History of Development and Application of the Capabilities of Modern CAE Systems in Designing Innovative Rolling Stock

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Abstract
This article is devoted to determining of the development of CAE-systems influence (Computer-AidedEngineering) finite element analysis railway carriage building industry. There are stages of development of CAE-systems, their capabilities in the design of innovative rolling stock on the example of LTD «UKBV» considered here, and the dependence of the complexity of calculating the body on the method used is determined.

Keywords: CAE-systems, FEM, rolling stock, design, force method, strength, stability, kinematics, labor intensity.

Introduction

The main requirements for the design of innovative rolling stock are the reduction of the tare weight, the increase in axle loads, the increase in overall dimensions, the speed of movement and the mass of freight trains, increased life, lower life cycle costs. Creation in a short time of competitive products that meet the requirements are possible with the use of modern CAD systems, which include CAE-systems of finite element analysis, allowing to assess the stress-strain state of parts and components, their operation and interaction conditions of operation at the design stage.

MCE (finite element method) allows one to approximate numerically a wide range of physical problems that are mathematically formulated as a system of differential equations or in a variational formulation. This method can be used to analyze the stress-strain state of structures, thermal analysis, to solve problems of hydro / gas dynamics and electrodynamics. The historical precursors of the FEM were various methods of structural mechanics and mechanics of a deformable solid.

The history of development of CAE-systems of finite element analysis is conditionally divided into three stages. The first stage began in the 1970s. In the course of it, a number of scientific and practical results were obtained, which proved the fundamental possibility of designing complex industrial products. In the second stage (1980s), CAE-systems of mass application appeared and began to spread quickly. The third stage of development (from the 1990s to the present) is characterized by the improvement of the functionality of CAE-systems and their further distribution in high-tech industries (where they have best demonstrated their effectiveness).

Main part

In LTD «UKBV» in 2000, CAE-system ANSYS Mechanical was introduced, replacing the method of forces and displacements (Fig. 1).
An example of strength calculation in ANSYS using beam elements is shown in Fig. 2. To increase the convergence of the results of calculations and tests, a transition was made from the use of beam elements to the plane. An example of strength calculation in ANSYS using planar elements is shown in Fig. 3.
In 2010, ANSYS Workbench was introduced. The combination of modern functionality, availability and quality of built-in tools had a positive impact on the timing of the calculations and the convergence of the results with the test results, and also expanded the list of performed calculations. In addition to the static analysis (Figure 4), it became possible to calculate the loss of stability (used to determine the critical loads and forms of loss of stability in a linear formulation based on stationary analysis). Calculation of the stability of the boiler is shown in Fig. 5. In the same way, it became possible to estimate the kinematics by the example of the unloading mechanism of the hopper car (Fig. 6), and the brake linkage (Fig. 7).
In ANSYS Workbench, unlike the predecessor, where there were problems with applying the finite element mesh, you can work with complex geometry, for example, cast parts. The calculation of cast parts of a three-axis trolley is shown in Fig. 8. The economic effect obtained from the introduction of various methods of calculation is presented in Table 1.

Table 1. Economic effect

<table>
<thead>
<tr>
<th>Calculation method</th>
<th>Execution time of the body calculation, months</th>
<th>Labor time, normo hours</th>
<th>Reducing labor costs, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force and displacement method</td>
<td>6</td>
<td>1056</td>
<td>*</td>
</tr>
<tr>
<td>FEM in ANSYS (beam elements)</td>
<td>4</td>
<td>707</td>
<td>33,3</td>
</tr>
<tr>
<td>FEM in ANSYS (planar elements)</td>
<td>3</td>
<td>528</td>
<td>50</td>
</tr>
<tr>
<td>FEM in ANSYS Workbench</td>
<td>1</td>
<td>176</td>
<td>83,3</td>
</tr>
</tbody>
</table>
Conclusion

Today, the use of CAE-systems has become the standard of engineering activity in all industries due to the following advantages:

— it is often the only possible method of designing the majority of complex real technical objects and systems because they can’t be accurately described using analytical formulas and relations;
— allows you to calculate the parameters of the product, its performance characteristics even before the material embodiment of the product;
— allows you to significantly reduce the costs and laboriousness of research and development in comparison with the use of material samples and real technical systems.

References