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DIMENSIONAL AND GEOMETRICAL OPTIMIZATION OF STRUCTURES AND MATERIALS FOR CURVED OR MOLDED CHAIR FURNITURE

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Abstract : *Based on the finite element method from COSMOSXpress package, Solid Works, the study analyses the possiblity for dimensional and geometrical optimization of sitting furniture structures, made of wood or composite materials based on wood. Concentrated or distributed load is applied to structures, according to the real load incurred at structures in use. As a result of test analysis, the structures can be dimensionally optimized. By observing the stress zones and maximum deformation zones, the designer can intervene on the 3D structures remodel.*
Another important aspect of the study is to enlarge the Solid Works database, by introducing new solid and composite wood materials. The finite element analysis process for the new materials requires the program library to have the following parameters: Elastic modulus, Poisson's ration, Shear modulus, Mass density and Yield strength.
Keywords : *Analysis, SolidWorks, optimization, chair, curved, molded structure*

1. INTRODUCTION

The study analyses different types of sitting furniture (chairs, armchairs, couches, benches, etc), processed by curving the wood or by molding different materials based on wood, or other materials. After selecting the processing method, using the finite element research option included in Solid Works, several tests are performed on the curved and molded structures.
Concentrated or distributed load can be applied to the structures, similar to the normal stress applied to a sitting furniture item. Critical load can be simulated for tracking emerging strains and tensions and areas of maximum concentration of loads and deformations. After the analysis of the structures, the designer can optimize the dimensions or even the shape.
To optimize the shape of the furniture item, the designer can intervene in its draft and remodel the 3D draft, followed by another analysis and optimization of the structure.
Another important part of the study is the enrichment of the SolidWorks database with new properties of the wood- based materials that do not appear in the original software. There is no wood-based material in the SolidWorks library, and even the existing wood types are having only images and densities. For an analysis and wooden structures optimization, several parameters should be determined and introduced in the SolidWorks materials library: Elastic modulus, Poisson's ration, Shear modulus, Mass density and Yield strength, etc.

2. CURVED SEAT STRUCTURE OPTIMIZATION STUDY

The study analyses a common structure found in sitting furniture elements made by curving technique or by molding technique, depending on the used material, being a continuation of studies made on fully curved structures or their skeleton [3], [5], [6] and [8]. The structure is subjected to distributed load over the sitting area and backrest area, being constrained to an extruded skeleton that will have attached a sitting and support system to it.
It is deemed that dimensional geometry elements related to curved or molded structure of the sitting – backrest ensemble are very important. The rest of the component elements are neglected and by a simulation study based on the finite element method from the SW Cxpress the designer tries the dimensional optimizatin based on the curved structure and the wood esence used or on the wood –based materials studied [4]. Tests were done with

wood based materials and composite materials obtained using different technologies like molding, extrusion, injection, casting, etc.
Figure 1 shown the structure analyzed in this study. The structure has an initial thickness of 20 mm, the angle between seat and horizontal $\alpha1 = 5°$, the angle between backrest and vertical $\alpha2=$ variable, and fillet radius variable, R, between the seat and backrest.

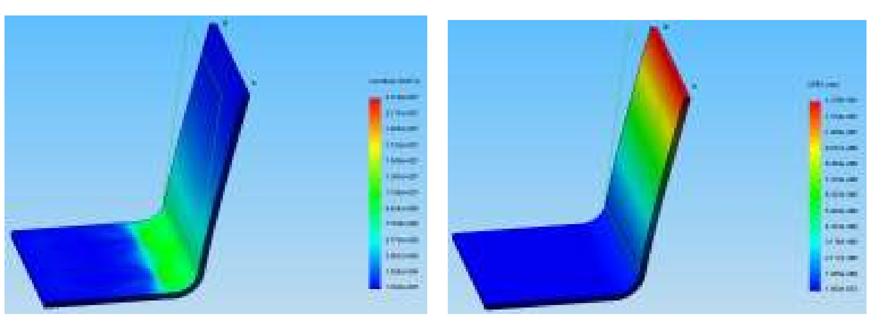
a. **b.** **c.**

Figure 1: A curved Seat Structure,
a. Front wireframe view, **b**. Isometric view (Hidden Lines Visible), **c**. Shaded view.

A material is allocated to the test structure. Models are created for the different types of wood and wood- based materials. Because the SolidWorks library does not have any wood-based materials, main properties were selected and added to the library [1], [7]. The Materials Editor window from material's property is accessible by activating the button Create/Edit Material.
The window has 4 pages: the General Information page, where we introduce the following fields: Database Selections, Material Classification and Material Name, the Visual Properties page with the fields: Real Physical Properties, with the option to edit Value of Material Properties: Elastic Modulus (EX), Poisson Ratio (NUXY), Shear Modulus (GXY), Density (DENS), Tensile Strength (SIGXT), Yield Strength (SIGYLD), etc and the Crosshatch page.
After the test model was defined, different models are created from solid curved wood from the following species: pine, beech, oak, walnut, ash, birch and spruce, and also curved elements made of beech, pine, spruce and poplar plywood.

3. OPTIMIZATION STUDY FOR THE CURVED CHAIR

We tested the structures made of wood- based materials and plywood of the essences mentioned before. We set the restrictions on the lower fixing areas and simulated uniformly distributed load on the seat and backrest, at the critical stress level. Following the analysis phase of the structure in COSMOSXpress we tried to optimize it, based on the observation and the interpretation of the
output parameters. By varying the radius between seat and backrest we could chose the optimal value. We also varied the value of the $\alpha2$ angle, of the backrest to be able to select an optimal value.
For the cases and materials studied we initiated the optimized thickness calculation of the respective structure for a safety factor (FOS) of 1.5.



a. **b.**

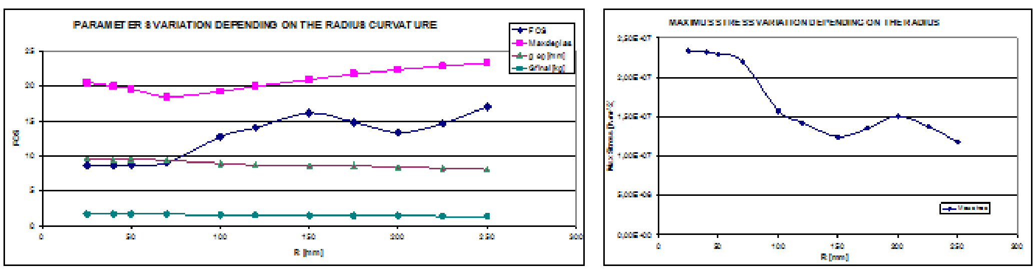
Figure 2: The COSMOSXpress Analysis of a curved Seat Structure,
a. the stress distribution in the model, **b**. the displacement distribution in the model

All the tested structures initially had the same construction parameters, same dimensions and same geometrical parameters. The only difference between the structures was the type of material used, solid curved wood, plywood or multilayer wood, curved or molded plywood, curved composite materials, casted, molded or injected. Although we studied the solid wood, as well as wood –based composite materials or even materials based on synthetic resins, fiberglass, metal fittings, etc., this study was restricted to different essences of solid wood structures and curved or molded plywood, based on veneers of different species.

Following the simulations on the curved chair structures after selecting the seating base, that doesn't allow any displacements, and after positioning the loads on the seat and backrest, we initiate the calculation phase and the finite element method from the COSMOSXpress. We calculate the structure safety factor (FOS), distribution of stresses and strains in the structure, to highlight the most strained areas and the critical areas, where the maximum strains and displacements occur. As an analysis result we can modify the dimensional parameters to optimize the structure.

The COSMOS software has the option to optimize one parameter, g, the whole structure thickness, initial value being 20mm. Optimized thickness, gop, is calculated considering a safety factor of 1.5. We take into account the material density of the chair structure and also we calculate the initial and final mass, and the percentage mass reduction.

For the dimensional and geometric optimization of the structures intended for curved sitting furniture, we observed a tension concentrator in the value interval of the connection radius, R, between the seat and the backrest of structure. We attempt to optimize this value using the optimization method from the COSMOS software. We simulated different structure models, for R taking values in the interval 5mm to 250mm (using testing values of 5, 10, 15, 25, 40, 50, 70, 100, 120, 150, 175, 200, 225 and 250mm). The tests were conducted on a structure based on solid pine wood. Figures 3a and 3b show the variations for the main tested parameters, the safety factor (FOS), the Maximum displacement, the optimized structure thickness, structure final mass (figure 3a) and the Maximum Stress (figure 3b).



a. **b.**

Figure 3: Graph variance parameters dependent radius R;
a. Parameters variation dependingon the Radius Curvature;
b. Maximus Stress variation depending on the Radius Curvature.

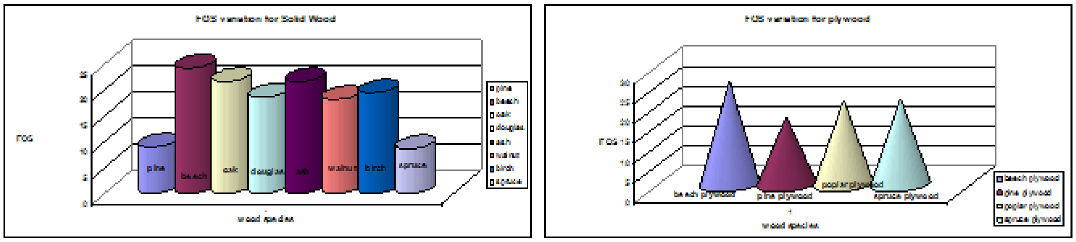
After analyzing the resulting values, we chose the optimal value of the radius, R, for the pine structure, R=70mm. The test is than applied to all the other wood essences, for each structure.

As the resulting values are in a small interval, we consider this value satisfactory to all the other structures of the present study.

If it is intended to manufacture the structure in a mass production, I recommend redoing and verifying all the optimization calculations, for each specific structure, based on calculation method described before.

Another studied parameter is the alpha2 angle, between the vertical plan and the structure backrest. The optimization calculations were done with same optimization model and on the same solid pine structure. The testing values for the angle were 2, 4, 7,10,12,15,17,20,25 and 30 degrees. The simulation results were graphically processed the same way as previously, for an optimal value of alpha2 of 10degrees, for all types of essences and plywood. The value also corresponds ergonomically.

Following tests carried out on all models of these structures can generate graphs of variation factor of safety (FOS) of the test structures shown in Figure 4 for Solid Wood (a) and plywood (b).



a. **b.**

Figure 4: Variation of the safety factor (FOS)Variation of factor of safety (FOS);
a. FOS variation for Solid Wood; **b.** FOS variation for plywood.

4. CONCLUSION

The study analyzes and optimizes the wood structures and plywood structures to obtain a model of curved chair.
It is recommended to continue tests for other models of structures and also to test new materials based on synthetic resins or wood –based materials, fibreglass, carbon fibre or even metallic network.
Also can be tested based-wood materials obtained through new technologies like MDF, OSB, PAL, PFL, or other composite materials based on lignocelluloses fibre, or other sources than wood.
Based on the method presented in the study, wood structures can be tested and optimized for chairs, for any area of use, if the conditions and the stresses incurred in the models are known.

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