FEA Deformations Analysing of the Polyurethane Armchair Seat

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In this paper it will be presented the deformations analysis using the finite element analysing method, for an armchair seat redesigned from an wooden original model, into a polyurethane more compact structure. In order to perform the testing required, a 3D PU design was made after the wooden model. This new design was made in such way which will enhance the productivity, to be more compact, more lightweight and also more resistant than the original design.

Keywords: armchair seat frame, deformations, FEA, polyurethane (PU 300 kg/m^3)

A very important problem in the furniture industry is the lack of wood, the high cost of it and the growing consumption of wooden base products, like furniture. So, in this way, appeared the need for other alternative materials, like polyurethane, for making furniture parts.

Regarding the alternative materials for making furniture, substitute materials for wood can be polyurethane (PU), plastic or other composites [5-8].

Polyurethane furniture foams have been studied by authors like Smardzewski [1] and also Tranisan [2]. The current paper is a continuation of a former research of the authors which presented the Von Mises Stress analysing based on the same wooden armchair, selected from a local furniture company, product which was modified on a PU structure [3].

The software used for analysing is Catia V5, in the module called Generative Structural Analysis [4] which can be used to study, the new 3D structure, using FEA.

Those researches showed that the PU seat frame is more resistant than the wooden base frame. In this case, the necessity of continuation of the researches appeared because it is also necessary to have results regarding the deformations of the seat frame. Also, it has to specify that, in wooden structures, the only deformation that counts is the elastic deformation. The elasticity is the property of the material to deform under the action of external forces and to come back to it's initial form after the force that produced the deformation stopped it's action. The maximum allowed elastic deformation for wooden structures, stated by the furniture companies, is 29.5 mm.

In this paper it will be presented the deformations analysis using the finite element analysing method, for an armchair seat redesigned from a wooden based original model, into a polyurethane (PU) more compact structure and the steps are similar to the previous paper [3].

The paper presents the 3D of the original wooden model and also the PU modified model, made from injected polyurethane foam at a certain density and also the deformation analysis of the polyurethane model. The paper will be finished with a comparison between the deformation admissible value for the original wooden base armchair seat and the value of deformations for the polyurethane version of it, using high density polyurethane (300 kg/m^3).

Experimental part

The wooden base original armchair

The original wooden armchair is presented in figure 1. The paper will focus with analysing of the seat of the armchair because is the most tensioned part and it supports the weight of a person of 100 kg.

In order to analyse the deformation of the PU structure of the seat using FEA, first was redesigned the original seat frame, as presented in figure 2.

Designing the PU 3D model seat

The original model, as seen in figure 2, is a complex structure with complex forms and shapes. On the seat are assembled a number of springs, on the top part, for giving elasticity and comfort and which are fixed using plastic clips stapled to the wooden frame. The bottom of the seat frame has four wooden legs

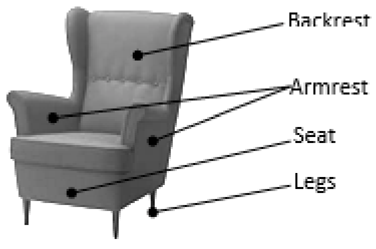

Fig.1. The original armchair

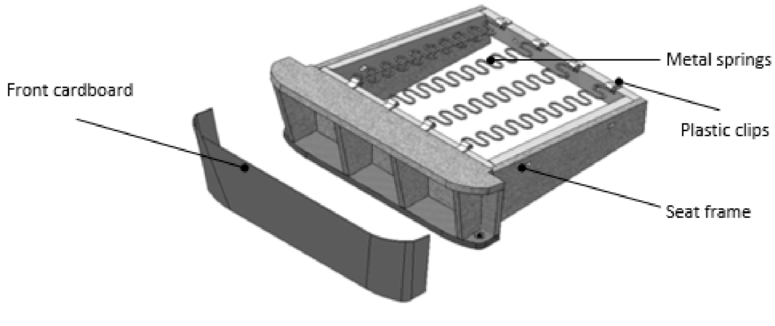

Fig.2. Seat frame 3D model of the original armchair

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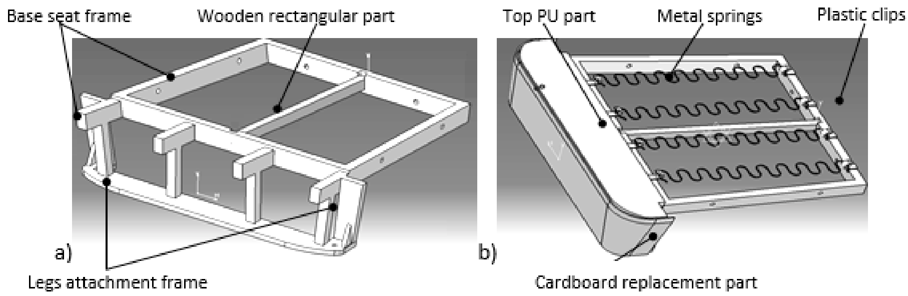

Fig.3. PU designed 3D model seat frame components: a) PU frame; b) complete frame

attached, which are assembled with the seat using a threaded rod, as seen in figure 1.

The new PU structure was designed using Catia V5 in such way in order to have less components, which means less time to assemble and will be more lightweight but also more resistant.

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

To have these requirements, the new PU designed structure will be done from three parts [3]:

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

The PU components are assembled together using staples or PU glue and the wooden rectangular part is fixed using wood screws.

As one can see, in the figure 2, the original seat frame has in front a rounded edged plate made of special cardboard which can be shaped around the frame and give the desired aspect.

For manufacturing the PU seat frame, it is necessary to have a mold for injecting the PU and because the cost of the mold is high and keep the requirements, the frame was made from two parts of PU and the third from wood because it's cheap.

The last step in building the PU model is attaching the plastic clips using staples or wood screws and inside the plastic clips will be inserted 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. Both parts mentioned are presented attached in figure 3b.

The front special cardboard part and the top plate, as seen in figure 2, can be made keeping the same material or from low density foam (40 kg/m^3), as seen in fig. 3b), because they are parts not very tensed.

Because these two parts have no resistance purpose, the FEA deformations analysis will be made without them, observing much better the behavior of the PU structure in this case.

FEA deformations analysing for the PU seat

In order to check if the new designed model has the same characteristics as the original wooden version, or better, the most important aspect that had to be checked is, if it's deformations are less than the maximum admissible value, both for the springs and the PU structure.

The most expensive part in making the frame of the PU version is the mold. A mold is very expensive and in order to make the prototype for this design, every component

Fig.4. Tensile test testing samples.

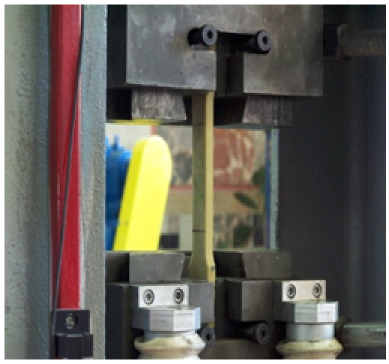

Fig.5. Testing the samples on the tensile testing machine

would have had to be produced. After making the mold and the components, the result could have been a fail and, that would mean money loss and, after that, modifications and everything had to be repeated. That takes money, work and time. The simple way is to make a virtual testing using Catia V5 Generative Structural Analysis Module.

The steps for analysing the PU frame for determining it's deformations are similar to the ones used in stress analysing [3]:

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

The PU is obtained from mixing isocyanate with polyol, in different proportions, components that react together creating the PU foam that takes shape when put in a specific mold.

The different proportions of the mixture of those two ingredients create the 300 kg/m^3 density desired for the resulted foam.

Being a new material means that some of the properties are unknown and that leads to the need of making more tests.

In this analysing, the most important feature when creating the 3D material, for the structure analysing is the tensile strength.

In order to be more accurate, three testing samples with rectangular section 20x5mm were made, as presented in figure 4. The samples were subjected to a tensile test, as presented in figure 5.

After testing, a series of values were obtained and are presented in table 1.

For creating the desired *material for the PU* structure, in the program, a series of values were input:

- density 300 kg/m^3;
- Young module $2.13 \cdot 10^6$ N/m^2;

Sample no.	Section area [mm^2]	Breaking force [kN]	Tensile strength [N/mm^2]
1	200	1.58	7.9
2		1.62	8.1
3		1.61	8.05
		Average	**8.01**

Table 1
TENSILE STRENGTH TEST RESULTS

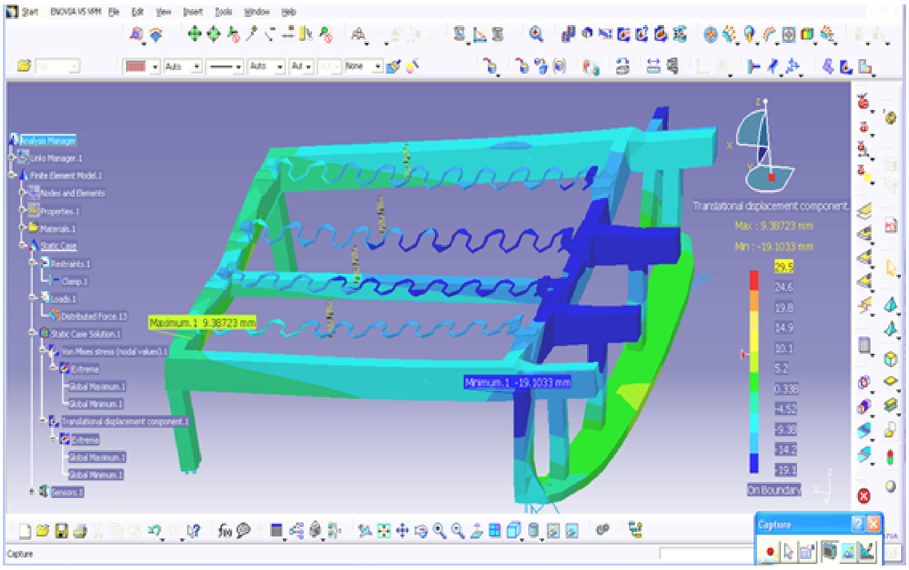

Fig.6. FEA deformations analysing of the PU seat frame

- Poisson coeficient $0.3 \cdot 10^6$ N/m^2;
- tensile strength $8 \cdot 10^6$ N/m^2;
- thermal conductivity 0.06 W/m·K.

For creating the desired *material for metal springs* because, it has to be known when doing the analysing, the values that were input are this:

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

Applying the constraints

In the program, the constraints for the 3D model where the PU structure in real conditions would be fixed and also the forces would be applied on the springs, are set up in the same way as in the previous researches.

The structure is considered to be solid if:

- it withstands the weight of 100 kg (980N, the weight equivalent of a person);
- it doesn't deform more than 29.5 mm.

The force is evenly distributed on the four metal springs which are secured by the plastic clips and fixed to the PU structure.

Results and discussions

Determining the deformations of the PU seat

After setting these steps, the FEA deformations analysing was made and the results are presented in figure 6.

As it can be observed, in figure 6, the deformations can be seen on the 4 springs and also on both of the edges where the metal springs were attached. The maximum value that was recorded can be found on the back part of the PU frame, on the area where the backrest will be assembled with the seat frame and the value is 9.38 mm, which is way smaller than the maximum allowed absolute value which is 29.5 mm, for the PU structure and wood, no matter the direction and the sense of deformation. This value was obtained, by the local furniture factory that produced the wooden original armchair, through their own testing and the same requirements had to be fulfilled also for the PU version. This value is the maximum value on which the material returns to it's initial form. The minimum value registered by the PU seat frame is -19.5 mm, which it's negative but it's still deformation that doesn't exceed the maximum admissible absolute value.

The results of the FEA analysing can be observed in the figure 6 and the values are presented next:

- the maximum deformation value obtained for the PU structure is 9.38 mm. The maximum admissible absolute value for the structure is 29.5 mm;
- the minimum deformation value obtained for the PU seat frame structure is negative and the value is -19.5 mm. The maximum allowed value is the same as in the first case.

Conclusions

This paper has a series of conclusions:

-both of the values obtained, no matter the direction and the sense of deformation are under the maximum allowed absolute value;

-the PU structure can successfully replace the wooden structure because it respects the conditions for the deformations to be under the admissible value of 29.5 mm for the entire structure;

- the PU material at 300 kg/m^3 density it deforms less than the maximum admissible value.

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