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ALGORITHM FOR NUMERICAL SIMULATION OF THE STRESS-STRAIN STATE DURING BENDING-TORSIONAL VIBRATIONS OF CYLINDER HEADS OF DIESEL LOCOMOTIVE ENGINES

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ABSTRACT

The article presents algorithm for numerical simulation of the stress-strain state during bending-torsional vibrations of cylinder heads of diesel locomotives; numerical studies were carried out in the MATHCAD 15 programming environment.

АЛГОРИТМ ДЛЯ ЧИСЛЕННОГО МОДЕЛИРОВАНИЯ НАПРЯЖЕННО-ДЕФОРМИРОВАННОГО СОСТОЯНИЯ ПРИ ИЗГИБНО-КРУТИЛЬНЫХ КОЛЕБАНИЯХ КРЫШЕК ЦИЛИНДРОВ ТЕПЛОВОЗНЫХ ДИЗЕЛЕЙ

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ABSTRACT

В статье представлен алгоритм для численного моделирования напряженно-деформированного состояния при изгибно-крутильных колебаниях

Дизели тепловозов, головки цилиндров дизелей тепловозов, численное моделирование напряженно-деформированного состояния при изгибно-крутильных колебаниях головок цилиндров дизелей тепловозов, алгоритм, программа для среды программирования MATHCAD 15.

крышек цилиндров тепловозных дизелей, численные исследования проведены в среде программирования MATHCAD 15.

A significant contribution to improving the operational reliability of transport diesel engines and the development of modern mobile diagnostic methods and tools was made by such scientists as: A.E. Simson, S. Manson, B. Boli, J. Weiner, D.A. Gokhfeld, V.A. Chetvergov, V.I. Kiselev, A.N. Savoskin, I.I. Lobanov (MIIT), V.V. Strekopytov, I.G. Kiselev, L.K. Poilov, V.N. Ivanov, M.N. Panchenko, A.V. Grishchenko, I.A. Rolle (PGUPS), N.D. Chainova, A.P. Gusenkova and others [1÷2].

In Uzbekistan, a significant contribution to the further development and improvement of theoretical calculation methods and experimental research on the diagnostics of rolling stock units and components was made by such scientists as Academician of the Academy of Sciences of the Republic of Uzbekistan, Professor, Doctor of Engineering Sciences. Glushchenko A.D., professors Fayzibaev Sh.S., Khromova G.A., Shermukhamedov A.A., Rakhimov R.V., Khamidov O.R., as well as Ph.D. Kasimov O.T., Valiev M.Sh., Tursunov M.Sh., Kudratov Sh.I. and others [3÷5].

To study the occurrence of mechanical stresses in the cylinder heads of locomotive diesel engines under mechanical impacts and the pulsating effect of steam gas pressure in the cylinder of a 1A-9DG diesel generator for the UzTE16M diesel locomotive, iterative and piecewise linear approximation methods were used in the MATHCAD 15 programming environment.

The stress-strain state (SSS) of the cylinder heads of locomotive diesel engines is characterized by mechanical stresses from gas pressure in the cylinder and thermal stresses from high temperatures, resulting in a complex stress-strain pattern, especially in the contact areas with the cylinder liner, valves, and injector. This condition can lead to cracks, deformations, and a general loss of seal integrity, reducing the durability and reliability of the locomotive's diesel engine.

Due to the complexity of the diesel cylinder head design, it is difficult to obtain an analytical solution to the problem of calculating their stress-strain state, therefore, it is advisable to use numerical methods.

A mathematical model for modeling the stress-strain state during bending-torsional vibrations of cylinder heads of diesel locomotives under mechanical influences was compiled using differential equations for bending-torsional vibrations of the shell under

the influence of pulsating pressure from steam gases in the diesel cylinder and is presented in articles [6÷9].

The block diagram for numerical studies of bending-torsional vibrations of the model of the interval bridge of the cylinder head in the form of an elastic plate is shown in Figure 1.

The numerical study analyzes two dynamic contact problems (the block diagram is shown in Figure 1):

1). *Problem 1.* Loading the boundary element of the interval bridge of the cylinder head in the form of an elastic plate with a quasi-static load, taking into account the increase in static mechanical loading over a certain time interval t_0.

2). *Problem 2.* Loading the boundary element of the interval bridge of the cylinder head in the form of an elastic plate with a harmonic load under pulsations of the vapor gas pressure in the cylinder $q_P(X, Y)$. In this case, we perform the second solution option for the system of equations (1)÷(2) for the conditions of decomposition of the functions of the external dynamic load into series corresponding to the harmonics arising from pulsations of the vapor gas pressure in the cylinder $q_P(X, Y)$ [7].

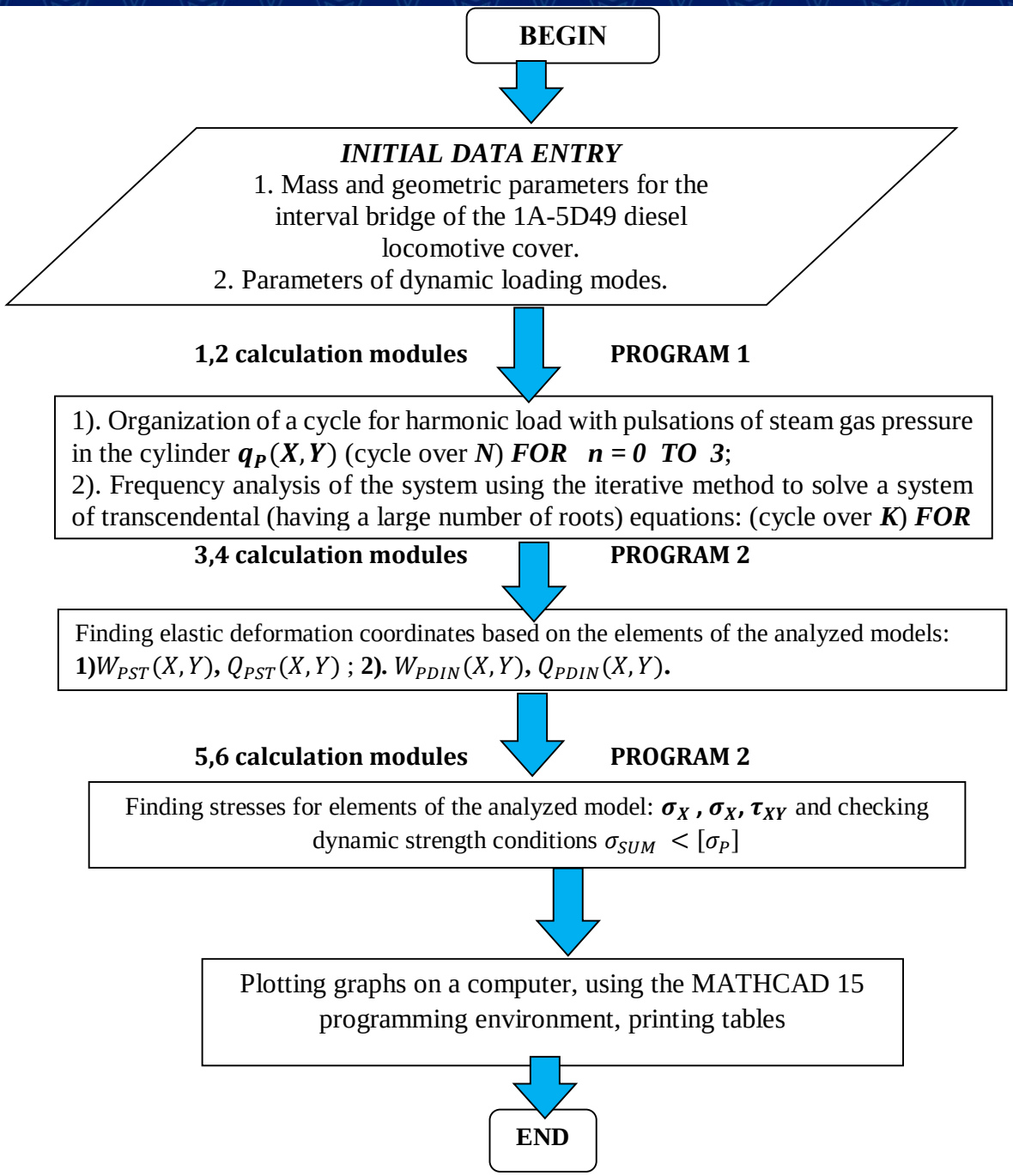

Figure 1. Block diagram for numerical studies of the stress-strain state of cylinder heads of a 1A-5D49 diesel engine under mechanical influences.

For bending-torsional vibrations of a rectangular element of the model of the interval bridge of the cylinder head of a 1A-5D49 diesel locomotive engine $W_K(X)$ and $Q_K(X)$, the following system of equations can be written (taking into account the variability of mass and rigidity for the equivalent supporting frame of the cylinder head)

$$\frac{m_k(x)}{G_n(x)}\frac{d^2W_k}{dt^2} + 2b_2\frac{d^2W_k}{dz^2} + \frac{b_1+2b_2x}{G_n(x)}\frac{d^3W_k}{dx^3} + \\ + \frac{d^4W_k}{dx^4} - \frac{i_k(x)}{G_n(x)}\frac{d^4W_k}{dx^2dt^2} - \frac{\delta_1+2\delta_2x}{G_n(x)}\frac{d^3W_k}{dxdt^2} = \frac{n_W(x,t)}{G_n(x)}, \quad (1)$$

$$\frac{i_k(x)}{G_K(x)}\frac{d^2\theta_k}{dt^2} - \frac{r_1+2r_2x}{G_K(x)}\frac{d\theta_k}{dx} - \frac{d^2\theta_k}{dx^2} = \frac{n_K(x,t)}{G_K(x)}. \quad (2)$$

A solution for the actual design dimensions of the interval bridge of the 1A-5D49 diesel locomotive's cylinder head was obtained numerically for a boundary element in the form of an elastic plate using piecewise linear approximation and node coupling. The MATHCAD 15 programming environment was used for the numerical analysis.

As a result, graphs are constructed for the flexural-torsional vibrations of the most heavily loaded element of the intervalve bridge of the 1A-5D49 diesel cylinder head. The natural frequencies of the intervalve bridge elements of the 1A-5D49 diesel cylinder head, associated with the boundary conditions of the clamping along the contour, are found using frequency equations using the iterative method for a boundary element in the form of a plate clamped along the contour.

As a result of numerical studies on the stress-strain state of the elements of the interval bridge of the 1A-5D49 diesel engine cover, the following general conclusions can be drawn:

- under mechanical impacts from pressure pulsations $\boldsymbol{P_E}$, the maximum torsional stresses are small $\boldsymbol{\tau_{TORS}(x)}$ and vary along the length $\boldsymbol{0 < X < \ell_P}$ from 0 to 2.455 MPa (Figure 2);

- the maximum bending stresses $\boldsymbol{\sigma_{SUM}(x)}$ are significantly higher and vary along the $\boldsymbol{X}$ coordinate from 0 to **-60,518 MPa**;

- the maximum total stresses $\boldsymbol{\sigma_{SUM}(x)}$ under mechanical impacts do not exceed **65,203 MPa** with pressure pulsations $\boldsymbol{P_E}$ from 4.9 MPa to 5.05 MPa (according to the results of experimental studies) (Figure 3).

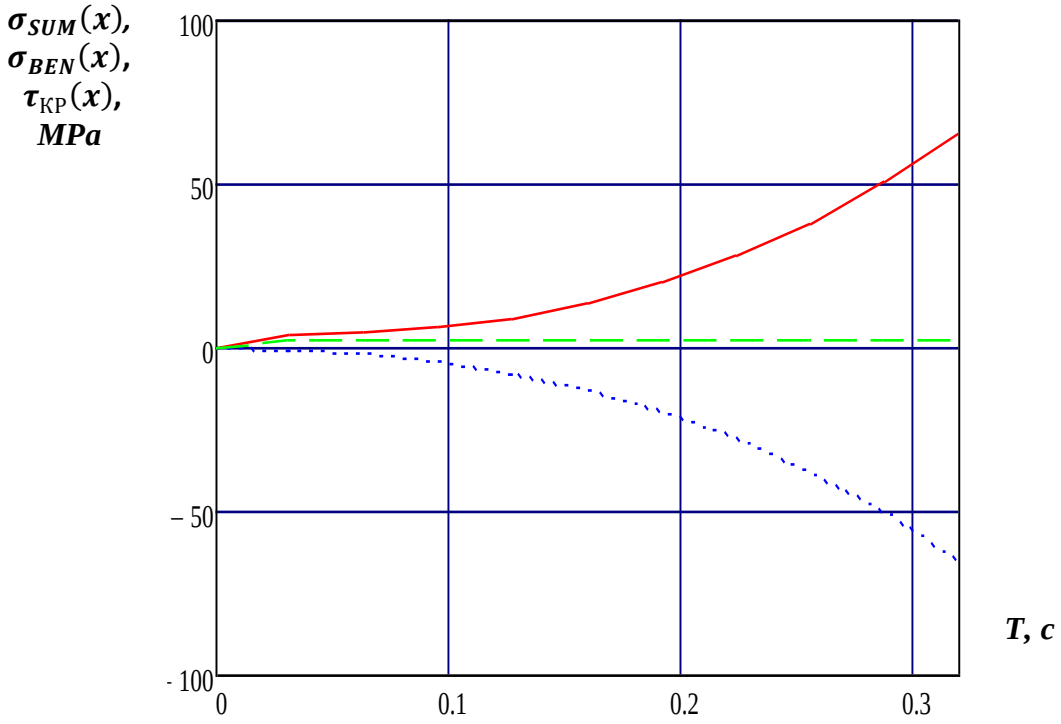

Figure 2. Graph of the change in maximum stress along the length of the intervalve bridge of the 1A-5D49 diesel cylinder head made of VCh50 cast iron with a change in coordinate $\mathbf{0} < \boldsymbol{X} < \ell_P$:

——— total maximum stresses $\boldsymbol{\sigma_{SUM}(x)}$;

- - - - - - - - - - - maximum bending stresses $\boldsymbol{\sigma_{BEN}(x)}$;

— — — — - maximum torsional stresses $\boldsymbol{\tau_{TORS}(x)}$.

This article develops a comprehensive analytical and numerical method for studying the stress-strain state of the most heavily loaded element of the intervalve bridge of the 1A-5D49 diesel cylinder head under mechanical stress and vapor pressure pulsations in the cylinder. We have developed a methodology for engineering calculations of the stress state of locomotive diesel cylinder heads under mechanical stress and vapor pressure pulsations in the cylinder, with the selection of rational parameters for rolling stock based on theoretical, experimental, and design work based on previously completed scientific research [6÷9].

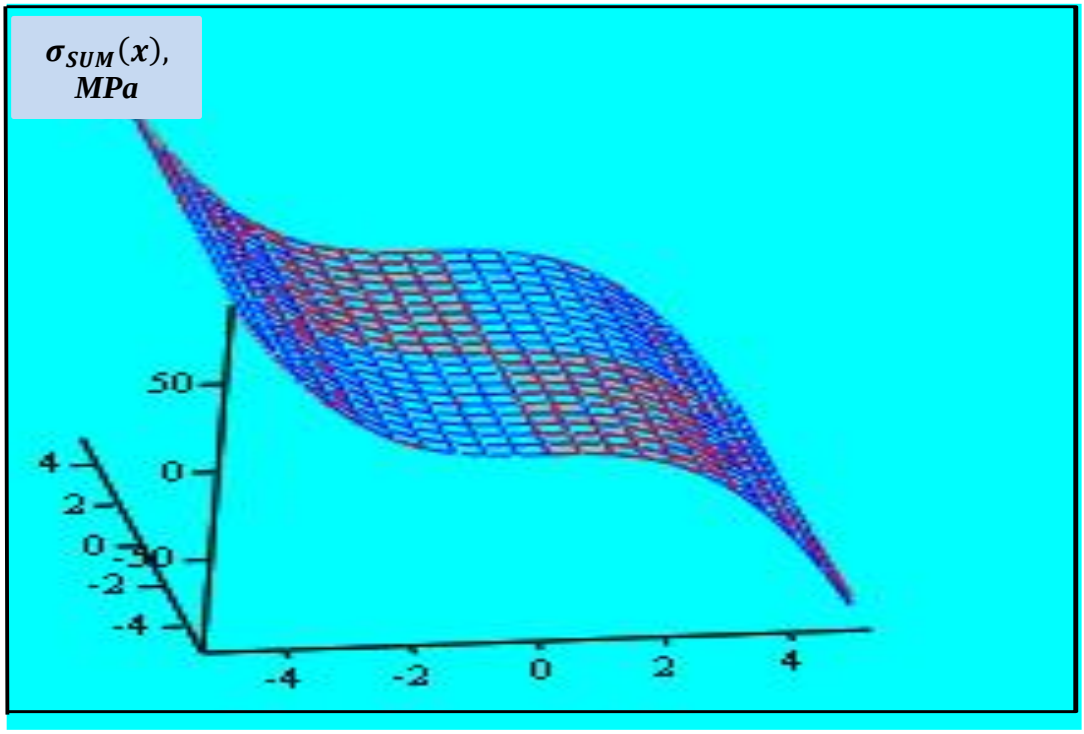

Рисунок 3. График изменения максимальных напряжений по длине межклапанной перемычки крышки цилиндра дизеля 1А-5D49 из чугуна марки ВЧ50 $\sigma_{SUM}(x)$ при изменении координаты $0 < X < \ell_P$ и при пульсациях давления P_E от 4,9 МПа до 5,05 МПа (по результатам аппроксимации экспериментальных исследований сплайн-функцией).

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