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CHARPY TESTS IN CASE OF THE GLASS REINFORCED COMPOSITES

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ABSTRACT
Some composite materials reinforced with E-glass woven fabrics or / and E-glass chopped fibres are considered. Three types of woven fabrics made of E-glass fibres, were used to reinforce an epoxy resin (RAKO-TOOL EH-2900) and composite plates were prepared. One of composite plates was additionally reinforced with E-glass chopped fibres. Then, 30 specimens for Charpy test were manufactured from the composite plates. The paper presents and analyses the results of the Charpy test (failure energy U and resilience K) in case of the composite materials tested. Some important remarks concerning the failure are presented. Finally, the paper notes the advantages of the supplementary reinforce with E-glass chopped fibres.
Keywords: composite, *Charpy* test, failure energy, resilience.

1. INTRODUCTION
Charpy test has been used for many years [1, 2] to determine the energy absorption, notch sensitivity, fracture toughness and fracture behaviour of monolithic materials through information obtained from standardised type pendulum breaking standardised specimens in a bending mode. For these tests, swinging a weight from a fixed height toward a notched specimen produces an impact load. The notch is introduced into the material specimen in order to produce a stress concentration and thus promote failure in the case of the ductile materials. A typical *Charpy* impact specimen (fig. 1) consists of a rectangular cross-section beam notched at the beam midpoint, simply supported, and struck by the impacting weight at this point.
The impact is produced by swinging a weight against the test specimen from a height h. When it is released the weight swings through an arc, hits the target specimen and after fracturing, it reaches a height h'. The difference between the initial energy and the remaining energy represents a measure of the energy required to fracture the specimen. This quantity is called *failure energy in Charpy test* and it is denoted by U.
The ratio between *the failure energy in Charpy test* and the area of the notched cross-section of the specimen, represents the resilience denoted by K.
The energy lost by the pendulum can be expressed as the sum of various energies: the energy required to initiate fracture of the specimen; the energy required to propagate fracture across the specimen; the energy required to propel the broken specimen. There are other minor sources of the energy dissipation: bending of the specimen; vibration of the pendulum components; friction effects within the pendulum system.
Herein, three kinds of specimens made of *E*-glass woven fabric / *Rako-tool EH-2900* epoxy resin, were subjected to *Charpy* test to analyse their dynamical behaviour. Some specimens were supplementary reinforced with E-glass chopped fibres. An improvement of the resilience K was detected in that case.

2. MATERIALS AND WORK METHOD

Three types of woven fabrics made of *E*-glass fibres (fig. 2), were used to reinforce an epoxy *Rako-tool EH-2900*) as shown in the table 1. Table 2 shows us the densities of the *E*-glass fibre woven fabrics used while the physical characteristics of the *Rako-tool EH-2900* epoxy resin are presented in the table 3.

The first of all, three composite plates of dimensions 150 *mm* x 80 *mm* x 4 *mm* were manufactured by using an wood mould and hand lay-up technology. The volume ratios and weight ratios of the composite materials are shown in the table 1. The wood mould was covered with a *Trenmitel* solution to easily extract the composite plate after manufacturing and conditioning.

Table 1. Composite materials and number of specimens tested

Composite material	**Reinforcement**	**Matrix**	**Number of laminas**	**Weight ratio** W_f **[%]**
C1	*E*-glass woven fabric 1 (fig. ,a)	*RAKO-TOOL EH*-2900 Epoxy resin	6	69
C2	*E*-glass woven fabric 2 (fig. ,b) + *E*-glass chopped fibres		5	80
C3	*E*-glass woven fabric 3 (fig. ,c)		4	80

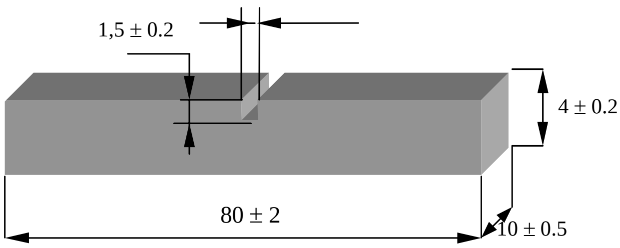

Figure 1. Composite specimen for Charpy test

The conditioning time was 2 weeks at room temperature. Then, the composite plates were cut to obtain the specimens according to [3, 4] as shown in the figure 1. A total number of 30 specimens (10 specimens made of each composite material involved) were prepared.

Table 2. Densities of the E-glass fabrics used to reinforce the composites analysed

No.	**Type of fabric**	**Density** $\left[g/cm^3\right]$
1	*E*-glass woven fabric 1 (fig. ,a)	170
2	*E*-glass woven fabric 2 (fig. ,b) + *E*-glass choped fibres	225
3	*E*-glass woven fabric 3 (fig. ,c)	400

Table 3. Physical properties of the RAKO-TOOL EH-2900 Epoxy resin

Viscosity [*mPas*]	400 - 700
Flash point [℃]	101
Density [g/cm^3]	1.72
Solubility with water	Reactive
State of aggregation	Liquid

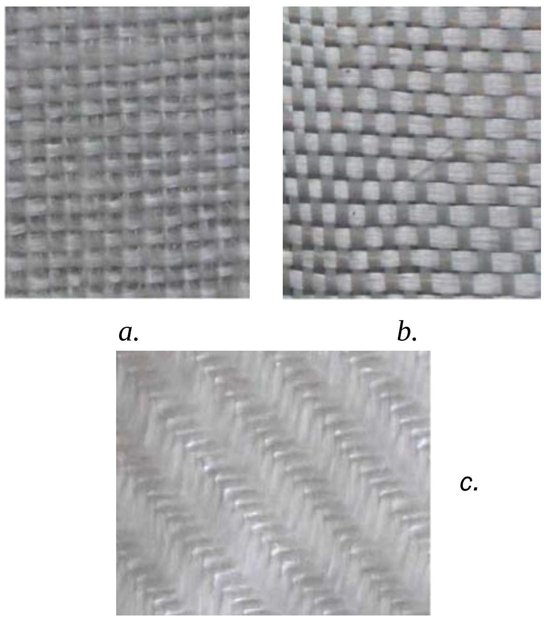

Figure 2. E-glass woven fabrics used to manufacture the composite materias tested: a. E-glass woven fabric 1; b. E-glass woven fabric 2; c. E-glass woven fabric 3.

b.

a. c.

Figure 3. Experimental stand for the Charpy test:
a. Pendulum impact testing-machine; b. Hammer of the Charpy pendulum; c. Composite specimen simply supported on the Charpy pendulum.

Then, the specimens were subjected to *Charpy* test by using the experimental stand shown in the figure 3. The distance between the simple supports was 60 *mm* (fig. 3, c). The failure energy denoted by *U*, was recorded in case of each specimen tested. Finally, the resilience of each composite specimen was computed by using the following formula:

$$K = \frac{U}{A}, \tag{1}$$

where *A* represents the aria of the specimen cross-section where the notch is manufactured.

3. RESULTS

A photo of the composite specimens after *Charpy* test is shown in the figure 4 while the results concerning the failure energy *U* are presented in the table 4.

The greater value of the failure energy in case of the composite material *C2* occurs owing to the supplementary reinforcement by using *E*-glass chopped fibres

a. b. c.

Figure 4 . Specimens subjected to Charpy test: a. E-glass woven fabric 1 / RAKO-TOOL EH-2900 epoxy; b. E-glass woven fabric 2 / RAKO-TOOL EH-2900 epoxy; c. E-glass woven fabric 3 / RAKO-TOOL EH-2900 epoxy.

One may note that the smallest value of the failure energy measured in case of the composite *C2*, is grater than the greatest value $\left(27.5 \cdot 10^{-2}\ N \cdot m\right)$, corresponding to the composite *C3*.

One may also note that the lowest value of the failure energy $\left(18 \cdot 10^{-2}\ N \cdot m\right)$ in case of the composite *C3* is approximately equal to the maximum value $\left(18.5 \cdot 10^{-2}\ N \cdot m\right)$, measured in case of the composite C1.

Then, the resilience *K* was computed by using the relation (1). Analysing the results concerning the average value of the resilience *K* (fig. 5), one may observe that in case of the composite *C2* this quantity is double with respect to the corresponding value obtained in case of the composite *C1*.

Table 4. Results concerning the failure energy in Charpy test

No. of specimen	Failure energy U $\left[x10^{-2}\ N \cdot m\right]$		
	Composite material C1	**Composite material C2**	**Composite material C3**
1	18.5	33.5	22.5
2	17.5	31.0	19.0
3	16.0	36.0	26.0
4	18.5	34.0	26.0
5	14.0	29.5	19.0
6	15.0	29.5	18.0
7	14.5	30.0	24.0
8	14.5	35.5	26.5
9	15.0	32.5	27.5
10	13.5	31.5	19.0
Average value	**15.7**	**32.3**	**22.75**

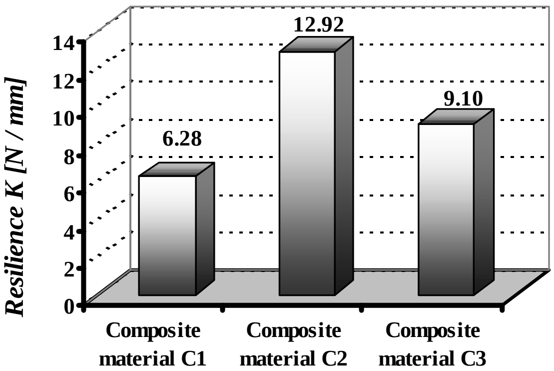

Figure 5. Results concerning the average value of the resilience K in case of the composites tested

Some important remarks concerning the failure modes should be noted. It could be observed that the specimens made of the composite material *C1* were completely broken after *Charpy* test while only some layers are damaged in case of the others two composite materials tested. An explication would be that the specimen excessively deformed during the dynamic loading. Therefore, the hammer got out the specimen from the simple supports and dropped it. This could be the reason that only the first layers were damaged after impact, in case of the specimens made of *C2* or *C3* composite materials.

4. CONCLUSIONS AND DISCUSSIONS

To improve dynamic properties (resilience *K*) of the polymeric composites reinforced with *E*-glass woven fabric, one may recommend the using of the supplementary reinforcement with *E*-glass chopped fibres.

This method should be used in case of every other polymeric composite reinforced with woven fabrics to improve dynamic properties.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] Abrate, Serge – Impact on Composite Structures, Cambridge University Press, ISBN-0-521-47389-6, 1998,

[2] Sierakowski, R.L.; Chaturvedi, S.K. – Dynamic loading and characterization of fiber reinforced composites, ISBN 0-471-13824-X, 1997, A Wiley-Interscience Publications John Wiley & Sons, Inc., New York,US,

[3] SR EN ISO 179-1, Plastic materials, Determination of the properties in *Charpy* test, the 1st Part: Un-instrumentally dynamic test. Determination of the characteristics of the materials under *Charpy* test, November 2001,

[4] SR EN ISO 179-2, Plastic materials, Determination of the properties in *Charpy* test, the 1st Part: Instrumentally dynamic test, Force-deflection curve. Force-time curve, September 2002.