Conference on Current Issues in Global Furniture

Furniture Design Optimization with FEA Analysis

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Abstract

Wood is one of the most common materials in furniture construction. Nowa days, new materials based on wood are commonly used for furniture constructions. The use of these materials in furniture design is a high challenge. Main criteria in furniture design are aesthetic, ergonomic and safety. As safety we refer to furniture strength. Designers have to consider strength as much as ergonomy and aesthetic. One of the methods to check and improve furniture strength is Finite Element Analysis (FEA) application. In our study we are going to use a strength analysis in order to check specific wooden products as bookcase or shelve unit made of different materials based on wood. In our study we are going to use Ansys Computer Aided Engineering (CAE) program.

Keywords: Computer Aided Design (C.A.D.);Fined Element Analysis (F.E.A); Furniture design; Design optimization; Furniture stability; Wood properties

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1. Introduction

The design and development of product design process comes thru from specific stages. Nowadays, the use of computer is a in all stages. In all steps of product design development the use of computer programs it is a necessity. An appropriate tool in study process is Computer Aided Design (CAD) programs. In these programs the designer/ engineer specifies the dimensions, shape, aesthetic and the safety of the final product with accuracy. The specifications and our needs have to be covered by the designed models.

A physical prototype in real dimensions or under scale should be one of the methods in order to be approve that a designed part is proper for production. The prototype can be used in order, model aesthetic, functionality, ergonomic design as well as safety reasons, to be approved. With the production of physical prototypes some problems occurred:

1) Additional cost in product development process

2) It is possible to produce more than one prototype until develop the final product

3) For different materials we have to produce more than one prototype.

A most efficient way for a designer to evaluate a 3d model is the use of CAE software. Several studies can be executed in CAE, like real-world forces, vibrations, heat transfer, fluid flow, and other physical effects. FEA shows whether a product will break, wear out, or work the way it was designed performing stress and thermal analyses. Stress analysis can be applied to entire structure or to a specific part. Analyses for entire structure are definitely the most reliable type in perspective of small separate parts of the construction.

Bookcase is wide used furniture. During the product development process of a bookcase it is necessary specific design criteria to be fulfilled. One of the design criteria is bookcase stability which is important for the structure safety. In order to check the stability of the bookcase we have to study the total load from books in each shelve. The appropriate CAE study for this problem is stress analysis. The designed model of the bookcase made from particleboard, one of the two materials that usually used (the other one is Medium Density Fiberboard), but the most common material, for structures like this.

2. Materials and Methods

2.1. Finite Element Analysis

Modern designs are comprised from complex shapes and probably from different materials. FEA is the most popular numerical method to solve complicate problems like stress - strain and thermal distribution. In this method the study starts with the approach that the CAD model is divided in mesh elements.

Even Though FEA is a very powerful simulation method a major point is the input data preparation such as the model structure, meshing, the boundary conditions, material selection and the selected type of analysis. These boundary conditions have to be connected with the total force, movement in exactly parts of the model. Also, it is possible to use separated CAE software in order to insert the model from a CAD program, or to study the model in CAD program direct using integrated CAE software. In our study the model will be tested in Ansys software. The steps of analysis are described below.

First step: Create 3D CAD model. The designed model dimensions are 1200 mm length, 400 mm width and 1200 mm height (Fig. 1).

Second step: Defining materials properties. For a typical stress analysis Modulus Of Elasticity (MOE) and Poisson's ratios it is necessary to be defined. In our study the only material is particleboard, the MOE is E=2500 N/mm^2 and poison's ratio is v=0,2 (DIN – Taschenbuch 60, 1999).

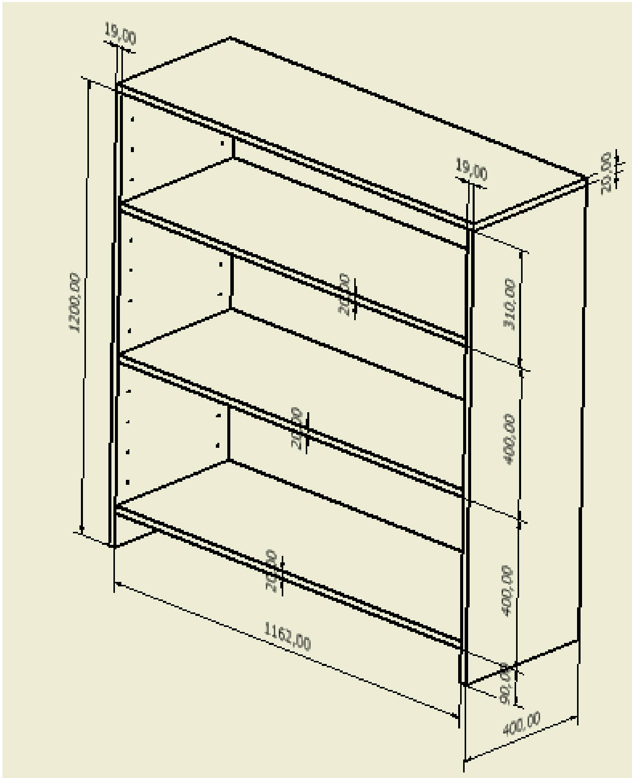

Figure1. the bookcase 3d model

Third step: Defining a load case. The applied external load is 0,001 N/mm^2 which means that for each shelve the applied load is about 465N. The load is applied on the upper surface of each shelve uniformly.

Fourth step: Meshing. In order to improve productivity and simulation accuracy we are going to use shell elements which are produced with the use of an automatic generation method of CAE program (Fig.2).

Fifth step: Defining boundary conditions. In structural analyses, boundary conditions are applied to those regions of the model where the displacements and/or rotations are known. In this model the bottom- left and light portion of the frame is constrained completely and, thus, cannot move in any direction (Fig. 3).

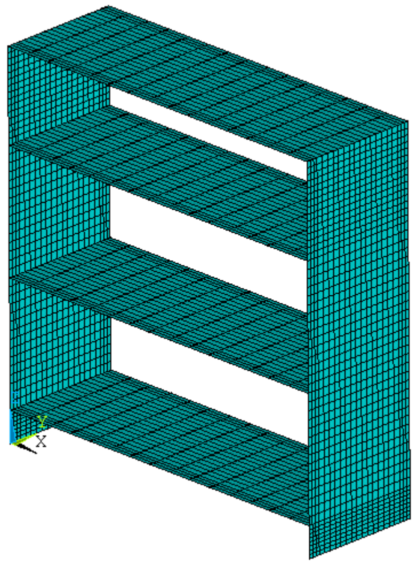

Figure 2. Meshing with shell elements

Concisely the main characteristics of the model are:

- Number of DOF's : 22440
- Number of Elements: 3486
- Type of elements: Shell elements (ANSYS Shell 63) with both bending and membrane capabilities, with six degrees of freedom at each node.
- Material properties: Linear isotropic (even if it is produced from small wood particles, it has isotropic behavior on strength properties. It is not happened the same for hygroscopical properties where it

behaves in anisotropic way.), MOE =2500 N/mm^2, Poisson's ratio ν=0,2

- Boundary conditions: Nodes of the bottom of the side panels have fixed DOF's.
- The shelves are loaded with uniform pressure 0,001 MPa. The resulting total reaction force is 1417,2 N.

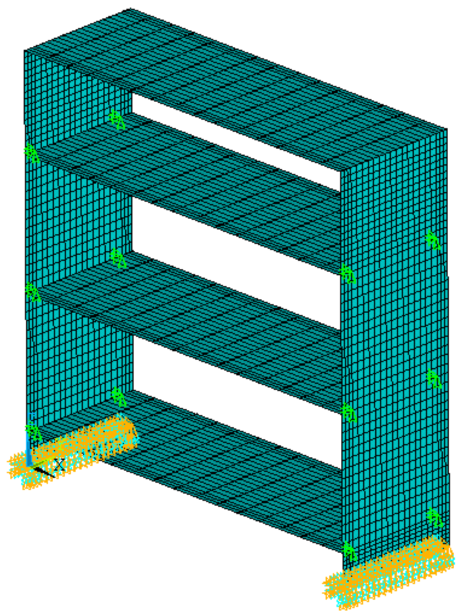

Figure 3. Boundary conditions definition

It is well known that joints determine the behavior of structures like the bookcase. Thus three different model-variations are examined in this work. Their differences are in the way the joints between the side panels and shelves are modeled. In the first variation side panels and shelves have common all nodes they are on the appropriate lines. In the second variation they have coupled all Degrees Of Freedom (DOF's) in unique nodes. These nodes are located at the positions of the self support elements (Fig. 3). In the third variation only the translational DOF's of the same nodes remain coupled.

3. Results and Discussion

The first variation is the stiffest. The maximum deflection is 3,9 mm and is obtained in the middle of the shelves. The maximum stresses arise at the joints. The second variation seems to be more representative for the case that side panels and shelves are connected with mini fix bolts (Jerzy Smardzewski, and Tomasz Papuga. 2004). Maximum stress intensity is obtained near the coupled nodes (Fig. 4, 5). The maximum deflection is 6,5 mm at the middle of the selves (Fig. 6).

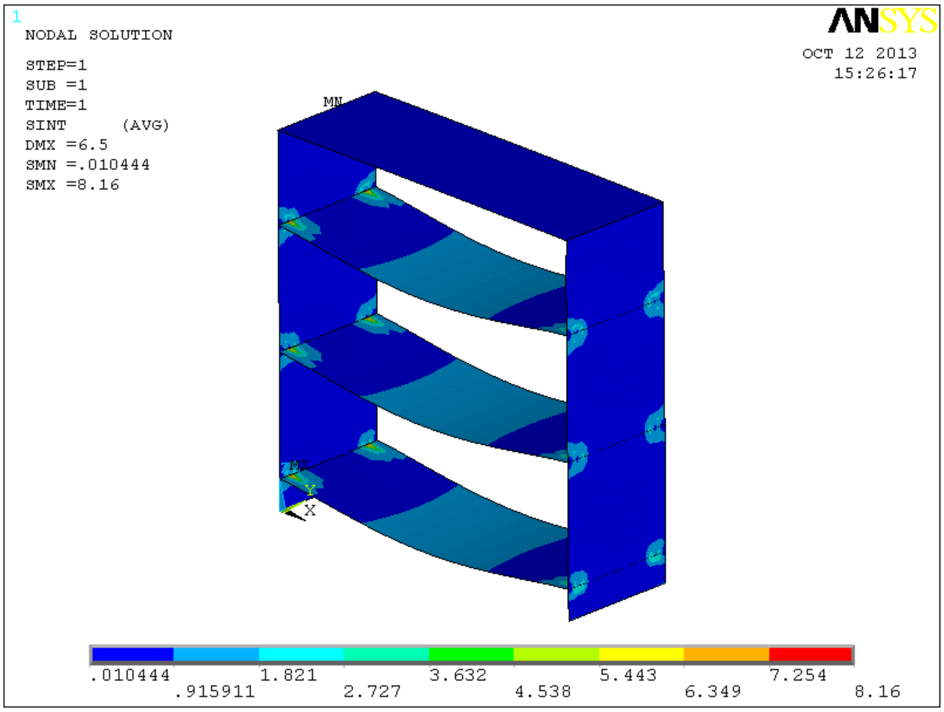

Fig.4. Stress Intensity

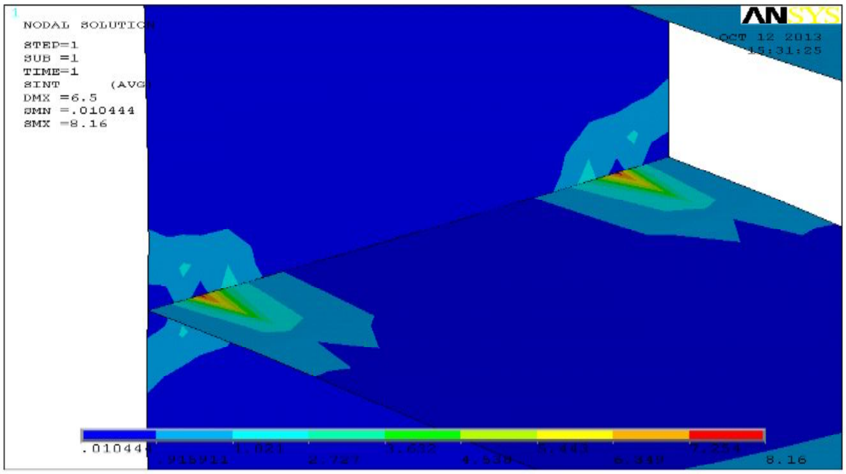

Fig.5. Stress Intensity, detail view at joint nodes

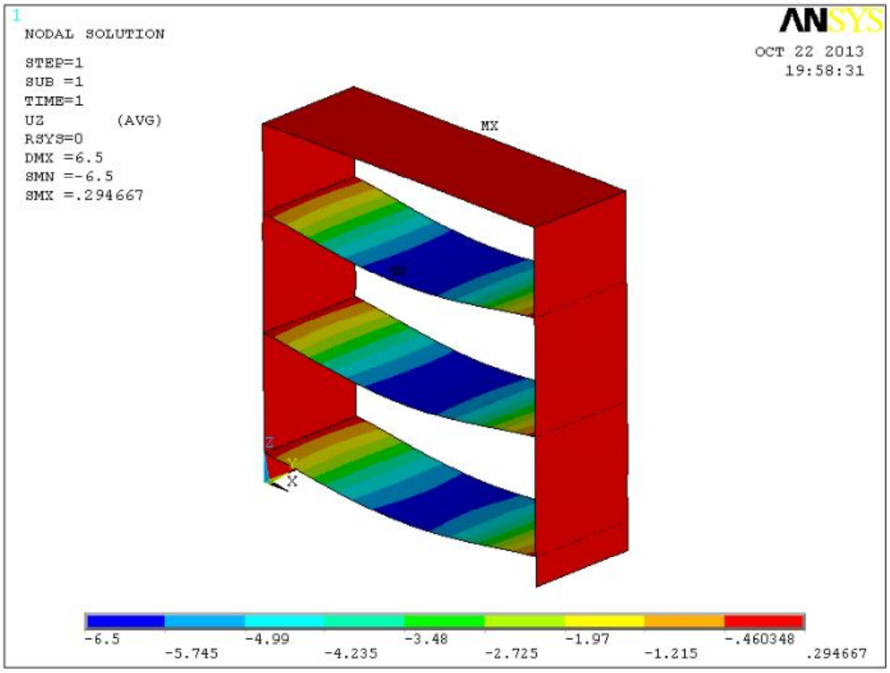

Fig.6. Deformation Z-direction (vertical) [mm]

The case that shelves are simple supported with wood cotters on the side panels is simulated with the third variation. Maximum stresses arise now at the middle of the shelves (Fig. 7, 8). The deflection is about 15 mm and is more the double that of 2nd variation.

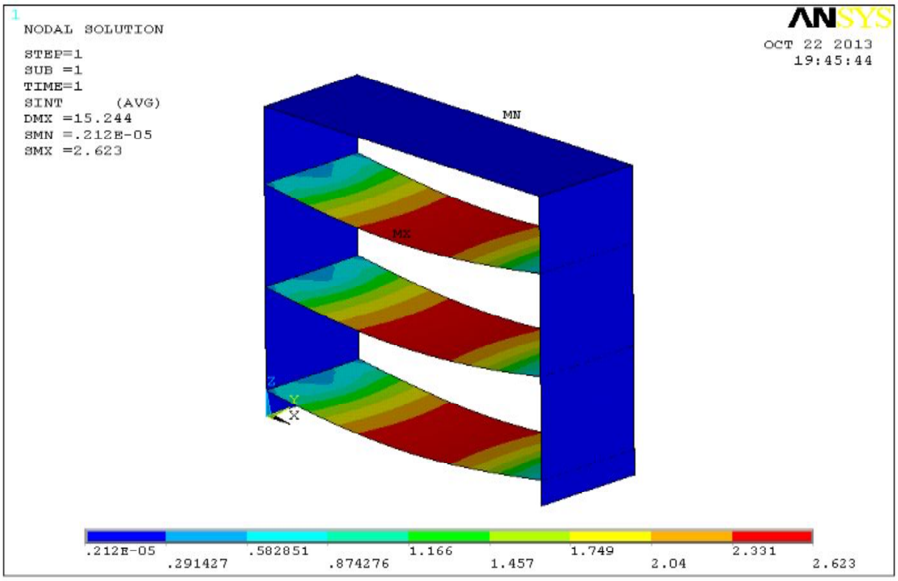

Fig.7. Stress Intensity

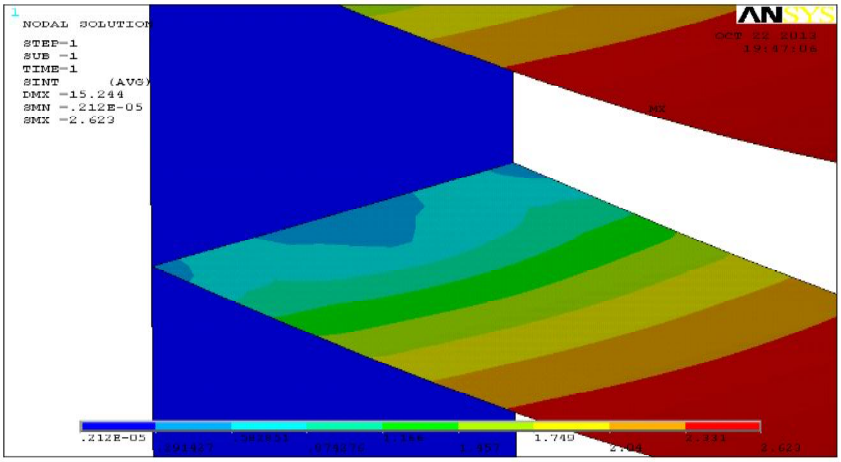

Fig.8. Stress Intensity, detail view at joint nodes

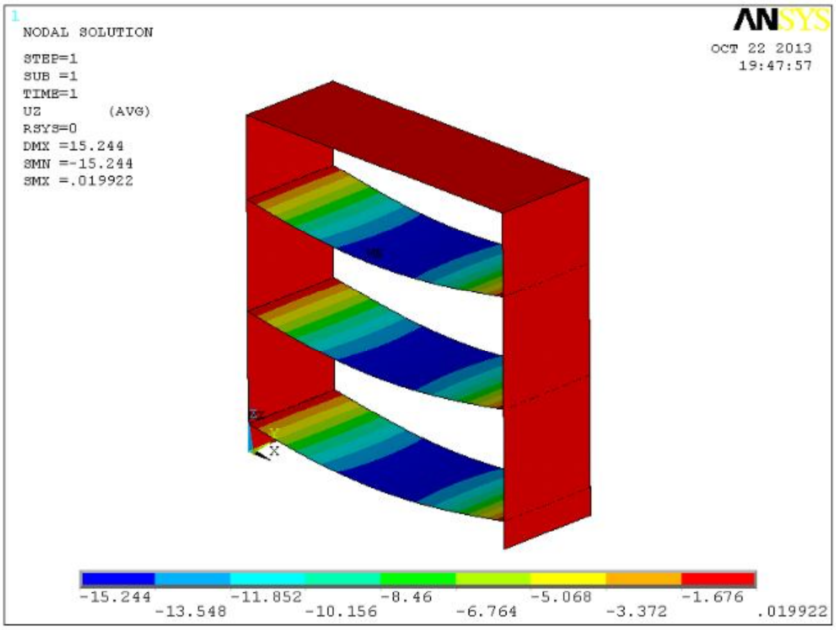

Fig.9. Deformation Z-direction (vertical) [mm]

It is obvious that modeling of the joints between side parts and shelves plays a dominate role and affect calculated stresses and deformations.

4. Acknowledgement

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