JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 15, No.3 - 4, March – April 2013, p. 176 - 181

A new epoxy glass roving fabric material with a nonwoven PES fibers structure used in a composite laminates

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This paper deals with experimental researches regarding the behavior of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates subjected to tensile loads until break. The reinforcement material is a 300 g/m^2 specific weight biaxial [0°/90°] glass roving fabric with a nonwoven PES fibers structure. From cured plates of one, two and three layers of epoxy 1050 resin impregnated GBX300L-1250 glass fabric, various specimens have been cut according to SR EN ISO 527-4:2000: "Plastics - Determination of tensile properties - Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites". Over forty-five mechanical properties have been determined during tensile tests including: Young's modulus, stiffness, load/stress/strain at maximum load/extension, load/stress/strain at minimum load/extension, load/stress/strain at break, tensile strength, elongation at fracture and so on.

(Received July 30, 2012; accepted April 11, 2013)

Keywords: Epoxy resin, Glass fabric, Tensile test, Composite laminate, Young's modulus

1. Introduction

The one axis tensile test is appreciated to be the most important as well the most used from static tests due to its simplicity to obtain some strength and stiffness features. Mechanical properties of a fiber-reinforced composite material are strongly influenced by the reinforcement material, matrix type, fibers volume fraction as well as fibers disposal embedded in the matrix material [1], [2]. Any fibers-reinforced composite material is manufactured from at least two components: matrix (usually a thermosetting resin) and "endless" fibers in various types, shapes and specific weights. There is a huge variety of fiber-reinforced composites. A special class of polymer matrix composites is the pre-impregnated composite materials (called also prepregs). The prepregs are three-phase composite materials with short fibers (usually up to 50 mm length glass fibers) randomly disposed in a thermosetting resin as well as a filler (usually calcium carbonate). To predict the elastic properties of a three-phase prepreg, homogenization as well as averaging methods can be used. For instance, for a 27% fibers volume fraction Sheet Molding Compound (SMC), the Young's and shear moduli have been computed using averaging and homogenization methods. The comparison between theoretical approach and experimental data shows a good agreement between the two approaches [3]. Some experimental researches regarding the mechanical behavior of three-phase polymer matrix composites subjected to static cyclic tension-compression loadings have been carried out. Composite specimens have been subjected to various numbers of cycles, different load limits and test speeds [4], [5]. Theoretical approaches regarding the simulation of elastic properties of various types of polymer matrix laminates are presented in references [6-9].

2. Material and method

Plates of one layer (0.8 mm thickness), two layers (1.2 mm thickness) and three layers (1.2 mm thickness) of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates have been cured in an autoclave (Fig. 1).

Fig. 1. Curing autoclave from Belco Avia Ltd.

From each type of plate, eight specimens have been cut using a diamond powder drill and subjected to tensile loads until break occurs. The tensile tests have been carried out on an LS100Plus universal materials testing machine produced by Lloyd Instruments, which presents following features:

- Force range: up to 100 kN;
- Test speed accuracy: < 0.2%;
- Load resolution: < 0.01% from the load cell used;
- Displacement resolution: < 0.1 µm;
- Type of load cell: XLC-100K-A1;
- Type of extensometer used: Epsilon Technology;
- Length between extensometer's lamellae: 50 mm;
- Software: NEXYGEN Plus.

Some tensile test features and specimens dimensions are presented in table 1.

Table 1. Tensile test and specimens features

Feature	Value
Gauge length (mm)	150
Preload/stress (kN)	0.0056
Preload/stress speed (mm/min)	21
Test speed (mm/min)	1
Specimens width (mm)	25
Specimens thickness (mm)	0.8/1.2
Specimens cross-sectional area (mm^2)	20/30

3. Results

Distributions of Young's modulus, stiffness, tensile strength, strain at maximum extension, strain at break, load at break, machine extension and mean test time of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates are presented in Figs. 1-12.

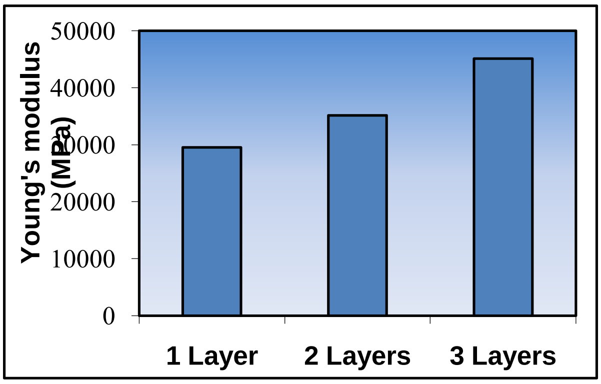

Fig. 2. Young's modulus distribution of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

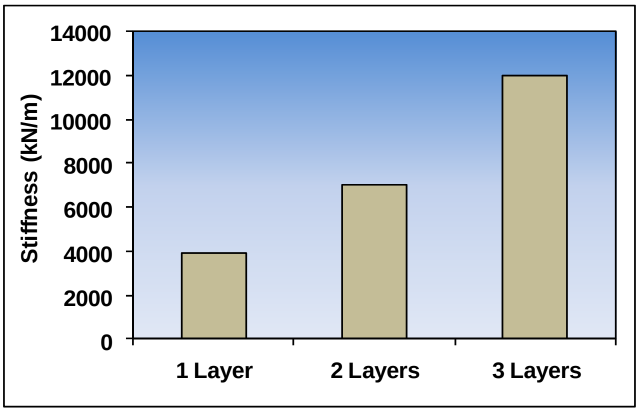

Fig. 3. Stiffness distribution of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates.

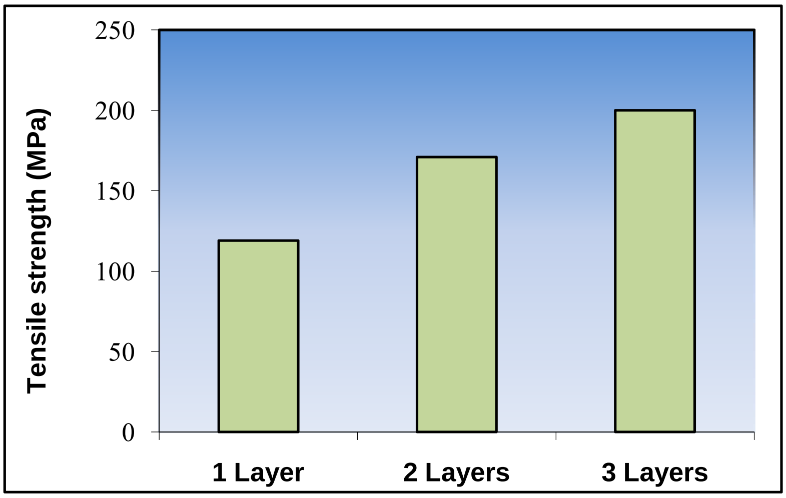

Fig. 4. Tensile strength distribution of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

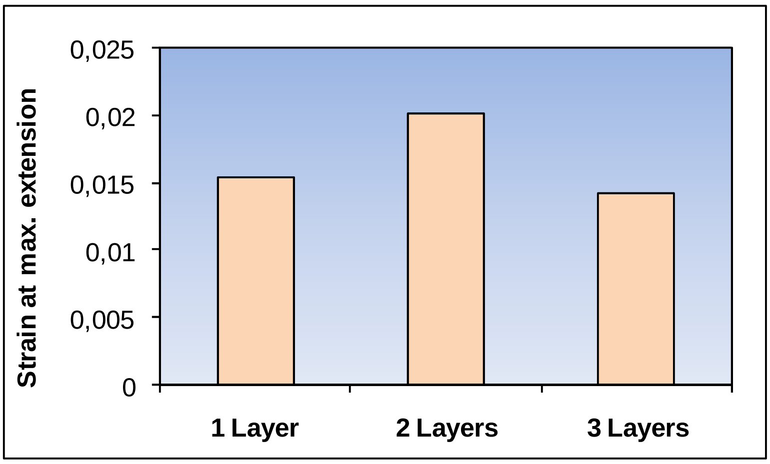

Fig. 5. Strain at maximum extension distribution of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

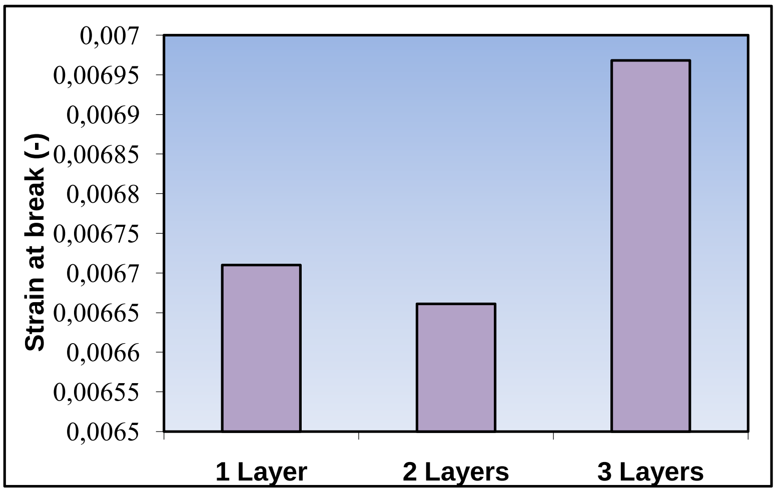

Fig. 6. Strain at break distribution of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

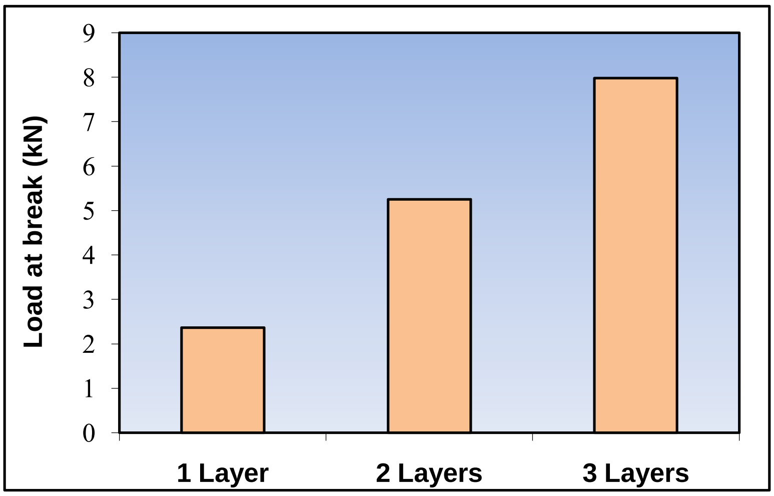

Fig. 7. Load at break distribution of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

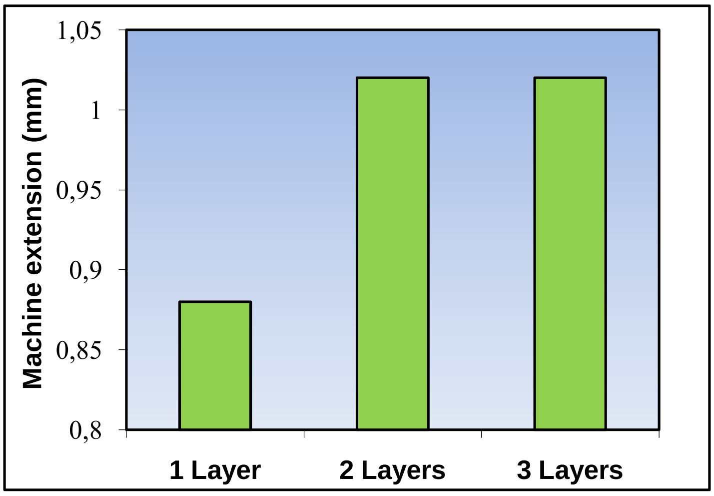

Fig. 8. Machine extension distribution of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

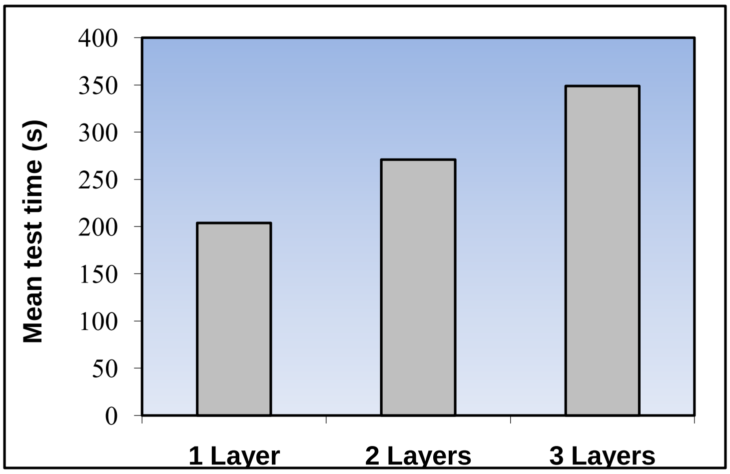

Fig. 9. Mean test time distribution of one, two and three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

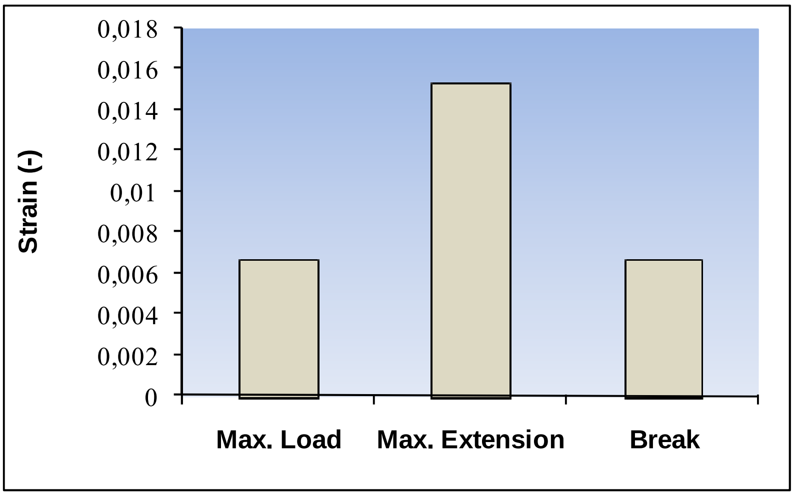

Fig. 10. Different strains distribution of one layer of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

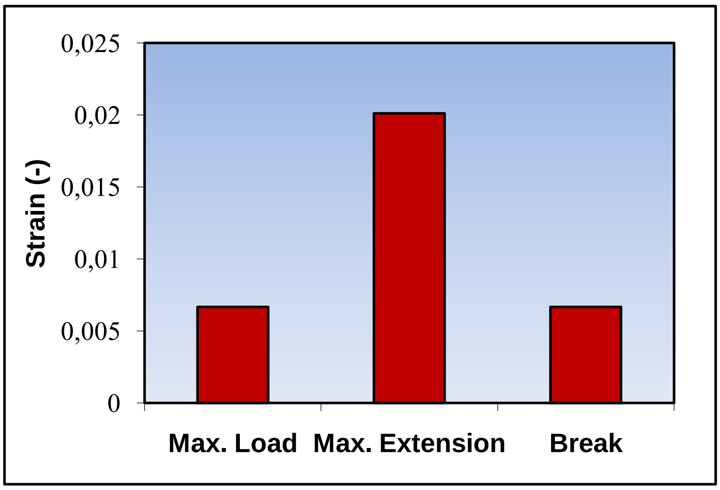

Fig. 11. Different strains distribution of two layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

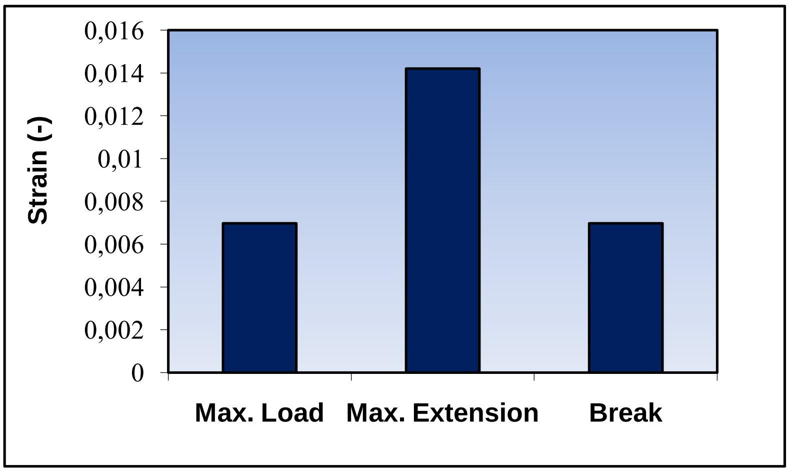

Fig. 12. Different strains distribution of three layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates

4. Discussion

Young's modulus, stiffness, load at maximum break, machine extension and tensile strength show increased distributions with the increase of number of layers. Strain at maximum extension presents a maximum value in all three types of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates. Strains at maximum load and break present half values unlike the strains at maximum extension ones. A special strain at break distribution can be noticed in Fig. 6 where the value of strain in case of two layers laminate is lower than the strain at break in case of one layer laminate. Maximum stress distribution between 100 and 200 MPa versus percentage strain of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates is presented in Fig. 13. Between 0.62 and 0.63% strain the maximum stress distribution presents a less steep slope.

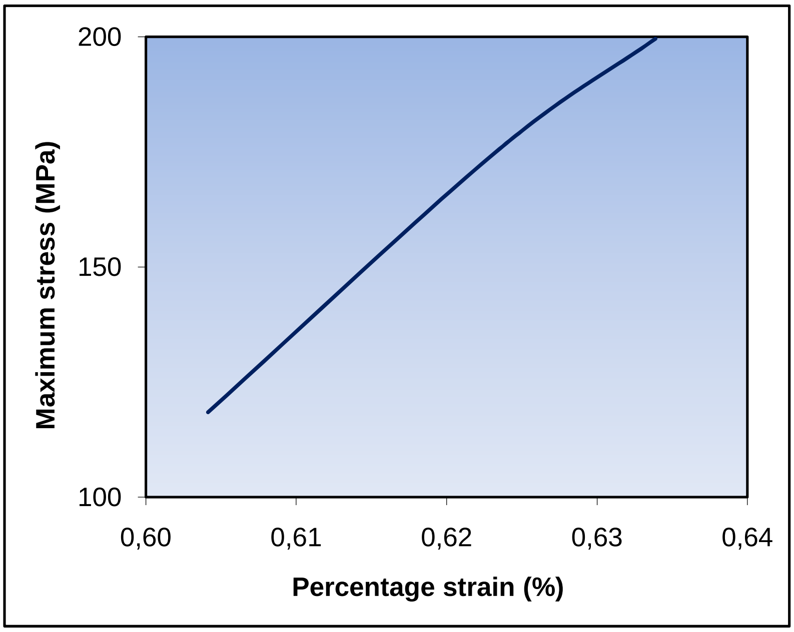

Fig. 13. Maximum stress distribution versus percentage strain of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates (one, two and three layers)

5. Conclusions

The biaxial GBX300L-1250 glass fabric represents an excellent choice to reinforce quite large types of thermosetting resins. This kind of reinforcement can be used to obtain laminates for all kind of applications where the loads can be applied in perpendicular directions. The maximum stress distribution versus percentage strain of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates (one, two and three layers) can be compared with a polynomial distribution with following equation:

$y = - 5x^2 + 60x + 60$ ($R^2 = 1$).

The Young's modulus distribution with the increase of number of layers shows a polynomial distribution with following equation:

$y = - 200\, x^2 + 2900x + 8800$ ($R^2 = 1$).

Acknowledgements

This paper issupported by the Sectorial Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/89/1.5/S/59323.

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