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SOME RESEARCH ON FINITE ELEMENT ANALYSIS OF COMPOSITE MATERIALS

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ABSTRACT

The aim of this paper is to verify the accuracy of composite materials data input into ANSYS Parametric Design Language for the numerical analysis. For this purpose, some specimens of the laminated composite were subjected to a bending moment and the deformations were measured. At the same time, the data obtained by simulating the specimens with the help of ANSYS APDL, were analyzed and compared to the experimental data in order to establish the degree of the accuracy.

Keywords: deformations, composites, bending, specimens, FEM analysis

1. INTRODUCTION

1.1 . Properties of Glass/Polyester Composites

The rotor blades of the laminated glass fibre composites with polyester resin as the matrix material, are still widely used, today. The glass used in the blade construction is E-glass, which has good structural properties in relation to its cost [2].

The plate elements forming the spar of a GFRP blade are normally laminates consisting of several plies, with fibres in different orientations to resist the design loads. Within a ply (typically 0.25–0.6 mm in thickness), the fibres may all be arranged in the same direction, unidirectional (UD) or they may run in two directions at right angles in a wide variety of woven or non-woven fabrics.

Although the strength and stiffness properties of the fibres and the matrix are well defined, only some of the properties of a ply can be derived from them, using simple rules. Thus, for a ply reinforced by UD fibres, the longitudinal stiffness modulus, E_1, can be accurately derived from the mixtures' rule formula:

$$E_1 = E_f V_f + E_m (1 - V_f)\text{, [GPa]} \quad (1)$$

where E_f is the fibre modulus (74 GPa for E-Glass), E_m is the matrix modulus (in the range 4 GPa) and V_f is the fibre volume fraction [3].

The transverse modulus, E_{12}, is determined by the formula:

$$E_{12} = E_m \left[\frac{1}{(1-V_f) + \frac{E_m}{E_f} V_f} \right], \text{[GPa]} \quad (2)$$

The in-plane shear modulus of a ply, G_{12}, can be estimated from:

$$G_{12} = G_m \left[\frac{1}{(1-V_f) + \frac{G_m}{G_f} V_f} \right], \text{[GPa]} \quad (3)$$

where G_m is the shear modulus of polyester ($G_m = 1.4\ GPa$) and G_f is the shear modulus of E-glass ($G_m = 30\ GPa$)

The Poisson coefficient can be obtained from the formula:

$$\nu_{12} = \nu_f V_f + \nu_m V_m \quad (4)$$

Clearly, the longitudinal stiffness and the strength are both limited by the obtainable fibre volume fraction. For hand lay-up, the fibre volume contents of 30–40% are typical, but the use of *vacuum bagging*, in which trapped air and excess volatile compounds, such as residual solvent, are extracted, consolidates the composite and allows a volume fraction of 50% or more to be achieved.

2. EXPERIMENTAL ANALYSIS

2.1. Preparation of Test Pieces

The pieces were obtained from a laminated plate, which, in turn, was manufactured by Vacuum Assisted Resin Transfer Molding (VARTM) [4] (Fig. 1).

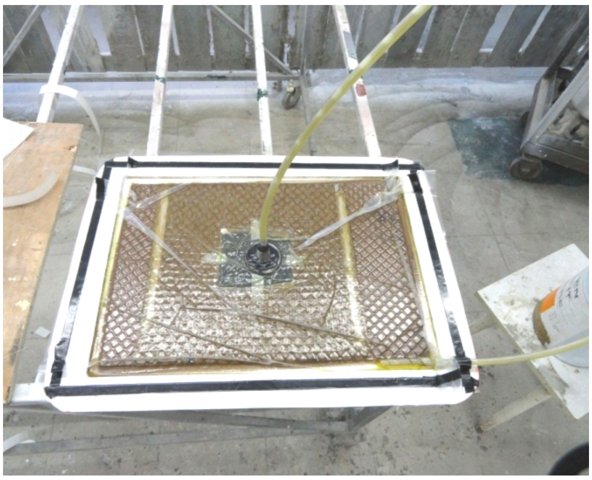

Fig. 1. The vacuum Assisted Resin Transfer Molding

The laminate specifications employed in the specimen design, are the following:

• 4 layers of unidirectional glass fabric with 600 g/m2 [0° E-glass fibres (2400 tows) and 90° E-glass fibres (300 tows)];

- in the middle, one layer of Chopped Strand Mat, with 810 g/m^2.

The process of vacuum resin transfer was performed at 0.7 atmospheres. So, it was obtained a 2.6 mm thick laminate with a fibre volume fraction of 67%.

After the curing process of about 10 days, from the plate test specimens were cut having the dimensions of 250 mm x 25 mm (Figs 2 and 3).

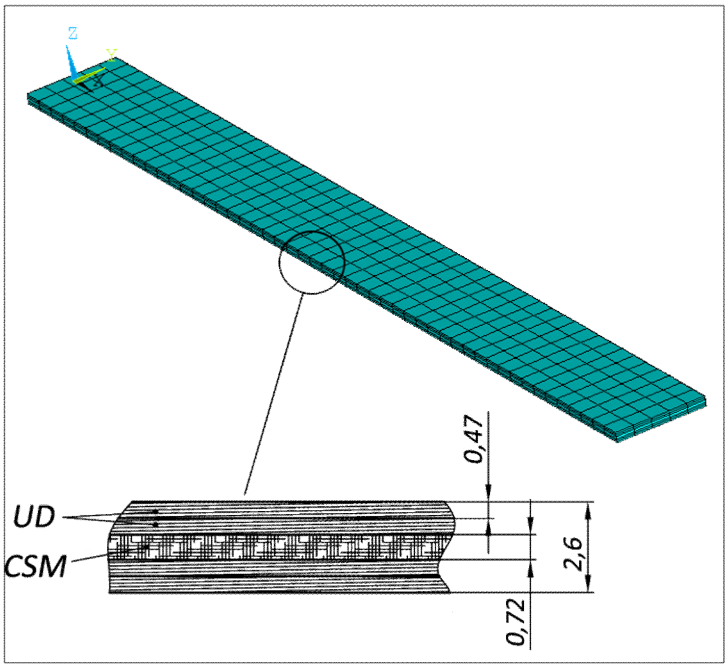

Fig. 2. Test laminate structure

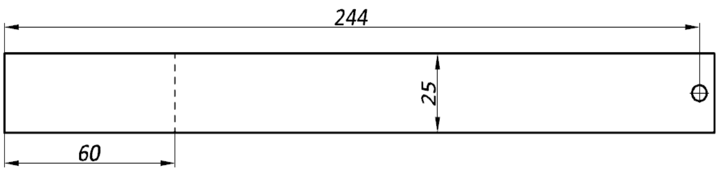

Fig. 3. Test specimen

2.1. Bend Testing

Two specimens were fixed by one end between table and another plate on a segment of 60 mm as shown in Fig. 4. Then, the specimens were bent with an electronic spring balance to 1, 2, 3, 4 and 5 kg force. At the same time, for each load level, the displacements were measured. There is a little difference between results obtained for each specimen.

The results are presented in Table 1.

Fig. 4. The specimen loading

Table 1 Test results

Force, N	Displacement, mm	
	Specimen 1	Specimen 2
10	20	23
20	34	38
30	51	54
40	70	73
50	89	92

3. NUMERICAL MODELING AND ANALYSIS OF THE SPECIMEN

The specimen was modeled with ply input data obtained by the formulas presented in the introduction of [1, 7] and shown in Table 2.

The numerical simulations were performed with the help of ANSYS Parametric Design Language [5, 6]. The specimens were modeled with 250 SHELL99 8-node layered shell elements (Figs 5 and 6) [9].

The middle layer of CSM was considered as a material with linear isotropic properties.

Table 2 Summary of the material properties for a ply employed in the specimen design

Property	**E-Glass Fiber/ Polyester Composite**	
Fiber orientation	UD	CSM
Fiber Volume Fraction	67%	50%
Tensile Modulus E_{11}, GPa	50	12
Transverse Modulus E_{12} , GPa	8.5	12
Shear Modulus G_{12}, GPa	3.87	
Poisson's ratio, υ_{12}	0.3	0.28
Poisson's ratio, υ_{21}	0.06	0.28

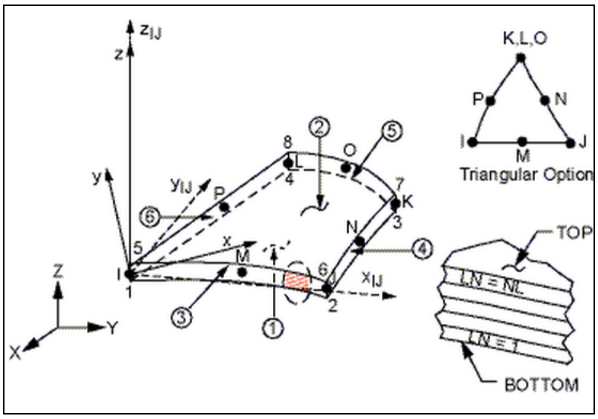

Fig. 5. SHELL99 Geometry

The modeled specimen was subjected to the same forces as the real test piece. Loads definition is shown in Fig. 6.

The displacements and the tensions that occur in the tested specimen are shown in Figs 7 and 8, for the load of 50 N.

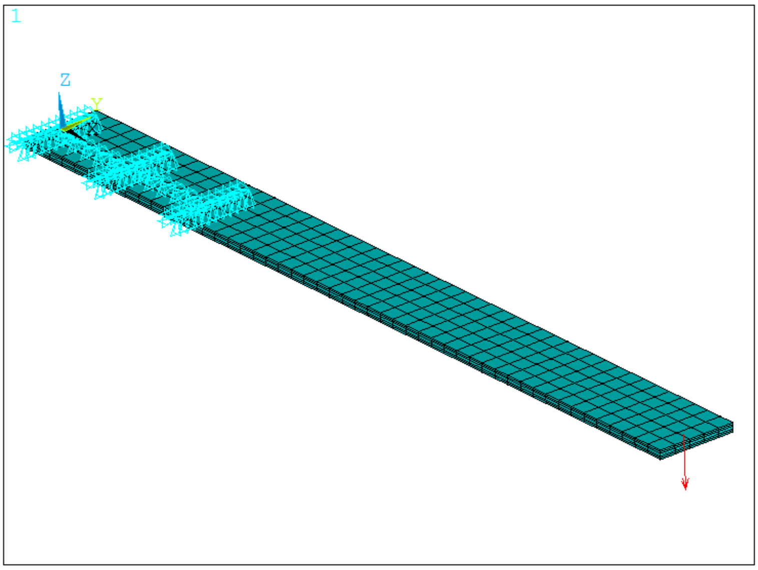

Fig. 6. Finite element model of the specimen and the loads' definition

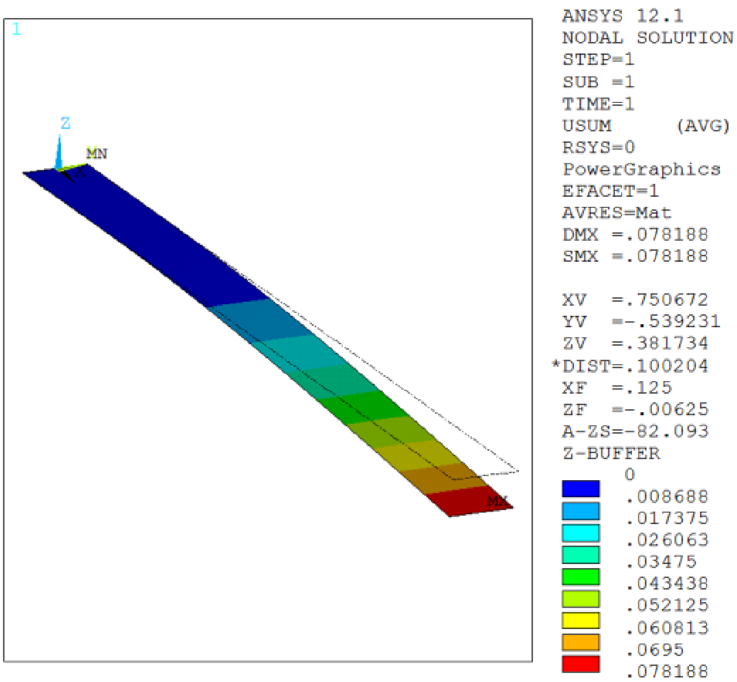

Fig. 7. Sample displacement vector sum for 50 N bending

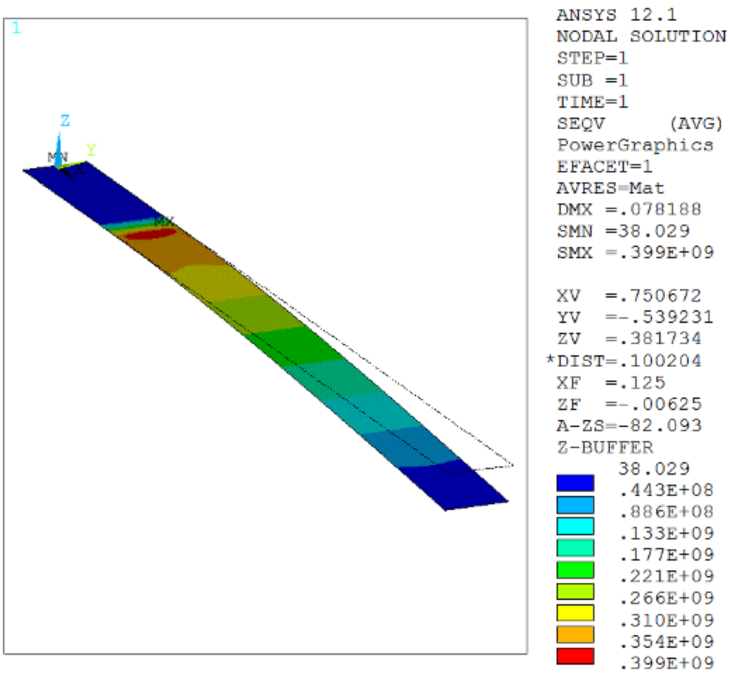

Fig. 8. von Misses stress for 50 N bending

The FEA results are presented in the table below.

Table 3. FEA results

Force, N	Displacement, mm
10	16
20	31
30	47
40	62
50	78

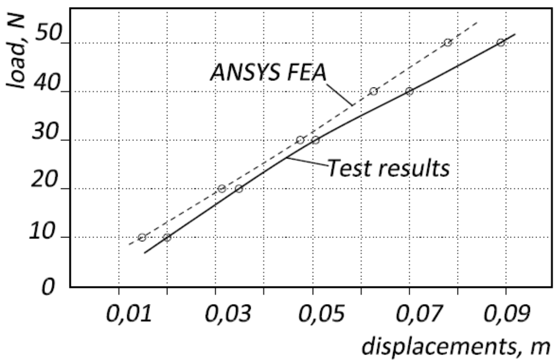

Fig. 9. The comparison of the testing analysis and the numerical results for the displacements

The comparison of the test results and the finite element analysis results are shown in Fig. 9.

4. CONCLUSIONS

The difference between the measured displacements and the simulated ones is about 20%. The cause of such a difference could be the ply input data inaccuracy.

Using the rule of mixture, correct values can be obtained for the material properties of layered unidirectional composite.

From the results of numerical analysis, the following facts have been observed:

- for the middle layer of CSM, the linear isotropic material properties do not affect the specimen FEA results. For tensile modulus E_{11} equal to 1 and Poisson's ratio equal to 0.1, the same results were obtained as the values given in Table 2. What matters is the thickness of this layer.

REFERENCES

1. **Banu M.,** 2007, Tehnologia Materialelor Compozite (Technology of Composite Materials) (in Romanian), pp. 41-46. Available from (18/11/2011), http://www.scribd.com/doc/39170376/ Tehnologia-Materialelor-Compozite.
2. **Burton T., Sharpe D.,** 2001, Blade materials and properties, Wind energy handbook, John Wilei&Sons, LTD, pp. 381-358, West Sussex, England.
3. **Gay D. et at.,** 2003, Composite Materials Design and Applications, CRC Press, pp. 216-225.
4. **Hermann Thomas M. et al.**, 2006, Fabrication, Testing and Analysis of Anisotropic Carbon/ Glass Hybrid Composites. Volume 1: Technical Report, Sandia National Laboratories, pp. 12-24.
5. **Madenci E., Guven I.,** 2006, The Finite Element Method and Applications in Engineering Using Ansys, Springer, pp. 397-403.
6. **Nakasone Y. et al.,** 2006, Engineering Analysis With ANSYS Software, Elsevier, pp. 52-75.
7. **Rosato Donald V., Rosato, Dominick V.**, 2004, Reinforced Plastics Handbook, 3rd edition. Elsevier Science, pp 956-996.
8. **Vasiliev Valery V., Morozov E.,** 2001, Mechanics and Analysis of Composite Materials, Elsevier Science, pp. 121-256.
9. **Wetzel Kyle K. et al.,** 2006, The WEI6K, a 6-kW 7 m Wind Turbine, Final Technical Report, pp. 25-35.