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THE MECHANICAL RESPONSE OF TEXTILE COMPOSITE MATERIALS TO DYNAMIC IMPACT TESTS

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Abstract: *This paper presents an analysis of the results obtained from the dynamic impact of composite materials reinforced with woven fabrics. The specimens used were manufactured by reinforcing an epoxy resin with woven fabric EWR300 made of E-glass fibers. The specimens were made though different manufacturing methods. The hand lay-up technology is used to prepare the specimens with different pressures (low and high pressure) in the molding step. The energy method and experimental tests are employed to determine the response of the composite material subjected to low velocity impact. The composite specimens were subjected to the flexural test (the three points method - Charpy test) and at the impact experiments of impactor in low velocity impact on the rectangular plates. The results obtained were compared taking into account the two kinds of manufacturing methods.*

Keywords: *fabric composite, manufacturing, dynamic test, mechanical properties.*

1. INTRODUCTION

The composite materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure [9,13]. Most of composite materials are anisotropic and heterogeneous. These two characteristics apply to the composite materials since the material properties are different in all directions and locations in the body. These properties are in contrast to those of any common isotropic material, such as for example steel, which has identical material properties in any direction and location in the body. Common textile composites are classified according to the fiber architecture and include braided, woven, knitted stitch bonded and non-woven materials. The composite materials reinforced with woven fabric have complex structure and sophisticated micromechanical models and it is necessary to predict their elastic properties in all directions. Thus, the difficulty in analyzing the stress-strain relationship of composite materials becomes greater. Composite materials reinforced with woven fabric have recently received considerable attention, due to their structural advantages of high specific-strength and high specific-stiffness as well improved resistance to impact, crash and fatigue [9]. When compared to unidirectional composites [13], the interlacing of fiber bundles in textile composites prevents the damage progression and hence provide an increase to impact toughness. Besides their advantageous mechanical properties, composite materials reinforced with woven fabric are easy to handle and have excellent formability and hence are widely employed in aircraft, boat and defense industry. Due to their high specific stiffness and strength, fiber reinforced polymer composite materials have long been used in the aerospace industry [1,9,12,13,14,15]. Other notable engineering applications include pressure vessels and waste water pipes and fittings. Composites have the limitations of high cost, low damage tolerance and impact resistance. The increased application of composites has required a new method for predicting their elastic mechanical properties. For these reasons, in this paper, some structural properties of textile composites will be investigated. Other papers [14, 15] discusses the developments in the modeling and characterization of fabric reinforced composite materials and structural components. The interlaminar mode I fracture toughness of wood laminated composite materials has been evaluated using the critical strain energy release rate associated with the onset of crack growth in double cantilever beam specimens (DCB) [2]. The structural optimization of composite materials loaded in an aggressive environment [3] and the water effects on composite made of E-glass fabrics woven fabrics was presented in [4,5,6,7]. The papers [8,12,14] present the computation of mechanical elastic constant of woven fabric composites. The goal of this paper is to determine the characteristics of composite materials reinforced with woven fabrics by using the experimental investigation developed in the dynamic impacts tests. The activities include prediction of the elastic properties of the specimens manufactured by reinforcing an epoxy resin with woven fabric EWR300 made of E-glass fibers and surface inspection of textile composites.

2. MECHANICAL BEHAVIOUR OF WOVEN COMPOSITE REINFORCEMENTS

The ballistic impact definition can be found in several works [1,7,10,11,12]. The term ballistic impact is used in the case of an impact resulting in complete penetration of the composite materials reinforced with woven fabric while non-penetrating impact referred to low velocity impact. Overall, other than this impact, stress wave propagation has no effect through the thickness of the laminate for the case of low velocity impact. As the projectile hits the target, the compressive and shear waves propagate outward from the impact point and reach the back surface, reflecting back afterwards. After several reflections through the thickness of the laminate, the plate motion is generated. The damage established after the plate movement is called low velocity impact [1]. However, there is also a threshold velocity which distinguishes low and high velocity impact. As implied by [1], 20 m/s is a transition velocity between two different types of impact damage and it allows a definition of high and low velocity impacts. The main focus of this paper is to study the response of composite materials reinforced with the woven fabric when impacted at low velocity by using experimental tests.

By Fracture Mechanics studies we determined the G_c, energy per unit area or the control energy release rate at crack initiation. The Charpy scheme has been adopted to measure G_c by using sharp notches and measuring energy at both low and high rates. The simple method of determining G_c is via fracture load F, and the specimen compliance C(a) via

$$G_c = \frac{F^2}{2b}\frac{dC(a)}{da} \tag{1}$$

where b is the thickness and a is the crack length. If the elastic behavior is assumed, the load is related to the energy at the fracture U via $U=F^2C/2$ and hence G_c may be find from U,

$$G_c = \frac{U}{bC}\frac{dC}{da} = \frac{U}{bh\Phi(a/h)}, \tag{2}$$

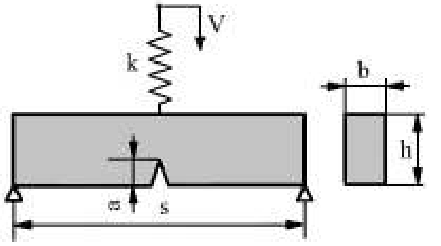

Figure 1 The Charpy three point bend test

where

$$\Phi(a/h) = \frac{C}{dC/d(a/h)}, \tag{3}$$

is a calibration function for energies which may be deduced from C(a/h) and is evaluated for the Charpy three point bend specimen [12].

3. EXPERIMENTAL TESTS

In the impact experimental tests, the target was a square woven composite plate firmly clamped on the edges.. The specimens used were manufactured by reinforcing an epoxy resin with woven fabric EWR300 made of E-glass fibers. The hand lay-up technology is used to prepare the specimens with different pressures (low and high pressure) in the molding step. Using a digital microscope, we have captured pictures of the specimens made for trying to shock with Charpy pendulum, to analyze the structure of composite material manufactured by the two types of manufacturing technologies by pressing. To that end, it presents photos of composite structure of E Glass /polyester Colpoly 7233 manufactured by the method of the hand lay-up technology

- by pressing at low pressure (fig. 2);
- by pressing at high pressure (fig. 3).

Analyzing the figures 2 and 3, we can make a few observations:

- When using high pressure manufacturing tehnology (fig. 2), the reinforced glass layers are better consolidated, have better defined borders inthe digital photographs taken with the digital microscope.
- When using low pressure manufacturing tehnology, the cut specimens from composite plates (fig. 1) the glass layers are harder to identify even if the images are magnified with a zoom factor of 200 x (fig. 1, e şi f).

Figure 2 The composite material Glass R/ polyester 7233 (low pressure manufacturing)

Figure 3 The composite material Glass R/ polyester 7233 (high pressure manufacturing)

The effects of the pressing manufacturing technology on the mechanical behaviour in an attempt to shock with Charpy pendulum were obtained using pieces of parallelepiped shape, sized 80 mm x 10 mm x 6 mm in accordance with European standards EN ISO 179-1 (2001) for the case of reinforced plastics.

Table 1 – The results of impact absorbed energy U for breaking the test-piece

Composite material/ The hand lay-up technology by pressing	Sample code	A [mm^2]	U [J]	U/A [kJ/m^2]	Composite material/ The hand lay-up technology by pressing	Sample code	A [mm^2]	U [J]	U/A [kJ/m^2]
E Glass/ Colpoly 7233 polyester / Low pressure (1)	P211	32.01	2.90	90.60	E Glass / Colpoly 7233 polyester / high pressure (2)	N46	34.22	4.13	120.69
	P212	35.28	3.91	110.83		N47	32.70	4.06	124.16
	P213	33.25	3.25	97.74		N48	34.50	4.20	121.74
	P214	35,36	3.42	96.72		N49	30.52	3.75	122.87
	P215	33.33	3.34	100.21		N50	32.48	3.79	116.69
	P216	34.30	3.44	100.29		N51	27.75	3.47	125.05
	P217	34,20	3.28	90.63		N52	29.00	3.63	125.17
	P218	32.10	3.12	97.20		N53	28.08	3.45	122.86
	P219	36.04	3.56	98.78		N54	30.16	3.78	125.33
	P220	27.84	2.98	107.50		N55	29.12	3.52	120.88
	Average value			99.50		Average value			122.54

The dimensions of the section were recorded for each specimen before the test of impact and we then computed the cross area. Test specimens were then subjected to the Charpy Test. The impact was generated by turning the pendulum hammer until the height h. When it was released, the hammer has described an arc, hitting the target sample, and after breaking the test-piece, reaching the rebound height h '. The difference between the initial potential energy and the potential energy of the impact is a measure of the energy required to break the test-sample. This quantity is called the energy bursting in the Charpy Test and is denoted by U. Were analyzed 10 samples made from two types of samples from different technology training by pressing (with the low pressure or high pressure) the two ways mentioned previously. The results obtained in shock with Charpy pendulum have been summarized in table 1. Analyzing the results, it follows that the resilience, the ratio between the breaking energy U and the cross-sectional area of the cut, is greater in the case of specimens made from composite material formed by high pressure pressing. In this case, the average value of resilience (impact resistance) was 122,54 kJ\/m2 (table 1), with 23,16% higher than the average value of 99,50 kJ\/m2 (table 1).

The second mode of testing was done on composite plates subjected to low velocity impact. The experimental evaluation of composite boards to conduct concentrated loads were studied on two types of standard specimens reinforced with glass fiber fabrics applied to concentrated loads that are applied dynamically. The test-sample dimensions were 150 mm x 100 mm x 4 mm and the supports and the loading application were made as shown in Figure 1. The test samples were obtained by two different manufacturing processes mentioned above. We then subjecting to resiliency testing the denoted 1-pieces numbered from 190-220 and the second group of pieces, type 2 are numbered 30-50. For the application of the load has been used a device designed for that purpose, rendered in Figure 2. The weight of the projectile was about 1.2 kg and the request was made at speeds ranging between 1 and 5 m/s. We have tested on at least two pieces for each of the selected drop height. We measured the height of fall and the acceleration during the impact. The integration was determined through variation of the speed and the movement during contact results and variance energy transferred to the plate. Figure 4 shows from the abutments and plates. Figure 5 presents the location of the accelerometer that able to transmit video signal for processing. The signal processing was performed with LabView. All graphics have been processed through Matlab code.

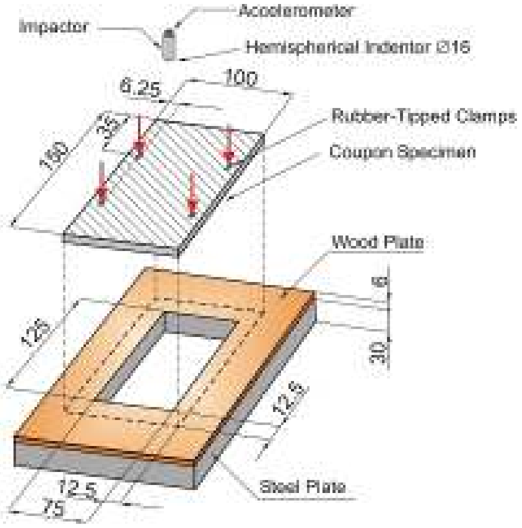

Figure 4 The supports of the test-piece and application of concentrated load

Figure 5 The positioning of the fixing screw the accelerometer

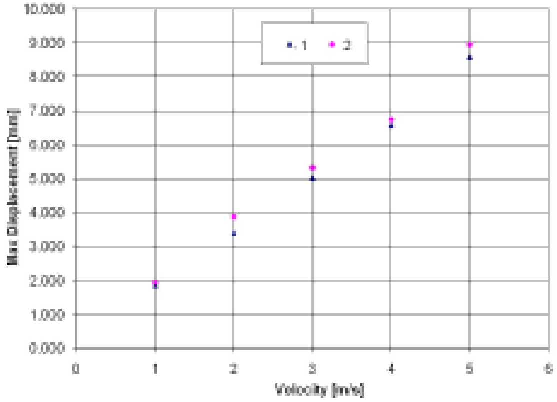

Figure 5. The average recorded displacements depending on the speed of the impactor for each type of test tube

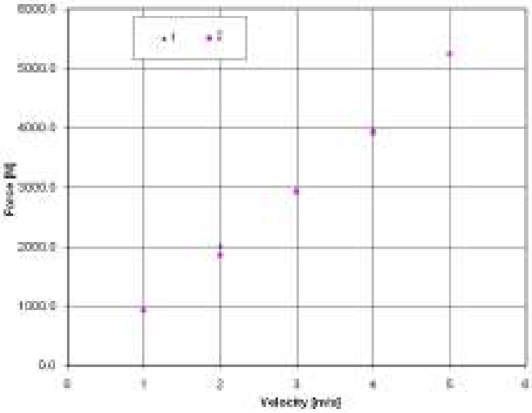

Figure 6. The average values of maximum contact forces recorded at the moment of impact depending on the speed of the projectile for each type of test specimen

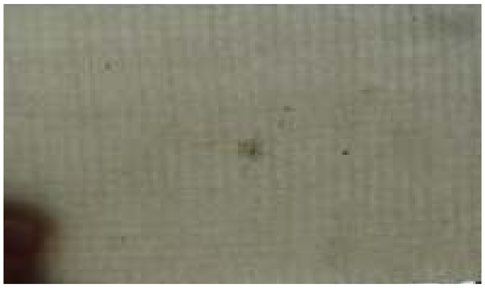

Figure 7 Damage in the case of the test-piece introduced 209 (1 type) the impact of the projectile velocity of 2 m/s

Figure 8 Damage in the case of the test-piece introduced 31 (2 type) the impact of the projectile velocity of 2 m/s

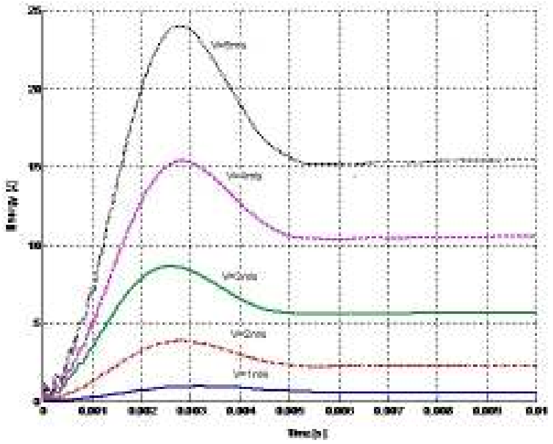

Figure 9 Variation of energy transferred to the moment of impact (pieces of type 1)

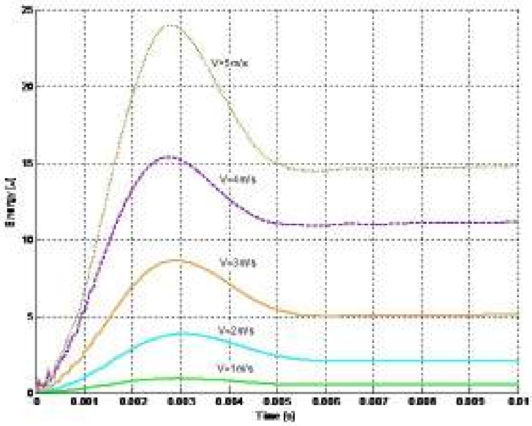

Figure 10 Variation of energy transferred to the moment of impact (pieces type 2)

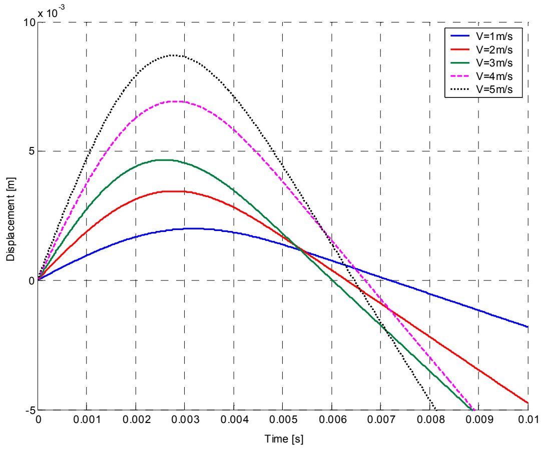

Figure 11 Travel-time curves recorded during the impact (pieces of type 1)

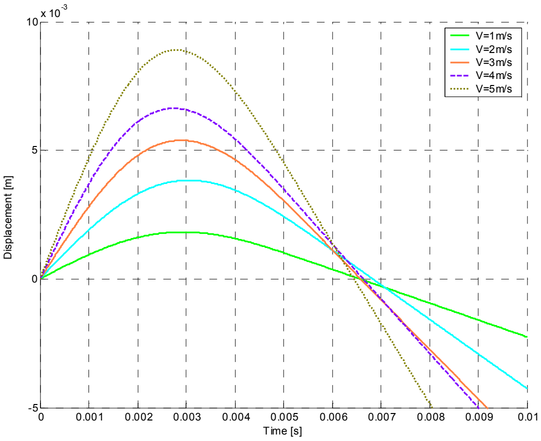

Figure 12 Travel-time curves recorded during the impact (pieces of type 2).

In figures 7, 8 are given recorded damage pieces of type 1 and 2, the initial impact with a speed of 2 m/s projectile. Arise certain differences between energy variation after time 0.005 s. The projectile's weight remained constant and height of fall increased progressively (corresponding to initial velocity of 1m/s, 2m/s, 3 m/s and 5 m/s) . At high velocities the contact force decreases and the composite plates starts to penetrate. If the speed of the project grows then it will grow and the maximum displacement of the leaf as shown in figures 11 and 12.

3. CONCLUSION

In this paper we tried to present the importance of the manufacturing of woven composite materials on the mechanical characteristics. Considering the obtained results presented in figures 5 to 12, we can draw the following conclusions:

- the resilience is greater in the case of specimens made from composite material formed by high pressure pressing. The average value of resilience (impact resistance) was 122,54 kJ\/m2 (table 1), with 23,16% higher than the average value of 99,50 kJ\/m2.
- type 2-pieces have been smaller displacements at approximately the same values of maximum contact forces during impact,
- visible damage occurred for initial projectile velocity of 2 m/s; In the case of type 1 specimens we observed occurrence of matte areas in which matrix has been damaged. Applied load determined the

appearance of delaminations and radial fissures which start from the contact zone. In the case of type 2 specimens, the visible matte area corresponding to the matrix and the delaminations damage in the right point of application of the load, the radial cracks are very small.

- the damage incorporated was higher in the case of type 1 specimens; the matte area on the opposite face of the impact is greater in the case of these pieces, compared to that for the type 2 pieces.
- in order to increase the resistance of the composite materials, we could use an outer layer of sacrifice to allow the concentrated load applied to disipate, thereby reducing the generated damage.
- in case of low velocity (and, therefore, low-energy) impacts, strength reduction and eventual failures are dominated by inter-laminar debonding processes, customarily termed delamination.

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