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RESPONSE ANALYSIS OF WEIGHT-BALANCEND COMPOSITE LAMINATES SUBJECTED TO BENDING LOADS

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Abstract: *Four types of composite laminates based on thermoset resin reinforced with roving glass fibers fabrics and mat structure, presenting different specific weights have been taken into account to analyze their response to bending loads. Sets of ten weight-balanced specimens for each type of composite material, manufactured at Compozite Ltd., Brasov have been tested on a LR5K Plus materials testing machine from Lloyd Instruments using the three-point bend method and NEXYGEN Plus software. Load-deflection distributions as well as stiffness, flexural rigidity and Young's modulus of bending have been recorded and plotted in boxplot representations using the MATLAB software. The experimental analysis put into evidence that the eight layers of MAT300 composite laminate presents more than double flexural rigidity towards the other composite laminates taken into consideration.*
Keywords: *composites, bending, stiffness, flexural rigidity, deflection*

1. INTRODUCTION

In the last decades, extended researches have been carried out on fibers-reinforced polymer matrix composites (PMCs) subjected to a variety of loadings. Pre-impregnated composite materials like Sheet Molding Compounds having short glass fibers as well as chopped strand mats composites have been taken into analysis to determine their elastic properties [1], [2]. Not only short glass fibers but also continuous fibers disposed in mats and roving glass fabrics are used as reinforcement element to increase the overall mechanical properties of PMCs [3 – 5]. Some references deal with the action of short-time cyclic loadings on three and multiphase polymer matrix composites subjected to various test speeds and having various cyclic limits. The hysteresis effect of these materials has also been determined [6], [7]. The finite element analysis as well as modeling and simulations of various loadings in case of a wide range of composite laminates including natural composites are used [8 – 10]. Experimental researches both on glass and carbon fibers reinforced PMCs with various applications have been carried out showing the advantage of using carbon fibers in applications where high stiffness and strength are significant requests [11 – 15]. Thermoplastic based composites with applications in the water supply networks have been also mechanically characterized in references [16], [17].

2. MATERIAL SAMPLE DEFINITION

The experimental determination has been made using four types of structural, composite laminates, weight-balanced grouped by specific weight as the Table 1 is showing; each set of material containing ten specimens. Structurally, they are a combination between a thermoset polymer and different numbers of glass fibers fabric plies as reinforcement element. The material acronym suggests the shape and orientation of fibers within structure, *RT* marking an ordinate grid displacement, while *MAT* category describes mats of short glass fibers with random distribution. The samples have been manufactured at Compozite Ltd., Brasov using the hand lay-up process respecting the SR EN ISO 14125 standard.

Table 1: Samples material definition

Material	No. of plies	Specific weight (g/m^2)
RT800	3	800
RT500	5	500
RT300	8	300
MAT300	8	300

Water cooled diamond powder mill has been used to cut the specimens at the right size and shape, avoiding any possibility of internal stress inclusion. Figure 1 represents the initial state of MAT300 samples before testing.

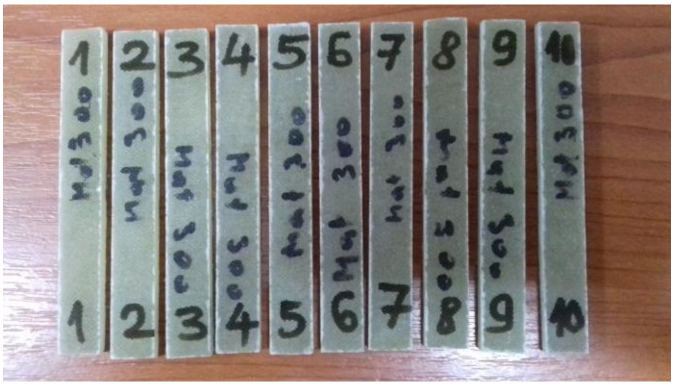

Figure 1: MAT300 specimen's geometric characterization (courtesy of Compozite Ltd., Brasov)

3. TESTING METHOD AND RESULTS

Testing and data results acquisition has been made using as equipment the LR5KPlus materials testing machine (5 kN load cell) manufactured by Lloyds Instruments and the NEXYGEN Plus software. The specimen has been placed on two supporting exterior pins, from the top being pressed by a third loading pin which is connected with the mobile part of the testing machine. The three-point bend test method, presented by SR EN ISO 14125 standard, has been used to load the weight-balanced composites with a test speed of 10 mm/min in the compression direction, as Fig. 2 is showing, generating a shear force and a bending moment in material. For each set of material, maximum load versus deflection at maximum load curves have been drawn using the MATLAB software for comparison and behavior analysis (see from Figs. 3 to 6).

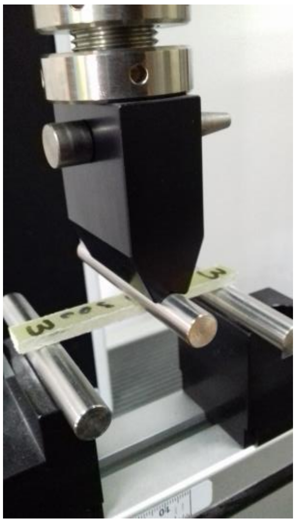

Figure 2: Specimen alignment in the machine test set-up before testing

By analyzing the curves of the graphs, it has been clearly defined that the lowest bending stress performance we can find it in the composite laminates reinforced with RT800 glass fibers fabrics in three plies. Most of samples tested has been broken at forces around 200-220 N, the deflection being within interval 10-14 mm. The RT500 and RT300 reinforcement fabrics are showing values between 220 and 300 N load at maximum load with deflections reaching 7 to 11 mm. Similarities are found also in the shape of curves and failure mode. A special case could be considered the specimens obtained by association between thermoset polymer and eight layers of MAT300 reinforcement glass fibers mat; the interval of deflection values at maximum load (5-7 mm) together with the load values easily over 330 to 400 N are demonstrating an enhanced behavior of this material type among rest of them (Fig. 5). It is important to mention that there is significant influence of glass fibers orientation in the reinforcement element, the random distribution being superior to grid displacement when the compression force is applied perpendicularly.

In Fig. 7 we have been compared and grouped using boxplot representation the stiffness, flexural rigidity and Young's modulus of bending of tested structural composite laminates.

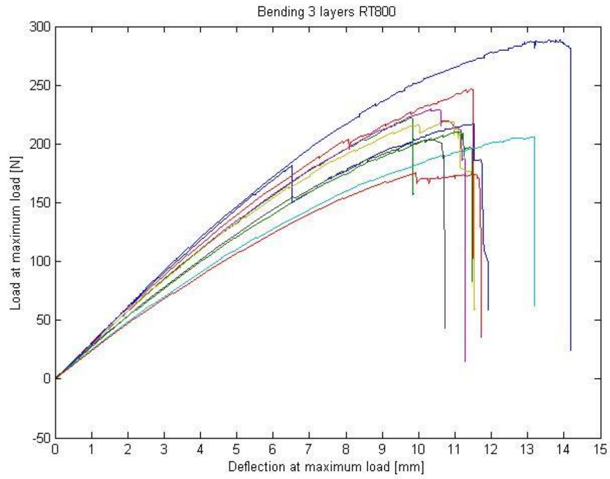

Figure 3: Load-deflection distribution of three layers RT800 composite laminate under bending loads

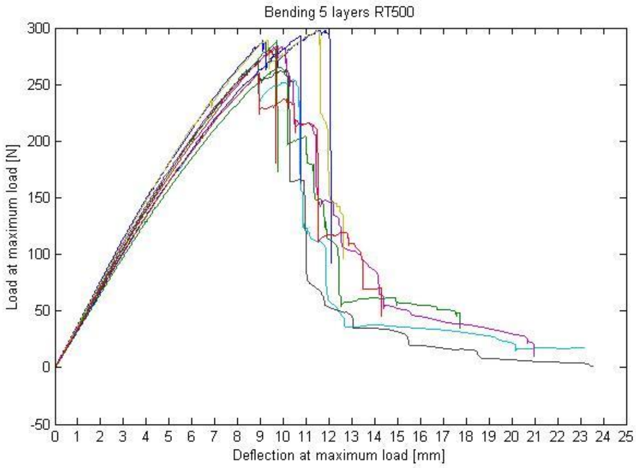

Figure 4: Load-deflection distribution of five layers RT500 composite laminate under bending loads

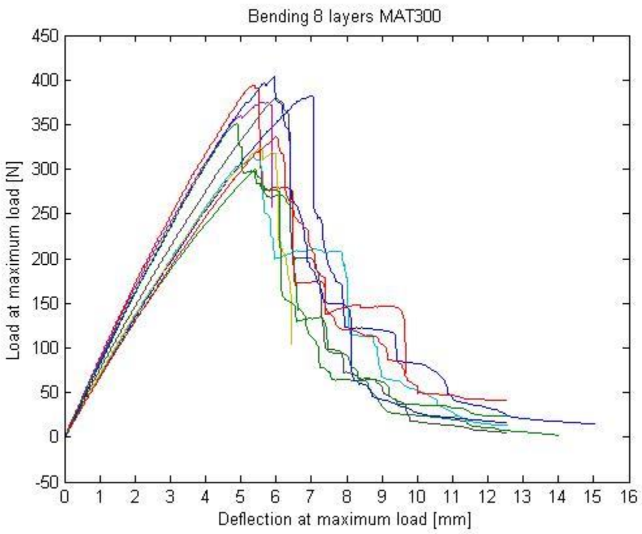

Figure 5: Load-deflection distribution of eight layers MAT300 composite laminate under bending loads

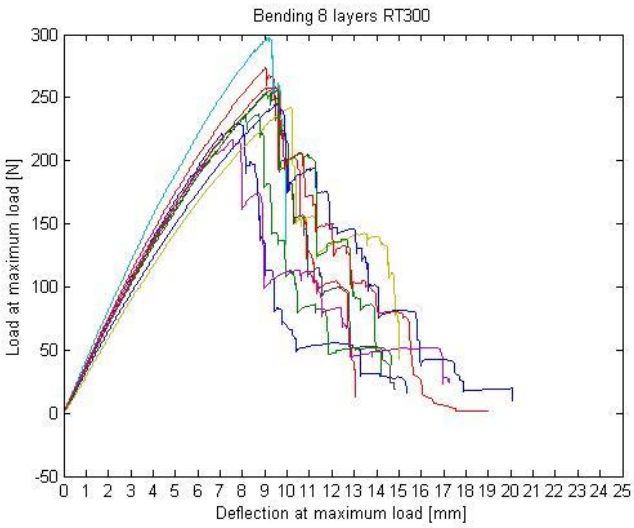

Figure 6: Load-deflection distribution of eight layers RT300 composite laminate under bending loads

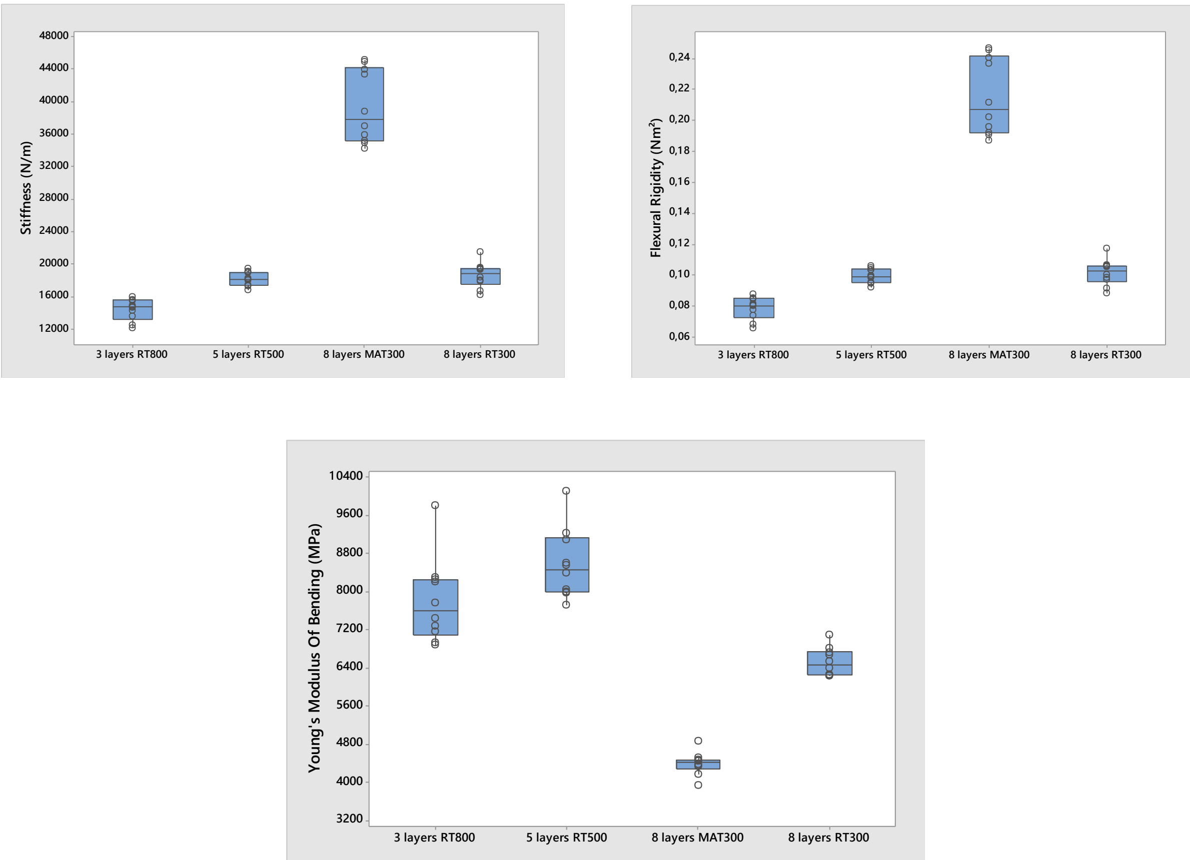

Figure 7: Stiffness, Flexural rigidity and Young's modulus of bending of four weight-balanced composite laminates, in boxplot representation

By far away the eight layers MAT300 is leading in terms of stiffness and flexural rigidity characteristics as an addition to the graphic represented in Fig. 5, observing a significant difference between it and the rest of materials. On the other hand, RT500 in five layers and RT300 in eight layers are working in the same range of values having a high grade of similarity. The measure of how material stiffness resists when a perpendicular force is applied called flexural modulus, also known as bend modulus, is defining the relation between stress and strain in the elastic region of composites subjected to bending. Looking in the graphic, the MAT300 differentiates by the rest of weight-balanced structures by relatively low values of bend modulus, between 3800-4800 MPa. The RT800 and RT500 fabrics given interval values which are overlaying, without any significant difference, hence the elastic behavior of materials is similar.

The most common failure mode of specimens is described by Fig. 8, the material breaking appearing in the closest region of force applying, the sections having the aspect of a paint brush, where the broken glass fibers are exposed.

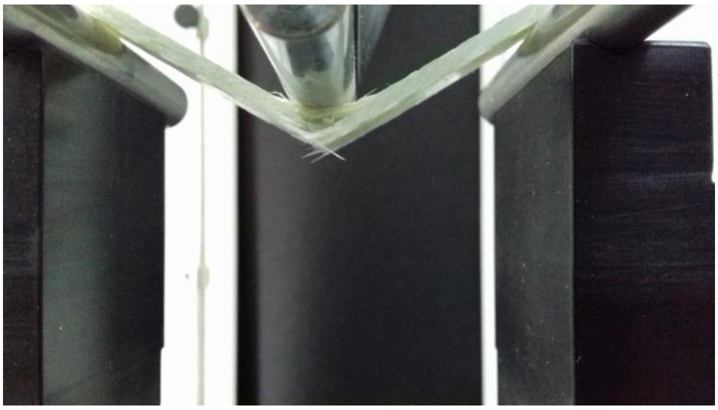

Figure 8: Specimen failure mode after testing (8 layers MAT300)

4. CONCLUSION

The orientation and the shape of reinforcement element in the structure of weight-balanced composite laminates has a crucial role in the material response supposed to bending loads. The eight layers of MAT300 differentiates by high values of load and relatively small deflections, compared with RT's category, observing and increase of performance with 25%. This statement is sustained by obtained stiffness and flexural rigidity characteristics values two times bigger than RT fabrics reinforcement, which are working in the same ranges with a high grade of similarity.

REFERENCES

[1] Teodorescu-Draghicescu, H., Vlase, S., Homogenization and Averaging Methods to Predict Elastic Properties of Pre-Impregnated Composite Materials, Comp. Mater. Sci., 2011, 50, 4, 1310-1314.

[2] Stanciu, A., Teodorescu-Draghicescu, H., Vlase, S., Scutaru, M.L., Călin, M.R., Mechanical Behavior of CSM450 and RT800 Laminates Subjected to Four-Point Bend Tests, Optoelectron. Adv. Mat., 2012, 6, 3-4, 495-497.

[3] Vlase, S., Purcarea, R., Teodorescu-Draghicescu, H., Calin, M.R., Szava, I., Mihalcica, M., Behavior of a new Heliopol/Stratimat300 composite laminate, Optoelectron. Adv. Mat., 2013, 7, 7-8, 569-572.

[4] Modrea, A., Gheorghe, V., Sandu, V., Teodorescu-Draghicescu, H., Mihalcica, M., Scutaru, M.L., Study of a New Composite Material Rt800 Reinforced with Polyte 440-M888 in Endurance Conditions, Procedia Technology, 2016, 22, 182-186.

[5] Teodorescu-Draghicescu, H., Gheorghe, V., Munteanu, R., Szava, I., Modrea, A., Advanced RT300 Glass Fabric/Polylite Composite Laminate Simulation, Procedia Engineering, 2017, 181, 293-299.

[6] Teodorescu-Draghicescu, H., Vlase, S., Scutaru, L., Serbina, L., Calin, M.R., Hysteresis Effect in a Three-Phase Polymer Matrix Composite Subjected to Static Cyclic Loadings, Optoelectron. Adv. Mat., 2011, 5, 3, 273-277.

[7] Vlase, S. Teodorescu-Draghicescu, H., Motoc, D.L., Scutaru, M.L., Serbina, L., Călin, M.R., Behavior of Multiphase Fiber-Reinforced Polymers Under Short Time Cyclic Loading, Optoelectron. Adv. Mat., 2011, 5, 4, 419-423.

[8] Vlase, S. Teodorescu-Draghicescu, H., Călin, M.R., Serbina, L., Simulation of the Elastic Properties of Some Fibre-Reinforced Composite Laminates Under Off-Axis Loading System, Optoelectron. Adv. Mat., 2011, 5, 4, 424-429.

[9] Teodorescu-Draghicescu, H., Stanciu, A., Vlase, S., Scutaru, L., Călin M.R., Serbina, L., Finite Element Method Analysis Of Some Fibre-Reinforced Composite Laminates, Optoelectron. Adv. Mat., 2011, 5, 7, 782-785.

[10] Stanciu, M.D., Ardeleanu, A.F., Teodorescu-Draghicescu, H., Reverse engineering in finite element analysis of the behaviour of lignocellulosic materials subjected to cyclic stresses, Procedia Manufacturing, 2018, 22, 65-72.
[11] Vlase, S., Teodorescu-Draghicescu, H., Călin, M.R., Scutaru, M.L., Advanced Polylite composite laminate material behavior to tensile stress on weft direction, J. Optoelectron. Adv. M., 2012, 14, 7-8, 658-663.
[12] Teodorescu-Draghicescu, H., Scutaru, M.L., Rosu, D., Calin, M.R., Grigore, P., New Advanced Sandwich Composite with twill weave carbon and EPS, J. Optoelectron. Adv. M., 2013, 15, 3-4, 199-203.
[13] Modrea, A., Vlase, S., Teodorescu-Draghicescu, H., Mihalcica, M., Calin, M.R., Astalos, C., Properties of Advanced New Materials Used in Automotive Engineering, Optoelectron. Adv. Mat., 2013, 7, 5-6, 452-455.
[14] Heitz, T., Teodorescu-Draghicescu, H., Lache, S., Chiru, A., Calin, M.R., Advanced T700/XB3585 UD carbon fibers-reinforced composite, J. Optoelectron. Adv. M., 2014, 16, 5-6, 568-573.
[15] Teodorescu-Draghicescu, H., Vlase, S., Stanciu, M.D., Curtu, I., Mihalcica, M., Advanced Pultruded Glass Fibers-Reinforced Isophtalic Polyester Resin, Mater. Plast., 2015, 52, 1, 62-64.
[16] Scutaru, M.L., Teodorescu-Draghicescu, H., Vlase, S., Marin, M., Advanced HDPE with increased stiffness used for water supply networks, J. Optoelectron. Adv. M., 2015, 17, 3-4, 484-488.
[17] Teodorescu-Draghicescu, H., Scarlatescu, D., Vlase, S., Scutaru, M.L., Nastac, C., Advanced high-density polyethylene used in pipelines networks, Procedia Manufacturing, 2018, 22, 27-34.