Toward the use of irradiation for the composite materials properties improvement

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This paper aims at the development of advanced composite materials with high strength to radiations, with applications in automotive industry but also in making automotive components to reduce their weight and manufacturing costs, as well as to improve recycling, in the same time meeting the structural and performance of passive protection. A composite material may be subjected to radiations because it is part of a constituent material operating in an environment with radiations or may be subjected to radiations deliberately, in order to obtain superior properties of the material. In this second sense, the challenge is to achieve high structural static and dynamic performances, by developing composite materials with enhanced properties that bring better value to the concept of composite type structure.

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1. Introduction

Because the composite materials is an interdisciplinary field and more than a stable connection between disciplines such as chemistry, physics or engineering, experience of this is essential for the development of new materials with well-defined applications. The triangle: synthesis and manufacture - composition and structure - properties and performance are essential relationships in the field of composite materials.

The properties of a given material composition depend to a large extent on the method by which it was manufactured, which are the consequence of different structures [1]. Conversely, special applications require specific structural properties, and therefore a precise composition, which involves proper synthesis procedures and manufacturing processes.

The idea of using composite materials does not reduce only to the replacement of metals or other composite materials but also to use in a constructive way these materials, taking into account the special properties and possibilities of manufacturing to create innovative structures, new forms, to be used for private construction.

So, first, a material with increased fatigue strength is designed, recyclable, easy to manufacture and then it is irradiated and is looking to integrate this type of material, taking into account the properties of the practical structures used in mechanical engineering and beyond [2,3].

2. Material and method

In order to investigate the mechanical behavior of composites, the industrial method of sterilization by irradiation has been used. This method is best understood from the scientific point of view, inducing a clear, precise and nuanced methodology, with strong theoretical base, implemented in ISO, EN and ASTM. Very important in this method is to achieve the total absorbed dose that can be achieved by incremental additions. More specifically, this method is a sterilization method for irradiation used to improve product performances.

The technological irradiation IRASM Center operates a gamma irradiator of type SVST Co-60/B (Fig. 1) with Co-60 sources and current activity of ~ 300k/Ci.

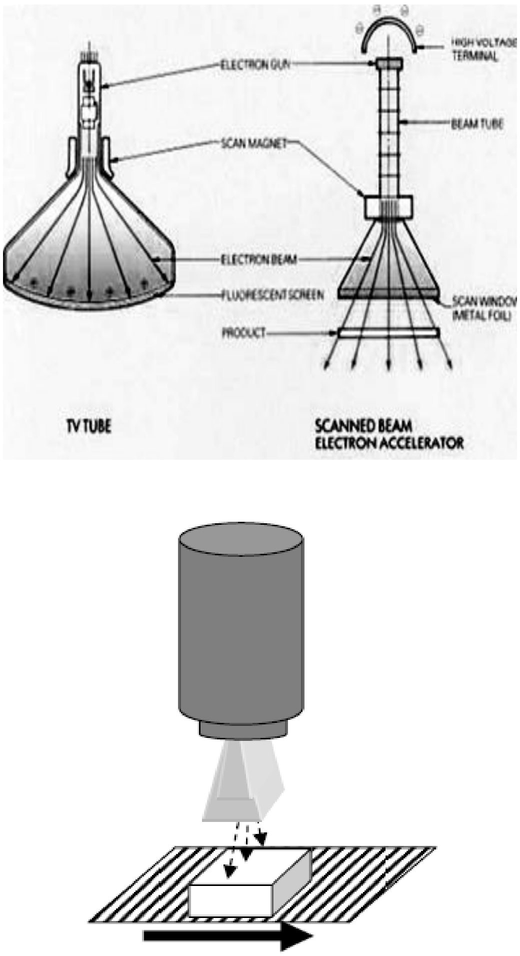

Fig. 1. Schematic representation of an irradiator with electrons accelerator.

SVST Co-60/B irradiator presents following characteristics:

• Irradiation source: Co-60 encapsulated in stainless steel;
• Source type: Type CoS-43 HH, ø11x451mm;
• Type of source grid: rectangular, split;
• The number of racks of sources: 3;
• The number of source modules (in a rack): 4;
• Number of sources in a module: 33;
• Ability grid sources: up to 396 pcs. Sources;
• The movement of the source: pneumatic;
• Lowering the source: gravity;
• Storage: water (pool);
• The basis for shielding: up to 74 PBQ (2Mci) activity of Co-60 source;
• The surface dose rate allowed at the irradiation room wall: max. 2μSv / h;
• Transport products: system “tote-box”;
• Dimensions of the products container (tote-box): 50x50x90 cm;
• Useful dimensions of container products: 47x47x88 cm;
• Useful capacity to container products: approx. 200 l;
• Maximum load per container products: 120kg;
• Present ability sterilization (medical devices): 1 500 m^3/year;
• Maximum capacity sterilization (medical devices): 30000 m^3/year;
• Storage of 500 m^2.

Intense fields of ionizing radiations required for sterilization process are obtained with equipment called irradiators: gamma irradiators (with isotopic sources of gamma radiations) and electron accelerators.

In case of gamma irradiators, the irradiation takes place in a chamber called chamber of irradiation which must maintain the gamma radiation (very penetrating) avoiding the personnel and population affecting as well as the environment. The gamma irradiators should have a storage system of radiations source (when the irradiation does not operate) and a transport system of the products in the chamber of irradiation.

For gamma irradiators is very important that the geometry of gamma irradiation should allow the best possible uniformity of the radiation throughout the volume irradiated product. The transport system of products presents multiple passes around the source of radiation.

Several passes around the source means better efficiency in use of radiation. The factor characterizing the uniformity of radiation is called absorbed dose uniformity factor (ratio of absorbed dose to the minimum and maximum absorbed dose irradiation) for a certain category of products (which have a certain apparent density = mass of products/ irradiated volume).

Such composite made of hemp-based fabric and being tested a number of eight specimens in order to study the behavior of this material at static tensile loadings [4,5]. The irradiation of specimens for testing has been conducted on IRASM irradiator (www.irasm.ro) and the absorbed dose has been measured with the ECB dosimetry [6], [7], [8]. Irradiations have been performed in the 1-250 kGy range covering the doses used in most applications of radiation technology, but very high doses also, where the effects of degradation can be put in evidence with certainty. Thus, specimens made of composite materials based on thermosetting resin and hemp fibers have been irradiated part with a dose of 2 kGy and a part with a dose of 56.7 kGy. After this “operation” we performed a macroscopic analysis, after which failures could be highlighted that have been formed in various stages of the manufacturing processes.

According to current standards eight specimens have been cut (Fig. 2) from a panel with five layers of thermosetting resin with hardener, type DERAKANE 411-350 epoxy vinyl esther resin reinforced with unidirectional hemp fabric of type CERTEX PVR-R1 with an average length of 3-6 mm fibers. These specimens have been subjected to tensile loads at a constant rate until break or until stress (load) or strain (extension) reached a predetermined value [9,10,11,12,13,14].

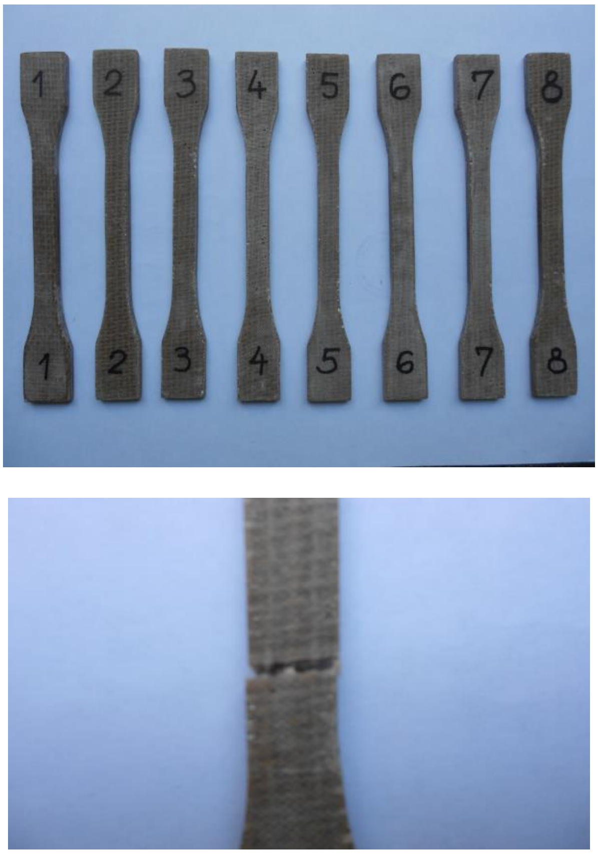

Fig. 2. Hemp fabric based specimens before and after tensile testing.

Another batch of specimens have been cut and irradiated with 56.7 kGy dose and 2kGy respectively, after which they have been tested at tensile loads in order to track the changing in mechanical properties (Figs. 3-4).

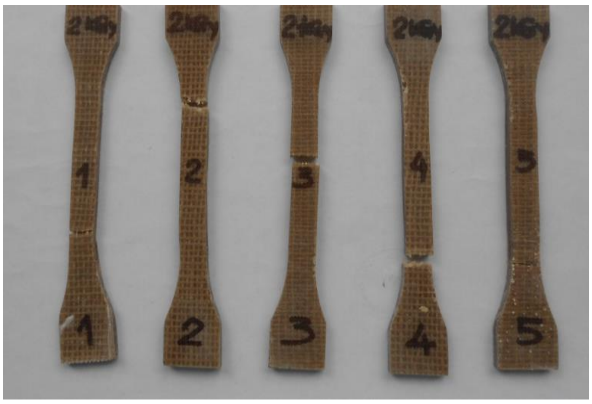

Fig. 3. Hemp fabric based specimens irradiated with 2 kGy dosis, after tensile testing.

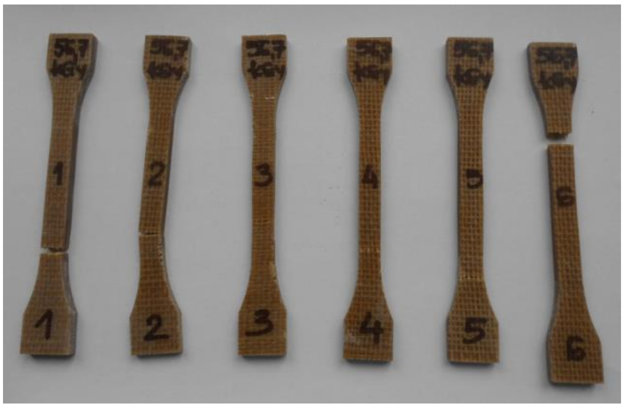

Fig. 4. Hemp fabric based specimens irradiated with 56.7 kGy dosis, after tensile testing.

3. Results

The visualization in detail has been done with a powerful microscope that can enlarge the studied area 500 times to 2000 times, and the images have bee made as clear as possible and even to the depth of the material. Microscopy results have been carried out both in 2D and 3D, noting also how the structure of these materials has been changed (Figs. 5-8).

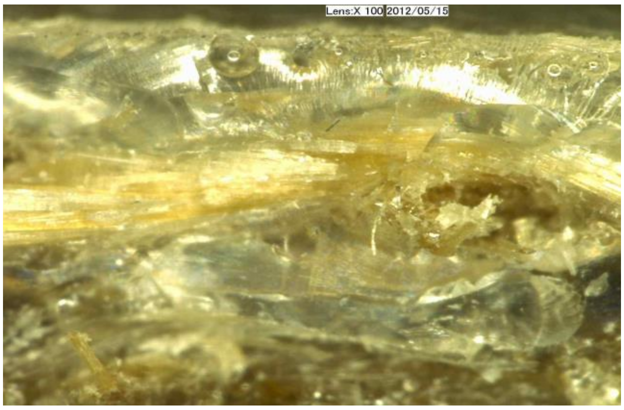

Fig. 5. Cross-section through a hemp fabric based specimen irradiated with 2 kGy dosis (100X magnitude).

Fig. 6. Cross-section through a hemp fabric based specimen irradiated with 56.7 kGy dosis (100X magnitude).

Fig. 7. Side view of an irradiated hemp fabric based specimen (20X magnitude).

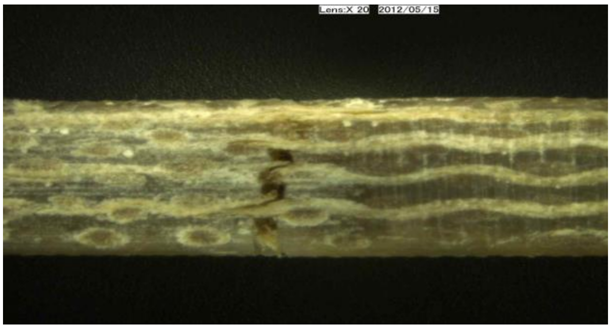

Fig. 8. Side view of a non-irradiated hemp fabric based specimen (20X magnitude).

The synthesis of experimental data obtained at tensile tests of non-irradiated as well as irradiated specimens with 2 kGy respective 56.7 kGy doses are presented in Tables 1-2. From these tables, the Young's modulus as well as the tensile strength distributions are graphically shown in Figs. 9-10.

Table 1. Young's modulus [MPa] of hemp fabric based specimens subjected to tensile tests.

Specimen	Non-irradiated	Irradiated with 2 kGy dosis	Irradiated with 56.7 kGy dosis
1	6131.09235	9673.29606	6605.46446
2	7611.57485	91675.9776	6242.42647
3	7236.70744	6349.83073	6520.34653
4	12138.8127	5613.87164	35292.4633
5	8222.60575	15225.2716	6512.11349

Table 2. Tensile strength [MPa] of hemp fabric based specimens subjected to tensile tests.

Specimen	Non-irradiated	Irradiated with 2 kGy dosis	Irradiated with 56.7 kGy dosis
1	6180141.09	9005838.63	7133901.61
2	7826221.26	1114779.89	6741820.58
3	7233812.76	7365803.64	7100657.38
4	12133957.2	6682752.8	37946456.5
5	7967704.97	16747798.8	6764783.5

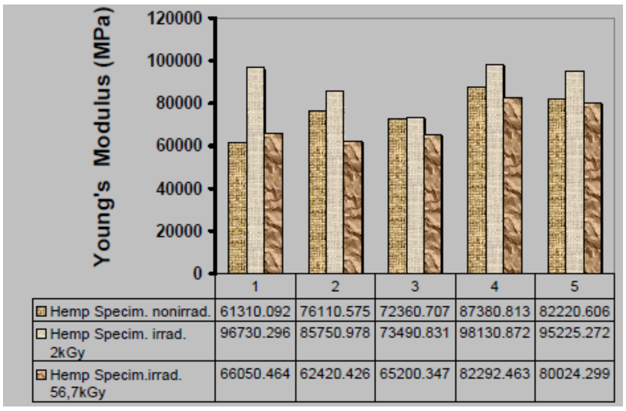

Fig. 9. Young's modulus distribution of irradiated and non-irradiated hemp fabric based specimens.

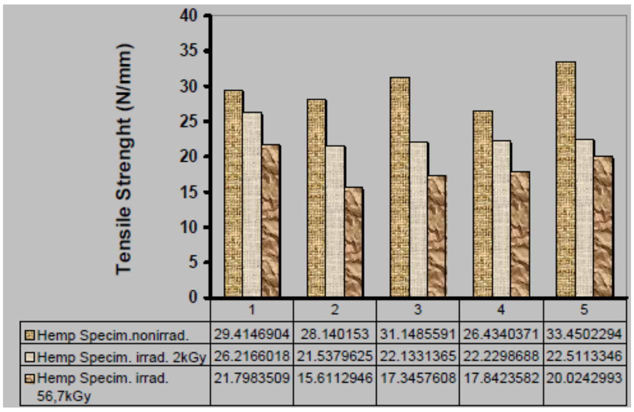

Fig. 10. Tensile strength distribution of irradiated and non-irradiated hemp fabric based specimens.

4. Discussions and conclusions

The hemp fabric based specimens irradiated with 2 kGy dosis presents higher Young's modulus values than the specimens irradiated with 56.7 kGy dosis showing that the maximum Young's modulus is between these two radiation doses.

In Figs. 11-12, the mechanical work as well as the tensile strength distributions of non-irradiated and irradiated hemp fabric based specimens with 2 kGy and 56.7 kGy doses put in evidence the higher mechanical properties of 2 kGy dosis irradiated specimens than those irradiated with 56.7 kGy dosis.

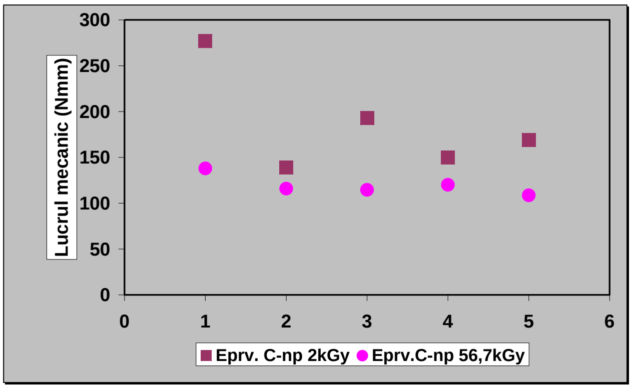

Fig. 11. Mechanical work distribution of irradiated hemp fabric based specimens with 2 and 56.7 kGy doses.

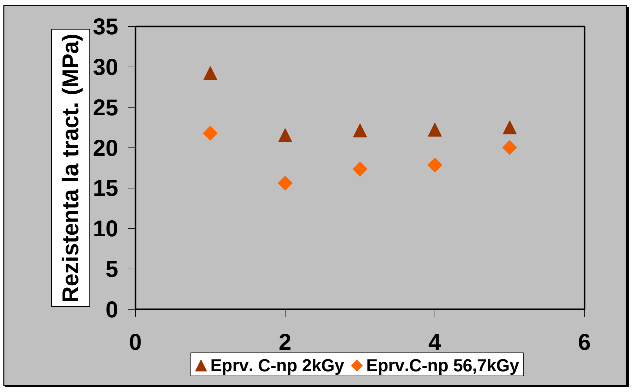

Fig. 12. Tensile strength distribution of irradiated hemp fabric based specimens with 2 and 56.7 kGy doses.

The hemp fabric based composite material irradiated with small doses of radiation meets the requirements of structural and passive protection for medium loaded automotive parts.

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