TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 58, Issue II, June, 2015

STUDIES REGARDING THE USE OF RECLAIMED WOOD IN THE MANUFACTURE OF MODERN FURNITURE – PART I

Amalia BADIU, Ionuț BADIU, Mihai DRAGOMIR

Abstract: *In this article, the authors present the first part of a larger research demarche, aimed at analyzing the applicability and related issues to using reclaimed wood as a raw material in the furniture industry. The attached product risks are discussed in parallel, between two versions of the same product (in this case a lounge chair), one made from reclaimed material and one made from new material. These versions correspond to two possible market niches, one interested in "new and shiny" and one interested in "old with value". The instrument used in the paper is the Failure Modes and Effects Analysis, which reveals a map of all possible risks that a company must take into account when developing and designing either of the two.*

Key words: *Furniture, risks, reclaimed wood, FMEA.*

1. INTRODUCTION AND GENERAL CONSIDERATIONS

Reclaimed materials, also known as recovered, salvaged or reused materials, are a possible sustainable source of raw materials for product manufacturing in most production industries, as well as in civil engineering [1]. When speaking about reclaimed materials, one may refer to all those structures or parts of structures made of wood, metal, plastic, glass, rubber, composites, etc., which have served a purpose - either as stand-alone products or as components of products and buildings of any kind - which, relative to the purpose served, have reached their end of life [2][3].

In addition to issues related to manufacturing costs, the use of such materials is a form of environmental consciousness, mostly because of the critical way in which are regarded nowadays on a global level both the management of raw materials, as well as the handling of waste [1]. Such an industry that could benefit from the use of reclaimed materials is the furniture industry, whose main raw material – that is timber - is subject to new sustainability and management directions, starting from a delicate subject, already well known among consumers, namely wood processing industry and actions dedicated to protecting this resource. Beyond the commitments that furniture manufacturers may adopt towards their compliance with a set of standards and their assignment to one or more certifications related to sustainable forest management (see [4]), the use of recovered resources is in itself an act of responsibility towards the environment and the benefit of future generations.

However, the lack of concrete action on the use of reclaimed materials for furniture production and not only is due to a lack of knowledge concerning the properties, processability, risks and costs of using such materials. The reason, as emphasized in [5], consists of the major difference that is between product design which follows the conventional method and product design based on the idea of using salvaged materials. According to [5], the conventional method assumes the process of design and establishment of a product's specifications in the first place, followed by the allocation of materials according to the result of this process. On the contrary, manufacturing

based on reclaimed materials starts from the identification of a suitable source for the provision of such materials, and only afterwards followed by the establishment of product specifications and details.

2. THE ANALYSIS OF RISKS REGARDING THE USE OF RECLAIMED WOOD IN THE MANUFACTURE OF FURNITURE

2.1 Using the FMEA method

Assuming the adoption of reclaimed wood as a raw material for the development of new products in a furniture company focused on innovation, the authors of this paper wish to highlight issues related to the risks by means of the Failure Modes and Effects Analysis (FMEA) method.

The product chosen for the development of the two analyzes is a lounge chair designed for outdoor areas, made of wood and metal elements (Figure 1). The reason for this is the very area for which the product was designed and it reflects the authors' desire to highlight the risks regarding the choice of materials, given the environmental conditions which are less favorable for their conservation. The analysis was conducted comparatively on a single product, but in different embodiments, as follows: a first embodiment in which the entire structure of the lounge chair is assumed to be built using exclusively new manufacturing materials, and a second embodiment for which the seat elements of the chair are assumed to have been made from reclaimed wood.

Fig. 1. Lounge chair designed for outdoor areas

Failure Modes and Effects Analysis (FMEA) is a prevention tool for errors that may arise regarding a particular product, system or process and the possible effects that these errors may cause [6]. The purpose of such an analysis is to support the actions of avoidance or reduction of failures concerning a given subject and starting with those that have the highest priority. This hierarchy is established based on coefficients regarding severity of failure, its occurrence, as well as the estimated rate of detectability of the causes or effects following the application of certain control measures [7].

In this paper, the authors aim to identify possible differences in behavior regarding the two versions of the lounge chair during their use, in terms of the two main functions of the product: the basic function, namely that of supporting the weight of a person and the aesthetic function, as it has resulted from the design specifications.

For an effective illustration of the results of the comparative analysis and considering that the difference between the two versions of the product consists only in the origin of the materials and not in their nature, the authors decided to join the two FMEA analyzes in a single table (Table 1), with emphasis on those factors that vary from one case to another. Also, the study excludes the analysis of the product's metallic parts (e.g. the handle), given that these components are found identically in the configuration of both versions and do not influence, from the analysis point of view, the elements of the seat made of wood. It is also worth mentioning that for the lounge chair made of reclaimed wood, it is assumed that the latter has previously been tested in terms of physical properties and corresponding chemical treatments have been applied to it so that from a qualitative and aesthetic point of view, would not differ from the version made of freshly harvested timber. Only the non-material characteristics make the difference between the two product versions.

2.2 Obtained results

The constitutive elements of the analysis are illustrated in Table 1, where:

- S is the severity of failure;
- O* is the possibility of failure occurrence for the lounge chair made of new materials;
- O** is the possibility of failure occurrence for the lounge chair made of reclaimed wood;
- D is the detectability of failure after the application of a preventive measure;
- RPN*= S×O*×D and it is the risk coefficient regarding the lounge chair made of new materials;
- RPN**= S×O**×D and it is the risk coefficient regarding the lounge chair made of reclaimed wood.

The values of the coefficients for the three analyzed factors, namely S, O* / O** and D, vary on a scale from 1 to 10 (where 10 is the worst case) and take into account the recommendations provided in [6].

For a better view of the output regarding FMEA, the results thereof were ranked in Figure 2, depending on the potential causes of failure and the occurrence of such damages. Thus, one can easily see that only four possible causes out of a total of 14 provided in the analysis have obtained an equal score for both versions of the product in terms of possibility of failure. These causes concern cases of product misuse by mishandling or overload by the user and cases where the product was not properly prepared for the transport operation or the manufacturer has not complied with the dimensional control protocol of the product during its manufacturing.

However, for this research a special meaning is carried by those potential causes of failure which, by the probability of occurrence provided within the FMEA scenario, yielded a considerably higher coefficient (by 3 extra points) for the product made of reclaimed wood compared to the one made of entirely new manufacturing materials.

As a result, these values generate a high RPN coefficient, thereby indicating the major risk areas to be considered by the manufacturer when wanting to use salvaged wood as a raw material. In this case, the main potential cause of failure which presents a significant risk factor and possible unintended consequences in the use of the product is related to the premature aging of wood. Thus, the likelihood of certain failures affecting both the basic function, as well as the aesthetics of the product is somewhat higher when using reclaimed wood, given the considerable differences between the output values of the RPN coefficients in the following circumstances:

- **RPN** = 210** compared to **RPN* = 120** in the case of a possible breakage of the seat;
- **RPN** = 147** compared to **RPN* = 84** in the case of a possible failure of the seat by detachment of a component from the assembly;
- **RPN** = 112** compared to **RPN* = 64** in the case of a possible seat damage due to environmental factors.

The following two cases listed in the hierarchy according to FMEA, covering also a significant difference (of 2 points) between the coefficients generated by the two product versions, take into account the actual stage of material preparation for manufacturing and cannot be neglected given the results of the two priority risk numbers:

- **RPN** = 120** compared to **RPN* = 80** in the case of a possible miscalculation of the seat resistance;
- **RPN** = 196** compared to **RPN* = 98** in the case of a possible ineffectiveness of surface treatments applied to the wood.

Finally, with a difference of only one point regarding the possibility of failure, at the expense of the product made from reclaimed wood, are found those possible causes of failure that are derived from prolonged or repeated exposure of the product to unfavorable environmental factors (during its use or as a result of improper storage), or from the manufacturing stage because of improper assembling of the elements that build up the seat.

Table 1. Comparative FMEA regarding the two product versions

Function	Failure mode	Potential effects of failure	S	Potential causes of failure	O *	O **	The current control of the process	D	RPN *	RPN **
Supporting the weight of a person	Seat breakage	- Risk of injury to the user - The customer is very dissatisfied - Impossible to reuse	10	The seat resistance was not calculated correctly [a]	4	**6**	Submission to resistance testing	2	80	**120**
				Seat overload by the user [b]	6	6	Delivery with instructions for use	5	300	300
				The aging of wood [c]	4	**7**	Determination / testing of mechanical properties of the material	3	120	**210**
	Displacement of the seat from its holder	- Risk of injury to the user - The customer is very dissatisfied - Impossible to reuse	10	Product misuse[d]	6	6	Delivery with instructions for use	5	300	300
				Faulty assembling [e]	3	**4**	Compliance with the technical design and manufacturing technology	3	90	**120**
				Poor transportation [f]	5	5	Shock protected packaging	3	150	150
	Change in shape of the seat over time	- Uncomfortable to use - The customer is dissatisfied - Product loses its aesthetic value	7	Unfavorable weather circumstances [g]	6	**7**	None	10	420	**490**
				Improper storage [h]	6	**7**	Delivery with instructions for use	5	210	**245**
				Inefficiency of surface treatments [i]	2	**4**	Regular reapplying of surface treatments	7	98	**196**
	Detachment of a component from the seat	- Uncomfortable to use - Product loses its aesthetic value - Weakened assembly - The customer is dissatisfied	7	Improper fitting of engaging elements [j]	3	**4**	Dimensional control during manufacturing	2	42	**56**
				Weakening of joints over time [k]	7	7	Delivery with instructions for use	5	245	245
				The aging of wood [l]	4	**7**	Determination / testing of mechanical properties of the material	3	84	**147**
Aesthetics	Deterioration of wood / seat as a result of environmental factors	- Product loses its aesthetic value - Weakened seat - The customer is somewhat dissatisfied	4	The aging of wood [m]	4	**7**	Application of periodic chemical treatments	4	64	**112**
				Improper storage [n]	6	**7**	Delivery with instructions for use	5	120	**140**

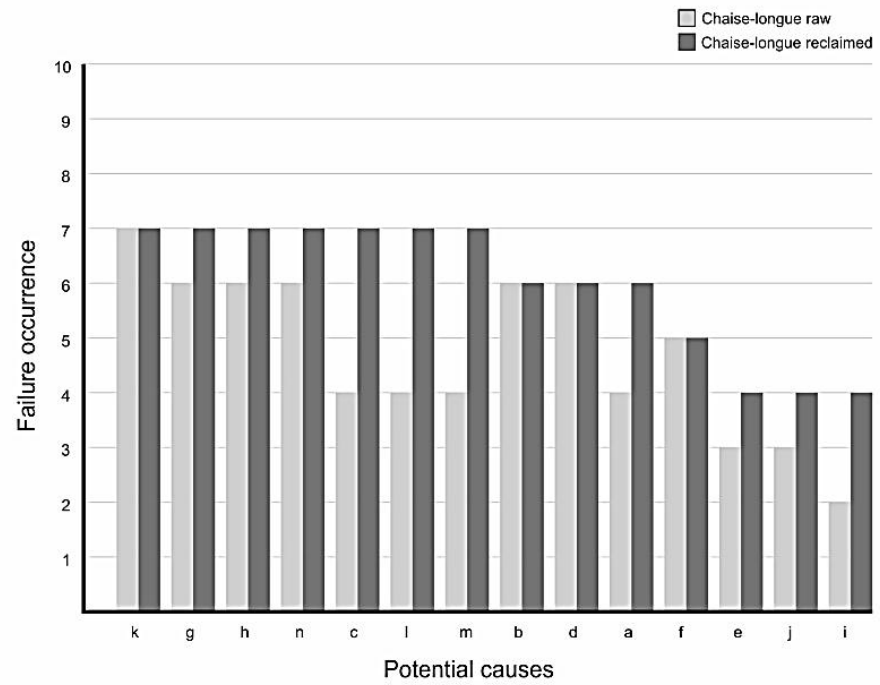

Fig. 2. Hierarchy of potential causes of failure depending on the possibility of failure occurrence

In conclusion, although it is assumed that, in the case of use of recovered materials, these have been previously verified, tested and treated in such a way that, from a behavioral point of view, the two versions of the product will have an identical life cycle, the risks highlighted using FMEA should be considered especially when there is the option of using salvaged materials as an alternative source of raw materials. The more so as the origin, age and previous use of the reclaimed wood are difficult to estimate.

4. CONCLUSION

In this paper, for the first version of the studied product, there were considered exclusively new manufacturing materials, while for the second version the choice of materials was aimed at the use of reclaimed wood for the manufacture of the seat.

As a way of highlighting the risks on the use of salvaged wood, the authors have identified the possibilities of failure regarding the product's functions, along with the causes and effects of these failures, by means of FMEA. Thus, the differences between the two versions were formed around the values of the risk priority number, whose notable variation was mainly due to:

- the premature aging of wood with the probability of seat breakage;
- preparatory phase of the manufacturing materials with the potential damage of the seat as a result of environmental factors;
- prolonged and repeated exposure of the product to unfavorable environmental factors with the possibility of lack of efficiency of surface treatments applied to the wood elements of the seat.

Thus, it turned out that the probability of certain failures affecting the product functions is considerably greater when using salvaged wood, although it is assumed that, before its processing to meet product specifications, it has been tested and approved as being qualitatively and aesthetically similar to a timber on its first use.

In conclusion, from the point of view of this paper, the benefit of using reclaimed wood as a raw material at the expense of freshly obtained timber is relatively small and it involves a number of notable risks in terms of its use and projected lifetime. Especially if the manufacturer has no experience in this regard, nor a reliable source for the acquisition of such a material, and does not have sufficient

knowledge about the diagnostic methods of reclaimed wood in terms of its age, quality, workability and life expectancy.

5. ACKNOWLEDGEMENT AND DISCLAIMER

This paper has benefited from the support of the project "Research for the development and implementation into production of innovative furniture", contract no. 12 P01 001 13 C3, beneficiary Smart Furniture SRL Cluj-Napoca, partner Technical University of Cluj-Napoca. The project is part of the Competitiveness Pole 12 P01 001 "Transylvanian Furniture Cluster" financed through the Sectorial Operational Program "Increase of Economic Competitiveness 2007-2013" by the European Regional Development Fund.

This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

5. REFERENCES

[1] Siddique, R., *Waste Materials and By-Products in Concrete*, Springer-Verlag Berlin Heidelberg, (2008).

[2] Smith, M., Use of Recycled and Reclaimed Timber. In A. Richardson (ed.) *Reuse of Materials and Byproducts in Construction: Waste Minimization and Recycling* (pp. 111-149), Springer-Verlag London, (2013).

[3] Bramston, D., Maycroft, N., Designing with Waste, *In Materials Experience: Fundamentals of Materials and Design* (pp. 123-133), Butterworth-Heinemann Ltd, (2013).

[4] Mission & Vision of the Programme for the Endorsement of Forest Certification, accessed in 13 Nov. 2014, www.pefc.org/about-pefc/who-we-are/mission-vision.

[5] Addis, B., *Building with Reclaimed Components and Materials, A Design Handbook for Reuse and Recycling*, Earthscan Publishing, London, (2006).

[6] Brad, S., *Fundamentals of Competitive Design in Robotics: Principles, Methods and Applications* (pp. 164-182), Editura Academiei Române, Bucureşti, (2004).

[7] Tague, N.R., *The Quality Toolbox* (pp. 236-240), Second Edition, ASQ Quality Press, (2004), accessed in 4 Nov. 2014, www.asq.org/learn-about-quality/process-analysis-tools/overview/fmea.html.

Studii privind utilizarea lemnului recuperat la fabricarea mobilierului modern - Partea I

Rezumat: *În acest articol autorii prezintă prima parte a unui demers de cercetare mai vast, care urmăreşte să analizeze aplicabilitatea şi problemele asociate cu folosirea lemnului recuperat ca materie primă pentru industria mobilei. Riscurile de produs implicate sunt discutat în paralel, între două versiuni ale aceluiaşi produs (în cazul dat, un şezlong), una realizată din material recuperat şi una din material nou. Aceste versiuni corespund cu două nişe de piaţă posibile, una interesată în produse "noi şi strălucitoare" şi una interesată de produse "vechi cu valoare". Instrumentul folosit în această lucrare este Analiza Modurilor de Defectare şi a Efectelor acestora, care relevă o hartă a tuturor riscurilor posibile pe care o companie trebuie să le aibă în vedere atunci când dezvoltă şi proiectează mobilier într-una din variante.*

Amalia BADIU, PhD. student, eng., Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, amaliambadiu@gmail.com, 0040 721 673837

Ionut BADIU, PhD. student, eng., Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, ionut.badiu@muri.utcluj.ro, 0040 732 819961

Mihai DRAGOMIR, Dr. eng., Associate professor, Technical University of Cluj-Napoca, Department of Design Engineering and Robotics, mihai.dragomir@muri.utcluj.ro, 0040 722 588538