Proceedings of the World Congress on Engineering 2011 Vol III
WCE 2011, July 6 - 8, 2011, London, U.K.

Analysis of Bending Specific Deformation in Composite Materials Using Comparative Methods

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***Abstract*— The paper presents the study of bending specific deformation for some types of composite materials using two methods in order to be able to compare the results. The theoretical method is based upon the finite element method (FEM) and the results are experimentally checked by help of electric tensometers measurements (ETM) using strain gauges inserted between the material layers in an original way.**

***Index Terms*— composite materials, finite element method, strain gauges**

I. Introduction

It is a well known fact that the composite materials, as a combination of two or more materials, whose mechanical properties may be significantly improved this way, cannot be treated as homogeneous materials. Especially if you deal with multi-layer structures, there are big differences between the properties within each layer and also at the contact between layers. This is the reason why the necessity of analysis of specific deformations on each layer occurs and also the experimental checking of the theoretical results.

In our research we used two methods that allow us to compare the results: finite element method (FEM) (assuming the visualization of the deformed stages of the finite elements structure and also its representation based upon various possibilities like: diagrams, lists, graphical representations, etc. of the obtained parameters) and electric tensometers (strain gauges) measurements (ETM) (a method allowing the measurement of non-electric quantities using general electric measurements). Only by comparing the results obtained by at least two different methods, we can be sure about their accuracy, considering the obvious anisotropy of the composites.

Manuscript received March, 4; revised July, 2011. This work was supported in part by CNCSIS Romania under grant ID_744/2009

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II. Theoretical Method (FEM)

The study was made for the following types of composite materials:

- MAT450, structured on 4 layers
- Roving RT800, structured on 4 layers, weft disposition
- Roving RT800, structured on 4 layers, warp disposition

The material behavior was studied during pure bending, when subjected to a force of 600N and the postprocessor program used was MSC Nastran. The specific deformation was determined in the proximity of the strain gauges locations in order to be able to perform the comparison between the theoretical approach and the experimental one.

In the following figures we presented the maximum values of the specific deformations obtained by help of FEM for the selected samples of material. We chose to represent the layers where the deformation reaches the maximum values.

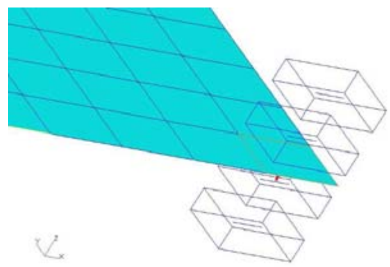

Fig.1 Sample made of MAT450

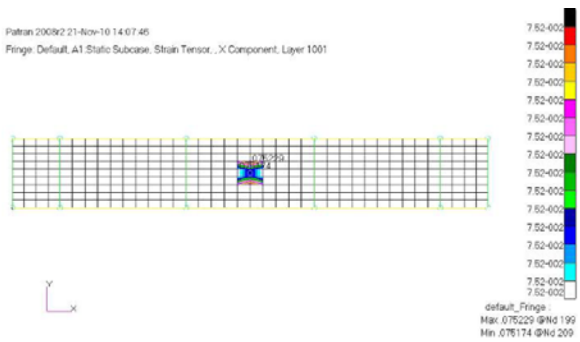

Fig.2 Specific deformation distribution for layer 1

In fig.3 and 4 we show the sample made of RT800, provided with warp disposition of fabric together with the specific deformation distribution diagram for layer 1, then in fig.5 and 6 the sample made of RT800 with weft disposition of fabric together with the specific deformations distribution

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

obtained also for layer 1.

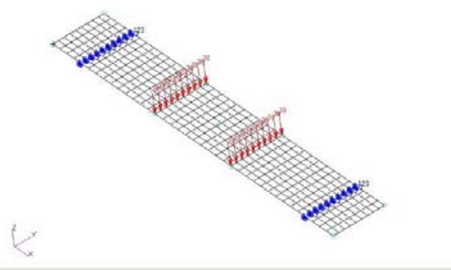

Fig.3 Sample made of RT800 (warp)

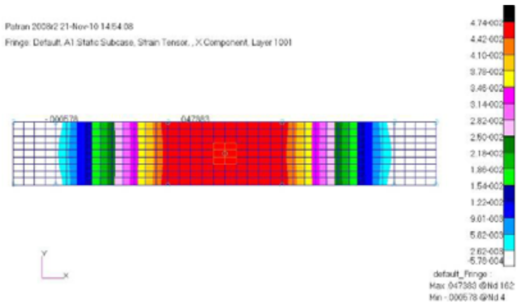

Fig.4 Specific deformation distribution for layer 1, RT800 (warp)

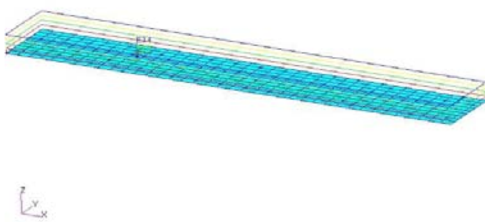

Fig.5 Sample made of RT800 (weft)

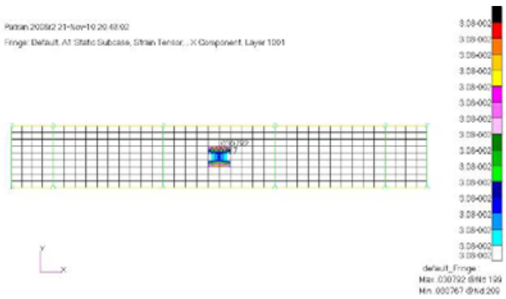

Fig.6 Specific deformation distribution for layer 1, RT800 (weft)

For the first type of material (MAT450) the specific deformation was determined to be between -0.025 and 0.025, for the second type RT800 (warp) we obtained values between -0.016 and 0.015, while for the third type RT800 (weft) the range was somewhere between -0.014 and 0.014.

III. EXPERIMENTAL METHOD (ETM)

For the experimental setup we used Spider8 equipment, the results being recorded by help of dedicated software CATMAN. A number of 3 strain gauges were introduced between the layers in order to be able to see what happens when the material changes its physical properties, the gauges were connected to Spider8 (fig.8) and in the meantime the sample was introduced in the bending machine.

The location of the strain gauges is presented in fig.7.

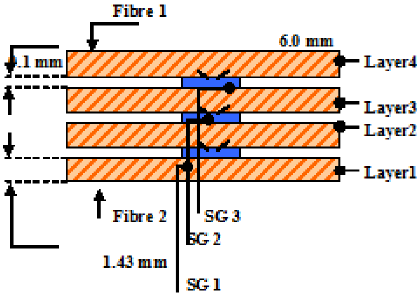

Fig.7 Strain gauges positioning

Fig.8 Spider8 equipment

After each testing we obtained graphical representations of the specific deformations for each of the three strain gauges, which were positioned between the 4 layers. Thus, in fig.9 we presented the testing of the MAT450 sample, using the 4 points bending machine, while in fig.10, the graphical representations of specific deformations provided by the software for each strain gauge.

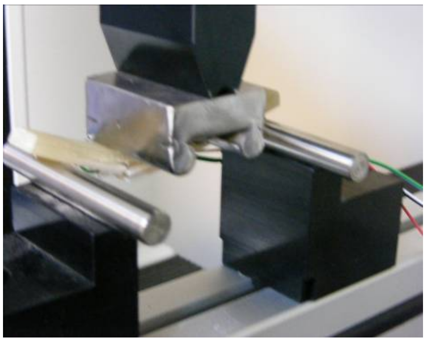

Fig.9 Bending machine

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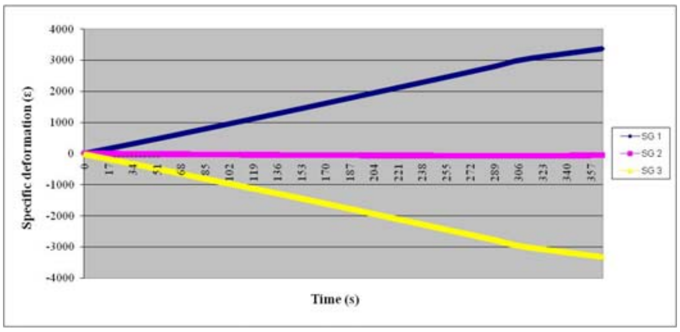

Fig.10 Specific deformation in time for MAT450

We notice that the stress measured by SG3 is close to the one measured by SG1. The tension measured by SG2 is almost 0 Mpa, because it is located in the vicinity of the neutral axis. It becomes obvious that the tensions along the external fibres are approximately equal in magnitude but of different signs (tensile on one fibre and compression on the other one).

The following diagram presents by comparison the results obtained using the theoretical FEM method and the ones obtained experimentally after applying the strain gauges (fig.11).

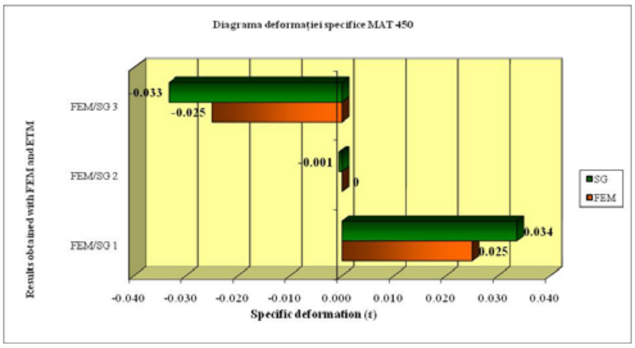

Fig.11 Comparison diagram of specific deformations for MAT450

The analysis based on electric tensometers measurements by help of strain gauges for the RT800 sample, with warp structured fabric, on 4 layers was presented in the diagram shown in fig.12. The sample was subjected to bending, along 353,6s using a 600N force, providing the following maximum specific deformations SG1-(0.02565), SG2-(0.00235), SG3-(-0.02336).

The same type of experiment was performed upon the sample made of RT800, with weft structured fabric, on 4 layers, obtaining the diagram in fig.13. The sample was subjected to bending along 346,6s using again a 600N force and the maximum values obtained for each strain gauge placed between the layers are: SG1-(0.01744), SG2-(0.00255), SG3-(-0.01616).

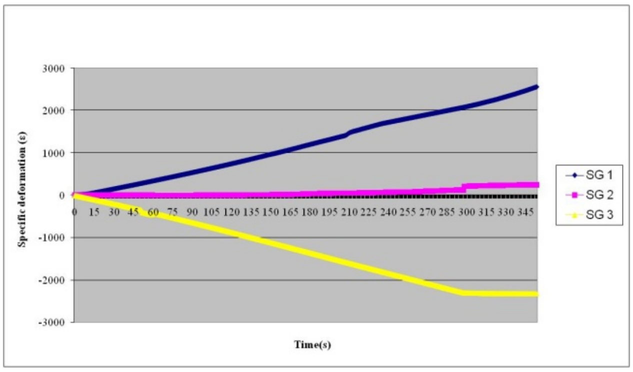

Fig.12 Specific deformation in time for RT800 (warp fabric)

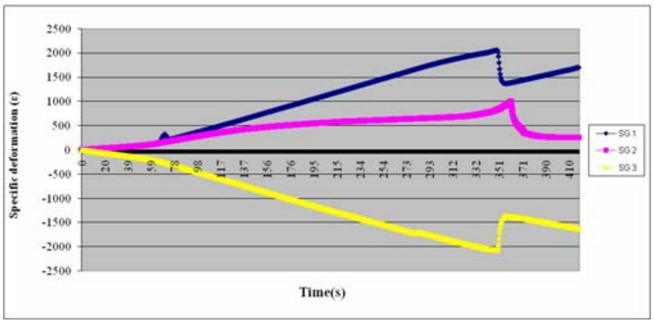

Fig.13 Specific deformation in time for RT800 (weft fabric)

In order to present the comparison between the values obtained using the two methods we created the diagrams shown in fig.14 and 15 for the samples made of Roving, both for warp and for weft fabric.

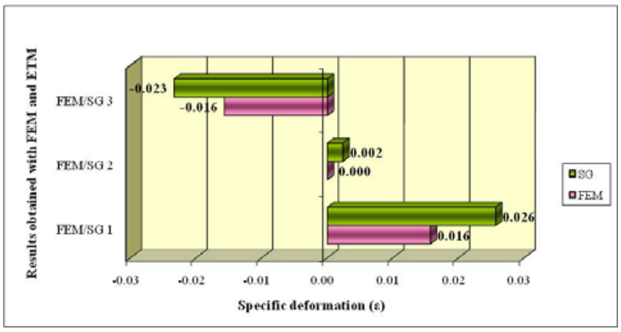

Fig.14 Comparison diagram of specific deformations for RT800 (warp fabric)

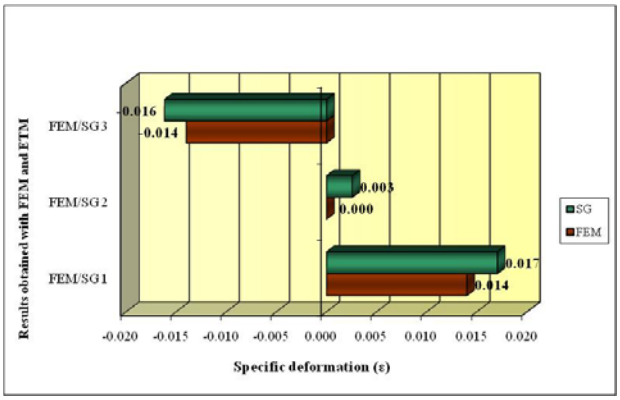

Fig.15 Comparison diagram of specific deformations for RT800 (weft fabric)

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

IV. CONCLUSIONS

By comparing the maximum values of the specific deformations for the three types of tested samples, we found the following:

- For MAT 450, the maximum specific deformation experimentally determined was between -0.033210 and 0.033580. The deformation obtained by FEM was between -0.025 and 0.025, but very close to the experimental one.
- The maximum specific deformation of the roving material RT800 (warp fabric) was experimentally obtained between -0.023369 and 0.025651, while the theoretical values were in the range of -0.016 and 0.015, the errors being acceptable
- The sample made of 4 layers of RT800 (weft fabric) provided the theoretical values in the range of -0.014 and 0.014, while experimentally we got values between -0.016164 and 0.017041.

We find that using the finite element method for the study of anisotropic materials such as the composite materials we are able to easily change the load, boundary conditions, way of application, having the opportunity of selecting the optimum choice, the dimensions and required characteristics of materials. Each part of the material can be assessed and the results are checked out by help of the experimental determinations.

Based on this type of researches, the specialists will be able to select the proper combination of elements, so that their common properties respond to the requirements for the designed product.

ACKNOWLEDGMENT

These researches are part of the national research grant ID_744/2009 with CNCSIS Romania and used the equipment of SAVAT research platform from Transilvania University of Brasov, Romania.

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