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PRODUCT DEVELOPMENT THROUGH FINITE ELEMENT METHOD

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ABSTRACT
The most affected wood species in Romania are the oak and the holm-oak. The physical, mechanical and the aesthetical characteristics of these wood species are those which decide the grade of using them to furniture manufacturing, depending on their feet dried level. Due to the fact that the chair is the most stressed piece of furniture, it was subjected theoretically, using Finite Element Method, to strains and the stresses and deviations were compared for different chair components made of different species of wood and various grades of feet drying oak wood. The following wood species have been used for the theoretical analysis in order to compare the results: health oak, feet dried oak (with different levels), spruce, nut and ash wood. The analysis has been done using the materials mentioned above and various sizes for the rails and legs section (60 x 20 and 60 x 30). The conclusion of using oak wood on some feet drying levels is presented in the paper after making the comparison between some mechanical properties obtained through a theoretical analysis applying Finite Element Method. The results of this theoretical method show that FEM can be applied in order to develop the product after designing it, finding the optimum materials and parts structure.
Keywords: oak, deviations, Finite Element Method.

1. INTRODUCTION
The increased wood consumption in the last years was determined by the demographic increase, by a higher standard of life and by the scientific and technical progress. Being an accessible material, easy to be processed, very close to the people, emotionally and practically connected with them during the time, the use of wood has increased more and more in furniture manufacturing, building constructions, auto industry, consumer goods, etc.
The irrational wood exploitation needed to increase the use rate of the solid wood by increasing the raw materials yield in the final product. More than that, new solutions are looking to find new use of the depreciated wood, and in this category is also included the feet dried wood from the forest. This solution is imposed by the large area of feet dried wood not only in Romania, but in USA and Japan, too.
In order to compare the resistance of the oak wood having different levels of feet drying wood with the other species of health wood (included the oak wood) a chair has been chosen as a product on which a theoretical analysis using Finite Element Method (FEM) has been applied. The chair must fulfil certain requirements regarding the stiffness, stability and strength. When designing a chair, the appropriate solutions for structure, static and dynamic strains and materials must be known. Knowing the physical and elastic properties of various species of health wood and feet drying oak wood at

different levels of depreciation, the distribution of stresses and deformations has been studied for the chair, using FEM, considering that the chair is made of the wood species mentioned above. The shape and dimensions of the chair used for this purpose is shown in figure 1.

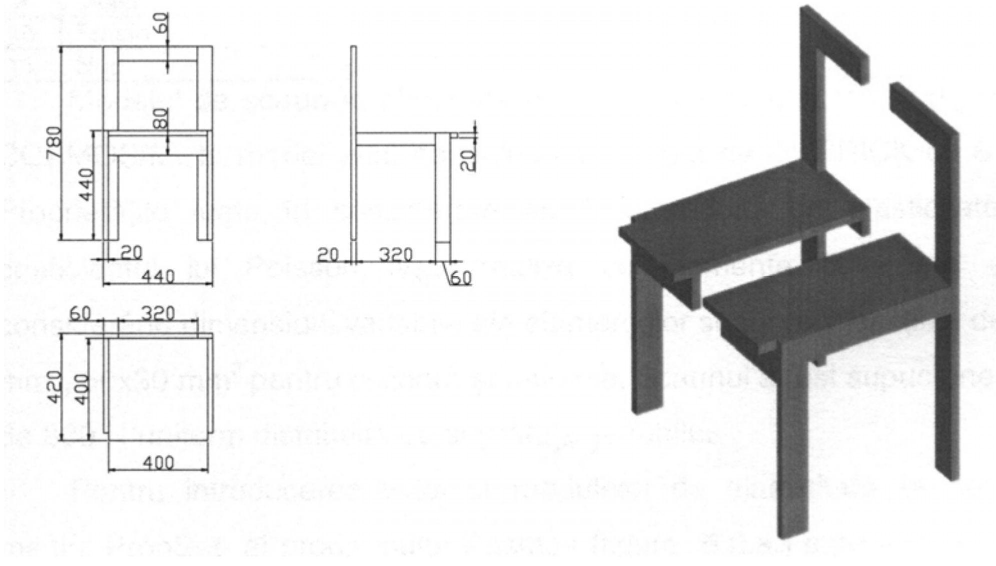


Figure 1. Chair used for FEM analysis

2. THEORETICAL ANALYSIS USING FEM

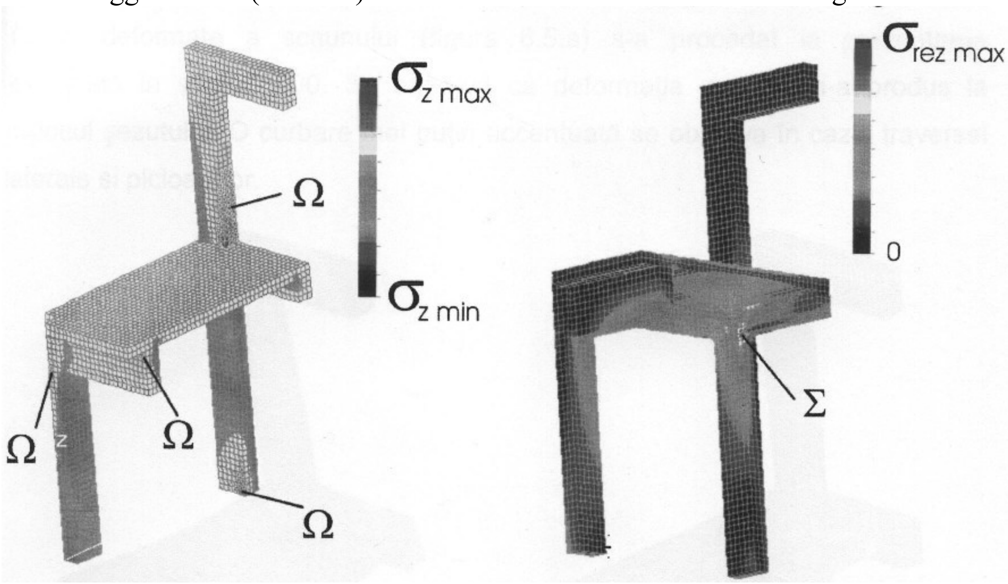
The following wood species have been considered for the theoretical analysis: health oak wood, beech, spruce, ash and nut wood and also oak wood exploited from the dried trees in the forest , being on five grades of depreciation. The modulus of elasticity on the longitudinal direction of the wood has been experimentally determined for the depreciated oak wood and the values for the other species were selected from the literature [1].

The data necessary to perform the theoretical analysis are shown in the table 1.

Table 1. The data necessary to apply the FEM analysis

No.	Wood species	Modulus of elasticity, E_L [$N/mm^2 \cdot 10^8$]	Density, ρ_{12} [kg/m^3]	Coefficient of elasticity, $C_{eE} \cdot 10$	Poisson coefficient, ν
1	Health oak wood	130	750	1.73	0.3
2	Depreciated oak wood (grade 1)	138	706	1.95	0.3
3	Depreciated oak wood (grade 2)	116	691	1.68	0.3
4	Depreciated oak wood (grade 3)	120	671	1.79	0.3
5	Depreciated oak wood (grade 4)	105	671	1.56	0.3
6	Depreciated oak wood (grade 5)	77	611	1.26	0.3
7	Depreciated oak wood (grade 5D)	43	590	0.73	0.3
8	Beech wood	140	740	1.89	0.3
9	Spruce wood	97	440	2.2	0.3
10	Ash wood	140	740	1.89	0.3
11	Nut wood	128	690	1.86	0.3

The FEM analysis has been applied for two types of wood section (60 x 20 and 60 x 30, in mm) for legs and legged frame. The chair seat has been considered to be subjected to an uniformly distributed load of 800 N. because the chair is a symmetric object, just a half of it has been analyzed using FEM. The chair has been considered to be set in the floor. The distribution of the stresses on the vertical direction and also the distribution of the equivalent stresses (von Mises) are shown in figure 2. The maximum stresses are indicated on the picture with Ω and Σ. Analyzing the distribution of the stresses, the most stressed parts of the chair by σ_z are as follows: the part of the back leg situated above the seat jointing area (interior zone), the contact area of the back leg with the floor and the half region of the front rail of the legged frame (Ω and Σ). The stresses distribution is shown in figure 2.



a *b*

Figure 2. The stresses distribution; a) on the vertical direction; b) Von Mises stresses distribution

The deformed chair and the distribution of deformations obtained through FEM analysis is shown in figure 3. as can be seen in figure 3, the maximum deformation is obtained on the central area of the seat. A lower deformation can be observed for the legs and back rest (back leg).

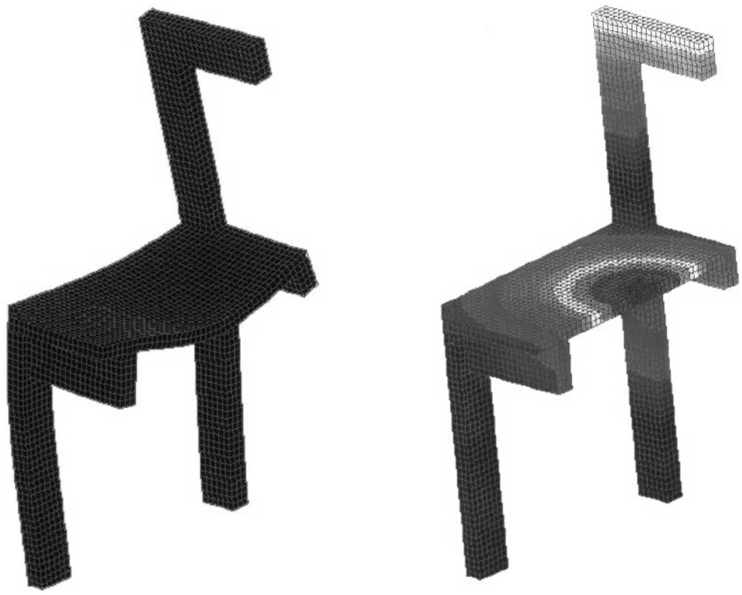


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Figure 3. The deformation of the chair and their distribution; a) the theoretical model; b) deformations distribution

3. THEORETICAL RESULTS

The results of the theoretical analysis using FEM are presented in table 2. Based on the results in table 2, the diagram in figure 4 shows the maximum deformation of the analyzed species, for the two sections of component elements (60 x 20 and 60 x 30). The diagram in figure 5 shows the variation of the ratio between the modulus of elasticity of health oak wood and the modulus of elasticity of the other species of wood analyzed in this paper.

Table 2. The results obtained using FEM analysis

No.	Wood species	Modulus of elasticity, E_L [$N/mm^2 \cdot 10^8$]	Ratio E_{Loak} /E_{Lsp}	Maximum deformation, mm Section 60x20	Maximum deformation, mm Section 60x30
1	Health oak wood	130	1.0	0.0535	0.0059
2	Depreciated oak wood (grade 1)	138	0.942	0.0504	0.0055
3	Depreciated oak wood (grade 2)	116	1.12	0.0600	0.0066
4	Depreciated oak wood (grade 3)	120	1.08	0.0579	0.0064
5	Depreciated oak wood (grade 4)	105	1.24	0.0662	0.0073
6	Depreciated oak wood (grade 5)	77	1.69	0.0903	0.0100
7	Depreciated oak wood (grade 5D)	43	3.02	0.1617	0.0180
8	Beech wood	140	9.28	0.0496	0.0055
9	Spruce wood	97	1.34	0.0716	0.0080
10	Ash wood	140	0.929	0.0496	0.0055
11	Nut wood	128	1.02	0.0543	0.0603

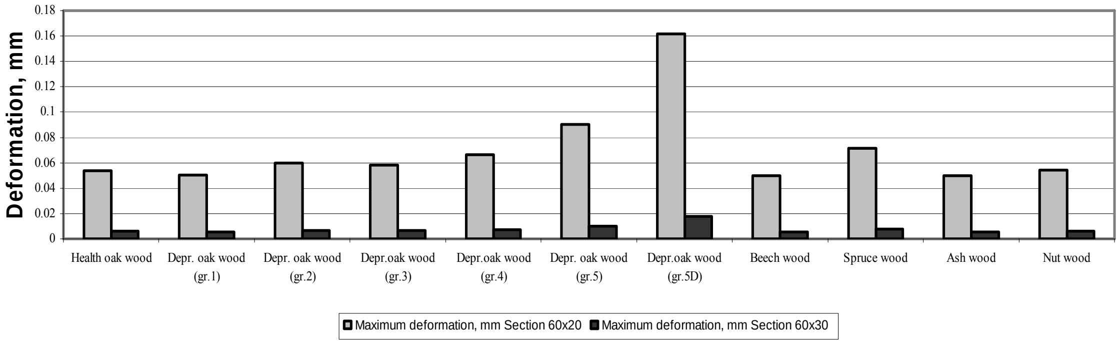

Figure 4. The variation of deformation

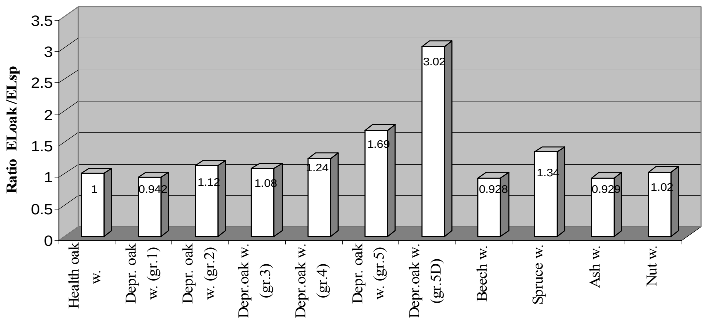

Figure 5. The variation of the ratio E_{Loak} /E_{Lsp}

4. CONCLUSIONS

The depreciated oak wood (grade 5 and 5D) behave similar with spruce wood, which is the softer wood from those analyzed. The depreciated oak wood of grade2, 3 and 4 behave better than spruce wood, but more bad than beech and ash wood. The depreciated oak wood of grade 1 can be considered similar with beech and ash wood. The deformations are almost ten times higher for the section 60x20 than for the section 60x30, but the comparison presented above is valid for both cases.

5. REFERENCES

[1] Curtu, I., Ghelmeziu, N.: Wood and Wooden Based Materials Mechanics (in Romanian language), Editura Tehnică Bucureşti, 1984.

[2] Curtu, I., etc. - Research on the strains of the resistance structure of chairs (in Romanian Language), Revista Industria Lemnului, nr.3-4, 1987.