Mechanical behavior of epoxy 1050_GBX300L-1250 glass fabric laminates subjected to three-point bend tests

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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 three-point bend tests. 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 five, six and seven layers of epoxy 1050 resin impregnated GBX300L-1250 glass fabric; various specimens have been cut. Following mechanical properties have been determined during three-point bend tests: Young's modulus of bending, stiffness, flexural rigidity, maximum normal stress/strain in bending at maximum and minimum load/deflection, load/stress/strain at maximum and minimum load/deflection and so on.

(Received February 3, 2012; accepted April 11, 2012)

Keywords: Epoxy resin, Glass fabric, Three-point bend test, Young's modulus of bending, Flexural rigidity

1. Introduction

The objectives of the paper are the determination of the mechanical properties of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates subjected to three-point bend tests. The three-point bend test represents the second important mechanical test after tensile test, in which a material or structure can be characterized. Nowadays, the four-point bend test is increasingly used. There is a huge variety of fiber-reinforced composites. 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. 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 [6-7].

2. Material and method

Plates of five layers (2.8 mm thickness), six layers (3.0 mm thickness) and seven layers (3.4 mm thickness) of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates have been cured in an autoclave below the glass transition temperature of the material (Fig. 1). Various specimens have been cut according to ISO 14125:1998 [8].

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 three-point bend tests. The tests have been carried out on a "Texture Analyzer TA Plus" universal materials testing machine produced by Lloyd Instruments, which presents following features:

- Force range: up to 1 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-1K-A1;
- Software: NEXYGEN Plus.

Some three-point bend test features and specimens dimensions are presented in Table 1.

Table 1. Three-point bend test and specimens features.

Feature	Value
Span (mm)	40
Specimens width (mm)	10.8
Test speed (mm/min)	5
Five layers thickness (mm)	2.8
Six layers thickness (mm)	3.0
Seven layers thickness (mm)	3.4

3. Results

Distributions of Young's modulus of bending, stiffness, maximum load, maximum extension, maximum stress of five, six and seven layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates are presented in Figs. 2-6. Other specific features are presented in Figs. 7-12.

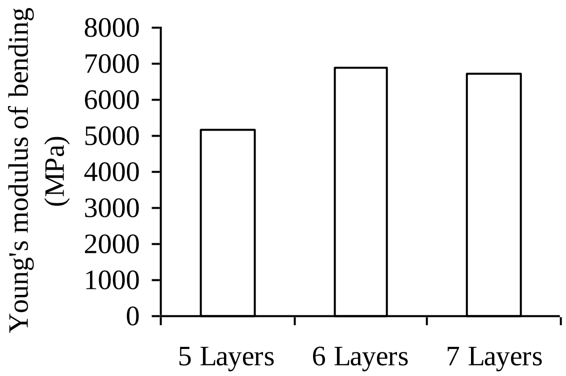

Fig. 2. Young's modulus of bending distribution of five, six and seven layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates.

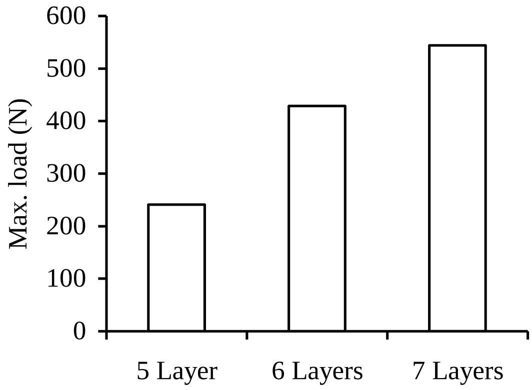

Fig. 3. Maximum load distribution of five, six and seven layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates.

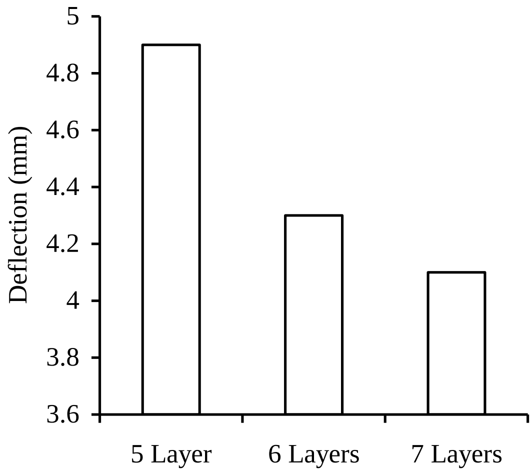

Fig. 4. Maximum deflection distribution of five, six and seven layers of biaxial GBX300L-1250 glass fabric - reinforced epoxy 1050 resin laminates.

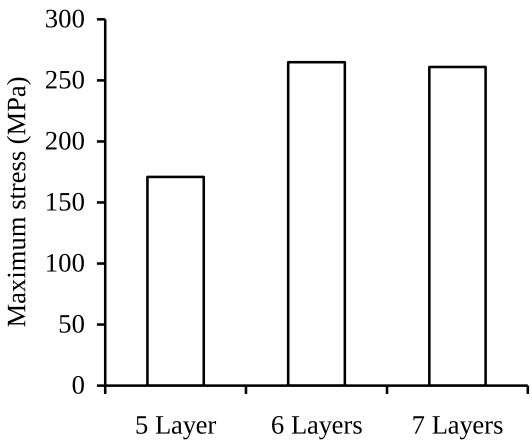

Fig. 5. Maximum stress distribution of five, six and seven layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates.

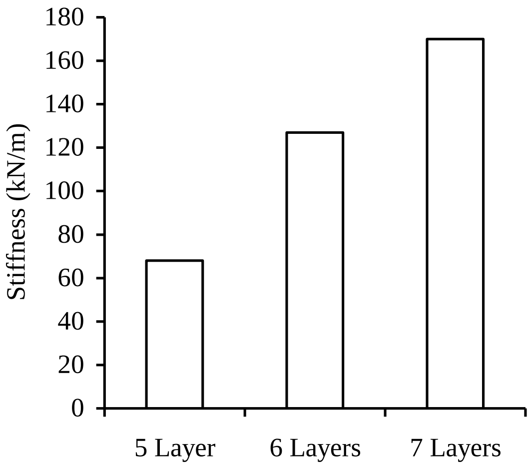

Fig. 6. Stiffness distribution of five, six and seven layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates.

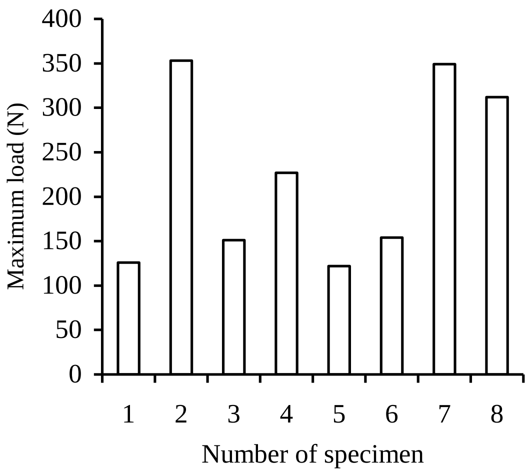

Fig. 7. Maximum load distribution of five layers of biaxial GBX300L-1250 glass fabric - reinforced epoxy 1050 resin laminates.

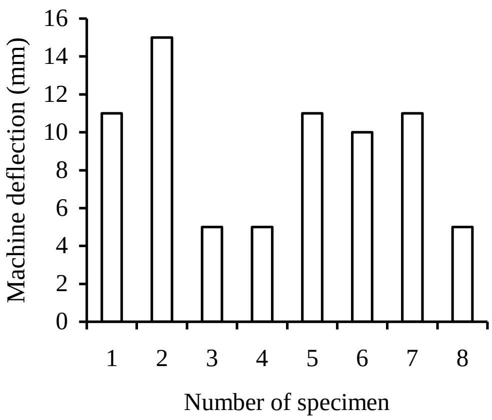

Fig. 8. Machine deflection distribution of six layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates.

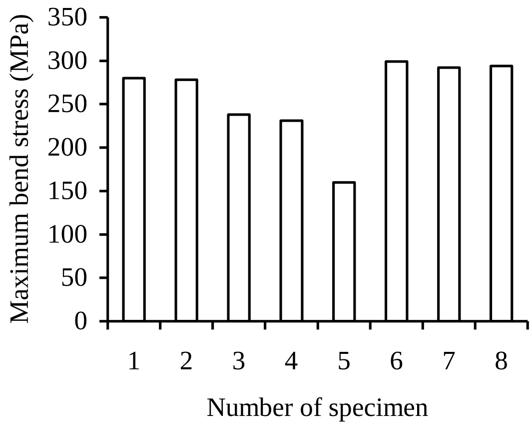

Fig. 9. Maximum normal stress in bending distribution of seven layers of biaxial GBX300L - 1250 glass fabric-reinforced epoxy 1050 resin laminates.

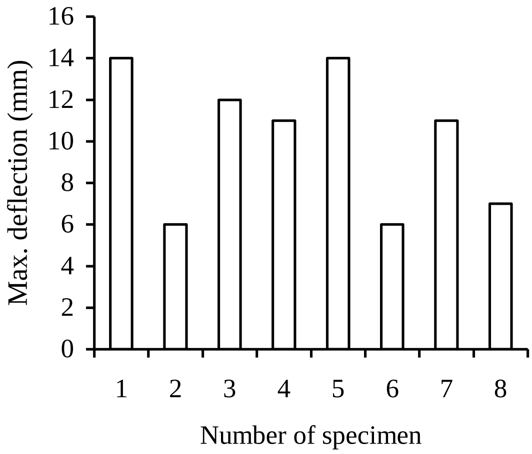

Fig. 10. Maximum deflection distribution of five layers of biaxial GBX300L-1250 glass fabric - reinforced epoxy 1050 resin laminates.

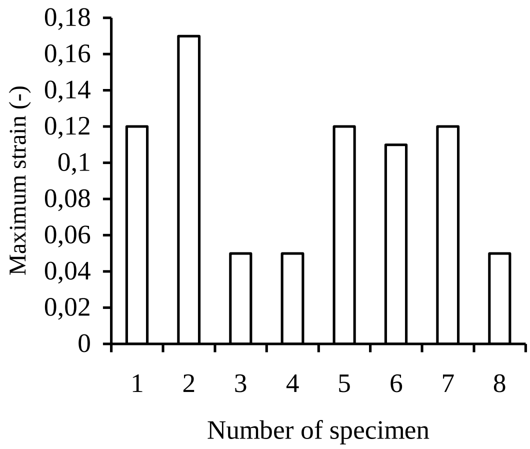

Fig. 11. Maximum strain distribution of six layers of biaxial GBX300L-1250 glass fabric - reinforced epoxy 1050 resin laminates.

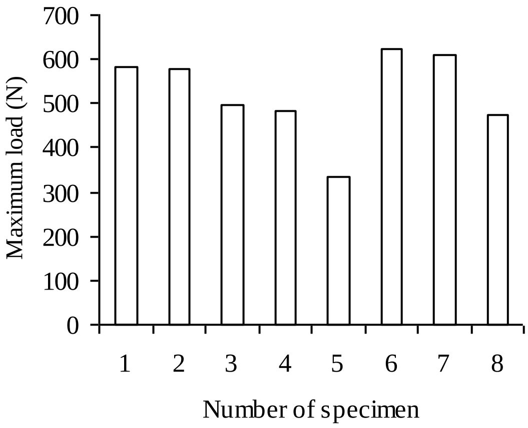

Fig. 12. Maximum load distribution of seven layers of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin laminates.

4. Discussion

As shown in Figs. 3 and 6, the maximum load and stiffness distributions present an increased tendency with the increase of layers. The term "stiffness" represents the ratio between load and deflection. The maximum deflection distribution presents a decreased tendency in all three types of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates (Fig. 4). The distributions of Young's modulus of bending and maximum stress show an increased distribution with the increase of layers but from a certain number of layers these distributions remain almost constant (Figs. 2 and 5). During the three-point bend tests, the variation of Young's modulus of bending versus the load presents an increased tendency up to a maximum of 450 N load, then this variation decreases. The maximum stress variation versus the extension presents a short increase up to a maximum of 4.2 mm extension and from this peak value this variation decreases. All three types of biaxial GBX300L-1250 glass fabric-reinforced epoxy 1050 resin composite laminates have presented variations in their thickness and therefore the results obtained in three-point bend tests present scattered values.

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. To increase the overall stiffness of a composite laminate, a nonwoven polyester mat can be introduced between the laminate's layers.

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