STRUCTURAL CHARACTERISTICS OF THE MULTI-PLY WOVEN FABRICS

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REZUMAT. Țesăturile tehnice în straturi multiple sunt structuri realizate în două până la șase straturi reunite prin însăilare cu fire proprii sau cu fire speciale. Aceste structuri sunt utilizate la realizarea de țesături tehnice folosite ca: benzi transportoare, curele de transmisie, chingi în industria mobilei, aeronautică, agricultură, echipamente sportive, etc. Proiectarea acestor țesături se face în raport cu funcționalitatea produsului. De regulă, țesăturile tehnice în straturi multiple sunt produse cu alungire minimă, chiar nulă și cu forță de rupere mare. De asemenea grosimea și masa țesăturii sunt considerate caracteristici de funcționalitate. În lucrare sunt propuse și verificate, relații de calcul pentru gradul de ondulare a firelor în țesătură, masa și grosimea țesăturii pentru cele două tipuri reprezentative de structuri.

Cuvinte cheie: țesături în straturi multiple, țesături, ondulare, masa, grosime

Abstract. The multi-ply woven fabrics are compound structures made of 2 up to 6 layers stitched together with their own yarns or with additional yarns. Their applications include: conveyer belts, driving belts, narrow fabrics in furniture industry, military application, aerospace industry, sport goods etc. These structures are technical textiles and they have specific destinations, so must be designed to provide required properties. These fabrics have high strength and minimum elongation on warp direction. The paper presents the most important structural characteristics of the multi-ply fabrics: the shift, stitch profoundness, the crimp of the yarns, the structure weight and thickness. Using the relations presented one can design the multi-ply structure according to its utilization.

Keywords: multi-ply fabrics, woven fabrics, weave, crimp, weight, thickness.

1. INTRODUCTION

The technical textiles are the protagonists for the being time, and are used frequently in fields as: agriculture, construction and architecture, automobile industry, chemical industry, medicine, sport, entertainment business, mining and mineral oil industry.

The multi-ply fabrics consist of two or more fabrics woven (up to six) one above the other and stitches together with their own yarns or with extra special yarns. The industrial belts, conveyer's belts, girths for furniture industry, safety belts, are multi-ply fabrics.

The multi-ply fabrics, like all technical textiles, are products with determined functionality. A high resistance and low elongation characterize the most part of these products.

Most of them are called resistant products.

That is the reason for the multi-ply fabrics are designed so that their compactness and dimensional stability to be maximum [2, 4].

2. THE STRUCTURAL PARAMETERS OF MULTI-PLY FABRICS

The most important parameters of the multi-ply fabrics, that are adopted or calculated when designing the fabrics, are the fineness of yarns, the density of yarns in the fabric, the weave, the crimp of yarns, the weight and thickness.

The fineness of yarns and their nature is adopted depending of the fabric destination and the stress conditions to which this is subjected. Generally for this kind of fabrics yarns is used cotton, wood, linen or synthetic twisted.

The yarn fibers must present a high quality because these kinds of fabrics during the exploitation are subjected to different high level stresses.

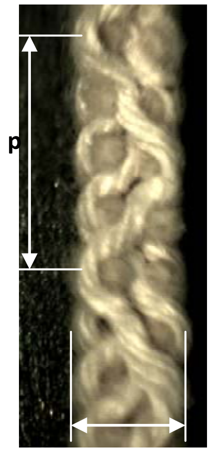

Fig. 1. Structural parameters.

The multi-ply fabrics are not balanced structures, the number of warp yarns per cm being greater than the number of weft yarns per cm.

As a result, the fabric strength presents a high resistance on warp direction. The low density of the weft yarns is proffered for economical weaving. At the same time, this more un-balance of the density of yarns determines the orientation of structure to the extreme phases of fabric construction.

The weaves used for the multi-ply fabrics can be with or without extra special systems for interlacing. Indifferent of the king of weave, a longitudinal cross-section is presented for a multi-ply weave construction.

The position of all warp yarns from the repeat plain must be represented compared with the weft yarns. Generally the weave is used for each individual fabric of the multi-ply fabric.

The weave is constructed by diagram of studying the position of each warp yarns, from the section, relatively to the weft yarns [1, 4].

Figure 1 shows the longitudinal section for a tow-ply fabric where all the warp yarns take part in stitching.

The distance between two successively appearances of yarn on the same side of the fabrics is called shift „*p*“. The number of weft yarns between the two neighboring appearances expresses this distance.

The stitch profoundness *P* represents the number of layer (individual fabrics) crossed by the warp yarn in order to stitch the fabrics together.

For the structure shown in figure 1 the shift is $p = 3$ and the stitch profoundness is $P = 2$.

The warp repeat R_u and weft repeat R_b of the weave used for multi-ply fabrics are calculated with the following relations:

$$R_u = n_s \cdot R_s + n_{fi} \quad (1)$$

$$R_b = n_s \cdot R_i \quad (2)$$

where: n_r represents the number of simple fabrics (layers); R_s – the weave repeat individual fabric; n_{fi} – the number of extra yarns for stitching from the repeat of the weave; R_i – the stitching repeat; for a constant shift $R_i = p + 1$ and when the shift has different values an unic shift is calculated (as the most lower common multiple).

The relations (1) and (2) are valuable if there is a relation of equality or multiplicity between the weave repeat on individual fabrics (layer) and the stitching repeat. Also, for technical textiles, the distribution of warp and weft yarns on the layers must be so that a balanced structures to be obtained [1, 4]. The stitching without extra systems can be made with all warp yarns of the weave repeat or only with a part of them. The stitching zones must be distributed so that the stresses on which the structure is subjected during its exploitation to be taken over uniformly by all the structure components.

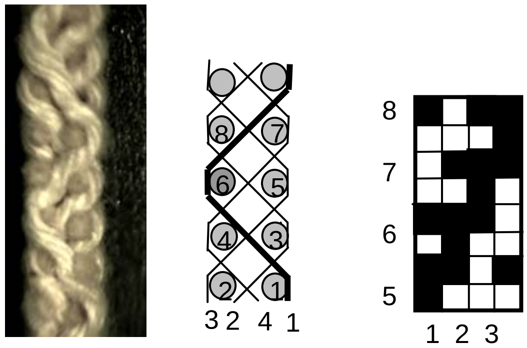

Fig. 2. Longitudinal section and the weave for a two-ply fabric.

Figure 2 shows the longitudinal section and the weave for a two-ply fabric where all the warp yarns take part in stitching.

The warp yarns numbers correspond to sequence of their appearance on fabric side. On this case all the warp yarns realize a stitching with shaft $p = 3$, and the profoundness of the stitching is $P = 2$.

The warp repeat of this weave is 4 and the weft repeat is 8.

For a multi-ply fabric made by four or five individual fabrics the succession of weft insertion is not indicated always by the succession used for a fabric with multiple breadths [1].

Figure 3 shows the longitudinal section and the weave for a multi-ply fabric obtained by four layers. The stitching of the layer is made using the yarns I and II, with shift p=1 and the profoundness $P = 4$.

The warp repeat of the weave is 10 and the weft repeat of the weave is 8.

The succession of the weft yarns insertion is shown in figure 3.

Because the great differences of the yarns densities determine an orientation of the structure to the extreme phases of structure construction, where the warp yarns are maximum crimped and the weft yarns are minimum crimped (they have a straight position) the crimp is calculated for each category of yarns of the structure using the geometric model.

The crimp „C“ is calculated by relation [3, 4]:

$$C = \frac{l_f - l_t}{l_t} \cdot 100 \quad [\%] \quad (3)$$

where l_f represents the length of the yarn used to obtain the length l_t of fabric.

For the multi-ply fabrics without extra system for stitching one calculate separately the crimp for the yarns which interlace only on layer C_{tus} and for the yarns participating to the stitching C_{tui} using the following relations:

$$C_{tus} = \frac{\sqrt{l_b^2 + \left(d_u + d_b\right)^2} - l_b}{l_b} \cdot 100 \ [\%] \quad (4)$$

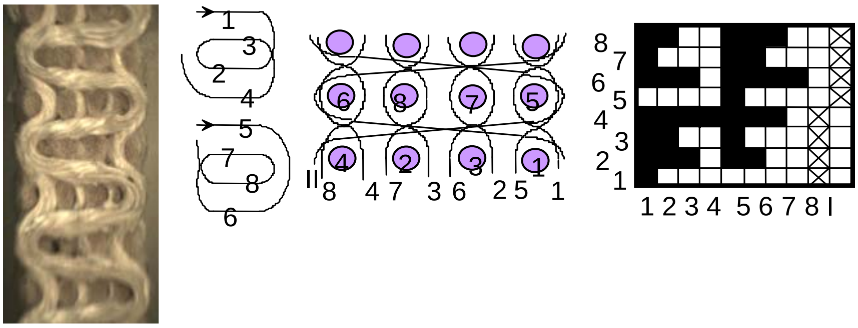

Fig. 3. Longitudinal section and the weave for a multi-ply fabric with four layers.

$$C_{tui} = \frac{\sqrt{[P\cdot(d_u+d_b)]^2+\left(\frac{p+1}{2}\cdot l_b\right)^2}-\frac{p+1}{2}\cdot l_b}{\frac{p+1}{2}\cdot l_b}\cdot 100 \quad [\%] \qquad (5)$$

where: d_u and d_b represent the warp respectively weft yarns diameter, mm; $l_b = \frac{100}{P_b}$ – the geometrical density of the weft yarns on the layer, mm; P_b – the density of the weft yarns on the layer, yarns/10 cm;

For the multi-ply woven fabrics, without extra yarns stitching, to whom all yarns participate to stitch (figure 2), the contraction is calculated using the equation (5).

For the multi-ply fabrics with extra systems for stitching the crimp of the warp yarns that interlace only within the layer is calculated using the relation (4) and the crimp of the extra warp yarns that realize the stitching C_{tfs} with relation (6):

$$C_{tfs} = \frac{\sqrt{l_b^2+[n_s\cdot(d_u+d_b)]^2}-l_b}{l_b}\cdot 100 \ [\%] \qquad (6)$$

where: n_s represents the numbers of the layers of the structure.

The multi-ply fabrics consisted of 2-6 layers (having the maximum thickness because the differences between the yarn densities) determine the orientation of the structure on the phase that have maximum thickness.

The thickness of the fabric „G“ obtained by warp yarn with „d_u“ diameter and weft yarn with d_b diameter, made of n_s layers with extra systems for stitching (figure 3), can be calculated using the relation (7):

$$G = n_s\cdot(2\cdot d_u + d_b) \ [\text{mm}] \qquad (7)$$

For the multi-ply woven fabrics, without extra yarns stitching, to whom all yarns participate to stitch (figure 2), the thickness of woven fabric, can be calculated using the relation (8).

$$G = n_s\cdot(d_u + d_b) + d_u \ [\text{mm}] \qquad (8)$$

The mass of the multi-ply fabric can be calculating summing the mass of all warp and weft yarns:

$$M = \left[P_{us}\cdot T_{texus}\cdot\frac{1}{100-c_{tus}}\right]\cdot n_{sb} + P_{ui}\cdot T_{texui}\cdot\frac{1}{100-c_{tui}} + n_s\cdot 10\cdot P_{bs}\cdot T_{texb} \quad [\text{g/m}^2] \quad (9)$$

where: P_{us} represents the number of warp yarns on the layer, yarns/10 cm; P_{bs} – the number of weft yarns on the layer, yarns/10 cm; T_{texus}, T_{texui}, T_{texb} – the linear density of the warp yarn on the layer, warp yarn for stitching and respectively weft yarn on the layer, tex.

3. RESULTS AND DISCUSSIONS

The above relations afford calculating the structural characteristics of the multi-ply fabrics and on the other hand designing the parameters of these fabrics according to the structural required properties. Also, studying and analysing the designed parameters one can decide the number of beams necessary and the multiplicity of the warp length on the different beams in order to obtain a certain length of fabric. One can also decide the type of the weaving machine and the elements necessary to estimate the prix per unit of product.

The structural elements for a multi-ply fabric obtained by four layers, with extra-yarns for stitching (figure 3) are presented in Table 1. 100% cotton yarns were used. The structural parameters correspond to a structure obtained according to figure 3. The yarn warp fineness used on each layer is Nm=2.2, the fineness of the weft yarns Nm 1 and the fineness of the yarns I and II used for stitching are Nm 1.7.

The small differences (max. 5%) between the values of designed and calculated parameters point out the correctness of the work presented in this paper.

In Table 2 are presented the structural elements for a multi-ply woven fabric, two layers, and all yarns participating to stitching.

Table 1

Characteristics	Yarns fineness N_m	Technical density [yarns/cm]	Yarns crimp calculate [%]	Woven weight calculate [g/m^2]	Woven thickness calculate [mm]
	Yarns diameter [mm]	Geometrical density [mm]	Yarns crimp determinate [%]	Woven weight determinate [g/m^2]	Woven thickness determinate [mm]
Warp yarn within the layer	2.2	10x4 layers	15.66	2156	-
	0.89	1	15.4	2206	
Warp yarn for stitching	1.7	6	53.55	759.82	-
	0.94		48.2	742	
Weft yarn	1	3x4 layers	0	1200	-
	1.23	3.33		1200	
Woven	-	-	-	4115.82	12.04
				4148	12.9

Table 2

Characteristics	Yarns fineness, N_m	Technical density yarns per cm	Yarns crimp calculate [%]	Woven weight calculate [g/m^2]	Woven thickness calculate [mm]
	Yarns diameter [mm]	Geometrical density [mm]	Yarns crimp determinate [%]	Woven weight determinate [g/m^2]	Woven thickness determinate [mm]
Warp yarn	2	24	54	1848	
	0,909		47	1764	
Weft yarn	2	10	0	500	
	0,909	1,81	0		
Woven	2			2348	4,54
	0,909			2264	5,1

4. CONCLUSION

1. The extension of the technical textile utilization imposes a good knowledge of the structural characteristics and technological particularities.

2. When designing the multi-ply fabrics must take into account the yarn characteristics and their structure to assure the exploitation requirements.

3. The analysis of the designed structural parameters affords taking the best decisions regarding the multi-ply fabrics production.

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