TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 61, Issue IV, November, 2018

DECREASING THE MASS OF A SOFA SIDE MADE OF COMPOSITE MATERIALS BASED ON VEGETABLE FIBERS

Emanuela POP, Mihai STEOPAN, Cornel CIUPAN, Ioan FILIP

Abstract: *The paper presents numerical research on decreasing the consumption of the necessary material for the thermoforming of a couch side, while maintaining the rigidity parameters imposed by the standards. The authors redesigned the reinforcement structure of a sofa side, currently made of wood to be made of composite material based on vegetable fibers and polypropylene. To optimize material consumption, the authors studied the states of stress, deformation and safety factor for two different ribbing models: a) with "+" ribs arranged vertically and horizontally; b) with "X" ribs disposed at an angle of 45 degrees to the vertical. For all the analyzed cases, the thickness of the external wall was varied and the parameters of the rib were kept constant. In conclusion, there is a variation in wall stiffness relative to the type of rib and rib step, thus considering a given displacement a weight reduction of the sofa side can be achieved.*
Key words: *composite material, thermoforming, finite element analyses.*

1. INTRODUCTION

The use of composite materials has increased considerably in recent years and has expanded in many areas. The composite materials consist of a matrix material, thermoplastic or thermosetting, epoxy, polypropylene, polyester, urethane etc. and a reinforcement material. The most widely used composite materials are composite materials reinforced with synthetic fibers such as glass, carbon, aramid due to the high stiffness and hight strength to weight ratio compared to common materials such as wood, glass, steel etc. In addition to these advantages, synthetic fiber composite materials also have a number of disadvantages such as weight, cost and environmental impact. To reduce these disadvantages have been developed composites materials based on natural fibers, by combining synthetic natural resins with a mixture of vegetable fibers [1]. The advantages of using natural fibers are that they are reneawable, cost effective, low density, low weight, high specific strength and stiffness to weight ratio, good thermal and acoustic insulating properties, fully or partially recyclable and biodegradable providing competitive mechanical properties, which makes them an attractive alternative for the manufacture of composites [1,7]. The most used natural fibers are flax, hemp, cotton, jute, sisal, kenaf, banana, pineapple.

2. STATE OF THE ART

The use of natural fibers as reinforcements for composites becomes very attractive and is used in various sectors such as automotive, building components, furniture, packaging etc. [3,11,12,13]. Given the attractiveness of these materials, consideration should be given to improving the mechanical properties of the material. Paper [14] studies various methods that can be used to increase the properties of randomly oriented fiber reinforced composite materials.

A method of reinforcing the composite material is by surface treatment for the hemp and weaved fabric to improve the mechanical properties of the composite, although a poor treatment or severe will degradate them. Also, the use of hemp textiles obtained through twisted fibers in unidirectional and 0/90o architecture leads to an increase in properties [2].

The paper [1] analyzes by the FEA method that the variation of the volume of fiber and fiber reinforced Polypropylene and Kenaf Fiber Reinforced Epoxy Composites influences the tensile properties of the material under tensile load.

Also in the paper [4] it is studied how the fiber volume fraction increases the mechanical and elastic properties of the composite. The results were obtained using a method of structural analysis, FEA, the most important data obtained are stresses, deformations, displacements, oscillations, etc. The analysis is made on specimens, manufactured according to ASTM standards, made of different proportions of natural fibers with matrix material, thermoplastic or thermosetting of composite material. The analysis includes both mechanical testing on test machines and numerical simulations.

In the paper [15] is analyzed hemp fibers and how they influence the mechanical properties of the material due to non constant cross section and complex geometry, using micro-traction test, numerical imaging treatment and FEA to determine the traction load vs displacement until the fiber is broken.

The difference between thermoplastic and thermosets is that thermoplastic reduces the processing times, favorable recycling capabilities, increased storage times [5,6]. In the papers is demonstrated by both experimental and by Finite Elements Analysis which are the values of the parameters involved in the composite material, as well as the productivity of the thermoforming process and were determined the optimal parameters for the consolidation of this type of composite showing the possibility of reducing the experimentally determined time of 10 minutes at about 3 minutes.

Navaranjan and Neitzert [7] study the impact resistance of Natural Fiber Composites (NFC) and impact testing methods. The impact strength of NFC is low compared to synthetic fiber composites [8] and is influenced by strength, elastic modulus, fiber length and orientation, fiber length and orientation. The impact test methods are based on low impact or high speed impact.

The most important aspects when designing parts of composite materials are that the properties of the material should be sufficient to meet the companies standards, but at the same time the ability to achieve at a lower cost. In order to reduce the cost, it is necessary to reduce the consumption of material, implicitly the weight of the designed part with the maintenance of the properties.

3. FURNITURE PARTS MADE OF HEMP REINFORCED COMPOSITE MATERIAL

Taparo SA is a romanian company, from Maramures County, which manufactures upholstered furniture. To cope with a highly competitive market, Taparo has developed a composite material reinforced with hemp fiber, for which they also owns a patent. The company makes parts of the resistance structure of upholstered furniture of the patented composite material.

The purpose of the work is to optimize the resistance structure of a sofa side made of composite material based on vegetable fibers.

In the papers [16,17] the authors studied the influence of the different types of ribbing the structures on the mechanical properties in relation to the reduction of the mass. The results have shown that the mass of the product can be reduced by rigidizing the product with ribs, starting from a 2 mm thick of the product wall.

The chosen sofa side is shown in Figure 1. To reach the resistance structure the comfort material is removed.

Fig. 1. Sofa side with comfort material

This paper is using finite element analysis to simulation of two ribbing models for the couch side, one with cross ribs, one with ribs in X (Figure 2, 3).

The purpose of the study is to highlight the influence of the ribs on the mechanical properties of the sofa's side and the possibility of reducing the mass by reducing the thickness of the wall.

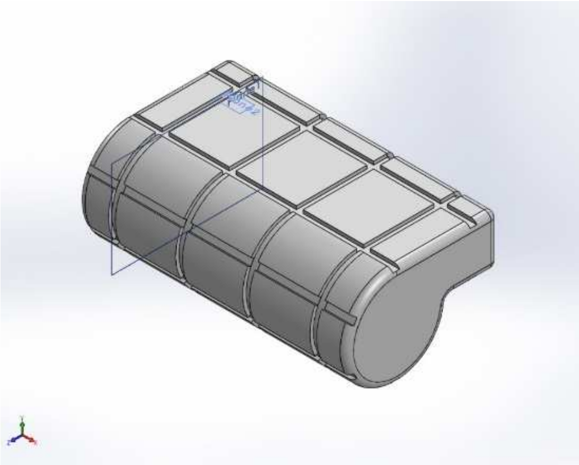

Fig. 2. Sofa side with "+" ribbed model

Redesigned sofa side of composite material is in the form of a box made of two semi-sides, assembled by stapling on the contour.

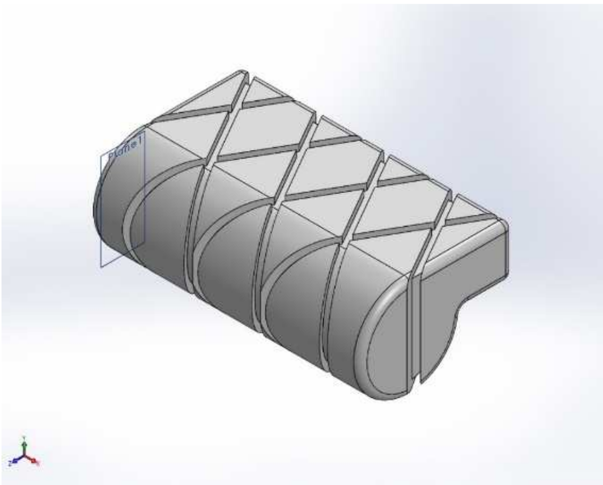

Fig. 3. Sofa side with "X" ribbed model

4. FINITE ELEMENT ANALYSES OF SOFA SIDE MODELS

By finite element analysis (FEA), the variation of the deformation of a sofa side made by thermoforming of composite material was followed in order to reduce the quantity of composite material. FEA analysis was done using the SolidWorks application for two types models: "+" ribs and in "X" ribs. The fixing conditions were determined from the assembly condition and the requirements were chosen according to the testing standards of the sofas SR EN 1728. The 3D models were meshed with a 2 mm grid. Fixed surfaces were set on the floor contact area.

The parameters considered in the simulation are:

- thickness of the wall variation : from 2 mm to 6 mm, considering a 1 mm increase increment resulting in a total of 5 tests per model.
- statically applied horizontal load of 350 N;
- statically applied vertical load of 750 N

The characteristics of the material used in the simulation are:

- Breaking strength: 32 MPa
- modulus of elasticity : 1500 MPa
- Poison's ratio : 0.39

In the figure 4 we can see the maximum displacement for model with "+" ribs, considering a wall thickness at about 2 mm, at a mass of 2.46052 kg and in figure 5 for the model with "+" ribs, considering a wall thickness, just over 6 mm. For this case the values for diplacement are 3,99 mm respectively 5.03 mm.

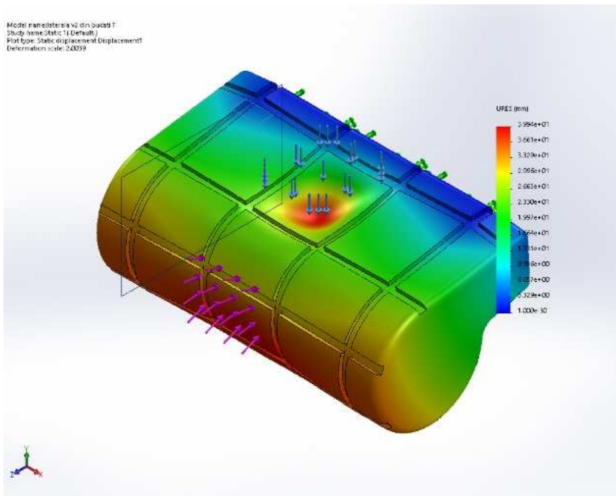

Fig.4. Displacement for "+" ribbed model

The variation of the deformation in mm in relation to the mass of the product is shown in Table 1. For each graph we determined the 2nd order polynomial regression functions with respect to the weight of the product.

The determined R^2 parameter was between 0.98 and 0.99.

Figure 6 and 7 shows the results of the analysis, considering deformation on the vertical axis, in mm, and on the horizontal axis the weight in kg.

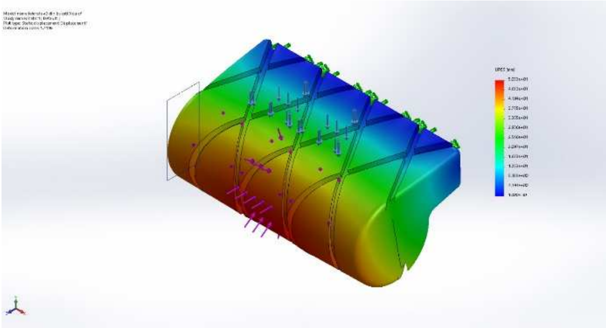

Fig.5. Displacement for "X" ribbed model

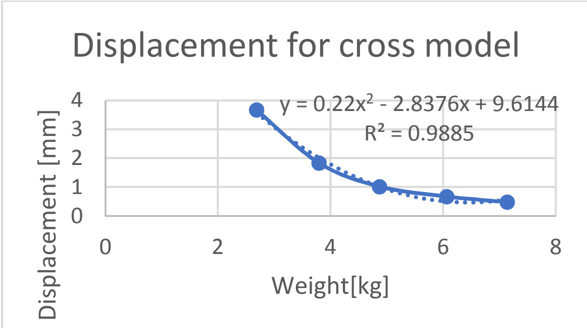

Fig.6. Displacement for "+" ribbed model

Table 1

Regression functions for each of the studied models

Model	**y(x) – 2nd degree polynomial regression function**	**Wall thickness [mm]**	**Weight [kg]**	**Displacement [mm]**
"+" ribbed model	$y = 0.22x^2 - 2.8376x + 9.6144$	2 mm	2.684959	3.670632
		3 mm	3.795448	1.835316
		4 mm	4.872445	1.01962
		5 mm	6.06108	0.6716
		6 mm	7.138078	0.48104
"X" ribbed model	$y = 0.1143x^2 - 1.9523x + 8.7906$	2 mm	3.153352	3.88292
		3 mm	4.704603	1.89643
		4 mm	6.238483	1.09978
		5 mm	7.754854	0.71146
		6 mm	9.297419	0.41989

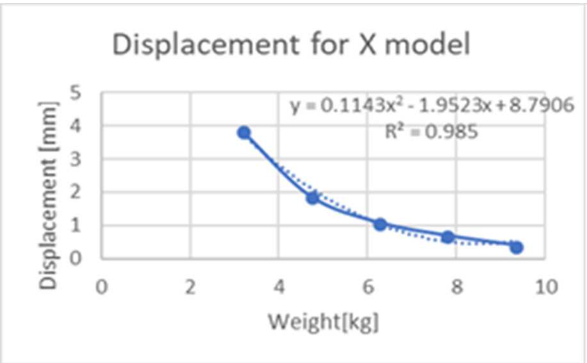

Fig.7. Displacement for "X" ribbed model

5. CONCLUSIONS

The analysis of the results obtained by th the numerical simulations shows the following:

- The rigidity of the two models is slightly influenced by the type of the ribs, the deformations of the two models being approximately equal for the same thickness of the walls.
- For wall thicknesses below 5 mm, the "+" ribbed model offers better rigidity than the "X" ribbed model, and for thicknesses over 5mm, the ribbed "X" is stiffer (Figure 6, 7).

  This is explained by the fact that in the "+" ribbed model the vertical force (750N) is applied along the vertical ribs on the side walls and the lateral force (350 N) is partially distributed along the same ribs which continue on the rounded top surface of the model. The "X" ribbed model offers lower stiffness at low thickness due to the tendency to deform the parallelogram formed between the ribs, which gives the model greater elasticity.
- With the increase in wall thickness, the stiffness of the "X" ribbed model becomes superior to the "+" ribbed model due to increased total stiffness and reduced elastic deformation of parallelograms between the ribs.

Considering the different degree of complexity of the two models and the fact that for the thickness of the 5 mm wall, both models are according to the load standards, the "+"

ribbed model is preferred, because the model is easier to achieve.

6. ACKNOWLEDGMENTS

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS/CCCDI – UEFISCDI, project number PN-III-P2-2.1-PTE-2016-0179, within PNCDI III.

7. REFERENCES

[1] A. Dyson Bruno, M.Baskaran, *Analysing the Mechanical Properties of Natural Fiber Reinforced Polymer Composites Using FEA*, International Journal of Engineering Sciences & Research Technology, 3(1), ISSN: 2277-9655, pp 269-282, http: // www.ijesrt.com, (2014).

[2] G. Cicală, G. Cristaldi, and G. Recca, *Hemp reinforced composites: surface treatment, manufacturing method and fabric type effects, Vth International Conference on Times of Polymers and Composites*, AIP Conference Proceedings 1255, 147 (2010);

[3] Magurno A. *Vegetable fibres in automotive interior components.* Die Angew Makromol Chem 1999; 272:99–107.

[4] Lohitesh Jaga Kumar, Praveen D.N., R. Thara, Irfan G., *Experimental & Finite element analysis of sisal fibre reinforced composites*, International Journal of Recent trends in Engineering & Research, Volume 2, Issue 07, pp. 155-160, ISSN 2455-1457, (July 2016).

[5] Kim, S.H.; Park, C.H. *Direct impregnation of thermoplastic melt into flax textile reinforcement for semi-structural composite parts.* Ind. Crops Prod., 95, 651–663, (2017).

[6] Sarah Vogt, Behnaz Baghaei, Nawar Kadi and Mikael Skrifvars, *Determination of Processing Parameters for Thermoplastic Biocomposites Based on Hybrid Yarns Using Finite Elements Simulation*, Journal of composites science, Sci. 2, 11, ISSN 2504-477X, (2018).

[7] Namasivayam Navaranjan and Thomas Neitzert, *Impact Strength of Natural Fibre Composites Measured by Different Test Methods: A Review*, 2nd International Conference on Materials Science and Nanotechnology (ICMSNT 2017), MATEC Web of Conferences 109, 01003 (2017).

[8] K.L. Pickering, M.G. Aruan Efendy, T.M. Le. *A review of recent developments in natural fibre composites.* Composites: Part A 83, pp 98–112, (2016).

[9] N S Venkatesha Gupta1, Akash 1 a, K V Sreenivasa Rao1, and Arun kumar D S1, *Fabrication and evaluation of mechanical properties of alkaline treated sisal/hemp fiber reinforced hybrid composite*, IOP Conf. Series: Materials Science and Engineering 149 (2016).

[10] F. Erchiqui,1 A.S. Fotso Talla,1 H. Kaddami , *A Numerical Investigation of the Use of Novel Melt Processed PET-Hemp Fiber Composites for Thermoforming Applications*, POLYMER ENGINEERING AND SCIENCE (2016).

[11] De Bruijn J.C.M. *Natural fibre mat thermoplastic products from a processor's point of view*. Appl Compos Mater;7: 415–420, (2000).

[12] Soury E., Behravesh A.H., Rouhani Esfahani E., Zolfaghari A. *Design, optimization and manufacturing of wood-plastic composite pallet*. Material and Design, 30:4183-4191, (2009).

[13] Singh B., Manorama Gupta, Anchal Verma*, Mechanical behaviour of particulate hybrid composite laminates as potential building materials*, Construction and Building Materials, vol.9, No.1, pp.39-44, (1995).

[14] Andersons J., Sparnins E., Joffe R., *Stiffness and Stregth of Flax Fiber/Polymer Matrix Composites*, Polymer Composites, vol.27, issue 2, 221-229, (2006).

[15] Abel CHEROUAT, Guillaume MONTAY and Florent ILCZYSZYN, *Numerical simulation of composite hemp fibers behavior for aircraft Application*, Advanced Materials Research Vol 1099 , pp 25-31,(2015) .

[16] Steopan M., Ciupan C., Campean E., Pop E., Filip I., Stelea L., *Optimizing a sofa side made of composite materials based on vegetable fibre*, Proceedings of the XXIth International Scientific Conference "INVENTICA 2017", Iasi, June 29-30, pp. 95-103, (2017).
[17] Cornel CIUPAN, Mihai STEOPAN, Emanuela POP, Emilia CAMPEAN, Ioan FILIP, Emilia CIUPAN, *Comparative analysis of different ribs used to rigidize the resistance structure of a sofa side made of composite materials based on vegetable fibers*, Acta Technica Napocensis, series: Applied Mathematics and Mechanics, Vol. 61, Issue I, , Cluj-Napoca, Romania, Editura U.T. Press, ISSN 1221-5872, http://www.atna-mam.utcluj.ro/, (2018).

SCADEREA MASEI UNEI CANAPELE DIN MATERIAL COMPOSIT, BAZATA PE UTILIZAREA DE MATERIALE DIN FIBRE VEGETALE

Rezumat: Lucrarea prezintă cercetări numerice privind reducerea consumului de material necesar pentru termoformarea unei canapele, menținând în același timp parametrii de rigiditate impuși de standarde. Autorii au reproiectat structura de armare a unei canapele, realizată în prezent din lemn pentru a fi realizată din material compozit pe bază de fibre vegetale și polipropilenă. Pentru a optimiza consumul de materiale, autorii au studiat stresul, deformarea și factorul de siguranță pentru două modele diferite de nervuri: a) cu nervuri "+" aranjate vertical și orizontal; b) cu nervuri "X" dispuse la un unghi de 45 de grade față de verticală. Pentru toate cazurile analizate, grosimea peretelui exterior a fost variată și parametrii nervurii au fost menținute constante. În concluzie, există o variație a rigidității peretelui în raport cu tipul de nervură și treaptă de nervură, luând în considerare o deplasare dată, se poate obține o reducere a greutății canapelei.

Emanuela, POP, Lecturer Eng., PhD, Technical University of Cluj-Napoca – Department of Design Engineering and Robotics, emanuela.pop@muri.utcluj.ro.
Mihai STEOPAN, Lecturer Eng., PhD, Technical University of Cluj-Napoca – Department of Design Engineering and Robotics, mihai.steopan@muri.utcluj.ro.
Cornel CIUPAN, Professor, PhD, Technical University of Cluj-Napoca – Department of Design Engineering and Robotics, cornel.ciupan@muri.utcluj.ro.
Ioan FILIP, Taparo SA, ioan.filip@taparo.ro