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EVALUATING THE EFFECT OF DAMPING STRUCTURES IN THE DESIGN OF A LOCOMOTIVE CAB DURING A COLLISION

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INTRODUCTION:

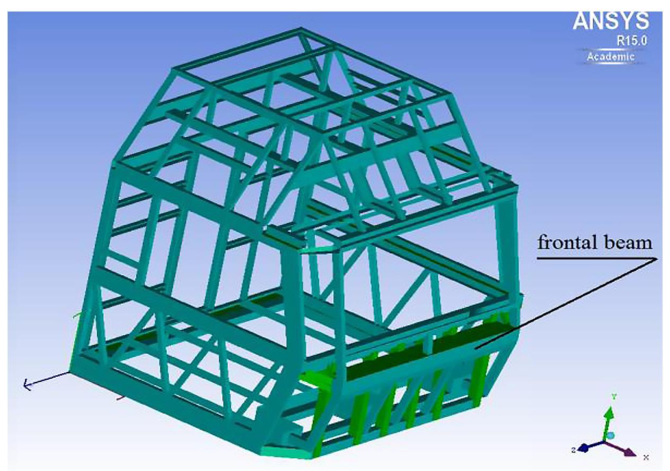
In the operation of a railway rolling stock there may be cases that locomotives encounter various obstacles, as well as collisions of trains with each other, etc. Quite often, there are collisions of locomotives with cars and other vehicles at railroad crossings.
Therefore, it is necessary to create locomotive cab structures that would provide protection for the crew of drivers and cab equipment in such accidents. However, it is not possible to create a safe design for all kinds of accidents. When designing cabs, one is guided by the statistical data of the accidents that have occurred. For example, for high-speed trains in Europe, possible collision scenarios are based on the results of analysis of collision statistics. Some of these scenarios are given in Standard EN 15227: 2008 [1]. Emergency scenarios for Russian trains are given in GOST 32410-2013. Naturally, these scenarios do not cover all possible cases of collisions. Therefore, when designing cabs, it is necessary to choose such parameters of structural elements, that the design allows minimizing the damage from all possible accidental collisions. The difficulty of solving this problem is that we do not know beforehand about the locomotive speed in an emergency collision and the obstacle parameters.

MATHEMATICAL FORMALIZATION OF THE PROBLEM AND RESEARCH METHODS

This study presents calculation results on the energy-absorbing capacity of damping honeycomb elements for the cab of a GT1h gas turbine locomotive. This does not exclude the operation of some elements of the cab and honeycombs in the area of plastic deformation. Consequently, in determining the impact force F [2, 3], the stiffness of the system can have a nonlinear law,

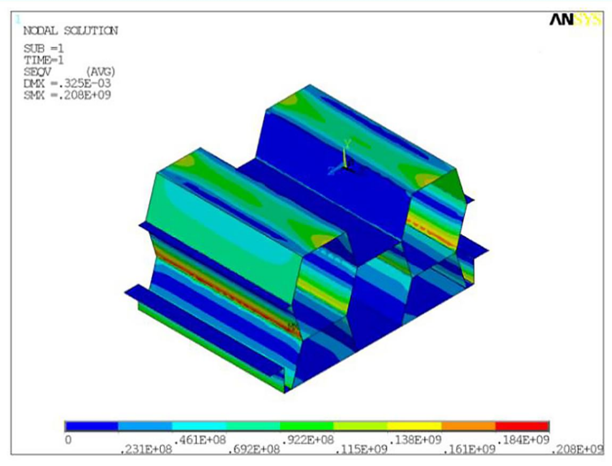
$$c^{-1} = \sum c_i^{-1},$$

where c_i^{-1} is the stiffness of the cab, honeycomb elements, obstacles, coupling, etc. At the same time, the rigidity of honeycomb elements and cabs will depend on F.
The design of the locomotive cab represents a complex beam-rod structure assembled from thin-walled bent profiles. In this figure, honeycomb energy-absorbing elements are not shown. They were calculated as an independent design.



Calculation scheme of a locomotive cab built by means of ANSYS ICEM CFD 15.0

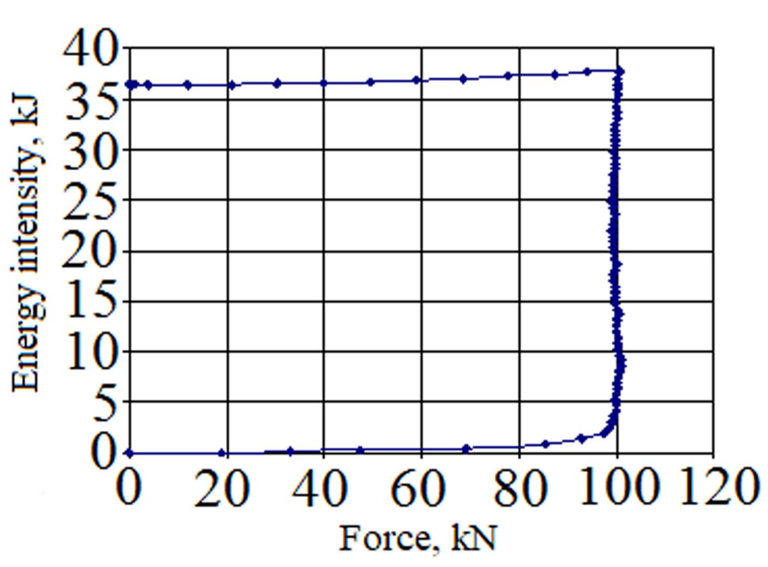
The frontal beam, its fastening elements and the damping structures of the cab can be destroyed during a collision with an obstacle, reducing the impact force on the horizontal power belt. In this case, the front beams of the power belt and the side elements should not receive significant residual deformations in order to protect the crew of drivers and cab equipment. To determine the stress-strain state of the cab, the ANSYS-14 computational complex based on the finite element method was used. Since all cab elements have thin-walled profiles, the model uses the SHELL181finite element.



All the structural elements of the cab and the honeycomb damping structure are made of steel (St3sp5 plain carbon steel). The steel characteristics are as follows: yield strength σ_Y = 210 MPa, ultimate strength σ_{ult} = 500 MPa, Poisson's ratio ν = 0.3, the limit value of relative residual strain δ_{max} = 0.25.
The calculation of the strength and survivability of the locomotive cab in a collision refers to problems with unknown parameters. The possible speed of movement, mass and stiffness of the obstacle construction, the place of load application upon impact is conveniently estimated using interval parameter values. A concrete scenario of deformation, and hence the energy intensity of the cab, can be determined only for a given known load. When designing, it is recommended to perform calculations for the most probable case of loading – the force uniformly distributed along the length of the frontal beam. The total value of the maximum force is limited to F = 300 kN. Our calculations show that, for a given load, the stresses in the frontal beam are close to the yield strength of the material.
The inclined fastening elements of the frontal beam are destroyed at a total force of F = 50 kN, and they do not have a significant effect on the energy intensity of the process. Before contacting with the honeycomb elements, the frontal beam remains elastic. Despite the significant movement of points in the central section of the beam (up to 130 mm), the relative deflection of the beam is not large. In view of the fact that the calculations are of an approximate nature, the energy of the elastic deformation of the frontal beam can be neglected. The main contribution to the energy absorption of the cab is made by cushioning crumple honeycomb elements.

RESULTS

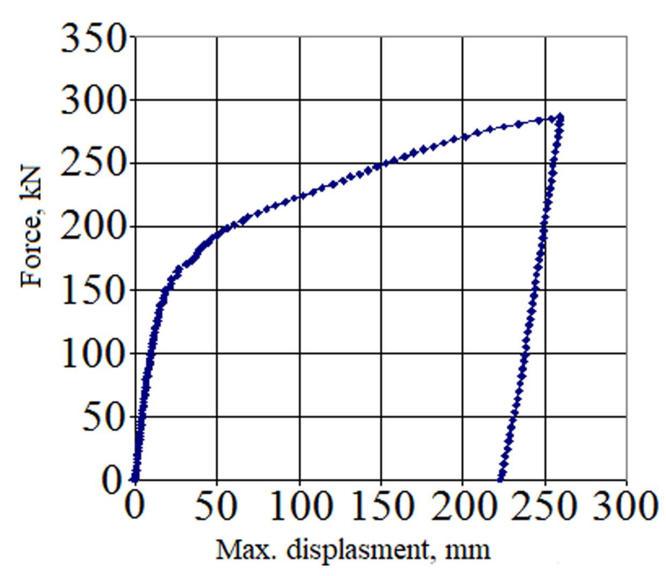
The damping structure is a honeycomb structure of bent profiles connected by spot welding. For this purpose, six blocks of honeycombs are installed along the width of the cab, which are attached to the front beam from the inside of the cab. We solve the problem of pressing of the packet with honeycomb elements, evenly loaded with the force F, which allows us to determine the energy intensity of the damping structure. After solving this problem, the stress state of the honeycomb element is determined.
When calculating the energy intensity, we determine the following two parameters: the total reaction and the movement of the honeycomb element. The maximum displacement is 130 mm, with a maximum force of F = 100 kN. The total energy intensity of six blocks of cellular elements is about 220 kJ.



Energy capacity of one block of honeycomb elements

In addition to the damping structures, a certain contribution to the energy absorption of the cab is made by the deformation of the power frame of the locomotive cab. To calculate the energy absorption in an emergency collision, a static uniformly distributed force is applied to the front beam of the power frame of the cab.

The force is applied gradually in steps, and in each subsequent step the total strain state achieved in the previous steps is taken into account. The geometrical and physical nonlinearity of the material and structure is taken into account in the calculation. At all the force steps, the total reaction and displacement are determined.



Force-displacement diagram for the load-unload cycle

The energy absorption of the carcass of the cab is determined by formula

$$W = \sum_{1}^{n} \frac{R_{i-1} + R_i}{2} \cdot \delta_i,$$

where the work of external forces is expressed in J, R_i is the value of the total reaction at the i-th step of the force, δ_i is the displacement at the i-th step of the force.

CONCLUSION

As a result of the calculations, it has been found that the energy absorption of the carcass of the cab is 36 kJ. Thus, according to the calculation results, it is has been found that more than 80% of the impact energy is absorbed the buffer device. Consequently, the placement of the packet with honeycomb elements between the front and the frontal beams is an effective way of protecting the working area of a gas turbine cab.