The 4th International Conference
"Advanced Composite Materials Engineering "
COMAT 2012
18- 20 October 2012, Brasov, Romania

DETERMINATION OF THE STRAINS DEVELOPED IN FURNITURE PARTS MADE OF GLASS FIBRES COMPOSITE MATERIALS

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Abstract: *The paper shows the results experimentally obtained concerning to the strains developed in the seat-backrest part of a chair. This component was made of an hybrid composite material reinforced with both glass fabric and wood flour. The resistive tensometry method was used to measure the strains developed in the seat-backrest. Therefore, some strain gage rosettes 0/45/90 and two universal amplifier elements MX840 with eight channels were used for data acquisition. The numerical analysis shows that the greatest values of the stresses develop in the seat part of the component made of composite material. Taking into account these results, the chair was mechanically loaded just on the seat part by using the test weights. Finally, the values of strains experimentally measured were compared with the ones obtained by numerical modeling with the finite element method (FEM).*
Keywords: *composite, glass fibres, tensometry method, strains.*

1. INTRODUCTION

Nowadays, the incorporation of the recycled materials in composite materials is known as a new research direction in the field of manufacturing of the composite materials. For this purpose, there was interest for recycling of the large amount of wood waste [1, 2] obtained during the different stages in the wood processing and wood applications such as furniture industry and building constructions.
It is already known [2, 3] that cellulose fibres are recommended as fillers for plastic composites because these kinds of fibres lead to reducing of the costs concerning materials while mechanical characteristics are better than those that characterized the plastics with no reinforcing. These were the reasons for manufacturing and mechanically testing some hybrid composite materials reinforced both with glass woven fabric and with wood flour. The results of those tests were published in some previous papers [4, 5].
Then, some applications of that kind of composite were found such as the seat-backrest component of a chair (Figure 1, a). Moreover, that kind of chair could be successfully used as garden furniture because the hybrid composite material of the seat-backrest is characterized by good mechanical behaviour and stability under the actions of the aggressive environmental conditions (humidity, thermal cycles).
In a previous paper [6], it had already published some aspects concerning to the advantages of using of the composite materials reinforced with glass fibres to manufacture some components of garden chairs. Another papers [7, 8] also treated aggressively aspects regarding the environmental effects on composite materials reinforced with glass fabric and / or wood flour.
The main objective of this work consists in to experimentally analyse the chair shown in the Figure 1,a from strains state point of view. The seat-backrest component of the chair is made of a hybrid composite based on resin reinforced both with glass fibres and with wood flour.

2. MATERIALS AND WORK METHOD

The first of all, it was made the numerical analysis of the chair involved. The results showed that the greatest values of the stresses develop in the seat part of the component made of composite material. Taking into account these results, the chair was mechanically loaded just on the seat part by using the test weights whose mass is equal to 10 kg (Figure 1, a). The test weights have disk shape and the contact surface with the chair seat has circular shape whose diameter is equal to 234 mm. To improve the contact between the test weights and the surface of the chair seat, it was used a rubber piece having also a circular shape whose diameter is equal to 234 mm while its thickness is equal to 6 mm.

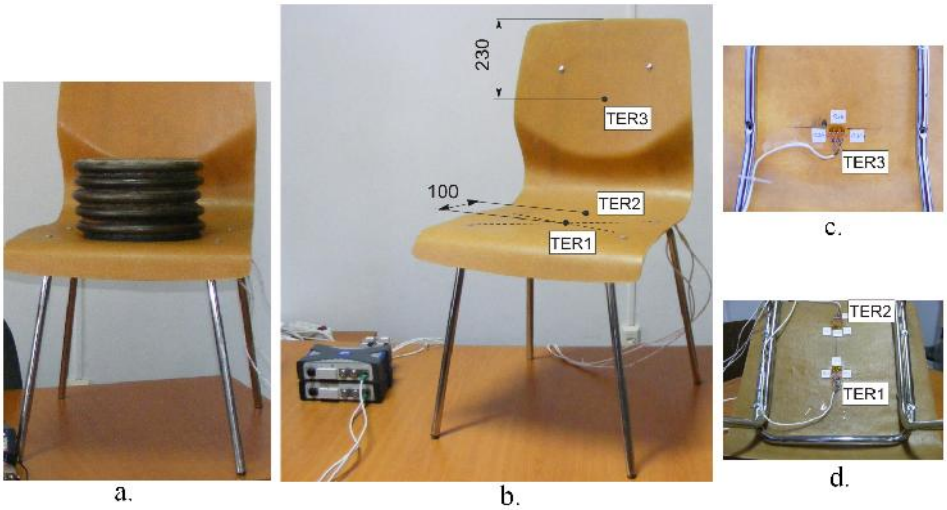


Figure 1: Mounting of the strain gauges of rosette type to measure strains developed in chair seat: a. The tested chair mechanically loaded; b. Positioning of the strain gauges on the seat-backrest part; b. TER 3 strain gauge glued on the back site of the backrest; c. TER1 and TER2 glued on the bottom of the chair seat

2.1. Materials

To measure the normal strains ε that develop in the seat component of the chair when this is mechanically loaded, it was used the followings:

- bonded strain gage rosettes 0/45/90, 1-RY88-6 / 350Ω (Figure 1, b si c) made by HBM having the following characteristics: electric resistance 350.0Ω ± 0.3% (at 24°C); the constants of the strain-gauge for each electric resistance $k_a = 2,.3 \pm 1\%$, $k_b = 2.15 \pm 1\%$, $k_c = 2.13 \pm 1\%$ (la 24°C); transverse sensitivity $(a: 0\%, b: -0.3\%, c: 0\%)$; the length of measuring a = 6 mm;
- adapter units for working with strain-gauge ¼ or ½ bridge strain gauges with electric resistance120/350 Ω;
- two universal amplifier elements MX840 (Figure 1, a), each of these contains 8 channels for data acquisition having the following characteristics: the frequency of data acquisition up to 19.2 kHz for each channel; converter A/D of 24 bits of each channel to synchronize the parallel measuring; contains filter Bessel, Butterworth 0.01Hz - 3.2 kHz (-3dB); electric supply 10...30V; provides electric supply 5-24 V for transducers; allows the identification of the connected transducers TEDS; sleeve joints of type D-SUB-15HD; the range of the work temperatures $-20...+65^{\circ}C$; accuracy class 0.05; compatible with transducers with strain gauges with full and half bridge deck, inductive transducers in full bridge and half bridge LVDT, voltage / current, resistance thermometers PT100 and PT1000, thermocouples, potentiometers, counter of impulses, CANbus; adapter for use with ¼ bridge strain gauges; soft Quantum X; sleeve joints for 8 gauges.
- *Easy Catman* software package for processing data: parameterization of the amplifier with automatic recognition of the type of transducer; possibility of creating virtual channels to achieve real-time the mathematical calculations for strain gauges of rosette type; setting of limits and monitoring functions; visual analysis of the data by synchronization and real-time overlay; data export in common formats of type: Excel, ASCII, DIAdem, nSoft, compatible with MX840 systems, MGCplus, MGCsplit or Spider8.

2.2. Work method

To experimentally measure of the strains developed in seat part by using the tensometry method, the following steps were covered:

- choice of the type of strain gauge - 0/90/0 rosette type, 1-RY88-6 / 350Ω;
- establishment of the piece areas where the electrical resistive strain gauges (TER) will be mounted so these places are easily accessible and free of defects or cracks;
- preparation of the surfaces where the strain gauges will be applied, step that consists in mechanical cleaning in order to bring to an adequate roughness, marking of the seating position for strain gauges, chemical cleaning of the area in order to obtain as clean surfaces and neutralize of the surface by using a solution;
- application of strain gauges on the work piece surface by bonding with special glue (Figure 1, b-d);

- wiring of the strain gauges (Figure 1, b-d);
- connection of the strain gauges to the jacks of the two amplifiers of type MX840 with 8 channels via adapters to work with strain gauges mounted in quarter (¼) bridge circuit and half (½) bridge circuit with resistance of 120/350;
- connection of the amplifiers of type MX840 to the computer;
- using of the Catman Easy software compatible with MX840 acquisition system for measuring of the deformations, step that begins with: setting of the channels (Figure 1); their initialization to 0, setting of the constants for each strain gauge and for their corresponding resistances ($k_a = 2.13 \pm 1\%$, $k_b = 2.15 \pm 1\%$, $k_c = 2.13 \pm 1\%$); setting of the transversal sensitivities $(a : 0\%, b : -0.3\%, c : 0\%)$; creating of the real-time graphics for measured quantities and for calculated quantities;
- making of the actual measurements (a sufficient number of measurements required for subsequent statistical processing of the signals) to measure specific linear deformations ε_a, ε_b, ε_c recorded by each strain gauge rosettes.

Measurements were performed for the following values of the loading force: 98.10 N, 196.2 N, 294.30 N.
Acquisition of signals from the electrical resistances of the strain gauges, was performed through acquisition board MX840 having amplification role of the signals from the channels were the resistances were connected and then, transmitting to the computer. Then, these signals can be processed either with the QuantumX software supplied with the amplifier MX840 or with Catman Easy software specialized on tensometry.
Finally, the results experimentally measured by using resistive strain gauge method were compared with the results obtained by numerical modelling.

3. RESULTS

In the Figure 2, it is shown the results of the measurements concerning to the specific normal strains ε recorded by the two strain gauges glued on the underside of the chair seat (three directions A, B, C for each strain gauge). These results were recorded during loading with three calibrated mass units: 10 kg (98.10 N); 20 kg (196.2 N); 30 kg (294.30 N).

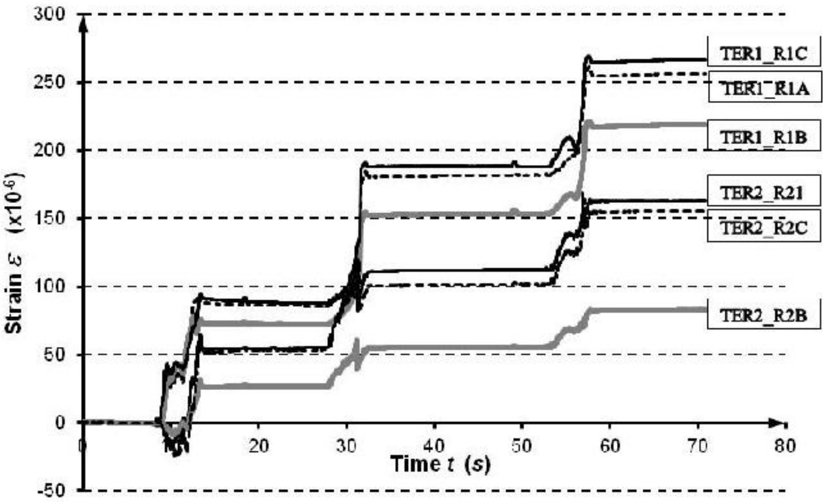


Figure 2: Time variation of the normal strains ε recorded by the both TER1 and TER2 strain gauges glued on the bottom of the chair seat

Finally, to validate the numerical model, the theoretical results were compared with the experimental ones for the cases corresponding to the loading scheme showed in the Figure 4 when the following forces were applied: 98.10 N, 196.2 N, 294.30 N.
For this purpose, Figure 3 shows the finite element model of the chair while Figure 4 presents the loading scheme used in the numerical model.
The values of the strains ε experimentally measured were compared with the ones obtained by numerical modelling for 117505 and 116967 elements (Figure 5, a) on the measurement directions corresponding to the strain gauge rosettes. In this sense, two coordinate systems were created (Figure 5, b) and the strains were displayed with respect of them: CSYS-1 coordinate system (x-axis coincides with the direction of the resistances R1B and R2B); CSYS-2 coordinate system rotated by 45° compared to the first.

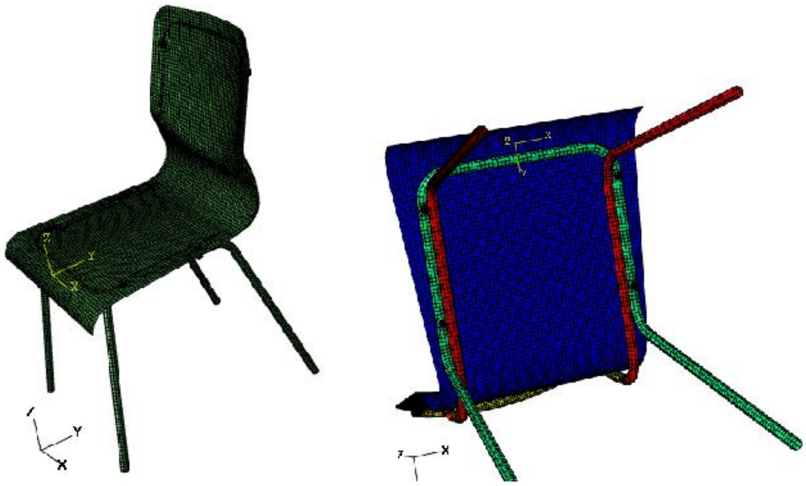
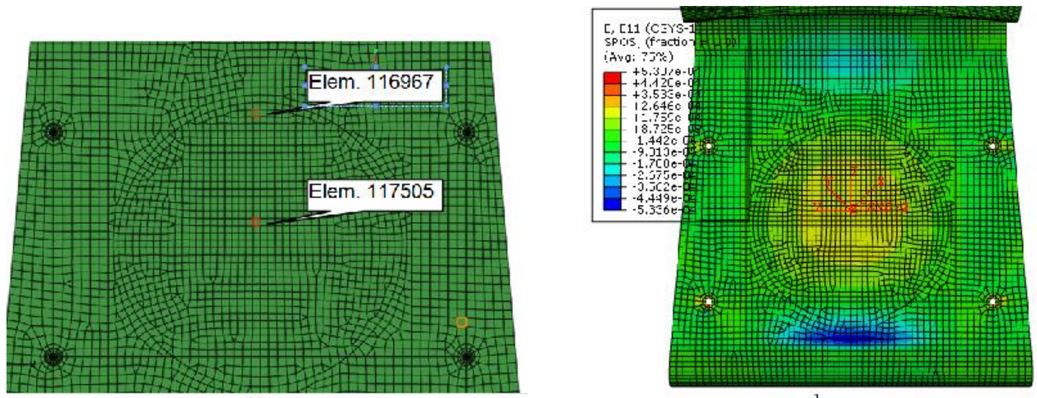


Figure 3: Finite element model of the chair

Figure 4: Loading scheme for the numerical model of the chair



a. b.

Figure 5: Establishing the model elements and coordinate systems used to obtain theoretical results

a. Considered elements in the numerical model; b. CSYS-1 and CSYS-2 coordinate systems used for displaying the results in FEM analysis

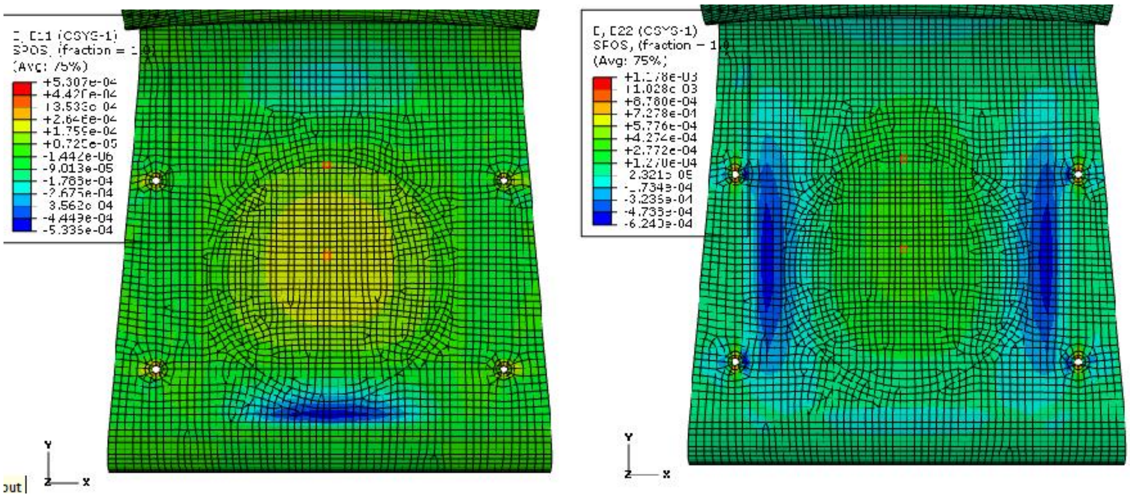


Figure 6: State of the normal strains ε relative to CSYS-1 coordinate system whose 1 axis conincides with Y axis (F=294,3 N)

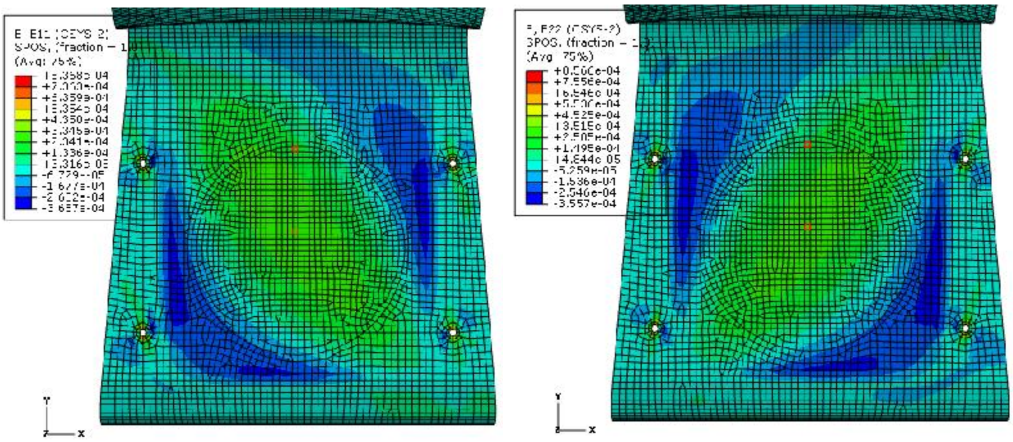


Figure 7: State of the normal strains ε relative to CSYS-2 coordinate system whose 1 axis is rotated with 45° relative to the Ox axis (F=294,3 N)

The first of all, it is shown the results obtained by finite element analysis for the case when $p = 0.004562\ \text{N}/\text{mm}^2$ (corresponding to the force F = 294.3 N) was the pressure applied on the chair seat in the numerical model.

In this context, it is presented the distribution of specific strains ε developed on the chair seat in relation to the coordinate system CSYS-1 (Figure 6) and relative to the coordinate system CSYS-2 (Figure 7).

Tabel 1: Comparison between the theoretical results and the experimental ones

Force (*N*)		98.1			196.2			294.3		
Pressure p (N/mm^2)		0.00228112			0.004562			0.006843		
		ε (x 10^{-6})		*Err [%]*	*ε (x 10^{-6})*		*Err [%]*	*ε (x 10^{-6})*		*Err [%]*
		Teoretical	*Exp.*		*Teoretic*	*Exp.*		*Teoretic*	*Exp.*	
Strain gauge TER 1	*R1A*	97.19	86.41	11.10	194.81	181.20	6.99	292.43	255.18	12.74
	R1B	81.04	72.25	10.85	164.16	152.82	6.91	247.28	217.98	11.85
	R1C	97.19	88.56	8.87	194.81	188.43	3.28	292.43	265.50	9.21
Strain gauge TER 2	*R2A*	58.02	54.52	6.03	117.30	111.78	4.70	176.58	162.67	7.88
	R2B	29.01	26.52	8.58	60.35	55.22	8.50	91.68	82.34	10.18
	R2C	58.02	53.08	8.52	117.30	101.23	13.70	176.58	154.87	12.29

Both the results obtained by numerical modelling and the ones experimentally measured by using electrical resistive strain gauges, were systematized in Table 1. Finally, the errors expressed as percentage were calculated for each case. It is noted that the error values are greater for the strain gauge rosette denoted with TER2.

4. CONCLUSIONS AND DISCUSSIONS

Analyzing the results shown in Table 1, it may observe that the values of the strains experimentally measured do not significantly deviate from the theoretical values obtained by analysis with the finite element method.
Measurement errors that occurred during the experimental investigation could be due to: misalignment of the strain gauge to the direction of the load application; transverse sensitivity of composite materials; improper bonding of the strain gauge rosettes, so an angular variation between 0º to 4º could lead to the increasing of the error value up to 65%.
Comparison between the theoretical results and the experimental ones (Table 1) regarding the state of strains developed in the composite part analysed (seat-backrest component of the chair), confirms the correctness of the numerical model with finite elements.

ACKNOWLEDGEMENT

This work is supported by CNCSIS –UEFISCSU, project number PNII – IDEI 733.

REFERENCES

[1] Kamdem D. P., Jiang H., Cui W., Freed J., Matuana L. M., Properties of wood plastic composites made of recycled HDPE and wood flour from CCA-treated wood removed from service, Composites: Part A, vol. 35, 2004, pp. 347-355.
[2] Klyosov A.A., Wood-plastic composites, Wiley Publishing, 2007, pp. 75-122.
[3] Stancato A.C., Burke A.K., Beraldo A.L., Mechanism of a vegetable waste composite with polymer-modified cement (VWCPMC), Cement & Concrete Composites, ISSN 0958-9465, vol. 27, 2005, pp. 599.
[4] Cerbu C., Curtu I., Ciofoaia V., Rosca I. C., Hanganu L. C., Effects of the wood species on the mechanical characteristics in case of some E-glass fibres/wood flour/polyester composite materials, in Rev. Materiale Plastice, MPLAAM 47 (1) 2010, Vol. 47. nr. 1 – martie 2010, Bucuresti Romania, ISSN 0025/5289 – ISI (CNCSIS A), pp.109-114.
[5] Cerbu C., Luca-Motoc D., Solutions for Improving of the Mechanical Behaviour of the Composite Materials Filled with Wood Flour, Proceedings of The World Congress on Engineering 2010, Vol II, ISBN 978-988-18210-7-2, WCE 2010, June 30 - July 2, 2010, London, U.K; Publisher: Newswood Limited; Organization: International Association of Engineers; pp. 1097-1100.
[6] Cerbu Camelia, Itu Călin, Curtu Ioan, The problem of the using of the composite materials reinforced with glass fibres to manufacturing of some components of the garden chairs, Revista ProLigno, vol. 6, Nr. 3, septembrie 2010, ISSN 1841-4737, pp. 51-60.
[7] Cerbu, C., Materialele compozite şi mediul agresiv. Aplicaţii speciale, Editura Universitătii Transilvania, 2006, Brasov.
[8] AdhikarY K. B., Pang S., Staiger M. P., Long-term moisture absorption and thickness swelling behaviour of recycled thermoplastics reinforced with Pinus radiata sawdust, Chemical Engineering Journal, doi: 10.1016 /j.cej.2007.11.024.