12th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

THE EFFECTS OF THE MANUFACTURING ON THE MECHANICAL CHARACTERISTICS OF THE E-GLASS / EPOXY COMPOSITES

Camelia Cerbu
Vasile Ciofoaia
Ioan Curtu
“Transilvania” University of Brasov
B-dul Eroilor 29, 500036 Brasov,
Romania

ABSTRACT
The paper describes the aspects concerning the effects of the manufacturing process on the mechanical characteristics of some E-glass / epoxy composites. In this paper, the specimens were manufactured by reinforcing an epoxy resin with woven fabric EWR300 made of E-glass fibres. Some characteristics of this kind of woven fabric, are known: weight, thickness, minimum tensile strength. The hand lay-up technology is used to prepare the specimens with different pressures in the molding step: low and high pressure. Then, the composite specimens were subjected to the flexural test (three points method). Herein, the mechanical characteristics of the specimens were analysed taking into account the different manufacture methods used. A comparison concerning the results obtained in cases of the two kinds of reinforcements used, will be also shown.
Keywords: composite, manufacturing, mechanical tests, mechanical properties

1. INTRODUCTION
Composite materials reinforced with woven fabrics are increasingly used in case of the application of aerospace industry, automotive industry, naval applications [2]. Over the years the manufacturers and researchers from aviation field, automotive industry, analysed theoretically / experimentally [1, 3] the composite materials reinforced with woven fabrics. Therefore, that class of the composite materials was considered as composites having good mechanical characteristics while the manufacturing costs are lower.

To obtain laminated composite material typical manufacturing processes are represented by the following technologies: hand lay-up technology, prepreg lay-up technology, bag molding, compression molding, resin transfer molding, pultrusion, autoclave of the woven fabrics before molding and using of the pre-stressed composite materials to reinforce thermoplastic resins etc.

2. MATERIALS AND WORK METHOD
The specimens are made woven fabrics EWR300 / epoxy composite material.

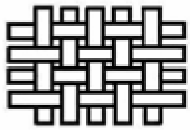

Figure 1. The structure of the woven fabrics EWR300

Some characteristics of this kind of woven fabric (fig. 1.2), are known: weight $\gamma = 315 \pm 5\% \, g/mm^2$, thickness $g = 0.3 \pm 0.05\, mm$, tensile strength $\sigma = 1750\, N/a\ narrowstrip\ of\ 50x0.3\ mm^2$ in case of the warp, tensile strength $\sigma = 2500\, N/a\ narrowstrip\ of\ 50x0.3\ mm^2$ in case of the weft.

The woven fabrics EWR300 are made of continue *E*-glass fibers with cut margins which are consolidated with filament by using a *Dreher* bond. These woven fabrics are used as isolator material

in case of constructions applications: buildings, pipes. By reinforcing of the epoxy / polyester resins they are also used to manufacture tanks, cisterns for chemical industry or to manufacture laminated or structure elements for machine-building industry.
There are usually four main steps of the manufacturing process in case of the composite materials reinforced by the woven fabrics as is shown in the figure 2. Herein, hand lay-up technology was used in the forth step to manufacture two laminated composite plates: high pressure was used to manufacture one of the plate while low pressure was used in case of the other one.
The structure of the laminated composite analysed within the present paper is shown in the table 1.

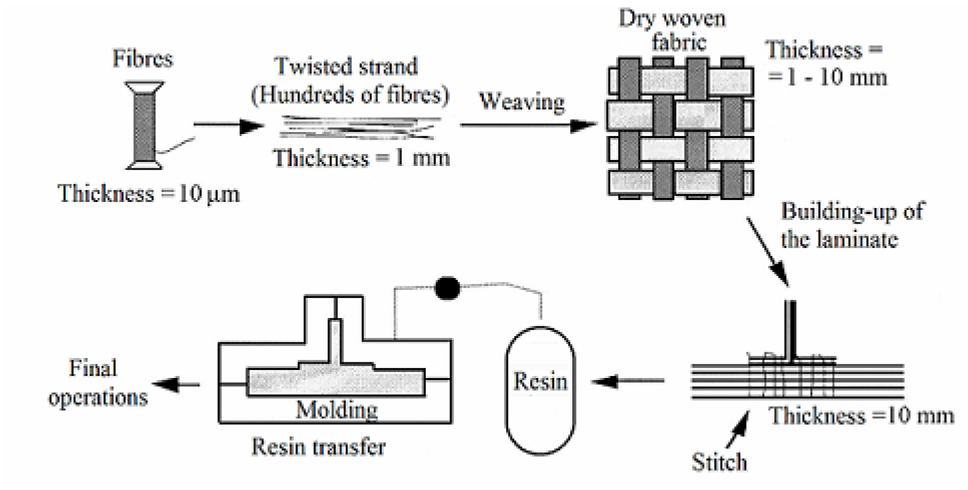

Figure 2. The steps of the manufacturing process in case of the composite materials reinforced by the woven fabrics

Table 1.The structure of the laminated composite materials analysed

Composite	Resin	Layers / Reinforcement	Manufacturing processes
Composite material 1	Epoxy	• 9 layers randomly reinforced / chopped E-glass fibres 100 g / m^2 • 8 layers / woven fabric EWR300 made of E-glass fibres 300 g / m^2	*Hand lay-up technology – high pressure*
Composite material 2		• 8 layers / woven fabric EWR300 made of E-glass fibres 300 g / m^2 • 10 layers randomly reinforced / chopped E-glass fibres 100 g / m^2	*Hand lay-up technology – low pressure*

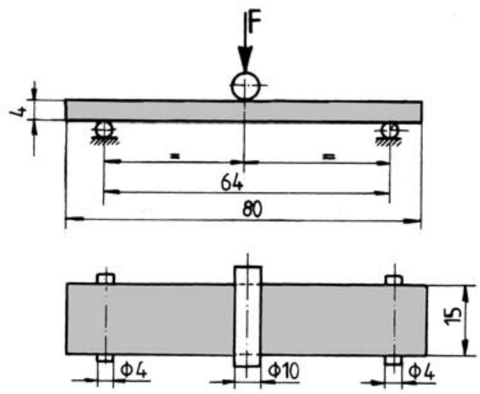

Figure 3. Dimensions of the specimen and scheme of loading for the bending test

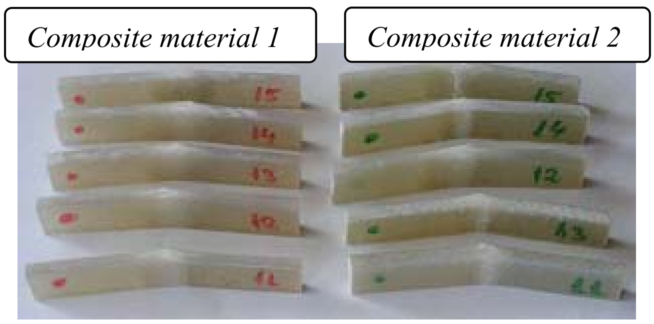

Figure 4. Specimens made of composite materials analysed

Then a number of five specimens where cut from each plate for the bending test (three-point method). The dimensions of the specimen and the scheme of loading (three-point method) for the flexural test are shown in the figure 3 [4]. The specimens subjected to the flexural test are shown in the figure 4.
The testing equipment used for flexural test consists of hydraulic power supply The maximum force capacity is ±15 *kN*. The speed of loading was 1.5 *mm/min* in the flexural test as the standard recommends.
Before each flexural test of a specimens, the dimensions of the cross-section were accurately measured and then, they were considered as input data in the software program of the machine. The testing equipment allowed us to record pairs of values (force F and deflection v at midpoint of the specimens, stress σ and strain ε) in form of files having 3000-5000 lines. The testing machine gives us the results of a statistical calculus for each set of specimens tested.
Therefore, the average values of the following quantities are automatically computed: *Young*'s modulus of bending, flexural rigidity, load at maximum load, maximum bending stress at maximum load, deflection at maximum load, maximum bending strain at maximum load, work to maximum load etc.

3. RESULTS

Experimental results from text files may be graphically drawn by using $F - v$ coordinates or σ - ε coordinates. In the figure 5 are shown σ - ε curves of the experimental data in case of the composite materials tested that was molded by usig high or low pressure. Analysing σ - ε curves we may observe that the slopes of the curves on the linear portion are greater in case of the composites subjected to high pressure during the molding than in case when the composites were subjected to the lower pressure. This means that the *Young*'s modulus is greater in case of the composite manufactured by using molding with high pressure. It follows that the stiffness of these composites is greater.

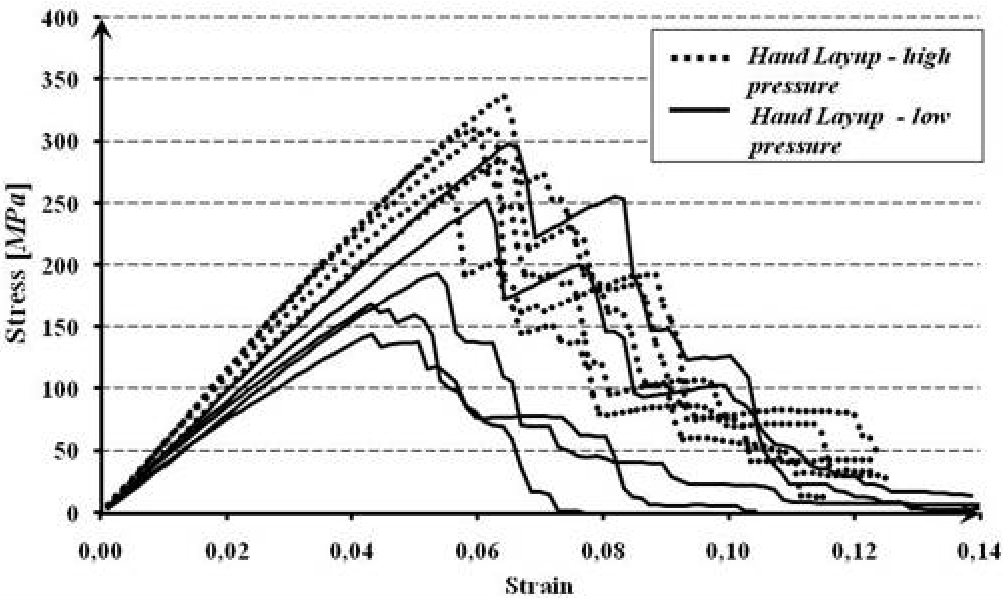

Figure 5. The $\sigma - \varepsilon$ curves obtained from the bending tests in case of the composite materials tested

On the other hand, the results of the statistical calculus gives us by the testing machine are shown in the table 2. It may be noted that *Young*'s modulus of bending was computed on the linear portion of the stress σ-strain ε curve.
Analysing the experimental results of the statistical calculus shown in the table 2, some important remarks may be shown bellow.

- The values of the *Young*'s modulus E were *5264,4 MPa* and 4167MPa in case of the composite materials tested molded by using high pressure or low pressure, respectively. It follows that *Young*'s modulus E decreases about 20.8 % in case of the using of low pressure in the molding step of the manufacture process.

- Maximum bending stress σ_{max} at maximum load was 265,25 *MPa* in case of the composite material molded by using high pressure while 145,92 *MPa* is recorded in case of the using of a low pressure44. Likewise, a decreasing of ≅ 44.98 % for the maximum bending stress σ_{max} may be observed in case of the using of a low pressure in the manufacturing process.

Table 2. Mechanical characteristics of the composite materials tested

		Woven fabric EWR300 / epoxy resin	
		Composite 1	**Composite 2**
Width of the specimen	[*mm*]	15,2	15
Thickness of the specimen	[*mm*]	4,7	5,5
Area of the cross-section	[mm^2]	72,38	82,5
***Young*'s modulus of bending**	[*MPa*]	5264,4	4167
Flexural rigidity	[$N\cdot m^2$]	0,80171	0,93548
Load at maximum load	[*kN*]	1,1652	0,85599
Maximum bending stress σ_{max} at maximum load	[MPa]	265,25	145,92
Deflection at maximum load	[*mm*]	6,539	4,4629
Maximum bending strain at maximum load	-	0,055581	0,043435
Work to maximum load	[$N\cdot cm$]	418,12	214,33
Maximum bending strain at maximum deflection	-	0,1175	0,13751

4. CONCLUSIONS AND DISCUSSIONS

We note that the using of a lower pressure during the manufacturing process of the composite materials the decreasing of the flexural strength and flexural modulus. Decreasing of the flexural strength was ≅ 44.98 % while the decreasing the *Young*'s modulus E was about 20.8 %.

From point of view of the reasons shown in this paper, it is recommendable to take into account the results of this paper in the manufacturing process of the structures made of the composite materials.

5. ACKNOWLEDGEMENT

The research described within the present paper was possible owing to a national scientific project exploratory research, Project ID_191, no. UEFISCU 225 / 2007, supported by Ministry of Education and Research of Romania.

6. REFERENCES

[1] Cerbu Camelia: Aspecte privind degradarea caracteristicilor elastice şi mecanice de încovoiere ale materialelor compozite sticlă / polimer din cauza absorbției de umiditate, Revista Materiale Plastice, vol. 44 (2), ISSN 0025 / 5289, Iunie, 2007, pp.97-102,

[2] Cerbu Camelia, Curtu I: About advantages of using of the composite materials in the naval applications,Proceeding of the International Symposium - Composite Wood Materials, vol. VI, ISBN 80-228-1169-6, Zvolen, Slovacia, 21-23 iunie, 2006, p. 288-293,

[3] Cerbu Camelia: Conservation of the mechanical properties under the action of the environmental effects in case of the e-glass / vinyl-ester composites,Proceeding of The 10th International Research / Expert Conference - Trends in the Development of Machinery and Associated Technology, ISBN9958-617-30-7, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006, p. 277-280,

[4] SR EN 63: Glass fibre reinforced plastics, Determination of flexural properties, Three point method, CEN, Bruxelles, 1998.