Mechanical behavior of CSM450 and RT800 laminates subjected to four-point bend tests

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Within this paper, three types of composite laminates have been subjected to four-point bend tests using the resistive stress analysis: 4 layers epoxy reinforced chopped strand mat of 450 g/m^2 specific weight (denoted epoxy/4CSM450), 4 layers epoxy reinforced glass roving fabric of 800 g/m^2 specific weight on warp direction (denoted epoxy/4RT800U) and 4 layers epoxy reinforced glass roving fabric of 800 g/m^2 specific weight on weft direction (denoted epoxy/4RT800B). Between these layers, three strain gages have been applied and connected to a Spider8 device. Distributions of load versus time as well as specific deformation versus time for all three types of composite laminates have been experimental determined in four-point bend tests using the CATMAN software.

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1. Introduction

Epoxy reinforced composite laminates are usually used in a wide range of composite structures. As reinforcement, glass fibers in form of chopped strand mats and roving fabrics of various specific weights are commonly used [1]. One of the most important problems in manufacturing of composite structures is to ensure them a good stiffness. There are many methods to increase the overall stiffness of a composite laminate. One method is to choose an appropriate way to orient the fibers in a laminate, to obtain an equal stiffness in any direction a load can be exerted. Many simulations have been carried out on different composite laminates with various fibers disposal angles and off-axis loading systems [2]. Even for pre-impregnated composite materials, known as prepregs, the Young's and shear moduli can be predicted using averaging and homogenization methods. An interesting approach in this direction is described in reference [3]. For a great importance in the characterization of composite structures is not only the tensile test but also the cyclic tension-compression test. For three-phase composite laminates as well as for RT glass fibers-reinforced structures the static cyclic tension-compression tests have been used to determine the hysteresis effect. Various numbers of cycles and test speeds have been carried out [4-5]. Simulations regarding the distributions of Young's modulus and shear modulus as well as the Poisson ratio versus the fibers disposal angle in a composite laminate have been carried out. Some combinations of thermosetting resins and glass, carbon and Kevlar fibers with various plies sequences subjected to various off-axis loading systems have been used in the some theoretical approaches [6]. Other theoretical approaches include the use of the finite element method to determine the most important features of commonly used epoxy based laminates with various forms of glass fibers [7].

2. Material and method

Three types of specimens have been cut from cured plates obtained in the hand lay-up process:

- Four layers epoxy reinforced chopped strand mat of 450 g/m^2 specific weight (denoted epoxy/4CSM450);
- Four layers epoxy reinforced glass roving fabric of 800 g/m^2 specific weight on warp direction (denoted epoxy/4RT800U);
- Four layers epoxy reinforced glass roving fabric of 800 g/m^2 specific weight on weft direction (denoted epoxy/4RT800B).

Between the layers of all these types of composite laminates, strain gages have been applied and connected to a SPIDER8 device suitable for resistive stress analysis (Fig. 1). All specimens have been subjected to pure bending up to 1000 N load, using the four-point bend test. The distributions of load versus time as well as specific deformations versus time have been experimentally determined using the CATMAN software.

Fig. 1. Specimen connected to SPIDER8 device.

For instance, the epoxy/4CSM450 specimens with three strain gages applied between layers and three compensation strain gages have been connected to the SPIDER8 device and subjected to four-point bend test using a special device designed especially for this purpose (Fig. 2).

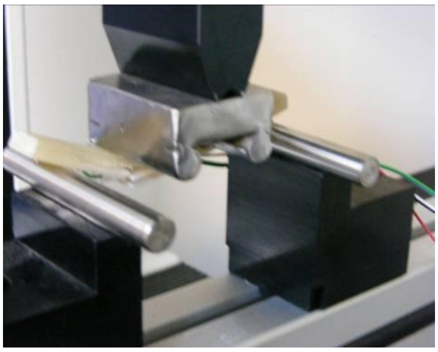

Fig. 2. Epoxy/4CSM450 specimen subjected to four-point bend test.

3. Results

Using the resistive stress analysis, the distributions of load versus time and the specific deformation versus time have been experimentally determined and presented in Figs. 3-8 for all types of composite laminates.

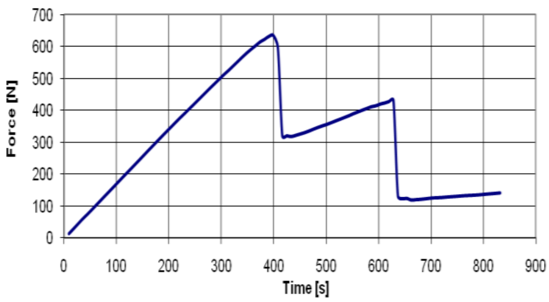

Fig. 3. Load versus time for epoxy/4CSM450 specimens subjected to four-point bend test.

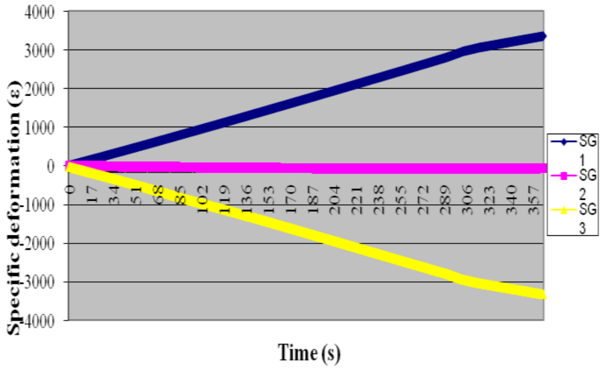

Fig. 4. Specific deformation versus time for epoxy/4CSM450 specimens in four-point bend test.

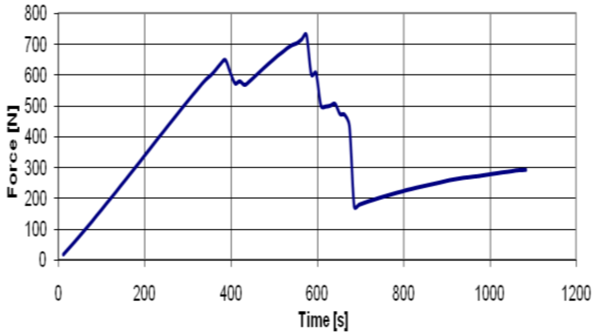

Fig. 5. Load versus time for epoxy/4RT800U specimens subjected to four-point bend test.

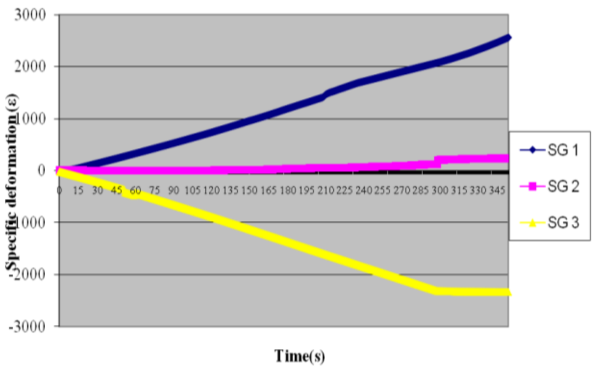

Fig. 6. Specific deformation versus time for epoxy/4RT800U specimens in four-point bend test.

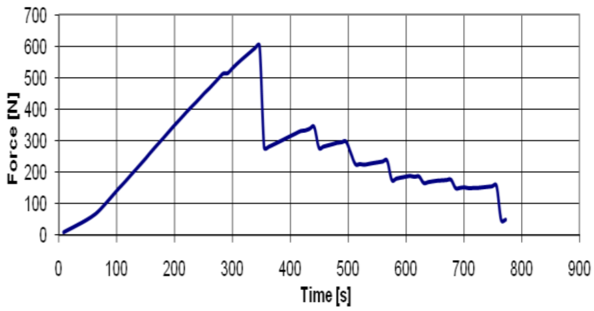

Fig. 7. Load versus time for epoxy/4RT800B specimens subjected to four-point bend test.

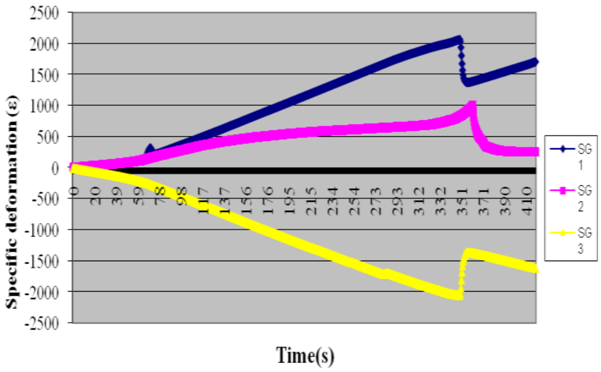

Fig. 8. Specific deformation versus time for epoxy/4RT800B specimens in four-point bend test.

4. Discussion

In case of the epoxy/4CSM450 specimen with three strain gages and three compensation strain gages, subjected to four-point bend test, it has been noticed that the stress at strain gage number 3 is close to stress value determined at strain gage number 1. The stress at strain gage number 2 is almost zero because the strain gage is positioned close to the neutral axis of the specimen. The stresses in the outer layers are equal in module (namely some of them are subjected to tension and some of them are subjected to compression). The strains measured with the strain gages are according to the layers where they have been applied. The maximum strains on the outer layers have not been measured with the strain gages. The specific deformation has been determined on each single layer. During the four-point bend test of this kind of specimen, following data have been obtained:

- Maximum load at bending: 630 N;
- Time from the beginning of the test: 365 s.

At the SPIDER8 device using the CATMAN software, following specific deformations have been determined:

- At strain gage number 1: 0.03355;
- At strain gage number 2: - 0.00058;
- At strain gage number 3: - 0.03318.

In case of the epoxy/4RT800U specimen with three strain gages and three compensation strain gages, subjected to four-point bend test, following data have been determined:

- Maximum load at bending: 725 N;
- Time from the beginning of the test: 353.5 s.

Using the SPIDER8 device using the CATMAN software, following specific deformations have been determined:

- At strain gage number 1: 0.02565;
- At strain gage number 2: 0.00235;
- At strain gage number 3: - 0.02336.

In case of the epoxy/4RT800B specimen with three strain gages and three compensation strain gages, subjected to four-point bend test, following data have been obtained:

- Maximum load at bending: 603 N;
- Time from the beginning of the test: 346.6 s.

At the SPIDER8 device using the CATMAN software, following specific deformations have been experimentally determined:

- At strain gage number 1: 0.01744;
- At strain gage number 2: 0.00255;
- At strain gage number 3: - 0.01616.

Due to the anisotropy of the epoxy/4RT800 specimens, it can be noticed that the maximum load at bending in case of epoxy/4RT800U specimen is greater than the analogue value in case of epoxy/4RT800B specimen. For epoxy/4RT800B specimen, the maximum load at bending is even lower than the analogue value in case of epoxy/4CSM450 specimen.

5. Conclusions

Embedding strain gages between the layers of a composite laminate, helps the determination of material's behavior especially between the layers with more accuracy. This method allowed a complete analysis of the specific deformations between the layers of composite laminates.

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