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MODELING AND ANALYSIS OF THE ELEMENTS AND STRUCTURE OF THE ARMCHAIR FOR A REST

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ABSTRACT

Upholstered furniture consists of supporting structure (skeleton) and upholstery. The proposed work presents modeling and analysis of the elements and structure of an armchair for a rest. The study is done on the base of modern software products, using traditional research of this type of sizes and load schemes According to the study, some necessary recommendations for the design optimizing concerning its practical implementation with specific parameters are given

Key words: Armchair for a rest, modeling, the design optimizing

INTRODUCTION

Bodies of furniture for a rest can have a very complicated form of building. The aim of the furniture form of building is to maximize the convenience and the comfort by following the contours of the human body in the relevant position when furniture is used. Upholstered furniture consists of two main systems – upholstery and supporting structure. Fig. 1 shows a general view of the furniture for a rest. The structure of the upholstery defines functional properties (deformation, coefficient of softness and behavior under load) and the microclimate of the furniture. The manner to build the skeletal structure directly affects the strength, durability and safety of use of the furniture.

Figure 1: General view of the furniture for a rest

The following main groups can be identified depending on the materials used to build skeletons and accordingly adopted technologies (Genchev J., R. Simeonova, 2010):

- *Skeletons of solid wood and wood* plate *materials*;

- *Skeletons of solid wood;*
- *Skeletons of layer wood;*
- *Skeletons of pressformed elements of wood materials;*
- *Skeletons of plastics;*
- *Skeletons of metal;*
- *Skeletons of composite materials;*

The most commonly used structure of skeletons for soft furniture consists of solid wood friezes and plates – plates from chipboard and plates from oriented wood particles, plywood and etc.

The main caution in the field of furniture design is on strength and deformation characteristics of structural elements and connections between them. This applies with full force to the furniture, made of solid wood and of furniture plates (Zhivkov V. 2001, Korolev I. 1976, Marinova A., J. Genchev 2000). The construction of skeletons of the upholstered furniture is addressed to individual elements such as beams, frames and chairs (Korolev I. 1976, Marinova A., Genchev J. 2000). The determination of load and stress calculation of the cross sections of parts and connections between them in the design of the chairs is a subject to scrutiny and study (Zhivkov V. 2001, Korolev I. 1976, Marinova A., J. Genchev 2000, Eckelman C. 2003).

The difficulty of solving these problems is mainly the result of the diversity of the form building of the grid structure of the skeleton, and that leads to a variety of material combinations and connections between them. A research on stress and deformation under load skeleton constructed by friezes of solid wood and wood materials is done in this work. Chosen design scheme is one of the most commonly used because of rationality of design and uniformity of structural elements.

The aim of the proposed study is to model and investigate the supporting structure of an armchair for a rest, taking into account the characteristics of its components. Mechanical – mathematical modeling is done using modern methods, which are entering more widely in practice. Modern applied software is used in the current study. Some traditional patterns and sizes of loads are applied. They have proven their reliability in the practical study of the furniture design. Some reasonable recommendations for optimization of the construction in its practical implementation with specific parameters can be formulated. It could be possible on the base of the results of the investigation.

The study of the supporting structures of upholstered furniture can be successfully based on the use of modern 3D CAD systems for design and study (Georgieva D., P. Dichev 2011). The main advantage of these systems is the availability of software cores for simulation and study of the developed models. The basis of these studies generally includes calculations by the finite element method (FEM). As it is known, the FEM provides reliable numerical algorithms for analysis of engineering structures. It is applicable as a universal tool for calculation and analysis of the behavior of the elements of the supporting structures of upholstered furniture in big variety of powers and thermal loads. It can be successfully used to solve optimization problems in these structures. The essence of the FEM requires digitizing the structure to a relatively small volume called „elements“. In practice, 3D (volumetric) or 2D (surface) finite elements for static, dynamic, kinematic engineering analysis are used. The elements are elastic connected at certain points – they are „nodes“. The coordinates of the nodes of the element are defined in the global coordinate

system (Angelov I., V. Slavov 2010). Generalized vector of the nodal coordinates $\mathbf{q_g}$ of the mechanical system is represented as

$$q_{\mathbf{g}} = [q_1 \quad q_2 \quad \dots \quad q_n]^{\mathrm{T}}, \qquad \textbf{(1)}$$

where: n is the total number of nodal coordinates of the system.

The vector of nodal coordinates of the element is represented by nodal coordinates of the mechanical system by the expression:

$$q_g^j = B^j.q_g, \qquad \textbf{(2)}$$

where: B^j is a Boolean matrix.

The vector of coordinates of nodes in the kinematics restrictions is written as

$$q_g = \left[q_f^{\mathrm{T}} \quad q_s^{\mathrm{T}}\right]^{\mathrm{T}}, \qquad \textbf{(3)}$$

where: q_s is the vector of the specified coordinates;

q_f – the vector of free nodal coordinates.

If the specified nodes are fixed, the vector q_g can be written by the DOF's of the system:

$$q_{\mathbf{g}} = B_{\mathbf{c}}.q_{\mathbf{f}}. \qquad \textbf{(4)}$$

Deformations in the elements are described by interpolating polynomials whose coefficients are defined by physical constants describing the displacements of the element's common points. The calculations use the relation „relative movement – stress".

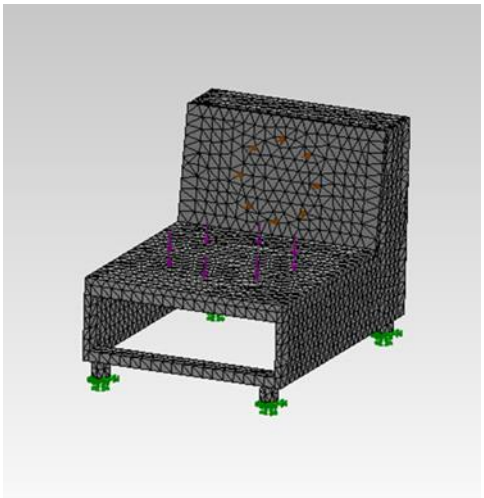
Using this method, it is possible to study stress, deformations, natural frequencies, to predict fatigue, its thermal conductivity and etc. Modern engineering practice shows that in cases where it is necessary to model, study and analyze a structure, using finite element method is particularly promising.

MODELING AND STUDY OF THE CONSTRUCTION

Supporting structure of the chair for rest, drawn in 3D space with the software Solid Works (www.solidworks.com), is shown in Fig. 2. The construction embraces elements from solid wood – these are friezes (supporting, bottom, backrest and rearmost) and legs, as well as chipboard – these are side plates, seat and backrest.

Figure 2: Supporting structure of the chair for rest

Then, using the product Cosmos Works, a mash of four node 3D finite elements is modeled – it is shown in Fig. 3.



Mesh type	Solid Mesh
Mesher Used	Standard mesh
Jacobian points	4 points
Element size	21,2833 mm
Tolerance	1,06417 mm
Mesh quality	High
Total nodes	45129
Total elements	23958
Maximum Aspect Ratio	10,122
Percentage of elements with Aspect Ratio < 3	97,9
Percentage of elements with Aspect Ratio > 10	0,00417

Figure 3: Supporting structure of the chair for rest, modeled with a mash of finite elements

Some of the traditional patterns and sizes of loads of this type of constructions are used for the purposes of the study. Fig. 4 shows these load patterns – they allow studying the specific practical cases. It is supposed a case in which the load acting on the structure is „just sitting“, and the second one – „sitting and leaning“. The load is applied as it is shown in the figure. Its size in the dynamic factor which is 3 is obtained 800,3 = 2400 N, where 800 N is the power of a person's weight.

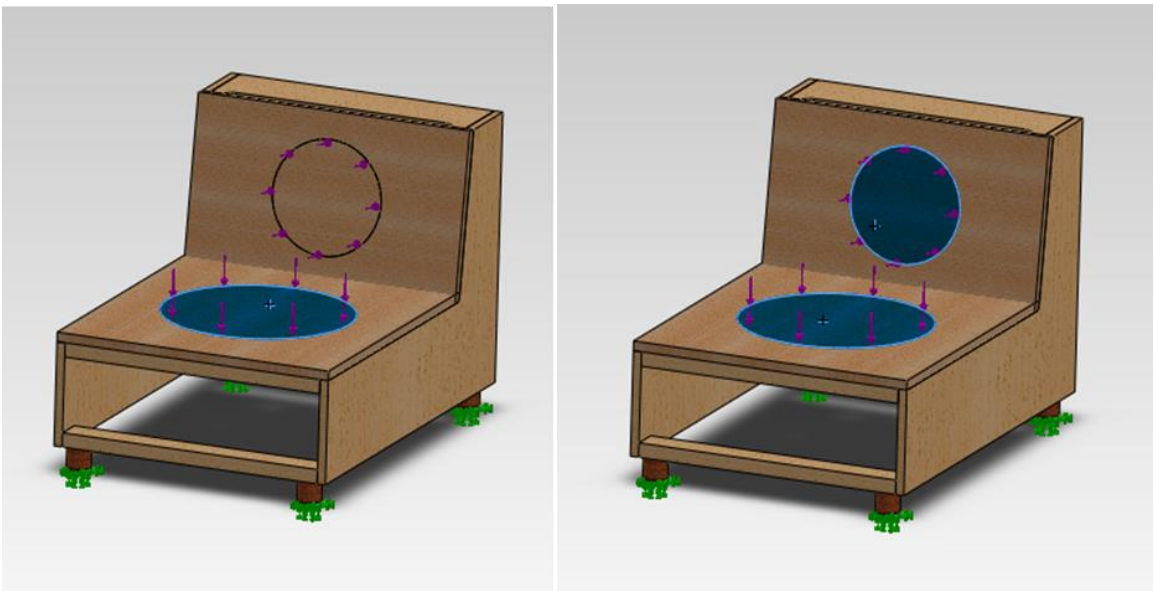


Figure 4: Scheme of the loads of the supporting structure in an armchair for relax

RESULTS

The investigated supporting structure of the chair for rest is drawn in 3D space with the Solid Works software and it is modeled with four node 3D finite elements. The model renders an account the physical and mechanical properties of materials of all elements. At the same time it is given an opportunity to present in details features of each material that is used at the determining load in the proper constructive element. The calculations of the stresses and the deformations, obtained by the action of the applied loads in both variants, are performed using the Cosmos software. Fig. 5 shows the stresses, and Fig. 6 – deformations in the studying construction.

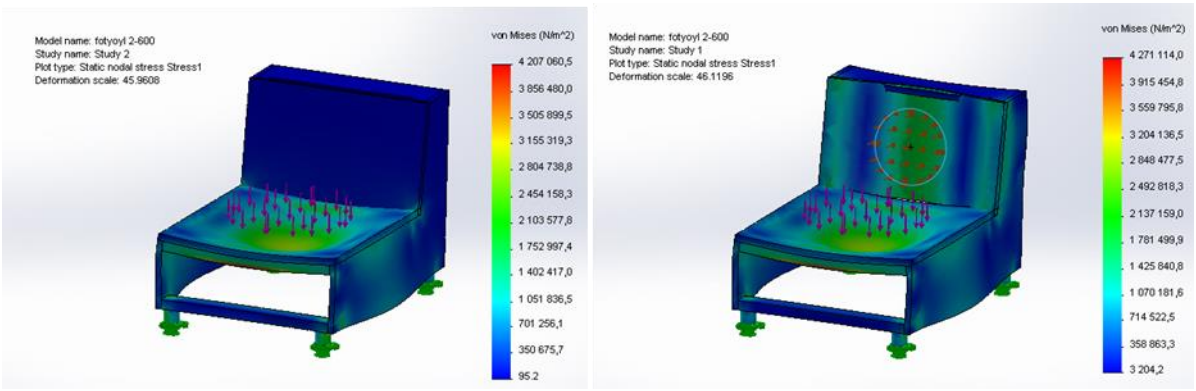


Figure 5: Stresses in the construction

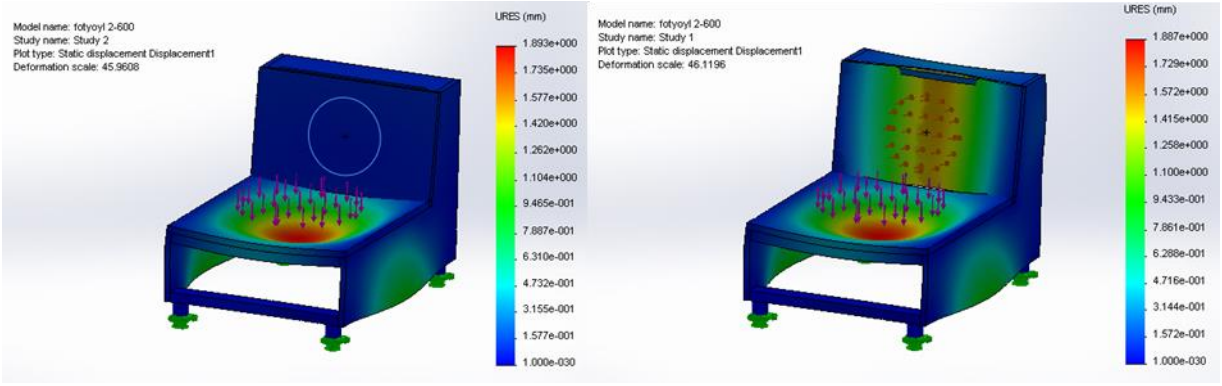


Figure 6: Deformations in the construction

The obtained diagrams show that besides the expected significant stresses and deformations of the seat and backrest, similar ones of the supporting frieze are available. However, large stresses and deformations in some areas of the side plates are of particular interest – they are clearly visible in the figure. The resulting load stresses are not symmetrical with respect to the plane of the side plates – they are larger inside. On the one hand, this result imposes increased demands to the design of these structural elements. On the other hand, this result explains the rapid wear of the upholstery materials in these areas known from practice.

CONCLUSION

The work presents the developed comprehensive mechanical – mathematical model for analyzing the supporting structure of the armchair for rest. The model is based on the classical techniques for analysis of this type of constructions. It renders an account the characteristics of the construction and the physical and mechanical properties of materials of all elements. This model allows simulating different loads and investigating the raised stresses and deformations in the construction. On the basis of this study, it is possible to formulate important recommendations for optimizing of the construction in its practical implementation by specific parameters.

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