

Von Mises Stress Analysing of the Polyurethane Armchair Seat

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Von Mises Stress in a finite element analysis method is widely used by designers because it helps them to check whether their design will withstand a given load condition, in other words, if the maximum value of the Von Mises Stress induced in the material is more than the strength of the material or not. In this paper it will be presented the Von Mises Stress analysis of an armchair seat redesigned from an wooden based model, into a polyurethane more compact structure. In order to perform the testing required, a 3D design was made after the wooden model. This model was made so it will be easier to build, more compact, and with a lower weight and maybe having a more resistant structure compared to the wooden design.

Keywords: Finite element analysis (FEA), polyurethane, Von Misses Stress, Armchair

Because of the world population growing and expanding, constant developing of new trends in the matter of furniture has become a constant concern. In order to sell the products, the client's needs have to be fulfilled so in this way, the constant designing of new models of furniture have to be made in order to be competitive on the market.

In order to be competitive, a company has to have outstanding designs, cheap products, high quality products or a very low production cost.

In this paper it will be analyzed a new design for a wooden based armchair, selected from a local furniture factory.

Because the world is in constant expansion, the woods are threatened to be extinguished, so new materials are required to be researched in order to act as substitute for wood, or wood products. Substitute materials can be polyurethane (PU), plastic or other composites [8-11].

Studies regarding the polyurethane furniture foams have been made by Smardzewski [1], or Tranisan [2].

Modern technologies for upholstering were researched and presented by Dobre [3]. Other material, like polyurethane that can be used to be shaped in a mold is plastic and researches in plastic have been made by Iclăzan [4] which presented technologies for processing the plastic materials, or Seres [5] which researched the injection molding. The analysis were made using Catia V5, program which has a module called Generative Structural Analysis [6] that can be used to study the 3D structure built using FEA (finite element analysis).

Other programs, like SolidWorks, in comparison with Catia, were used by Buna [7], for modeling furniture and using the parametric design approach.

In this paper it will be presented the 3D wooden model and the modified model, made from injected polyurethane foam at a certain density and also the Von Mises Stress analysis of the polyurethane model. The paper will be finished with a comparison between the tensile strength for the armchair seat and the tensile

strength value for the polyurethane version of it, made using high density PU (300 kg/m³).

Experimental part

Designing the 3D model

In this paper it is analyzed the seat of an armchair because the part from the armchair that is most tensioned is the seat, all because it has to withstand the whole bodyweight of the person. The wooden base armchair is presented in figure 1.

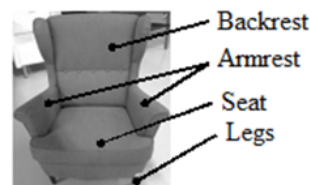


Fig.1 The wooden base armchair

To be able to analyze the resistance of the PU structure of the seat, first it had to design the seat structure based on the original 3D model of the wooden based seat, presented in figure 2.

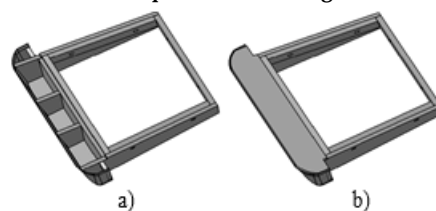


Fig.2 Wooden 3D model:
a) without the top plate, b) with top plate

The modeling of the new structure, made of PU was made using Catia V5 and the structure was designed in such way that it will have less components, less time to assemble and will be more lightweight but more resistant.

As it can be observed in the figure 2, the wooden base model is a complex structure with complex forms.

On the top of the structure will be assembled a number of springs, for giving elasticity and comfort to the armchair, and which will be assembled using plastic clips stapled to the wooden frame.

In the bottom of the seat frame are attached a pair of four wooden legs which have each a threaded rod for

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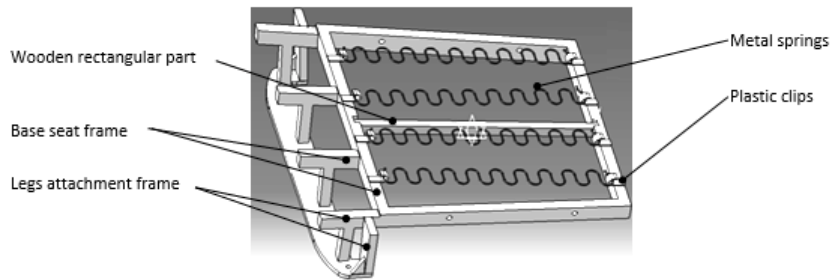


Fig.3. 3D model components

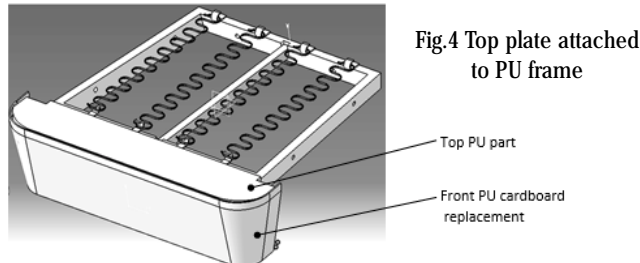


Fig.4 Top plate attached to PU frame

assembling with the armchair seat.

In order to keep the same aspect of the armchair, the wooden legs and the springs have to be attached to the seat frame in the same way.

In order to respect this requirements, the PU seat structure was designed from three parts:

- the PU base seat frame;
- the PU legs attachment frame;
- a wooden rectangular part for rigidity and strength.

As presented in figure 3, the first part done was the PU base seat frame, made in such way in order to respect the same exterior aspect of the armchair. The second part designed to be from PU is the seat attachment frame. This two components can be fixed together using staples or PU glue, specially designed for this types of materials.

In the slot designed in the PU seat frame will be inserted a wooden rectangular part and which can be fixed using wood screws.

As it can be observed in the figure 2, the wooden frame has in front a rounded edged plate made of special cardboard which can be shaped around the wooden frame and give it's desired aspect and the second part that it's missing from the design from figure 3 is the top plate which is also made of wood.

For making the PU frame, it is necessary to have a mold in which the PU will be injected.

Because the cost of the mold is high, and in order to be able to be executed as required, the frame was made from two parts from PU and the third from wood because it's cheap and making a mold for that part is too expensive. The same thing can be explained with the two parts not present in the figure 3 (special cardboard and the top plate).

The next step in building the PU model is attaching the plastic clips. This plastic clips can be attached to the PU frame using staples or wood screws.

In the next part of assembly will be attached the metal springs which will support directly the weight of the occupant of the armchair and which are necessary to be introduced in the designed when testing it. The plastic clips and the metal springs are also presented in figure 3.

The front special cardboard part and the top plate can be made also from PU but because they are parts not very tensed, having basically only aspect purpose, can be made from low density foam (40 kg/m^3). The only problem is with the shape of the front cardboard because the mold will have to be made in a complex design, for keeping the

same aspect, as presented in figure 2.

In order for the seat frame to be complete, the top plate made from PU, like the cardboard replacement part, was attached to the PU frame and this two components are presented in figure 4.

Because the last two parts attached, presented in figure 4, have no resistance purpose, the von mises stress analysis was made only for the rest of the seat frame, observing much better the behavior of the PU structure in this case.

Von Mises Stress analyzing for the PU seat

In order to be able to testify that the PU seat frame is approximately the same like the wooden seat frame structure, or better, the PU frame had to be checked if its resistance is correspondent to its needs.

In order to test the PU frame that was designed, it had to be produced and in order to be produced, it would require for every PU part a mold in which the part might take shape. Because the mold making process is expensive, the more simple and more rapid way to test the PU frame is to use the Generative Structural Analysis module from Catia V5 and do a Von Mises Stress analyzing.

Because the front PU cardboard replacement part and the top PU plate are parts that give little resistance to the structure, the structure that was subjected to testing is the one presented in figure 3.

The steps for analyzing the PU frame in order to determine its resistance are:

- introducing the 3D model into the program;
- creating the material desired for using in the part;
- applying the fixing constraints;
- applying the force on the metal springs;
- running the test and obtaining the results.

For creating the desired *material for the PU* structure, the next values were input:

- density 300 kg/m^3 ;
- Young module: $2.13 \cdot 10^6 \text{ N/m}^2$;
- Poisson Coefficient: $0.3 \cdot 10^6 \text{ N/m}^2$;
- tensile strength: $8 \cdot 10^6 \text{ N/m}^2$;
- thermal conductivity: $0.06 \text{ W/m} \cdot \text{K}$.

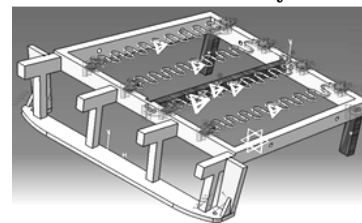


Fig.5 Setting the physical constraints and fix planes

For creating the desired *material for metal springs* because it has to be known when doing the analyzing, the next values were input:

- density: 7.860 kg/m^3 ;
- Young module: $2 \cdot 10^{11} \text{ N/m}^2$;
- Poisson Coefficient: 0.266 N/m^2 ;
- tensile strength: $1.95 \cdot 10^9 \text{ N/m}^2$;
- thermal conductivity: $1.17 \text{ W/m} \cdot \text{K}$.

The next step, as previously explained, on the 3D model will be to set the constraints, were the PU structure in real conditions would be fix, as presented in figure 5.

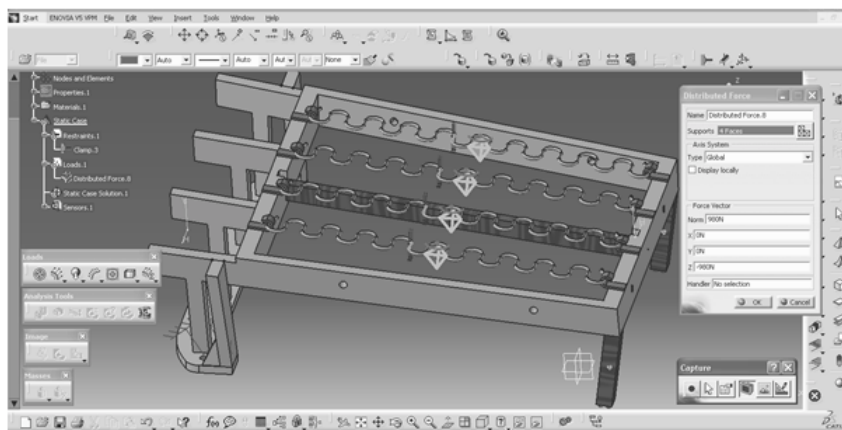


Fig.6 Applying the forces

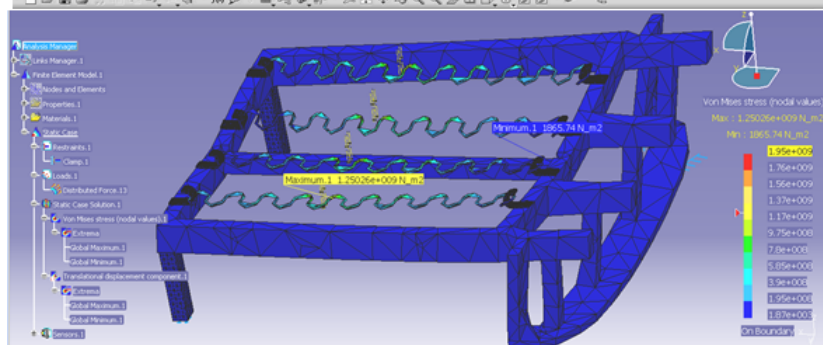


Fig.7 Von Mises Stress analyzing of the PU seat

After setting up the constraints, the next step is applying the forces on the metal springs (body weight), as presented in figure 6.

A structure is considered to be solid if the material used for modeling the frame withstands the maximum effort conditions. The condition that has to be fulfilled is to withstand a weight of 100 kg, the weight equivalent of a person, so the force applied, as one can observe in figure 6 is 980N. This force is evenly distributed on the four metal springs which are hold by the plastic clips, and fit to the PU frame.

After setting this steps, the Von Mises Stress analyzing was done and the results is presented in figure 7.

Results and discussions

As it can be observed, in figure 7, the values obtained after the analyzing process had been completed, were around minimum for PU (blue) and medium for the metal springs (yellow).

Both values obtained were under the maximum allowed value for both PU and for the metal springs.

If we divide, for the PU, the maximum allowed value (Mv_{PU}) to the experimentally obtained value (ov_{PU}), we obtained how many times smaller is the obtained value compared to the maximum allowed value, as presented:

$$\frac{Mv_{PU}}{ov_{PU}} = \frac{8 \cdot 10^6 [N/m^2]}{1,87 \cdot 10^3 [N/m^2]} = \sim 4278 \quad (1)$$

The results for the analyzing can be observed in the figure 7 and the values are presented next:

- the Von Mises Stress value obtained for the springs is 1.25×10^9 N/m². The maximum allowed value for the metal springs is 1.95×10^9 N/m²;
- the Von Mises Stress value obtained for the PU frame is 1.87×10^3 N/m². The maximum allowed value for the PU is 8×10^6 N/m²;

Conclusions

- both values obtained are under the maximum allowed value for either metal springs or PU structure;
- the PU structure can successfully replace the wooden structure;

- the PU material at 300 kg/m³ density is resistant than the wood in this case;
- the value obtained for the Von Mises Stress for the PU designed structure, as presented in equation (1), is around 4278 times lower than the maximum allowed value.

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