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The Influence of Technological Parameters on the Mechanical Properties of Some Biodegradable Polymer Matrix Composite Materials

Marian Mareş, Bogdan Leiţoiu, Mihai Dărângă,
Ioan Iacob, Adrian Buhu

Technical University "Gh. Asachi", Bd. Mangeron 61, Iaşi
e-mail: mmares@tuiasi.ro

Abstract

The present paper is referring to a class of composite materials, having a proteic polymer matrix and being reinforced with some textile vegetable material (woven flax strands). As a result, an important degree of biodegradability can be expected, for the final material. The influence of the variation of some parameters of the sample consolidation process on the mechanical properties of the composites was investigated. Little influence was observed, for the variation of time duration, together with a slightly negative influence of increasing the pressure values. It was also emphasized that, when the curing process of the polymeric matrix is realized during the consolidation stage, the resulting sample is compact and uniform in structure and its stress-strain dependence curve is quasi-linear in aspect.

Key words: *polymer matrix composite, mechanical properties.*

Introduction

The properties of composite materials are intensively investigated nowadays, because they are representing a very large material category, experiencing a particular capability, with practically unlimited resources, of adapting their structure and characteristics to the requirements of various practical uses. As a consequence, the expertise of scientists working in the composite research domain could be considered as an important opportunity for new classes of materials to be created, having the property of being almost entirely biodegradable, beyond their lifetime duration. Such a characteristic could be obtained, for example, using as constituents some raw materials originating in vegetable or animal bodies [1].

The structure and properties of such composite materials can be tailored, according to the practical objectives that are proposed, and on the basis of some reliable experimental analysis regarding the influence of various technological parameters on the mechanical response of the final material [2]. The present paper is focused on some composite materials with a polymeric (proteic) matrix (having an animal glue as the main component), and with textile reinforcements made on bast fiber (woven flax strands) [3].

Materials and methods

Many combinations of technological parameters values were proposed to be experienced, for the studied composite materials. The structural pattern of the samples consists of reinforcing layers that are oriented with the warp strands running in the longitudinal direction (parallel to the length of sample). That model of composite structure was proven, on the basis of some previously conducted tests, the suitable one for obtaining a good combination of mechanical properties for the final material.

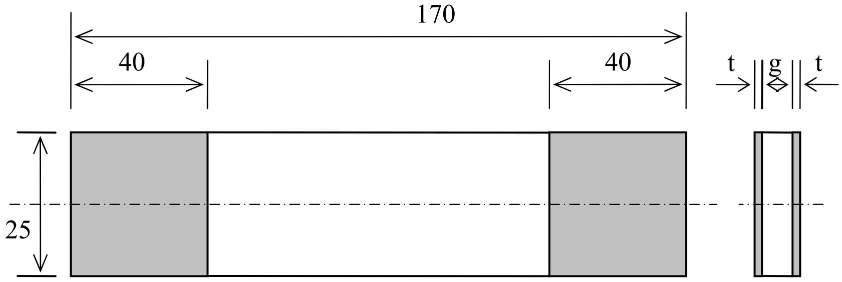


Fig. 1. The composite specimen for tension tests.

The material characteristics, as resulted from the uniaxial tension tests, have been the basic criterion, for comparing the materials that are described in the present paper. The tests were conducted following the requirements of the standard method [4] that is usually recommended for establishing the tensile properties of polymer matrix composite materials. The prismatic specimens (see Fig. 1), with bonded aluminum end-tabs, have 25mm width and the same thicknesses as the samples from which they have been cut.

The tests have been made using a universal, computer assisted testing machine (Fig. 2), having a maximum loading capability of 50kN. The variation of load-elongation dependence was registered, during the tests, including the stress-strain dependence curves. Uniaxial tensile tests to failure yielded the following mechanical properties of the studied composite materials: tensile strength (R_m), ultimate tensile strain (A_r), and Young's modulus (E).

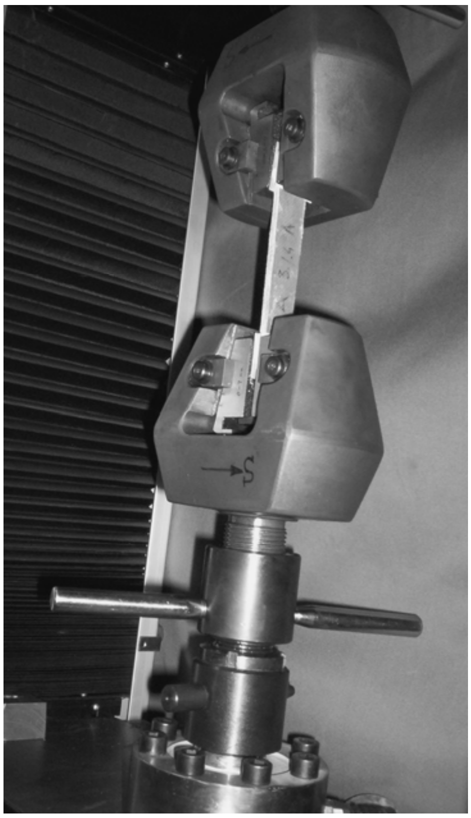


Fig. 2. The fixture for tensile tests.

Technological parameters

The manufacturing process of the composite material samples is starting by a forming operation, conducted at temperatures up to 60°C and some low pressure values (below 0.5MPa), followed by the consolidation stage, at temperatures up to 90°C and some pressure values of maximum 1.75MPa.

Experimental results and discussion

a. The influence of time duration for the consolidation process

Three different values of time duration (2 min., 5 min., and 8 min., respectively) have been experimented, for pressing the composite samples at 0.88MPa and a temperature of 90°C. The cited time values are low enough, in order to avoid the expulsion of the polymeric matrix material, during the samples consolidation process.

The analysis of experimental data leads to idea of a moderate influence of time duration on the mechanical properties of the studied composites: some little significant increases were observed, for tensile strength values, coupled with some small variations of the values of Young's modulus and ultimate tensile strain (see Fig. 3). An average value of 5 min. was established, on that basis, for the consolidation process, to be used for the following experiments.

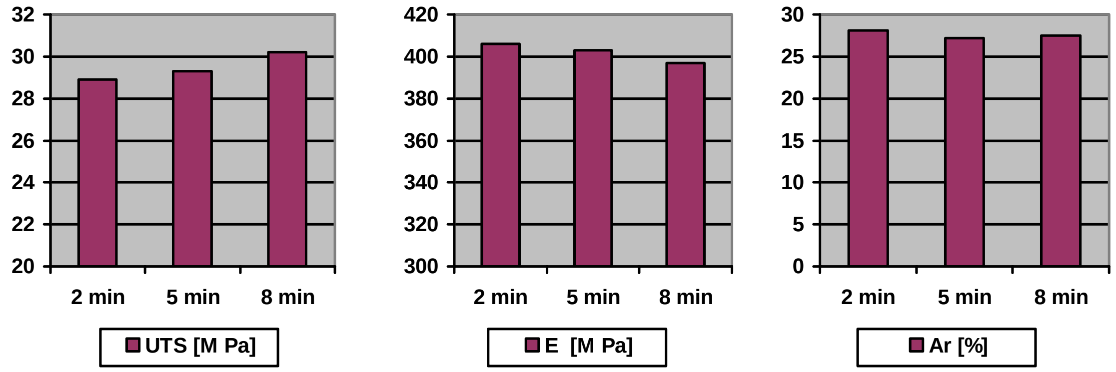


Fig. 3. The influence of time duration of sample consolidation process, on the composite materials mechanical properties.

b. The influence of the consolidation pressure value

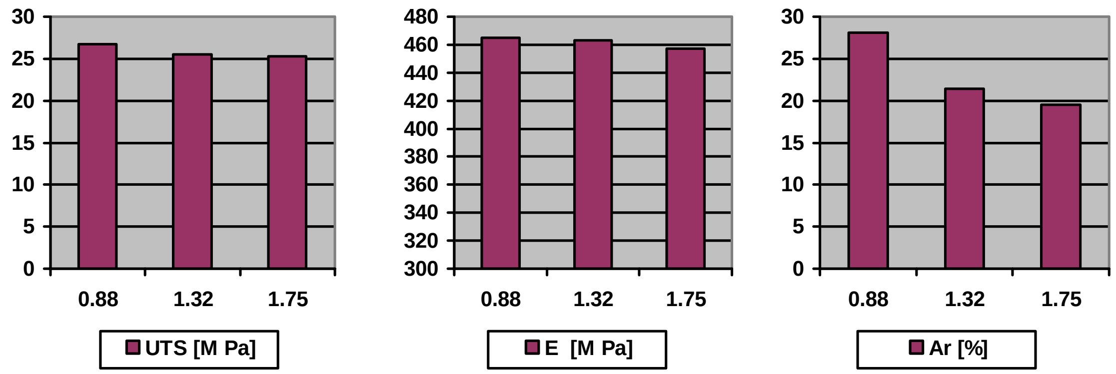
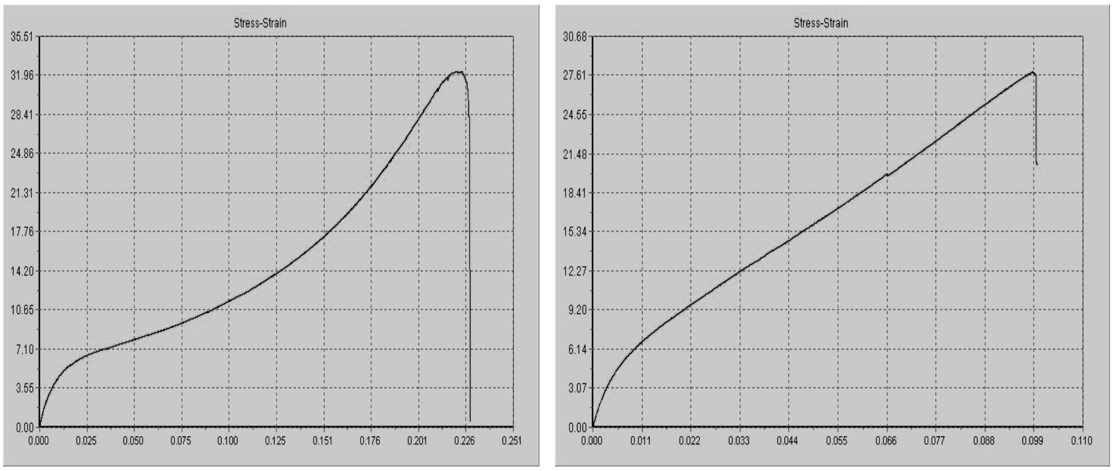


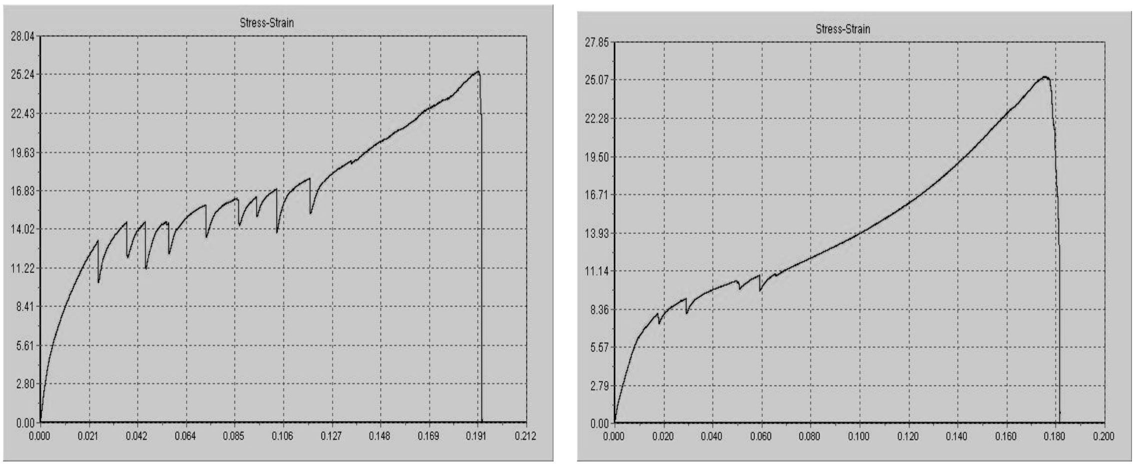
Fig. 4. The influence of pressure value [MPa], in the sample consolidation process, on the composite materials mechanical properties.

Each consolidation process was conducted, for 5 min., at temperatures up to 90°C, and using three different variants for the pressure values: 0.88, 1.32, and 1.75 [MPa], respectively. The experimental results indicate (see Fig. 4) a tendency of a moderate decrease, when the pressure value is increasing, for all the mechanical characteristics of the studied composite materials (the most important loss was observed for its ductility). It can be considered, on that basis, the fact that an increase of the pressure, during the sample consolidation process, is not a favorable measure in order to improve the mechanical properties of the studied composite materials.



(a) (b)

Fig. 5. Typical stres-strain dependence curves for the studied composite materials.



(a) (b)

Fig. 6. Typical stress-strain curves, including some „notched" zones.

On the other hand, a significant typical aspect was observed, regarding the stress-strain dependence curves that were obtained for all the composite samples, including two obviously distinctive regions (see Fig. 5a):

- an initial zone, starting with a linear segment and then continuing as a curve (with up-oriented convexity); that region is corresponding to a mechanical response which is dominated by the polymeric matrix material; it can be assumed that the textile reinforcement is not (yet) really participating in supporting the tensile load;
- a stabilized zone, extended to the major part of the total stress-strain curve, having a prominent curvature (and a down-oriented convexity); that aspect of a stress-strain

dependence is considered to be characteristic for textile materials, so it is corresponding to the reinforcement nature in the composites that are studied here; the mechanical response that are described by a stress-strain dependence of that kind is referring to the state succeeding the initial elongation of the layers of polymeric matrix material, in a measure that allow the textile reinforcement to support the main part of external load.

It must also be noted that, during the increase of tension loading and corresponding to the stabilized region of the stress-strain dependence curve, some transverse cracks can be observed, into the polymeric matrix material, resulting in the appearance of many discontinuities (that lead to a “notched” aspect), on the corresponding curve (see Fig. 6). It is important to observe the fact that such phenomena do not modify the global trend of the curve, which always follows the particularities of the above-described evolution.

On the other hand, it can be said that, for some of the composite samples, a premature failure was experienced, when comparing with the typical response of the studied composite materials, without the appearance of the entire stabilized zone on the stress-strain dependence curve (see Fig. 5b). It must be emphasized that those samples had also a particular structural consistency, and the global aspect of their stress-strain curves was quasi-similar to a linear dependence evolution. One can assume that kind of mechanical response as resulting from a real synergetic contribution of the two composite constituents in supporting the external load.

When investigating the background of such a phenomenon, one can consider that it is corresponding to some composite samples, which curing process for the polymeric matrix material was not completed, into the initial forming stage, so that it was realized, mainly, during the consolidation stage of the sample.

Concluding remarks

1. Some samples of composite materials have been obtained, using a proteic polymer (based on animal glue) as the matrix, and woven flax strands as reinforcements.
2. Because the raw materials are originating in vegetable and animal bodies, a high degree of biodegradability can be expected for the studied composite materials (that issue is experimented in present).
3. The influence of some parameters of the samples consolidation process on the mechanical properties of the composites was investigated. Little influence was observed, for the time duration, together with a slightly negative influence, for the increase of the pressure values.
4. When the cure of the polymer matrix was produced mainly during the consolidation stage, the resulted samples experienced compacted structures, with high levels of uniformity, and their mechanical response was closely to linear stress-strain dependence. It could be a suitable procedure to improve the mechanical characteristics of the studied composite materials.

Acknowledgements

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Influenţa factorilor tehnologici asupra proprietăţilor mecanice ale unor compozite biodegradabile cu matrice polimerică

Rezumat

Lucrarea se referă la o categorie de materiale compozite cu matrice polimerică de natură proteică (pe bază de clei animal) şi armare cu ţesături de fibre provenite din plante, despre care se poate estima că prezintă un grad ridicat de biodegradabilitate. S-a luat în atenţie influenţa exercitată asupra proprietăţilor mecanice ale compozitelor de variaţia valorilor unor parametri ai procesului tehnologic final, prin care probele de compozit sunt consolidate. S-a constatat o influenţă redusă a duratei de menţinere, respectiv o uşoară influenţă negativă a creşterii presiunii la consolidare. Totodată, s-a observat că probele pentru care procesul de reticulare a matricei s-a produs în cea mai mare parte în faza de consolidare a compozitului au o structură compactă şi uniformă, iar curba lor caracteristică la tracţiune este cvasi-liniară.