Chapter 2

Woven Fabrics for Technical and Industrial Products

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Additional information is available at the end of the chapter

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Abstract

Textile products are classified into products for clothing, household, and technical textiles. Products for clothing and household goods such as curtains, textile wallpapers, fabrics, furniture, carpets, and so on can be easily defined. Textiles that do not fit into these categories may be considered technical textiles. Technical textiles are products designed to perform a specific function. In this category are the woven fabrics presented in this chapter, such as webbings or woven fabrics used to produce reinforcing elements of composite materials.

Keywords: technical textiles, tyre cords, weaving, webbing, composites

1. Introduction

For millennia, humans have been using fibers and textiles. The most common product is clothing, which is also the most important in terms of amount of production. Textiles were and still are being used for medical applications, such as a wound dressing made from silk in Roman times. Today, parts of organs, blood vessels, and ligaments are produced using textile structures. Without fiber-reinforced composites, modern aircraft production would not be possible, and in the house and road-building industries, fibers and textiles are increasingly being used (**Figure 1**). Another category of textile products is represented by filters, which are made from textile structures using a wide range of textile materials ranging from polymers (like polyester) to steel.

For this wide range of products, fibers and textiles are used for three reasons: their mechanical properties, such as tenacity, elongation, shrinkage, and E-modulus that can be adjusted; their unique high ratio of surface to mass; and their variable porosity. Depending on their field of application, textile products have to fulfill the specific requirements like:

1. Aesthetic properties:
    - handle;
    - optical appearance and look;
    - color; and
    - susceptibility to dirt.
2. Physiological properties for wear:
    - skin-friendly wear properties;
    - air permeability;
    - water resistance; and
    - moisture take-up.
3. Physical properties:
    - strength;
    - elongation;
    - wrinkle resistance; and
    - abrasion resistance.
4. Chemical/biological properties:
    - resistance to chemical cleaning agents;
    - resistance to microorganisms and pests;
    - fastness against light, sweat, and friction; and
    - water fastness.

Depending on the specific fields of application, these requirements are of greater or lesser importance. For example, the aesthetic properties can be very important for jeans wear, depending on the type of use (as street wear or for work). The physiological properties for wear and the physical properties are even more important because they influence the personal comfort of the user. In addition, the consumer expects good durability. Chemical properties, however, are somewhat less important, in Ref. [1]. For carpets and rugs, the evaluation of properties is completely different. The aesthetic parameters are very important as well as the purchase price. The physiological character is rather unimportant because it does not influence the physical comfort of an individual. Good physical properties are essential because a carpet has to be long lasting in wear and look. The chemical properties must be distinguished between lightfastness, which is important, and resistance against chemical cleaning, which is desirable but of minor importance.

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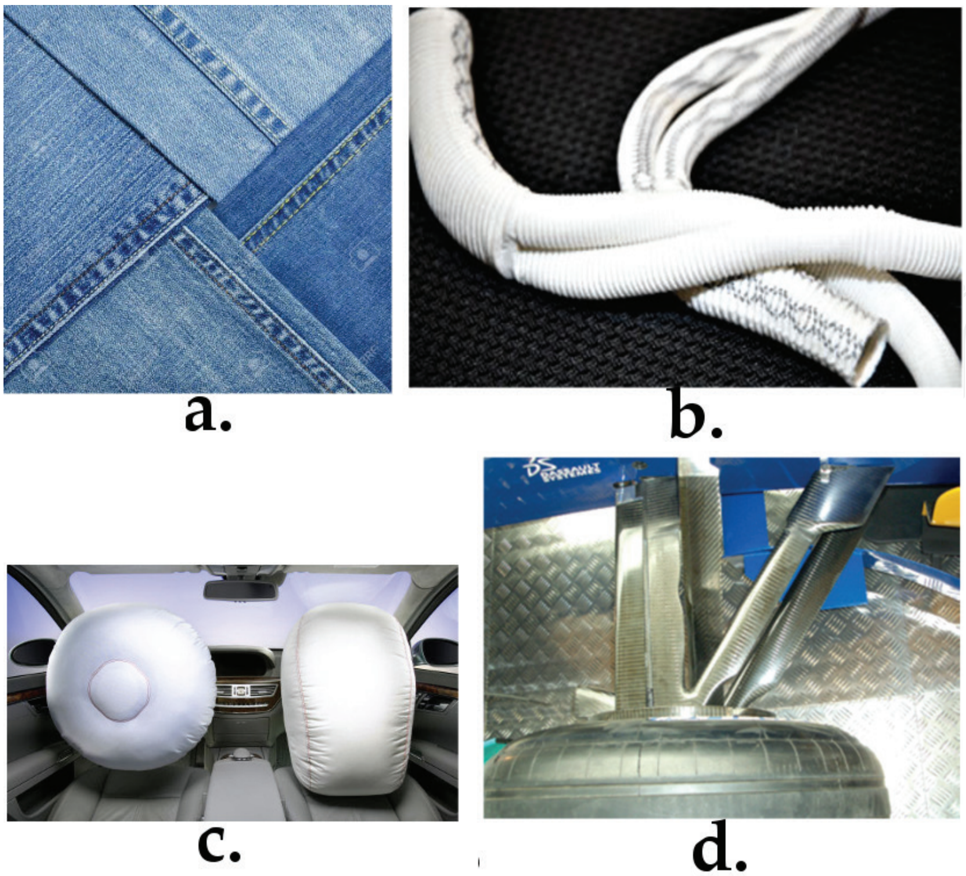

Figure 1. Textile products: (a) denim; (b) medical textiles; (c) airbag; and (d) wheel suspension made from CFC.

The airbag is not affected by fashionable influences; therefore, aesthetic aspects may be neglected. The physiological properties are less important because no direct body contact occurs in normal use. The airbag is a safety product; therefore, the physical properties are essential (it has to be temperature resistant). These aspects determine which raw fiber materials need to be used, and the price must be considered. Thus, when designing a product, it is important to choose materials that fulfill its specific requirements.

2. Woven structures for technical applications

Textile products are classified into products for clothing, household, and technical textiles. Clothing and household products (curtains, wallpaper, textiles, upholstery materials, carpets, and floor coverings) seem to be easily defined. It can be concluded that all other textile products constitute technical textiles group, but this definition cannot be accepted easily. For example, pressurized suits for astronauts, cold water-resistant suits for divers, and protective clothing for steelmakers cannot enter the field of clothing, which are technical textiles. A definition of technical textiles could be: "Technical textiles are all those products that are designed especially to meet their functionality," in Ref. [1]. The terms that define technical textiles are presented in **Table 1**.

Agrotech	Horticulture, landscaping, agriculture, forestry, and livestock breeding
Buildtech	Membranes, light and heavy construction, industrial construction and temporary interior design, hydraulic engineering
Clothtech	Clothing, footwear
Hometech	Upholstery, interior decoration, carpets, floor coverings
Geotech	Construction of underground galleries, drains and waste deposits, mining: protective nets, scaffolding, textiles for preventing erosion, shoreline and sandbars reinforcement
Indutech	Filtration, cleaning, mechanical engineering, chemical and electrical industry, composite, belts, conveyor belts, abrasive discs
Medtech	Health, hygiene, underwear, workwear, veins, dialysis, implants, and medicinal thread
Mobiltech	Bicycles, cars, motorcycles, trains, buses, ships, vehicles, aviation and aerospace, hot air balloons, aeroplanes, kites, airbags, seat belts, seat covers, upholstery, automotive interiors, carpets, upholstery, door networks heart, fabric awnings, toothed belts, pipes, fittings clutch and brake, sealants, composites, armor for vehicles
Ecotech	Environmental protection, recycling, storage
Packtech	Packing, armoring, cord nets, tapes
Protech	Protection of staff and the environment, insulation, water retention, body armor, vests warning, soundproofing, protecting buildings
Sporttech	Sport and leisure, functional sports clothing, sports equipment, textile membrane for surfboards, and sailing and gliding

Table 1. Technical textiles classification.

Based on this definition, one can identify a variety of products including textiles. For example, plastics reinforced with fibers fulfill the criteria that other materials hardly can achieve: low density, stiff adjustable attenuation, good thermal expansion that reduces the direction of the fibers, increased stability to vibration for longer due to insertion of fibers along the lines of force, increased chemical resistance, and a high capacity for absorbing energy from destruction. It can be used for different types of textile structures and the matrix can be used for thermosets or thermoplastics, as shown in **Figure 2a**, [2, 3].

Another example is the conveyer belts that are used, for example, in the paper industry or in the construction and food industry, the baking belts to transport different materials. They are usually made of one or two layers, strengthening material being carried out by an elastomeric bonding and between them an intermediate layer of reinforcement. Textile insertions can be made of polyester or polyamide placed in the longitudinal direction, on a low elongation, or they can be placed in transverse direction on a low elongation and a good draping. Higher layers, intermediate and binding, are elastomers (rubber, synthetic rubber, PVC, polyester, silicone), and the top layer is fixed by vulcanization. Safety and protection belts used in mines must be made of flame retardant synthetic materials, (**Figure 2b**), [4].

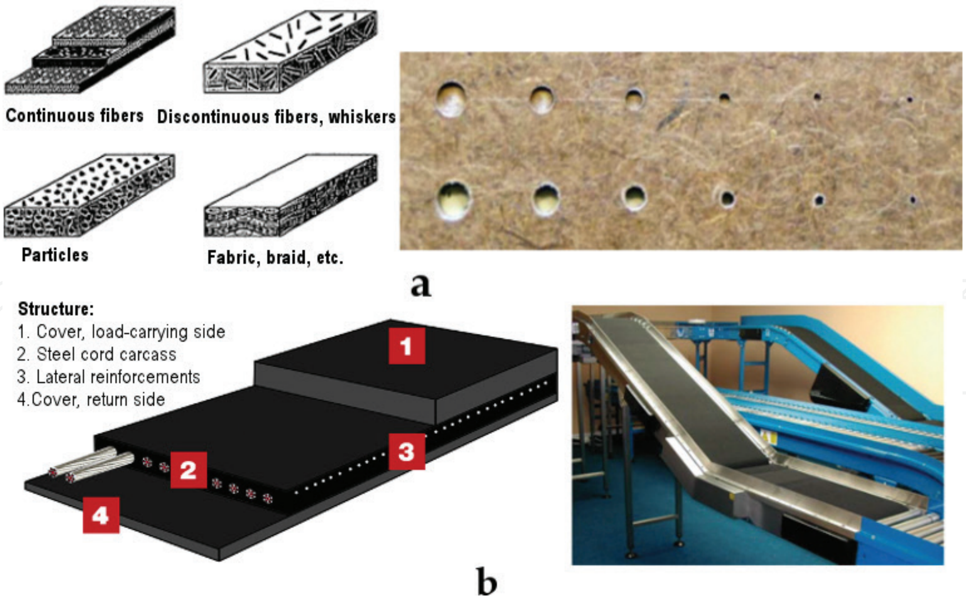

Figure 2. Technical textiles products. a) plastics reinforced with fibers; b) conveyer belts with textile insertions.

2.1. Tyre cords fabrics

A product that includes fabrics is tyres, which support a large and dynamic load and must be flexible. A rubber matrix defines the shape of the tyre functions and acts as a protective elastic layer, and the resistance layer embedded absorbs the forces exerted on the tyre. The main requirements that must meet this layer of resistance are dimensional stability (high Young's modulus, low shrinkage), fatigue resistance, and resistance to adhesion to rubber and rubber chemical products. Depending on the intended use, there are different types of tyres with different structures (for bicycles, motorcycles, cars, aeroplanes, trucks, etc.) [1].

The carrier part of tyre is carcass, which is composed of different layers of fabrics which are wrapped around the bead. Tape made of woven nylon or steel stabilizes the rolling track. The rolling track is made of a nonabrasive rubber with high adhesive capacity. Inside the tyre is inserted a layer of rubber. In the case of diagonal tyres, the fabric layers are arranged diagonally (at an angle between 30 and 45°) from one bead to the other, and these tyres are radial. Radial strips of fabric are diagonally arranged to each other (at an angle from 20 to 25°). These tapes guarantee stability and tyres are made generally of steel fabrics because they are superior textile tapes. For several years, using a tape of twisted polyamide yarns over these bands decreases the danger of separation edges tape and increases the capacity running at high speeds. The tyre housing is made of viscose fabrics, polyester, or polyamide and sometimes by aramid. Viscose yarns adhere well to rubber and are used for tyres speed in Europe. Polyamide is used in particular diagonal tyres because the rubber has a good grip and high resistance to fatigue. Polyester has gained a market share of radial tyres because it has an excellent price/performance ratio (**Figure 3**), [5, 6].

The purpose of obtaining technology yarns cord is to increase the fatigue strength of the material under compression. This is done by twisting after spinning when there are cord

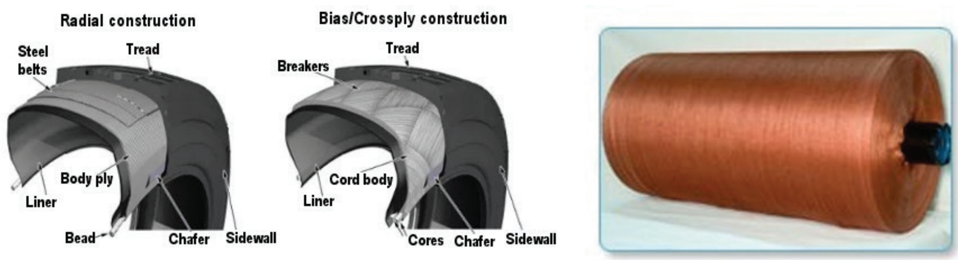

Figure 3. Technical textiles used for tyre cord: structure of tyre and tyre cord made by nylon.

yarns, a process that consists of two distinct phases of pretwisting and twisting. The first phase gives torsion to untwisted filament yarns in normal sense Z. Then twisting two yarns in the S sense is such to eliminate previous twisting on a ring twisting machine and the winding bobbin is cylindrical. These bobbins are fed from a double-twist twisting machine. The pretwisting process step is dropped in the process of direct cabling. One bobbin with untwisted filament yarns is situated in the stationary twist pot of the bobbin (inside thread), and a second bobbin is fixed in the railing above the machine (exterior/outside thread). The inside thread is led directly to the outside thread in an axial direction upward to the joining point. The outside thread is guided from the bottom up into the rotating part of the bobbin. At the storage disk, it appears again, forms a balloon of thread, and covers the inside yarn above the twisting pot. The two yarns must be wrapped with tension equal in the point of contact to prevent a yarn with length variations that affect tensile strength and fatigue.

After twisting the cord yarns, they will be woven. The warp and weft systems of normal fabrics have close densities, but in terms of deformation and vulcanization behavior of these features are not suitable. Therefore, cord fabrics of yarns have different structures and densities. Tyre cord fabrics will have 10 picks/10 cm, and cotton yarn structure is open. The weft does not have any effect upon the casing; it constitutes a yarn support to facilitate following operations.

The fabric cord was impregnated to increase adhesion with rubber and to change its contraction modulus for a better dimensional stability. Impregnating machine has a length of 100 m and a height of five floors. The tyre cord fabric is pulled off the woven fabric and passed through an impregnating bath with a resorcinol-formaldehyde-latex solution that improves the adhesiveness on the rubber. This impregnating is sufficient for viscose and polyamide, but polyester and aramid have to be pretreated additionally with bonding agents based on epoxy resin. After the drying zone, the fabric passes through a heat-setting zone in which it is subjected to a defined temperature and tension treatment for the adjustment of modulus and shrinkage. According to the material used, it may be necessary to add a normalization zone for the compensation of inside tensions or a second impregnating bath with an additional drying zone. After passing the machines, the fabric is coiled on a cylinder. The impregnated fabrics are coated with a thin rubber layer by calendering. In the last processing step before the actual tyre production, the fabric is cut under a certain angle in tapes with a desired width.

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2.2. Textile webbing

The webbings are narrow fabrics that are distinguished by the type of yarns that are produced, variation in tensile strength, and width. Webbings are produced on narrow looms. Overall, narrow fabrics are compared to ropes because they are used primarily for harnesses. Because these are versatile fabrics, these have various industrial applications used in on the military field and the automotive industry. Typically, the webbings obtained are compact or tubular having different applications and functions. If the ropes are thick, webbings are lightweight products. The raw materials used are made up of different types of polyester, polyamide, or polypropylene. Cotton webbings are not only used mainly in clothing but also in other commercial applications. The webbings can be obtained in a variety of structures, colors, and prints. Manufacturers can produce reflective straps for safety applications (**Figure 4**).

Typical applications of webbings may be associated with the following industries:

- seat belts and harnesses—automotive industry;
- equipment for hiking, climbing harnesses, and backpacks—consumer sports equipment;
- safety and signaling strips—hospitals and medical industry;
- upholstery (support for chairs, etc.)—the production of furniture; and
- uniforms and accessories for different professions—police, fire, and military.

The webbings are known as compact and flat webbings, having different thicknesses and are distinguished by being flat and having different uses such as safety belts. They are likely to be lightweight to intense tear that tend to affect the surface of the product. Flat webbings are too rigid to be used in applications requiring knotting, and for this reason, it is used for products that are high on sewing, for example, the backpack straps. Tubular webbings are thicker and more durable than the compact and are composed of two fabrics. They are used in applications requiring knotting (as a rope to lift) and support higher tensions. For destinations such as climbing, it is recommended to use tubular webbing woven into a continuous loop.

Figure 4. Applications of textile webbings.

2.2.1. Raw materials for webbing

Polyamide webbings are elastic products of high strength and are used to produce. In the wet environment, polypropylene elongates by 2% and it is recommendable that the fabric cannot be exposed to water for a long time. Polyamide webbings tend to absorb water which leads to mold growth if they are not properly maintained.

Polyester webbings are durable and have an appearance similar to that of polyamide webbings. The products are recommended for applications that require lifting heavy weights. Also, these webbings do not absorb a lot of water, being resistant to mold. Common uses are for racing harnesses and seat belts.

Polypropylene webbings are used for the products used for the environment activities. Some of these products include mesh for windows, webbing, and bags. In terms of physicochemical properties are comparable to those of polyamide, but the polypropylene products are lighter than similar polyamide. It is used to produce materials which are resistant to water and UV radiation. Products have different thickness and have a low resistance to abrasion and suitable for work that requires medium resistance.

Based on the properties of these fabrics, when are used for seat belts, harnesses, and other safety products, a periodic check should be carried out. This is required to see if the equipment security requirements have been modified. The webbings used as harnesses and belts in motor racing industry lose their elasticity and break when they are used frequently or exposed to oil or heat. It is recommended to replace them after a period of 2–5 years or sooner if used frequently, such as seat belts or seats.

Another problem raised by webbing is maintenance. As a general rule, they must be kept clean and dry, even if polypropylene is waterproof. It is recommended to wash with mild detergent because these materials are painted while the colors fade or even disappear if subjected to certain environmental conditions or cleaning.

Textile products must satisfy certain quality requirements, depending on their destination. These requirements refer, but are not limited, to the type of the raw material, the fineness of yarn, the density of the fabric structure, the fabric weight, breaking strength and elongation at break, and color and finish. One of the requirements for leather goods webbing is to respect certain values for breaking force. For this reason, it is necessary that the yarns be selected as appropriate, with appropriate breaking force. Characteristics of the polypropylene yarns used for warp and weft are shown in **Table 2**.

2.2.2. Mechanical characteristics of leather goods webbings

Samples subjected to testing were obtained from the black polypropylene yarns, having a width of 30 mm. All fabrics had the same number of yarns in the warp, respectively 104 yarns, but instead were varied in the following characteristics: density of the weft yarns and the warp and weft yarn fineness. These fabrics are made on short technology: the direct warping of yarns on narrow warping machines, warp installation in weaving machine, and weaving on a weaving narrow loom.

Characteristics		Values	
Raw material	–	polypropylene	
Color	–	black	
Count	Dtex	550	1100
Tenacity, min.	cN/dtex	3	2.5
Elongation	%	20 ± 3	
Breaking force, mean	cN	1610	2665

Table 2. Warp and weft yarns characteristics.

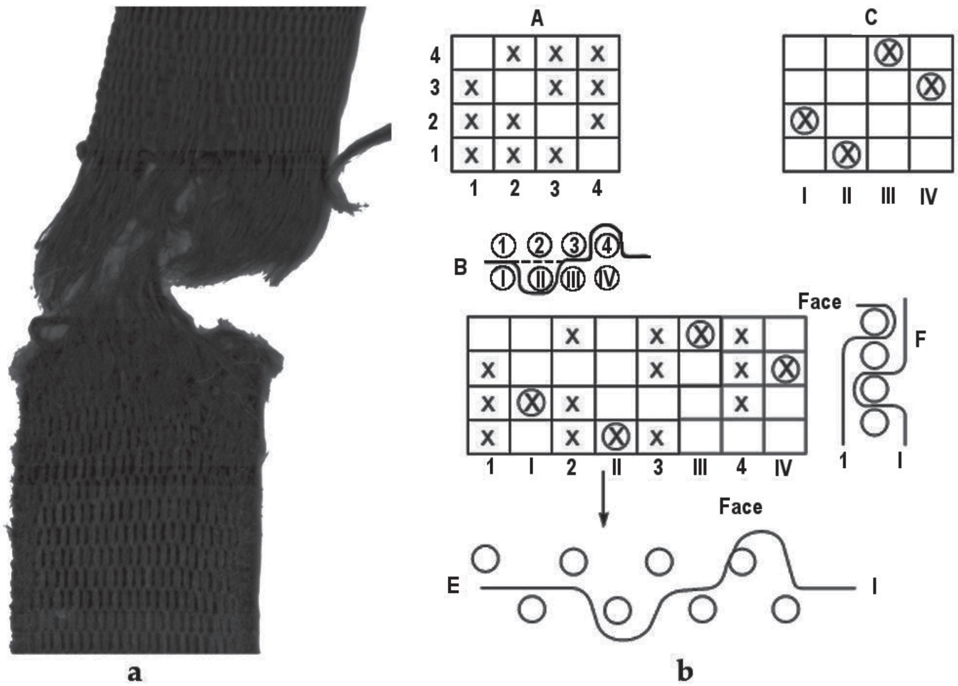

Figure 5. Webbing for leather goods: (a) aspect and (b) structure [7].

Variants	Tt_{wa} (dtex)	Tt_{we} (dtex)	Fr_{wa} (N)	Fr_{we} (N)	D_{we} (fire/cm)	F_{maxt} (kN)	a_{wa} (%)
1	550	1100	161	266.5	8	2.13	26.11%
2	550	550	161	161	8	2.35	22.56%
3	550	550	161	161	10	1.95	18.69%
4	550	1100	161	266.5	10	1.65	26.65%
5	550	1100	161	266.5	6	1.86	18.26%
6	550	550	161	161	6	1.87	17.51%

Table 3. Values for breaking force and breaking elongation.

Woven fabric structure was backed by the warp; the structure and aspect is presented in **Figure 5**.

The test was performed on a universal testing machine WDW 50E of mechanical type, with computer-aided control and maximum load capacity of 50 kN and the distance between grips was set at 300 mm. The values obtained for the variants tested are shown in **Table 3**.

Tensile tests were performed to breakage of test pieces, until recording time to the maximum load value was considered as $F_{maxt,}$ that were the first warp yarn breakages. Load-elongation curves of the leather webbings had a similar look for all variants analyzed webbings.

Shown below are two effort-elongation curves of these fabrics for specific two of the six tested variants, presented in **Figures 6** and **7**.

Analyzing the following figures aspect, it is found that this curve shows three distinct zones. Of these, the central area presents a linear evolution, i.e. the force applied to the sample and the corresponding elongation varies directly proportional.

- an initial area, of relatively slow growth (hyperbolic), up to a loading level between 8 and 10% of maximum force F_{max};
- an area of relatively abrupt increase, linear with a slope greater, up to a force of almost 95% of maximum force F_{max}, respectively; limits of these zones are between 8 and 95%. In this area, the fabric behaves almost proportional having a relatively high modulus of elasticity;
- an area with a small length, in which the breakage occurs. In this area, two situations are revealed: in the first situation, breakage occurs gradually due to break on all the threads, and the second situation is where breakage occurs suddenly.

Processing of data results has led at extracting meaningful data from this set of values. Values for the breaking force of tapes for handbags were grouped according to two criteria: the strength of the weft and warp breakage. These criteria are grouped according to the values shown in **Table 4**.

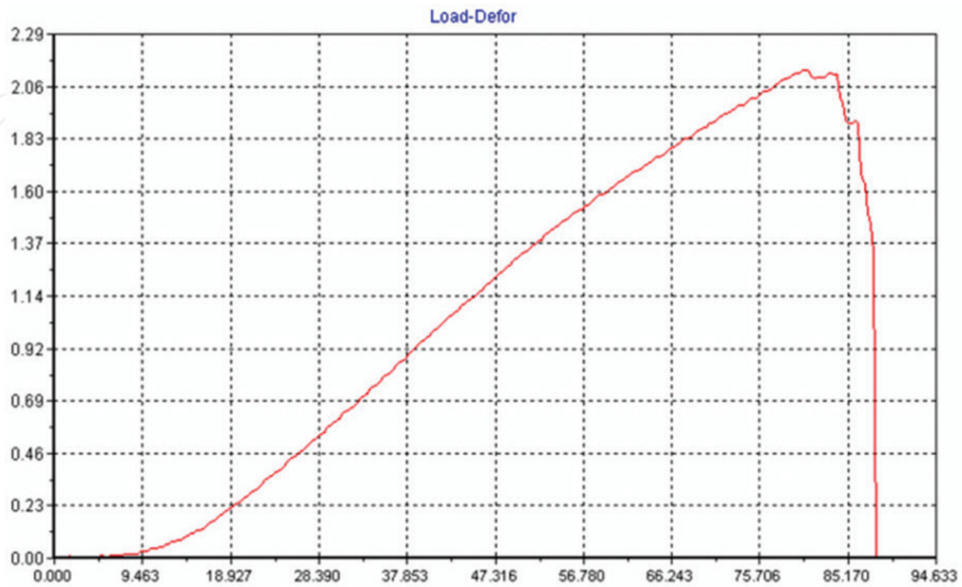

Figure 6. Curve load, deformation for variant 1.

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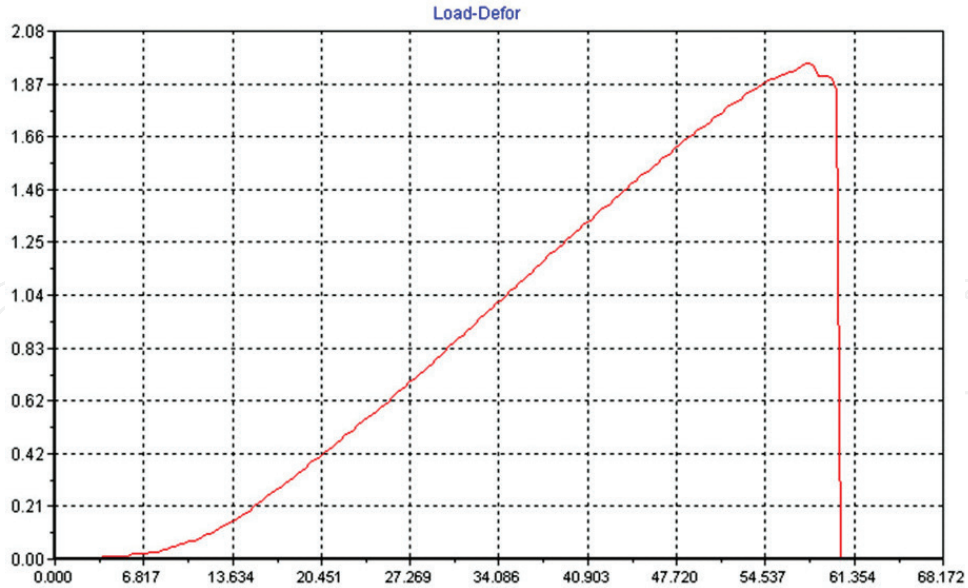

Figure 7. Curve load, deformation for variant 3.

Db, (ends/cm)	Fru (cN)	Mean values of Fru (kN)	au (%)
6		**2.80**	**18.7**
	161	1.87	19.0
	266.5	3.74	18.5
8		**3.09**	**23.8**
	161	2.24	22.9
	266.5	3.94	24.7
10		**2.74**	**29.2**
	161	1.80	24.1
	266.5	3.69	34.3

Table 4. Medium values for breaking force and elongation.

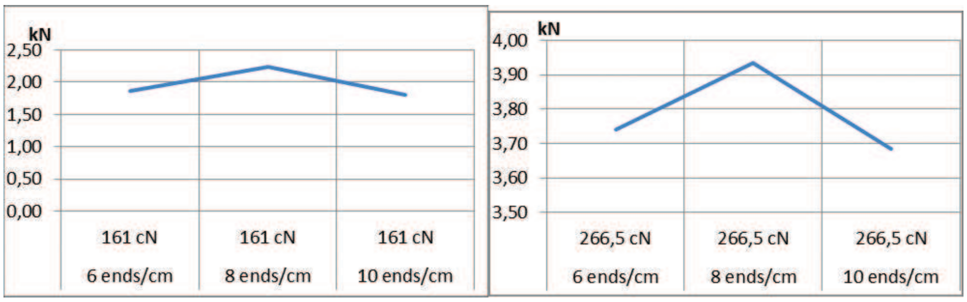

Figure 8. The mean values of webbings breaking force.

The values of webbings breaking force are comprised between 1.8 and 2.4 kN for warp yarns with breaking force of 161 cN and between 3.69 and 3.74 kN for warp yarns of breaking force of 266.5 cN. The bold values in Table 4 are the average values for fabrics of the same density in the weft directions, but with different yarns in the direction of the warp. These values are not significant in the performed analysis because these are not referred at the same fabric. So if the warp yarns are used with greater resistance, resistance webbing in proportion will increase. (**Figure 8**).

The maximum values for both warps appear at weaves with the weft density average value (8 ends/cm). Even if woven webbing with a greater density, 10 ends/cm, is more compact and appears more resistant, in reality, the higher density caused the biggest undulation and crushing of yarns in fabric. The effect is manifested through subsequent breakage of the warp yarns to the breakage of the strap. The breaking of the webbing was occurred suddenly, for the fabrics with weft density with 8 ends/cm and those of the webbing with weft density of 6 yarns/cm.

In the case of variant elongation, the values are shown in **Table 4**, and the change in elongation in the weft according to the breaking force and the wefts is represented in **Figure 9**.

The values of elongation of webbing are comprised between 19 and 24.1% for the warp yarns with breaking force of 161 cN and between 18.5 and 34.3% for warp yarns with breaking force of 266.5 cN. If the weft yarn density increases, the elongation at break increases, as shown in **Figure 9**. The weft density influences the degree of crimping of the warp yarns, respectively, its increase, and so the elongation will be greater due to the higher recovery of crimping.

Observation of effort-elongation curves leads to the conclusion that between breaking force and elongation at break is a relationship of proportionality.

The checking of the correlation of experimental data packet, Data Analysis, using Microsoft Excel and the result is presented in **Table 5**. The bold values in the table represent significant correlation coefficients.

From this table, it is observed that between the breaking force of the webbing and breaking forces of the weft and warp yarns, there is a certain dependency (coefficient of 0.914, −0.301), and elongation at break is influenced by the breaking force by the warp yarns and the weft density (0.348, respectively 0.654).

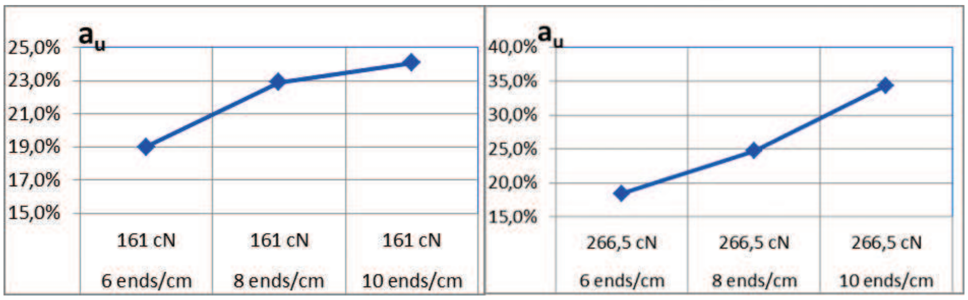

Figure 9. The mean values of elongation of the webbing.

	Fru	Frb	Db	Frt	au
Fru	1				
Frb	0	1			
Db	0	0	1		
Frt	**0.914408**	−0.30089	−0.02464	1	
au	0.347696	0.294629	**0.654416**	0.215268	1

Table 5. Matrix of correlation coefficients.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,962956
R Square	0,927285
Adjusted R Square	0,900017
Standard Error	0,328369
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	11,000	3,667	34,006	0,000
Residual	8	0,863	0,108		
Total	11	11,863			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	0,526	0,721	0,729	0,487	-1,137	2,188	-1,137	2,188
Fru	0,017	0,002	9,591	0,000	0,013	0,021	0,013	0,021
Frb	-0,006	0,002	-3,156	0,013	-0,010	-0,002	-0,010	-0,002
Db	-0,015	0,058	-0,258	0,803	-0,149	0,119	-0,149	0,119

Figure 10. Regression analysis of the breaking force of the webbing.

Regression analysis of the experimental values was performed with regression package. This package was applied to the original experimental data; results are presented in **Figure 10**.

It is observed that experimental data are correlated (coefficient 0.927), and the model is especially significant. Testing the significance of the coefficients leads to the following observation: the breaking force of the webbing is influenced by the breaking force of the warp yarns and the weft yarns. It reforms the statistical analysis and removes the weft density.

The new values resulting from the statistical analysis are better than previous (higher correlation coefficient, 0.91) and the coefficients are significant. On the basis of the output data of the regression, the equation is shown in Eq. (1):

$$F_{rt} = 0.406 + 0.017 \cdot F_{rwa} - 0.006 \cdot F_{rwe} \quad (1)$$

In Eq. (1), breaking force of the webbing (F_{rt}) depends on the breaking force of the warp (F_{rwa}) and the weft (F_{rwe}) yarns. The increase by 1 cN of breaking force of the warp yarns will increase, to 0.423 kN, the breaking force of the webbing. Breaking force of weft does not significantly influence the strength of the webbing as its growth causes a reduction of total breaking force, as shown in Eq. (1).

Of the regression analysis on the influence of mechanical characteristics of yarns on elongation of webbing, it is noticed that in this case, the correlation coefficient is lower (0.428) which requires the consideration and other factors.

Based on these results the following conclusions may come off:

- the breaking force of the webbing is proportional to the breaking force of the warp yarns because they all participate in the strength of the fabric;
- the weft yarns do not influence the breaking strength since it has been found that to using resistance yarns, usually thicker warp yarns break more easily;
- fabric structure affects the strength by creating an equilibrium between the crimping of yarns and the number of bonding points in which frictional forces appear;
- webbing testing requires the use of grips to take up the tensile force along the fabric and to do fixing without crushing the fabric portion between the clamps.
- tightening pressed of webbings from filament yarns produces jaw-crushing yarns and breaking occurs near them. This affects the veracity of values.

2.3. Textiles used in composites

In the last two decades, the uses of textile structures made from high-performance fibers are finding increasing applications in composites. High-performance textile structures may be defined as materials that are highly engineered fibrous structures having high specific strength, high specific modules, and designed to perform at high temperature and high pressure (loads) under corrosive and extreme environmental conditions. Significant developments have taken place in fibers, matrix polymers, and composite manufacturing techniques. Composites that are a part of industrial textiles have a significant role in many applications especially in automobiles and aerospace applications [8].

Composite materials reinforced with woven fabrics, braids, and knits are becoming increasingly popular in various structural applications from automotive, aerospace, furniture, and so on. Processing techniques of materials to obtain composites include technologies to obtain reinforcement layers, stratification technology, transfer resins in textile layers through molding, molding with vacuum/pressure, and autoclaving fabric (reinforcement structures) for impregnation products with properties of thermosetting and compression/preforming molding of thermoplastic and thermosetting composites [9].

2.3.1. 2D woven structures in composites

Preimpregnated fabrics play an important role in the technology of composite structures because they can perform various structures from different natural materials (fibers and textile fabrics, glass fibers, aramid fibers, carbon, and mixed structures). Advantages of woven reinforced composites are reduced cost, improved machinability, and, in particular, the use of a wide range of textile structures. Woven reinforced polymeric composite materials have broad applications in the structure of aeroplanes and ships, having good stability and easy machinability. Inserting textile elements in composite structures aims to:

- improve the mechanical behavior of the composite material, the advantageous orientation of the textile insertion relative to the direction of mechanical stress; and
- improve the resistance of bonding areas of the pieces.

The stiffness and strength of textile-reinforced composites depend on the characteristics of the yarns, the matrix properties, and structure parameters of the insertion (the thickness of the fabric, warp and weft density, tensile strength in the direction of the two yarn systems, and the structure of the insertion). The thickness depends on the density and fineness of the fabric yarns, while the structure determines how the warp and weft yarns interact. Typical structures of plies which can be used in the composites are presented in **Figure 11**.

Depending on the type of loads that are subject to insertions, they may have the same strength and stiffness in both directions (warp and weft). If the request is important only in one direction (e.g., warp direction) fabrics can be obtained with a large number of yarns in that direction and less in the opposite system (weft). These fabrics are called unidirectional because they offer high strength and stiffness in one direction. Unidirectional composites have high machinability.

Compared to unidirectional composites and nonwovens, composites that use fabrics like the reinforcement system are more resistant to impact and have uniform properties in all directions [10].

Textile structures used as insertions in composites can be obtained by different methods of binding/joining of textile materials (fibers, fiber preforms, yarns, etc.) such as weaving, knitting, and braiding. They are different textile structures used as reinforcement, such as fabrics, braids, and knitted ones (**Figure 12**).

The choice of a particular type of textile fabric used as reinforcement elements for the production of composites depends on the capacity of multiaxial reinforcement and between the layers, namely the ability to obtain different forms of spatial composites. Depending on how composites processing and requirements, certain structures of reinforcement elements may be adopted.

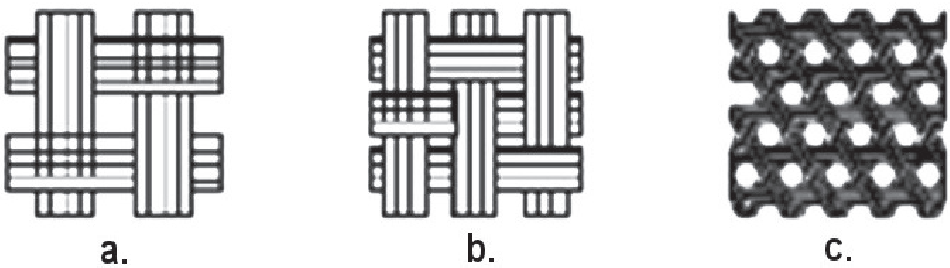

Figure 11. Different types of textile structures: (a) plain woven fabric; (b) twill fabric; and (c) braid.

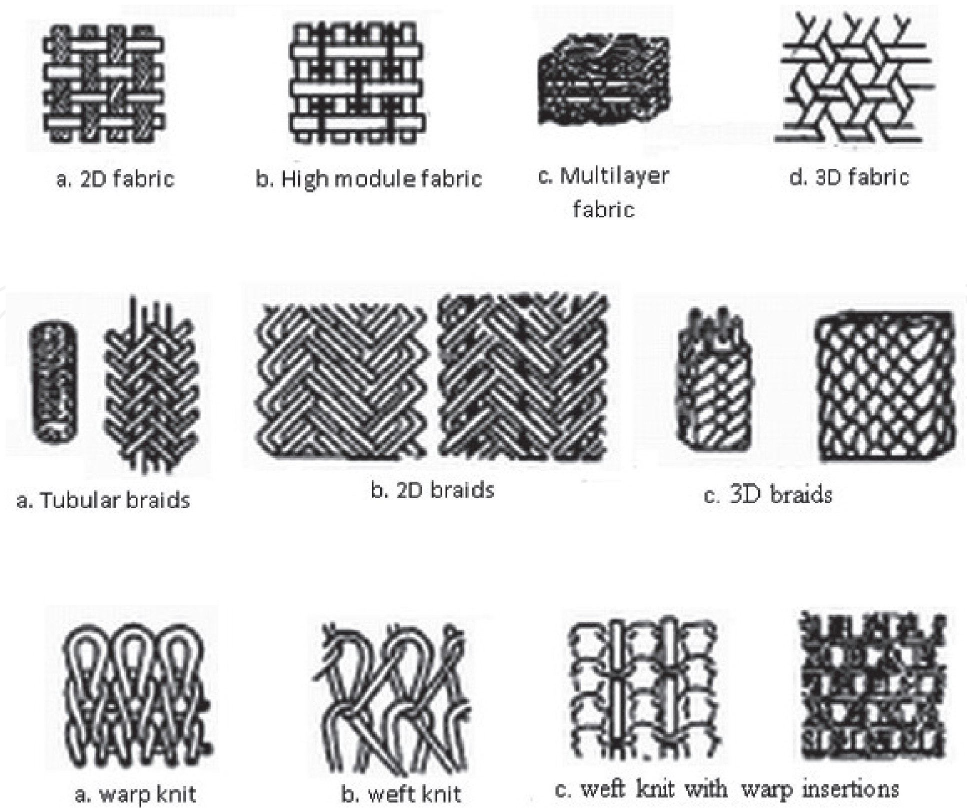

Figure 12. Textile structures used like insertions.

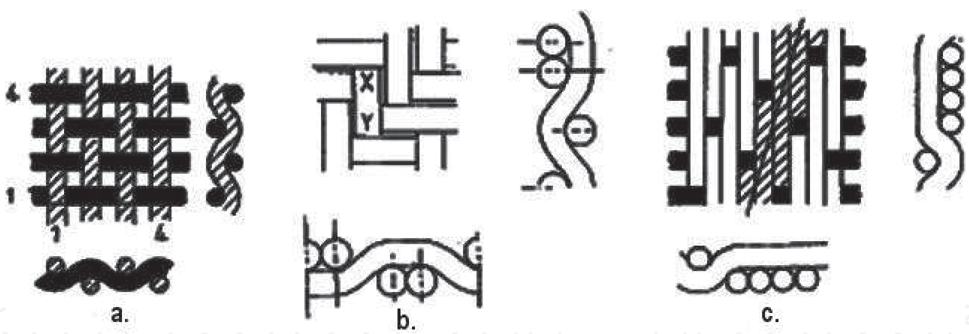

Figure 13. Fabrics fundamental ties: (a) plain; (b) twill; and (c) atlas.

The armor drawing used for connecting yarn systems participating in the fabric affords numerous combinations of woven. Bi-dimensional fabrics (plane) obtained by combining the two systems of yarn (warp and weft) disposed mutually at an angle of 90° by repeating the cell structural or topological model.

Regarding fabric structures, fundamental ties are distinguished, as presented in **Figure 13**, which entail all other types of ties between yarn systems participating in the fabric: plain weave, twill, and satin. The differences between the three types of ties are the number of binding points and lengths of the segments associated with each yarn system that binds the opposite system.

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A plain weave fabric is characterized by:

- the most frequent crimping the warp and weft yarns in the ratio tie, which leads to a maximum shrinkage of yarn systems to weaving;
- fabric surface is monotonous, and the reflected light is diffuse;
- if the density of warp yarns is equal to the density of weft yarns, and the count of the yarns of the two systems is same, the effect will be the same on both sides of the fabric and there is no dominant system, and the fabric has the same behavior to mechanical load of the two yarn systems;
- it has high resistance to wear and friction applications; and
- plain weave gives the fabric a high level of structural integrity and greater expandability due to high frequency crimping.

Satin fabric is characterized by:

- smooth, shiny uniform appearance due to distribution points binding;
- uneven distribution of yarn systems on the front and back fabric leads to a dominating system (weft on the face and warp of the back face of the fabric);
- Increasing the system effect, i.e. the length of the warp segment in the weave repeat causes a decrease in the compactness and mechanical properties of the fabric;
- allowing a better transfer of the structure of yarns and fabrics for resisting a translation module efficiently due to low binding yarns of opposing systems, allowing better mobility between them.

Braided reed or cane is used for a long time to obtain pieces of furniture (chairs, tables, etc.) and triaxial ties between systems are used to build the structure. There was a concern for construction machinery to carry out such structures naturally [11].

2.3.2. 3. D woven structures in composites

Due to their flat surfaces, modeled fabrics can be profiled. In this case, the fabric must be materials with high-capacity stretching. Obtaining the reinforcing fabric to be used as textile insertions in composites with three-dimensional geometry requires:

- A series of complex weaving technologies, such as weaving with binding between the two fabric layers of 2D and 3D weaving surface (fabric structures comprising semi double, double);
- Methods for the design of links that generate smooth fabrics to cover certain areas of the composite and methods to predict and prevent various defects such as creasing, folding, and tearing [12, 13].

At the same time, textile fabrics used as insertions have benefits as good machinability and a corresponding draping. In terms of mechanical properties, textile-reinforced composites are advantageous over unidirectional laminate composites because they have no reinforcements oriented in the thickness direction. On the other, the textiles are characterized by 3D architecture due to the connections between the yarns that are part of different systems and crossing the different layers of the insertion [14].

By technologies of weaving, braiding, and knitting, it can produce bi- or 3D structures. The orientations of yarns, their distribution in the insertion structure, and number of yarns from preform thickness determine the type of structure (bi or three-dimensional). A bi-dimensional structure assumes the existence on the thickness of the insertion of two or three yarns, which are oriented in the x-y plane.

A 3D structure is obtained by using three or more yarns and the thickness of the yarns go through the structure in all three directions.

Characteristic of triaxial fabric structures is the hexagonal orientation of yarn systems, participating in the structure, as shown in **Figure 14**, which leads to elevated shear strength of the fabric.

3D woven structures are obtained mainly by using multiple warp and weft systems. In this connection, multilayers or double structures were used for making packaging, laces, textile tapes, and carpets. By using these types of ties, it is possible to produce a solid orthogonal panel(**Figure 15a**); solid panels with variable thickness (**Figure 15b**); panel coreless structures like beams(**Figure 15c**); or similar structure types of lattice girders (**Figure 15d**).

The inconvenience of plane reinforcing elements, respectively, low resistance in the diagonal direction, is removed by replacing with multilayer fabric made by using the triaxial weaving technology.

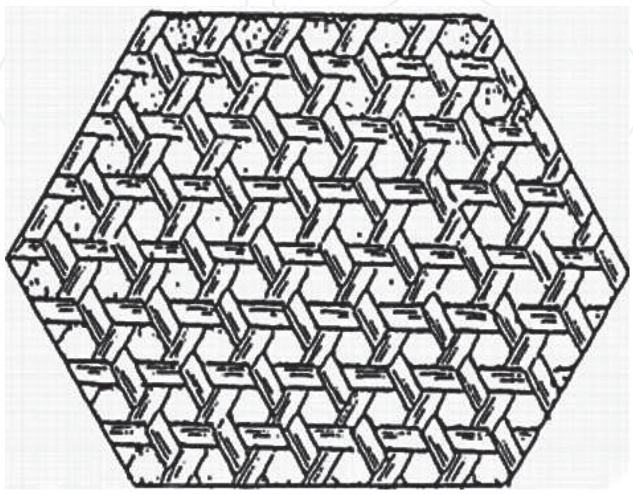

Figure 14. The structure of a triaxial braided cane.

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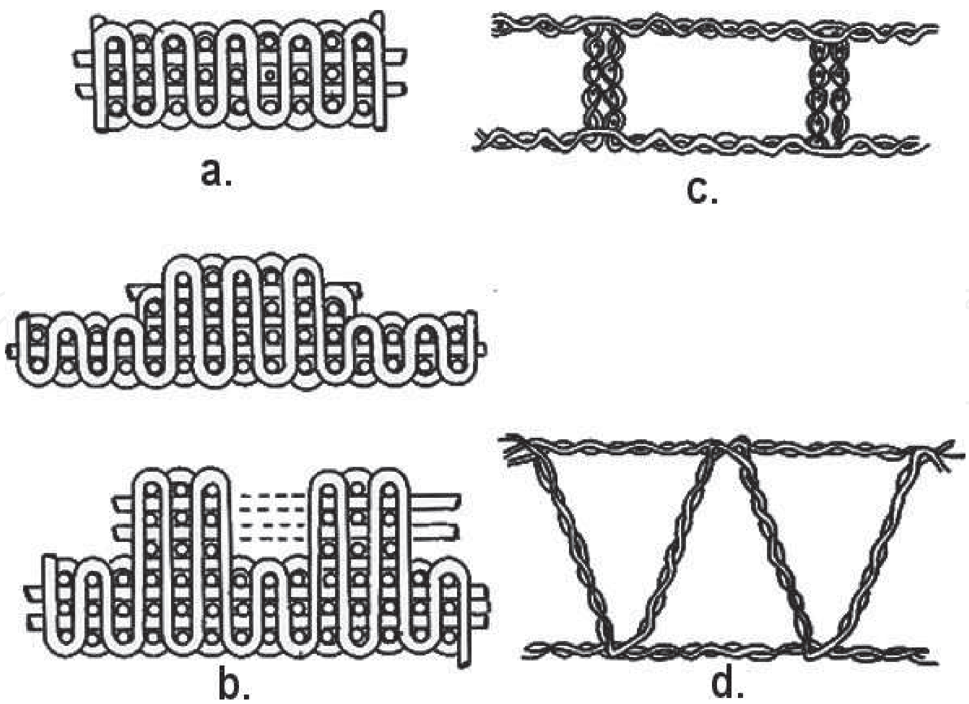

Figure 15. Types of 3D structures used as reinforcing element of composite. a) solid orthogonal panel; b) solid panels with variable thickness; c) panel coreless structures like beams; d) lattice girders.

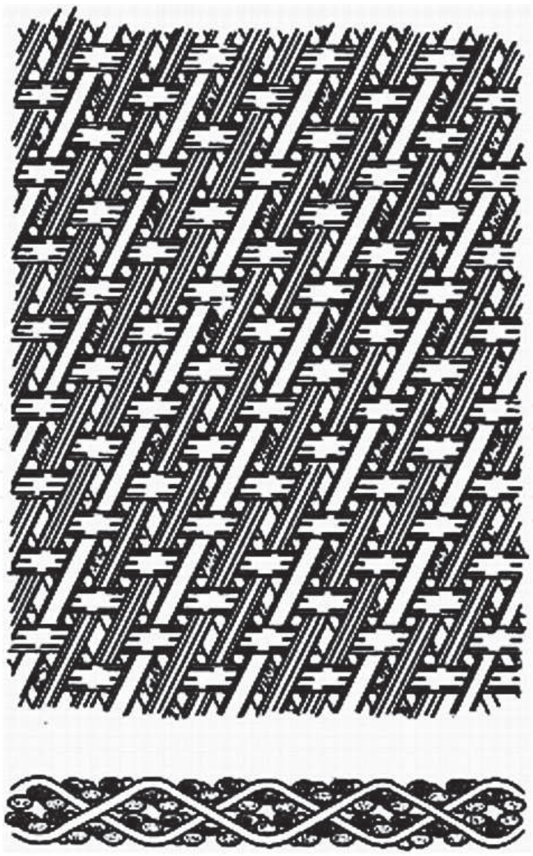

Figure 16. Woven 3D structures, multilayer.

The 3D fabrics, thanks to low draping characteristics, require overlaying multiple layers that allow for a smooth transfer of loads. In the structure of composite material, fabrics used as insertions are placed so that the yarn systems participating in the fabric systems (perpendicular) are to be at a ± 45^0 angle to the composite axis. Thus, textile insertion takes external efforts in a uniform manner in all directions of application, avoiding the different behaviors of the composite during its use. For example, in combination with the unidirectional reinforcing materials are produced the composite materials to achieve tennis rackets, materials with shear strength, and high rigidity [15, 16].

2.3.3. Biodegradable woven structures for composites

Plain woven fabric, from bast yarns, can be used to obtain cheap and biodegradable composite materials. Biodegradable composites—currently based on biopolymers with natural fiber reinforcement—are intended to be compostable, after their lifetime use, in order to prevent the growth of permanent environmental pollution. This class of composites is based on some raw materials that are available on our internal market—animal glue (together with some curing and stabilizing agents) and bast fiber fabrics. The samples are firstly preformed, by impregnating the polymeric matrix in the suitable textile reinforcement arrangements, and then consolidated by moderately hot pressing. The evolution of composite tensile properties was studied, in dependence with the parameters (temperature and pressure) of consolidating process, in order to obtain their suitable values for optimizing the composite mechanical response [17].

The biodegradable composite materials were manufactured as rectangular samples of crossply laminates, using a polymeric (proteic) matrix, based on animal glue, initially as an aqueous solution containing some curing and stabilizing agents. For every sample, the reinforcement, in a weight fraction $W_f = 0.49$, was composed by four plies of flax fiber fabrics, alternately disposed with the principal directions (corresponding to the warp and the weft yarns) on the long axis of the composite sample. On the basis of some experimental results, (Mareş et al.), previously obtained by the authors of the present chapter, four different levels were used for the processing temperature, namely 45, 55, 65, and 75°C, successively combined with four pressure level values, 0.15, 0.20, 0.25, and 0.28 [18]. The biodegradable composite materials that are presented herein were intended to be used for components (from the ambient design, for example) that must not have high levels of mechanical strength. In that, it must be said that the composite samples, as resulted from the moderate hot pressing process, are comparable in stiffness with the plywood samples of similar thicknesses.

The composite load-elongation dependence (**Figure 17**) has a pronounced nonlinear aspect, with a down-right oriented convexity, that is typical for woven textile reinforcements, as it could be observed from the load-elongation curve which was obtained for the jute woven, as shown in **Figure 18**, before starting the composite manufacturing process.

As it can be observed on the above presented load-elongation curves, the principal Young's modulus (E_1) of the composite, corresponding to the specimen loading direction in the tensile test, could be considered as increasing with the applied force: the modulus value is relatively low at the beginning of the curve, but it is many times bigger at the last portion of the curve, before its maximum point (F_{max}). One can say that, having in view the values of ultimate ten-

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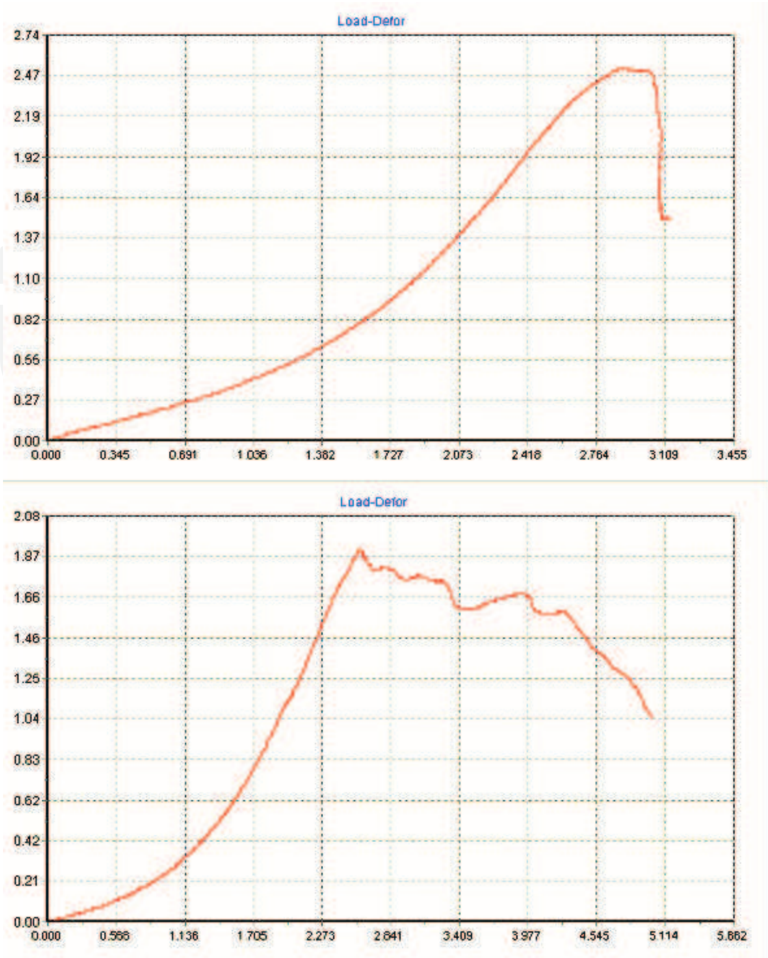

Figure 17. Typical aspects of the load-elongation dependence for the studied composites.

sile strength (24–27 MPa) for the studied composites, it is convenient for these materials to be utilized in samples that have to support, on the principal material direction, normal stresses of approximately 16–22 MPa. Such a mechanical load will lead to a material response corresponding to its maximum stiffness level. In **Figure 19** are briefly presented the evolution of the average tensile strength of the studied biodegradable composites in dependence with the technological parameters (temperature and pressure) of the forming process.

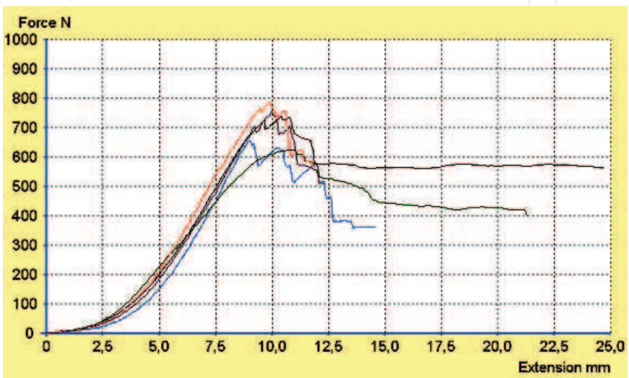

Figure 18. The load-elongation dependence for the jute woven reinforcement.

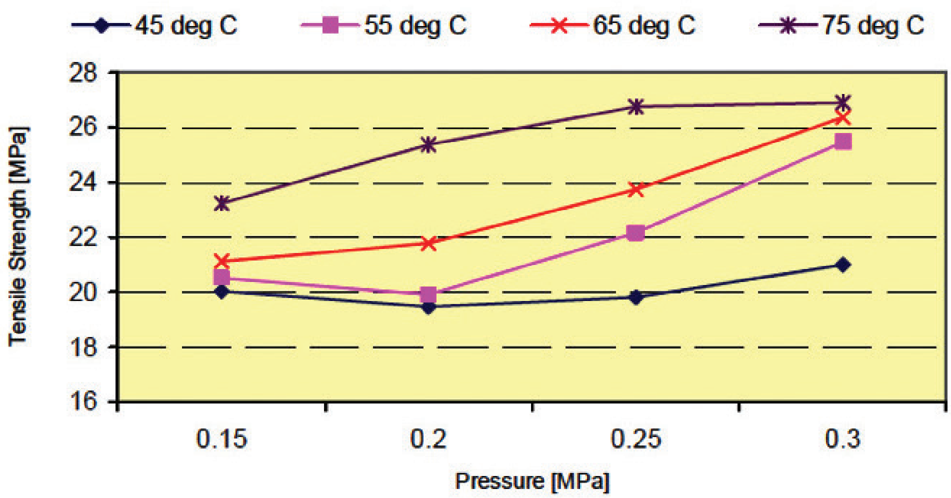

Figure 19. Tensile strength variation as a function of forming pressure, for different values of processing temperature.

Some particular issues could be observed, in the figures from above, for the studied biodegradable composites, regarding their mechanical response:

- as a general tendency, an increase in strength and stiffness could be observed, when temperature and pressure levels are both increasing;
- an interesting effect can be seen, regarding the results that are obtained for the upper levels of temperature—namely those of 65 and 75°C, mainly for the pressure levels overtaking 0.2 MPa; for using these values of the technological parameters, the suitable mechanical properties are corresponding to the temperature of 65°C, instead of the highest level (75°C), as it could be expected;
- on that basis, one can conclude that the best combination of composite mechanical stiffness and strength was obtained for the samples that were pressed at 0.3 MPa and 65°C, that can be retained as the optimum parameter values for composite consolidating process.

2.4. Conclusions

The fabrics presented in this chapter are only a small fraction of the technical fabrics which are produced. Also, these fabrics can have other applications, and they will take into account the fact that the design and development of the technical textile product need basic understanding and application of textile science and technology. Technology advances in the industry are driven by forces outside the pure textile sector, that is, polymer and fiber producers and, in some cases, the machinery producers of fabric manufacturing techniques. There is a growing need for nontextile application know-how in many segments of the industrial textiles market. Textile technologists are needed who understand the various engineering aspects of potential industrial applications so that suitable textile structures can be produced.

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