SELECTED ABSTRACTS OF PH.D. THESES SUBMITTED AT RUSSIAN TRANS-PORT UNIVERSITIES

The texts of the abstracts originally written in Russian are published in the first part of the issue.

Тексты авторефератов на русском языке публикуются в первой части данного выпуска.

Khmelev, A. S. Improving information interaction in decision support systems and managing the transportation process of raw materials supplies. Abstract of Ph.D. (Eng) thesis [*Sovershenstvovanie informatsionogo vzaimodeistviya v sistemakh podderzhki prinyatiya reshenii i upravleniya perevozochnym protsessom syrievykh postavok. Avtoref. dis… kand. tekh. nauk*]. St. Petersburg, Emperor Alexander I Petersburg State Transport University, 2022, 18 p.

Metallurgical enterprises of the full cycle are characterised by a significant volume of cargo transportation, a large range of products and complex production technology. Consolidation of all data from the carrier, rolling stock operator and metallurgical enterprise into a single network will allow employees to fully control the supply chain, while significantly reducing the amount of operational interaction.

The objective of the study is to improve information interaction in the control systems of the transportation process of raw materials supplies by developing an information decision support system within a single space for all participants in the transportation. The goal is achieved by solving the following tasks:

1) Analysis of the current state of the theory and practice of information interaction in the management systems of the transportation process between the carrier, enterprise and operator companies and identification of existing problems.

2) Study of the technological process of transportation of raw materials for the needs of ferrous metallurgy.

3) Development of a mathematical model and algorithms for functioning of the decision support information system.

4) Determination of the technical and economic efficiency of possible solutions.

Scientific novelty:

1) A methodology was developed for construction and operation of an information decision support system for organisation, management and control of movement of raw materials, which allows end-to-end monitoring of the entire logistics chain.

2) The analysis of the statistical time series of trains running with blast-furnace coke at Zarinskaya-Novolipetsk test site was carried out, the numerical characteristics of random variables were calculated, an assessment was made for the correspondence of the studied distributions to the normal one, and stochastic models for forecasting the arrival and stocks of cars were built.

3) The concept of a single information field for all participants in the transportation process in the field of supplies of raw materials from ferrous metallurgy was practically applied and a mathematical model of transport services for a metallurgical enterprise was suggested based on the proposed new principles of information interaction.

The main results of the study are as follows.

1) The Russian ferrous metallurgy and railway cargo transportation markets are characterized by a high level of concentration of production assets, which necessitates continuous improvement of railway transportation and cost reduction by optimizing logistics costs.

2) The functioning of the decision support information system in organisation, management and control of movement of raw materials allows closing the information gap, providing end-to-end monitoring throughout the supply chain and making management decisions in case of deviations in accordance with the decision matrix. In the course of the study, a mathematical apparatus was developed and algorithms for operation of such an information system were built.

3) The arrival forecasting model was developed using probabilistic methods. Four statistical series of train running times were compiled and analysed, the sample for each of which consisted of 100 values.

On the developed model, experimental calculations of real input data were performed using Statistica and MathLab software packages. As a result, probabilistic graphs were constructed for each type of metallurgical coke in the summer and winter periods.

4) The annual economic effect of implementation of the information system only regarding blast-furnace coke will be 11 million 646,2 thousand rubles.

2.9.4. – Management of transportation processes.

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

Mikhailov, S. V. Vertical dynamic forces in the contact areas of vehicle wheels and rails in a ballastless track structure. Abstract of Ph.D. (Eng) thesis [*Vertikalnie dinamicheskie sily v kontaktakh koles ekipazha i relsov v bezballastnoi konstruktsii puti. Avtoref. dis… kand. tekh. nauk*]. Moscow, RUT (MIIT) publ., 2022, 24 p.

At present, the railway transport of Russia faces the task of increasing the mass of goods and the speed of transportation, which requires development of heavy and high-speed traffic. The increase in speed of movement and axle load, as well as various climatic conditions, require the use of new structures for the track superstructure, subject to the obligatory preservation of its stability. To solve such problems, ballastless structures are widely used in world practices, however, studies of the areas of their use in the conditions of Russian railways have demonstrated their limited applicability. Thus, the task of choosing the optimal structures of the track superstructure for specific operating conditions is extremely relevant, and its solution requires the calculation of the life cycle cost. At the same time, full-scale tests are very difficult, and often not economically feasible, which indicates the need for mathematical simulation. One of the widely used practical models for solving this problem is the model of track oscillations as a three-layer beam lying on a modified Winkler foundation. This model makes it possible to obtain probabilistic estimates of such characteristics of the track superstructure as the angles of rotation of sections, bending moments, transverse forces, deflections, and stresses in structural elements. Knowledge of such estimates allows solving the problems of increasing the service life of the structure, predicting repairs of the track superstructure, studying the behaviour of the structure during impact interaction between the wheel and the rail, and makes it possible to estimate the probability that these characteristics will exceed the existing standard values. The use of this model makes it possible to calculate the average values and standard deviations of random processes for each of the considered layers, which is important for a number of problems related to the study of ballastless structures. Finding these probabilistic characteristics requires calculating the matrix of mutual spectral densities of vertical dynamic forces acting on the track, however, at present there is no method for finding it for a three-layer structure model, and an approximate estimate is used to solve current problems.

The objective of the study is to develop a method for predicting the service life of a ballastless track, taking into account vertical dynamic forces caused by track irregularities in the profile. To achieve this objective, the following tasks were set and solved:

1. Development of a method for calculating the matrix of mutual spectral densities of vertical dynamic forces through track roughness in the profile in the model of a three-layer beam lying on a modified Winkler foundation.

2. Obtaining characteristics of random processes of change in deflections and stresses in the layers of a ballastless structure from the effect of vertical dynamic forces caused by track irregularities.

3. Determination of the influence of random processes of change in deflections and stresses

275

in the layers of a ballastless structure on its service life.

4. Evaluation of the discrepancies between the results of calculations of the service life of a ballastless track obtained using the proposed method compared to the existing one.

The main results of the study are as follows.

1. A method was developed for finding the matrix of mutual spectral densities of vertical dynamic forces through track irregularities in the profile in the model of track vibrations as a three-layer beam lying on an elastic Winkler foundation, which makes it possible to evaluate the statistical characteristics of the stress state and deflections in structural elements of a ballastless track.

2. The developed mathematical and computer model for calculating the service life of ballastless track structures using the method proposed by the author can be used in calculating the life cycle of the ballastless track for various operating conditions and substantiating the feasibility of using one or another ballastless structure or ballast track.

3. The difference in the results of calculating the service life of a ballastless track structure for existing HSR conditions using the model of a single-layer beam and a three-layer beam is about 5–10 %.

4. With an increase in the speed of movement and load on the axle, the discrepancy between the results of calculations performed using the models of a single-layer and three-layer beam increases, and, with sufficiently large values of these parameters (more than 160 km/h and 25 t/axle), can exceed 20 %, which makes it reasonable to use the method proposed in this paper in the future.

5. The proposed mathematical model and numerical calculations were used to determine the permissible geometric dimensions of a concrete bearing slab in development of the first edition of GOST R [Russian State standard] «Ballastless track of high-speed railway lines. Safety requirements and control methods», as well as for formation of proposals for changing GOST 32698-2014 «Intermediate rail fastening of the railway track. Safety requirements and control methods». The calculation results were used in development

of a new type of rail fastening (applications for patents No. 2022112623, 2022112624, 2022112625, 2022112626, 2022112627 dated 11.05.2022).

6. The tasks of determining the influence of the values of random processes of changing deflections and stresses, taking into account vertical dynamic forces, set in the work, were solved, the objective of the work to determine the service life of a ballastless track was achieved.

7. The prospects for further development of this topic are to carry out calculations for various types of vehicles, track designs and operating conditions, and apply the proposed model for statistical estimates of random processes that occur when calculating impact interaction in the carriage–railway system.

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

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

Volchanina, M. A. Improving the methods of diagnosing the insulation of power transformers of the traction power supply system using mobile technical means. Abstract of Ph.D. (Eng) thesis [*Sovershenstvovanie metodov diagnostirovaniya izolyatsii silovykh transformatorov sistemy tyagovogo elektrosnabzheniya s primeneniem mobilnykh tekhnicheskikh sredstv. Avtoref. dis… kand.tekh.nauk*]. Omsk, OSTU publ., 2022, 20 p.

The task of creating conditions for sustainable, safe, and efficient functioning of railway transport as an organising element of the country's transport system is reflected in the «Strategy for scientific and technological development of the holding company Russian Railways for the period up to 2025 and for the future up to 2030 (White Book)». Ensuring reliable trouble-free operation of power supply systems in operation in railway transport corresponds to priority areas for development of science, technology, and engineering in the Russian Federation. The analysis of data on failures of power transformers of traction substations of JSC Russian Railways shows that transformers

whose service life corresponds to the period before the first overhaul and is about 12 years are mainly susceptible to damage. According to statistics, the most damaged parts of power transformers are the winding – 52 %, and bushings – 27 %. This is explained by the fact that, compared with substation transformers of power systems and industry, power transformers of the traction power supply system operate in more difficult conditions. GOST 52719-2007 «Power transformers. General Specifications» does not give an accurate assessment of reliability indicators for power transformers of traction substations of electric railways. In this regard, during operation of power transformers in the traction power supply system, it is recommended to carry out additional diagnostics of their condition periodically. The level of reliability of the traction power supply system (TPS) directly affects both safety of train traffic and uninterrupted movement of trains, which is especially important when passing heavy trains, since the current loads increase significantly and become higher than the nominal values. The use of continuous diagnostic methods makes it possible to determine the actual technical condition and residual life of power transformers in the traction power supply system. Thus, creation of technical means, methods, and algorithms for functioning of mobile automated systems for diagnosing the insulation of power transformers is an urgent task.

The objective of the thesis work is to increase the efficiency of operation of power transformers as part of a traction power supply system by improving methods for assessing the technical condition of insulating structures using mobile diagnostic tools.

To achieve this objective, the following tasks were formulated and solved in the work:

1. To study the causes for formation and types of defects in the insulating structures of power transformers of the traction power supply system and to determine methods for diagnosing their technical condition.

2. To determine the threshold values for development of defects in insulating structures of power transformers and to justify the diagnostic parameters for determining the presence of defects.

3. To develop a method for assessing the technical condition of the insulation of power transformers of the traction power supply system during operation.

4. To develop a method for determining the location of a possible formation of an insulation defect and a method for diagnosing the state of the inputs of power transformers of the traction power supply system based on measuring the parameters of the electric field.

5. To improve the technology of overhaul testing of power transformers of the traction power supply system to ensure uninterrupted operation of the traction power supply system.

6. To develop mobile technical means for assessing the technical condition of the insulating structures of power transformers and to test them.

As a result of the research carried out, new scientifically based technical and technological solutions and developments were obtained, aimed at improving the technology and technical means for diagnosing the insulating structures of power transformers of the traction power supply system. Their application will improve the efficiency of operation of power transformers in the traction power supply system.

The main scientific and practical results of the thesis work are as follows:

1. The analysis of the causes of failures of power transformers and of existing methods for diagnosing the insulating structures of power transformers of the traction power supply system has been carried out, the advantages of using acoustic control methods with registration of partial discharge parameters and measurement of electric field parameters near high-voltage bushings have been substantiated.

2. The threshold values of indicators of recorded signals for the «Normal», «Pre-emergency» and «Limit» states of insulation are determined by identifying the laws of distribution. The parameters of signals with partial discharges and acoustic emission signals caused by mechanical influences are indicated.

3. A method has been developed for detecting the pre-emergency state of the insulation of the

277

windings of power transformers of the traction power supply system during operation, taking into account development of insulation defects under conditions of seasonal temperature changes.

4. A method for determining the location of formation of a defect in the insulation of a power transformer is proposed, taking into account the propagation speed of acoustic pulses in transformer oil and metal structures. The influence of interfering factors on obtaining data on the current state of the transformer insulation has been leveled.

5. A technique has been developed for diagnosing the state of power transformer bushings based on the analysis of electric field distribution data near the bushings under study. It was found that the deviation of the symmetry of the field strength in one phase by more than 10 % indicates the appearance of insulation defects.

6. Mobile technical means have been developed for diagnosing the insulation of power transformers, which include a defect simulator that measures the parameters of an acoustic signal under conditions of seasonal temperature changes. A criterion is proposed for detecting the growth of a defect from the normal state under conditions of seasonal temperature changes by the value of the reference voltage of the defect simulator.

7. An improved technology for overhaul testing of power transformers of the traction power supply system is proposed, which makes it possible to ensure the uninterrupted operation of the traction power supply system by detecting the pre-emergency state of power transformers without shutting them down. As recommendations and prospects for further development of the thesis topic, it is proposed to conduct research aimed at developing a control system for a digital traction substation of a traction power supply system, studying the effectiveness of control actions based on signals from various subsystems for diagnosing the state of insulating structures of power transformers.

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

The work was performed and defended at Omsk State Transport University.

Zhuravlev, A. N. Improving the efficiency of a diesel gas diesel engine by regulating the ratio of air and fuel in cylinders. Abstract of Ph.D. (Eng) thesis [*Povyshenie effektivnosti raboty teplovoznogo gazodizelya putem regulirovaniya sootnosheniya vozdukha i topliva v tsilindrakh. Avtoref. dis… kand. tekh. nauk*]. Samara, SSTU publ., 2022, 20 p.

Reducing the cost of fuel and energy resources (FER) is one of the priority areas for development of the locomotive complex of JSC Russian Railways and industrial railway transport enterprises. The use of alternative fuels, such as hydrogen, natural gas, etc., makes it possible to reduce the cost of fuel and energy resources, provided that the power plant is stable in the entire range of operating modes and that the required ratio of fuel and air in the cylinders is regulated. The most attractive from an economic point of view and the most time-consuming technical solution is modernisation of the existing power plants of diesel locomotives intended for operation using a combined cycle, for example, gas-diesel. The domestic experience of transferring diesel locomotive power plants to the gas-diesel cycle has shown the impossibility of ensuring stable (without fuel ignition in the cylinder) operation at idle and low loads (up to 40 % of the rated power) due to unstable supply of the pilot portion of diesel fuel and low volumetric concentration of gas in the cylinder, therefore, in these modes, only diesel fuel was supplied.

In the thesis work, the performance of a power plant equipped with working fluid throttling devices was studied when some of the cylinders were turned off to solve the problem of providing the required conditions for igniting natural gas in the entire range of operating modes.

The objective of the study is to ensure stable and economical operation of a gas-diesel engine of a shunting diesel locomotive at idle and low loads by controlling the ratio of air and fuel in the cylinders. To achieve the objective set in the work, the following tasks were formulated and successfully solved:

1. A study was carried out and an analysis is made of the features of implementation of

the gas-diesel cycle in relation to diesel power plants.

2. A refined mathematical model was proposed for calculating the performance indicators of a diesel power plant when it is transferred to a gas-diesel operation cycle.

3. A calculation was made to determine the range of change in the throttle valve section, which ensures stable operation of the power plant.

4. The number of working cylinders was determined, which ensures stable operation of the power plant under load.

5. An algorithm for controlling the throttle valve cross section and the number of operating cylinders of the locomotive power plant was developed.

6. Technical and economic assessment of effectiveness of implementation of the results of the work was carried out.

Based on the results of the research, the following main conclusions were drawn:

1. The analysis of features of implementation of the gas-diesel cycle in relation to diesel power plants showed that there is a problem of gas ignition at low positions of the driver's controller, associated with an unstable supply of a small amount of pilot portion of fuel and a low volume concentration of gas. The most advantageous solution to the problem from the point of view of minimal intervention in the regular engine systems is the use of an air throttling device at the engine inlet, as well as turning off part of the cylinders.

2. The developed refined mathematical model of the working process of a diesel locomotive when operating a gas-diesel cycle with air throttling at the intake manifold inlet and shutting off part of the cylinders makes it possible to quantify the change in the performance of a gas-diesel generator set depending on the throttle valve cross section and the number of working cylinders.

3. As a result of the research, it was found that in order to ensure safe operation of a gas diesel engine based on 1-PD4D power plant of TEM18DM shunting locomotive in terms of maintaining the permissible values of the temperature of the working fluid, the throttle

valve cross section should change within the range of 0,004–0,0002 m^2.

4. Based on the results of mathematical modelling, the number of working cylinders was determined, at which the permissible temperatures of the working fluid behind the exhaust valves and in the exhaust manifold before the turbine are provided: at idle and at the first position of the driver's controller (PDC) – at least 2 cylinders; at the second PDC – at least 3 cylinders; at the third PDC – at least 4 cylinders.

5. The conducted complex of studies showed that when the working fluid is throttled and some of the cylinders are turned off, it is possible to provide a volume concentration of gas in the cylinder of at least 2,7 %, which is necessary for igniting gas fuel in the entire range of operating modes.

6. In order to automatically maintain the volume concentration of gas in the cylinder of at least 2,7 % and not exceed the permissible values of the temperature of the working fluid at the outlet of the cylinders, an algorithm has been developed that includes a flexible change in the cross section of the throttle valve and cyclic fuel supply, as well as turning off part of the cylinders.

7. The use of devices for throttling air and shutting off part of the cylinders when operating a gas-diesel cycle will provide a positive economic effect, the value of which will depend on the engine load modes. When loading a shunting diesel locomotive in accordance with GOST 34514-2019, the annual savings in operating costs for fuel in comparison with the standard configuration of a diesel locomotive is 5,3 million rubles per TEM18DM locomotive.

As recommendations and prospects for further development of the topic of the thesis work, it is proposed to clarify the processes of mixture formation and take into account the technical features of devices and methods for ensuring gas supply and organising operation of an engine within a gas-diesel cycle.

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

The work was performed at the joint-stock company Scientific Research Institute of Railway Transport (JSC VNIIZhT), defended at Samara State Transport University. ●

279