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CALCULATION OF A THIN PLATE BY NUMERICAL METHOD IN THE LIRA CAD SOFTWARE PACKAGE

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Abstract

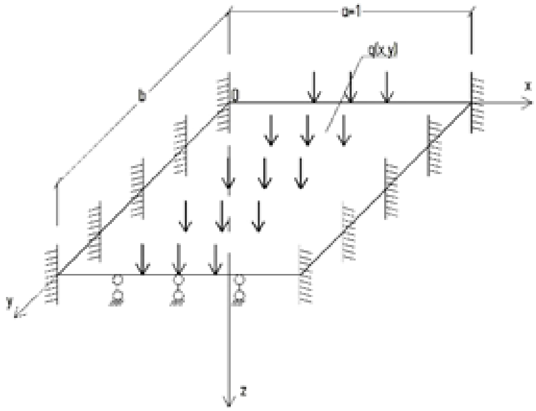
The method of calculating a thin plate using the LIRA CAD software package is an important aspect of modern engineering analysis. In this study, a thin rectangular plate is considered, and finite element analysis is used, which allows us to study in detail the behavior of materials under the influence of various loads. The LIRA CAD software package allows not only to model such structures, but also to conduct a comparative analysis using analytical methods, which makes it possible to evaluate the accuracy and effectiveness of various approaches. The analytical calculation method based on finite integral transformations provides a closed solution for plates of various sizes and shapes. This solution has been found to be the most accurate and versatile, which allows it to be used in various software packages.

Keywords: *thin rectangular plate, CAD LIRA, differential equation*

The use of analytical methods is especially relevant in cases where high accuracy is required, for example, in the aerospace or shipbuilding industries, where structures are subjected to significant loads and impacts. Structures made of flexible shells and plates are widely used in various fields such as mechanical engineering, aviation and construction. In construction, thin slabs are used for floors, coverings and canopies, which makes them an integral part of modern buildings and structures. However, despite its widespread use, the calculation of such structures can be a complex and time-consuming process. Approximate methods such as the grid method are also used to solve problems related to the analysis of thin plates. These methods can only provide point information and require special conditions for approximating functions. Unlike analytical methods, approximate approaches, such as the finite element method (FEM) (Reddy, J., 2006; Senitsky Yu.E., 2011), allow you to split complex areas into simpler elements, which greatly simplifies the modeling process. There are also new directions in the development of methods for solving differential equations, which are aimed at reducing the time it takes to find a solution. These methods make it possible to process large amounts of data more efficiently and get results faster, which is critically important in the context of modern design and calculation requirements. Modern technologies, including machine learning algorithms, are also beginning to find applications in the field of engineering analysis (Ratmanova O. V., Kalmova M. A., 2022). These algorithms, with proper selection and training, can significantly improve traditional calculation methods, allowing you to quickly find optimal solutions for complex problems. The LIRA CAD software package actively uses such technologies, which makes it one of the most advanced tools in the field of design and analysis of structures. Thus, the method of calculating a thin plate using the LIRA CAD software package in combination with analytical and approximate methods, as well as new approaches based on machine learning, opens up new horizons in the field of engineering analysis. This allows not only to increase the accuracy of calculations, but also to reduce the time required for the development and design of complex structures, which is an important aspect in today's competitive environment.

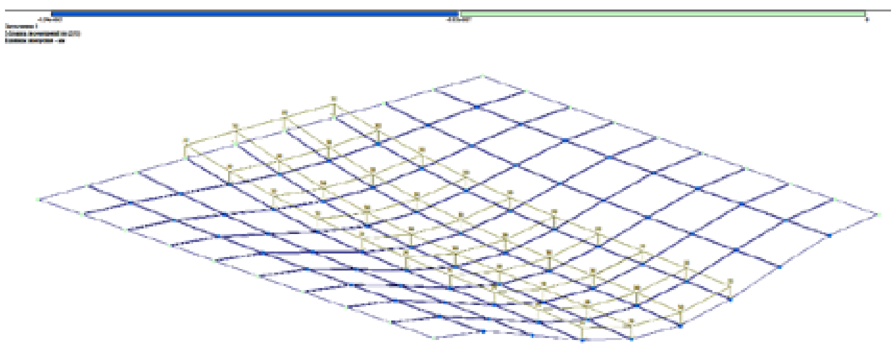
Let's analyze the calculation scheme shown in Figure 1, the dimensions of the plate are 1×1, the fixation along the ordinate axis is rigid on both sides, hinged and free along the abscissa axis, the load is applied to 1/3 of the plate in the center.

Figure 1. *Design scheme of the plate*



The advantage of the CAD LIRA is the rapid variability in the characteristics of the plate, including stiffness and fastening, as well as the type and distribution of the load. Calculating the design in the LIRA CAD software package, the following deformation pattern is obtained:

Figure 2. *Plate movements under load*



Considering the problem by an analytical calculation method, the differential equation and boundary conditions are presented in a dimensionless form:

$$\frac{\partial^4 W}{\partial \tilde{x}^4} + 2\frac{\partial^4 W}{\partial \tilde{x}^2 \partial \tilde{y}^2} + \frac{\partial^4 W}{\partial \tilde{y}^4} = q^* . \qquad (1)$$

$$\tilde{x} = 0,1 \quad W = 0 , \; \frac{\partial^2 W}{\partial \tilde{x}^2} = 0 \, (M_x = 0), \qquad (2)$$

$$\tilde{y}=0 \qquad \frac{\partial^2 W}{\partial \tilde{y}^2}+\mu\frac{\partial^2 W}{\partial \tilde{x}^2}=0 \quad M_y=0, \tag{3}$$
$$\frac{\partial^3 W}{\partial \tilde{y}^3}+(2-\mu)\frac{\partial^3 W}{\partial \tilde{x}^2\partial \tilde{y}}=0 \ \left(Q^*_{yz}=0\right),$$
$$\tilde{y}=p \qquad W=0,\ \frac{\partial^2 W}{\partial \tilde{y}^2}=0 \tag{4}$$

where $\{W,\tilde{x},\tilde{y},p\}=\{w,x,y,b\}/a,\ q^*=\frac{q}{D}a^3,$ $D=\frac{Eh^3}{12\left(1-\mu^2\right)}$

The solution of the problem is carried out using the sine Fourier transform with finite limits on the variable, using the following transform

$$W_s(n,\tilde{y})=\int_0^1 W(\tilde{x},\tilde{y})\sin(j_n\tilde{x})\,d\tilde{x},$$

and the conversion formula

$$W(\tilde{x},\tilde{y})=2\sum_{n=1}^{\infty}W_s(n,\tilde{y})\sin j_n\tilde{x},\ \ (j_n=n\pi).$$

A structural calculation algorithm has been developed, according to which a solution is subsequently carried out, namely equations (1) and (3), (4) are multiplied by $\sin(j_n\tilde{x})$ and integrated in parts in the interval [0,1]. Thus, we get a new boundary value problem:

$$\frac{d^4W_s}{d\tilde{y}^4}-2j_n^2\frac{d^2W_s}{d\tilde{y}^2}+j_n^4W_s=q_s, \tag{5}$$

$$\tilde{y}=0,p \qquad \frac{d^2W_s}{d\tilde{y}^2}-\mu j_n^2W_s=0,$$

$$\frac{d^3W_s}{d\tilde{y}^3}-j_n^2(2-\mu)\frac{dW_s}{d\tilde{y}}=0, \tag{6}$$

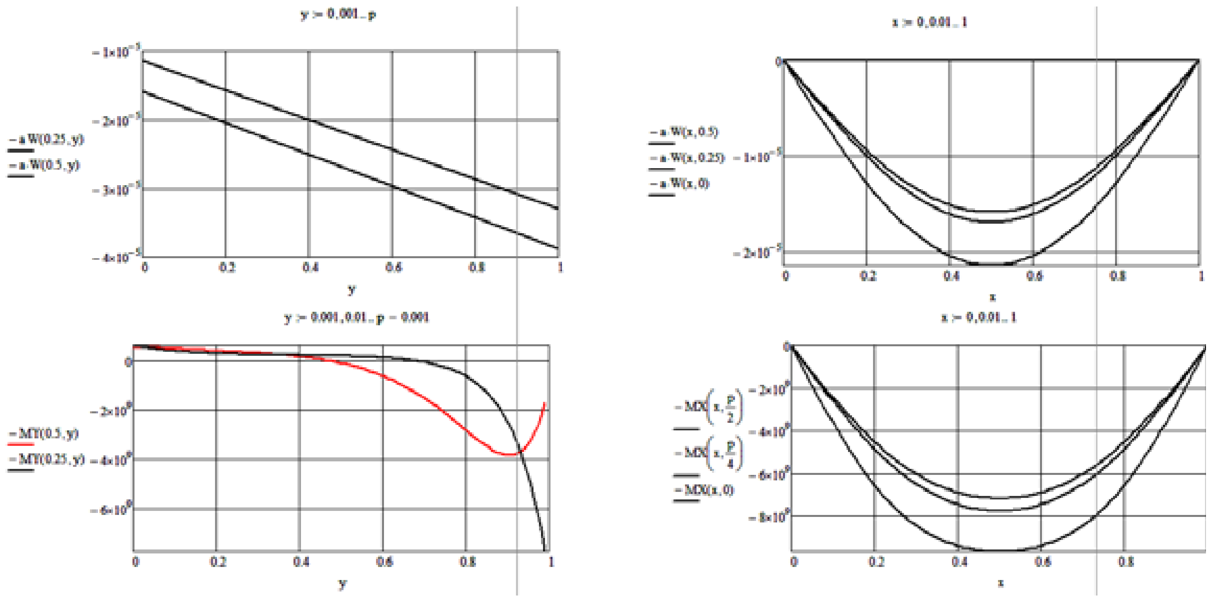
where $q_s(n,\tilde{y})=\int_0^1 q^*\sin(j_n\tilde{x})\,d\tilde{x}$.

The general integral of the differential equation (5) has the form:

$$W_s(n,\tilde{y})=C_{1n}\operatorname{ch}(j_n\tilde{y})+C_{2n}\operatorname{sh}(j_n\tilde{y})+C_{3n}\tilde{y}\operatorname{ch}(j_n\tilde{y})+C_{4n}\tilde{y}\operatorname{sh}(j_n\tilde{y})+$$
$$+\frac{1}{2j_n^3}\int_0^{\tilde{y}}q_s(n,\tau)\left[j_n(\tilde{y}-\tau)\operatorname{ch}\left(j_n(\tilde{y}-\tau)\right)-\operatorname{sh}\left(j_n(\tilde{y}-\tau)\right)\right]d\tau, \tag{7}$$

As a result of substituting (7) into (5), a system of algebraic inhomogeneous equations is formed, which makes it possible to determine the integration constants $C_{1n}...C_{4n}$>. Having calculated this problem using Mathcad, we get:

Figure 3. *Graphs of plate movement*



A comparison of the results of calculating the bending of the plate obtained using the LIRA-CAD software package (Fig. 2) and the analytical method (Fig. 3) demonstrates the advantage of the analytical approach in achieving high accuracy. The analytical method based on the solution of differential equations of the theory of elasticity allows us to obtain an accurate solution for the linear elastic problem of plate bending under given boundary conditions and load distribution. Graphs (presumably showing deflections or stresses) clearly illustrate this difference. The deviations observed when comparing the results may be due to a number of factors inherent in finite element modeling (CAM) used in LIRA-CAD. LIRA-CAD, as a typical representative of CAM programs, discretizes a plate into a set of finite elements, approximating its geometry and physico-mechanical properties. The accuracy of the result directly depends on the size and type of elements used, as well as on the approximation scheme used. A finer finite element grid increases accuracy, but at the same time increases computational costs. In addition, the accuracy is influenced by the accepted simplifying assumptions in modeling, such as the idealization of the material (linear elastic behavior, lack of plasticity, creep, etc.), the idealization of boundary conditions (rigid pinches, hinge supports, etc.) and the method of accounting for distributed load. In real designs, these assumptions can lead to significant discrepancies with the results of the analytical method. While LIRA-CAD provides a convenient tool for quickly analyzing various design options by changing geometric parameters, material, types of supports and loads, the analytical method remains the standard of accuracy, especially in cases where a high degree of reliability of the results is required. For example, when designing critical structures such as aerospace engineering elements or high-precision instruments, the use of an analytical solution is critical to ensure safety and reliability. However, the analytical method is often limited to solving only relatively simple bending problems, whereas LIRA-CAD allows modeling complex structures with nonlinear material properties and geometric nonlinearity. The optimal approach is to combine these methods: using an analytical method to verify and calibrate the model in LIRA-CAD, as well as to evaluate the accuracy of the obtained CAM results. Depending on the complexity of the task and the required accuracy, the choice between the analytical method and the use of a software package such as LIRA-CAD should be reasonable and balanced.

References:

Reddy, J. Theory and Analysis of Elastic Plates and Shells / J. Reddy – CRC Press, 2006. – 2 nd Edition. – 568.

Ratmanova O. V., Kalmova M. A. Dynamicactions of a two-layer freely supported beam / O. V. Ratmanova, M. A. Kalmova // LNCE, 2022. – T. 189. – P. 3–9.

Senitsky Yu. E. The method of finite integral transformations – a generalization of the classical decomposition procedure by eigenvector functions // Izv. Saratov University. A new series. Math., mechanics., computer science, 2011. – № 3(1). – P. 61–89.

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