and blocking section units, as well as by other structural units of automation and telemechanics facilities.

• A method for calculating unregulated volumes of work of the production process of technical operation of systems and devices of railway automation was developed, based on the composition of the laws of distribution of random variables.

• An algorithm was developed for assessing and analysing the time reserve for performing unregulated volumes of work when planning production activities for centralized signalling and block section units.

• A new method of planning performance indicators of structural units of automation and telemechanics facilities of JSC Russian Railways was proposed and substantiated, considering the technical risks associated with unreliable operation of transport infrastructure facilities and their impact on the indicators of the transportation process.

• A practical method has been developed for calculating the expected and planned values of integral, basic and additional indicators of activities of various structural divisions of the automation and telemechanics economy, as well as an indicator of quality of infrastructure functioning within the boundaries of the production activity of the signalling system distance.

• The analysis of the process model of maintenance and repair of systems and devices of railway automation in the distance of the signalling system was carried out, recommendations were formulated for improving the process model, considering the proposed methods of planning production activities.

• The methods, technological and organizational and managerial solutions proposed in the work have been tested and found practical application on the railway network of the Russian Federation. At present, the technique is being tested at test sites of all railways. On the basis of the methods and techniques proposed in the thesis, two branch documents (techniques) of JSC Russian Railways were developed with direct participation of the author, approved and accepted for practical use.

In the long term, the most urgent task is to automate methods and techniques for planning the activities of structural subdivisions of the infrastructure complex of JSC Russian Railways. The solution to this problem is planned in the Roadmap for implementation of the project «Digital transformation of automation and telemechanics economy processes» as part of implementation of the Digital Transformation Strategy of JSC Russian Railways until 2025.

05.02.22 – Organization of production (transport). The work was performed at Russian University of Transport.

Pugachyov, A. A. Energy-efficient electric drives with asynchronous motors for mainline locomotives. Abstract of D.Sc. (Eng) thesis [*Energoeffektivnie elektroprivody s asinkhronnymi dvigatelyami dlya magistralnykh lokomotivov. Avtoref. dis... doc. tekh. nauk*]. Moscow, RUT publ., 2020, 48 p.

New scientifically grounded technical solutions aimed at ensuring high energy efficiency of electric drives on main-line locomotives, the introduction of which makes a significant contribution to development of the country, are outlined.

New scientific results have been obtained, formulated in the following provisions:

With a fan load of auxiliary electric drives of locomotives, considering cost indicators of modern frequency converters, it is more expedient to use variable frequency drives with scalar control algorithms.

A scalar control system for an electric drive with an asynchronous motor is synthesized, which minimizes stator current and, consequently, the power loss in steady-state operating modes. When the moment of resistance is not equal to the nominal one, the efficiency value due to the use of the stator current minimization system can be increased by 20 %, and the power losses can be reduced by 50 %.

Comparative analysis of electric drives showed an obvious advantage of scalar control systems operating on the principle of minimum stator current, which maintain the required torque value with lower values of stator current, stator voltage, and, consequently, with a lower magnetic flux value, which leads to an increase in the quality factor and a decrease in electromagnetic loads. At the same time, the analysis showed the need to consider the influence of the winding temperature on the stator voltage values and control system parameters in connection with the influence on the values of the stator current minimum and, especially, the optimal absolute slip, which provides extreme control of the stator current minimum.

An algorithm for generating a reference for stator currents and flux linkage of an induction motor rotor when using a vector control system, providing a minimum power loss, has been developed. Limiting factors were applied to the limits on the current and voltage of the stator of the engine, the power of the diesel generator set. A control system for a traction electric drive with an asynchronous motor has been synthesized, providing direct control of wheel slip, with a subordinate system for minimizing power losses. It was found that the use of the developed control system leads to a decrease in power losses. The greatest absolute effect at any moments of resistance is achieved in the vicinity of the nominal frequency of rotation of the stator magnetic field m_{0nom}, and when the frequency m approaches the frequency m_{0nom} from the side of smaller values, the effect from the use of the developed system increases to a much greater extent than when m approaches m_{0nom} from the side values.

A simplified thermal equivalent circuit is proposed for determining the temperature of the winding and stator magnetic circuit. Equations of thermal equilibrium are synthesized. A method has been developed for determining the values of stator thermal resistances using a laboratory setup, which takes into account the cooling features of a specific type of motors and eliminates the need to consider an induction motor as an aerodynamic system. The results of experimental studies made it possible to establish the influence of the engine rotor speed and the volume of cooling air on the values of thermal resistance.

A method has been developed for identifying active resistance of the rotor winding of an induction motor based on signals from the stator current and voltage sensors and the rotor shaft speed sensor. An algorithm for determining resistance and temperature of the rotor winding is synthesized based on algebraic equations describing electromechanical conversion of energy in mutually perpendicular rotating axes. The results of simulation modelling of the proposed method in MatLab Simulink software package for an 11 kW induction motor showed high convergence, the maximum discrepancy did not exceed 9 %.

A method is proposed for determining the resistance and temperature of the stator and rotor windings by periodically adding to the stator voltage a high frequency voltage and/or a constant voltage component, and its accuracy is assessed. The addition of a DC voltage component allows determination of the stator winding resistance and temperature; the addition of high frequency voltage makes it possible to determine the resistance and

temperature of the stator and rotor windings at the same heating. In case of unequal heating of the stator and rotor windings, it is necessary to jointly add constant and high-frequency voltage components. The influence of the non-ideal characteristics of the power switches of the voltage inverter is shown. The simulation results showed that the error in determining the stator winding resistance is 1 %, while the error in determining the rotor resistance can reach 6 % when adding an alternating voltage component with a frequency of 150...250 Hz.

Automatic temperature control systems have been developed for traction motors, traction frequency converters and a power plant of an autonomous locomotive with the use of an electric cooling fan drive as an executive-regulating device, which provide an expansion of the range of variation of the fan shaft speed, and, consequently, a decrease in the range of variation of the controlled temperature.

A control system has been developed that reduces power losses in power semiconductor devices of an autonomous voltage inverter of a traction frequency converter and controls their temperature, intended for use as part of a traction electric drive control system. The input signals of the system are temperatures of the crystals of power semiconductors and the stator current of the traction motor. The output signals of the system are the setting for the switching frequency of power semiconductor devices and the setting for the maximum current.

Assessment of the economic efficiency of using an electric drive of a cooling fan with a frequency converter and an asynchronous motor with an energy-efficient scalar control system as part of an automatic temperature control system of a power plant, carried out according to the method developed at VNITI, showed that fuel savings can be 16 t 992 kg per year per cooling system of the power plant of an autonomous locomotive with a capacity of 2200 kW in comparison with a relay control system.

05.09.03 – Electrotechnical complexes and systems. The work was performed at Russian University of Transport.

Solomin, A. V. Development of the theory of linear traction devices of high-speed maglev transport. Abstract of D.Sc. (Eng) thesis [*Razvitie teorii lineinykh tyagovykh ustroistv vysokoskorostnogo magnitolevitatsionnogo transporta. Avtoref. dis... doc. tekh. nauk*]. Rostov-on-Don, RGUPS, 2020, 38 p.

As a result of the study, the scientific problem of increasing traffic safety of high-speed vehicles on a magnetic suspension (MLT) was solved by improving lateral dynamics with the help of new designs of multifunctional traction linear induction motors (LIM) with longitudinal-transverse magnetic flux, which develop lateral self-stabilization efforts of levitating vehicles relative to the track structure, and the scientific problem of increasing efficiency the use of linear induction motors on a high-speed MLT by developing their theory, which made it possible to increase the accuracy of calculations and create new LIM designs. The research carried out allowed us to formulate several main conclusions.

Analysis of publications, the level of technology and economy in the Russian Federation and other industrialized countries allow us to conclude that at the first stages of creating trains with speeds of 350–500 km/h, maglev transport systems with traction linear induction motors are more promising.

High MLT speeds require a significant increase in traffic safety. One of the ways to solve this scientific and technical problem is creation of new traction linear asynchronous drives operating on a new principle of action, which is proposed in the thesis, with improved transverse dynamics, developing not only traction forces, but also the efforts of transverse self-stabilization of the high-speed maglev vehicle relative to the track structure.

A method for improving the transverse dynamics of high-speed maglev transport with LIM traction using a new physical principle of magnetic fields counter-running in the transverse direction in linear motors is determined. If their symmetry is violated (lateral displacement of the vehicle), lateral forces are created that return the MLT vehicle to its previous position. Based on solving field problems, the foundations of the theory for determining lateral self-stabilization were created, considering the relationship between the geometric dimensions of the inductor and the secondary element of LIM and the value of the lateral displacement.

The solution to the optimization problem made it possible to establish the zones of the most advantageous use of LIM with transverse magnetic flux, which is necessary for design of linear motors for maglev transport. It is shown that the coefficient of attenuation of the electromagnetic force (tractive effort) depends on distribution of the current density in the secondary element of the LIM, methods for its reduction by directionally changing the ratio of its geometric dimensions are determined.

Analytically, relations were obtained for calculating the attenuation coefficient of the electromagnetic force of traction LIM with a transverse magnetic flux, considering the distribution of the current density in the secondary element, the size of the air gap and the transverse edge effect. The optimal values of the current density of the secondary element are determined, taking into account the speed of the MLT and the geometric dimensions of the engine.

Analytical relations are established for calculating the current density of LIM traction inductors with longitudinal and transverse magnetic flux by solving differential equations, considering the geometric dimensions of the inductor and the secondary element and their mutual influence on the current density distribution in the winding frontal parts, which increases the accuracy of calculating the traction force.

The boundary field problem was formulated and solved, which made it possible to obtain relations for calculating the current density in the secondary element of LIM traction with a longitudinal magnetic flux, considering the influence of the magnetic field outside the inductor, which makes it possible to increase the accuracy of calculating the traction forces. The results of theoretical studies made it possible to establish that the efficiency of the interaction of the currents of the inductor and the secondary element of the LIM with the longitudinal magnetic flux depends on the magnitude of their phase shift and has a significant effect on the magnitude of the traction force of the MLT. Analytically, relations have been obtained for calculating the coefficient of attenuation of the electromagnetic force (tractive effort) depending on distribution of the current in the secondary element, which can be used in design of a linear induction motor for high-speed maglev transport.

Mathematical models have been developed for calculating the currents in the secondary element of a LIM with a transverse magnetic flux on the basis of Maxwell's equations, which make it possible to take into account the size of the air gap with the magnetic suspension of a high-speed vehicle, distribution of magnetic induction in the transverse direction and the relationship between geometric dimensions of the inductor and the secondary element. A new mathematical model of distribution of currents in the secondary element, considering the transverse edge effect, is proposed, which allows choosing its rational dimensions at the design stage of the maglev transport system with LIM. New relations are obtained for determining the coefficient of attenuation of the electromagnetic force of the LIM for high-speed MLT, taking into account the median effects, which increases the accuracy of calculations.

The optimal values of the average current density of the secondary element of LIM for MLT have been determined, considering the relationship between speed of movement and the geometric dimensions of the engine. It is proved that the increment of the current density of the secondary element of the traction LIM when it is displaced from the axis of symmetry in any direction will be negative. The study of the vicinity of the extremum (maximum) of the average current density of the secondary element showed that even a slight deviation from the optimum leads to a significant decrease in the current density and a decrease in the tractive effort. This is especially pronounced at low values of the pole pitch of the motor.

The features of regulation of a linear induction motor with a variable resistance of the short-circuited winding of the secondary element are investigated. Several field problems have been solved, establishing the relationship between the parameters of the groove of the secondary element of the LIM controlled traction and the magnetic field of the secondary element with partial closure of the rod conductors. Regularities of changes in the coefficients of an increase in the active and a decrease in the inductive resistance of the winding of the secondary element, depending on the number and location of short-circuited conductors, have been established. It has been proven that the effect of current displacement

in the secondary element groove manifests itself especially sharply when a part of the conductors that occupy more than 50 % of the groove height is short-circuited. In such cases, when calculating an adjustable LIM traction in the modes of starting the MLT from rest, while braking, changing the speed of movement, it is necessary to consider the displacement of the current in the groove.

Experimental studies on laboratory and prototypes of LIM for high-speed maglev rolling stock showed that the discrepancy between theoretical and experimental results does not exceed 10 %.

Designs of new traction LIM for maglev transport have been developed, protected by 2 copyright certificates of the USSR and 25 patents of the Russian Federation.

The results of the thesis research have received practical application in the design of the stand for the study of the equilibrium, stability and motion of combined electromagnetic and electrodynamic suspensions for high-speed maglev transport (NIIEFA named after D. V. Efremov, JSC State Atomic Energy Corporation Rosatom), as well as are used in research on new modes of transport within the framework of the RFBR_RZD grant No. 17-20-04236 «Magnetic cooling of promising transport and energy systems» at Kotelnikov Institute of Radio Engineering and Electronics of the Russian Academy of Sciences when developing stands for the study of atmospheric and vacuum maglev transport systems, in the educational process of RSTU, adopted for implementation at transport and industrial enterprises.

05.22.07 – Rolling stock of railways, train traction and electrification; 05.09.01 – Electromechanics and electrical devices. The work was performed at Rostov State Transport University.

Trofimova, L. S. Scientific foundations of the current planning of the operations of a freight motor transport enterprise under conditions of uncertainty in its development. Abstract of D.Sc. (Eng) thesis [*Nauchnie osnovy tekushchego planirovaniya raboty gruzovogo avtotransportnogo predpriyatiya v usloviyakh neopredelennosti razvitiya. Avtoref. dis... doc. tekh. nauk*]. Omsk, SibADI publ., 2020, 32 p.

The performed studies of the relationship between freight road transport, maintenance and technical support of rolling stock during operation of motor transport enterprise using new information technologies in the form of computer programs under conditions of uncertainty in development can be qualified as new scientific and organizational developments for current planning aimed at solving a problem that is important in fulfilment of the target indicators outlined in the Transport strategy of the Russian Federation for the period up to 2030 in the field of effective development of road transport in the Russian Federation.

Due to the developed concept of current planning, a set of principles for application of methods of current planning, mathematical models and methods of innovative orientation, a major scientific problem of great economic importance has been solved – theoretical and methodological foundations for current planning of motor transport enterprise work have been developed, taking into account the relationship of cargo transportation and implementation of technical maintenance and current repair of rolling stock to comply with the main provisions of the Federal Law «On Road Safety» and aimed at achieving indicators of development of road transport, indicated in the Transport Strategy of the Russian Federation for the period up to 2030 in the context of existing uncertainty. The approbation and implementation of research results will ensure development of the Russian economy through implementation of the important socio-economic role of the current planning of the work of motor transport enterprise when the terms of contracts are fulfilled.

The performed analysis of indicators characterizing the current state of road transport in the Russian Federation made it possible to establish that the indicators of the Transport strategy of the Russian Federation for the period up to 2030 depend on performance indicators of the motor transport enterprise, which are formed taking into account changes in demand for road transport services in the structure of transported goods, their volumes, requirements with the parties of the Customers to the specialized rolling stock, the terms of cargo transportation. Indicators have been established that affect the results of motor

transport enterprise functioning in conditions of development uncertainty, which must be considered in current planning in relation to transportation of goods, maintenance and repair of rolling stock by motor transport enterprise standard sizes in order to fulfil contracts and make a profit.

The conceptual apparatus, aimed at developing theoretical foundations of the current planning of motor transport enterprise work, has been clarified, considering the probabilistic state of indicators of transportation of goods, maintenance and repair of rolling stock and the properties of types of activities in their mutual influence on each other, identified in the course of the developed classification of motor transport enterprise activities.

A strategy for application of the current planning of motor transport enterprise work has been developed, based on a new concept of current planning of motor transport enterprise work, the guiding idea of which is the synthesis of transportation of goods, maintenance and technical requirements of rolling stock, and includes the principles of applying the methods of current planning in operation of motor transport enterprise; a conceptual scheme for current planning of motor transport enterprise work, ensuring achievement of quantitative and qualitative indicators, according to which the motor transport enterprise can operate to fulfil the terms of contracts and make a profit.

Methods for current planning of motor transport enterprise work are proposed, aimed at determining the probabilistic indicators of functioning of rolling stock of the motor transport enterprise standard sizes when transporting goods in the city and in intercity traffic to fulfil the terms of contracts and make a profit.

The developed theoretical and practical toolkit for current planning of motor transport enterprise operation includes created mathematical models for functioning of a specialized rolling stock of motor transport enterprise standard sizes for fulfilling the terms of contracts for transportation of goods in the city and in intercity traffic, and software and mathematical support for the developed mathematical models.

The probabilistic parameters of mathematical models were determined with a confidence level of 0,95 according to the established dependences of the influence of technical and operational indicators on production and mileage of a specialized substation of standard sizes of motor transport enterprise, obtained as a result of studies carried out experimentally in production conditions. A logarithmically normal law of distribution of length of a ride with a load in the city and in intercity traffic, the normal law of distribution of the mass of a shipment of cargo in intercity traffic has been established.

Methods have been developed for current planning of operation of specialized rolling stock of standard sizes of motor transport enterprise for transportation of goods in the city and in intercity traffic, in which mathematical models and software and mathematical support are applied to them, allowing:

• to plan operation of specialized rolling stock of standard sizes of motor transport enterprise to fulfil the terms of contracts in terms of production and mileage indicators with a confidence level of 0,95;

• to determine the volume of cargo transportation, taking into account the probability of performing transport work by a specialized substation of standard sizes of motor transport enterprise in the city, assessing the volume of cargo transportation by a specialized substation of standard sizes of motor transport enterprise in intercity traffic under contracts, if the lengths of trips with cargo correspond, the values of which are set with a confidence level of 0,95;

• to choose the working hours and the way of organizing the work of drivers to fulfil the terms of contracts on time of transportation of goods in intercity traffic;

• to determine quantitative and qualitative indicators of cargo transportation, maintenance and repair of rolling stock, costs, results, and profits.

Theoretical and experimental approbation of the developed methodological foundations, carried out at the motor transport enterprise and in the educational process of the university with the use of new computer programs, confirms the scientific and practical significance of the research results. The established volumes of cargo transportation, which were indicated in the contracts between the motor transport enterprise and the Customer, were fully implemented, a profit was obtained that

exceeded the profit calculated according to the indicators of the previously developed methodology by 14,5 % (339 248 rubles) – when transporting goods in the city, by 10,8 % (1 281 170 rubles) – when transporting goods in intercity traffic. The use of new computer programs made it possible to reduce the total labour intensity by 7,7 people • hours when planning cargo transportation in the city, by 9,6 people • hours when planning long-distance freight transportation for rolling stock of the same standard size of motor transport enterprise. The effectiveness of new computer programs is determined by the minimum response time of the system to the actions of the manager and was no more than three minutes. Practical testing of the developed requirements and recommendations for determining the working hours and the way of organizing the work and rest of drivers made it possible to avoid accidents due to the fault of drivers associated with fatigue while transporting goods in intercity traffic.

Further research will be aimed at development of improved theoretical foundations and methodological concepts for planning the operation of motor transport enterprise, the application of which is aimed at solving the problems of development of road transport in accordance with changes in the economy of the Russian Federation.

05.22.10 – Operation of road transport. The work was performed at Siberian State Automobile and Highway University (SibADI).

Zhukov, A. S. Substantiation of the design of a body of a passenger car made of extruded aluminium panels. Abstract of Ph.D. (Eng) thesis [*Obosnovanie konstruktsii kuzova passazhirskogo vagona iz ekstrudirovannykh alyuminievykh panelei. Avtoref. dis... kand. tekh. nauk*]. Tver, JSC NO «TIV», 2020, 20 p.

Based on the analysis of foreign and domestic experience in the design and manufacture of passenger cars with bodies of aluminium alloys, a variant of the body structure of a passenger car with a cross-section and end parts formed from extruded aluminium profiles (panels) is proposed.

The necessity of supplementing the existing regulatory framework for carrying out design work with the requirements for the elements of the roof cladding and side walls of the car body with a design different from the traditional one has been determined.

An approach is presented that allows at the design stage to check the compliance of the body of a passenger car with a design different from the traditional one to safety requirements specified in the regulatory documentation and formulates the requirements for the elements of the roof and side walls of the car body with a cross section made of extruded aluminium panels.

A finite element model of an aluminium body was developed, calculations were carried out for I and III design modes, which confirmed the compliance of the proposed design option with strength requirements.

To verify the model and determine dimensions of finite elements that provide the required accuracy of calculations with a minimum amount of time spent on the calculation, an experimental study of the extruded panel, proposed for forming the cross-section of the car body, was carried out.

A method for calculating extruded aluminium profiles has been developed, which makes it possible to significantly simplify the initial stages of developing the body structure.

A comparative calculation of the life cycle of aluminium and steel cars was performed, the results of which confirm the possibility of creating an economical structure using aluminium alloys.

The results obtained during implementation of the thesis work can be used to develop design solutions for design of bodies of passenger and freight cars with a design different from the traditional one, from various structural materials.

The prospect of further development of the topic is to consider optimization of the proposed design (reduction of metal consumption, the use of aluminium alloys with improved characteristics, etc.), its refinement, considering the methods of installing undercarriage and car interior equipment (including when considering the possibility of large-block assembly), clarification of the economic aspect within the framework of the steel and aluminium car.

05.22.07 – Railway rolling stock, train traction and electrification. The work was performed at Tver Institute of Wagon Design (CJSC NO TIV). The defence took place at Russian University of Transport. ●