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THE CARDBOARD ROLLS CHAIR – AN EXAMPLE OF EXTENDING A PRODUCT USEFUL LIFE

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Abstract: *The paper proposes to demonstrate that reusing is the optimal solution for the end-of-life stage of a product. As an example, the cardboard roll has been chosen. This is a useful supporting product that becomes relatively quickly a waste and is in good condition. Collecting them and with little improvement to their aesthetics it can become a valuable second raw material. The authors propose a solution, using these cardboard rolls as components for new products, like furniture. Three chair concepts are proposed and analysed. The result of this analysis shows that the structure based on reused cardboard rolls resists and has all the qualities required to a product.*

Key words: *cardboard, furniture, eco-design, reuses.*

1. Introduction

Reuse represents a sustainable possibility of extending a product current useful life, by using less resources and producing less wastes and emissions.

The paper presents some solutions of designing new products by reusing components of a current product which arrived at its end-of-life stage.

According [2], the product life-cycle is defined as "*consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal*". A product is as more sustainable as its useful life is longer, but, at the same time, appropriate to the product type.

On the market, there are products with components which are not finishing their capacity of fulfilling the function for which they were designed and produced [5]. Consequently, they should be recovered in order to be reused.

Such an example is represented by the cardboard rolls having the function of supporting different rolled materials as paper, corrugated cardboard, textiles, plastics [13], [15]. After using these materials, usually, the cardboard rolls reach their end-of-life stage and they are recycled becoming a material resource for other products. A better solution considering the sustainability could be reusing these rolls. Reusing the cardboard rolls as they are, or by including them as components in different other products, is increasing the life span of the rolls becoming the sum of the two life spans corresponding to the first product and to the second as a reused element.

2. Reusing the cardboard rolls

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The research performed over the existing products which design includes the cardboard rolls reusing, revealed numerous sources of inspiration. There were found many products build exclusively or partially from this reused components.

Fig.1. *Examples for cardboard rolls reusing in furniture design*

Some of the products are presented in Figure 1. Besides furniture, this auxiliary, out-of-use product is reused for making toys, decorations and even small buildings.

The research permitted identifying some advantages for using this ñwasteò for building new products. Briefly, cardboard is non-toxic, resistant, durable, easy to shape, aesthetic ï easy to paint, attractive texture.

3. Designing products using cardboard rolls as second raw material

Most of the products that reuse cardboard rolls and identified during the research, belong to the furniture category. Therefore, for this study, this category of products was chosen to demonstrate that cardboard rolls can be reused and the products resulted have good qualities to compete with those build from traditional materials.

The chair was considered the most representative piece of furniture [6] and also one which, by its functionality, requires resistance to forces/weights that stress the structure during use.

The design process starts with a research focused on existing products and on potential user for the chair [6]. As concerns the user, the anthropometry is more important from the necessity of choosing the most appropriate rolls dimension. 50^{th} percentile male [3], [14] was considered a sufficient superior limit for dimensioning the chair, weighting maximum 80 kilograms.

Three concepts were designed [10], [11]:

- A tall chair, like the bar-type chairs, to be used in bars or by students in universities, working on computers at higher level tables, benchtop type;
- A classic shaped chair that can be used at home, or in waiting rooms ï airports, hospitals, railway stations etc.
- A lounger that can be used for relaxation at home, or in hotels.

The construction solution is the same for all three concepts: a number of reused cardboard rolls fixed between two PB or MDF panels [1], [12]. Construction design involves materials choosing and dimensioning.

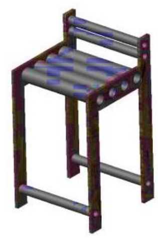		
Chair concept 1	Chair concept 2	Chair concept 3

Fig.2. *Three concepts for a chair reusing the cardboard rolls*

4. Verifying the cardboard chairs structure

Based on the three concepts previously presented, 3D models are built. To confirm the constructive solutions, a verification of the structures needed to be performed. In Figure 3a, the models used for the finite element analysis (FEA) are presented. All the models were created and assessed using CATIA V5R19 software.

The materials used for building the physical components, parts of each model ensemble, are cardboard and PB. For the basic components analysed in this study, the regular materials usually used in mass production were considered.

Because the von Mises tensions are studied between the chairs arms and the cardboard tubes, the materials for these two components are of a greater interest.

In order to perform the analysis, the following characteristics of cardboard (tubes) are presented:

-Young modulus $E = 1.8 \times 10^{9}$ N/m^2;

-Poisson coefficient $\nu = 0.29$;

-Density $\rho = 1100$ kg/m^3.

Also, the same characteristics for PB (Particle board) are presented:

-Young modulus $E = 1.3 \times 10^{10}$ N/m^2,

-Poisson coefficient $\nu = 0.1$,

-Density $\rho = 769$ kg/m^3.

4.1. Steps for Finite Elements Analysis

From the structures resistance perspective, the finite elements analysis basically has two calculation methods [7]:

- *forces method*, where the unknowns are represented by the forces that appear in the structure`s physical model nodes, when the structure is subjected to a random load;
- *the displacements method*, where the unknowns are represented by the displacements that appear in the structure`s physical model nodes, when the structure is subjected to a random load.

Between these two methods, usually the displacements method is used due to the advantages of the matrix calculus. Thus, in this paper, only this method will be used [8].

4.2. Describing the finite elements model

The numerical evaluation of the concepts studied and presented above assumes, in this case, determining the state of deformation and the contact distribution between the components found in contact. Determining the state of tension is not considered because the applied forces are not so high and the physical models construction is rigid enough so that it will support for sure higher loads [8], [9].

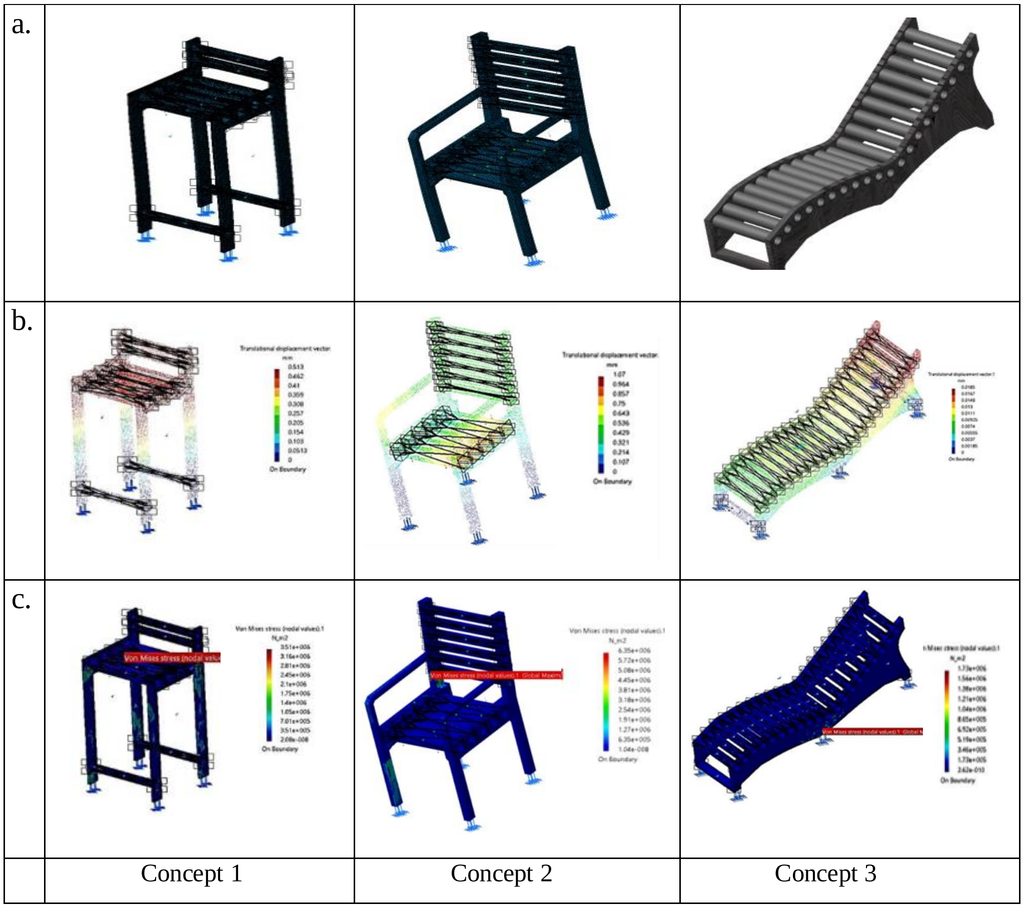

Fig.3. *Finite elements models of the three studied concepts*

Figure 3 illustrates the three concepts meshed with finite elements. To each, the corresponding material properties were assigned. Thus, for the chair sides PB was used and for the sitting area and backrest cardboard rolls was used, as they were described earlier.

For each concept a distributed force F = 800 N was applied and the translation displacements at the basis was cancelled. For the components in contact it was built a finer mesh of the surface, respectively with more rows of finite elements and nodes, in order to have a better convergence of the results and contacts in that area.

As a result of the applied force of 800 N, it was obtained a distribution of displacements (Figure 3b) as it follows:

- Concept 1: maximum displacement is 0.05 mm;
- Concept 2: maximum displacement is 0.034 mm;
- Concept 3: maximum displacement is 0.018 mm.

Following this first analyse it can be noticed that a significant difference between concept 3 and the other two variants occurs. This difference could be caused by the distance from the contact point between the chair and the ground.

The distribution of the von Mises

tensions for all three concepts is shown in Figure 3c.

Consequently, one can observe that for these three concepts it was obtained a tension variation as it follows:

- concept 1 ï the tensions distribution is on all the connecting surface of the rolls with chair arms, and the maximum value is 3.51MPa;
- concept 2 - the maximum value of the equivalent tension appears in the contact zones between the chair arms and the grip rolls. In this case, the von Mises tension value is 6.25 MPa;
- concept 3 - the von Mises tension value is 1.7 MPa.

As a result of this verification calculus performed with finite elements method the following observations can be stated:

- The maximum displacement of 0.0513 mm was obtained for concept 1;
- Von Mises tension, of maximum 6.35 MPa was obtained for concept 2;
- Concept 3 is more rigid considering the other analysed concepts.

The finite elements method is a fast computation method which offers approximated results with a graphical visualization on the whole studied model. This numerical simulation can give results close to reality, if the finite elements models are first calibrated with experimental results obtained from physical tests. A major disadvantage would be the necessity of a higher computation power for models with a higher number of nodes and elements.

After the study made through the finite elements method on these three concepts, in Table 1 there were systematized the obtained results.

Table 1. *The results systematization of the three concepts.*

Concept	Force [N]	Displacement [mm]	Von Mises [MPa]	Material
C1	800	0.0513	3.51	Cardboard/PB
C2	800	0.034	6.35	Cardboard/PB
C3	800	0.0182	1.73	Cardboard/PB

The evaluation of the models capacities of stress resistance and displacement revealed values inside the accepted limits. A reasonable force of 800 N was applied corresponding to a person weighting 80 kilograms and the simulation revealed that the stress and displacement maximum values are below the admissible limits for all three concepts. Obviously, the differences between the three concepts are small enough to consider that all designs can be developed into products. Only in the case of the second model the values of von Mises tensions have a significant difference in the ground contact area. However this ñlargerò value is still far beneath the admissible value and the structure will definitely resist.

5. Conclusion

The objective of this study was to create and build products to include cardboard rolls reusing. A cardboard roll is a relatively abundant waste, which whether recovered in good condition can be reused for different applications. For this study, some pieces of furniture were designed, all having a simple construction based on cardboard rolls.

The design process followed the steps of the traditional design even that our process, considering the objectives, the solutions and materials used can be considered as Eco-design [2][16].

Three chair concepts were created, possible products to be used by different users in different situations. All were designed considering restrictions like ergonomics and aesthetics. Following the design steps, the three concepts evolve to 3D models. These models helped performing verification by numerical simulation in order to confirm the cardboard rolls mechanical characteristics necessary for this specific piece of furniture. The simulation results proved that chairs build from cardboard rolls are not only aesthetic, but also functional, meaning they resist and can have a second useful life.

References

1. Ashby, M.: *Materials and Design*. Elsevier, 2006.
2. Bârsan, A., Bârsan, L.: *Ecodesign for sustainable development. Vol.1, Fundamentals.* ĂTransilvaniaò University of Braкov Press, 2008.
3. Bârsan, A., Bârsan, L.: *Fundamentals of product design.* ĂTransilvaniaò University of Braкov Press 2004.
4. Bârsan, L., Bârsan, A.: *Some Aspects Concerning the Design for Recycling and Waste Minimisation.* Proceedings of the 2-nd International Conference on EGô2009, Transilvania University 24-26 sept 2009, pp.274-277. Published by WSEAS Press
5. Diaconescu, D., Neagoe, M., Jaliu, C., Saulescu, R.: *Product's conceptual design*. Editura Universitatii Transilvania din Brasov, 2005.
6. Fantu, A., Bârsan, L.: *'Urban Mar' - An Essay about Outdoor Furniture Design*. In: Bulletin of ñTransilvaniaò University of Brasov, Romania 2011. New Series, Vol.4(53) No.2, series I, pp. 39-44.
7. Lates, M. T.: *Metoda elementelor finite.* Transilvania University Publisher, Brasov, 2008.
8. Madenci, E., Guven, I.: *The Finite Element Method and Applications in Engineering Using ANSYS.* Springer, 2005.
9. Moaveni, S.: *Finite Element Analysis Theory and Application with ANSYS*. vol. III, Prentice Hall, 2007.
10. ķiкman, V.: *Tehnici de machetare şi modelaj – curs*. ĂTransilvaniaò University of Braкov Press 2008.
11. ķiкman, V.: *Concepţia formei în design –indrumar de proiectare*. ĂTransilvaniaò University of Braкov Press, 2012.
12. http://furnish.bg/en/news/what_is_MDF_and_PB.html
13. http://www.deceiubimcartonul.ro/reciclare. Accessed 05.2016
14. https://zh.scribd.com/doc/257954558/Dimensiuni-antropometrice-ale-omului. Accessed 06.2016
15. http://www.ama-sa.ro/masina-confectionat-tuburi-de-carton.html. Accessed 06.2016
16. https://www.biopack.ro/ Accessed 05.2016.