Bending Behaviour of the Composite Materials Made by Recycling of the CDs and DVDs

Camelia CERBU, Horatiu TEODORESCU-DRAGHICESCU

Abstract— **The paper describes the aspects concerning a methodology of recycling of CDs (compact disks), DVDs to develop a new composite material made of a polyester resin reinforced with chopped material of CDs, DVDs. It is known that polycarbonates are mainly used to manufacture of CDs, DVDs while a very thin aluminium layer is additionally used to record information. The first of all, the hand lay-up technology is used to prepare a board made of the composite material involved. Then, the composite specimens were cut from the board and subjected to the flexural test (three points method). Herein, the mechanical characteristics of the specimens were analysed. Moreover, the photos acquired by using a metallographic microscope are presented to discuss about the homogeneity of the composite structure. Finally, some applications of the new composite material are proposed by taking into account the experimental results shown and above all, the recycling necessity of the large quantity of CDs / DVDs wastes.**

Index Terms— **bending; composite; mechanical properties; recycling of compact disks.**

I. Introduction

All products will sometimes be unusable and thus result in being an end-of-life product. In the past, disposal was commonly used to get rid of these products. Nowadays sustainable solutions should be sought in order to minimize the negative impacts on the environment and minimize the consumption of resources.

It is well-known the actual trend of manufacturing of new composite materials by recycling [1]-[4] of the following materials: wood wastes, plastics, paper wastes, textiles, pets, rubber of tyres, composite material reinforced with fibres, asphalt etc. Some works [5], [6] analysed the degradation of the mechanical characteristics due to the effects of the aggressive environment while the others papers studied the effects of the manufacturing technology [7] of the composite materials on their mechanical characteristics.

The main objective of the present research is to manufacture new composite materials by reinforcing of a polyester resin with chopped CDs or DVDs. Then, the specimens made of the composite developed were subjected to bending test (*three points method*).

The first of all some important remarks are needed regarding the component materials and structure of the CDs or DVDs. From manufacturing point of view, it may be noted that repetitive manufacturing of CDs / DVDs is made by injection of the polycarbonate in a mould at temperature of 345 *°C* [8]. An aluminium layer having the thickness of 50 *nm* is set over the surface containing information, to read subsequently. The method is called sputtering. To protect the aluminium layer, a varnish transparent coat is applied over. The varnish coat is dried by exposure to an *UV* lamp.

Herein, the following characteristics of the CDs and DVDs, are significant: sub-layer material – polycarbonates; disk diameter – 120 *mm*; disk thickness 1,2 *mm* ± 0,1 *mm*; usually aluminium is used as coating material; number of tracks 20000 etc.

Usually, polyesters of the carbonic acid are called polycarbonates and their general structure is

Polycarbonates are generally stable under the action of water, organic acids and minerals. It is known that the tensile strength, elasticity modulus decrease when the temperature increases.

Polycarbonates are widely used as row material in automobile industry, electronic equipment industry and building materials. It is recycled in similar products. Polycarbonate is a type of thermoplastic resin. In practice there are many products made of polycarbonates: boards made of cellular polycarbonates; black RPC, 900 CH are boars made of recycled polycarbonate in the first phase; brick system made of polycarbonate; manufacturing of some medical devices; applications such as biomaterials etc.

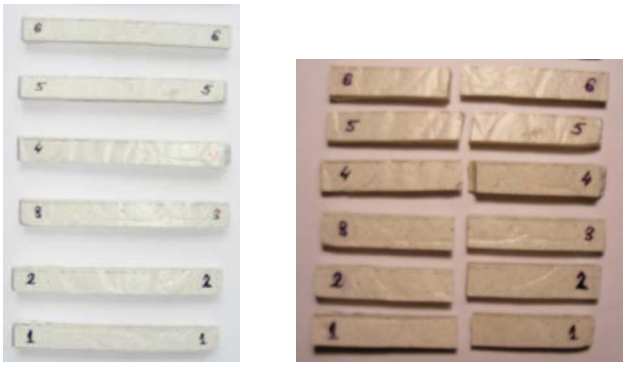
II. Materials Tested and the Method of Work

The hand lay-up technology is used to manufacture a composite plate. The first of all, the CDs / DVDs were cut by using hitch for sheet metal, at approximate dimensions of 1x1 mm^2. Then, they are chopped by using a laboratory centrifugal mill with a sieve having mesh dimension of 1 mm. In the next step, the polyester COLPOLY 7233 resin, additive and titanium oxide were added first and blended for five to ten minutes to ensure complete melting. After this, the chopped chips of CDs / DVDs were slowly added and the

Manuscript received March 1, 2009. This work was supported in part by the *Ministry of Education and Research of Romania* under Grant *ID_733 / 2009* (sponsor and financial support acknowledgment goes here).
Camelia Cerbu is with Strength of Materials and Vibrations Department, Faculty of Mechanical Engineering, „Transilvania" University of Braşov, 29 Eroilor Av., Braşov, Romania, 500036 RO, (e-mail: cerbu@unitbv.ro; cerbucamelia@yahoo.com).
Horatiu Teodorescu-Draghicescu is with Mechanics Department, Faculty of Mechanical Engineering, „Transilvania" University of Braşov, 29 Eroilor Av., Braşov, Romania, 500036 RO, (e-mail: hteodorescu@yahoo.com).

mixture is continually melded to avoid the compacting or agglomeration of CD / DVD particles.

Finally, a homogeneous mixture was resulted and it was introduced in a metal mould to obtain a plate made of the new composite material. The proportion used between the two components was: 214 *g* chips of CDs and DVDs / 140 *ml* polyester COLPOLY 7233 resin.



(a) Before bending test *(b) After bending test*

Fig. 1. Specimens for bending test

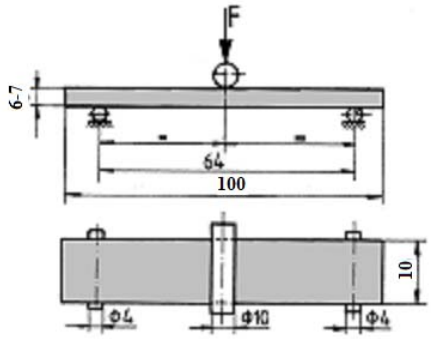


Fig. 2. Dimensions of the specimen and scheme of loading for the bending test [9]

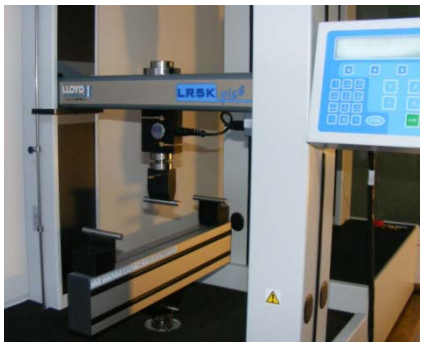


Fig. 3. Bending device (three point method) of the testing machine

Then, a number of six specimens (Fig. 1,a) where cut from the plate for the bending test (three-point method). The dimensions of the specimen and the scheme of loading (three-point method) for the flexural test are shown in the Fig. 2 [9]. A photo of the specimens after the flexural test is shown at the Fig. 1,b.

The testing equipment used for flexural test (Fig. 3) consists of hydraulic power supply. The maximum force capacity is ±15 *kN*. The speed of loading was 1 *mm/min* in the flexural test as the SR-EN-ISO standard [9] recommends.

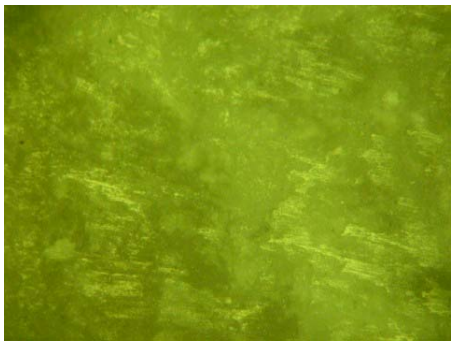
Before each flexural test of a specimen, the dimensions of the cross-section were accurately measured and then, they were considered as input data in the software program of the machine. The testing equipment allowed us to record pairs of values (force F and deflection v at midpoint of the specimens, stress σ and strain ε) in form of text files.

The testing machine gives us the results of a statistical calculus for each set of specimens tested. Therefore, the average values of the following quantities could be automatically computed: *Young*'s modulus *E* of bending, flexural rigidity EI_z , maximum bending stress σ_{max} at maximum load, deflection v_{max} at maximum load, maximum bending strain ε_{max} at maximum load, mechanical work to maximum load or the stored strain energy etc.

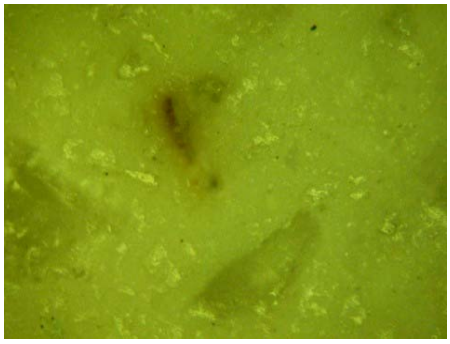
III. Results And Discussions

Before mechanical testing, some specimens were cut and then, the areas of cutting were photographed (Fig. 4) by using a metallographic microscope (with zoom of 100x) to analyse the homogeneity of the new composite material. It may remark that the silver areas represent the chips of chopped CDs / DVDs while the white areas represent the polyester resin used.

(a)



(b)



(c)

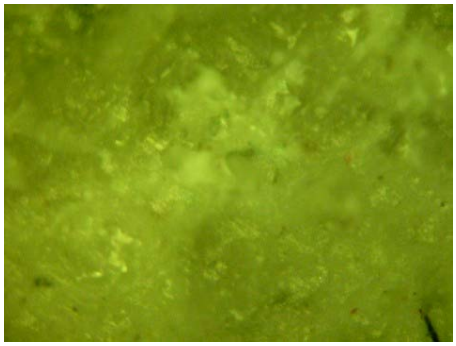


Fig. 4. Photos acquired by using a metallographic microscope (zoom =100x)

Table I: The experimental results from bending test in case of the specimens analysed

No.	Width (*mm*)	Thick ness (*mm*)	Area [mm^2]	Flexural Rigidity (*N•mm^2*)	Young's Modulus *E* (*MPa*)	Load at Max. Load (*N*)	Maximum Bending Stress at Max. Load (*MPa*)	Extension at Max. Load (*mm*)	Maximum Bending Strain at Max. Load	Work to Max. Load (*N•mm*)
1	11	6	66	209110.34	1056.11	45.79	10.41	1.405	0.0140	34.375
2	12	6	72	251667.42	1165.13	55.12	11.48	1.224	0.0122	34.663
3	11	7	77	263972.02	839.56	59.05	9.86	1.298	0.0151	39.500
4	11	8	88	340305.11	725.08	76.96	9.84	1.223	0.0163	48.341
5	11.2	6.3	70.56	187755.02	804.51	62.35	12.62	1.883	0.0198	61.207
6	12	6.4	76.8	254556.65	971.06	91.51	16.76	1.845	0.0197	85.793
Average values				**251227.76**	**926.91**	**65.13**	**11.83**	**1.48**	**0.02**	**50.65**

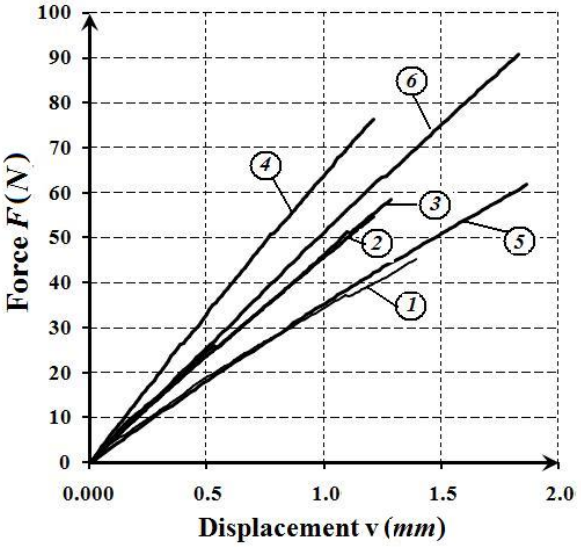


Fig. 5. Force – displacement (*F-v*) curves

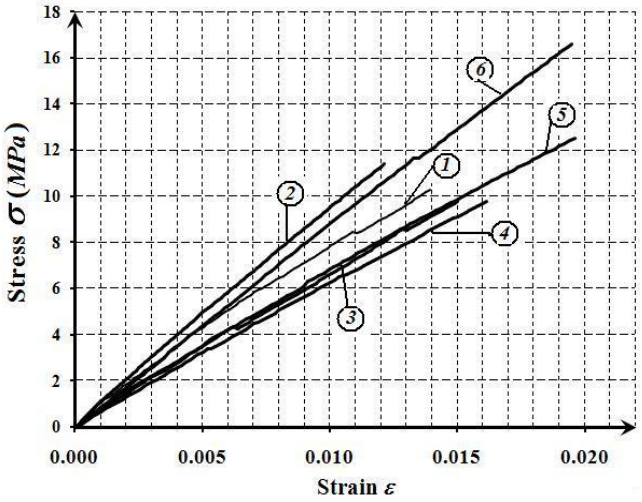


Fig. 6. Stess-strain (σ - $\mathcal{E}$) curves

Some very small particles in dark grey are made of aluminum while the coloured particles (Fig. 4, b) would be the labels of CDs / DVDs. Generally speaking it may be deduced that the homogeneity of the new composite is quite good.

Other specimens were subjected to bending test (three point method) and the experimental results were electronic recorded in form of some text files having 100-150 records. These results may be graphically drawn. In the Fig. 5 are shown F - v (force-displacement) curves of the experimental data in case of the composite materials tested while Fig. 6 shows σ - ε (stress-strain) curves. Moreover, some experimental data for each specimen tested are shown in the table I. The average values of the mechanical characteristics involved are computed in the last row of the table. Analyzing σ - ε curves (Fig. 6) we may observe that the slopes of the curves on the linear portion are very small. It follows that the values of the modulus of elasticity *E* (computed for linear portion of σ - ε curve) are small in case of the new composite analyzed (table 1). In the same time, the values recorded for maximum bending stress σ_{max} are also very small.

A photo of the rupture acquired by using a metallographic microscope is shown in the Fig. 7. The very small craters like that located to the bottom-right corner of the photo, could be given by detachments of the chips of CDs / DVDs from the polyester resin mass.

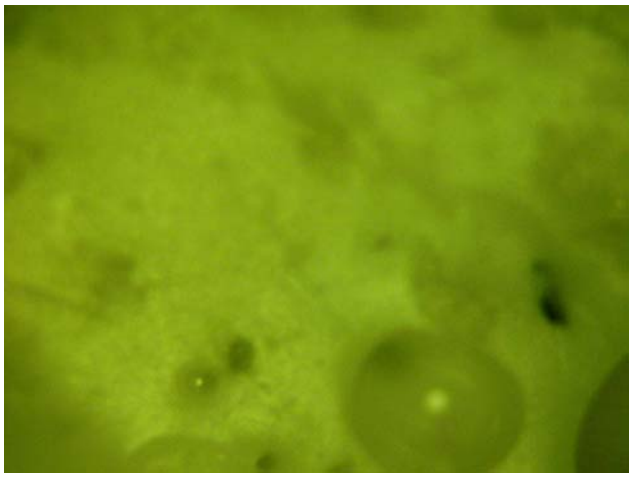


Fig. 7. Photo of the rupture acquired by using a metallographic microscope (zoom =100x)

IV. Conclusions

The new composite material developed during the research of whose results are shown in the present paper, could be used in automobile industry, electronic equipment industry, electrical applications and building materials. Taking into account the low mechanical characteristics in bending, this

composite should be used only to manufacture products that are not strength members. However, taking into account the recycling necessity of the large quantity of CDs / DVDs wastes, the low costs of manufacture for the new composite, it may recommend it for boards in construction, furnish ornaments, carcases, electrical switches, plating, coatings etc.

Moreover, the fine structure with a good homogeneity, shown in the photos acquired by a metallographic microscope, could be a reason to use the injection in mould or spray-technology to manufacture products made of the new composite material.

The next objectives of this research is to experimentally determine others mechanical characteristics by using compression test, toughness test. It should also try to manufacture this new composite material with different proportions between CD / DVD chips and polyester resin.

REFERENCES

[1]. 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, July 2005, 83(B4): 351–358;

[2]. Susan E. Selke, Indrek Wichman, *Wood fiber/polyolefin composites*, Composites: Part A 35 (2004), pp. 321–326;

[3]. Khalid Mahmood Zia, Haq Nawaz Bhatti, Ijaz Ahmad Bhatti, *Methods for polyurethane and polyurethane composites, recycling and recovery: A review*, Reactive & Functional Polymers 67 (2007) pp. 675–692;

[4]. Kamal 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 39 (2008), pp. 807–815;

[5]. Camelia 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, Iunie, 2007, pp.97-102;

[6]. Camelia Cerbu, V. Ciofoaia, H. Teodorescu-Drăghicescu, I.C. Roşca – *Water effects on the composites made of E-glass woven fabrics*, Proceedings of International Conference Advanced Composite Materials Engineering „COMAT 2008" under FISITA Patronage, vol.1B, ISSN 1844-9336, Braşov, 9-11 octombrie, 2008, p. 310-313;

[7]. Camelia Cerbu, V. Ciofoaia, I. Curtu – The effects of the manufacturing on the mechanical characteristics of the E-glass / epoxy composites, Proceedings of The 12th International Research / Expert Conference "Trends in the development of machinery and associated technology"- TMT2008, ISBN 978-9958-617-41-6, Istanbul (Turkey), 26-30 august, 2008, p.229-232;

[8]. How Products are made: Volume 1, Compact disc, http://www.madehow.com/Volume-1/Compact-Disc.html

[9]. SR EN ISO 178:2001, Plastics. Determination of flexural properties, Three point method, CEN, European Committee for Standadization, Bruxelles, 2001.