MATEC Web of Conferences **116**, 03003 (2017) DOI: 10.1051/matecconf/201711603003
Transbud-2017

Software analysis for modeling the parameters of shunting locomotives chassis

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Abstract. The article provides an overview of software designed to perform the simulation of structures, calculate their states, and respond to the effects of loads applied to any of the points in the model. In this case, we are interested in the possibility of modeling the locomotive chassis frames, with the possibility of determining the weakest points of their construction, determination of the remaining life of the structure. For this purpose, the article presents a developed model for calculating the frame of the diesel locomotive chassis, taking into account technical, economic and other parameters.

1 Introduction

Because of the high degree deterioration of the Ukrainian railways traction rolling stock (more than 90%) on the one hand, and the lack of free investment resources for modernization, on the other hand, and production capabilities of manufacturing plants, tasks to ensure the safe operation of traction rolling stock fleet cannot be solved by its instant updating [9]. Accordingly, searching for a better use of qualitative characteristics of the available operated machinery is necessary, including through the achievement of safe operation of the traction rolling stock beyond the established standard service life.

The condition of the operated fleet of traction rolling stock on industrial transport is hardly better, requiring no less expert studies to assess the remaining resource with the possibility of extending the service life. And every year, this need increases at times.

If now enterprises are prohibited to operate locomotives that have already outlasted the standard service life, it is unclear how they can continue their activity. The situation will be same for Ukrzaliznytsya, except for locomotives of M62 and ChME3 series, which make up a significant part of its operated fleet, the service lives of has already been successfully extended.

Despite this, an important area of research for scientists is further development and improvement of effective control of the traction rolling stock resource which will significantly increase the time of its safe operation. Especially, increasing the role of assessment of the technical state of the base parts of locomotives in order to determine the

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remaining resource and the possibility of its further operation, its further development and improvement of methods and means.

The possibility of further operation of diesel locomotives after expiration of their standard service life is due, firstly, to a sufficient margin of strength and reliability of the equipment, and secondly, to the fact that most of the mechanism components are suitable for repair with the possibility of restoring the resource.

Standard service life for each locomotive type and series is set by the manufacturer on the based on the reliability of its basic construction parts, provided it will be operated intensively and maintained in accordance with the standards.

However, the conditions of locomotive operation and repair basically differ from those offered.

The standard resource depends significantly on how the locomotive was operated and maintained throughout its "life", and whether or not it got into emergency situations.

Thus the important components of the examination in terms of technical diagnosis are:

—assessment of intensity and operating conditions;

—analysis of the faults accumulated during operation;

— assessment of the training level of the personnel engaged in operation;

—assessment of the conformity of the locomotive repair system to the industrial standards.

The combination of all these factors is individual for each locomotive, but only analyzing them in aggregate allows to predict most accurately the value of the remaining life of the locomotive.

One of the bases is the chassis of the locomotive. Creating the most complete calculation model that takes into account a multitude of factors is necessary to perform the qualitative and efficient calculation of its parameters. The task can be solved only using a computer.

2 Objective of work

Analysis of existing methods for simulating the chassis of rolling stock, and the technical means that are used for this purpose with the aim of constructing a model for calculating the chassis parameters of TGM4 and TEM2diesel locomotives, to perform work on modeling the strength and reliability of their chassis parts. The main requirement for the model is taking into account in the calculation such important parameters, as performance characteristics; technical specifications; economic and safety parameters [10].

3 Main part

The procedure for determining the residual life and service life of a locomotive is a large complex of measures, including:

a) analysis of technical documentation and information on operating conditions of locomotives;

b) determination of technical condition, collection and analysis of operational data on damage to the base parts of the locomotive series;

c) dynamic strength tests of the locomotive;

d) bench tests of the base parts of the locomotive, their fragments or samples of materials to assess their fatigue resistance;

e) computational studies of the stress-strain state, fatigue life and survivability of the base parts of the locomotive;

f) choosing criteria and making conclusions about the extent of the residual resource;

g) development of recommendations on design and technological measures to ensure the necessary resource;

h) deciding on the termination or continuation of the operation with the establishment of an additional service life.

Schematically, the algorithm for determining the residual life and service life of the traction rolling stock and the general rolling stock is shown in Figure 1.

The use of modern technologies makes it possible to simplify and speed up the process of performing certain procedures included in the complex for determining the residual life of rolling stock, by eliminating the need to perform dynamic strength tests of the locomotive, bench tests of the base parts of the locomotive, their fragments and material samples to assess their fatigue resistance. All this is achieved by modeling, and in addition to the above benefits, there is a significant reduction in the cost of implementation of these procedures.

Simplification, acceleration and increase of accuracy in the calculation of the study of stress-strain state, fatigue life and survivability of locomotive base parts, the selection of criteria and the formation of conclusions about the magnitude of the remaining resource using a computer.

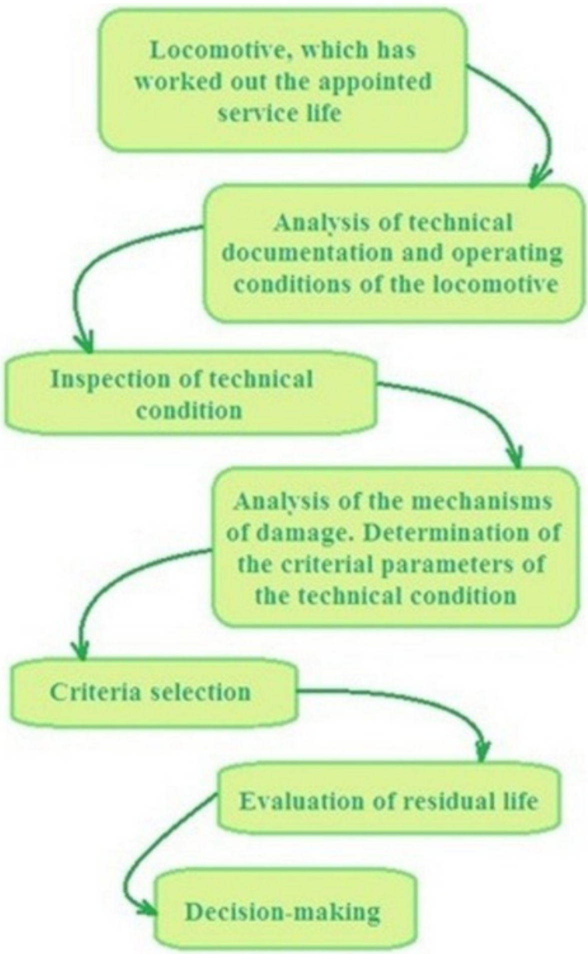

Fig. 1. Block diagram of the procedure for determining the remaining service life extension.

By this time, a number of software programs have been developed enabling to perform a multivariate analysis of calculations taking into account all the loads to obtain sufficiently accurate results. In most calculations, the frame of locomotive chassis is adopted in the form of a rod system. As the practice has shown, in the areas of the junction of the frame beams, in the areas of attachment of brackets, overlays and in other nodes of complex shape, the stresses cannot be determined with the help of a bar chart [1]. In this regard, it is advisable to use modern software and methods of calculation, primarily the finite element method, the application of which will improve the accuracy of calculations and determine the stresses in elements of complex shapes, primarily in the joins of the beams and in the areas where individual parts are attached to the bearing elements.

In work [2], the stressed strain state of the lateral frame of the freight car was investigated using the finite element method with the Siemens NX package-CAD software. For the calculation, the construction of the lateral frame of the 4th execution of the stamped TsNIIKhZO car was used. The method of geometric modeling was used, which was to specify the geometric limits of the model, the dimensions of the elements and to assign the necessary forms of control. In the form of a solid state finite element, a tetrahedron was used (figure 2), because the actual construction is a solid in three-dimensional space. The frame model with an attachment of a tetrahedral grid 7 mm long was divided into 336,416 elements. The number of grid nodes is 104,565. On Figure 3, simulating the calculation of the static space of the deformation theory was carried out in package-CAE software of the Siemens NX. The sections of stresses, displacements and deformations were considered and numerical results were obtained in the form of graphs, tables and diagrams. The result of the calculation showed the accumulation of high stresses in the area of technological hollow and the technological opening of the side frame of the trolley, which precisely determines the "dangerous zones" of the structures, the increase in rigidity of which will result in increasing the strength of the side frame of the freight car.

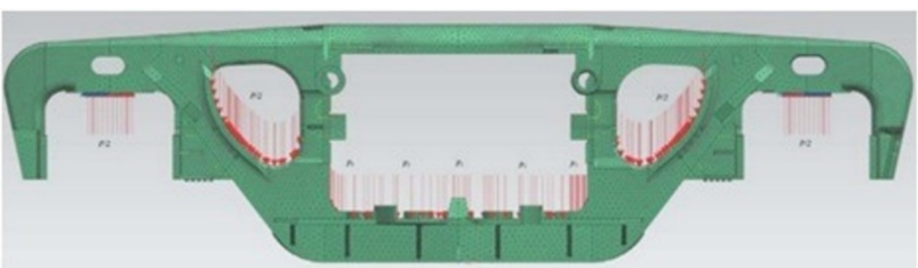

Fig. 2. Use of a tetrahedron as a solid-state finite element.

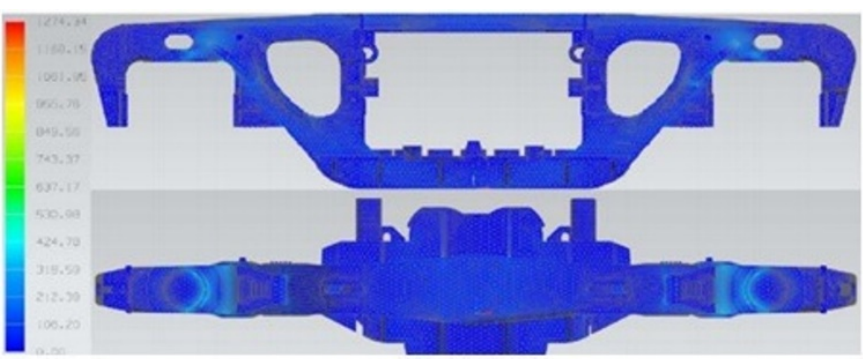

Fig.3. Modelling the calculation of the static space theory of deformation in the package-CAE software of Siemens NX.

In work [3], the task was to develop and verify the procedure for calculating the strength, cast side frames of freight car chassis, taking into account internal defects. The proposed methodology consists of the following main stages: development of initial data for constructing a solid model of a new side frame design; construction of a solid model of the side frame without casting defects and calculation for strength; development of technology and simulation of casting processes when pouring the side frame, determining areas and sizes of internal defects; construction of a solid model of the side frame with internal casting defects, and calculation of strength; development of drawings of the parts and casting of the side frame; manufacturing.

Modern MAGMA software complexes allow determining the areas of occurrence of internal casting defects [4], but their dimensions, distances from the casting surfaces to the defect can be estimated only conditionally, not according to the solid model, but from the JPEG image (fig. 4).

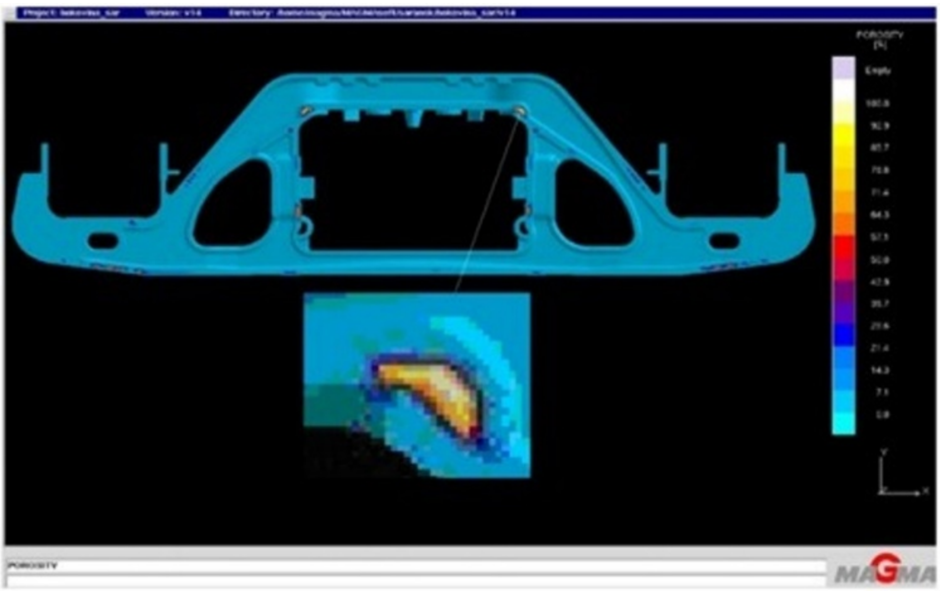

Fig. 4. The distribution of internal casting defects in the longitudinal section of chassis side frame 18-100, determined in MAGMA software.

The results of simulation of casting processes in MAGMA with subsequent strength calculations of the lateral frame with defects cannot be used directly, MAGMA does not picture defects in the solid model. However, the areas of possible location of defects, the type of defect, the nature of its boundaries (sharp edges, rounded forms) can be predicted.

The influence of internal casting defects with sharp peaks are estimated most correct by the methods of fracture mechanics. The technique [4] uses an algorithm for constructing an internal crack with a small radius at the vertex and determining the stress intensity factor (KIN) for KI separation implemented in the finite element ANSYS package version 14.5. Since this software allows to define a semi-elliptical crack only on the surface, an internal crack inside the side frame element directly cannot be constructed, then an alternative method for modeling the internal acute defect is used. In ANSYS 14.5, the lengths of the semi-axes and the radius at the vertex are specified. The finite element mesh for the side frame and for the created crack are automatically built in the Crack module, the boundary conditions are set and the calculation is started. The result of the calculation are the KIN KI values at the crack tip (fig. 5), the Mises stresses.

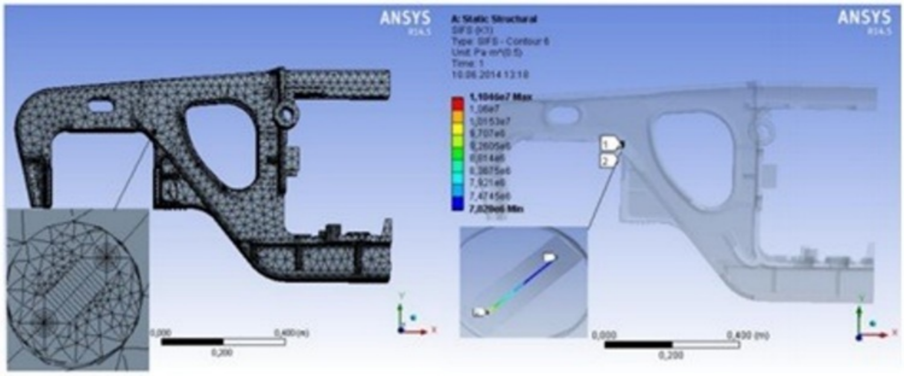

Fig. 5. The finite element grid at the top of the crack (a) and the results of calculating KI (b) from the effect of the vertical load on the side frame 18-100.

In work [5], an FEM was implemented in the SolidWorksSimulation software package for analysis of the stress-strain state, in the editor of which a calculation model was created. The application is focused on the preparation of a full-fledged finite element model with maximum capabilities, taking into account the geometric features, strength character and the performance of various types of calculations. Calculation of the force factors effecting the chassis was carried out according to [6]. At generating a grid of finite-element idealization of the object of investigation, volume finite elements in the form of a tetrahedron were used. The model consists of 46,155 elements and 90,898 nodes. The results of calculating the stress values in the frame of the diesel locomotive chassis under static loading are shown in Fig. 6.

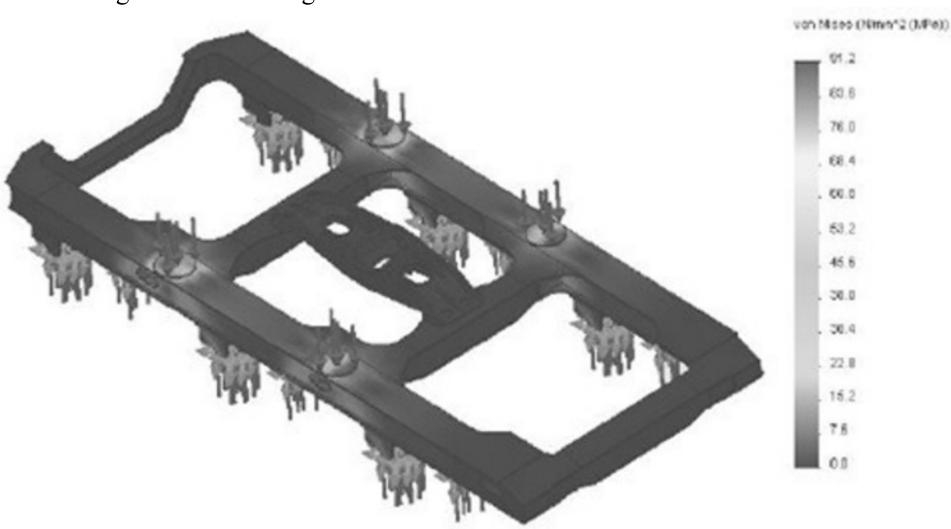

Fig. 6. Results of calculation of stress values in the frame of the diesel locomotive chassis under static loading in the SolidWorksSimulation software package.

Currently, in the software market, this direction is represented by a rather large number of universal software, such as SYMPACK, MSC. ADAMS, LMS. DADS and applications focused on specific objects (MEDYNA, NUCARS and Vampire are aimed at modeling the dynamics of rail vehicles) [7]. All applications of this type automate the process of forming the motion equations of a specific mechanical system based on the description of inertial, geometric and kinematic parameters, models of force interactions selected or specified by the user. To further investigate the dynamics of an object, numerical methods for analyzing the equations of motion are used, for example, numerical integration. The Universal Mechanism software complex (UM) [8], developed in the laboratory of computing mechanics of the Bryansk State Technical University has become quite widely used.

Currently, the complex includes a powerful universal core that meets all modern requirements and a number of specialized modules for simulating the dynamics of cars, railway chassis, caterpillar vehicles, optimization modules, calculating the longevity (figure 7), etc. At the same time, the UM complex has interfaces with other software products (the elastic body modelling module supports the import of data from ANSYS and MSC. NASTRAN, the UMControl module imports models from Matlab / Simulink, the module for importing 3D models from CAD programs now supports SolidWorks, KOMPAS, AutodeskInventor and Pro/ENGINEER).

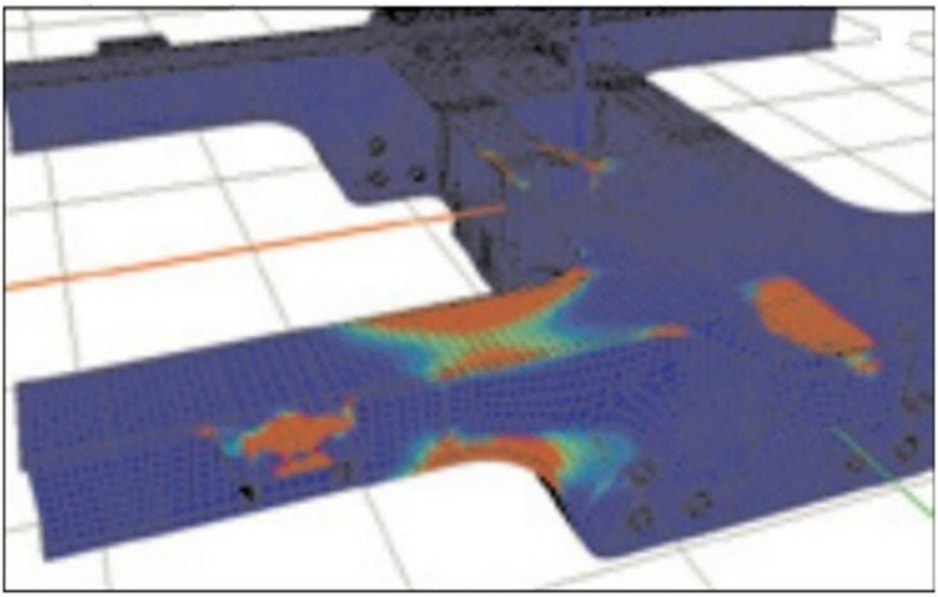

Fig. 7. Results of calculating the longevity of the locomotive chassis frame in the "Universal Mechanism" PC.

In the models considered in the article, during performing calculations, the complex of technical, operational; economic and security parameters is not taken into account.

Taking into account the above parameters, which must be allowed for in calculations, a more detailed model of traction rolling stock chassis technical condition and a separate calculation model have been developed. Mathematically, it has the form

$$P = P1+P2+P3+ P4, \tag{1}$$

where*P1* — is the set of technical parameters;
P2 — is the set of operation parameters;
P3 — set of economic parameters;
P4 — is the set of security parameters.

For more detailed explanation of calculations structure in the developed model, Fig. 8 schematically shows the sequence of the procedure for calculating the parameters of locomotive chassis.

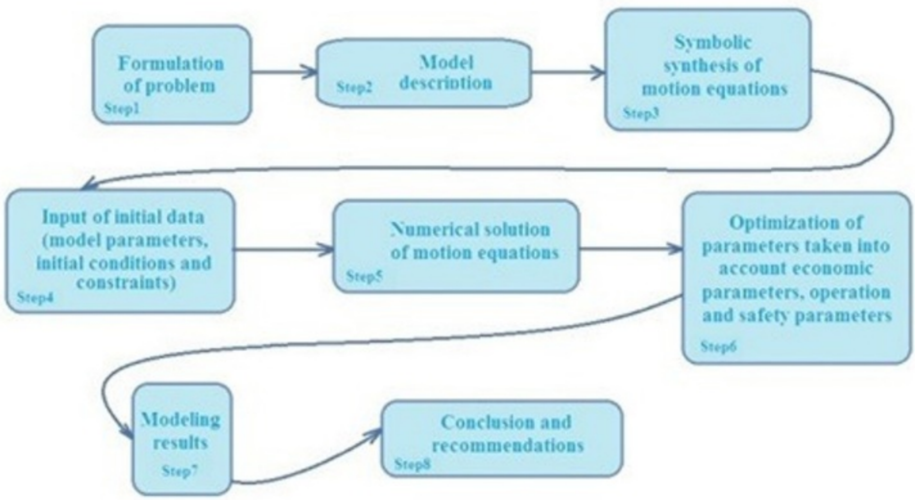

Fig.8. The procedure for calculating the calculation parameters for rolling stock chassis.

The initial step is defining the tasks, in our case this is determination of the residual resource of chassis of TGM4 and TEM2shunting locomotives, in particular, determination of the areas of heaviest impact able loads causing significant loss of strength, which leads to failure of the entire structure and its destruction.

The next step is the implementation of the model description, careful detailing of the design features of diesel locomotive chassis, in this case, TEM2 and TGM4shunting locomotives.

After the symbolic synthesis of the equations of locomotive chassis motion is implemented which implies a painstaking process of combining different parameters characterizing the process of locomotive chassis movement into a structured set. Here, all the features of the process are taken into account, such as acceleration, loads from unevenness of the track, loads from the interaction of the locomotive itself with the elements of the trolley and so on.

The next step is one of the most important in the model, when the input of initial data is performed, such as model parameters, its main dimensions, strength values of materials from which the chassis was manufactured, their strength characteristics etc., initial conditions and values of limitations exceeding. It is inadmissible for the elements of the chassis structure.

Next, is a numerical solution of the motion equations of the bogies is made based on all the initial data. The calculation is carried out automatically by the software.

After the optimization of intermediate results, the equations the locomotive chassis movement is calculated in accordance with economic parameters, operation parameters and, most importantly, safety of their operation as one of the most important requirements. The final output of the results simulation of locomotive chassis is carried out on the basis of which further conclusions and recommendations are made regarding the technical condition, the remaining life, the strength and so far of the simulated locomotive chassis.

4 Conclusions

1. The work analyzes the existing software for simulating the parameters of rolling stock chassis.

2. A calculation model for chassis parameters for TEM2 and TGM4 diesel locomotives was created allowing for technical, operation, economic and safety parameters.

3. Further, a model of TGM4 and TEM2 locomotive chassis should be compiled in order to carry out the corresponding calculations in ANSYS and SolidWorks software.

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