

# Solutions for Improving of the Mechanical Behaviour of the Composite Materials Filled with Wood Flour

Camelia CERBU, Dana MOTOC

**Abstract**— The paper describes some aspects concerning the mechanical characteristics determined in flexural test, in case of some composite materials filled with different kinds of wood flour. Some specimens were made of urea-formaldehyde resin Urelit®R filled with: beech wood flour; fir wood flour; carpinus wood flour. The other composite specimens were made of Colpoly 7233 polyester resin with oak wood flour. Another composite material was made of the same Colpoly 7233 polyester reinforced with the both oak wood flour and E-glass woven fabric. Then, all composite specimens manufactured were subjected to the flexural test by using three points method. Finally, the analysis of the results obtained, shows that the mechanical properties of the fir wood flour / urea-formaldehyde resin are better than the ones corresponding to the composites made of the same resin but filled with beech / carpinus wood flour. On the other hand, better mechanical characteristics were recorded in case of the composite made of oak wood flour / Colpoly 7233 polyester. Moreover, the additionally reinforcing with E-glass woven fabric of the composite filled with oak wood flour, leads to the improving of the mechanical behaviour in flexural test. Finally, the paper marks out two ways for developing of the material structure of the tested composite materials filled with wood flour: the using of the oak / fir wood flour instead to the beech / carpinus wood flour to reinforce the composites; additionally reinforcing with E-glass woven fabrics.

**Index Terms**— composite material; wood flour; wood flour; flexural test; recycling.

## I. INTRODUCTION

The first of all, this work analyses the effects of some internal factors such as the kind of wood flour or the type of resin, on the mechanical characteristics of the composites resulted by their mixing.

Nowadays, it is known the great interest for recycling of the large amount of wood waste as in [1]-[3], in the form of wood flour, fibres is suitable as a filler for polyolefin matrix composites or for recycled plastics. A published research [4] shown that the composites made of high-density polyethylene

Manuscript received March 18, 2010. This work was supported in part by the UEFICSU (CNCSIS) of Romania under a national scientific Project of Exploratory Research (IDEI Program), Project ID\_733 / 2008 (CNCSIS). Assoc.prof.dr.eng. Camelia CERBU is with Department of Strength of Materials and Vibrations, Faculty of Mechanical Engineering, „Transilvania” University of Braşov, 29 Eroilor Av., Braşov, Romania, 500036 RO, (e-mail: cerbu@unitbv.ro; cerbucamelia@yahoo.com).

Assoc.prof.dr.eng. Dana MOTOC is with Precision Mechanics and Mechatronics Department, Faculty of Mechanical Engineering, „Transilvania” University of Braşov, 29 Eroilor Av., Braşov, Romania, 500036 RO, (e-mail: danaluca@unitbv.ro).

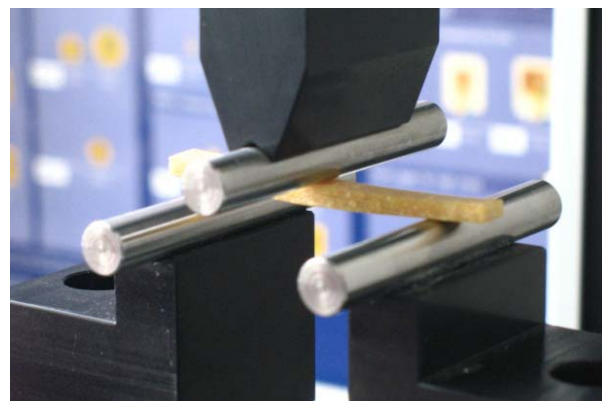


Fig. 1. Specimen made of fir wood flour / urea-formaldehyde resin subjected to bending test

and fir wood flour as filler, treated with coupling agents, could be desirable as building materials.

On the other hand, there were preoccupations concerning the recycling of fibre materials [5] such as the textiles, carpets, composite materials reinforced with fibres etc; the recycling of the CDs / DVDs [6].

In [7] it is consequently analysed the effect of the salts content of the seawater on both aspect of the composite surface and bending behaviour of the specimen after immersion in seawater. Dark spots appeared on the specimen surfaces because the oak wood contains tannins which are water-soluble phenol and poly-phenol compounds [3].

Herein, an urea-formaldehyde resin was used to manufacture three types of composite material reinforced with the following: fir wood flour, beech wood flour or carpinus wood flour. Moreover, a polyester resin Colpoly 7233 was reinforced only with oak wood flour to manufacture another composite.

Table I. Coding of the specimens made of composite materials filled with wood flour that was tested

No.	Code of the specimens	Resin	Reinforcement
1	F1, F2....	Urelit®R urea-formaldehyde resin	Beech wood flour
2	C1, C2...		Carpinus wood flour
3	R1, R2...		Fir wood flour
4	S1, S2, ...	Colpoly 7233 polyester resin	Oak wood flour
5	ST1, ST2,...		E-glass woven fabric + Oak wood flour

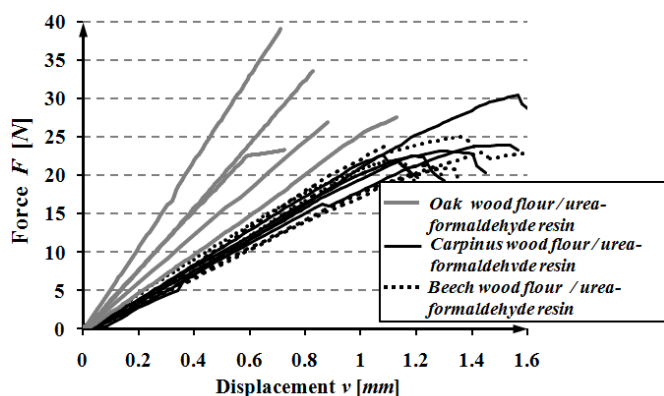


Fig. 2. F-v curves recorded in flexural test in case of the specimens made of urea-formaldehyde resin

The best mechanical characteristics in flexural test were recorded in case of the polyester resin filled with oak wood flour and additionally reinforced with glass woven fabric.

The mechanical behaviour of this composite is quite different with respect to the composites reinforced only with glass fibres without wood flour [8].

## II. MATERIALS TESTED AND THE METHOD OF WORK

The composition of the composite materials tested and their codification are shown in Table I.

The first of all, two kinds of resins (urea-formaldehyde, polyester) were used to manufacture four composite plates having the dimensions 350 x 250 mm<sup>2</sup> and 4 mm in thickness. The urea-formaldehyde resin Urelit®R was reinforced with fir wood flour, beech wood flour or carpinus wood flour. The polyester resin Copoly 7233 was reinforced only with oak wood flour.

Then, the fifth laminated composite plate having 6 mm in thickness, was manufactured by using E-glass woven fabric EWR145 to reinforce Copoly 7233 polyester resin mixed with oak wood flour. The hybrid composite material contained six layers of E-glass woven fabric and the same weight ratio of the wood flour (200 g / 500 ml resin) as the previous composites. To accelerate the polymerisation process, a chemical agent was certainly mixed with the polyester resin before of the admixture of the wood flour.

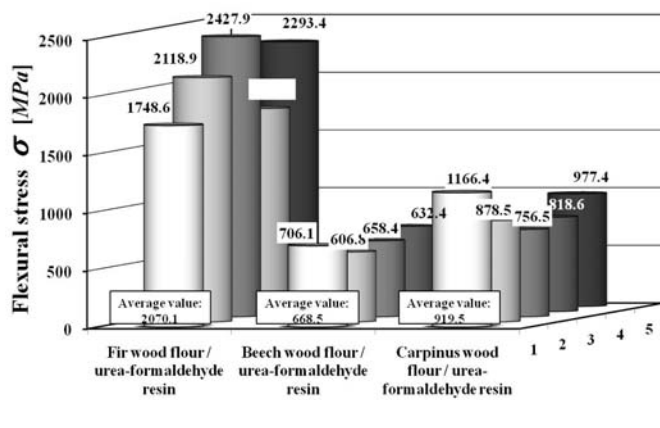


Fig. 4. Values of Young's modulus E in case of the specimens manufactured with urea-formaldehyde resin

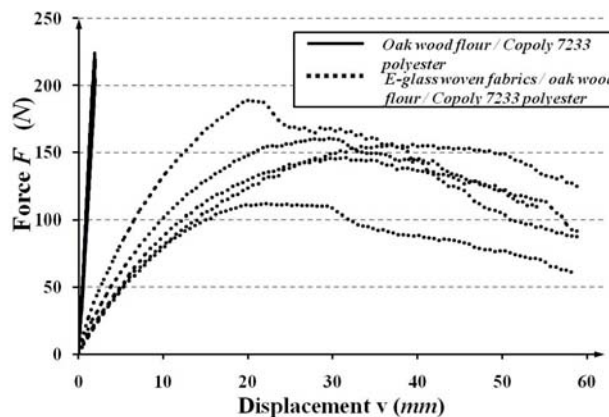


Fig. 3. F-v curves recorded in flexural test in case of the specimens made of polyester resin

Moreover, a coupling agent in form of power was used to improve the interaction between the polyester resin and the wood flour used as filler.

Urelit®R is an urea-formaldehyde resin [9] with higher stickiness and cold setting. The product is made by S.C. Viromet S.A. – Romania and it is usually used in the wood processing industry for bordering PAL panels, for pasting solid elements and for the manufacture of doors and windows.

Copoly 7233 [10] is an unsaturated polyester resin based on orthofthalic acid dissolved in styrene. This resin is thixotropic, with polymerization accelerator and contains peroxide factor. Copoly 7233 is recommended for all applications with glass fibres: crafts, boats, chairs, tanks, carrosserie elements, athletic equipage etc. The advantages of the using of this resin: low content of styrene; good mechanical properties.

The plates were kept at room temperature and dried environment for three weeks. Then, the specimens were cut from the plates for the flexural test (three-point method) according to the European standard [11].

Fig. 1 shows a specimen made of fir wood flour / urea-formaldehyde resin during the flexural test. LR5K Plus machine manufactured by LLOYD Instruments was used for the flexural test. This is power driven (maximum force  $F_{max} = 5$  kN).

The speed of loading was 3 mm/min. in case of the specimens made of the composite material denoted with ST

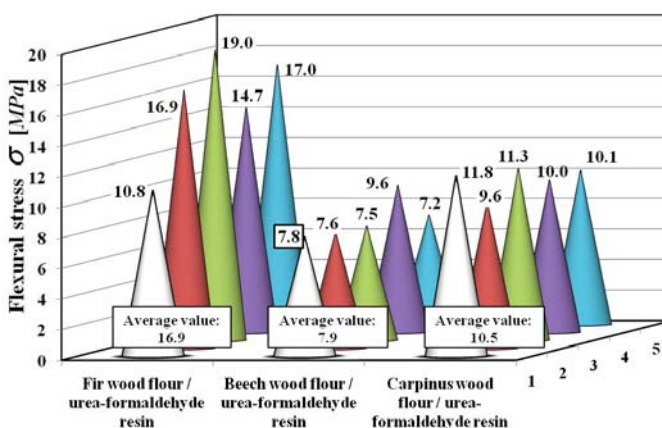


Fig. 5. Maximum values of flexural stress  $\sigma$  in case of the specimens manufactured with urea-formaldehyde resin

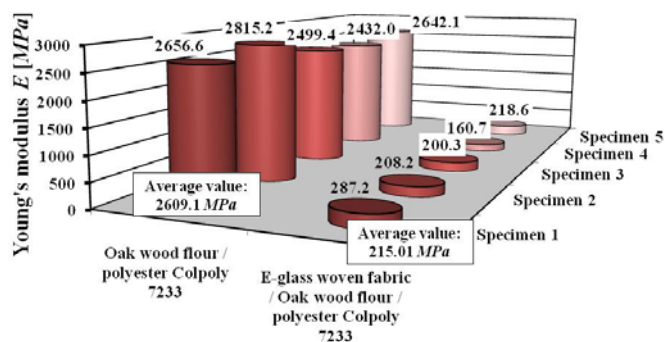


Fig. 6. Values of Young's modulus  $E$  in case of the specimens manufactured with the polyester resin

(Table I) and 1.5 mm/min. in case of the others composite materials tested. The speed of loading was greater in case of the composite ST because this is much more flexible. Consequently, the time of the flexural test was approximately 40 min. when the speed of loading was equal to 1.5 mm/min., in case of this composite material. It was remarked that the time of the flexural test halved by doubling of the loading speed while the shape of the curve obtained was approximately the same.

Before each flexural test of a specimen, the dimensions of its cross-section were accurately measured (0.1 mm). These 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) in form of files having 100-150 recordings. The testing machine also gave us the results of a statistical calculus for the set of the specimens tested.

### III. RESULTS AND DISCUSSIONS

The force-displacement curves ( $F-v$ ) recorded in case of all specimens tested are shown in the figures 2 and 3, respectively. It may easily observe that the slope corresponding to the linear portions of the  $F-v$  curves recorded in case of oak wood flour / polyester composite (fig. 3) is much greater than the ones recorded in case of the

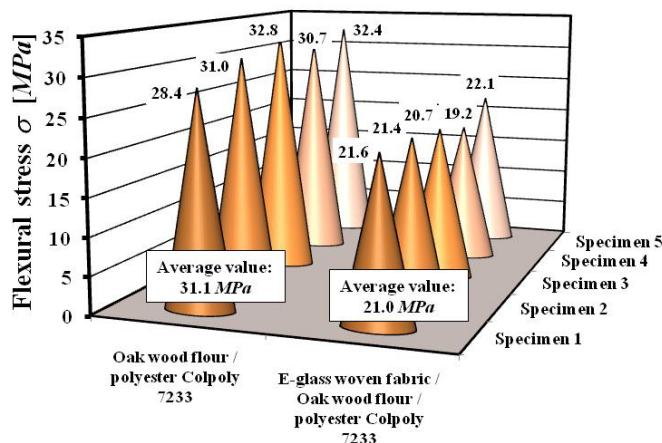


Fig. 7. Maximum values of flexural stress  $\sigma$  in case of the specimens manufactured with the polyester resin

composite materials made of urea-formaldehyde resin (fig. 2).

The experimental results concerning the modulus of elasticity  $E$  (fig. 4 and 6) reaffirm the concerning the best stiffness recorded in case of the oak wood flour / polyester composite. On the other hand, the average value of  $E$  recorded in case of reinforcing with beech wood flour is over three times less than the one recorded in case of reinforcing with fir wood flour when the urea-formaldehyde *Urelit®R* is used to prepare the composite materials.

Fig. 6 shows that the modulus of elasticity  $E$  is over 10 times less in case of the additionally reinforcing with glass woven fabric (composite ST) than in case of the composite denoted with S.

From strength point of view, it may remark that the maximum flexural stress 31.1 MPa recorded in case of oak wood flour / polyester composite (fig. 7) is just about twice times greater than the value 16.9 MPa recorded in case of the fir wood flour / urea-formaldehyde composite (fig. 5).

In case of composites manufactured with urea-formaldehyde (fig. 5), the lowest values of the ultimate normal stresses  $\sigma$  were recorded in case of the beech wood flour / urea-formaldehyde resin.

In case of the composite material ST reinforced with both glass woven fabric and oak wood flour, the average value of the flexural stress  $\sigma$  is with 32.48 % less than the average value of the same quantity recorded in case of the composite S

Table II. Average values of some mechanical characteristics determinate in bending in case of the composite materials tested

Composite material	Resin	Urea-formaldehydă Urelit®R			Polyester Colpoly7233	
	Reinforcement	Oak wood flour	Carpinus wood flour	Fir wood flour	Oak wood flour + E-glass woven fabric	
Young's modulus $E$ (MPa)		668.5	919.48	2070.1	2609.1	215.01
Maximum flexural stress $\sigma_{max}$ (MPa)		7.9	10.55	16.9	31.1	20.1
Strain energy to maximum load $W$ (N-mm)		15.8	17.73	13.8	192.2	3060.21
Flexural modulus $EI_z$ ( $\times 10^4$ N-mm <sup>2</sup> )		6.2387	6.7128	10.891	20.695	11.9264
Maximum force $F_{max}$ (N)		22.904	24.445	30.539	207.801	153.59
Max. vertical displacement $v_{max}$ to max. load (mm)		1.4059	1.3655	0.92725	1.977	28.89



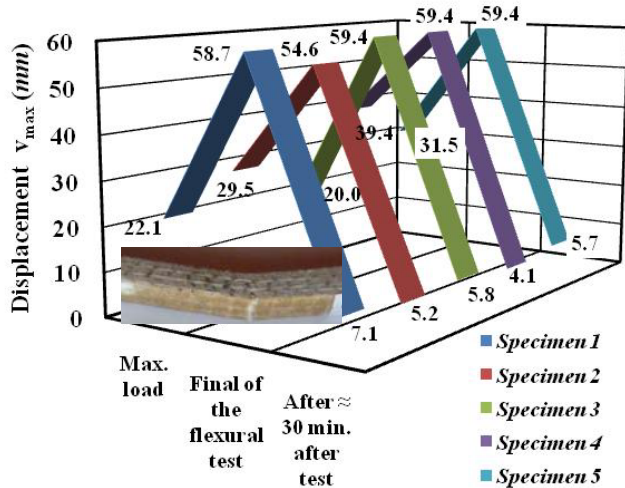


Fig. 8. Maximum values of deflection  $v_{max}$  in case of the specimens denoted with ST, made of glass woven fabric / oak wood flour / polyester resin

reinforced only with oak wood flour.

But, in case of the composite ST, the most important remark remains that concerning the values of the maximum deflection  $v_{max}$  of the midpoint of the specimens during and after the flexural test (Fig. 8). It may easily observe that the maximum residual deflection  $v_{max}$  after approximately 30min. after flexural test had finished, was much smaller than the maximum deflection recorded at maximum load and also, than the one recorded at the final test.

The reason of this mechanical behaviour could be assigned to the oak wood flour used to manufacture the composite specimen because no suchlike observation was recorded in the previous researches [8] when E-glass / polyester composite materials were tested. Practically, this unexpected mechanical behaviour of the new hybrid composite after the flexural test could be owing to a good combination between the rheological behaviour of wood and the shape memory, property that is assigned to the E-glass fibres.

#### IV. CONCLUSIONS

From both stiffness point of view and strength point of view, the composite material made of polyester resin is the best among the ones tested.

The paper demonstrates that the mechanical characteristics are also affected by the kind of species of wood the wood flour is made of. From this point of view, it is recommended to use either oak wood flour or fir wood flour as filler in composite materials instead of beech / carpinus wood flour.

Regarding the additionally reinforcing with glass fibres in

case of the wood composite materials, it is observed that the modulus of elasticity  $E$  considerably decreased (approximately by ten times). Moreover, a part of the deformation was vanished after approximately 30 min. the flexural test finished.

Taking into account the recycling necessity of the large quantity of wood wastes, none the less the values of mechanical characteristics are smaller, the composite materials tested could be used only to manufacture products that are not strength members (boards in construction, furnish ornaments, carcasses etc.).

To design new products the results of the present paper will be used to theoretically analyse by finite element method (FEM) of the stresses and strains developed in members or element structures made of composite materials tested (specially chairs or furniture elements).

Another objective of this research is to experimentally determine others mechanical characteristics by using compression test, impact tests, toughness test.

Moreover, in the next researches, it will try to improve the mechanical characteristics of the composite material denoted with ST by using of the other kinds of glass woven fabrics whose strength characteristics are better.

#### REFERENCES

- [1] D. P. Kamdem, H. Jiang, W. Cui, J. Freed, L. M. Matuana, "Properties of wood plastic composites made of recycled HDPE and wood flour from CCA-treated wood removed from service". *Composites: Part A*, 35, 2004, pp. 347.
- [2] S. E. Selke, I. Wichman, "Wood fiber/polyolefin composites", *Composites: Part A*, vol. 35, 2004, pp. 321-326.
- [3] A. A. KLYOSOV, Wood-plastic composites, Wiley Publishing, ISBN 978-0-470-14891-4, 2007, pp. 75-122.
- [4] K. B. Adhikary, Shusheng Pang, Mark P. Staiger, "Dimensional stability and mechanical behaviour of wood-plastic composites based on recycled and virgin high-density polyethylene (HDPE)", *Composites: Part B*, vol.39, 2008, pp. 807-815.
- [5] A. Bartl, A. Hackl, B. Mihalyi, M. Wistuba, I. Marini, "Recycling of fibre materials", *Trans IChemE, Institution of Chemical Engineers Part B, Process Safety and Environmental Protection*, vol.83(B4), July 2005, pp. 351-358.
- [6] C. Cerbu, H. Teodorescu-Draghicescu, "Bending behaviour of the composite materials made by recycling of the CDs and DVDs", In: *Proceedings (ISI) of The World Congress on Engineering WCE 2009*, vol. 2, London, 1-3 July, 2009, ISBN 978-988-18210-1-0, pp.1753-1756.
- [7] C. Cerbu, I. Curtu, V. Ciofoaia, I. C. Roşca, "Effects of the wood species on the mechanical characteristics in case of some E-glass fibres / wood flour / polyester composite materials", *Revista Materiale Plastice*, vol. 47 (1), ISSN 0025 / 5289, 2010, to be published.
- [8] C. Cerbu, "Aspects concerning the degradation of the elastic and mechanical characteristics in bending in case of the glass / polymer composite materials due to the moisture absorption", *Revista Materiale Plastice*, vol. 44 (2), ISSN 0025 / 5289, 2007, pp.97-102.
- [9] \*\*\*(2008) <http://www.viromet.ro> - Material data sheet Urelit®R, S.C. VIROMET S.A., Victoria (Romania), Accessed on: 2009-03-12.
- [10] ].\*\*\* Material data sheet - Polyester resin Colpoly 7233, S.C.Mediterana SRL, 25 iulie, 2007.
- [11] \*\*\* SR EN ISO 178:2001, Plastics. Determination of flexural properties, Three point method, CEN, European Committee for Standardization, Bruxelles, 2001.