ON THE PHYSICAL AND MECHANICAL PROPERTIES OF SOME BIODEGRADABLE POLYMER MATRIX COMPOSITES, WITH BAST WOWEN TEXTILE REINFORCEMENTS

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Abstract

The polymer matrix composites reinforced with textile fibers are a relatively new class of materials, showing a dynamic development. The characteristics of the final material could be tailored, by choosing suitable properties of the polymer matrix and the textile insertion, together with the proper proportion of the material constituents, and its manufacturing technology. As a result, one can obtain some composite materials having low densities, but high values of strength and flexibility, good corrosion resistance and sound insulation properties.

In the present paper, some different types of biodegradable composites, based on different variants of a proteinic polymer matrix, with bast woven textile reinforcements were tested.

In terms of mechanical behavior, one can assume that the investigated composites have quite similar properties, but it appears that the best of the strength and stiffness properties (combined with lowest ductility) were obtained for the proteinic matrix that was treated with plasticizers and cross-linking agents.

Keywords: composites, tensile testing, bast, woven textile, proteic polymer.

INTRODUCTION

The biodegradable materials are important subjects of the contemporary research, having in view the modern concepts of materials recycling and environmental friendly. In this area, a special attention is oriented to the composite materials, because of their various types and possibilities of properties combinations [1-5].

The present paper is focused on the mechanical and physical properties of some polymeric matrix biodegradable composites, with bast fiber textile reinforcements.

EXPOSITION

Five different categories of biodegradable composites were investigated; their constituents are described in Table 1, regarding their nature and volume content.

The composite samples were analyzed having in view their response at the tensile test, together with their corresponding mechanical characterristics.

Some prismatic composite specimens have been used, having the same thickness as the originated sample plates, and provided with bilateral aluminum end tabs. The specimen dimensions were established according to the ASTM Standard referring to the tensile testing of polymer matrix composites [6].

The tests were performed using a computer aided universal WDW 50E testing machine, with a maximum loading force of 50kN. The stress-strain dependence, for the studied material, was permanently observed during testing.

As a consequence, the Young modulus values were determined, corresponding to different strain levels, for each type of the tested composite materials, using the instantaneous conventional

(calculated as reported to the initial length and transverse area of the specimen, L_0 and S_0) stress and strain values, from different stages of the testing process.

Table 1.The nature and content of the composite constituents

Variants	Matrix		Woven insertion V_2 (number of layers)	Matrix / reinf. volume fractions [%]
	Composition	Components ratio		
CC2	CA/A1/A2	77 / 10 / 13	2	64,7 / 35,3
CCP1	CA/A1/A3	80 / 10 / 10	4	64,0 / 36,0
CCP2	CA/A1/A4	88 / 10 / 2	4	67,1 / 32,9
CCP3	CA/A1/A4	82 / 10 / 8	4	68,9 / 31,1
CCP4	CA/A1/A2/A4	75 / 10 / 13 / 2	4	67,5 / 32,5
CA= Proteinic material; PCL = Poly ε-caprolactone; A1 = Plasticizer; A2 = cellulose fillers; A3 = Fillers (synthetic biodegradable polymer); A4 = Cross-linking agent (cetonform-aldehyde resin)				

So, using the loading ($\Delta F_i = F_i - F_{i-1}$) and, respectively, the elongation ($\Delta L_i = L_i - L_{i-1}$) parameters, corresponding to the stage "i" of the tension test, when comparing with the previous stage "i-1", an instantaneous value of the material Young modulus can be calculated as:

$$E_i = \frac{\sigma_i}{\varepsilon_i} = \frac{\Delta F_i / S_o}{\Delta L_i / L_o} \qquad (1)$$

The tensile tests were completely performed, so conducted till the specimen failure, and the maximum load value (F_{max}) was practically recorded at the moment of the first crack that appeared into the composite specimen structure. Using the experimental data, together with the standard recommendations, some important mechanical characteristics values are determined, for the studied material, as follows:

The ultimate tensile strength:

$$R_m = \frac{F_{max}}{S_o} \ [MPa] \qquad (2)$$

The tensile ductility (elongation at failure):

$$A_r = \frac{L_u - L_o}{L_o} \cdot 100 \ [\%] \qquad (3)$$

It could be noted the similar aspect of the load-elongation curves (see the figures 1, 2 and 3) for all types of the studied composite materials.

One can observe, from the below-presented figures, the presence of two distinct linear zones, on which of the stress-strain curves, before the attendance of the maximum loading level (F_{max}):

—an initial zone, characterized by a relative abrupt slope, and corresponding to a loading level of about 25-35% from F_{max};

—a significant longer zone of the curve, that could be denoted as a "stabilized" one, being characterized by a considerable decrease in slope (and indicating a corresponding decrease of the Young modulus value, for the studied material).

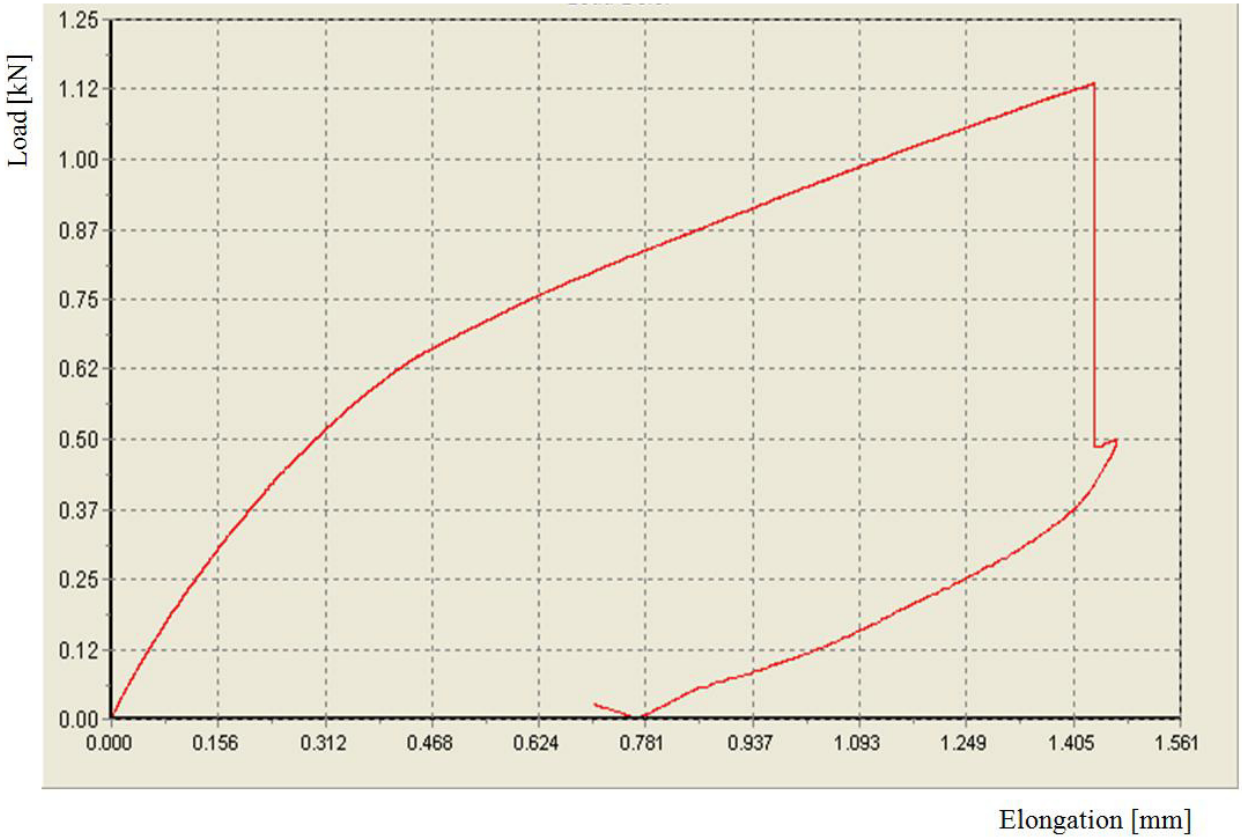


Figure 1. *Typical aspect of load-elongation curves for the CCP1 type composites.*

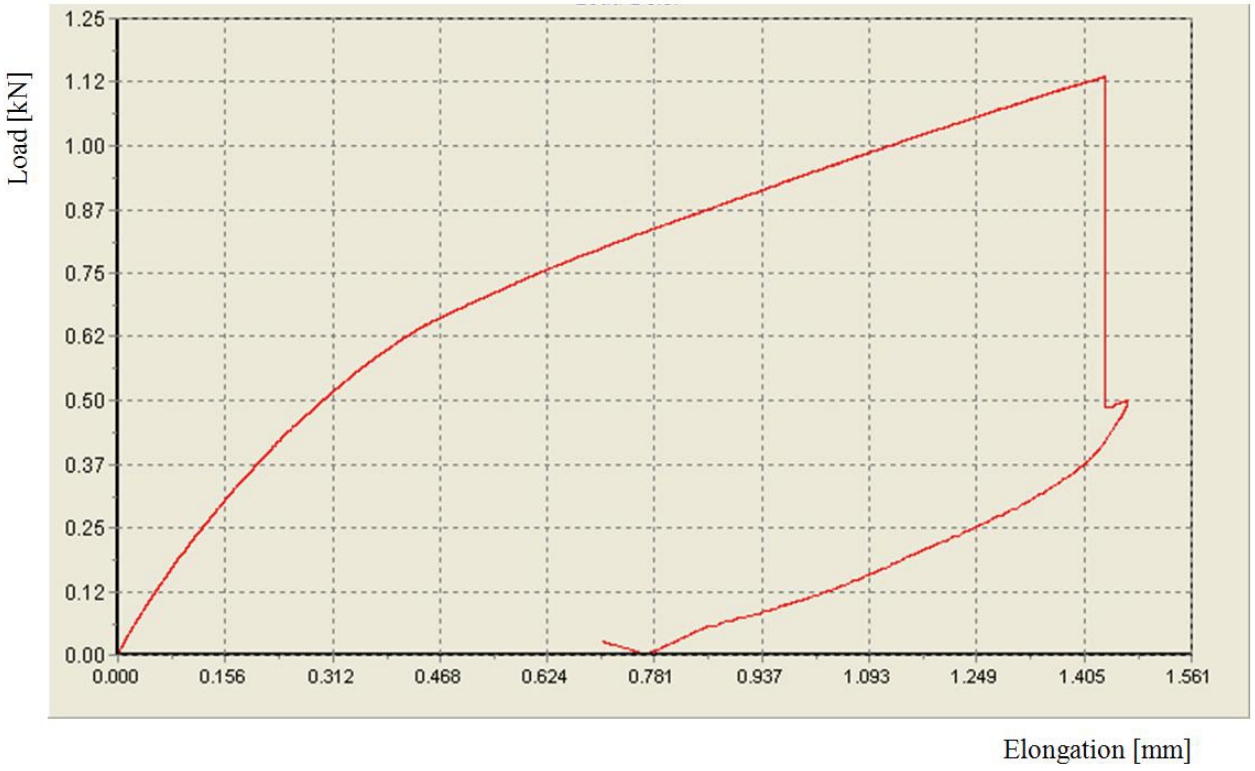


Figure 2. *Typical aspect of load -elongation curves for the CCP3 type composites.*

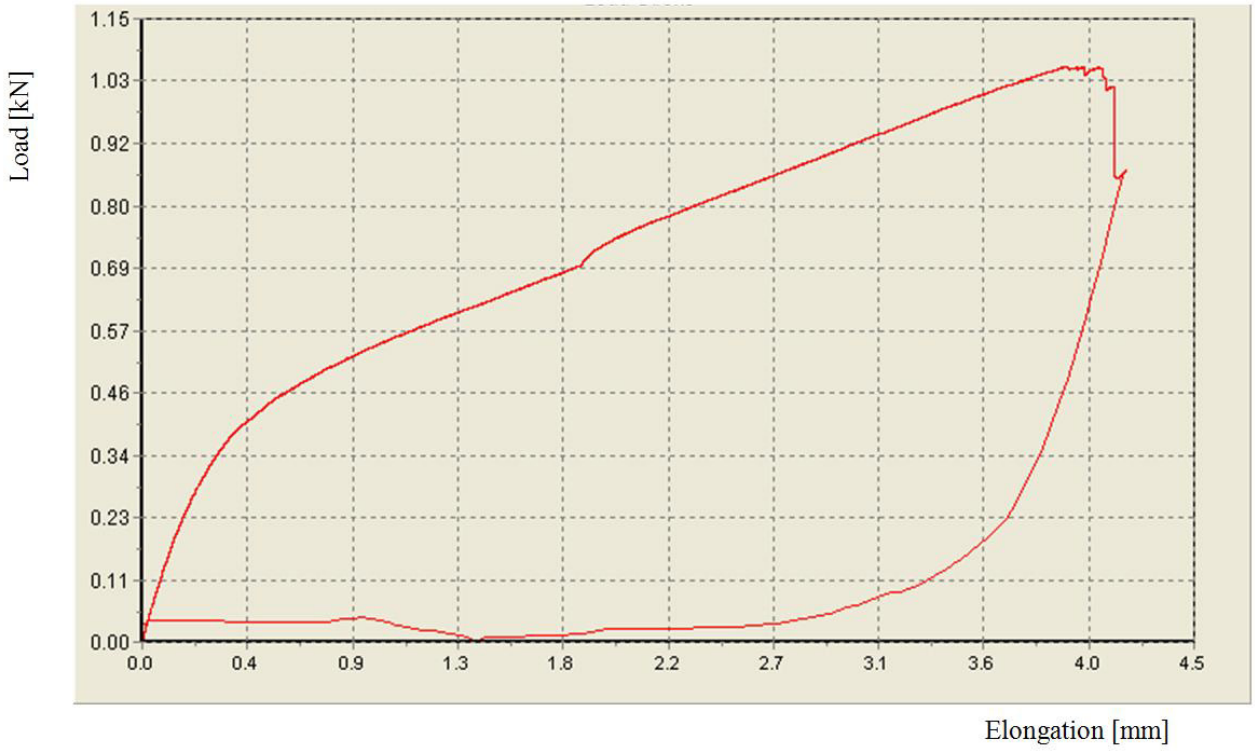


Figure 3. *Typical aspect of load -elongation curves for the CC2 type composites.*

The calculated Young modulus average values, for each type of the tested composite samples, are included into the following Table 2, together with the respective values of tensile strength and ductility (elongation at failure).

Table 2. Mechanical characteristics of the studied composite materials

Composite type	Tensile Strength R_m [MPa]	Elongation at Failure A_r [%]	Young Modulus E [MPa]	
			initial	stabilized
CC2	8,10	4,22	895	112-126
CCP1	9,82	5,75	719	65-144
CCP2	7,12	3,15	624	108-205
CCP3	11,05	1,71	1210	375-431
CCP4	2,69	2,68	270	77-80

As it appears from the above-presented data, the composite mechanical characteristics depend on both the nature and the volume fractions of its constituents, but also on the technological parameters of the composite manufacturing process. In fact, the strength and modulus of the studied polymer matrix composites are strongly influenced by the reinforcement nature and content: as it was expected, the highest values of tensile strength were obtained for the composites with highly cross-linked polymer matrix.

In terms of mechanical behavior, the investigated composites have quite similar qualities, but it appears that the best properties in strength and stiffness (combined with the lowest ductility - elongation at failure) were obtained for the protein matrix material that was treated with plasticizer and cross-linking agents (CCP3 composite version).

On the other hand, for the composites with the higher content of textile reinforcement (composite version CCP1), a relatively high mechanical strength was observed, combined with the highest ductility level (three times higher, in average values, than the CCP3 type composites, which showed, however, the highest stiffness values).

Table 3. Density variation, as a function of manufacturing process parameters

Composite type	Density (g/cm^3)		Variation of the material density (%)
	Before pressing	After pressing	
CC2	1,22	2,19	79,5
CCP1	0,94	1,65	75,5
CCP2	0,88	1,60	81,8
CCP3	0,74	1,08	45
CCP4	0,78	1,89	142,3

Depending on the applied pressure level, during the manufacturing process, some composite materials with different densities (less or more compact structures) could be obtained. On the basis of experimental data, one can conclude that, when applying a pressure of 1.5 MPa, at a temperature of 70^{o}C, the density of the composite samples was significantly modified, as could be observed in Table 3.

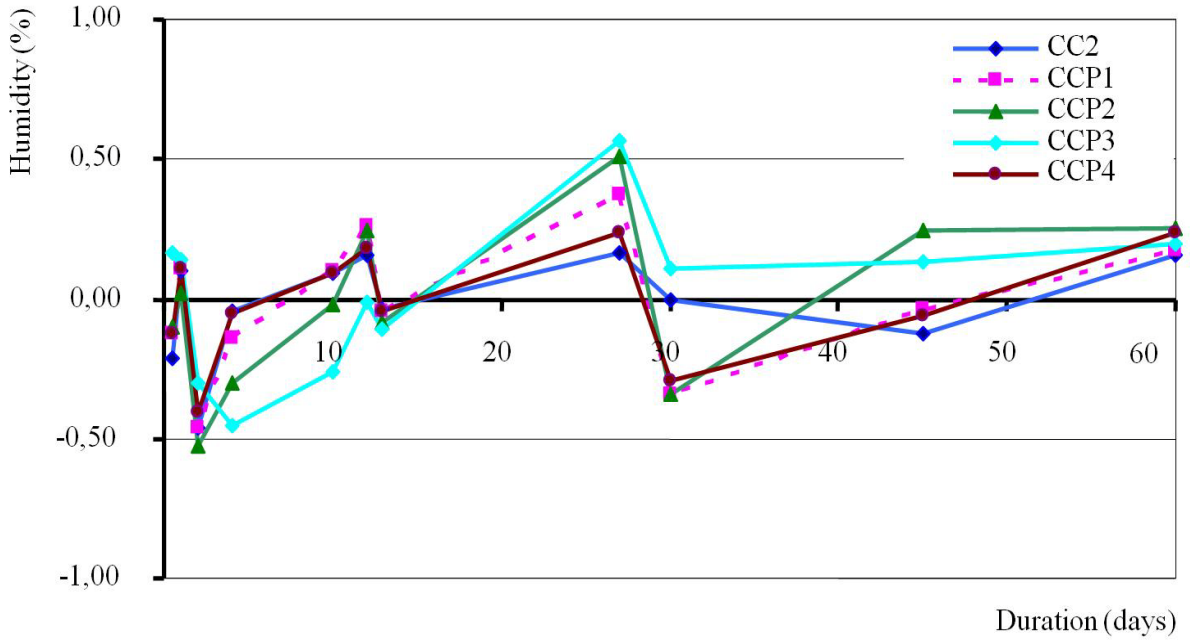


Figure 4. *The variation of the moisture content, for the studied composites, as a function of the environmental humidity.*

As a result, one can assume that the mechanical properties of the studied composites could also be tailored, by using some suitable parameters of the manufacturing process.

It is important to note that, regarding the materials that are used for manufacturing some environmental products, their capacity of water absorption must be evaluated; it is a material characteristic that strongly influences both its dimensional stability and its degradation rate after the lifetime.

Using the experimental data (for 60 days of

exposure) on the influence of environmental humidity on the moisture content of the investigated composites (see Fig. 4), one can observe some insignificant variations (± 0.5%) of that physical parameter, around its equilibrium value. It can be assumed, for the studied composites, a suitable behavior, from the hygroscopic point of view, and they could be recommended to be used for manufacturing some environmental products.

CONCLUSION

Some biodegradable polymer matrix composites were investigated, with bast wowen textile reinforcements.

The mechanical characteristics (ultimate tensile strength, ductility and Young modulus) in tensile tests were studied, for five different types of composites. Some similar properties were obtained, for all the composite samples, but the best qualities were observed for the highest cross-linked polymer matrix.

Regarding the environmental vulnerability of the investigated composites, a good stability of their moisture content was observed, after 60 days of exposure at room temperature and humidity.

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