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INDUCING THE BIODEGRADABILITY OF POLYMERIC COMPOSITE MATERIALS USING BIORANFORTS

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Abstract:
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. 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. 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) so that the resulting products to be biodegradable. 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 the glass fibers, commonly used in polymeric composites.

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1. INTRODUCTION

Great research efforts are being made to achieve a sustainable development and an intelligent use of resources in the field of industrial materials and technology, which 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).

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 [1-4]. 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 [1-4].

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. Fibers improve or maintain the properties of the matrix polymer and induce the end-of-life biodegradability [1-4, 7-15].

One of the research directions is related to technical textiles and textile products for strategic areas [1-3, 6-15]. 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 [1-3, 6-15]. Textiles or textile composites are designed to

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replace many of the current metal or plastic materials used in marine, aerospace, aeronautics, cars, security and defence [4, 5, 9, 13].

During the last decade there has been a renewed interest in the natural fiber as substitutes for glass, motivated by potential advantages of weight saving, lower raw material price, and "thermal recycling" or the ecological advantages of using resources which are renewable. On the other hand natural fibers have their shortcomings, and these have to be solved in order to be competitive with glass [2, 3, 10, 12, 15]. Natural fibers (fig.1) have lower durability and lower strength than glass fibers. However, recently developed fiber treatments have improved these properties considerably.

Composite materials based on bast fibers (fig.2) 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. By combining this polymeric matrix plant waste there are produced polymeric bio-composite materials with a lower cost price than those based on long fibers and with mechanical characteristics comparable to them [3, 6-9, 13-15].

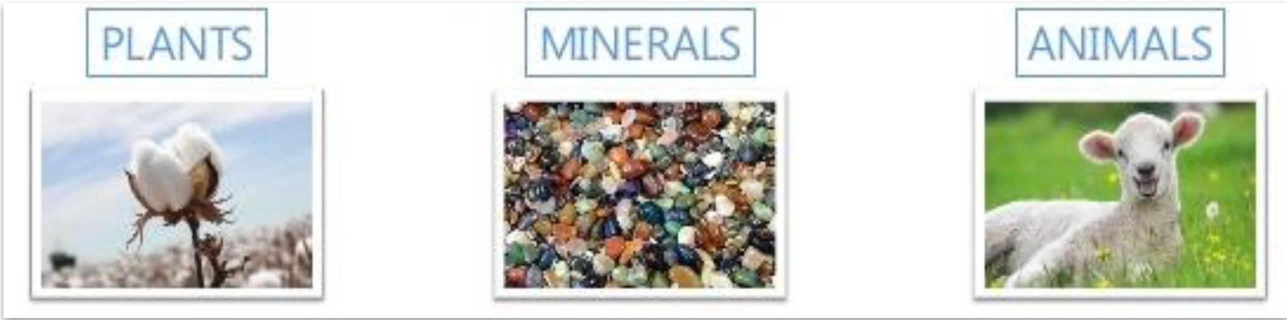

Fig. 1. Natural fibers

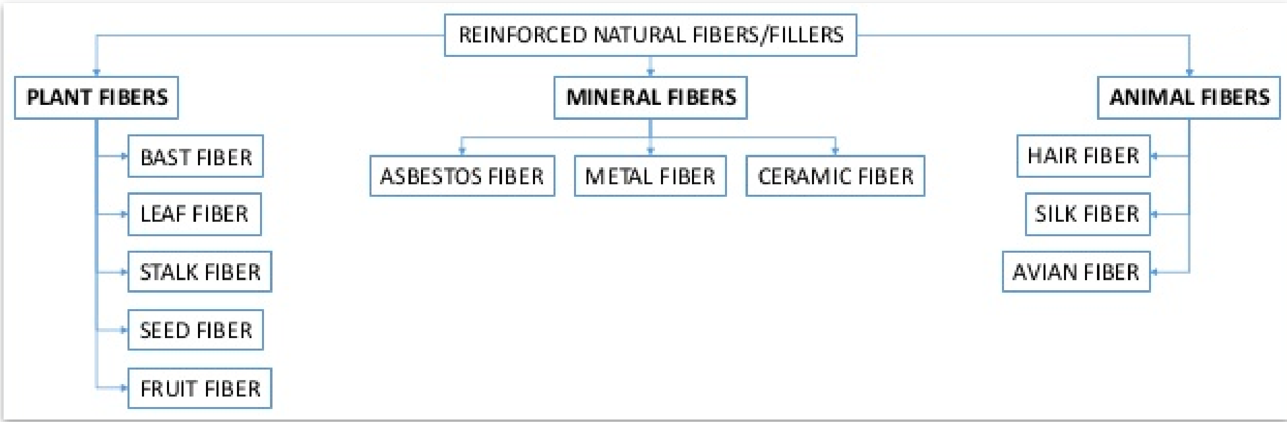

Fig. 2. Reinforced natural fibers

Fig. 3. Plant fibers: Category of bast fibers (collected from the skin or bast surrounding the stem)

The use of natural fibers (fig.3) for technical composite applications has recently been the subject of intensive research in Europe [5, 9, 12, 13]. Many automotive components (fig.4) are already produced in natural composites, mainly based on polyester or PP and fibers like flax, hemp or sisal. The adoption of natural fiber composites in this industry is lead by motives of:

1. price
2. weight reduction and

3. marketing ("processing renewable resources")

rather than technical demands. The range of products is restricted to interior and non-structural components like door upholstery or rear shelves[5, 6, 13].

Fig. 4. The use of natural fibers for technical composite applications in automotive industries

The use of natural fibers in automotive industries has grown rapidly over the last 5-10 years (fig.5). As far as composite applications are concerned, flax and hemp are two fibers that have replaced glass in a number of components, especially in the automotive industries [6, 10, 12].

The use of natural fibers in automobiles has largely been restricted to upholstery applications because of the traditional shortcomings of natural fiber composites, low impact strength and poor moisture resistance. Recent research results show that there is a large potential in improving those two properties. This potential can be found in either in pre-treatments of the fibers or in improving the chemistry while impregnating the fibers with the matrix material.

2. OPPORTUNITIES FOR LOW-INVESTMENT PRODUCTION

Production of glass fibers, followed by weave, mat and pre-preg manufacture, is based on machinery and high investments. The production of natural fibers however, can be carried out by manpower and traditional know-how [5, 6]. In countries where natural fibers can be grown quickly and at low cost, the material resources are local. Importing of non-domestic materials, like glass fibers, at high prices in foreign currency can be avoided.

Production techniques like vacuum injection, hand lay-up, and vacuum pressing are appropriate for a cheap and easy manufacture of parts with in principle infinite dimensions [5, 6].

There have been identified several ways of designing biodegradable polymeric materials. The most convenient is the use of synthetic polymers produced on a large scale to which biodegradable components are added. 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 [5, 6, 14, 15].

Thus, by inducing biodegradability, composite materials have been obtained in which the filler fibers are bio-reinforcement, most often vegetable waste (wool yarn, cotton yarn, cellulose fiber, hemp fiber, flax fiber, jute fiber, and so on) [1-4, 6-7, 9, 13-15]. 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 favorably than the matrix.

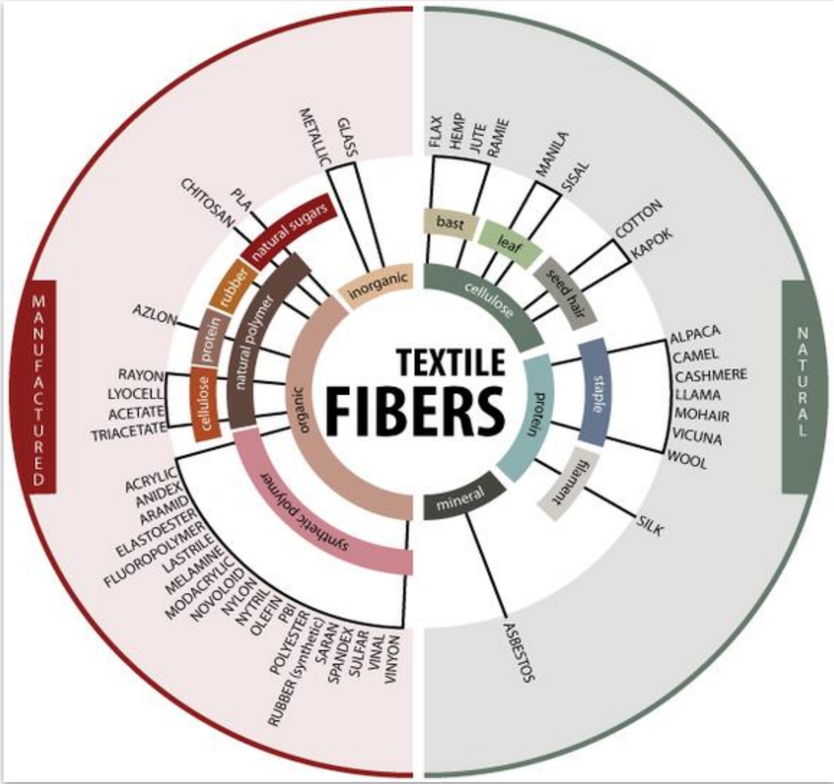

Fig. 5. Classes of textile fibers (natural vs synthetic/manufactured)

To understand how fibers should be treated, a closer look into the fiber is required [2, 5, 7, 11, 15]. 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 [2, 5, 7, 11, 15]. 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 [2, 5, 7, 11, 15]. 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 (fig.6) [2, 5, 7, 11, 15].

ASPECTS	PARAMETER	COMPOSITES	
		NATUAL FIBER	SYNTHETIC FIBER
TECHNICAL	MECHANICAL PROPERTY	MODERATE	HIGH
	MOISTURE PROPERTY	HIGH	LOW
	THERMAL PROPERTY	HIGH	LOW
ENVIRONMENTAL	RESOURCES	INFINITE	LIMITED
	PRODUCTION	LOW	HIGH
	RECYCLABILITY	GOOD	MODERATE

Fig. 6. Technical and environmental aspects between Natural Fiber Composites vs. Synthetic Fiber Composites

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 [5, 6].

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 [5, 6]. Therefore, today, there is no field of human activity that does not gain by the benefits of using polymers.

The main economic advantage of natural fibers may be found in their local availability. Automotive applications of natural fiber composites have proven themselves very well, especially in the automotive industries, but for the moment mainly with the fibers are the flax and hemp [5, 6].

Better opportunities for fibers are to be found in local use, such as in automotive industries or in the use in other local composite industries based on relatively expensive glass fibers [5, 6, 10, 13]. If the right technologies are introduced a very effective use of locally available materials can be found in all kinds of every-day structural applications.

3. RESULTS AND DISCUSSION

This paper describes the latest industrial applications for natural-fiber-reinforced composite materials. It also presents some approach of university research, various industrial products, and possible applications in the automotive sector, starting from non-structural components for ultra-light vehicles. The objective of the research is to develop new fully or 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 [1-4, 7, 14].

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.

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 a material with superior properties to those specific to each component. 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 in dissociable 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.

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.

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.

Bast fibers, belong to the category of natural textile fibers of vegetable origin, predominantly cellulosic, 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. Unlike other textile fibers, bast fibers are multicellular 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.

4. CONCLUSIONS

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 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.

Growing environmental concerns have sparked renewed interest in the development of natural-fiber composites and biodegradable materials, which could be the new bio-friendly alternative to fiber-reinforced plastics. The many advantages of these materials include specific mechanical properties, good thermal, acoustic and electrical insulating properties, low density, reduced tool wear, excellent formability, and safe crash behavior (no splintering). They are non-toxic, bio-/environment-friendly, and low-cost materials that are easily available and help promote healthier, safer work places.

As a consequence, natural fibers could be used as a low-cost reinforcement alternative to glass fibers. Considering that it is possible to use the same processes, tools, labor, equipment, controls and know-how, an easy substitution is possible at reasonable cost.

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