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INFLUENCE OF MANUFACTURING TECHNOLOGY ON MECHANICAL CHARACTERISTICS OF POLYMERIC COMPOSITE MATERIALS

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Abstract: *Manufacturing processes have a significant influence on the quality, productivity and competitiveness of polymer composite structures. This paper proposes to highlight the influence of manufacturing processes on the mechanical properties determined by compression test. Plates from reinforced fiber glass polymer composites obtained by hand lay-up and compression hand lay-up technology were studied. Also, the paper gives a mathematical model of the influence of structure on the compressive strength of bidirectional composites that use a regression analysis using a polynomial model. It is important to know the compressive strength and its dependence on the degree of reinforcement and the orientation angle of reinforcement material, because it gives information about the mechanical behavior of composite structure. Dependence of compression strength is determined by theoretical and experimental researches, using regression analysis of active experiment.*
Key words: *composite, fiber glass, hand lay-up, compression, polynomial model.*

1. INTRODUCTION

Composite materials represent a priority domain because nowadays the importance of pieces realized from these kinds of materials is growing, thanks to performances/cost characteristics and excellent mechanical and thermal properties reported at weight.

Composite materials represent a category of engineering materials that present special scientific and technical interest [1], [2].

Nowadays, on a worldwide level have been distinguished meaningful changes regarding the use of composite materials in different industrial branches, from household objects to aero spatial parts of high mechanical resistance [3], [4], [5].

These are the first materials that have the internal structural disposal conceived by the human that confers them favorable resistance [6].

For mathematical modeling of the structure influence on fracture strength of the bidirectional composite was used a regression analyze that used a polynomial model. Nonlinear mathematical model of 2nd order of compression strength can be expressed in a polynomial form [7], [8], such:

$$\sigma_c = a_0 + a_1 M_f + a_2 \theta + a_{11} M_f{}^2 + \\ + a_{12} M_f \theta + a_{22} \theta^2 \qquad (1)$$

where: σ_c - compression strength of unidirectional composites [MPa] – objective function; θ - angle between fibers direction in composite and stress direction [deg.] – independent variable; M_f - reinforcement degree [%] - independent variable; $a_0, a_1, a_2, a_{11}, a_{12}, a_{22}$ - unknown coefficients.

2. COMPRESSION STRENGTH DETERMINATION

The samples were cut from the composite plates using a diamond disc, having rectangular form. The compression tests of the composite were performed on the universal testing machine type Instron 1196.

The machine is equipped with an automatic recording system of variation force diagram

during the request, and force measurement is performed with a piezo-electric force transducer.

Specimen was embedded in two metal blocks and from total length of the specimen remaining 10 mm portion of the test. At the ends of the test-part aluminum protection were mounted. This prevents the damage of the composite material during compression. They were fixed by sticking with a structural epoxy glue of type *Bison Epoxy Universal*.

For compression tests were taken 5 samples from each plate.

Test speed was of 2 mm/min, and for failure resistance at compression (σ_c) we reported the maximum force where failure occurred at required sectional area, using the relationship:

$$\sigma_c = \frac{F_{max}}{S} \quad [MPa] \qquad (2)$$

where: F_{max} - maximum compression load at specimen failure, [N]; S – initial transverse sectional area of the specimen, [mm^2].

Compression tests were performed at temperature of 20 ºC.

The values of the forces can be read on the diagrams delivered of the press.

3. EXPERIMENTAL RESULTS

Here are presented the experimental researches realized to distinguish the mechanical features of composite structures made of bidirectional glass fiber fabric and polyester matrix. To determine the elastic constants and the mechanical resistances of composite plates was done experimental trials at compression. The experimental obtained data served at elaboration of mathematical models regarding the influence of the structure on compression resistance of bidirectional composite material.

It is very important to know the resistance at compression trial σ_c and its dependence on reinforcement degree M_f and angle of orientation θ of reinforced material, because give us indications regarding mechanical behavior of the composite structure [9]. The dependence of the resistance at compression trial is established at theoretical-experimental way using the regression analyze of active experiment.

The experimental researches were done on composite plates with bidirectional fibers, BD 450 g/m^2 / Polyester Lerpol TIX 3603/R. The experiments have consisted of compression trials, where the fibers were inclined at angles of 0º, 45º, and respectively 90º in report with the stress direction [10]. In Table 1 are presented the experimental results.

Table 1

The experimental results

No. Exp.	θ [grd.]	M_f [%]	σ_r [MPa] BD 450 g/m^2 / Polyester Lerpol TIX 3603/R
1.	0º	52	236,4
2.	0º	62	250,6
3.	0º	71	274
4.	45º	52	109
5.	45º	62	105
6.	45º	71	104
7.	90º	52	241
8.	90º	62	263
9.	90º	71	280

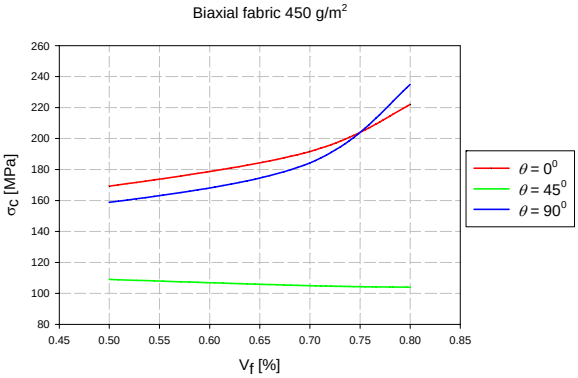


Fig. 1. Variation of compression strength in function of reinforcement degree for biaxial composite with 8 layers

From experimental results obtained for biaxial fiberglass fabric 450 g/m^2, Table 1, was drawn graphics compression strength variation in function reinforcement degree, fig. 1.

It was found that, when reinforcement was oriented at 0°, external force was taken by the

fibers, and when reinforcement was oriented at 45° it was found that external force was taken both fiber and matrix due to unfavorable fibers orientation.

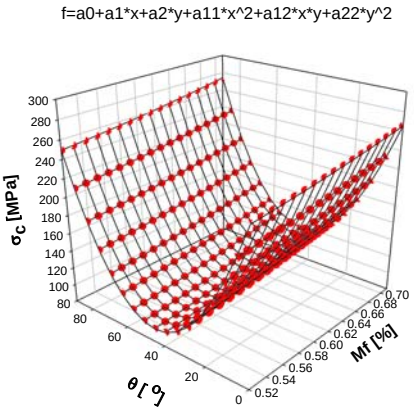
4. MATHEMATICAL MODEL

For mathematical model of structure influence on resistance at failure for bidirectional composite was used a regression analyze that utilized a polynomial model. From the generated reports by the program, mathematical models were obtained for compression strength of studied materials, equation 3.

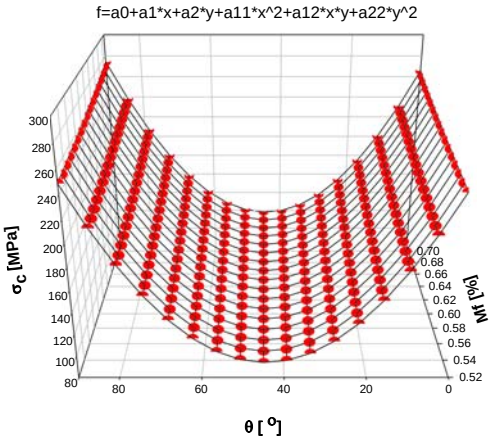
$$\sigma_c = 254{,}48 - 128{,}56\, M_f - 6{,}71\theta + \\ + 203{,}12\, M_f{}^2 + 0{,}09\, M_f\, \theta + 0{,}07\, \theta^2 \qquad (3)$$

The obtained models were graphically represented with the help of SigmaPlot 10.0. Software, figure 2, a and b. We can observe that the resistance at compression trial presents a maximum of 280 MPa (Table 1) in function of angle between fibers orientation in composite and trial direction. Attributing constant values to the reinforcement degree, the model can be converted in a function of one variable, that is $\sigma_c = f(\theta)$.

In polymeric matrixes case is important to realize a good adhesion between this and reinforced elements because the reinforced system take a big part from mechanical trials applied on composite. If the trials are strong, the fibers will break first and then the matrix [11].



a.



b.

Fig. 2. Graphical representation of the mathematical model of the resistance at compression trial.

On the base of the presented mathematical model before calculating the resistance at compression trial of bidirectional laminate in function of fibers reinforcement grade M_f and reinforcement angle θ. Those two structural characteristics have varied in intervals for that the mathematical model was done, $M_f \in [50 \ldots 70]\%$ and $\theta \in [0° \ldots 90°]$.

5. CONCLUSIONS

In this paper were presented the results of the experimental researches done on composite plates with bidirectional fibers, BD 450 g/m^2 / Polyester Lerpol TIX 3603/R. The experiments have consisted of compression trials, where the fibers were inclined at angles of 0º, 45º, and respectively 90º in report with the trial direction. The data obtained through mechanical trials for composite plates with bidirectional fibers served at elaboration of mathematical model regarding the structure characteristics influence on resistance at compression trial of bidirectional composite. It is remarking that the failure resistance at compression trial of the bidirectional composite declines meaningful for a fibers orientation angle bigger than 0º and 90º.

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INFLUENŢA PROCESULUI DE FABRICAŢIE ASUPRA CARACTERISTICILOR MECANICE ALE MATERIALELOR COMPOSITE POLIMERICE

Rezumat: *Procesele de fabricaţie au o influenţă semnificativă asupra calităţii, productivităţii şi competitivităţii structurilor compozite polimerice. În această lucrare se propune evidenţierea influenţei proceselor de fabricaţie cu privire la proprietăţile mecanice determinată prin încercarea de compresiune. Au fost studiate placi compozite polimerice armate cu fibre de sticlă obţinute prin procedeul de formare manuală şi formare manuala cu presare. De asemenea, lucrarea oferă un model matematic a influenţei structurii asupra rezistenţei la compresiune a compozitului bidirecţional care utilizează o analiză de regresie ce a utilizat un model polinomial. Este important să se cunoască rezistenta la compresiune şi dependenţa acesteia de gradul de armare şi unghiul de orientare a materialului de armare, deoarece oferă informaţii despre comportamentul mecanic al structurii compozite. Dependenţa rezistenţei la compresiune este determinată prin cercetări teoretice şi experimentale, utilizând analiza de regresie a experimentului activ.*

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