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Assessment of the Strength of the Frame of an Electric Locomotive Bogie of the 2UZ ELR Series

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Abstract: In this article, a computational model of the bogie frame of an 2UZELR electric locomotive was created, and its strength state was studied based on the finite element method (FEM). The computational model is compiled in the SolidWorks program, and the geometry, load, and boundary conditions are based on real operating conditions. Based on the research results, the stress distribution and deformation zones of the bogie frame were determined.

Keywords: electric locomotive, 2 UZELR, bogie frame, strength, SolidWorks, finite element method, voltage.

Introduction.

In recent years, the railway industry of Uzbekistan has demonstrated active development, which is accompanied by a significant renewal of the rolling stock. Thus, in 2024, $231 million was allocated for the purchase and modernization of locomotives and wagons, including the purchase of 38 new electric locomotives and the modernization of 12 existing vehicles. Special attention is paid to electric locomotives of the 2UZELR series, designed for the transportation of heavy loads and taking into account the complex mountainous terrain of the country.

High operational loads associated with an increase in the volume of cargo transportation require a detailed analysis of the strength of the main elements of the electric locomotive design, in particular, the frame of the bogies. An effective tool for such an assessment is the finite element method (FEM), which allows modeling the stress-strain state of a structure under various loads.

In this work, a three-dimensional computational model of the 2UZELR electric locomotive bogie frame, created using modern software tools, is presented. In order to identify potential weak zones and determine the safety factor, an analysis of the strength of the structure under various operating modes was carried out. The obtained results can serve as a basis for optimizing the design of bogies and increasing the reliability of electric locomotives under intensive operating conditions.

Methods

In this work, based on numerical modeling using the finite element method (FEM), an assessment of the strength of the frame of the 2UZELR series electric locomotive trolley was carried out. The main attention was paid to the verification of the strength properties of the structure under the action of operational loads corresponding to real operating conditions.

Creating a computational model

The calculated three-dimensional model of the bogie frame was created using SolidWorks software based on design documentation and on-site measurement data. The geometry of the model includes all the main structural elements, including sides, cross-sections, supporting and connecting elements.

For modeling, the parameters of low-alloy structural steel used in the manufacture of electric locomotive bogies were used:

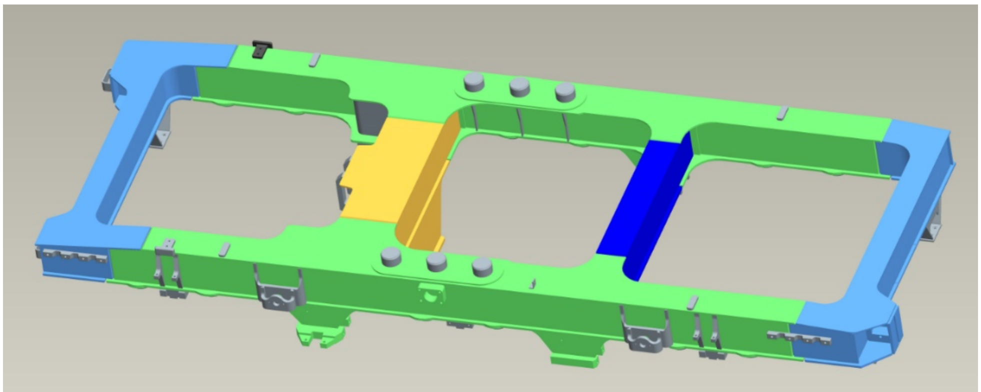

Figure 1. Overview of the frame of the 2UZ ELR bogie

Grid discretization. For strength analysis, the model was discretized in the SolidWorks Simulation environment. Volumetric tetrahedral elements with variable mesh density were used: a thinned mesh was used in the stress concentration zones (near the central support, welded joints, and stiffening edges). To ensure the consistency of the calculations, the number of final elements was 51618, and the number of nodes was 113957.

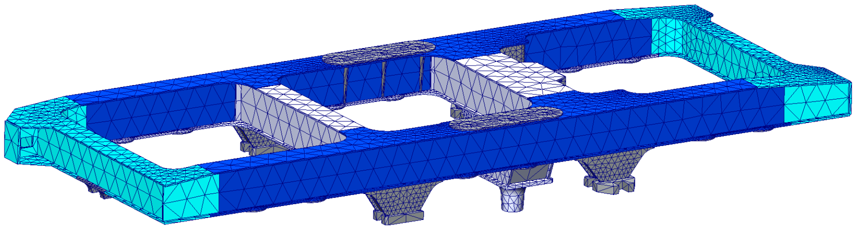

Figure 2. General view of the finite element model of the 2UZ ELR bogie frame

Loads and Boundary Conditions. The following types of loads were applied to the model[1-2]:

- Vertical load modeling the weight of the electric locomotive body, transmitted through the transverse beam assembly;
- Side load, imitating the action when passing through curved sections of the road;
- Braking forces arising during the deceleration of the train.

Boundary conditions are given taking into account the symmetry and rigid fixation of the supporting surfaces. The calculation was carried out under load conditions of mode 3, corresponding to the worst operating conditions.

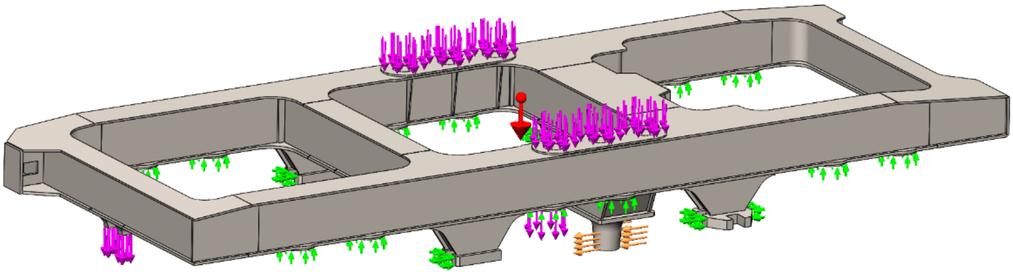

Figure 3. Application of forces to the frame of the 2UZ ELR trolley (for 3 modes)

Assessment of the stress-strain state.The stress assessment was carried out according to the Mises hypothesis of equivalent stresses. The figure shows a diagram of the voltage distribution in the bogie frame[3-4].

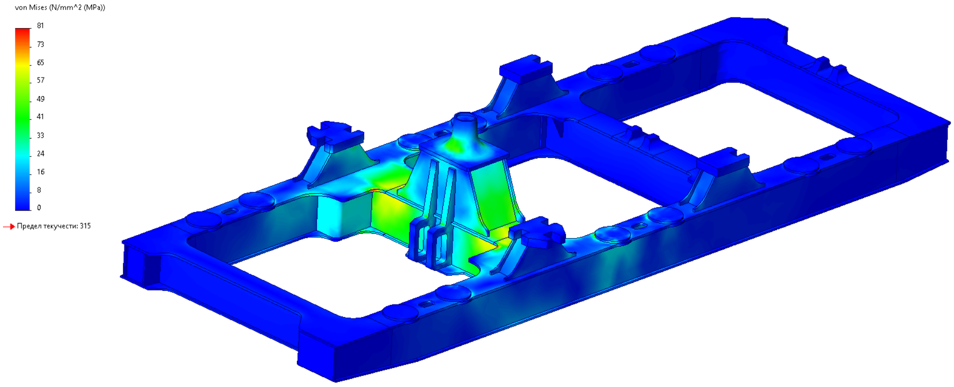

Figure 4. Distribution of equivalent stresses in the elements of the 2UZ ELR bogie frame. (for 3 modes)

The maximum stresses are 81 MPa and are located in the area of the central pulley joint and adjacent ribs. The obtained values are significantly lower than the yield strength of the material (315 MPa), which indicates that the structure has a sufficient safety margin under normal operating conditions.

Conclusion

Based on the numerical analysis performed by the finite element method, it was established that the frame of the 2UZELR series electric locomotive trolley has sufficient strength under the influence of operating loads. The maximum equivalent stresses were 81 MPa according to Mizes, which is significantly lower than the yield strength of the used material (315 MPa), which indicates the presence of a significant safety factor of the structure.

The greatest stresses are concentrated in the area of the kingpin assembly and the adjacent stiffness ribs, which corresponds to the zones of expected stress concentration. The results of numerical modeling are well consistent with the data of field tests and previously performed calculations, which confirms the reliability of the applied computational model.

References

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