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The study of the traction behaviour of knitted structures with controlled dimensional stability

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Abstract. This paper proposes a comparative study of the tensile behaviour of the knitwear under linen made of 100% cotton yarn in 1:1 rib with Nm 50/1 and 2:2 rib with Nm 40/1. The rib structures 1:1 are more dimensionally stable than the rib structures 2:2, on both directions, due to the higher number of yarn-yarn contact points and due to the distribution of the rib platinum loop. The studies made on the proposed structures have demonstrated that it can be obtained an almost identical dimensional stability, which fits in the limits ± 2 , if for the rib structures 2:2 thicker yarns are being used. After knitting and finishing, the structure parameters of the knits are determined and then they are subjected to the tensile strength, and the result after processing the obtained data, it is concluded that the behaviour of the knits at the tensile stresses is comparable to the real situation. The study is carried out on both directions of the knits, in the horizontal direction, of the rows of meshes and in the vertical direction of the strings. The performance-elongation diagrams are represented through graphics and the results obtained are interpreted, the data being used to determine the structure parameters of the knits in order to obtain maximum dimensional stability at wearing.

1. Introduction

The rib structures, regardless the relationship of the structure, regular, irregular or mixed, are structures whose dimensional stability is difficult to control. This is due to the yarn-yarn contact points, the contact surfaces between the structural elements and the arrangement of the platinum loop patent, [1, 2, 3].

In the case of rib structures, the platinum loop is disposed in a different plane than the two planes of the knitted fabric. A feature of the rib structures is the contraction in the direction of the stitch course direction, even in the loose fit of the knit [4 - 9]. The contraction in stitch course direction in free layout involves specific calculations for the constructive design of patterns and of garment templates, so that in this direction the templates are calculated with smaller sizes by 10-30% compared to the size of the finished product [1, 2, 3].

The present paper analyzes 1:1 rib structures made of 100% cotton yarns Nm, 50/1 and 2:2 rib structures made of 100% cotton yarns, Nm 40/1. The structures are made on circular knitting machines with large diameter; the knitted fabrics are tubular meterage, with imposed knitting and finishing parameters and controlled dimensional stability. The yarns from which the knitting fabrics are made in the two 1:1 rib structures are made of 100% combed cotton yarn. These type of the yarns were chosen due to the high uniformity on length, which is found also in the uniformity of the knitted loop stitches.



The knitted fabrics in both structures were made on Mayer & Cie circular knitting machines, with diameter of 20 inch, class fineness 16 E and 42 knitting systems. The knits, in both structures were made of yarns with S torsion, reverse the direction of rotary motion of the needle cylinder of the circular knitting machine. The torsion direction influences the spirality of the knitted fabrics, fact which is controlled starting the knitting process, being well known that an advanced spirality after knitting is impossible to be reduced after finishing. The unwanted effects of spirality effect and be often found in the final product, this representing a high quality issue.

The structures were knitted and finished with the strict observance of phase orders and of knitting and finishing processes technological parameters.

Of particular importance was the observance of the inter-phases relaxation times, 72 hours in enclosures meeting the standard atmosphere parameters $T = 20^{\circ}\text{C}$, $p = 1 \text{ atm} = 760 \text{ mm Hg}$, $\phi = 60\%$, after knitting and after finishing. During relaxation, the internal tensions that were introduced into the structures during knitting and finishing are balanced. The cumulative tensions are those introduced into yarns in the spinning process, in knits during the knitting process, but especially in the finishing of knits. For relaxation, the knits were deposited folded. In relaxation periods the internal stresses introduced into the structures are balanced and the shape of the structure's elements changes absolutely random. If the relaxation periods are eliminated, the internal stresses accumulated will be balanced in the finished product, which is a serious quality problem that can not be remedied [10,11].

In the present paper, knits are tubular metreage and dimensionally controlled. Dimensional stability is a knit quality parameter that involves optimizing the parameters of knitting and finishing technology to achieve minimal dimensional changes during use.

In order to obtain knitted fabrics with controlled dimensional stability, the connecting elements between knitting and finishing technologies with implications for dimensional stability are: the fineness and structure of the yarns, the knit structure, the wale density on the knitting machine and the type and parameters of the finishing process.

The fineness and structure of the yarn determines the thickness of the knit, the Mass square meter, the minimum and maximum width of the knit. The structure of the knit has a decisive importance on dimensional stability, due to the arrangement of its elements. Structure elements of the thread, such as thread twist, thread type (spun on ring machines or on open end machines) influence the structure only indirectly in terms of the possibility of using or not a thread type for a particular structure as well as the possibilities applying or not applying a particular finishing technology.

The wale density of the knitted fabric on the knitting machine, with respect to the fold-out relaxation periods after knitting, is parameter with direct influence on dimensional stability.

The structure of the knit has an influence on the dimensional stability determined by the yarn contact surfaces.

The finishing processes are chosen depending on the raw material of the knit, the structure and the structure parameters of the knit, the selection being influenced by the stresses introduced in the structure, namely the speeds of work chosen, the penetration actions of the more intense treatment solutions or less intense, or longer or shorter processes that are correlated with the concentrations of the solutions used. All of these parameters are correlated with the dimensional stability obtained after finishing. It is absolutely necessary to relax after the last phase of the finishing process, calendaring, in the present case. Calendaring can be compared with the final ironing of the tubular knitting. The frame size, the calendar cylinder temperature, the cylinder pressure on knit and the pressing time have a direct influence on the dimensional stability of the knit.

In order to increase the friction coefficient during yarn-yarn friction in the knit structure, detergents can be used in the finishing process to remove the wax from cotton fibers, as well as the paraffin waxes deposited during the winding operation. Paraffin deposition on yarns is necessary because the friction coefficient is reduced and consequently increases the yarn bending ability among needles in the knitting process.

The knitted fabrics in both structures were done on Mayer & Cie circular knitting machines with 20 inch needle bar diameter, 16 E fineness and 42 knitting systems.

For the production of the tubular knitted fabrics on circular knitting machines with large diameter, combed cotton yarn was used with S-twist direction, reverse the direction of rotation of the needle bar of the knitting machine. This selection of S direction for the torsion of yarns was made to reduce the spiral effect that occurs due to the execution type of the stitches.

It is known that with a complete rotation of the needle bar, a number of 42 normal stitch courses are made, equal to the number of knitting machine systems. These stitch courses result in a spiral and if the direction of the twist of the yarns is identical to the direction of rotation of the needle bar, the spiral effect would increase, the dimensional stability being difficult to achieve by finishing [1, 10 - 13].

The fact that the yarns are made of combed cotton, which are yarns with a high uniformity in length, leads to knitwear with high uniformity of the stitches and uniform appearance on the surface. The uniformity of the stitches of the 1:1 rib knitted fabrics and 2:2 rib knitted fabrics which are studied is also given by the knitting technique with final looping and by the technical performance of the new generation knitting machines. The phases of the technological processes that followed were: knitting, relaxation of the knits after knitting, in plain condition for 72 hours, in standard atmospheric conditions followed by knitting finishing.

The stages of the finishing technology process include bleaching-ready technologies whose purpose represent removing natural and technological companions, obtaining a certain state of expansion and fibre fixation as well as modifying the amorphous-crystalline ratio and the order of the amorphous cotton fibre zones.

By removing the companions, a greater moistening capacity is achieved. For cotton knits, appropriate quality parameters (capillarity, whiteness, dimensional stability, etc.) should be obtained. The results obtained from removal treatments of the companions contribute to improving of the touch and of the dimensional stability of knitwear.

2. The operations required for these objectives

2.1. Removal of oil stains

Oil and grease stains are inherent to common technological processes.

If these stains were removed in the past by organic solvents (petroleum products or chlorinated derivatives such as perchloroethylene, carbon tetrachloride or trichlorethylene), these substances have been banned today. Thus, there has been a need for the use of more potent emulsifiers such as polyethoxylated fatty alcohol products which have a high emulsifying power and can be used to remove greasy stains.

2.2. Washing

Washing, in the case of finishing of cotton knitted fabrics has the purpose of removing the technological companions, especially the paraffin used for knitting, as well as the maximum expansion of the fibre. From the dimensional stability point of view, the first wash is of particular importance, therefore, it is very important for this the selection of the washing agents used, the washing temperature, the duration of the process and the mechanical action. All preparatory processes are accompanied by additional washing processes which have the purpose of removing natural or technological companions, as well as of the reaction products resulting from different treatments.

Surfactants are adsorbed on the surface of the dirt particles, then due to the dispersing and protective colloid character, the impurities are passed into the solution and stored there in dispersed state.

2.3. Alkaline treatment

Alkaline treatment is carried out to remove hemicelluloses, pectic substances, waxes and fats and to pass lignin from cottonseed husks to a condition that allows their rapid removal in the subsequent bleaching processes. The operation is performed with sodium hydroxide, but other synergistic

additives (sodium carbonate, sodium phosphate, detergents) with the role of fiber protection (reducing agents) or the role of sodium silicate protecting colloid or various surfactants are important.

2.4. Bleaching

Bleaching is the chromophore destruction operation of natural organic cotton pigments and can be achieved with several chemical agents, among which the most important are: sodium hypochlorite, sodium chlorite, hydrogen peroxide, peracetic acid.

At the same time, cottonseed husks that have undergone advanced expansion during the alkaline treatment process are also removed by bleaching.

The 1:1 and 2:2 rib structures studied in this paper are bleached using modern technology and are designed for underwear.

3. The experimental part

The main stress at which the knitted fabrics are exposed both during processing and as well during wearing, is stretching. The stretch appears even under its own weight.

For the studied structures, the structure parameters were calculated and practically applied so that the dimensional stability of the knits to be within $\pm 2\%$.

For this study, maximal importance has the vertical density of the knits on the knitting machine and of the finished knit.

In table 1 are presented the wale densities values on the knitting machine and as well on the finished knitted fabric.

Table 1. The wale densities values on the machine and finished knitted fabric.

Knitting machine type	Knitted fabric structure	Type and finesse of the yarn	Wale density, Dv [stitches/cm]	
			on machine	finished
Mayer & Cie, needle bar diameter 20 inch, 16 E finesse and 42 knitting systems	1:1 Rib	100% cotton, Nm 50/1	10	11
	2:2 Rib	100% cotton, Nm 40/1	9.5	10.5

The second stage was the traction stress applied in each of the two directions, in the stitch course direction and in stitch course in vertical direction. The traction stress was made with the traction test machine, the applied force was 100cN in each of the two directions, and the results of the deformations were plotted.

The determinations were made according to the EN ISO 13934/1999 Textiles standard for the determination of the elongation during tensile strength. The preload was 2 N and the speed of the lower pulling jaw was 100 mm/min. For determination, three samples of each structure, each direction, stitch course and stitch course in vertical direction, were analyzed. The dimensions of the samples under analysis were 5cm x 27cm, according to the standard.

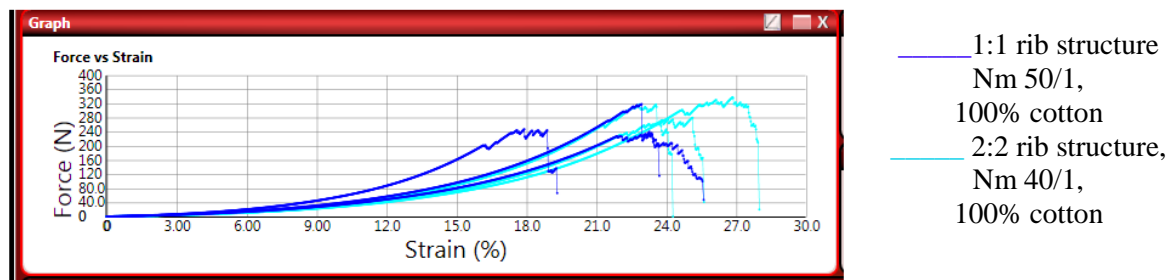
In table 2 there are presented the values of the tensile strength and elongation at break for the 1:1 rib structures of 100% cotton yarn, Nm 50/1 and the 2:2 rib structure of 100% cotton Nm 40/1 yarn. Determinations were made in the stitch course direction and in stitch course in vertical direction. On both directions, the structures have different behaviors, the elongation during traction much higher in the direction of the stitch course direction compared to stitch course in vertical direction

The results of force-elongation on both directions of the knit were graphically represented. The tensile force is expressed in N, and elongation at break is expressed as a percentage.

In figure 1 are represented the stress-strain results in stitch course in vertical direction for 1:1 rib structures, 100% cotton, Nm 50/1 and for 2: 2 rib structure, 100% cotton, Nm 40/1.

Table 2. The values for the tensile strength and elongation.

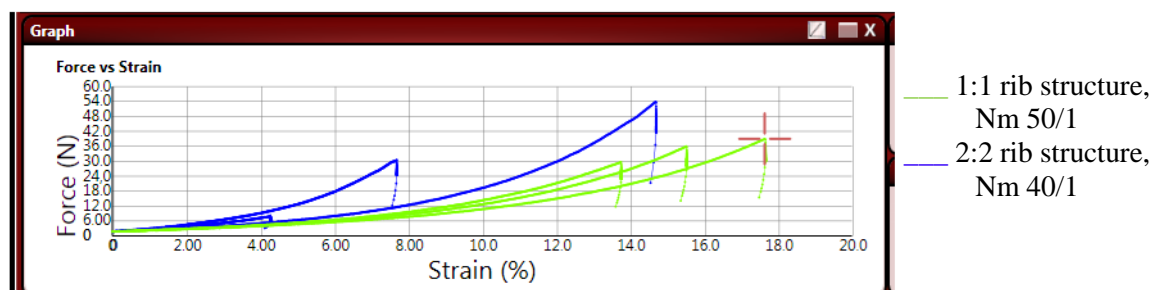
Structure	Tensile strength, [N]		Elongation at break, [%]	
	Vertical direction	Horizontal direction	Vertical direction	Horizontal direction
1:1 rib structure Nm 50/1	319.70	39.00	23.00	17.60
	237.80	29.67	23.40	13.80
	248.70	36.00	17.90	15.50
2:2 rib structure Nm 40/1	339.10	7.95	26.90	4.27
	281.20	30.50	25.10	7.69
	318.90	53.92	22.90	14.70

**Figure 1.** Diagrams of stitch course in vertical direction.

From the diagram in figure 1, the following conclusions can be drawn:

- for the 1:1 rib structures, the breaking force in the vertical direction is in the range 230-320 N, and the elongation at break is in the range 17-24 %.
- for 2:2 rib structures, the breaking force in the vertical direction is in the range 280-340 N, and the elongation at break is in the range 21-28 %.

In figure 2 is a there are graphically represented the effort-elongation results in the stitch course direction for 1:1 rib structures, made of 100% cotton yarn, Nm 50/1 and for 2:2 rib structure, made of 100% cotton yarn, Nm 40/1.

**Figure 2.** Diagram for stitch course horizontal direction.

From the diagram in figure 2, the following conclusions can be drawn:

- for the 1:1 rib structures, the breaking force in the horizontal direction is in the range of 29-39 N, and the elongation at break in the range of 13-18%;
- for the 2:2 rib structures, the breaking force in the horizontal direction is in the range of 7-53 N, and the elongation at break is in the range of 4-15%.

4. Conclusions

Following analyzes we can state that for 2:2 rib structures, forces and elongations have high variation values due to the high elasticity of the knitted fabrics, elasticity due to the character of the platinum

loop distribution and the migration of large quantities of yarns into the flanks of stitches in the needle and platinum loops. Even if the dimensional stability of the structure is within $\pm 2\%$, at the moment of traction stresses, especially in the stitch course direction, there may be different variations in thread migration, with implications concerning the force and deformation values. Also the breaking forces are by the order of hundreds of N in the stitch course in vertical direction, and by the order of the tens of N in the stitch course direction. This is explained by the fact that the structures have several elements on the length unit in the longitudinal direction than the horizontal direction. This can be proved by the fact that the height of the stitches is larger than the stitch loop pitch. On both sides of the knitted fabric, the 1:1 rib structures behave more evenly than the 2:2 rib structures, even if the dimensional stability of both structures is within $\pm 2\%$. The 1:1 rib structures are more balanced than the 2:2 rib structure from the point of view of internal stresses, this being one of the explanations for which the deformation values in both directions are more uniform.

Due to the high elasticity of both structures in the stitch course direction, during the constructive design of the patterns should be taken into account this stretching elongation in the horizontal direction, the size of the patterns in the stitch course direction being 20-30% smaller.

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