ASPECTS RELATED TO THE STRUCTURE AND PROPERTIES OF GLASS FIBER BRAIDS USED IN THE ELECTROTECHNICAL INDUSTRY

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REZUMAT. Datorită proprietăților electrice remarcabile, fibra de sticlă este folosită la fabricarea a numeroase produse electronice și electrotehnice, utilizate curent, dar și în domenii de vârf ale tehnicii. Textilele tehnice din fibră de sticlă utilizate în industria electrotehnică pot fi: structuri nețesute, structuri țesute sau structuri împletite. De asemenea, toate acestea pot fi la rândul lor, flexibile sau rigide (impregnate). Realizarea împletiturilor tubulare, față de țesăturile tubulare din fibră de sticlă, prezintă avantajul că, în procesul tehnologic de împletire, riscurile de rupere la încovoiere (îndoire) a fibrelor de sticlă este mult mai mic. În lucrarea sunt analizate comparativ structura și proprietățile mai multor împletituri tubulare de sticlă, neimpregnate și impregnate. Proprietățile testate sunt cele prioritare pentru aceste tipuri de produse.

Cuvinte cheie: fibre de sticlă, împletituri tubulare, impregnări cu polimeri termoplastici, proprietăți tensionale

ABSTRACT. Due to their remarkable electrical properties, the glass fiber is currently used for the manufacture of many electronic and electrotechnical products, but also in cutting-edge areas of technology. In the electrotechnical industry, the technical applications of glass fibers can be structures as non-woven fabrics, woven fabrics or braided fabrics. All of these structures can be flexible (non-impregnated) or rigid (impregnated). The advantage of tubular braids as against the tubular woven fabrics made from glass fibers is the lower risk of their bending stress in the technological process of braiding. In paper are analyzed comparatively the structure and properties of several tubular braids made from glass fibers, with or without impregnation. The tested properties are the priority properties for these types of products.

Keywords: glass fibers, braided tubes, impregnation with thermoplastic polymers, tension properties

1. INTRODUCTION

Thanks to its remarkable electrical properties, the glass fiber is used in the manufacture of many electrotechnical and electronic products, used in everyday life as well as in the most up-to-date industries, like printable circuit boards, circuit breakers, gears, carcasses, high voltage insulators, commutators, antenna protections, insulation for electric cables etc. all these products can be flexible (non- impregnated) or rigid (impregnated) [1].

For making the insulating sheaths of electrical cables, are preferred the braided

Glass fiber technical textiles used in the electrotechnical industry may be: non-woven structures, woven structures or braided structures. Also, structures, because can be easily accomplished the dimensional correspondence between the diameter of the cable and the diameter of the sheath. The braided structure may also provide the required physical and mechanical properties of the sheath, such that the cable, to perform its exploitation functions. The mechanical stresses, to which these glass fiber braids are subject during the exploitation, are the repeated bending, cyclic tension and friction. Since, the glass fibers, by definition, are not resistant to bending and cyclic stresses, to improve all these characteristics of the coating; these can be impregnated and transformed into a composite material [2].

In this paper, the authors discuss about analyze of the physical and mechanical properties of some types of glass fiber braids used as electrical cable insulators, before and after impregnation.

2. GENERAL ASPECTS OF IMPREGNATED GLASS FIBER BRAIDS

2.1. The glass fiber: structure and properties

The textile fiber with the highest frequency of use in reinforcing composite materials is the glass fiber. The glass fibers are relatively cheap and easy to produce in relation to their high performance features. The general properties that recommend the glass fibers for premium special-purpose products are:

– resistance to high temperatures;

- maximum resistance against chemical agents;
- mechanical resistance and high elastic modulus;
- low thermal conductivity;
- null hygroscopic.

The most used glass fibers for reinforcing composites are S-glass and E-glass fibers [3]. For glass fibers, the letter designation implies a special property or characteristic, specifically: letter E, from electrical, are glass fibers with a low electrical conductivity or letter S, from strength, the glass fibers have a high strength.

The E-glass fibers are used for dielectric strength properties (electrical insulating) and dimensional stability, but also have disadvantages which are mainly characterized by a very low breaking elongation (1-2.5%) and a low resistance to repeated bending cycles. The elimination of these disadvantages is achieved through producing glass fibers with a diameter of less than one micrometer or by including of glass fiber structures in polymers or resins with thermoplastic properties [4].

2.2. Composite materials

In principle, the composite materials are constituted by a matrix which embodying a complementary component.

In most cases, the matrix represents the plastic and deformable part of the composite material, which has a lower mechanical strength than the complementary material it includes.

There are also composite materials to which the matrix is the rigid component of the assembly.

The matrix of engineered composite materials must be formed from a material able to incorporate the complementary component, which not to destroy it by mechanical action or chemical modification, such as dissolution or melting.

The choice of the matrix is made depending on the intended purpose and the manufacturing possibility of the composite. With regard to the impregnation of the braided glass fiber for electrical insulation are usually used organic thermoplastic materials.

As thermoplastic materials frequently used to make organic composites can be listed the polyester resins, dense polyethylene, polypropylene, polyvinyl chloride, polyamides etc.

2.3. Elements of structure and technology of tubular braids

The 3D braided fabric is a manufactured product generally consists of a system of threads arranged by an oblique direction to each other and to the product edge [5].

Specific for tubular braids is the helical arrangement of threads as a result of the port-bobbins movement on the determined trajectories, adapted to the type of product. In all cases, the contouring of the braided product (including its diameter) is imposed by the shape and size of the used collector.

From all braided fabrics with circular section, the widest uses have those that require two groups of port-bobbins which are moving in opposite directions.

The braiding machines used for this purpose are equipped with an even number of wheels (minimum 6), each of them with 4, 6 or 8 sectors. The mount ratio is always equal with two and is obtained braided fabrics with biphilar, triphilar or tetraphilar structures.

On braiding machines equipped with wheels, where each of them has four sectors, the braided fabrics can be produced with 12 to 100 threads (with the step of 4 threads), respectively with 6 to 50 tooth of wheel.

The smallest braiding machine of this kind is equipped with 6 wheels, each of them with 4 sectors, and produces braided fabrics from 12 threads.

In figure 2.1 is presented the principle scheme of a braiding machine with 6 wheels and in figure 2.2 the 12/2 braided drawing, which is obtained on braiding machine [6].

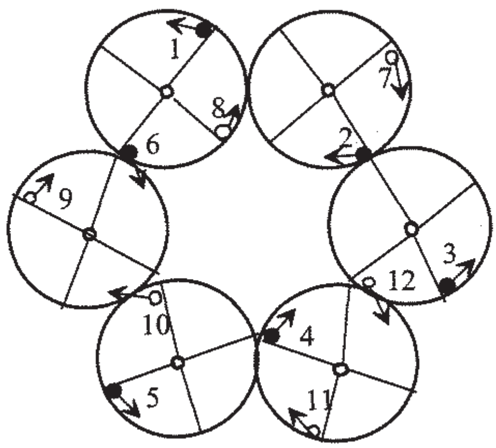

Fig. 2.1. Principle scheme of a braiding machine with 6 wheels, each of them with 4 sectors.

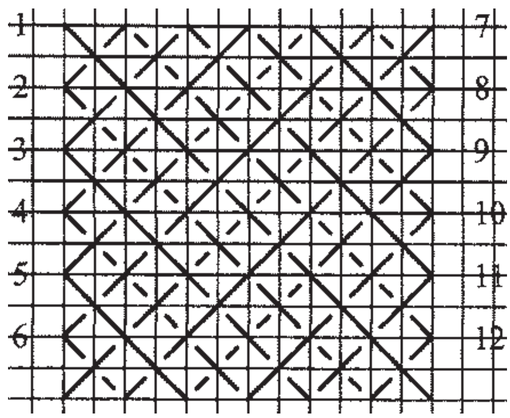

Fig. 2.2. 12/2 braided drawing.

The 12 port-bobbins are divided into two groups, of which 6 are move from left to right and the other 6 are moving from right to left. In this way, half of threads are disposed after a helical line oriented to the right and the other half of threads after a helical line oriented to the left.

The possible threads of filling, which can be electrical cables too, are placed in the center of the product, and the braided structure constitutes the insulating material of braided fabric.

3. THE STRUCTURE AND PROPERTIES OF ANALYZED GLASS FIBER BRAIDED TUBES

3.1. Experiments

In this paper, the authors aimed to analyze the physical and mechanical properties of some braided fabrics used as insulation material of electrical wires, tested before impregnation and after impregnation. The braided fabrics are made from E-glass fibers with standardized electrical insulation properties.

The authors have been chosen three types of products from the range of glass fiber braids, which are used to isolate electrical conductors. These products, different by their structural characteristics and consequently by their diameter, were analyzed in variants without impregnation and with impregnation. Three glass fiber braided tubes, named I, II and III, were impregnated with thermoplastic polymers.

In figure 3.1 are presented the three specimens of non-impregnated glass fiber braided tubes, and in table I, their structural characteristics are centralized. In table, it can be observed that the three tubes differ mainly by their number of threads, the width of the braided tube, the linear density of the threads, the diameter and the weight of the braided tube.

In figure 3.2 are presented the three specimens of impregnated glass fiber braided tubes with thermoplastic polymers.

On these specimens, the tense properties, as the tensile strength, breaking elongation and the stress-strain diagram were determined by using the Tinius Olsen H5KT equipment, in accordance with the international testing standard EN ISO 13934-1/1999 for maximum force and elongation, using the strip method. It was considered that it is not necessary to determine the dielectric properties, because these are standardized for the E-glass fibers used to make the braided tubes.

a

b

Fig. 3.1. Non-impregnated glass fiber braiding tubes
a - overview of analyzed specimens; b – detail.

Fig. 3.2. Specimens of impregnated braided tubes .

The experimental values of parameters which define the tension stress-stretch behavior of glass fiber braided tubes are presented in table 2.

In figures 3.3, 3.4 and 3.5 are presented the stress-strain diagrams of analyzed specimens.

Table 1. **The main characteristics of analyzed specimens with different designs**

Specimen of braided tube	Diameter of braided tube (mm)	Number of threads	Density (braided elements/cm)	Linear density of threads (tex)	Weight of braided tube (g/ml)
I	4	32	17	33.5 × 2	3.70
II	13	80	14	67.0 × 2	16.12
III	18	96	11	67.0 × 2	17.30

Table 2. **The tension stress-stretch behavior of analyzed specimens**

Specimen of braided tube	Tensile strength (N)		Breaking elongation (%)	
	non-impregnated	impregnated	non-impregnated	impregnated
I	459	380.4	9.60	17.98
II	992	1431	20.10	18.30
III	1534	2900	14.00	24.30

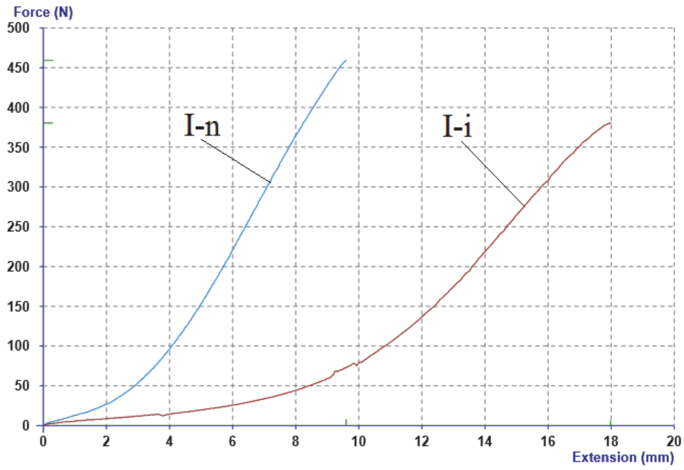

Fig. 3.3 Stress-strain diagram of glass fiber braided tube I, non-impregnated (I-n) and impregnated (I-i).

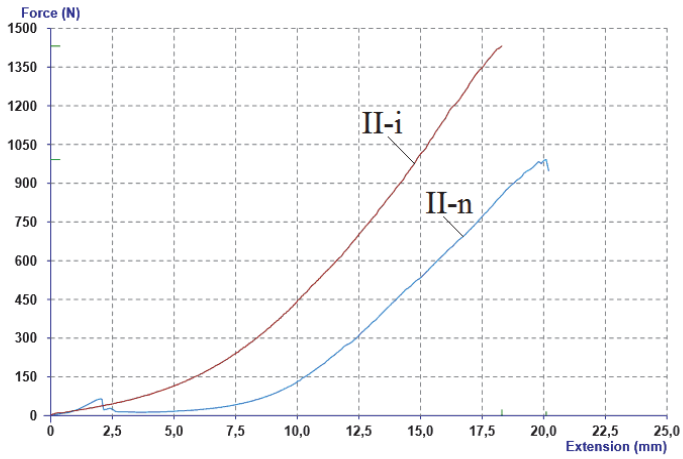

Fig. 3.4. Stress-strain diagram of glass fiber braided tube II, non- impregnated (II-n) and impregnated (II-i).

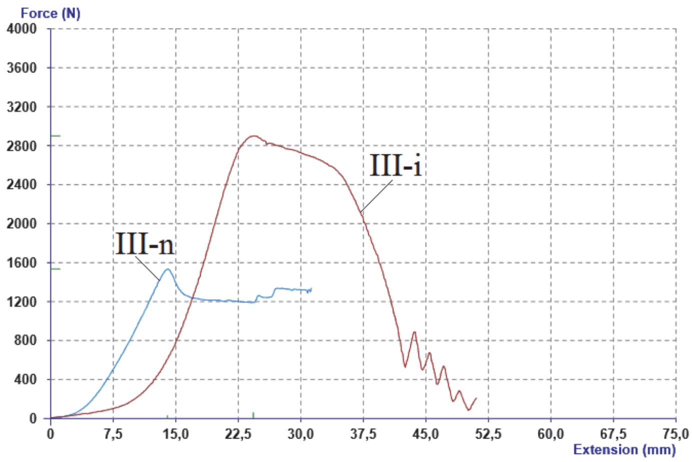

Fig. 3.5. Stress-strain diagram of glass fiber braided tube III, non- impregnated (III-n) and impregnated (III-i).

3.2. The analysis and interpretation of experimental data

From the analysis of the stress-strain diagrams presented in figures 3.3, 3.4 and 3.5 and all experimental data related to tensile strength and breaking elongation (table 2), the following observations are made with regard to analyzed specimens of glass fiber braided tubes.

To the first impregnated braided tube (specimen I) can be remarked that the breaking elongation significantly increases from 9.5% (non-impregnated) to 17.5% (impregnated). As a property of exploitation, this means an advantage to increase the flexibility of braided tube. After impregnation, the tensile strength was decreased with 17%. This decrease is due to the big density of braided tube (17 braided elements/cm), which was not allowed a deep penetration of thermoplastic polymer in braided structure and thus to strengthen it. In this case, the impregnation process could affect the characteristics of the raw material and of the braided tube.

After impregnation, the tensile strength of specimen II increased with 30%. This type of increasing is significant and characteristic of a composite material. The decrease of breaking elongation with 10% represents a significant disadvantage in exploitation.

For the braided tube III, the impregnation with thermoplastic polymer has produced an increasing both the tensile strength and breaking elongation. The increasing of tensile strength can be explained by the fact that the thermoplastic polymer has consolidated the braided structure such that, all glass fibers can participate to the stretching efforts. The elasticity of the braid fabric increased due to the properties specific of thermoplastic polymer and also because of the particular braided structure. The structure characteristics of specimen III have been optimally completed with the properties of the thermoplastic polymer.

The authors conclude that the number of threads and the density of braided elements have significantly determined how the thermoplastic polymer penetrated into the structure of braided structure. The relationship between the properties of glass fibers, the characteristics of the braided structure and the properties of the thermoplastic polymer can be a subject of research that needs to be approached more widely.

5. CONCLUSIONS

1. Due to its electrical insulation properties, the glass fiber braided tubes are used as insulators for electrical conductors.
2. For making the insulating sheath of electrical wires, the braided structures are preferred because can be easily accomplished the dimensional correspondence between the cable diameter and the diameter of the sheath. The glass fiber braided structures cannot be used as such because the glass fibers have a high potential to cause dangerous allergic reactions.
3. The impregnation of braided tubes with thermoplastic polymers has the advantage to improve their mechanical properties. The solution of this type of impregnation is used especially in the case of braided products with industrial uses.
4. The relationship between the properties of glass fibers, the characteristics of the braided structure and the properties of the thermoplastic polymer is a subject of research that needs to be approached more widely.

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