13th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

ABOUT THE EFFECTS OF THE MOISTURE ABSORPTION ON MECHANICAL BEHAVIOUR IN TENSILE TEST OF COMPOSITES MADE OF E GLASS WOVEN FABRICS

Vasile Ciofoaia
Camelia Cerbu
"Transilvania" University of Brasov
B-dul Eroilor 29, 500036 Brasov,
Romania

Dante Sechel
Polimat SRL,
Str. Lunga 54, 500058 Brasov,
Romania

ABSTRACT
The paper describes aspects concerning the effects of the water absorption on some mechanical characteristics of some composite materials reinforced with E-glass woven fabrics. The specimens were manufactured by reinforcing a polyester resin Copoly 7233 with both woven fabric EWR300 made of E-glass fibres and chopped E-glass fibres. The hand lay-up technology was used to manufacture the specimens with different pressures in the moulding step: low pressure and high pressure, respectively. The first of all, some specimens were immersed in water and the data regarding the moisture content were periodically recorded. Then, both dried specimens and wet specimens were subjected to the tensile test after 3500 hours of immersion. Finally, the experimental results obtained in case of the immersed specimens were comparatively analysed with the results recorded in case of the dried specimens subjected to the tensile test too. Moreover, the mechanical characteristics of the specimens were analysed taking into account the different manufacture methods used. It is also shown a comparison concerning the results obtained in cases of the two kinds of reinforcements used.
Keywords: composite; moisture; absorption; tensile test

1. INTRODUCTION
In the last years, there were some scientific papers [3] that experimentally analysed the mechanical behaviour of the glass woven fabrics or composite materials reinforced with woven fabrics.
The main objective of this study were to investigate the effects of the water absorption on some composite materials reinforced with both *E*-glass woven fabrics and chopped E-glass fibres. Generally, the problem of the mechanical behaviour of the composite materials under the action of the moisture effects consists in two steps. In the first step, the moisture content as a function of the immersion time is recorded. In the second step, the changes of the mechanical characteristics (modulus of elasticity, strength, strain energy) are analysed [1, 2, 4].

2. MATERIALS. WORK METHOD
In this research, both E-glass woven fabric and chopped E-glass fibres were used to reinforce a polyester resin *Copoly 7233*. The structure of the composite materials tested and the setting of the laminas are shown in the figure 1.
The first of all, the plates of composite materials were manufactured and then, they were cut to obtain the specimens according to the European standard [5]. A total number of 18 specimens were manufactured.
Prior to the immersion in water, the specimens were stored in an oven at 30 ± 1°C and weighted to ensure that they were dried prior to the environmental conditioning [6]. Water at room temperature

(20 °C) was used for the environmental exposure. The water tanks were covered to minimise evaporation and the water was changed every month to keep conditions constant.
To monitor the uptake of water, quantified by the moisture content, m, and the specimens were periodically removed from the tanks, dried superficially with absorbing paper and weighted on an electronic balance (maximum mass 250 g) accurate within ± 0.001 g.

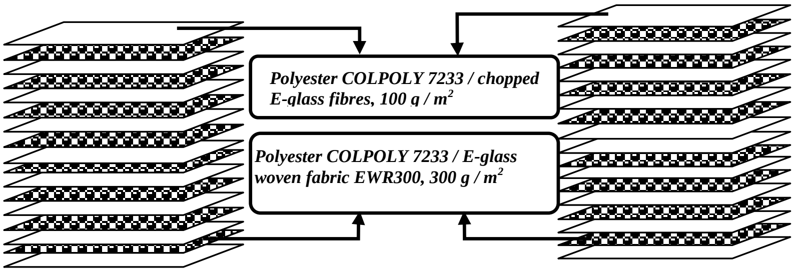

Figure 1. Laminas of the composite materials tested

After 5255 *hours* of immersion in water, the specimens were subjected to the tensile test.
LS100*Plus* machine manufactured by *LLOYD Instruments*, was used for tensile testing of the composite specimens involved. It is power drive (maximum force provided $F_{max} = 100\,kN$). It may be observed that to obtain more data about mechanical behaviour in tensile test, an extensometer is initially mounted on each tensile specimens tested. The extensometer is a strain-measuring device used to record data concerning the changing of the normal strain during testing.
The soft of the testing machine allows the statistical calculus of the average values of some quantities: elastic modulus *E* (*Young*'s modulus); tensile rigidity *EA*; maximum normal stress σ_{max}; elongation Δl; maximum normal strain ε_{max}; mechanical work done by the applied force or the strain energy stored *U* and so forth.

3. RESULTS AND DISCUSSIONS

3.1. Absorption data

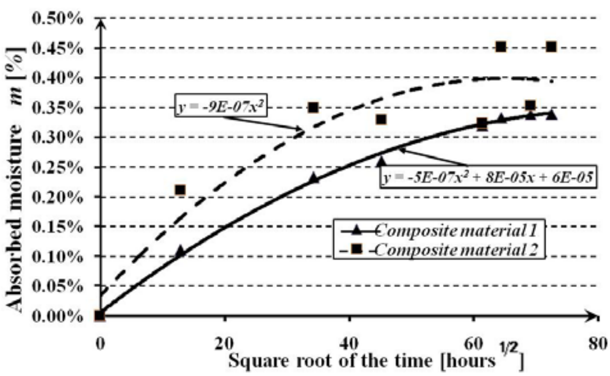

Figure 2. Absorption curves recorded in case of tensile specimens immersed in water

The first of all, the changing of the moisture absorbed was graphically drawn as function of the immersion time (fig. 2). These curves may be used to comparatively analyse the absorption of water in case of the two composite materials tested, during over seven months of immersion in water.
The absorption curves shown in the figure 2 shows us that the uptake rate of the water inside the composite material is a little greater in case of the *Composite material 2*.
However, the maximum quantity recorded for the water absorbed is quite small, between 0.34 % and 0.45 % of the initial mass of the specimens.

3.2. Results concerning the effects of the water on the mechanical behaviour in tensile test

Tensile tests were made after 5255 *hours* (over seven months) of immersion in water. The tensile modulus E was computed on the linear portion of the σ- curve (stress-strain curve) while the tensile normal stress σ corresponds to the end of the elastic domain. The results obtained in case of the wet specimens were compared with the ones recorded in case of the dried specimens. Hereinafter, important remarks concerning the effects of the water absorption on the tensile strength, *Young*'s modulus E will be noted.

Experimental results are graphically drawn in the figures 3 and 4, shape in the of σ- curves based on electronic data recorded from tensile testing machine by using the corresponding *NEXYGEN Plus* soft. It may be observe that the σ- curves recorded in case of the dried specimens are completely located below to the ones recorded in case of the specimens immersed in water during seven months. This remark shows that the water absorption leads to the increasing of the rigidity. On the other hand, the tensile strength of the composite 2 decreases due to the water absorption.

The experimental results concerning *Young*'s modulus E are shown in the figure 5 while the changing of the tensile strength is presented in the figure 6. It may be noted the great increasing of the modulus of elasticity E in case of both composite materials analysed (fig. 5). The value of *Young*'s modulus E is greater with 12.64 % in case of the *Composite material 2* than in case of the *Composite material 1* before immersion in water. The effect of the water on the tensile strength (fig. 6) is not so significant in case of the *Composite material 1*. The maximum value of the tensile stress σ_{max} decreases with 13.13 % in case of the *Composite material 2*.

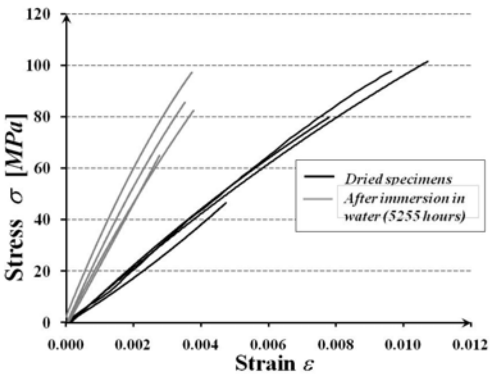

Figure 3. σ- curves recorded in case specimens made of Composite material 1

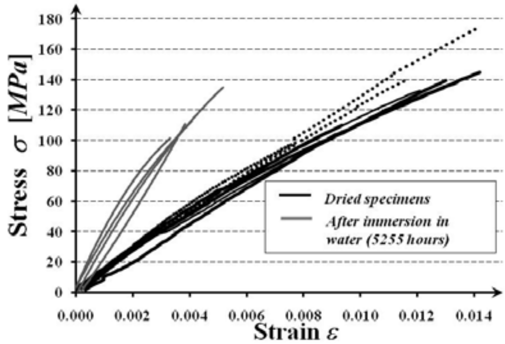

Figure 4. σ- curves recorded in case specimens made of Composite material 2

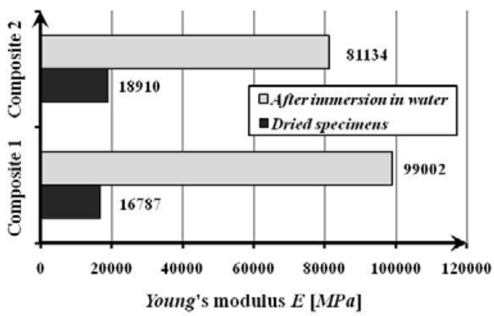

Figure 5. Changing of the Young's modulus after immersion in water

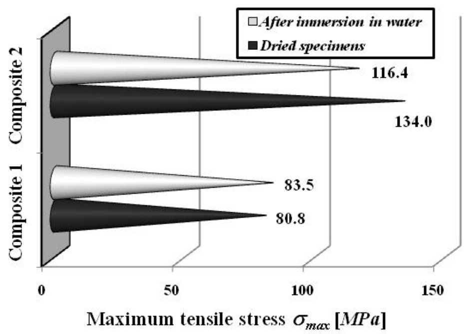

Figure 6. Changing of the maximum tensile stress σ_{max} after immersion in water

Table 1. Average values of the other mechanical characteristics obtained in tensile test

	Type of specimens	Maximum force F_{max} (*kN*)	Extension at maximum load Δl (*mm*)	Strain at maximum load	Mechanical work done until max. extension (*N·mm*)
Composite material 1	*Dried specimens*	13.461	0.41656	0.0083358	7278
	After immersion in water (5255 hours)	14.219	0.42019	0.0035016	3574
Composite material 2	*Dried specimens*	17.427	0.62843	0.0126	10458
	After immersion in water (5255 hours)	15.487	0.50115	0.0041762	7520

Figure 7. Degradation of the material during immersion in water

Table 1 shows the average values of some mechanical characteristics, values obtained from tensile tests in case of both dried and wet specimens.
The photo shown in the figure 7 marks out the damaged areas (black spots) developed on the specimen edge during immersion in water.

4. CONCLUSION

Some polymeric composites randomly reinforced with *E*-glass fibres were studied in previous works [1, 2] regarding the changing of the flexural properties due to the moisture absorption. Finally, the loss in the mechanical properties has been attributed to the plasticity of the matrix by water and degradation of the fibre/matrix interfacial bond due to moisture swelling of the matrix.
In case of the composite materials tested during our experimental research a little decreasing of the tensile strength was recorded. Contrary to our exception, the Young's modulus increased after due to the water absorption.

5. ACKNOWLEDGEMENT

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

6. REFERENCES

[1] Cerbu C.: Aspects concerning the degradation of the elastic and strength characteristics of the glass / polymer composite material due to the moisture absorption, Plastic Materials (ISI), 2007, 44, no. 2, Bucharest, p.97-102, ISSN 0025 – 5289;
[2] Cerbu C., Ciofoaia V., Curtu I.: The effects of the immersion time on the mechanical behaviour in case of the composite materials reinforced with E-glass woven fabrics, Plastic Materials (ISI), no. 2, 2009, Bucharest, ISSN 0025 - 5289;
[3] Launay J., Hivet G., Duong A. V., Boisse Ph.: Experimental analysis of the influence of tensions on in plane shear behaviour of woven composite reinforcements, Composites Science and Technology, 68, 2008, p. 506–515, ISSN 0266-3538;
[4] Takeshige F., Kawakami Y., Hayashi M., Ebisu S.: Fatigue behavior of resin composites in aqueous environments, Dental Materials, 23, 2007, p. 893–899, ISSN 0109-5641;
[5] SR EN ISO 527/2000: Plastics. Determination of tensile properties, European Committee for Standardization, Brussels, 2000;
[6] SR EN ISO 62 / 2008: Plastics. Determination of water absorption, European Committee for Standardization, Brussels, 2008.