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COMPUTER MODELLING AND NUMERICAL STUDIES OF NODAL CONNECTIONS OF STRUCTURAL STRUCTURES

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Abstract: Stress-strain states of two types of nodes - the MARKHI node and the author's node made on sheet mouldings - are investigated. The reliability of spatial structure nodes was analysed using modern calculation complexes of structural analysis of mechanical systems. The calculation complexes LIRA, ANSYS, SCAD were chosen as tools for the study.

Keywords: structural structures, node, node connector, sheet metal fittings, solid body, stress-strain state, numerical study, computer modelling.

INTRODUCTION

Structural structures belong to the class of spatial lattice structures. They are most often used as roof and floor structures in buildings. With increased stiffness compared to flat roof structures, structural structures can be used to span large spans [1-3].

The peculiarity of structural structures is the necessity to perform labour-intensive nodal connections [3-5]. Up to eighteen rods can be mated in the nodes of these structures [2, 4, 6]. Difficulties in the execution of nodes, as well as difficulties associated with the manufacture and installation of structural structures, are the main reasons limiting their mass use.

Structural structures are subdivided into types according to the design features of the nodal joints. Structural structures with nodes on sheet metal fittings, on bath welding, with ball connector, with polyhedron, with stamped fittings, on bolts, on 'hedgehogs', etc. are known. [6-9].

MATERIALS AND METHODS

Structural structures support external loads with all their elements, so each node connection is in a complex stress state. The design of the node connection largely determines the reliability and cost-effectiveness of the structural design. The reliability of a spatial structure node can be analysed and predicted at the design stage using modern calculation systems for structural analysis of mechanical systems. Such software packages as ANSYS, LIRA, SCAD, etc. allow to analyse the stress-strain state of the node joint of a structural structure [6, 7, 8, 9, 10].

The various nodes of structural structures lead to similar ones, uniting them by type. Among the nodes of these structures, we can distinguish two very different types - these are nodes performed on the basis of a solid part (Mero et al.) and nodes performed on the basis of thin metal sheets (Unistrat et al.) [1, 2, 3]. As studies show, the stress-strain states of assemblies performed on the basis of a solid part and assemblies performed on sheet mouldings are very different [4, 6, 10]. Solid assemblies are characterised by low deformability and the presence of areas with relatively low stress levels. The sheet moulded assemblies are characterised by ductility and the presence of areas with stress levels exceeding the yield strength of the material.

RESULTS AND DISCUSSION

The rational (optimal) design of structural nodes depends on the type of node connection. The optimal design techniques for solid nodes and for nodes made of thin-walled elements are very different. The search for the optimal solution of a structural structure node can be organised as an iterative process in which at each design step the geometrical parameter of the node is changed and its stress-strain state is analysed by means of modern calculation complexes. Studies show that it is convenient to organise such an iterative process for different types of nodes in different ways.

In assemblies based on a solid component, as a rule, stiffness is provided with a reserve, and internal stresses are distributed along the shortest directions from the loaded areas to the support. Therefore, it is possible to find areas in solid assemblies that are practically unloaded and can be 'painlessly' removed.

In assemblies on sheet mouldings there is a high deformability, the stiffness of the assembly has to be ensured using special techniques, and the stresses are locally concentrated. Therefore, it is necessary to look for solutions for local stiffening and strengthening of such assemblies, for example, by installing ribs or local thickening of the mouldings. The principle of material concentration is inherent in these assemblies, so there is virtually no excess material in their design.

The authors have carried out studies of stress states of the specified types of assemblies. The objects of research are the MARCHI node and the author's node made on sheet mouldings [10].

The aim of the research is to establish the actual stress-strain state of nodes of different types and to find ways of their constructive improvement.

To achieve the goal, the following tasks were set and solved:

1. Selection of a tool (means) for analysing the stress-strain state of the specified types of assemblies.
2. Construction of reliable geometrical models of the objects of research, allowing to take into account all their design features.
3. Creation of calculation models of research objects with the most reliable description of them.
4. Calculation of objects and analysis of the obtained results.

LIRA, ANSYS, SCAD calculation systems were chosen as tools for research. All of them work on the basis of the finite element method and are capable of analysing the stress-strain state of solid bodies. The choice of several calculation complexes was justified by the desire to limit the influence of peculiarities of individual complexes on the final result, by the attempt to get rid of possible calculation and software errors of complexes, by the desire to level the influence of calculation parameters of complexes (types of finite elements, creation of finite element mesh, possibilities of description of boundary conditions, loads and contacts of parts, etc.) on the final result of calculation.

To analyse the objects in ANSYS, geometric models of the research objects were built using ANSYS software package. To analyse the objects in LIRA and SCAD, the geometric model was built by means of the calculation complexes themselves.

When creating computational models, individual features of each computational complex were used to create the most reliable description of the models. The models built by different complexes had some differences. Common for the obtained models were: general geometry (except for some small details, such as, for example, rounding of edges), physical and mechanical characteristics of the material, the nature of loading and the nature of boundary conditions. The distribution of internal stresses in a solid body with internal voids in the form of 'intersection of bolt holes' has a characteristic form for crystalline structures. Stresses are concentrated from the places of force application and redistributed to the support along the shortest distances. The existing hollowness of the solid body in its upper part (bolt locations) causes stress concentration in 'narrow' places. In the lower part of the solid body of the connector (closer to the support plane), where there is more material and less hollowness, the stress level is reduced. The surface areas of the connector that are far from the contact boundaries, connector-nut and connector-bolt, are relatively little involved in the force operation of the assembly. These are the areas of the edges of the outer faces of the connector polyhedron. In these places, the material can be completely removed, so that the connector turns from a polyhedron into a ball (characteristic of the Mero node) and then into a more complex shape.

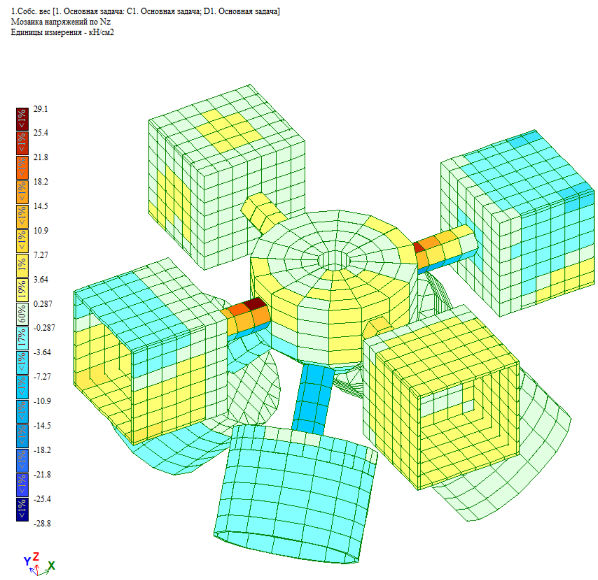

Figure 1. Stress-strain state of the Mero node

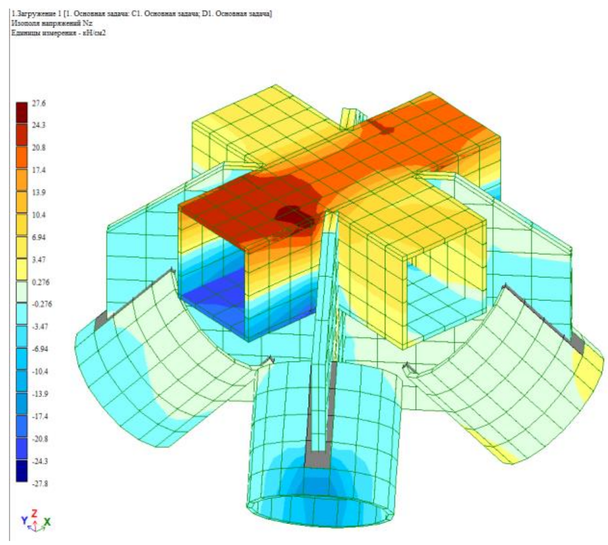

Figure 2. Stress-strain state of the author's node

CONCLUSIONS.

1. As a result of the calculation of each of the two nodes in four calculation complexes, stress distribution and deformation patterns were constructed. Their ‘weak points’ and low-loaded sections were found.

2. The algorithm of iterative search for the optimum geometry of the node is conveniently organised: for a solid part - by removing ‘extra’ material; for sheet mouldings - by adding ‘missing’ material.

3. In a node made on the basis of a solid part, there are areas with low stresses that can be ‘painlessly’ removed. As a result of successive removal of ‘extra’ material from the part, the geometry of the assembly tends to acquire a shape similar to a crystal.

4. In a sheet-moulded assembly, there is greater deformability and stresses are locally concentrated. As a result of successive addition of material in the form of ribs and local thickening of the chamfers, the node is transformed, arriving at a more rigid structure.

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