The 4th International Conference
"Advanced Composite Materials Engineering "
COMAT 2012
18- 20 October 2012, Brasov, Romania

ASPECTS CONCERNING TO THE IMPACT CHARPY TESTING IN CASE OF COMPOSITES MATERIALS FILLED WITH WOOD FLOUR

C. Cerbu
Transilvania University, Brasov, ROMANIA, cerbu@unitbv.ro

Abstract: *The paper analyses the effects of some internal factors (type of reinforcement, number of layers) on the impact characteristics in case of some composite materials reinforced with woven fabrics made of E-glass fibres. Therefore, three kinds of reinforcements were used to manufacture the composite materials: the first composite was reinforced with both four layers of glass woven fabrics and spruce wood flour while the other two composites were reinforced with seven layers of glass woven fabrics and additionally, reinforced with spruce wood flour or oak wood flour. The volume ratio of wood flour was the same for the last two composite analysed. The paper presents and analyses the results of the Charpy tests (failure energy U and resilience K) in case of the composite materials tested. Some important remarks concerning the failure areas of the specimens are presented. Finally, the paper graphically shows the effects of the type of the reinforcement on the dynamical characteristics obtained in Charpy test. The work also analyses the effects of the number of layers made of glass woven fabrics on the failure energy.*
Keywords: *composite, wood flour, Charpy test, failure energy, resilience.*

1. INTRODUCTION

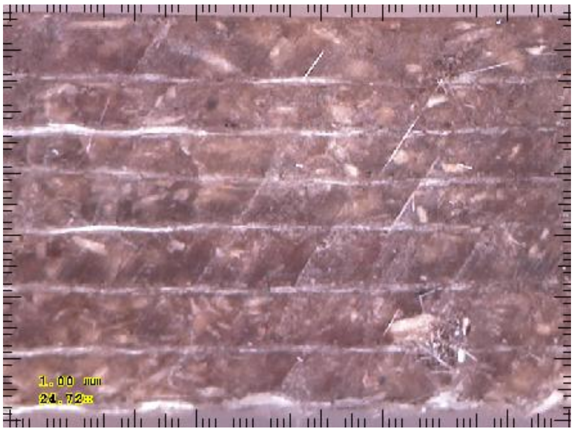
In the last decade, numerous works [1-3] have shown the need to use recycled materials as reinforcement / filler in the manufacture of composite materials. Such recycled materials could be: wood wastes; plastics; recycled rubber from tires; aluminium wastes; textiles; cartons; paper and so forth. Moreover, considering the class of wood-plastics composites, a recent paper [2] has already shown some aspects concerning to the manufacturing and improving of the interfacial bonding between wood fibres and recycled plastics.
Another recent work [4] also presented some results obtained in flexural test of a composite material based on epoxy resin, reinforced both with glass woven fabric and wood flour. Those works [3, 4] have shown some ways for improving of the mechanical behaviour of such composite materials.
In fact, the internal factors that act on the mechanical behaviour in case of such hybrid composite materials could be classified taking into account two main criteria: geometrical factors and component materials. Considering the first criterion, the internal factors are: layup setups; orientation of fibres in reinforcement layers; number of layers made of glass woven fabric. On the other hand, from component materials point of view, the effects of the following internal factors could be taken into account: type of the resin used; type of woven fabric used as reinforcement; species of the wood flour; length of the chopped wood fibre; reinforcement ratio.
The main objective of this work is to analyze the effects of two internal factors (species of wood flour, number of layers made of glass fabric) on the failure energy recorded in Charpy impact test in case of glass / wood flour / epoxy composite materials. Two kinds of wood flour were used to manufacture the composite materials: oak wood flour and spruce wood flour. Moreover, the composite materials tested were manufactured by laminating in five or seven layers of glass fabric.

2. MATERIALS AND WORK METHOD

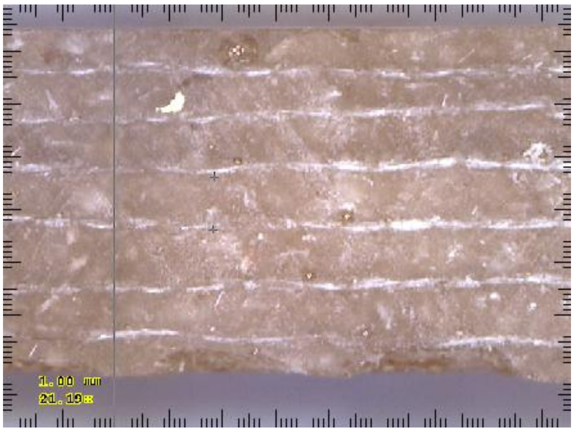
In this paper, E-glass woven fabric whose density is equal to ρ =200 g/m^2, was used to reinforce three kinds of composite materials. Table 1 shows that either spruce or oak wood flour obtained by recycling of the wood wastes, was used to additionally reinforce the composite materials tested (Figure 1). It may remark that the length of the wood fibre was less than 500 μm. In the both cases, an epoxy resin was used as matrix material. The weight fibre ratio was 40 % in case all composite materials analysed.

Table 1: Material structure of the hybrid composites tested

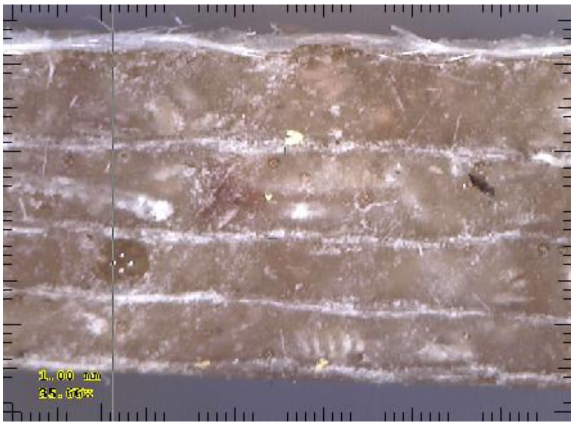
Material tested	Resin	Reinforcement
Composite 1	epoxy	E-glass (7 layers) / oak wood flour
Composite 2		E-glass (7 layers) / spruce wood flour
Composite 3		E-glass (5 layers) / spruce wood flour



a.



b.



c.

Figure 1: Photos of a cross-section of the laminated composite materials tested:
a.Composite 1; b. Composite 2; c. Composite 3

a.

b.

Figure 2: Equipment used for Charpy test
a. Pendulum impact tester HIT50P; b. Charpy specimen tested

The physical and chemical characteristics of the epoxy resin used are shown in the Table 1 while its mechanical characteristics without reinforcing are given in the Table 2 [7]. This resin is widely used for manufacturing of the laminated composite materials by using lay-up technology, injection with low pressure and filament wrapping. This kind of resin has a good behaviour for impregnation of timber.

Table 2: Physical and chemical characteristics of the epoxy resin [7]

Characteristic	Unit of measure	Value	Method
Density, 25 ^oC, in liquid state	g/cm^3	1.15	ISO 1675 : 1985
Viscosity, 25 ^oC, in liquid state	mPa*s	1550	Brookfield LVT
Concentration of hardner	g	32	-

Table 3: Mechanical characteristics of the epoxy resin without reinforcing [7]

Characteristic	Unit of measure	Value	Method
Glass transition temperature	^oC	80	-
Tensile stress in tension	MPa	70	ISO 527: 1993
Flexural stress	MPa	120	ISO 178: 2001
Modulus of elasticity E	MPa	3100	ISO 178: 2001
Impact strength (Charpy)	kJ/m^2	40	ISO 179: 1994
Elongation in tensile test	%	5	ISO 527: 1993
Toughness	Shore D15	83	ISO 868: 2003

The conditioning time for the plates made of composite materials was two weeks at room temperature. Then, the plates made of composite materials were cut to obtain the specimens whose dimensions were 15x100 mm^2 according to [8]. A total number of 10 specimens were manufactured in case of each composite material.
In case of the Charpy test, a notch is usually made on the specimen in order to produce a stress concentration and thus promote failure in the case of the ductile materials [5, 6]. Herein, the all specimens are unotched according to [8].
The dimensions of the cross-section were recorded for each specimen before impact testing. Then, the specimens were subjected to Charpy test to record the failure energy in impact.
An pendulum impact tester HIT50P manufactured by Zwich was used for Charpy test (Figure 2). The technical data for this equipment are: angle of release 147.96°; impact velocity 3.807 m/s; height of release 739.07 mm; pendulum length 400 mm; swing duration at t =50 – 63.45 s; test data recording rate – 500 Hz; PC connection – USB; pneumatic release by using compressed air connection 6 *bar* (± 1 *bar*).
The impact is produced by swinging the pendulum hummer (Figure 2, a) against the test specimen from a height *h*. When it is released the hammer swings through an arc, hits the target specimen and after fracturing, it reaches a height *h'*.
When the pendulum drops, all impulses are counted up until the pendulum reverses its direction. The angle of deflection is obtained if the number of impulses corresponding to the pendulum direction is subtracted after impact. The height of the reversal point and thus, the absorbed impact energy are determined from this angle of deflection.
The angle of deflection must be adjusted exactly. It is not possible to equal out possible friction loss by a larger angle of deflection.
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*.
Finally, the resilience of each composite specimen was computed by using the following formula:

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

where *U* represents the failure energy recorded in case of each specimen tested; *A* represents the aria of the specimen cross-section where the notch is manufactured.

3. RESULTS

The Table 4 shows the experimental results recorded during Charpy test. To easily analyse the values obtained for the resilience *K*, the last column of the Table 4 is graphically represented in the Figure 3.

Table 4: Experimental results recorded for all specimens tested in case of the Charpy test

Composite material	Number of specimen	*b* (*mm*)	*h* (*mm*)	*A* (mm^2)	*U* (*J*)	*U / A* (kJ/m^2)
Composite 1	1	15.32	9.73	149.06	5.92	39.71
	2	15.36	9.43	144.84	6.13	42.32
	3	15.27	9.81	149.80	5.86	39.12
	4	15.30	9.60	146.88	6.04	41.12
	5	15.31	9.68	148.20	5.91	39.88
	6	15.27	9.51	145.22	5.72	39.39
	7	15.30	9.60	146.88	6.05	41.19
	8	15.28	9.65	147.45	5.83	39.54
	9	15.29	9.57	146.33	5.69	38.89
	10	15.32	9.77	149.68	6.08	40.62
Composite 2	1	15.25	7.70	117.43	7.08	60.29
	2	15.29	8.58	131.19	7.71	58.77
	3	15.02	7.21	108.29	7.53	69.53
	4	15.24	8.29	126.34	6.84	54.14
	5	15.24	8.00	121.92	6.95	57.00
	6	15.28	8.40	128.35	7.64	59.52
	7	15.23	8.26	125.80	7.34	58.35
	8	15.25	8.40	128.10	7.62	59.48
	9	15.24	8.30	126.49	7.67	60.64
	10	15.28	8.00	122.24	7.73	63.24
Composite 3	1	15.37	4.28	65.78	3.86	58.68
	2	15.30	4.40	67.32	4.45	66.10
	3	15.34	4.50	69.03	4.79	69.39
	4	15.27	4.00	61.08	3.65	59.76
	5	15.34	4.44	68.11	4.08	59.90
	6	15.28	4.52	69.07	4.24	61.39
	7	15.30	4.55	69.62	4.63	66.51
	8	15.27	4.48	68.41	4.48	65.49
	9	15.24	4.45	67.82	4.23	62.37
	10	15.28	4.30	65.70	3.98	60.57

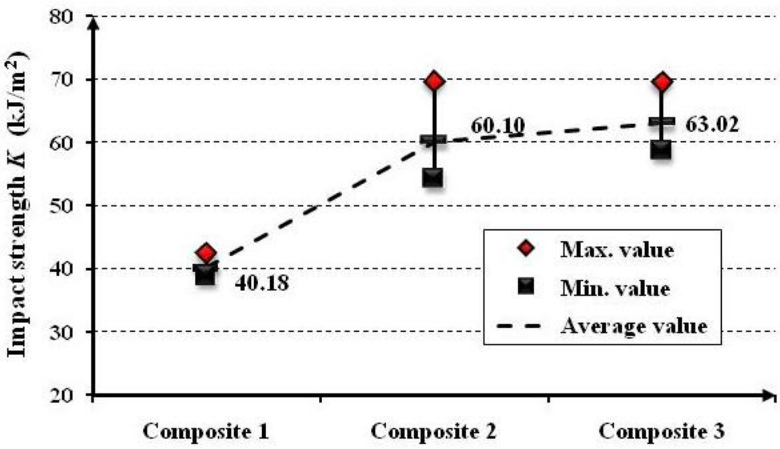


Figure 3: Mean values of the resilience U / A in case of the composite materials tested

One may remark that the scattering factor of the values of resilience *K* is quite small in case of each composite material tested (Figure 3).

Taken into account that only Composite 1 was additionally reinforced with oak wood flour, the results recorded in Charpy tests showed that an improvement of the resilience *K* was detected in the case of the composite materials additionally reinforced with spruce wood flour (Figure 3). Moreover the both Composite 1 and Composite 2 were reinforce with the same number of layers (7 layers) made of glass fabric while the volume

ratio of the reinforcement was the same. The average value of the resilience K recorded in case of Composite 2 was with 49.58% greater than the one recorded in case of the Composite 1.
Analysing the chart 5 shows that the values of the resilience K obtained in case of the Composite 2 and Composite 3 are approximately equal because both the ratio of reinforcement and the type of wood flour are the same.
The specimens made of Composite 1 or Composite 2 were completely broken in Charpy test. On the other hand, the specimens made of Composite 3 were partially broken during the impact test. This happened because the composite specimen was excessively deformed during the impact so that the hummer cached the specimen and dropped it before its complete rupture. This is the reason that only the first layers were completely damaged after impact test.

4. CONCLUSIONS AND DISCUSSIONS

The results presented within this paper, shows that the spruce wood flour should be used instead of the oak wood flour to improve the dynamical properties (resilience K) of the hybrid polymeric composite materials reinforced both with glass fabric and with wood flour.
More exactly, it was shown that the using of the spruce wood flour as filler material instead of the oak flour (the same ratio of reinforcement) at the interface between two layers made of glass woven fabric, leads to the increasing with 49,58 % of the resilience K.

ACKNOWLEDGEMENT

This work is supported by CNCSIS –UEFISCSU, project number PNII – IDEI 733.

REFERENCES

[1] Klyosov A.A., Wood-plastic composites, New York, US, John Wiley and Sons Publishing, USA, 2007, ISBN 978-0-470-14891-4, pp.71-122.
[2] Cui Y., Lee S., Noruziaan B., Cheung M., Tao J., Fabrication and interfacial modification of wood / recycled plastic composite materials, Composites: Part A, 39, 2008, pp. 655-661.
[3] Cerbu C., Curtu I., Ciofoaia V., Rosca I. C., Hanganu L. C., Effects of the wood species on the mechanical characteristics in case of some E-glass fibres/wood flour/polyester composite materials, Rev. Materiale Plastice, ISSN 0025/52892010, Vol. 47, nr. 1, 2010, pp.109-114.
[4] Cerbu C., Luca-Motoc D., Solutions for Improving of the Mechanical Behaviour of the Composite Materials Filled with Wood Flour, In Proceedings of The World Congress on Engineering WCE 2010, London, U.K, June 30 - July 2, 2010. London: Newswood Limited Publisher; Organization: International Association of Engineers, ISBN 978-988-18210-7-2, Vol II, 2010, pp. 1097-1100.
[5] Abrate S., Impact on Composite Structures. Cambridge: Cambridge University Press, 1998, ISBN-0-521-47389-6.
[6] Sierakowski R.L., Chaturvedi S.K., Dynamic loading and characterization of fiber reinforced composites, New York, US: A Wiley-Interscience Publications John Wiley & Sons, Inc., ISBN 0-471-13824-X, 1997.
[7] *** Certificate of epoxy resin. Certificate of hardener. Manufacturer: AXON Technologies, the 18th of September 2006.
[8] *** SR EN ISO 179-1: 2001. 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.
[9] **** Instruction manual for pendulum impact testers BPI-50COMC.10, Techical details, Zwick technical documentation, Zwich GmbH & Co., 2011.