OPTOELECTRONICS AND ADVANCED MATERIALS – RAPID COMMUNICATIONS Vol. 7, No. 5-6, May - June 2013, p. 452 - 455

Properties of advanced new materials used in automotive engineering

A. MODREA[a], S. VLASE[b,*], H. TEODORESCU-DRAGHICESCU[b], M. MIHALCICA[b], M. R. CALIN[c], C. ASTALOS[d]
[a]*PETRU MAIOR University, Faculty of Engineering, Mechanical Engineering Department Târgu Mures,*
[b]*Transilvania University of Brasov, Department of Automotives and Mechanical Engineering,*
29 Eroilor Blvd, 500036 Brasov, Romania,
[c]*"Horia Hulubei" National Institute for Physics and Nuclear Engineering - IFIN HH, P.O. Box MG-6, 077125, Magurele, Romania,*
[d]*Product Design GmbH, Germany*

To use composites in design of car components, their mechanical properties are for a great importance. A calculation of the stresses and loads of parts manufactured from composites can be carried out. To determine their mechanical properties, theoretical models can be used. Bearing in mind the differences in the charges of composite materials, even when the same manufacturer produces them, an experimental research is required on these materials. Within this paper, mechanical properties of glass fiber-reinforced HDPE and LDPE as well as carbon fiber-reinforced epoxy resin have been determined experimentally using three-point bend tests.

(Received December 12, 2012; accepted June 12, 2013)

Keywords: Three-point bend test, Composites, Mechanical properties, Glass fibers, High-density polyethylene

1. Introduction

Glass fiber-reinforced plastics and composites are frequently used in car building. They are used to replace metals, which are generally expensive and lack in properties. To introduce these materials in the structure of a car, strength calculations need to be carried out, which imply knowledge of mechanical properties. The main methods used in calculations are presented in [1], [2]. In practice, however, results differ from real values, which is because it is impossible to control adequately technological manufacturing processes. As a result, it is necessary to determine experimentally the values of engineering constants. To determine the mechanical characteristics of these types of materials bending tests were applied, more specifically the three-point bend test [3-8].

2. Specimen types used

The method used to determine bending properties is according to Romanian Standard SR ISO 178 and follows other standardized requirements as well. Testing equipment must be in accordance with ISO 5893.

Specimens' dimensions must follow the standard for the given material. The recommended type of specimen has following characteristics:

- Length $l = 80 \pm 2$;
- Width $b = 10.0 \pm 0,2$;
- Thickness $h = 4.0 \pm 0.2$.

Regardless of the specimen, the central thickness, over a third of the length should not vary by more than 2% from its mean value. The maximum width variation is 3%. The cross-section must be rectangular and have no rounded edges. During tests following composite materials have been studied:

- Glass fiber-reinforced HDPE and LDPE subjected to pull tests and three-point bend tests;
- Glass fabric-reinforced polyester resin cut on warp direction subjected to three-point bend tests;
- Glass fabric-reinforced polyester resin cut on weft direction subjected to three-point bend tests;
- Carbon fiber-reinforced epoxy resin subjected to three-point bend tests.

Specimens manufactured according to specified standards have been used in pull and three-point bend tests. Figs. 2 and 3 present a series of specimens manufactured of glass fiber-reinforced LDPE (low-density polyethylene). An identical series of specimens have been manufactured of glass fiber-reinforced HDPE (high-density polyethylene). They have been grouped according to the type of test used, in more sample sets, each of them being of ten specimens and a few spares for each sample set. When breaks occurred at the ends, a spare has replaced the specimens.

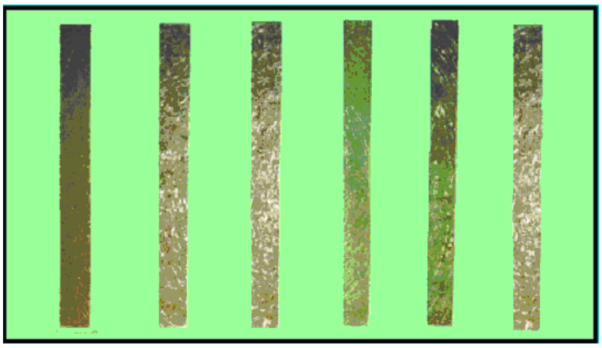

Fig. 1. Glass fiber-reinforced HDPE Polyester for three-point bend tests.

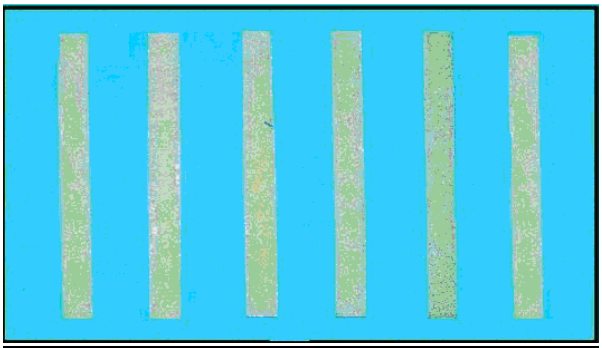

Fig. 2. Glass fiber-reinforced LDPE polyester for three-point bend tests.

Sample sets of ten specimens each, have been manufactured to be bend-tested for a material manufactured from carbon fiber-reinforced resin (Fig. 3).

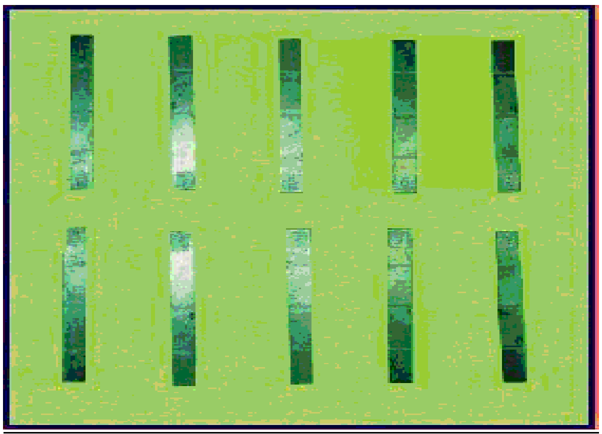

Fig. 3. Specimens made of carbon-fiber reinforced resins for the bend test.

Glass fabric-reinforced polyester specimens have been cut on warp direction and subjected to three-point bend tests (Fig. 4).

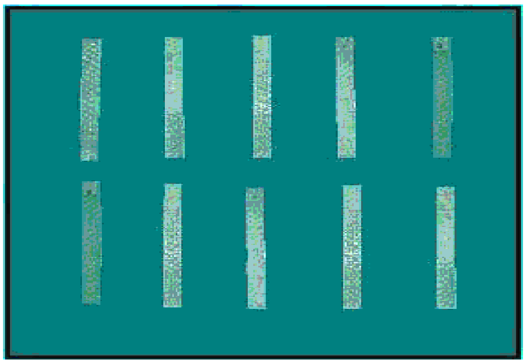

Fig. 4. Glass fabric-reinforced resin specimens cut on warp direction, for bending tests (FSMU).

3. Calculation and expression of results

Bending load σ_f for a load F is computed in [MPa], using the formula:

$$\sigma_f = \frac{M}{W} \tag{1}$$

where: M is the bending momentum for force F, given by the formula:

$$M = \frac{F \cdot L}{4} \tag{2}$$

W is the inertia modulus of the straight section in [mm^3], given by:

$$W = \frac{b \cdot h^2}{6} \tag{3}$$

In the previous formulae, F is the force applied, expressed in [N], L is the distance between the supporting blocks, in [mm], b and h are the width and thickness of the section expressed in [mm]. It follows then that the bending load is given by the relation:

$$\sigma_f = \frac{3F \cdot L}{2b \cdot h^2} \tag{4}$$

To determine the bending elasticity modulus E_b, a deflection curve is sketched. Starting from the linear section of the curve and using at least five values of the deflection line and of the force for the specimen, the elasticity modulus is computed. E_b is given by the formula:

$$E_b = \frac{L^3}{2bh^2} \frac{\Delta F}{\Delta d} \tag{5}$$

where: E_b - elasticity modulus [MPa];
L - distance between supporting blocks [mm];
B - width of specimen [mm];
h - thickness of specimen [mm];
ΔF - force variation of the initial straight line of the deflection curve [N];
Δd - deflection variation corresponding to force variation ΔF [mm].

The bending load corresponds to the surface of the specimen, supposing the neutral line at mid-thickness. During bend tests three types of breaks can occur:

a) surface pull breakage;
b) surface compression breakage;
c) inner shear breakage due to load.

For each specimen the breakage type is indicated. If breakage types differ, the values of bending loads are no longer statistically homogeneous and the results must be evaluated carefully. They were grouped according to the type of test used, into more sample sets, made of ten specimens each with a few spares in each sample set. When breaks occurred at the ends, a spare from the sample set replaced the specimens.

4. Experimental determination and discussion

Specimens FSMB-1 to FSMB-10 were bend-tested and the graphs present information about two of the tested specimens. They formed test set S01 (Figs. 5-6).

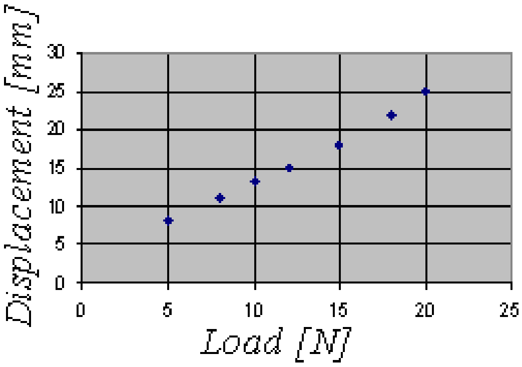

Fig. 5. Representation of the graph force-deformation for samples FSMB-1.

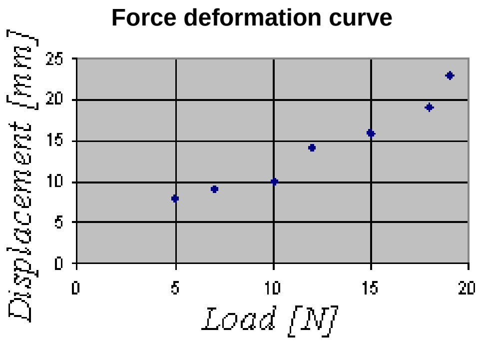

Fig. 6. Force-deformation distribution for samples FSMB-2.

Next, the tests results for glass fiber-reinforced resin specimens FCM, series S03 are presented (Table 1).

Table 1. Results for specimens' series S03.

No. of specimens = 10	Mean value
Force [N]	56.4
Deflection [mm]	6.07
Mean admitted square variation– force	9.02
Mean admitted square variation– deflection	0.94

Tests results for glass fiber-reinforced resins, test series S04 are presented in Table 2.

Table 2. Results for specimens' series S04.

No. of specimens = 10	Mean value
Force [N]	20.9
Deflection [mm]	24.9
Mean admitted square variation – force	1.85
Mean admitted square variation - deflection	1.66

The results of glass fabric-reinforced resin specimens FSMU, test series S05 are shown in Table 3.

Table 3. Results for specimens' series S05.

No. of specimens = 10	Mean value
Force [N]	28.5
Deflection [mm]	19.6
Mean admitted square variation – force	3.53
Mean admitted square variation - shift	1.07

The span between stocks was L=130 mm. The values obtained for the bending elasticity modulus were, respectively: E_{S03} = 30734 MPa; E_{S04} = 3717.88 MPa; E_{S05} = 5088.99 MPa. It follows that carbon-fiber reinforced resins have the highest elasticity modulus and the glass fabric-reinforced resins, cut on weft have an elasticity modulus 50% greater than those cut on warp.

The force necessary to break the specimens is quite small due to the matrix material. Specimens were fixed on stocks to obtain comparable results. Some specimens broke at the fixing ends. In these cases, another specimen was used from the spares so that the number of tests would remain the same, ten for each test series.

Aspects of breakage section are presented in Figs. 8-10.

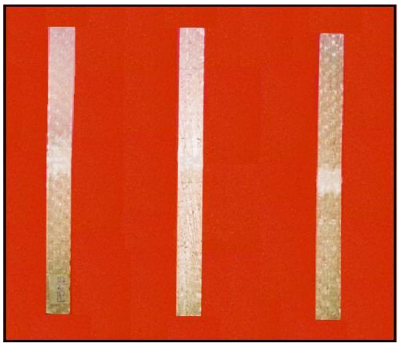

Fig. 7. Specimens of glass fabric-reinforced resin cut on warp direction subjected to three-point bend tests.

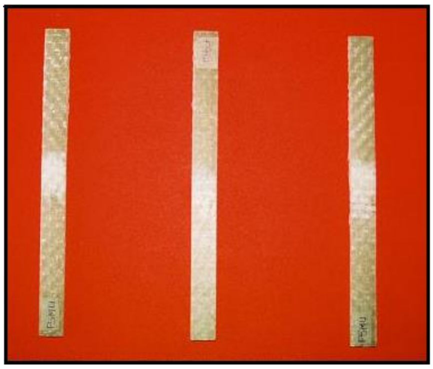

Fig. 8. Broken specimens of glass fabric- reinforced resin cut on weft direction.

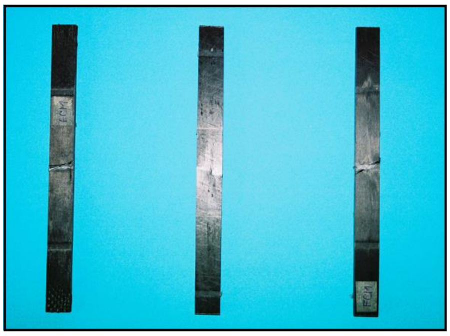

Fig. 9. Carbon fiber-reinforced resin specimens subjected to three-point bend tests.

The geometric characteristics of the tested specimens are presented in Table 4.

Table 4. Geometric features of the tested specimens.

Material	Width b [mm]	Thickness h [mm]	Area [mm^2]
FCM	16.4	4.5	73.8
FCT	10.5	4.5	47.25
FSMB	15.5	4.0	62
FSMU	15.5	4.5	69.75
FS 45^o	10	4.3	43
FSB	10	4.5	45
FSU	10	4.5	45

3. Conclusions

Glass fiber-reinforced resin specimens broke through fibers pulled-out in the breaking section. These specimens present a good bond of the fibers to the matrix shown in the fibers break. The breaks of specimens manufactured of glass fiber-reinforced polyester are finer, which means that the bond between the fibers and matrix broke and the composite behavior is weaker than in the previous example.

Calculations made for the analyzed specimens compared to experimental results show that specimens, theoretical values are significantly different than those obtained experimentally [2]. Due to the relative important differences that can appear, it is required to check theoretical results by performing simple mechanical tests to determine mechanical constants experimentally.

Three-point bending as well as pull tests are cheap and quick methods to determine the mechanical characteristics of fiber-reinforced composite materials.

Acknowledgements

This paper is supported 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.

References

[1] N. D. Cristescu, E. M. Craciun, E. Soos, Mechanics of elastic composites, Chapman & Hall/CRC, (2003).
[2] A. Modrea, Ph.D. Thesis, TRANSILVANIA University of Brasov, (2005).
[3] H. Teodorescu-Draghicescu, S. Vlase, Computational Materials Science **50**(4), 1310 (2011).
[4] H. Teodorescu-Draghicescu, S. Vlase, L. Scutaru, L. Serbina, M. R. Calin, Hysteresis, Optoelectron. Adv. Mater. – Rapid Commun. **5**(3), 273 (2011).
[5] S. Vlase, H. Teodorescu-Draghicescu, D.L. Motoc, M. L. Scutaru, L. Serbina, M. R. Calin, Optoelectron. Adv. Mater. – Rapid Commun. **5**(4), 419 (2011).
[6] S. Vlase, H. Teodorescu-Draghicescu, M.R. Calin, L. Serbina, Optoelectron. Adv. Mater. – Rapid Commun. **5**(4), 424 (2011).
[7] H. Teodorescu-Draghicescu, A. Stanciu, S. Vlase, L Scutaru, M. R. Calin, L. Serbina, Optoelectron. Adv. Mater. – Rapid Commun. **5**(7), 782 (2011).
[8] S. Vlase, H. Teodorescu-Drăghicescu, M. R. Calin, M. L. Scutaru, J. Optoelectron. Adv. Mater. **14**(7- 8), 658 (2012).

*Corresponding author: svlase@unitbv.ro