Selected abstracts of Ph.D. theses submitted at Russian Transport 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.

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Budkov, A. S. Development of a decision support system for the problem of four-dimensional navigation in civil aviation. Abstract of Ph.D. (Eng) thesis [*Razrabotka sistemy podderzhki prinyatiya resheniya dlya zadachi cheterykhmernoi navigatsii v grazhdanskoi aviatsii. Avtoref. dis… kand. tekh. nauk*]. Moscow, MAI publ., 2021, 22 p.

One of the directions for development of air navigation in accordance with the global air navigation plan of the International Civil Aviation Organisation (ICAO) is the introduction of the possibility of global control of four-dimensional trajectories. To implement this opportunity, it is necessary to modernize not only the ground air navigation infrastructure, but also existing airborne equipment complexes.

One of the main on-board systems that ensure the flight of an aircraft (AC) along a given route is the aircraft navigation system. It is the system, that, first of all, should be able to support flights along four-dimensional routes.

The key task of four-dimensional navigation is to ensure the ability of the aircraft to arrive at a given waypoint at a given time. The functionality of modern computing systems for aircraft navigation, owns already a function that, to one degree or another, solves this problem. This feature is called RTA (from the English Required Time of Arrival).

The objective of the thesis is to increase the flight safety by automating the operational on-board planning of four-dimensional routes, taking into account the influence of wind conditions, restricted areas and areas of adverse weather conditions.

The following main conclusions and results were obtained in the thesis.

The task of developing a decision support system that provides a solution to problems that arise during flights along four-dimensional routes has been posed and solved.

The architecture of the decision support system has been developed, which contains all the necessary elements and connections with external systems to ensure the functions assigned to it. The system consists of three modules and also interacts with the aircraft performance database, the aircraft navigation system, the source of weather data and data on restricted areas.

A technique for searching for optimal four-dimensional routes has been developed that satisfies the requirements defined for it as a result of the analysis of identified problems during flights along four-dimensional routes, namely:

• To provide search for solutions according to four optimisation criteria.

• To calculate a three-dimensional trajectory in one calculation step without separating the horizontal and vertical planes.

• To take into account the influence of wind conditions, as well as the presence of zones of difficult weather conditions or restricted areas.

• Aircraft performance characteristics.

The rules for generating a sign of unavailability of movement along the active route are developed, the conditions for informing the crew about the occurrence of an emergency situation during a flight along a four-dimensional route are determined for the functions of monitoring the active flight plan and decision support, respectively.

Algorithms have been developed that implement the main steps of the methodology for finding optimal four-dimensional routes, the rules for monitoring the status of implementation of a four-dimensional route, as well as development of signs of problems in the process of performing a four-dimensional route.

The developed software is implemented in the form of Java Script software, has a modular architecture, and includes: a search module for optimal four-dimensional routes, an active flight plan monitoring module, and a decision support module. The software «Simulator of the search module for the optimal four-dimensional route of the decision support system» is registered in the Register of computer programs (certificate of state registration of the computer program No. 2021616587 dated 23.04.2021).

Three stages of modelling were carried out, which fully confirmed operability and adequacy of the developed software and algorithmic support for calculating optimal four-dimensional routes.

Simulation results numerically confirmed the effectiveness of:

• Application of the selected optimisation criteria to solve the problem of finding optimal four-dimensional routes.

• Analysis of three-dimensional space in one step of calculations.

• Application of the A-star algorithm in terms of adequacy of the computation time on routes of different distances.

The results of the thesis are implemented in the research and development work «Development of on-board radio-electronic equipment for the MS-21 family of mainline aircraft (MS-21-200 and MS-21-300, with PW-1400 and PD-14 engines)» of the branch PJSC «Irkut Corporation» «Integrating Centre» and the educational process of the department 703 «System design of aircraft complexes» of the Institute No. 7 «Robotic and intelligent systems» of MAI, which is confirmed by the relevant implementation acts.

2.3.1 – System analysis, management, and information processing (technical sciences).

The work was performed and defended at Moscow Aviation Institute (National Research University).

Mikhaldykin, E. S. The use of pipe-concrete structures with a shell made of polymer composite materials in construction of small bridges. Abstract of Ph.D. (Eng) thesis [*Primenenie trubobetonnykh konstruktsii s obolochkoi iz polimernykh kompozitsionnykh materialov pri stroitelstve malykh mostov. Avtoref. dis… kand. tekh. nauk*]. Moscow, MADI publ., 2021, 25 p.

The relevance of development of new design solutions for construction of small bridges, allowing to reduce the cost and construction time, as well as to increase the service life of structures, follows from the state of the bridges of highways in the Russian Federation.

According to Rosstat [Federal State Statistics Service], the condition of more than 500 permanent structures is assessed as poor. In addition, temporary structures, such as wooden bridges with a limited service life, cause a big problem if in Ulyanovsk region the number of wooden bridges is 79, then in Khabarovsk region there are already 706 of them. As indicated in the conclusions of the international rating Global Competitiveness Report of the World Economic Forum 2019, the Russian Federation ranks 99th out of 141 in terms of road quality. Indirectly, the shortage of the bridges can be estimated by the number of permanent crossings – 257 summer and 3500 winter ones, as well as per the amount of transport excess mileage – 70–80 % for Moscow and at least 50 % throughout Russia. On the other hand, the relevance of the study – the use of polymer composite materials in construction – is confirmed by the inclusion of this topic in the State Program «Industrial development and increasing its competitiveness».

The topicality of the problem is confirmed by a comprehensive discussion on the need to include «Bridges and Overpasses» program in the National Project for «Safe and high-quality highways» (BKAD), as well as the inclusion of the issue of solving the problems of the bridges in «Comprehensive plan for expansion and modernization of the main infrastructure until 2024 (KPMI)».

The objective of the thesis is to develop a methodology for the use of arched pipe-concrete structures with a shell made of polymer composite materials in construction of small bridge structures.

As part of the thesis, in accordance with the goal, a general methodology for designing and calculating arched pipe-concrete structures with a shell of polymer composite materials was developed in construction of small bridge structures.

The results and main conclusions of the thesis are as follows:

• A review and analysis of existing studies and proven methods for calculating both traditional pipe-concrete structures with a steel shell and structures with a polymer composite shell was carried out. The historical retrospective of development of the direction of research of pipe-concrete structures is shown. The existing approaches to design of bridge structures with the main load-bearing elements of pipe-concrete structures are considered based on the analysis of the erected structures.

• A mathematical model of a pipe-concrete structure with a polymer composite shell was developed, based on a theoretical approach to distribution of deformations along the height of the section from the premise of compliance with the hypothesis of flat sections. Strength criteria are proposed based on well-tested models of concrete performance used in the current regulatory documentation. An algorithm for the method of calculating the bearing capacity of structures has been developed.

• A program for testing materials and structurally similar elements of full-size PCM beam and arch specimens was developed. Materials were tested to determine the mechanical and physical properties, resistance to aggressive media. It is shown that the test procedure existing in GOST 25.601-80 is not suitable for determining the ultimate strength of obliquely reinforced anisotropic specimens with biaxial weaving. A method for testing such materials is proposed.

• Based on the results of tests of structurally similar beam and arch specimens in full size, an analysis of possible defects of the shell and their influence on the bearing capacity was carried out. The absence of accumulation of deformations and other negative effects after low-cycle tests is shown. The absence of slippage between the shell and the concrete core is experimentally substantiated.

• Technological parameters for the manufacture of arched pipe-concrete structures have been worked out.

• The results of verification of the developed methodology and comparison of its reliability with other similar methods are presented. It is shown that the developed technique gives an average error of 13,5 %. A comparison was made with the approved methodology of the Maine State Institute, which showed an average error with the experimental data of this work of 75 %.

• Analysis of the experimental data made it possible to draw a conclusion about reliability and safety of operation of structures with the main load-bearing elements in the form of pipe-concrete structures with a shell of polymer composite materials. To confirm the conclusions made, a system for monitoring the status of the pilot facility was developed.

• Within the framework of this work, the main approaches to design of compressed-bent pipe-concrete structures with a shell of polymer composite materials were developed. Based on the analysis of the effect of various defects on the bearing capacity of the structure, requirements for permissible shell defects were developed.

05.23.11 Design and construction of roads, subways, airfields, bridges and transport tunnels.

The work was performed and defended at Moscow Automobile and Road Construction State Technical University (MADI).

Polyakova, E. Ya. Features of the aerodynamics of the undercar space of high-speed rolling stock. Abstract of Ph.D. (Eng) thesis [*Osobennosti aerodinamiki podvagonnogo prostranstva vysokoskorostnogo sostava. Avtoref. dis… kand. tekh. nauk*]. St. Petersburg, PSTU publ., 2021, 16 p.

One of the priority areas for development of modern railway transport is creation of a high-speed rail network that provides passengers with the best balance of speed, safety, comfort, and cost of travel. An increase in the speed of trains entails the need to solve a wide range of problems, including those related to the analysis of processes resulting from the aerodynamic interaction of ballast particles and pieces of ice (during the cold season) with air flows generated by passing high-speed rolling stock, since ballast particles, picked up by the indicated air flows, having a sufficiently high kinetic energy and moving along a rather complex trajectory, despite their small size, pose a serious danger both to outdoor signalling devices and rolling stock units, and to pedestrians, passengers and railway workers.

The objective of the thesis is to solve the scientific problem of studying the processes of movement of air masses in the undercarriage space of high-speed rolling stock, the mechanism of entrainment of particles by the air flow and their interaction with the body, undercarriage equipment and chassis.

The work carried out a set of theoretical and experimental studies to solve the scientific problem of movement of air masses in the undercar space of high-speed rolling stock, the mechanism of entrainment of particles by the air flow and their interaction with the body, undercarriage equipment and chassis. Wherein:

• It has been established that the existing concept of modelling high-speed rolling stock represents the object under study in the form of a thin body of high elongation with a poorly streamlined shape, which has intense turbulent diffusion in the area of the head and tail fairings, as well as in the recesses of the undercarriages and inter-car spaces. In such models, there is no way to determine particular cases of interaction between the air environment disturbed by the rolling stock and the objects of the surrounding infrastructure, for example, undercar space. It is shown that the existing models, methods, and regulations do not consider the possibility of lifting particles from the railway track in summer and ice particles in winter.

• A method has been developed to determine the direction of air volume flows from the lower part of the car body, the niches of the undercarriage in the lateral directions, as well as into the space between the body and the bogie frame. Its verification and software implementation were carried out based on comparison with the results of tests of models similar in geometry type in wind tunnels and in full-scale measurements.

• It has been established (experimentally and numerically) that at low-frequency vibrations of the railway track during movement of high-speed rolling stock, a ballast particle lying freely on a sleeper of road tracks can lose contact with the ground and hang in the air, which is called « particle hovering». The diameter of the particle, which can be entrained by the air flow from the surface of the superstructure of the track, is also determined.

A classification of damage to the lower hatches and side elements of the bulwarks of the undercarriage space by flying out crushed stone according to the characteristic form of residual plastic deformation into three types is proposed:

• «Bell-shaped» deformation, groove-like deformation and «breakdown» in the form of an irregularly shaped hole. Schemes of interaction of a hovering particle with the surface of the hull hatch are proposed: elastic ricochet, plastic ricochet.

• A mathematical description of the dynamic loading on the composite plate of a part of the protective board of the body under the impact of

a solid particle was developed using a modified Zener model.

• Three variants of numerical modelling of dynamic loading of the protective side of the body were studied: composite membrane, composite structure with beam volumetric elements, composite structure of layered representation. It is shown that the most adequate model, which corresponds to the real physical characteristics of high-speed dynamic loading, corresponds to the composite structure of the layered representation.

• Recommendations were given to prevent entrainment of ballast layer particles by high-speed rolling stock.

• A three-dimensional aerodynamic model of the structure of moving air masses in the undercar space of high-speed trains is proposed, which makes it possible to establish the features of formation of snow and ice deposits on the undercarriage structural elements that are critical for traffic safety.

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.

Strungar, S. A. Development of methods for stabilising the cylinder power of a diesel engine in idle mode with an electronic fuel supply control system. Abstract of Ph.D. (Eng) thesis [*Razrabotka metodov stabilizatsii tsilindrovykh moshchnostei dizelya na rezhime kholostogo khodapri elektronnoi sisteme upravleniya podachei topliva. Avtoref. dis… kand. tekh. nauk*]. Moscow, RUT publ., 2021, 24 p.

The objective of the thesis is to increase the efficiency of the 1-PD4D diesel engine of TEM18DM locomotives with ESUVT.01 by developing methods for technical diagnostics and stabilization of cylinder capacities in idle mode.

The following main results were obtained in the thesis:

• Analysis of operation of 1-PD4D diesel engines of TEM18DM locomotives with ESUVT.01 in operation in idle mode revealed an uneven distribution of indicator power over the cylinders, the value of which is up to 11,5 % of the total diesel power.

• A method was developed and tested for determining the indicator power of a diesel cylinder in idle mode by measuring the increment in duration of fuel supply by electrically controlled fuel pumps ESUVT.01 when the fuel supply to the cylinder is turned off.

• Methods for technical diagnostics of diesel cylinder operation were developed and tested, allowing to clarify the cause of cylinder failure.

• Calculation and experimental methods for stabilizing the cylinder capacities of the 1-PD4D diesel engine with ESUVT.01 in idle mode were developed.

• Based on the developed methods, algorithms for technical diagnostics of operation of cylinders and stabilization of the cylinder capacities of a diesel engine were compiled.

• Verification of algorithms on the bench diesel generator 1-PDG4D showed that as a result of power stabilisation according to the calculation method, the indicator power was redistributed among the cylinders. At the same time, the difference in the indicated powers did not change and remained equal to 2,2 kW. As a result of the power stabilization by the experimental method, a decrease in the difference in the indicated power for the cylinders was obtained from 2,5 kW to 1,8 kW.

• Verification of the algorithms on the 1-PD4D diesel engine of the TEM18DM No. 1022 diesel locomotive under operating conditions showed that as a result of power stabilisation by the experimental method, a decrease in the difference in the indicated power across the cylinders was obtained from 3,0 kW to 1,0 kW.

• Evaluation of effectiveness of implementation of the proposed technical solutions. Savings in operating costs over the service life of the ESUVT.01 system of 15 years due to implementation of algorithms for technical diagnostics and stabilization of cylinder capacities on diesel engines 1-PD4D of the fleet of diesel locomotives TEM18DM at the base of the operating locomotive depot Bologovskoye in the amount of 20 units is 4,35 million roubles. The payback period of the proposed technical solutions is 0,65 years.

• The results of this work are planned to be used for further improvement of the electronic fuel injection system for diesel locomotives.

As recommendations and prospects for further development of the topic of the thesis, it is proposed to adjust the calculation method for stabilising cylinder capacities in terms of clarifying the magnitude of the change in the indicator efficiency when varying the amount of fuel supplied to the cylinder, as well as clarifying the differences in mechanical losses for individual diesel cylinders.

05.22.07 –Railway rolling stock, train traction and electrification

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