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

Michail E. Smirnov
LTD «Ural design bureau of railway carriage building», Nizhniy Tagil
smirnoffme@bk.ru

Alexandr S. Troshin
LTD «Ural design bureau of railway carriage building», Nizhniy Tagil
alex_st1@mail.ru

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).

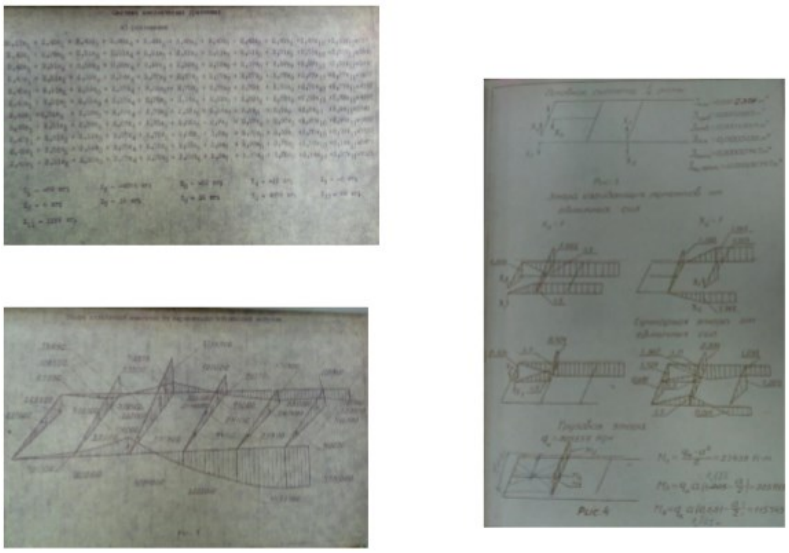

Figure 1. Calculation of the body by the method of forces and displacements

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.

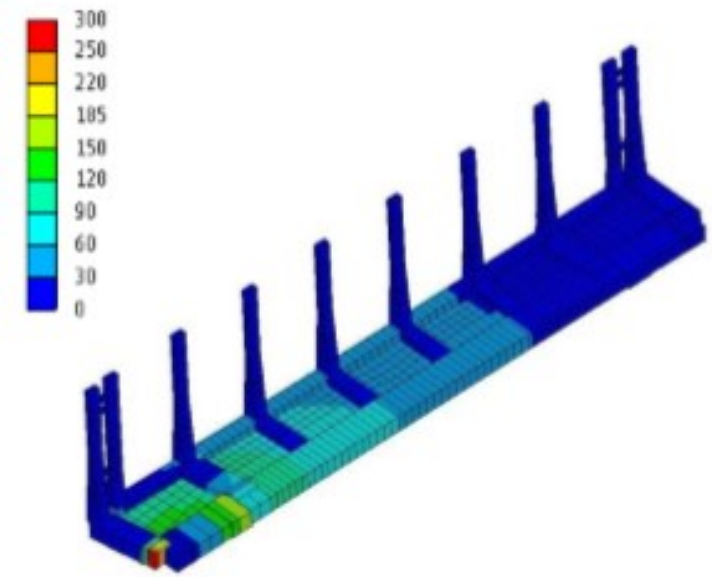

Figure 2. Calculation in ANSYS using beam elements

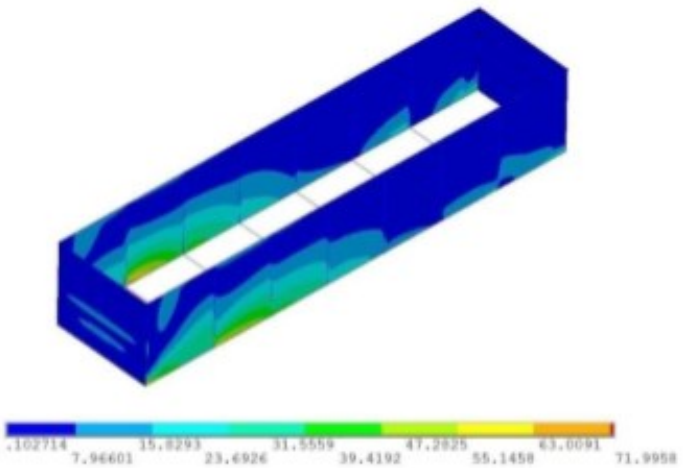

Figure 3. Calculation in ANSYS using planar elements

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).

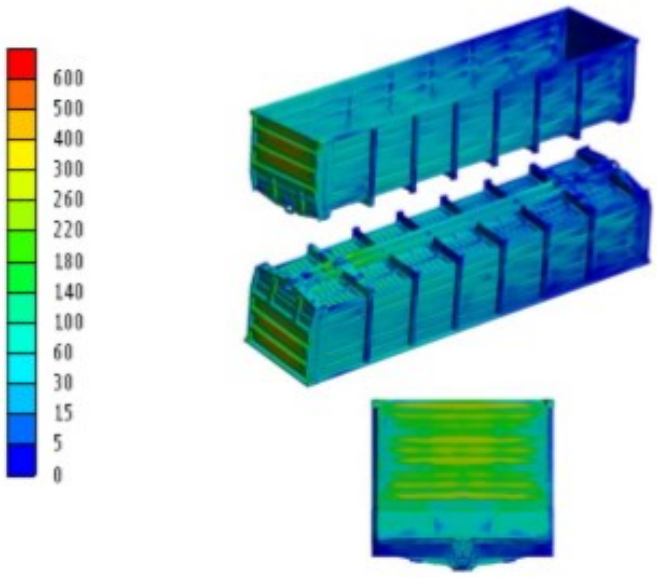

Figure 4. Static analysis in ANSYS Workbench

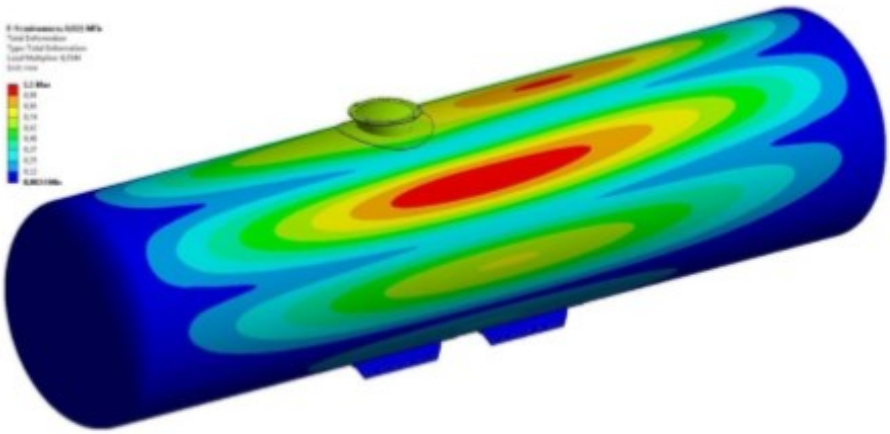

Figure 5. Calculation of boiler stability in ANSYS Workbench

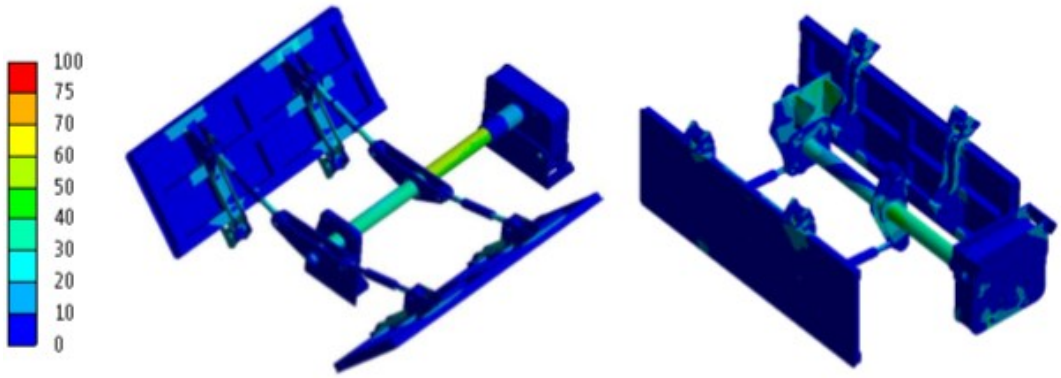

Figure 6. Calculating the unloading mechanism in ANSYS Workbench

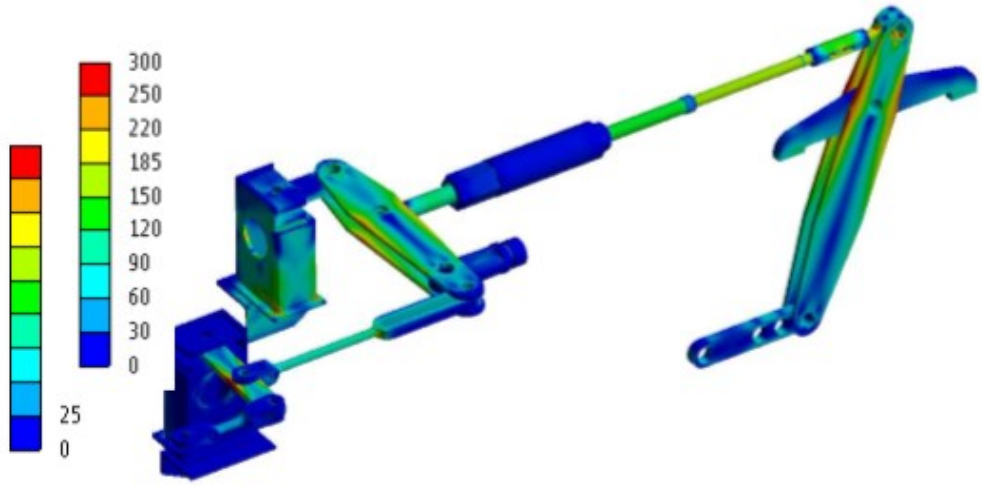

Figure 7. Calculation of the brake linkage in ANSYS Workbench

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

Calculation method	Execution time of the body calculation, months.	Labor time, normo hours	Reducing labor costs, %
Force and displacement method	6	1056	-
FEM in ANSYS (beam elements)	4	707	33,3
FEM in ANSYS (planar elements)	3	528	50
FEM in ANSYSWorkbench	1	176	83,3

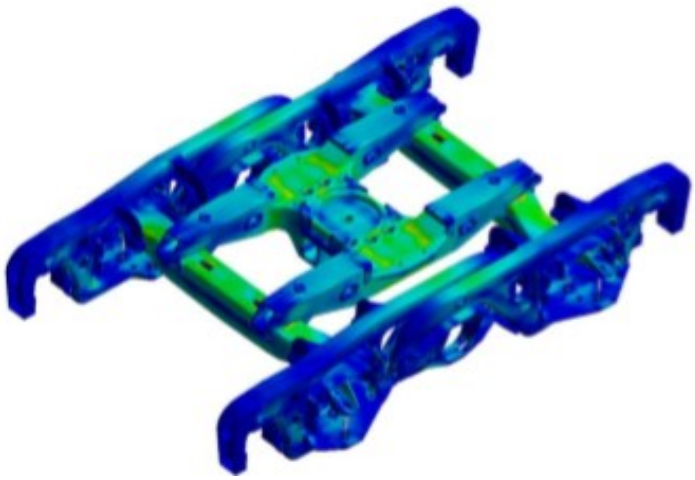

Figure 8. Calculation of cast parts of a three-axis trolley in ANSYS Workbench

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

1. Alyamovsky A.A. SolidWorks / CosmosWorks Engineering analysis by the finite element method. - Moscow: DMK Press, 2004
2. Alyamovsky A.A. and others SolidWorks. Computer modeling in engineering practice. - St. Petersburg: BHV-Petersburg, 2005..
3. Potyomkin A. Three-dimensional solid modeling. - Moscow: Computer Press, 2002.
4. Prokhorenko V.P. SolidWorks 2005: A Practical Guide. - Moscow: "Binom-Press", 2005
5. Sham Tiku. Effective work: SolidWorks 2005. - St. Petersburg: Peter, 2006.
6. Shelofast V.V. Chugunova T.B. Fundamentals of machine design. Examples of problem solving. - Moscow: Publishing house of the APM.