MODELING OF THE THERMAL STRESSES IN THE WELDED RAILS OF THE CONTINUOUS WELDED TRACK IN THE PERMAFROST ZONE

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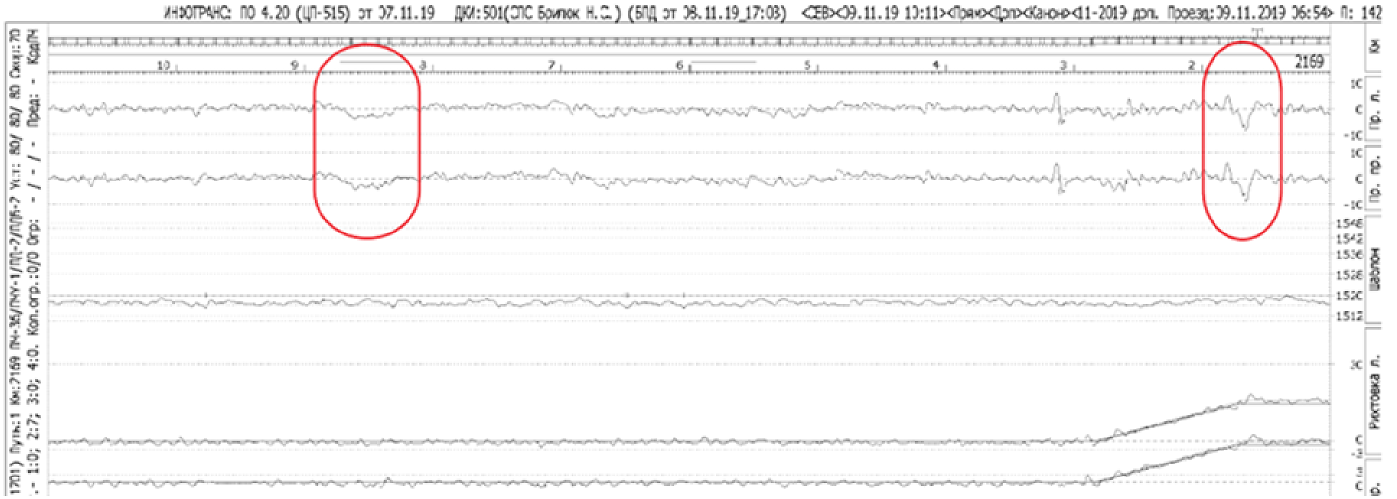
At present time the replacement works of the jointed track structure with the wooden roadbed into the thermal-stressed structure with the reinforced concrete roadbed within the realization of the project «The Northern Latitudinal Railway». It should be mentioned that the sections included in the project «The Northern Latitudinal Railway» are located in the complicated geological permafrost conditions that lead to the subgrade deformation and the track structure in general



The article focuses on the numerical methods that are used to solve heat conduction nonlinear problems with the help of the h-matrix to account for the relaxation of thermal stresses in continuously welded rails. A general mathematical model on the basis of the heat conduction nonlinear equation is presented to calculate the thermal field in an infinite unlimited plate. The developed mathematical model can be applied to choose the implementation modes of the continuously welded rails into the optimal thermal mode.

Methods and Results

The calculating method used for the laying conditions of the continuous welded railway track [3] does not take into account the stresses in the continuously welded rails emerging in the process of the thermal track grading deformations of the subgrade soil. The resulting track grading deformations also cause significant alternate stresses in the continuously welded rails. Modeling of the thermal conductivity processes and their influence on the stress-strain state of a prestressed continuously welded rail structure will solve the problem of the thermal optimization of the continuously welded rail initial fixing and the forecast of pre-buckling state of continuously welded rails.

The Helmholtz equation is considered to model the propagation of the thermal phenomena in a solid object. It is proposed to develop a numerical algorithm without any saturation that allows to solve the spectral problem for the homogeneous Helmholtz equation, the boundary value problem for the non-homogeneous Helmholtz equation and the non-stationary heat conduction problem.

$$\Delta\Phi(x,y,z)+\lambda^2 \Phi(x,y,z)=F(x,y,z),(x,y,z)\epsilon\Omega$$

$$\Phi_{\partial\Omega}=0$$

Here Ω – an axis rotation body Oz, дΩ – its boundary. If F is identically equal to zero, then the problem at eigen values is considered, otherwise, if λ2 – is a non-eigen value, the boundary problem is solved. Since the right part is arbitrary, the problem under consideration is three-dimensional.

If the Cauchy-Riemann conditions are met:

∂v/∂r=-∂u/∂r=1/r ∂v/∂θ

then the coordinate system (r, θ, φ) is orthogonal and in this coordinate system the Laplacian of the scalar function has the form:

$$\Delta\Phi = \frac{r}{\nu\omega^2}\left[\frac{\partial}{\partial r}\left(r\nu\frac{\partial\Phi}{\partial r}\right) + \frac{\partial}{\partial\theta}\left(\frac{\nu}{r}\frac{\partial\Phi}{\partial\theta}\right)\right] + \frac{1}{\nu^2}\frac{\partial^2\Phi}{\partial\varphi^2},\ w^2 = (\partial\nu/\partial\theta)^2 + (\partial u/\partial\theta)^2$$

The discrete Laplacian is obtained as an h-matrix $H = \frac{2}{L}\sum_{k=0}^{i} \Lambda_k \otimes h_k,\ L = 2L + 1$

Λ_k is the matrix of the discrete operator, corresponding to the differential operator $\frac{r}{\nu\omega^2}\left[\frac{\partial}{\partial r}\left(r\nu\frac{\partial\Phi}{\partial r}\right) + \frac{\partial}{\partial\theta}\left(\frac{\nu}{r}\frac{\partial\Phi}{\partial\theta}\right)\right] - \frac{k^2}{\nu^2}\Phi, k = 0, 1, , l$

with the boundary condition: $\Phi|_{r=1} = 0$.

To discretize the differential operator, we select a grid according to θ consisting of n knots: $\theta_\nu = \frac{\pi}{2}(y_\nu + 1), y_\nu = cos\varepsilon_\nu, \varepsilon_\nu = \frac{(2\nu-1)\pi}{2n}, \nu = 1, 2, \dots n.$ We also apply the interpolation formula:

$$g(\theta) = \sum_{\nu=1}^{n} \frac{T_n(x) g_\nu}{n\frac{(-1)^{\nu-1}}{\sin \varepsilon_\nu}(y - y_\nu)},\ y = \frac{1}{\pi}(2\theta - \pi),$$

$$g(\nu) = g(\theta_\nu), \nu = 1, 2, \dots . n,\ T_n(x) = cos(narc\,cos(x))$$

According to r, we select a grid consisting of m knots:

$$r_\nu = \frac{1}{2}(z_\nu + 1), z_\nu = cos\chi_\nu, \chi_\nu = \frac{(2\nu - 1)\pi}{2m}, \nu = 1, 2, \dots m,$$

we also apply the interpolation formula

$$q(r) = \sum_{\nu=1}^{m} \frac{T_m(r)(r-1) q_k}{m\frac{(-1)^{\nu-1}}{\sin \chi_\nu}(r_\nu - 1)(z - z_\nu)},\ q_\nu = q(r_\nu),\ z = 2r - 1$$

Conclusions

The presented nonlinear mathematical model makes it possible to apply scaling and adaptation procedures to various operating conditions of the railway track, as well as to consider various design characteristics of the permanent way. In general, the proposed model for calculating the dynamic behavior of the continuously welded rails will improve the calculation accuracy of thermal stresses and the optimal temperature of their fastening, and it can also be used in the integrated monitoring system of the pre-failure state of the continuous welded track.