Researches on the development of new composite materials complete / partially biodegradable using natural textile fibers of new vegetable origin and those recovered from textile waste

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Abstract. The objective of the research is to develop new fully / partially biodegradable composite materials by using new natural fibers and those recovered from various wastes. Thus, the research aims to obtain some composites with matrix of various types of polymeric materials and the reinforcement phase of textile materials (of different natures, morphologies and composites) so that the resulting products to be (bio)degradable. The textile inserts used as raffle are ecological, non–toxic and biodegradable and they contain (divided or in combination) bast fibers (flax, hemp, jute) and other vegetable fibers (cotton, wool) as plain yarn or fabric, which can replace fibers of glass commonly used in polymeric composites. The main activities described in this article are carried out during the first phase of the research (phase I – initiation of research) and they are oriented towards the choice of types of textile inserts from which the composites will be obtained (the materials needed for the raffle), the choice of the types of polymers (the necessary materials for matrices) and choosing the variants of composites with different types and proportions of the constituent content (proposals and working variants) and choosing the right method for obtaining samples of composite materials (realization technology). The purpose of the research is to obtain composite materials with high structural, thermo–mechanical and / or tribological performances, according to ecological norms and international requirements in order to replace the existing classical materials, setting up current, innovative and high performance solutions, for applications in top areas such as automotive industry and not only.

1. Introductory notes

Over the past fifty years composite materials have developed rapidly [1–8]. Due to its versatility, the volume and number of areas of use of composite materials have increased constantly, developing new solutions in order to improve product quality and attractiveness for new markets. Composites are no longer the privilege of the aerospace or defence industry, or even high value goods. They have quickly become a way to achieve high structural performance at a low cost and are found all around us. Using composites provides high performance, lower costs, low weight, and compliance with the environmental and safety regulations [1–8].

The original purpose of achieving composites was to increase the competitiveness of classical materials whose strength and stiffness properties could not be improved by other means [1–6]. From this point of view it is understood that the maximum efficiency of the reinforcement of a certain
material is obtained by introducing in its structure some reinforcement elements. Representing the most well–known category and marking the beginning of the industrial scale use of the new materials, the fiber composites are mainly imaginable in the form of plastics (polymer) matrices reinforced with fibers(long) [1–6].

The main reasons why polymers represent most of the matrices used for the production of composite materials (about 75% of composite material production) are the following [1–9]:

- polymers can be processed at low temperatures and thus the danger of destroying the reinforcement agent (reinforcement) does not exist
- polymers can be obtained using classical methods that do not require complex technology.

As a result of using high performance fibers, polymeric materials are increasingly replacing traditional materials in all domains. The unique properties of the polymeric materials as well as the possibility of their adaptation to the applicative needs have determined the extension of their use in all the domains of human activity [1–7].

![Figure 1. The general structure of long fiber reinforced composite materials.](image)

a) same oriented fibers reinforcement, b) cross–oriented fibers reinforcement, (c) randomly oriented fiber reinforcement

Crises manifested in the whole society have also generated local or global imbalances in the material flow management, including waste. Non–renewable natural resources (coal, oil, natural gas, ferrous and non–ferrous ores) or renewable (wood, industrial plants) have become insufficient, which has required strategies to ensure the sustainable development of our society [10–28].

Thus, the return to nature, both through the processes of obtaining polymers from renewable raw materials and by inducing their end–of–life biodegradability, is the strategy that can build the sustainability of nowadays society [7–17]. The only solution to meet material needs is to obtain synthetic materials to replace natural materials and whose production can be adjusted as needed [15], [17], [22–26]. A variation of synthetic materials that has conquered all current fields of activity, through the extraordinary ability to adapt their properties to the applicative requirements are the composite polymeric materials.

2. Research directions

A sustainable development can only be ensured by proposing rational solutions for industry, designing eco–products and eco–technologies, but also recycling waste whose biodegradation has lasted for decades and hundreds of years [6], [14], [15]. A sustainable development and an intelligent use of resources in the field of industrial materials and technology require the substitution of critical materials, the development of advanced recycling technologies of secondary materials and end–of–life materials, lightweight structures and materials for substitution of heavy steel components (fiber–reinforced composites) [7], [8].

Great research efforts are being made to achieve these goals [10–28]. But even if the possibility of obtaining polymers from bio–sources (natural sources) or biotechnologies from renewable sources has been demonstrated, their price is still high and biodegradable polymers have structures and implicit properties that do not cover the whole range of needs [6], [14], [15]. At present, the most readily applicable methods for reducing the impact of polymeric materials on the environment consist in composite materials made of polymeric matrices made from common polymers for which there is
production infrastructure and biodegradable natural materials (biodegradable) produced as secondary products in agriculture or even from industrial or domestic waste [9–12], [15], [19], [20]. Fibres improve or maintain the properties of the matrix polymer and induce the end-of-life biodegradability [15–17], [22–26].

![Figure 2. Most important nature of fibres](image1)

![Figure 3. Most important nature of matrix](image2)

One of the research directions is related to technical textiles and textile products for strategic areas. Although the textile industry is in recession worldwide, textile technical items are on the rise, proving that manufacturers of these products are concerned about finding solutions and creating high-performance articles. Textiles or textile composites are designed to replace many of the current metal or plastic materials used in marine, aerospace, aeronautics, cars, security and defence [26–28].

![Figure 4. Classes of textile fibres](image3)

![Figure 5. Reinforced natural fibers](image4)

Composite materials based on bast fibers have become the attention of researchers and manufacturers of composite materials to harness both long fibers extracted from plant stems and short fiber waste resulting from fiber extraction [15], [17], [26]. By combining this polymeric matrix plant
waste there are produced polymeric biocomposite materials with a lower cost price than those based on long fibers and with mechanical characteristics comparable to them.

**Figure 6.** Reinforced natural fibers – plant fibers class – bastfibers

In the textiles domain, the organic concept it is also applied to the textile waste resulting from industrial activity and the management of these wastes is a process by which these products are reduced, reused, recycled, collected, stored, transported or eliminated. The development of alternative solutions for the use of textile waste in high added value products by producing composite products containing recovered textile fibers constitutes an ecological alternative for the capitalization of textile waste. They are based on a textile backing that undergoes a consolidation process.

**Figure 7.** Bastfibers textiles

Composites with added polymeric matrices with high adherence to the fiber reinforced textile are usable as substitutes for classical materials [7], [15], [17], [26]. Reusable textile materials, also known as textile waste, come primarily from textile processing (spinning, yarn preparation, weaving, knitting, chemical finishing), fabrication or as a result of physical and moral wear after a certain amount of time. The categories of textile waste that can be processed into yarns are: technological waste, cotton / wool type knitted scraps and fabric scraps resulting from garments.

3. **Ways of inducing the biodegradability of polymeric composite materials**

There have been identified several ways of designing biodegradable polymeric materials [3], [4], [6], [15], [26]. The most convenient is the use of synthetic polymers produced on a large scale to which biodegradable components are added [10–12], [19], [20], [27]. At present, this method is also the most feasible, using all the existing facilities for synthesis polymers, it uses natural fibers that are easily obtained, renewable and biodegradable, thus providing a “buffer step” between a company buried in waste non-biodegradable plastic and a partially sustainable society that uses materials with a high degree of biodegradability.

Thus, by inducing biodegradability, composite materials have been obtained in which the filler fibers are bioreinforments, most often vegetable waste (wool yarn, cotton yarn, cellulose fiber, hemp fiber, flax fiber, jute fiber, and so on) [10], [12], [17–25]. It has been demonstrated that these composites, in addition to incorporating waste, by reducing their deposited quantity, maintain or
improve the properties of the polymeric matrix material (improve the thermal resistance, the irradiation and chemical resistance) and they can be recycled more favourably than the matrix [14], [17], [22–26].

Their properties can be modified and adapted to application requirements by reinforcing with organic or inorganic fillers (in the form of short or long fibers, filaments or yarns, knitted, woven or non–woven, or particulate powders of different sizes) or by modifying the structure and density of the composite (modification of the dispersion and branching of the reinforcement in the matrix). The surface treatments of fibers also can improve the contact at the interface with the matrix to obtain composite materials with special properties. Therefore, in recent years, the interest in composite materials based on natural fibers (bast fibers such as hemp, flax and jute, and exotic fibers such as banana, bamboo) has increased significantly [10–12], [14–17], [22], [24–26], [28]. The use of natural fibers in composites does not only improve the physical and chemical properties (low density, high chemical resistance, increased resistance to environmental conditions such as humidity, solar radiation, pH), mechanical (good mechanical strength, easy processing, good resistance to shock and fire) and material functionality (absorb vibrations better than artificial fibers, good thermal and sound insulation, low weight, low maintenance costs, a variety of forms, design dynamics and can be easily handled) as well as biodegradability by putting them in the category of organic materials [10–17], [28].

Composite materials in relation to traditional materials have important strengths and bring many functional advantages, their use contributes to increased security, and extends the life of structures due to their excellent properties. The ways of controlling the properties of polymers are virtually infinite.

All these lead to advantageous conditions for multiple applications. The main advantage of composite materials is the high ratio between their strength and their bulk density. Due to the superior mechanical properties and reduced mass, composite materials are met in various fields of activity, the industrial applications being the most important, successfully replacing traditional materials. Therefore, today, there is no field of human activity that does not gain by the benefits of using polymers.
4. Polymer composite materials with textile finishing
The problems that have arisen in trying to define the composite materials exactly as much as possible are a proof of the extremely wide field of this type of material, a field in continuous and rapid expansion. As a general definition, composite materials are systems of two or more components whose properties complement each other, resulting in a material with superior properties to those specific to each component [1–7]. Thus these components will cooperate, the deficiencies of some being supplemented by the qualities of others, conferring to the assembly properties that any component can have separately. As such, fibrillated composite fiber composites are continuous or discontinuous fiber arrangements that are immersed in a polymeric matrix whose mechanical strength is much lower. Thus the composite material is a unitary assembly in which the two phases act together. In particular, the constituent–process couple is indissociable because the properties of the structure depend directly and they will only be identified in the finished product stage. The result consists in a system that includes the nature of the reinforcement, the texture and shape of the reinforcement, its strength and volume, the nature of the resin and / or the additives, the quality of the reinforcement–matrix interface, the geometry of the work piece to be analyzed, the process used and so on [1–7].

The role of the matrix in the composite material is to determine the final shape of the product, to protect the fibers both in the forming process and during use, to prevent the buckling of the fibers, to ensure the chemical and thermal compatibility with the reinforcement and to avoid rapid propagation of composite cracks. The matrix is defined as forming the continuous phase of the composite [1–7].

Reinforcement represents the discontinuous phase, evenly distributed throughout the matrix volume and which is added to the matrix to improve or modify its properties. Fiber is the element that gives the assembly the characteristics of resistance to stress. The role of the textile material in the composite material is to reinforce, thus increasing the strength and rigidity of the composite, this rise being proportional to the volumetric fiber fraction [1–7].

Bast fibers, belong to the category of natural textile fibers of vegetable origin, predominantly cellulose, which are extracted by removing the wood from the free (stem) of plants such as flax, hemp or jute. Globally, there are over 1,000 plant species with processed bast fibers, with about 25 being profitable [10–12], [19–28].

Unlike other textile fibers, bast fibers are pluricellular fibers, consisting of clusters of elementary fibers, cemented between them by the medial lamella, and which form together an ensemble called technical fiber. The destruction of the median lamellar leads to the division of technical fibers into finer technical fibers (with fewer elementary stones cemented between them), or even in elemental fibers. Thus in the twigs, the fibers can be processed in the form of technical fibers.

Soft bast fibers (such as flax) are flexible fibers for a wide range of fine and thick fabrics. Heavy bast fibers (hemp, jute) are lighter than flax and are used to produce a wide range of thick or technical fabrics. In the bast fiber industry, their own yarns are used in homogeneous mixtures based on fibers of the same origin or in heterogeneous mixtures made up of different categories of own fibers with other fiber categories and even fibers of other nature, obtained from related textile branches.

![Figure 12. Natural fibers](image1)

![Figure 13. Fibres reinforcement](image2)
5. Reinforcing technologies

The criteria used in the choice of the technological process for the reinforcement manufacture refer to the dimensional stability, to the mechanical properties imposed, and to the rigidity properties of the reinforcement system. The variety of textile reinforcement types makes them a complex problem that requires several factors to be considered. Technical textiles may exist and can be used in various forms, such as simple fiber filament structures, to finished products with complex structures [1–7].

Reinforcing systems for composite materials comprise a wide range of preforms that can be constituted by the material obtained from all textile technologies: weaving, knitting, sewing or using non-woven fibers. To these there can be added the processes characterized by the reinforcement and the composite material in the same phase, such as filament winding and polishing.

![Figure 14. Reinforcing technology](image)

In order to select the optimal preforming technology, both the strengths and weaknesses of each technology must be considered. They have the advantage of mass / strength ratio, time reduction, elimination of waste resulting from the production and processing process, better control of the final shape of the product and superior quality.

In order to obtain composite structures, different methods are used:
- embedding reinforcement material (long or short fibers, knitting material, powder) into a matrix, which may be a substance with coagulation properties;
- reinforcing the base material with curing layers, resulting in a laminate.

The criteria used in the choice of the technological process for the reinforcement manufacture refer to dimensional stability, to the imposed mechanical properties, and to the draping / forming properties of the reinforcement system.

6. Concluding remarks

Composite materials have become a more and more common solution in setting up performing structures applicable in all industrial branches. Their implementation in various fields, as advantageous alternatives to classical materials, or the acquisition of new applications, otherwise difficult or impossible to achieve, raises a series of problems due to their very complex structure and the possibilities of obtaining the behavior still insufficiently known for various requests.

In every industrialized country composite materials are a priority area, located at the forefront of the continuous process of technological innovation. Research into composite materials based on plant fibers in general and on fiber–based fibers refers to aspects related to the determination of the factors that influence the performance of the composite materials based on bast fibers and to the finding of methods for their improvement, the analysis of the physical, chemical, mechanical and technological processes, as well as finding new composite materials in order to meet the economic needs.

The public and business interests in multiple applications of these versatile plants are in a rapid growth according to the acute need for renewable alternatives for industrial resources. Bast fibers
(flax, hemp, jute) are a viable good that can offer many solutions that equal or even exceed the products to be replaced.

The use of fiber composite materials has a beneficial effect in the machinery industry, which works under the pressure of reducing fuel consumption and implicitly of noxious emissions into the atmosphere. This desideratum is achievable in terms of reducing the mass of the vehicle.

Composite materials are good solutions for the mass reduction without cost increases. Synthetic fibers used as a plastic reinforcement material (carbon fibers, glass fibers, kevlar), despite offering a mass reduction of more than 50%, have the disadvantage that they are expensive. In this context, fiber–based polymer composites offer many advantages including freedom in design, mass reduction, corrosion resistance, cost reduction, and the production of complex aerodynamic and noise reduction devices. At the same time, recyclable textiles offer solutions for minimizing waste. Many technical textiles and textile fibers minimize production costs by recycling waste, thus ensuring environmental protection.

The advantages of natural fibers are major in terms of behavior in case of an accident. Combined with a polymeric matrix, natural fibers provide lightweight flexibility and lightweight to traffic safety requirements. In the case of natural fibers, there are no punctures or sharp points, having relatively low density, low manufacturing prices, and biodegradable, unlike glass fibers that crush during processing.

Natural fibers are indicated for reinforcement or reinforcing accessories with complex shapes that stretch over wide surfaces. The widest range of applications is to decorate the interior of the doors. At the same time we can try to obtain materials for safety belts, head restraints, chairs, benches, ceiling, flooring, the back of the machine and the trunk.

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