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# Estimating the Linear Density of Fancy Ribbon-Type Yarns and the Structure Indices of Fabrics Knitted from Them

## Abstract

This paper presents the results of analyses comparing the theoretical and practically established data of the structure parameters of ribbon-type knitted yarns and fabrics knitted from them. We propose a method for calculating ribbon-type knitted yarn's linear density. It was determined that the linear density of ribbon-type knitted yarn depends upon the linear density of the initial yarn, stitch length and course spacing. We present a method for determining the area density and tightness factor of knitted fabrics from fancy ribbon-type knitted yarns. The structure parameters of these knitted fabrics can be calculated using a new geometrical model of the knitted loop shape. The method presented enables us to perform calculations that may be used for practical purposes.

**Key words:** ribbon-type knitted yarns, linear density, knitted fabric, stitch length, area density, tightness factor.

## Introduction

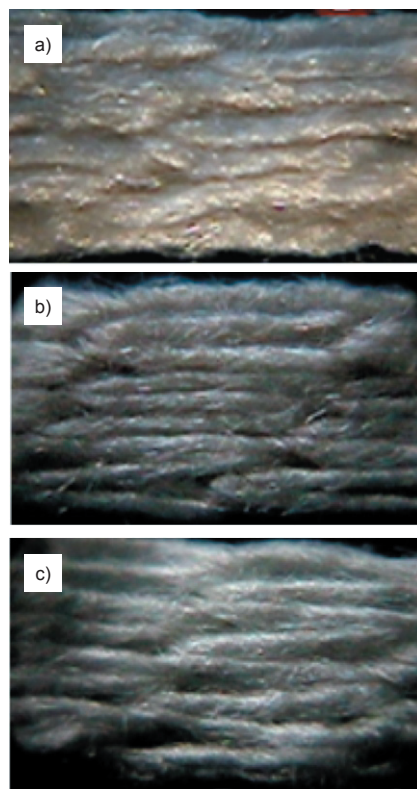
Designing knitted fabrics from new types of fancy ribbon-type knitted yarns and establishing the parameters of their technology present the problem of how to calculate the main structure parameters of the fabric. The need for such a calculation method is evident as the structure of this kind of yarns differs from that of well-known yarns. Direct and indirect methods for manufacturing fancy yarns are already familiar [1]. According to the direct methods, some fancy yarns are knitted on specialised equipment. Fancy yarns knitted on weft or warp knitting machines have a tape yarn structure. One type (knitted by forming two chains and inlay connected chains) is known as ladder-knit [2]; another has a ribbon-type structure. This kind of fancy yarns is manufactured on a small-diameter circular weft-knitting machine from 6 to 20 needles. After knitting and finishing operations, the structure of fancy yarns has a flat, tape-like effect. These yarns are known as tape yarns and are called ribbon-type yarns. Either type of yarn may be manufactured from filament or staple yarns.

In the literature, papers discussing fancy yarns have predominantly described the techniques used to achieve various effects, the problems of designing fancy yarns and the assortment of such yarns [3-5]. However, there are few studies about the fundamental parameters that characterise the various types of fancy yarn and the fabrics knitted from them.

Before beginning the process of knitting the garment from ribbon-type yarns, the technologist has to choose the tightness

factor of the new knitted structure [6]. To this end, the linear density of the fancy yarn and stitch length must be known. As yet no studies have been published explaining how to calculate the parameters of ribbon-type knitted yarns and which would show how to change them.

The aim of this study is to present the methods for calculating the linear density of fancy ribbon-type knitted yarns, area density and tightness factor of knitted fabrics produced from such yarns.



**Figure 1.** Images of different linear density ribbon-type knitted yarns; a - PAN 330 tex, b - PAN 450 tex, c - PAN 550 tex.

## Designing the linear density of ribbon-type yarns

Examples of images of PAN ribbon-type knitted yarns are shown in Figure 1. The ribbon-type yarn structure consists of some stitches. As we can see, the yarns are knitted from single yarns with six plain stitches (in the case of the 330-tex linear density yarns,  $n = 6$ ) or eight plain stitches (in the case of the 450 tex and 550 tex linear density yarns,  $n = 8$ ). In the photo we can see only one side of the yarn (i.e. three or four stitches) as after knitting, the yarns were ironed to give a flat effect. The linear densities of ribbon-type knitted yarns which we employed are commonly used for the fabrics manufactured on the flat-bed weft-knitting machines at a gauge of 3 or 5.

According to the geometrical model of a loop shape, the stitch length of a plain knitted structure [7] may be calculated using the following equations. The stitch length  $l$  of one plain knitted stitch in the ribbon-type knitted yarn may be presented in the following form:

$$l = \pi (0.5A + d_i) + 2B, \quad (1)$$

where:

$A$  – the wale spacing in the knitted yarn, mm,

$B$  – the course spacing in the knitted yarn, mm,

$d_i$  – the diameter of the initial yarn, mm.

The diameter of the initial yarn is calculated according to the formula [7, 8]:

$$d_i = 0.01785(\sqrt{T_i/\gamma} + \sqrt{T_i/\delta}), \quad (2)$$

where:

$T_i$  – the linear density of the initial yarn, tex,

$\gamma$  – the density of the initial yarn, g/cm<sup>3</sup>,  
 $\delta$  – the specific volume of the initial yarn, g/cm<sup>3</sup>.

In Figure 1 (see page 41), we can see that the course spacing  $B$  is different in all cases. The stitch length mainly depends on the course spacing  $B$ . This parameter of the knitted fabric must be known, and can be controlled during knitting. For the theoretical calculation, the wale spacing  $A$  of the ribbon-type knitted yarn will be  $4d_i$  [8], and then the stitch length  $l$  is calculated as follows:

$$l = 9.42 d_i + 2 B. \quad (3)$$

This means that the stitches of the ribbon-type yarn are knitted sufficiently tightly. The linear density  $T_r$  of the designed ribbon-type yarn will be as follows:

$$T_r = (T_i \cdot l \cdot n) / B \quad (4)$$

where:

$n$  – the number of plain stitches in the knitted yarn.

Using these formulas, calculations were made for the three various linear densities of the knitted ribbon-type yarns, and the results are presented in Table 1.

The results obtained allow us to conclude that this way of calculating may be used for practical purposes, as the difference between the actual and theoretical values of the linear density of ribbon-type knitted yarn is no greater than 7 percent.

### Designing the structure parameters of fabrics knitted from fancy ribbon-type yarns

The area density of knitted fabrics manufactured from fancy ribbon-type yarns was calculated using a new design method. Assessing the structure of the loops of the knitted fabrics under investigation, we drew the conclusion that the ribbon yarn's section in the fabric does not acquire a circular form, but in fact is flat. The designing theory [7] states that the section of the yarn in the needle loop is round. The main idea is that the height  $H$  of the vertical semiaxis for ribbon-type knitted yarn with a flat cross-section is no smaller than two diameters of the yarns with circular section [7].

On the basis of this explanation, the diameter  $D$  of ribbon-type knitted yarn can be calculated as usual, using formula (2). In this case, we must use the linear density of ribbon-type yarn  $T_r$ .

The length of the semiaxis  $H$  of the ribbon-type yarn will be calculated according to this expression:

$$H = 2 D. \quad (5)$$

As the horizontal semiaxis is  $0.5A_r$ , the needle loop length  $l_n$  (mm) will be calculated as follows:

$$l_n = 0.5 \pi (0.5A_r + 2D), \quad (6)$$

where:

$A_r$  – the wale spacing of the knitted fabric, mm,

$D$  – the diameter of the knitted yarn, mm.

The length of the sinker loop will be the same. This method enables us to calculate the stitch length of any plain knitted structure [9].

The stitch length  $l_r$  of the plain knitted fabric manufactured from ribbon-type knitted yarn will be:

$$l_r = \pi (0.5A_r + 2D) + 2B_r, \quad (7)$$

and the area density of the knitted fabric manufactured from ribbon-type yarns  $M_r$  (g/m<sup>2</sup>) is expressed by formula (8):

$$M_r = l_r \cdot T_r / (A_r \cdot B_r), \quad (8)$$

where:

$l_r$  – the stitch length of the fabric knitted from ribbon-type yarn, mm,

$B_r$  – the course spacing of the knitted fabric, mm.

From the data presented in Table 2, it is evident that the difference between

the actual and calculated data of stitch length and area density is no greater than 7 percent.

### Calculation of tightness factor

It is known that the tightness factor ( $TF$ ) is a ratio of the area covered by the yarn in one loop to the area occupied by that loop [6]. It is also an indication of the relative looseness or tightness of the plain knitted weft structure.

Using formulas (4) and (7), the tightness factor of fabrics knitted from the ribbon-type yarns will be as follows:

$$TF = \sqrt{T_r} / l_r \quad (9)$$

where:

$T_r$  – the linear density of ribbon-type yarn, tex,

$l_r$  – the stitch length of the knitted fabric, cm.

We can also calculate the stitch length  $l_r$  of the plain knitted fabric from ribbon-type yarn from the area density, which may be calculated using expression (8):

$$l_r = M_r \cdot A_r \cdot B_r / T_r. \quad (10)$$

Table 3 presents the results of the actual [10] and theoretically calculated data for the tightness factors of knitted fabrics. From the results presented in Table 3, we can see a good agreement between the experimental and theoretical results of  $TF$ .

Table 1. Results of calculation of linear density of knitted ribbon-type yarns.

Actual linear density of initial yarn $T_i$ , tex	Course spacing $B$ , mm	Nominal linear density of yarn $T$ , tex	Designed linear density of yarn $T_r$ , tex	Difference, %
22.67	3.0	330	352	6.67
21.30	2.8	450	445	1.11
26.67	2.6	550	585	6.36

Table 2. Results of calculation of area density of fabrics knitted from polyacrylonitril ribbon-type yarns [10].

Actual linear density of yarn $T$ , tex	Actual course density, cm <sup>-1</sup>	Actual wale density, cm <sup>-1</sup>	Actual area density $M$ , g/m <sup>2</sup>	Calculated area density $M_r$ , g/m <sup>2</sup>	Difference, %
324	2.55±0.05	1.85±0.05	330	321	2.73
431	2.90±0.05	1.95±0.05	510	494	3.14
540	2.85±0.05	1.95±0.05	655	614	6.26

Table 3. Results of calculation of tightness factor of fabrics knitted from ribbon-type yarns.

Actual area density $M$ , g/m <sup>2</sup>	Actual stitch length $l$ , cm	Actual tightness factor $TF$ , tex <sup>1/2</sup> /cm	Calculated area density $M_r$ , g/m <sup>2</sup>	Calculated stitch length $l_r$ , cm	Calculated tightness factor $TF_r$ , tex <sup>1/2</sup> /cm	Difference, %
330	2.10	8.6	321	2.09	8.6	0
510	2.11	9.8	494	2.03	10.2	4.1
655	2.08	11.2	614	2.04	11.4	1.8

It is evident that the area density of fabric knitted from ribbon-type yarns is augmented with the increase in the linear density of ribbon-type knitted yarn and the tightness of the knitted fabric.

## ■ Conclusions

- It has been determined that the linear density of ribbon-type knitted yarns depends upon the initial yarn linear density, stitch length and course spacing of knitted yarn.
- The area density of fabrics knitted from fancy ribbon-type knitted yarns can be calculated using a new formula based on the fact that the height of the flat-form needle loop is equal to two diameters of circular yarn.
- The investigations presented in this work allow us to determine the tightness factor of the fabrics knitted from fancy ribbon-type knitted yarns.



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