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A Technology of Soft Weft-Knitted Fabrics Manufactured from a Fibre Stream

Abstract
Extraordinary soft and fluffy knitted products may be obtained by a technology of weft-knitted fabrics which we have developed and manufactured with the use of circular open-top-knitting machines. The knitting features obtained in this way raise the level of the clothing's comfort of usage. This advantageous effect is the result of working-in a stream of untwisted fibres instead of the traditional yarn into the knitted fabric. The fibre stream, intended for the manufacture of the knitted fabric, is obtained as the result of roving which is drawn immediately before being fed into the knitting-zone of the knitting machine. This is done by using a drawing device which we have specially designed and constructed. The devices are mounted in each working zone of the knitting machine. Considering the decrease in machine efficiency caused by using the new technology, the manufacturing costs are higher than those for the classical technology. However, on the other hand, the possibility of using cheaper raw material than common yarn raises the economical effectiveness.

Key words: *jersey knitted fabrics, soft knitted fabrics, fluffy knitted fabrics, fibre stream, roving, drawing, cheap raw material.*

Introduction

The knitted fabrics currently manufactured are obtained from yarns which in general consist of mutually twisted fibres. The yarn twist assures an appropriate yarn tensile strength, which is necessary during yarn processing at further technological stages. However, a high yarn twist causes an increase in the yarn's rigidity and makes it less fluffy, which decreases the usage properties as well as the aesthetic values of knitted fabrics. This is why yarns designed for knitting are characterised by a smaller twist than those used for weaving, but maintaining the twist at a suitable level is necessary to obtain a pre-described tensile strength. This in turn protects the yarn against breakage during the knitting process with the use of knitting machines equipped with feeding devices, which have hitherto been known and used. The yarn is guided through these devices, from the cops to the knitting zone, over some guides and tensioners which generate a given tension in the yarn. These circumstances mean it is impossible to process a stream of fibres which have been mutually twisted to only a small degree, characterised for example by a carding sliver or roving. Furthermore, the above-mentioned products are characterised by too great a thickness, and they must be thinned before being fed to the knitting zone. This leads to a further decrease in their tensile strength, and at the same time makes the knitting process impossible.

In contrast, manufacturing knitted fabrics from a stream of untwisted fibres enables a product to be obtained which has usage and aesthetic properties better than those so far achieved. The knitted fabrics obtained from this kind of raw material are highly fluffy, soft, and are characterised by high filling, which latter feature gives a pleasant handle to the product, an aesthetic view, and improves the product's biophysical usage properties. Independently, such knitted fabrics are also characterised by an appropriate strength, caused by working-in each fibre stream into several different loops of the knitting, which ensure there will be no loss of continuity of the fibre stream during the drawing process.

The products manufactured on the basis of the new technology we have developed include an element of innovation, and are as yet unknown in Poland or other countries of the world [1].

Principles of the new technology of knitting from a fibre stream

The new technology of knitting from a stream of untwisted fibres consists in the following technique: instead of a thread feeding the knitting zone of the rib knitting machine, a half-finished spinning product in the form of roving is used. Before feeding the roving under the hooks of the knitting needles, it should be drawn, in order to decrease its thickness.

The thinning of the roving is performed by using different velocities at the input and output of the drawing zone which processes the fibre stream. A scheme of the roving drawing device is presented in Figure 1.

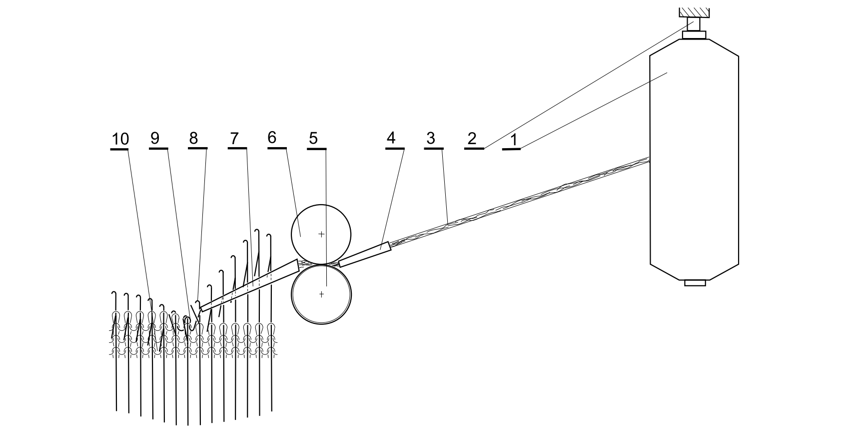

Figure 1. *Scheme of the roving drawing device; 1 – bobbin, 2 – rotary catch, 3 – roving, 4 and 7 – thickening guides, 5 and 6 – feeding rollers, 8 – hooks of the knitting needles, 9 – loops, 10 – knitted fabric.*

The device is fed by a pair of feeding rollers (5) and (6), with the bottom roller (5) of a surface with shallow incisions, and a rubber coat covers the surface of the upper roller (6). The rollers are pressed together by a spring.

The rotary movement of the bottom roller (5) is caused by a device coupled with the cylinder of a needle bearing. This results in the dependency of the velocity of the feeding roller on the rotary velocity of the needle bearing.

Two thickening guides (4 and 7) are fastened, one before and one after the feeding rollers (5 and 6). The roving (3), which is taken off the bobbin (1) and suspended on a rotary catch (2), is threaded through the guides (4 and 7). The output of the guide (7) is positioned under the hooks of the knitting needles (8) which are knocked-off into the region of the loop (9) formation of the knitted fabric (10).

The drawing magnitudewhich also means the roving thinning depend on the ratio of the velocity of working-in the fibre stream and on the tangential velocity of the feeding rollers. In turn, the working-in velocity of the fibre stream depends on the velocity of the needle bearing rotations and the depth of knocking-off the needles, i.e. the magnitude of the loops formed. Therefore, in order to assure control of the knitted fabric's tightness, as well as the control of the thickness of the worked-in fibre stream, the drive of the feeding rollers must enable a steady, continuously change of its rotary velocity.

The first trials of checking the proposed technology in practice were carried out with the use of a circular stocking knitting machine, and then with a circular open-top machine of greater diameter.

The knitted fabrics manufactured from the fibre stream were characterised by a soft, pleasant handle, and were fluffier than the conventional knitted fabrics. The structure of these knitted fabrics were more filled with fibres than fabrics manufactured from yarn, in which greater clearances between the loops were visible. Furthermore, the phenomenon of inclination of the wales in relation to the courses, which is exposed in knitted fabrics manufactured from yarn, and which increases with the increase in twist, was not observed in the new knitted fabrics.

Figures 2 and 3 present photos of the surfaces of a traditional knitted fabric

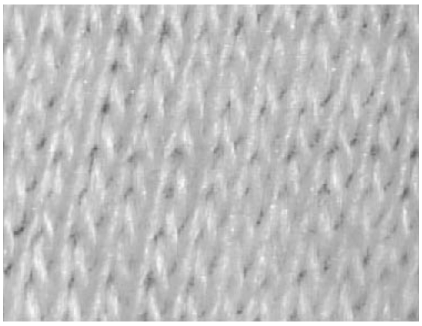

Figure 2. *Photo of a knitted fabric manufactured from yarn.*

manufactured from yarn, and of the new fabric obtained from a fibre stream.

The positive results obtained by preliminary tests, which concerned an analysis of the proceeding of the technological process, as well as the quality of the knitted fabrics obtained, formed the basis of starting the second research stage; this consisted in adapting an open-top machine to the technology of knitted fabrics manufactured from a roving.

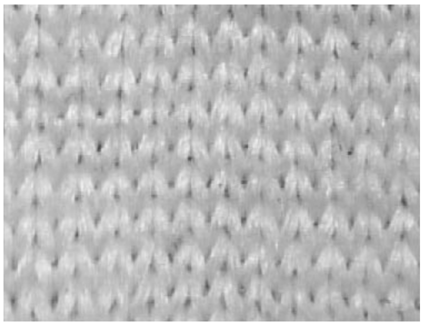

Figure 3. *Photo of a knitted fabric manufactured from a fibre stream.*

Feeding-device for feeding roving into the working-in regions

Maintaining a stable rotary velocity of the feeding rollers as a function of the cylinder's rotary velocity is the basic parameter for each feeding device. This parameter is decisive in maintaining a regular drawing, and a repeatable loop formation. For our purpose, this device was designed in order to ensure that no fibres have been drawn out uncontrolledly from the stream fed during the drawing

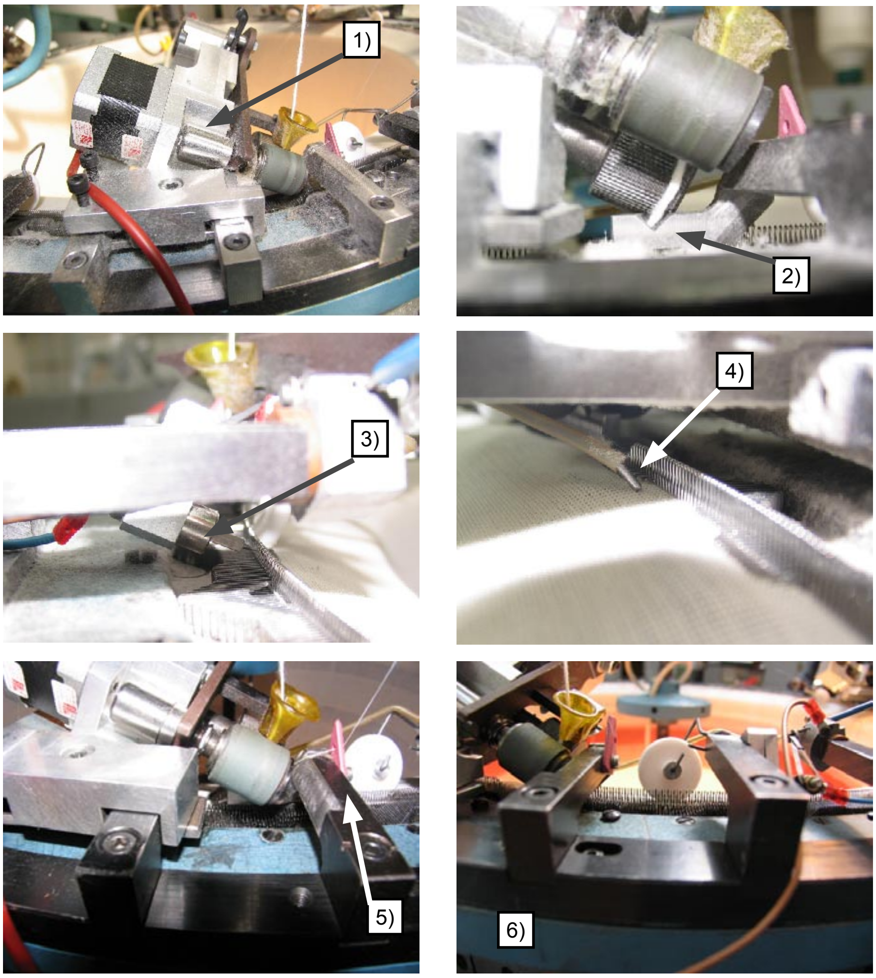

Figure 4. *Peculiarities of the feeding device; 1 – feeding device, 2 – funnel guide, 3 – sensor of open needles, 4 – sensor of loops not worked-in, 5 – guides for filaments, 6 – working region.*

process of the fibre stream, while at the same time providing an opportunity to set the optimum length of the drawing zone, whose length depends on the average fibre length. The peculiarities of the feeding device are shown in Figure 4 (page 63) by photos of the machine parts.

The direct drive of the grooved bottom roller, in connection with the pivoting, pressing upper roller (which is rubber-covered), forms the feeding device visible as (1) in Figure 4, and which ensure the repeatability and stability of the drawing process. The pivoting roller is pressed to the grooved roller by an appropriately selected force, and this structure also raises the roller in order to put the fibres through the guiding funnel (2). A typical thickening funnel is mounted on a lever directly over the contact line between the upper and the bottom rollers. Each working region (6) is equipped with a sensor detecting open needles (3) and a sensor detecting loops which are not worked-in (4). Both of these sensors control the proper manufacturing of the knitted fabric, and protect the process against a great number of faults occurring. Additionally, the devices are equipped with guides for filaments (5) which enables two-component knitted fabrics to be manufactured, and facilitates the beginning of the process of forming knitted fabrics from a fibre stream.

Independently operating drive units of the feeding rollers (small-size stepping motors with high working stability) are used to perform the above-mentioned functions. The drive control system is described in the following chapter.

Control of the roving feeding system

The modernised knitting machine was driven by a 3-phase asynchronous electric motor, supplied by a frequency converter, which enables stepless control of the machine's velocity.

A roving feeding-unit was mounted on the knitting machine. The driving system of this unit is composed of 3 stepping-motors, 3 controllers, a power pack, an encoder, and an electronic control-dividing unit. The scheme of this system and its view is shown in Figure 5.

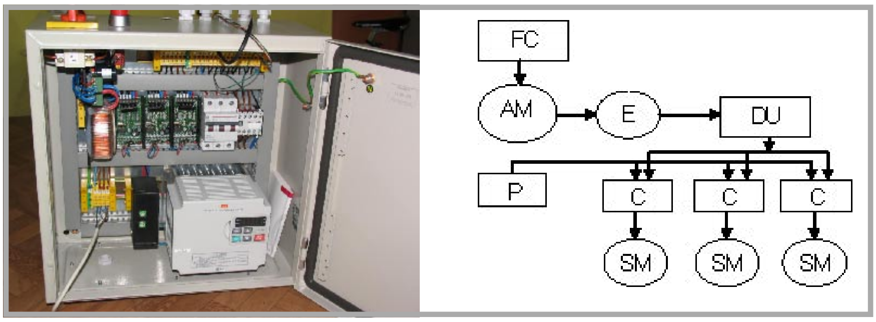

Figure 5. *Driving system; a) view of the equipment, b) block-scheme of the system; FC – frequency converter, AM - 3-phase asynchronous electric motor, E – encoder, DU – electronic control-dividing unit, P – power pack, C – controller, SM – stepping-motor.*

Table 1. *Characterisation of the knitted fabric variants.*

No.	Symbol of variant W/T	Raw material	Drawing ratio	Working-in W, mm	Linear density T, tex
1	750/30	yarn	-	750	30
2	750/390	roving	12.74	750	390
3	800/30	yarn	-	800	30
4	800/320	roving	10.63	800	320
5	800/340	roving	11.37	800	340
6	800/360	roving	11.77	800	360
7	800/390	roving	13.08	800	390
8	850/30	yarn	-	850	30
9	850/390	roving	12.51	850	390

The driving system works in the following manner: Impulses generated by the encoder, which cooperates with the asynchronous motor of the machine's main drive, are transmitted to the input of the electronic control-dividing unit. Next, the impulses adapted to the controllers are transmitted to their inputs, causing the generation of electric current impulses at their outputs connected to the stepping motors, and begin their rotation.

The use of an encoder as the source of impulses, which control the rotation of the stepping motors, enables a close linkage of the roving feeding velocity to the rotary velocity of the knitting machine. The higher the machine's rotary velocity, the higher is the frequency of the electric current impulses at the output of the encoder, and thus the higher the feeding velocity of the roving. A stoppage of the machine causes an interruption to feeding the roving.

The adjustable control-dividing unit enables the ratio of the signal frequency at the encoder's output to be changed, as well as those at the outputs of the stepping motor's controllers. The dividing value is adjusted with the use of two 16 position setting-units, which means there are 256 possibilities of setting the value.

By changing the ratio of the frequencies, we cause the same change in the ratio of the roving feeding velocity and the rotary velocity of the knitting machine, which as a result allows us to change the roving's drawing ratio.

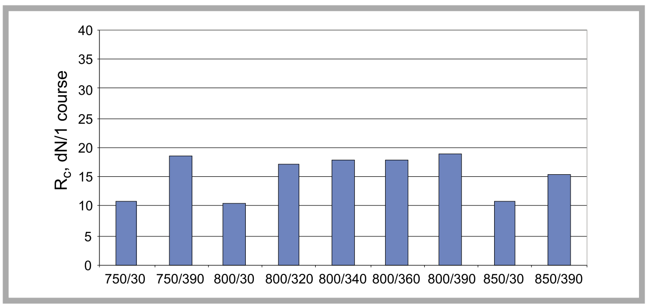

Figure 6. *Strength R_c of the courses of a knitted fabric stretched one-directionally.*

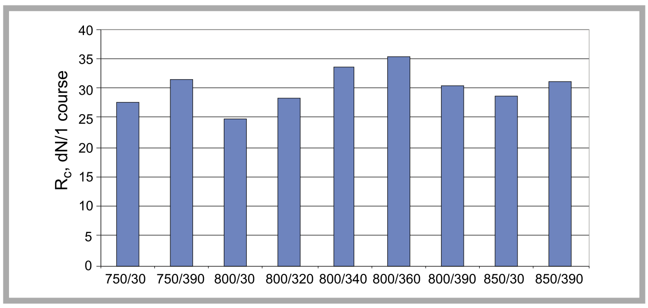

Figure 7. *Strength R_W of the wales of a knitted fabric stretched one-directionally.*

Analysis of selected features of the knitted fabrics

The knitted fabrics manufactured according to the technology we developed were analysed in order to compare their physical and usage properties with those of the traditional knitted fabrics manufactured from yarn. Cotton knitted fabrics with plain stitch were accepted for the tests, with the assumption that both the worked-in yarn and the drawn roving should have the same linear density of T = 30 tex.

Our assumption was that the tests of the knitted fabrics manufactured should also demonstrate the influence of the roving's drawing ratios (R), used while manufacturing the new knitted fabrics, and of the loop magnitude (i.e. the length of the thread in the loop), on the properties analysed.

In order to obtain different drawing ratios, we used rovings of various linear densities (T) which were drawn to an equal linear density of the worked-in fibre stream (30 tex). The technological parameters which were used during manufacturing the knitted fabrics' variants are listed in Table 1.

Among the many features of the knitted fabrics which were tested, only the following are presented, as we have stated that these parameters fundamentally influence the usability of the knitted fabrics:

- organoleptic estimation,
- the strength and the elongation at break while stretching the knitted fabrics one-directionally, and
- the pilling formation resistance.

Organoleptic estimation

The opinions of 5 experts were considered. Special attention was paid to the thickness regularity of the worked-in fibre stream, the shape, and the magnitude of the loops, the regularity of the relative surface cover factor, the touch feeling, and the general aesthetic of the kitted fabric.

Table 2. *Percentage difference between the strength R_c of the courses and the strength R_w of the wales of the knitted fabrics manufactured from roving in relation to the strength of knitted fabrics manufactured from yarn.*

Compared knitted fabric variants			Percentage difference between the strengths	
obtained from yarn	obtained from roving	Drawing ratio	R_c	R_w
800/30	800/320	10.63	39.1	12.9
	800/340	11.37	41.0	26.7
	800/360	11.77	41.3	30.5
	800/390	13.08	45.1	18.5
750/30	750/390	12.74	41.0	11.6
800/30	800/390	13.08	45.1	18.5
850/30	850/390	12.51	28.1	7.2

Table 3. *Percentage difference of the relative elongation ε_c along the courses and ε_w along the wales for knitted fabrics stretched one-directionally, manufactured from roving in relation to the relative elongation of knitted fabrics manufactured from yarn.*

Compared knitted fabric variants			Difference of relative elongation, %	
obtained from yarn	obtained from roving	Drawing ratio R	ε_c	ε_w
800/30	800/320	10,63	-48,7	32,9
	800/340	11,37	-50.0	36,9
	800/360	11,77	-61,7	36,9
	800/390	13,08	-54,8	35,7
750/30	750/390	12,74	-68,3	43,2
800/30	800/390	13,08	-54,8	35,7
850/30	850/390	12,51	-72,8	53,1

The organoleptic estimation demonstrated that the knitted fabrics manufactured from rovings are characterised by a more advantageous view of the surface. No faults in the shape of thin places of the worked-in fibre stream could be noted. The surface was smooth, homogenous, with a 'warm' touch feeling. The fabrics were characterised by a regular structure, considering the shape and magnitude of the loops.

One-directional stretching strength

The strength tests of the knitted fabrics when stretched one-directionally were carried out with the use of a H50K-S Hounsfield tensile tester in accordance with Standard PN-EN ISO 13934-1: 2002 [1]. The maximum force F_{max} and the relative elongation ε_{max} at maximum force were determined.

Figure 6 and 7 presents the strength of knitted fabric bands with a width of 50 mm re-calculated on the strength of a single course and a single wale.

The percentage difference between the strength R_c of the courses and the strength R_w of the wales of the knitted fabrics manufactured from roving and yarn in relation to the strength of knitted fabrics manufactured from roving are presented in Table 2.

The knitted fabrics' variants obtained from roving are characterised by a higher stretching strength in the direction of loop courses, as well as of loop wales, compared with the strength of fabrics manufactured from yarn.

Influence of the roving's drawing ratio at a constant working-in value

When analysing the influence of the drawing ratio, we stated that with the increase in the value of the drawing ratio,

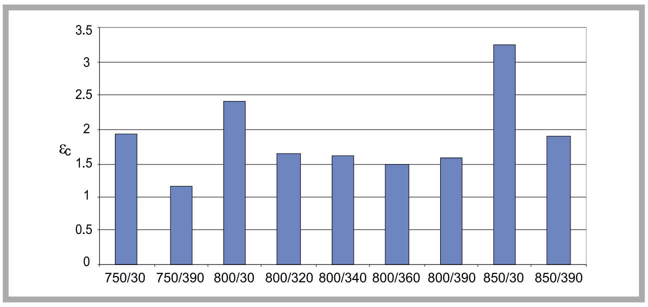

Figure 8. *Relative elongation ε_c of courses of a knitted fabric stretched one-directionally.*

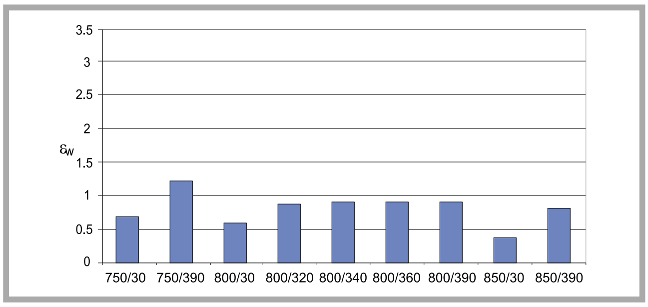

Figure 9. *Relative elongation ε_w of courses of a knitted fabric stretched one-directionally.*

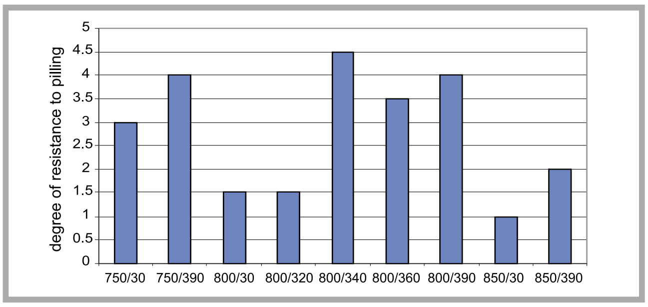

Figure 10. *The degree of the knitted fabrics' resistance to pilling determined on the basis of a photographic standard.*

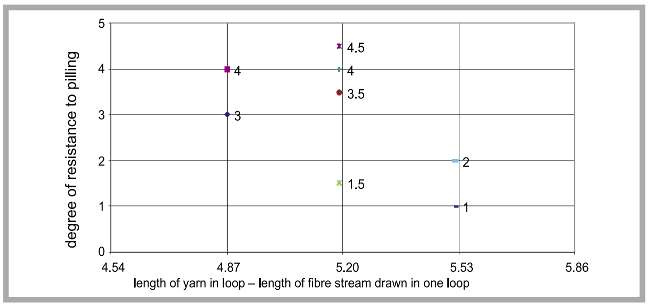

Figure 11*. Dependence of the degree of resistance to pilling on the length of yarn orthe fibre stream worked-in in a loop.*

the breaking force calculated in relation to a single course and a single wale of the knitted fabric loops generally increases. The range of the percentage difference of this parameter between the traditional and the new knitted fabrics oscillates around 40% for the direction along the wales, whereas for the direction along the courses it falls within 13% and 30%.

Influence of the working-in value at constant drawing ratio

We could not determine any explicit influence of the working-in value on the parameter analysed. The range of the percentage difference of this parameter between the traditional and the new knitted fabrics for the direction along the wales falls within 28% and 45%, whereas for the direction along the courses it falls within 7% and 18%.

Elongation of the knitted fabric stretched one-directionally

Figures 8 and 9 presents the values of the elongation of courses ε_c and wales ε_W of knitted fabrics stretched one-directionally and re-calculated on the strength of a single course and a single wale.

The knitted fabrics' variants manufactured from roving are characterised by a smaller longitudinal elongation along the wales while stretched one-directionally up to break, but by greater elongation along the courses compared to elongations of the traditional knitted fabrics.

Influence of the roving's drawing ratio at a constant working-in value

The drawing ratio value has no essential influence on this parameter. The elongation values for both directions are at a comparable level. The percentage difference range between elongations of the traditional knitted fabrics and the new fabrics reaches up to -62% for the direction along the wales, and is around 37% for the direction along the courses.

The percentage differences of the relative elongation ε_c along the courses and ε_W along the wales for knitted fabrics stretched one-directionally and manufactured from roving & yarn in relation to the relative elongations of knitted fabrics manufactured from roving are presented in Table 3.

Influence of the working-in value at constant drawing ratio

The tests indicated that with the increase in the working-in value for the traditional and the new knitted fabrics, the relative elongation of the courses increases, whereas that of the wales decreases.

The range of the percentage difference of the relative elongation of the traditional and the new knitted fabric variants reaches -73% for elongations along the wales, and up to 53% for elongations along the courses.

Resistance to pilling

The degree of the knitted fabrics' resistance to pilling was determined by comparing the degree of pilling increase in the tested samples with an appropriate photographic standard, in accordance with Standard PN-EN ISO 12945-1: 2002 [2]. Five persons carried out the estimation, and the results are presented in Figure 10.

Analysing the results of the tests, it can be observed that all variants of the knitted fabrics manufactured from roving have a greater resistance to pilling. For the variant of knitted fabrics manufactured at a variable working-in but a constant drawing ratio, the degree of resistance to pilling decreases with the increase in the length of the thread or the worked-in fibre stream (Figure 11).

No single surface of the knitting fabrics tested was worn through totally, even in those places where we stated before the tests that a smaller linear mass of the worked-in fibre stream would be visible.

Conclusions

1. The technology of knitted fabrics manufactured from roving may be applied under industrial conditions, with the use of modernised open-top knitting machines.
2. The knitted fabrics manufactured from a fibre stream are characterised by a soft, pleasant touch and are fluffier. The structure of these knitted fabrics is more filled with fibres than fabrics made from yarn.
3. For knitted fabrics manufactured from roving, the phenomenon of the inclination of the wales in relation to the courses is not observed, in contrast to the knitted fabrics manufactured from yarn, where the phenomenon is the more visible as the twist of yarn increases.
4. The knitted fabrics manufactured from roving, in comparison to the traditional knitted fabrics, are characterised by the following physical features:
   - higher strength under one-directional stretching, and
   - a smaller relative elongation in the direction of wales, but a greater elongation in the direction of courses.
5. The new kind of knitted fabrics is characterised by a greater resistance to pilling.

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