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

DOI: https://doi.org/10.30932/1992-3252-2022-20-2-14

Fedotenkov, G. V. Unsteady contact interaction of elastic shells and solid bodies. Abstract of D.Sc. (Physics and Mathematics) thesis [*Nestatsionarnoe kontaktnoe vzaimodeistvie uprugikh obolochek i sploshnykh tel. Avtoref. dis... doc. fiz-mat. nauk*]. Moscow, MAI publ., 2021, 38 p.

The rapid pace of development of modern modes of transport, aerospace, shipbuilding, automotive and aviation industries dictate increasingly high requirements for the accuracy of calculations of the stress-strain state of a structure under various types of non-stationary effects in contact interaction conditions. This area is currently among the least explored. The solution of such problems is complicated by the need to take into account the initial conditions, the mixed and nonlinear nature of the boundary conditions, and also, in some cases, the unknown in advance of the contact area, which depends on time. The heightened interest in these questions is explained, on the one hand, by the rather wide range of their practical application, and, on the other hand, by the openness of many questions in the theory of contact problems.

The objectives of the work are development of mathematical formulations of non-stationary contact problems for thin shells and elastic bodies, construction of methods and approaches to solving, creation and implementation of effective numerical-analytical algorithms for solving new non-stationary contact problems, obtaining and analyzing solutions to these problems in plane, axisymmetric and spatial formulations.

A mathematical formulation of non-stationary contact problems is given for thin cylindrical and spherical shells with and without a filler and an elastic half-space, taking into account the mobility of the boundaries and the multiply connectedness of the contact area.

A method for solving such contact problems based on the use of influence functions has been developed and generalized, including an iterative process for determining the contact area. The effectiveness of the applied approach to the solution is proved due to a significant reduction in the dimension of the problems under study.

Non-stationary two-dimensional and spatial influence functions for cylindrical and spherical shells with and without filler are constructed and studied.

A solution is constructed for nonstationary two-dimensional contact problems with moving boundaries for cylindrical or spherical shells and an elastic half-space. Two approaches are proposed and implemented that are valid at the supersonic and arbitrary stages of contact interaction. A comparison is made and the agreement of the results obtained with the use of these approaches is shown.

Solutions of non-stationary contact problems for two cylindrical or spherical shells are obtained taking into account the elastic filler. An analysis of the influence of the presence of a filler on the process of contact interaction was carried out.

For an arbitrary time interval, an algorithm has been developed and implemented for solving a spatial nonstationary contact problem with moving boundaries for a cylindrical shell and an absolutely rigid impactor bounded by a smooth convex surface. The results of calculations were obtained and analyzed.

01.02.04 – Mechanics of a deformable solid body.

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

Maung Maung Win Aung. Rational design and technological solutions for cable-stayed bridges with a reinforced concrete stiffening beam for the conditions of Myanmar. Abstract of Ph.D. (Eng) thesis [*Ratsionalnie konstruktivno-tekhnologicheskie resheniya vantovykh mostov s zhelezobetonnoi balkoi zhestkosti dlya uslovii Myanmy. Avtoref. dis... kand. tekh. nauk*]. Moscow, MADI publ., 2021, 25 p.

In recent years, in Myanmar, considerable interest has been paid to the use of cable-stayed

bridges, including those with a reinforced concrete stiffening beam, since this type of cable-stayed bridges, in terms of its structural, technological and economic indicators, is the most rational solution for road bridges of medium and large spans.

At present, there are no structural and technological solutions for cable-stayed bridges with reinforced concrete stiffening beams in Myanmar. Justification of the main ratios and general dimensions of cable-stayed bridges, taking into account structural and technological factors, as well as the study of the stress-strain state of their load-bearing elements, would make it possible to fully take into account all the specific features of operation of these structures for Myanmar conditions.

The objective of the thesis is to develop rational structural and technological solutions for cable-stayed bridges with a reinforced concrete stiffening beam in relation to the conditions of Myanmar based on a broad study of the stress-strain state of load-bearing elements, taking into account all the features of the bridge structure.

In the thesis, tasks were set and solved, using the methods of finite element analysis and computer modeling using the Midas/Civil software package, to develop rational structural and technological solutions for cable-stayed bridges with reinforced concrete stiffening beams in relation to the conditions of Myanmar. The analysis of the most widely used structural and technological solutions for cable-stayed bridges in Southeast Asia was preliminary carried out and the ranges of geometric parameters of constructed and operated bridges were determined. The most used technologies for construction of cable-stayed bridges in this region were also analyzed.

In this paper, the stress-strain state of cable-stayed bridges with a reinforced concrete stiffening beam in the elastic stage from the action of constant loads and live loads, as well as temperature and wind effects has been studied. A dynamic analysis of the cable-stayed bridge was performed with determination of the period of natural oscillations, as well as assessment of survivability of the cable-stayed bridge in case of a break in several cables. In the course of the study, a finite element design model of a cable-stayed bridge was developed for its detailed analysis and the most rational geometric parameters of cable-stayed bridges and arrangements of cables on them for Myanmar conditions were determined. Using Russian, American and European models, a study was made of the effect of long-term processes in concrete (shrinkage and creep) on the behavior of cable-stayed bridges at various levels of environmental humidity. Also, a comparison of various technologies for construction of cable-stayed bridges was carried out and, using a staged computer analysis, the most effective technology for construction of cable-stayed bridges in Myanmar was determined.

The conducted studies allowed us to formulate the following conclusions:

• The use of computational models based on finite element methods is an effective means of conducting scientific and engineering analysis of structures of various systems in order to select the most rational for certain conditions of construction and operation. Comparative analysis of the results of calculation of cable-stayed bridges with a reinforced concrete stiffening beam using various software packages shows that calculations using the Midas/Civil software package provide fairly reliable results.

• An extensive analysis of existing studies and the results of computer modeling, allowed to establish for the conditions of Myanmar the most rational ratios of the main parameters of superstructures, reinforced concrete stiffening beams, pylons, which are given in the work (ratio between spans L_j:L_{av}:L_2 = (0,45−0,5):1:(0,45−0,5), main panel length 16−20 m, stiffening beam height (1/15−1/18) L_{av}, edge panel length {1/4−1/2) from the length of the main panels, the height of the pylons (1/5−1/7) L_{av}).

• For Myanmar conditions, cable-stayed bridges with a reinforced concrete stiffening beam with a span of 100 to 500 m can be recommended as the most resistant to aerodynamic and other influences. Also, as a result of the analysis of the emerging forces and taking into account the aesthetic factor, it was found that the «fan» is the most rational layout of the cables. In addition, for cable-stayed bridges with one plane of cables, it is advisable to take a reinforced concrete stiffening beam of a box-shaped section, and with two planes of cables − box-shaped and slab-ribbed sections. The conducted comparative analysis of pylons of various shapes makes it possible to recommend the most rational area of application for each of them.

• The analysis of the results of computer modeling of the loading of the bridge structure according to Russian and American standards showed that the results of the calculation are quite close to each other, but in most cases, the largest

values are obtained from the Russian live load A14.

• When calculating according to Russian (SP 35.13330.2011), European (CEB-FIP 1990) and American (ACI) standards at 70 %, 80 % and 90 % humidity, the forces in the stiffening beam and cable-stayed bridge pylon change significantly. With an increase in humidity of the environment, the loss of forces in the shrouds slightly decreases. For the conditions of Myanmar, when designing, it is recommended to take a humidity value of no more than 70 %.

• The analysis of the results of numerical simulation confirmed that for the conditions of Myanmar the most rational is the technology of construction of cable-stayed bridges with reinforced concrete stiffening beams and guys according to the «fan» scheme, using the method of suspended balanced installation. Moreover, the use of the Midas/Civil software package makes it possible to simulate the stress-strain state of cable-stayed bridges during their construction, taking into account nonlinearity at all stages of construction.

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).

Parakhnenko, I. L. Research of the interaction forces in the «wheel−rail» contact following changes in the tribological condition of the rail surface. Abstract of Ph.D. (Eng) thesis [*Issledovanie sil vzaimodeistviya v kontakte «koleso–rels» pri izmenenii tribologicheskogo sostoyaniya poverkhnosti relsov. Avtoref. dis... kand. tekh. nauk*]. St. Petersburg, PSTU publ., 2021, 25 p.

The length of curved sections on the Russian railway network is 33 % of the total length, of which 13 % falls on radii from 400 to 700 m. The friction resistance that occurs when the vehicle passes curves, especially of small radius, causes an increase in energy consumption, a violation of stability of the track geometry, and intense wear of wheels and rails. These problems are closely related to the longitudinal and lateral forces that arise in the «wheel−rail» contact. Force interaction is influenced by many factors, but it is worth highlighting the main ones – dynamic and tribotechnical. Dynamic depend on design, technical condition of the track and rolling stock and the conditions of their interaction. Tribotechnical factors can be divided into tribological – the value of the coefficient of friction on the contact surfaces and technical – the state of the profiles of the «wheel−rail» set. Changing the tribological state of the surfaces of rail threads, that is, reducing the coefficient of friction in the wheel-rail contact zone (lubrication), is one of the main measures within the framework of the comprehensive resource-saving program «Development Plan of JSC Russian Railways until 2030», aimed at reducing wear of the set.

The use of resource-saving technologies is especially important with an increase in axial loads and speeds, the resource of superstructure elements up to 2,5 billion tons of missed cargo, a constant increase in prices for energy carriers, railway track elements and wheel sets. Reducing the resistance to movement of trains in curves, increasing the stability of the railway track, the resource of rails and wheels, and, consequently, the savings directly depend on the magnitude and constancy of the friction coefficient in the contact track – rolling stock.

Determination of the tribological state of the tread surfaces and the side surface of the rail head, which ensures the best interaction between the wheels of the rolling stock and the track gauge, reduces the force effect and thereby ensures the stability of the railway track and reduces the intensity of lateral wear of the rails in curved sections, is relevant for the entire railway network.

The development of new approaches to the strategy of lubricating the «wheel–rail» contact zone has been a popular direction in recent years. The presented work is development of scientific research in accordance with the Strategic Program for Ensuring Sustainable Interaction in the «wheel–rail» system adopted in JSC Russian Railways.

The objective of the thesis is to determine the influence of the tribological state of the rail tread surfaces on the interaction forces in the «wheel–rail» contact with various movement parameters (speed, axle load, train driving mode) and the outlines of the profiles of the wheel set and rails.

Experimental measurements of the friction coefficients on the side surface of the outer rail for different tribological states of the rail gauge were carried out, measurements were made on the tread surfaces of both threads. Values of friction coefficients were obtained for the dry state of rail threads – 0,4 and with the applied lubricant – 0,25.

The effect of the mode of driving a freight train on the forces of contact interaction is estimated. It has been established that the action of the traction force affects the change in longitudinal forces by an average of 6 %. The difference in the values of the lateral forces is on average no more than 7 %.

A significant influence of the tribological state of the rail tread surface on the longitudinal and lateral forces arising in the «wheel–rail» contact during the movement of a freight train with a load of 23,5 and 27 t/axle along curved sections of the railway track is revealed.

The functional dependences of the forces of interaction between the wheel and the rail are determined depending on the tribological state of the rail surfaces, speed of the freight train and the radius of the curves for the new and average network profile of the tribopair. The results obtained during the theoretical study are confirmed by comparison with experimental data. The convergence of the results within 15 % indicates the adequacy of the mathematical apparatus used.

The longitudinal forces arising from the movement of a freight train along curved sections of the railway track, when applying the «third body» to the tread surface of both rail threads, are reduced by 1,49 times (by 5,7 kN) at a speed of V = 40 km/h and by 2,21 times (by 5,6 kN) at V = 80 km/h in the curve R = 380 m. In gentle curves, the force decreases up to 1,5 times (up to 4,9 kN). The wear of tribopair profiles leads to an increase in longitudinal forces at all considered radii up to 3,3 times. The use of lubrication on the surface of the inner thread reduces the forces by an average of 11 % (3 kN), on the outer rail up to 17 % (5 kN).

The lateral impact of the wheel set on the track, in the unworn state of the tribopair, is less by 1,37 (4,5 kN)–1,47 (8,55 kN) times with a decrease in the friction coefficient on the surface of the inner rail in curves of a small radius. The use of lubricating the rolling surface of rail threads to reduce lateral forces in curves R > 700 m is not advisable. The lateral impact is reduced by the change in the profiles of the contact surfaces.

The influence of the coefficient of friction on the longitudinal and transverse vibrations of the vehicle has been established. The use of lubrication on the tread surface of the inner rail thread increases the length of the longitudinal wave up to 30 %, transverse up to 22 %, which helps to increase the stability of the railway track, reduce the wavy and lateral wear of the rail track.

A technique has been developed for selecting options for lubricating rail surfaces depending on the parameters of the curves. The values of the elevation of the outer rail thread, which ensure the minimum force interaction, are determined.

To substantiate the possibility of reducing the coefficient of friction on the running surfaces of the rails, the calculation of the main criteria for safety and uninterrupted movement was carried out – the stability of the wheel on the rail and the length of the braking distance. Lubrication of the surface of the inner thread reduces the possibility of «crawling» up to 1,87 times in small radius curves. In gentle curves with lubrication options, the stability of the wheel on the rail increases by 1,81 times. Lubrication increases the braking distance on the slopes by an average of 23 % (180 m).

The economic effect of reducing the coefficient of friction is calculated. The reduction in fuel and energy costs for train traction will be from to 27,95 rubles per 1 km of the curved section, depending on the speed of movement during the lubrication of both threads and 10,55 rubles when lubricating the inner thread. Savings on the replacement of rails upon reaching the wear limit – 99420 rubles/km per year with lubrication of the inner rail and 88490 rubles/km per year with a decrease in the friction coefficient on both rail threads.

A variant of the tribological state of rail threads is proposed, which reduces the longitudinal and lateral forces – lubrication of the rolling surface of the inner rail thread. It is recommended to use this method on long ascents in curves with a radius of up to 1200 m during heavy traffic and on straight sections of the railway track, due to the presence of a deviation in the profile plan, to reduce the likelihood of train fluctuations.

Methods for applying material to the rail thread surface by equipment used on mobile lubrication facilities and developed lubricants providing a friction coefficient of 0,2–0,25 are considered. The use of this method is recommended after preliminary high-quality polishing of the rails, in order to eliminate defects in the surface of the rail threads that contribute to the accumulation of lubricant.

05.22.06 – Railway track, survey and design of railways.

The work was performed at Ural State University of Railway Transport, defended at Emperor Alexander I St. Petersburg State Transport University.