Jovan Stepanovic,
***Dragan Radivojevic,**
****Vasilije Petrovic,**
Svetomir Golubovic

**Faculty of Technology,
University of Niš,**
Leskovac, Serbia

***High Professional School of Textile,**
Leskovac, Serbia

****Technical Faculty,
University of Novi Sad,**
Zrenjanin, Serbia

Analysis of the Breaking Characteristics of Twisted Yarns

Abstract

In many cases single yarns do not fulfill the requirements necessary for the production of certain types of textiles. At the same time, they do not have most of the characteristics that are important for textile production with outstanding quality parameters. Therefore, the twisting process is employed to produce twisted yarns which can be used to produce fabrics for various applications. The breaking properties of twisted yarn depend on the strength of the component yarns, the number of strands, the twisting amount, the friction forces between the yarns, as well as on the twisting method used. The use of known parameters of twisted yarns determines the relations defining their breaking force. The breaking force is here defined as a function of the breaking forces of the component yarns, the number of yarns twisted in the yarn, and their angle to the twisted yarn axis. In addition, based on experimental results and the theorethical equations, real mathematical relations were established which can serve to project the breaking forces of ring and rotor twisted yarns obtained by the method of double layer twisting. This will simplify and improve the technical preparation of the weaving process.

Key words: *ring-spun yarns , rotor yarns, twisted yarns, breaking characteristics.*

Introduction

Projecting the breaking characteristics of twisted yarns is a very complex task because textile materials differ from most other materials in that they lack form constancy and have increased relaxation properties.

Existing projecting methods do not give precise results, therefore the aim of this study is to develop applicable equations for projecting the breaking characteristics of twisted yarns made of staple fibres. An equation for projecting breaking forces was developed using a geometrical model of twisted yarn and results measured. Correction coefficients were introduced into the equations depending on the twisted yarn type. Special attention was given to the projecting of the breaking forces of twisted ring spun yarns, twisted rotor spun yarns and twisted yarns made of one rotor spun and one ring spun yarn. By combining one ring spun and one rotor spun yarn, an attempt was made to take advantage of the positive properties of two component yarns.

■ Theoretical background

Twisted yarn can be defined as complex linear textile structures with specific properties. The peculiarities of these structures are due to the fact that single yarns, which are complex but often unsuitable for further processing and exploitation, are subjected to the additional operations of rewinding and twisting, whereby some new properties are obtained that contribute to the enhancement of yarn quality and make processing and utilisation easier. Therefore, in spite of the additional expense of the twisting operation, this procedure is widely used to eliminate the weaknesses of single yarns: their insufficient strength, poor uniformity, abrasion resistance, and often inadequate surface and esthetic properties. Furthermore, twisted yarns excel in particular esthetic characteristics, and they are more resistant to abrasion due to the better cross linking of surface fibres [1 - 4].

All the properties of twisted yarns, with respect to quality and quantity, that make them different from single yarns can be explained by the position of fibres in the linear structure, which is essentially different for single and twisted yarns.

When a single phase twisted yarn is wound in the direction contrary to the twist direction of the component yarns (ZS twisted yarns), its components unwind, and the cross section of the twisted yarn has a circular shape. The properties of such twisted yarn depend on the characteristics of the component fibres and on the twisting intensity during winding and consequent twisting.

During the stretching of single phase ZS twisted yarn consisting of *n* component yarns at angle β_1 to the twisted yarn axis (***Figure 1***), its strength $F_{b,tw}$ can be determined by the equation [1]:

$$F_{b,tw} = F_{b,s} \cdot n \cdot \cos \beta_1 \text{ in cN} \quad (1)$$

where:

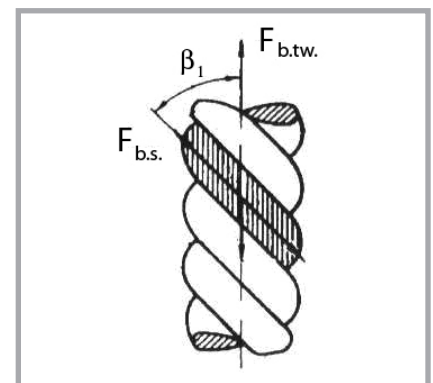$F_{b,s}$ - is the strength of single strands within the twisted yarn structure in cN

Figure 1. *Twisted yarn model.*

n - the number of single strands in the twisted yarn

β_1 - the angle of inclination of single strands with respect to the axis of the twisted yarn (deg).

The angle of single strands to the axis of the twisted yarn can be calculated from the equation [1]:

$$\beta_1 = \text{arc tg} \ (\pi \cdot ds \cdot T_{tw} \cdot 10^{-3}) \ \text{in deg} \quad (2)$$

where:

d - is the diameter of single strands in the twisted yarn in mm,

T_{tw} - the twisting amount of the twisted yarn in m^{-1}.

It is well known that when forming a single phase twisted yarn with the twisting direction contrary to the twist direction of the single yarns, its components become unwound. Therefore, the characteristics of twisted yarns depend on those of its component fibres, as well as on the twisting values during spinning and twisting. However, in a production process, single yarn characteristics are known before the stranding process. Besides, at the moment of twisted yarn breakage, the angle of single strands to the twisted yarn axis has a minimum value. Moreover, the breaking force projection equation does not take into consideration the friction forces between single strands nor the tension forces applied in the stranding and twisting processes. This indicates that the equation mentioned above cannot be directly applied for the accurate projection of the breaking forces of twisted yarns. Consequently, based on the investigation results of single strand and twisted yarns, the equation for the projection of the breaking forces of twisted yarns has been corrected.

Materials and methods

Twisted yarns of various linear density and raw material composition were investigated. A number of various types of single strand and twisted yarn lots were analysed. *Table 1* shows declaration values of twisted yarns obtained by twisting ring spun yarns consisting of PES/Co mixed fibres: 50/50%. *Table 2* shows declaration values of twisted yarns obtained by the twisting of rotor yarns.

Table 3 shows declared values of twisted yarns formed by twisting ring spun and rotor yarn.

Table 1. *Declared characteristics of the twisted yarns (PES/Co; 50/50%).*

Lot	Linear density, tex	Yarn twist, m-1	Lot	Linear density, tex	Yarn twist, m-1
1	25×2	581	10	25×2	506
2	25×2	581	11	25×2	506
3	25×2	581	12	25×2	581
4	25×2	554	13	25×2	581
5	25×2	506	14	20×2	602
6	25×2	506	15	20×2	554
7	25×2	506	16	20×2	554
8	25×2	506	17	20×2	554
9	25×2	506	18	16.66×2	602

Table 2. *Declared characteristics of twisted yarns obtained from cotton fibers.*

Lot	Linear density, tex	Yarn twist, m-1	Lot	Linear density, tex	Yarn twist, m-1
19	50×2	450	28	29.41×2	350
20	50×2	450	29	25×2	581
21	29.41×2	350	30	25×2	554
22	29.41×2	350	31	25×2	554
23	29.41×2	350	32	25×2	554
24	29.41×2	350	33	25×2	554
25	29.41×2	350	34	20×2	506
26	29.41×2	350	35	20×2	506
27	29.41×2	350	36	16.66×2	602

Table 3. *Declared characteristics of twisted yarns (PES/Co; 50/50%).*

Lot	Linear density, tex	Yarn twist, m-1	Lot	Linear density, tex	Yarn twist, m-1
37	20×2	620	46	25×2	580
38	20×2	602	47	25×2	580
39	20×2	640	48	25×2	580
40	20×2	602	59	25×2	580
41	20×2	620	50	25×2	580
42	20×2	620	51	25×2	580
43	20×2	602	52	25×2	580
44	20×2	620	53	25×2	580
45	20×2	620	54	25×2	580

Table 4. *Declared characteristics of combed woollen twisted yarns (W_o;100%).*

Lot	Linear density, tex	Yarn twist, m-1	Lot	Linear density, tex	Yarn twist, m-1
55	21×2	650	64	21×2	650
56	21×2	650	65	21×2	650
57	23×2	570	66	21×2	650
58	23×2	570	67	25×2	540
59	23×2	570	68	25×2	540
60	23×2	570	69	25×2	540
61	23×2	570	70	25×2	540
62	23×2	570	71	25×2	540
63	32×2	350	72	25×2	540

Table 4 shows declared values of twisted yarns obtained by twisting woollen yarns. The processing and utility value of the yarn depends on the series of its characteristic properties. Some of the more important properties of the textile yarn are linear density, twisting, breaking force and elongation at break.

The linear density of the yarn was determined by the hank method on a semi-automatic auto-sort machine according to Standard ISO 2060.

The twisting amount of the yarn was determined on a semi-automatic torsiometer according to Standard ISO 2061.

The breaking properties of the yarns were determined according to Standard DIN 53834/76 on an USTER TENSO-JET dynamometer.
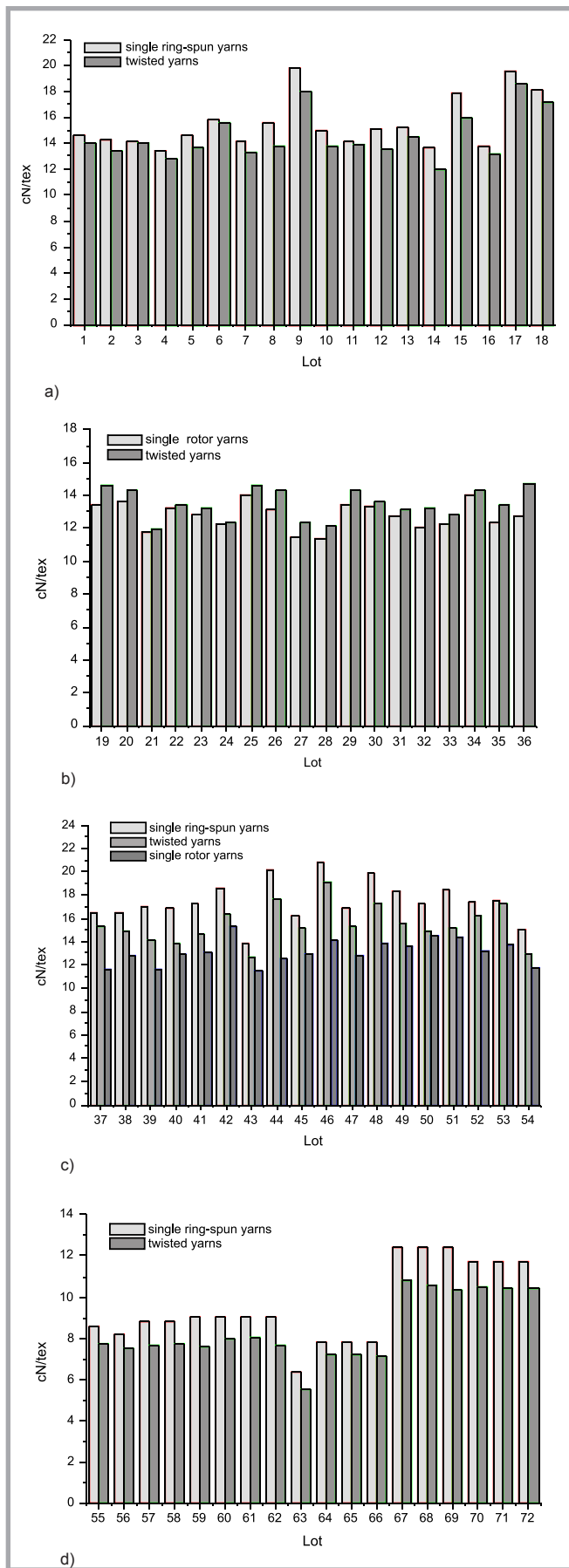
Figure 2. *Histogram of relative breaking forces of: a) single ring-spun and twisted yarns (1 to 18), b) single rotor and twisted yarns (19 to 36), c) single and twisted yarns (37 to 54), d) single and twisted yarns (55 to 72).*
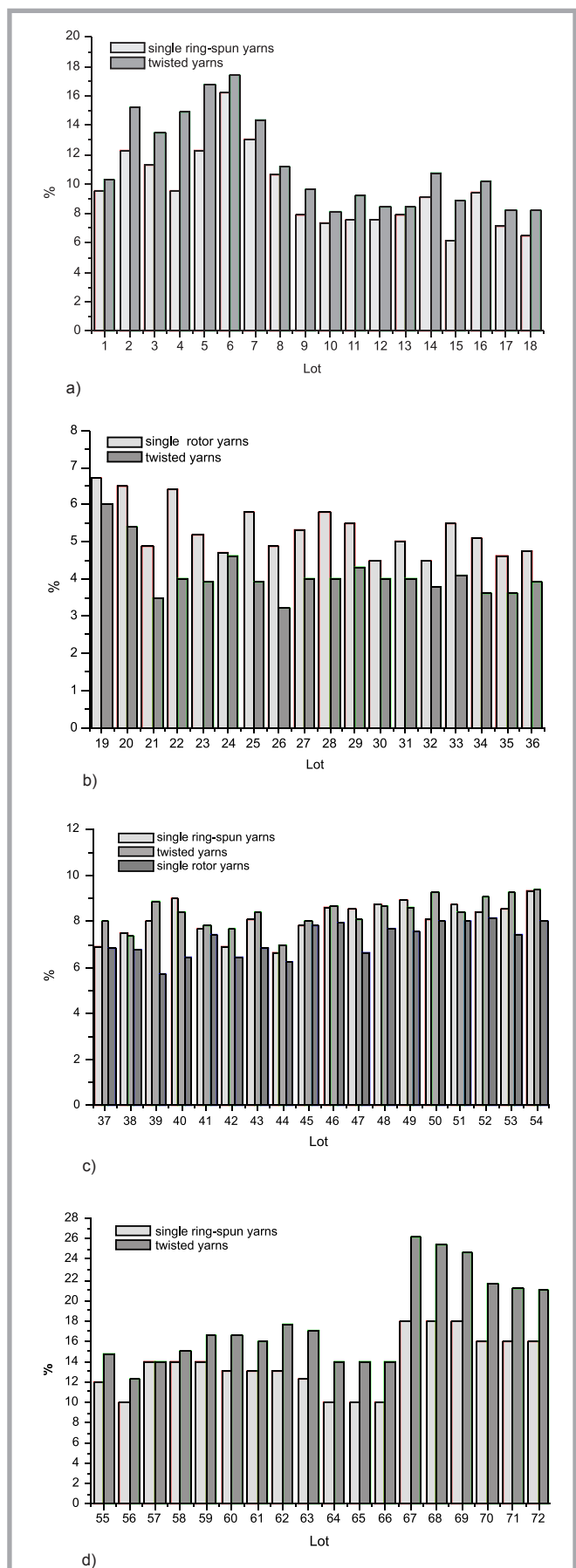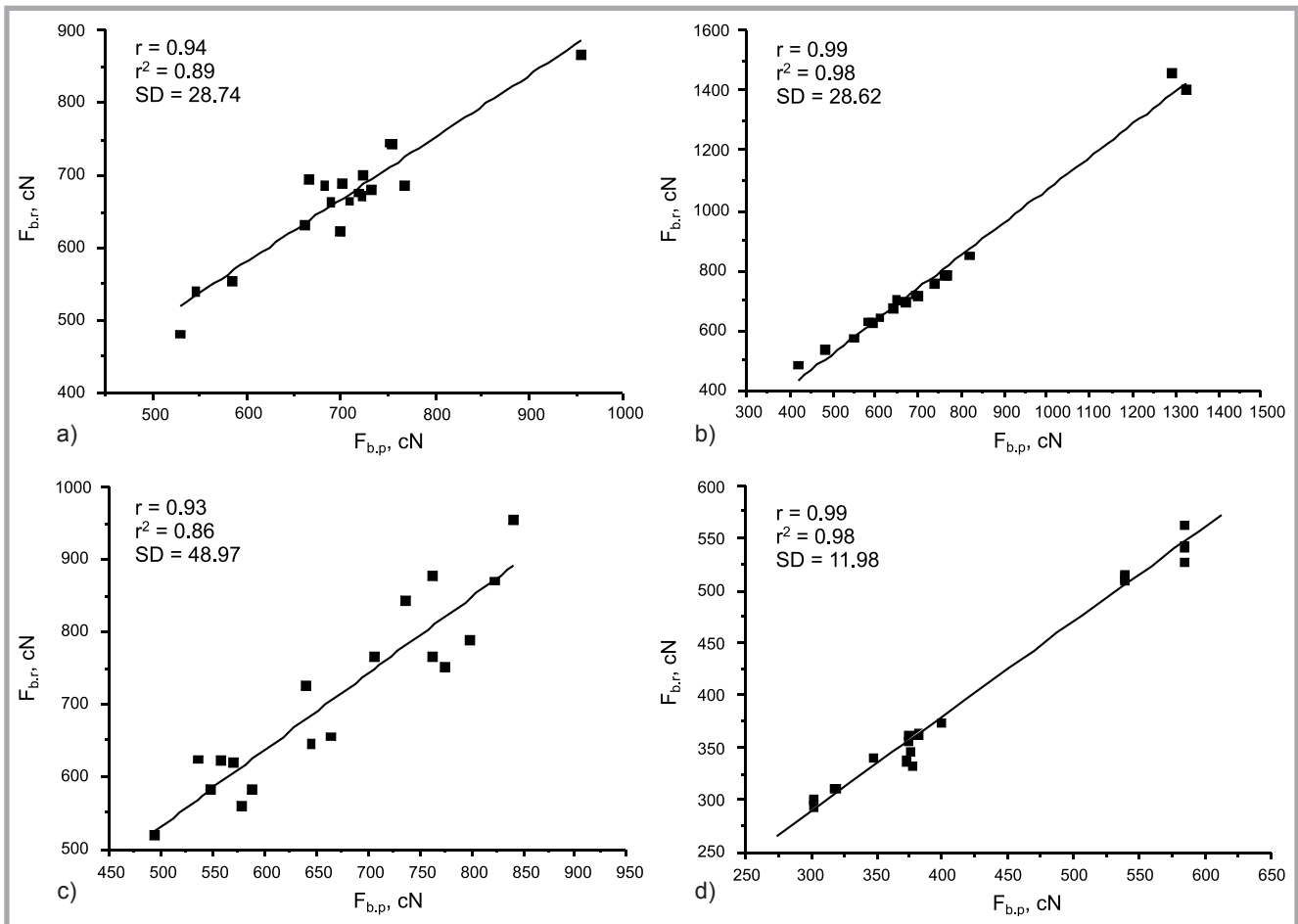

Figure 3. *Histogram of elongations at break of: a) single ring-spun and twisted yarns (1 to 18), b) single rotor and twisted yarns (19 to 36), c) single and twisted yarns (37 to 54), d) single and twisted yarns (55 to 72).*

Figure 4. Correlation of projected and real breaking force values of: a) single ring-spun and twisted yarns (1 to 18), b) single rotor and twisted yarns (19 to 36), c) single and twisted yarns (37 to 54), d) single and twisted yarns (55 to 72).

■ Results and discussion

Figure 2 show histograms of variations in the breaking properties of single yarns as compared to those of twisted yarns.

The results show that twisted ring-spun (S) yarns have lower relative breaking forces in comparison to single (Z) yarns (1 to 18, and 55 to 72). Lower relative breaking forces are the consequence of the unwinding of single yarns and their position within the twisted yarn. Since ring-spun yarns have a so-called external twist, the unwinding of (Z) twist single yarns occurs due to (S) twisting, giving the final yarn a greater elongation at break as compared to the elongation at break of the component single yarns.

Analysis of the values of the relative breaking forces of twisted rotor yarns leads to the conclusion that they surpass the values of the relative breaking forces of single yarns, which can be explained by the three-layer structure of rotor fibres [5]. Zone *III* of rotor yarns is formed by fibres accumulated in the connect-ing zone so that their ends protrude be-fore the drafting of yarn from the rotor wall (unwinding fibres). They form the outer cover of the fibre by a weak con-nection with the previous layer, being only wrapped around it. The structure of windings varies from the inner windings outwards, whereby the first part of the fibre is twisted in the opposite direction from the nominal twist. Afterwards sev-eral windings are wound in a single spot (2 to 3 windings of a thicker layer), while the rest of the fibre is wound backwards conforming in the direction of the nomi-nal twist of the yarn. The presence of non-arranged fibres (in real conditions - 7 to 15%, depending on the rotor diameters and fibre length) is one of the reasons that rotor yarns have a weaker strength than ring-spun yarns. However, by twisting the rotor yarns, these strands are incor-porated into the yarn, contributing to the significant improvement of the strength of twisted rotor yarns. Moreover, a de-crease in the elongations at break of the twisted rotor yarns was observed as com-pared to the elongation at break values of single yarns. The reason for this also lies in the structure of rotor yarns. By twisting rotor yarns (Z-single strand to S twisted yarns), the unwinding of the core rotor yarn occurs and, at the same time, the incorporation of loose strands, all of which can be the cause of the decrease in elongation at break of the twisted rotor yarns.

Furthermore, the results show that twisted yarns formed by combining one ring-spun and one rotor yarn have great-er relative breaking forces than single strand rotor yarns but lower than the cor-responding ring-spun yarns, which is a consequence of the different structures of ring-spun and rotor yarns; therefore, such combinations of twisted structures are not recommended. It can also be noted that such twisted yarns have greater elonga-tions at break compared to single strand rotor yarns. This observation is con-firmed by correlation between projected and real breaking force values of twisted yarns formed of one ring spun and one rotor spun yarn (*Figure 4.c*). However, the elongation at break values of twisted yarns formed in this way are sometimes

Table 5. Statistics; where: $\bar{k}$ - mean proportionality coefficient, SD - standard deviation, CV - coefficient variance, c - confidence limit (for 95% confidence level).

Parametar	Lot			
	1 ÷ 18	19 ÷ 36	37 ÷ 54	55 ÷ 72
$\bar{k}$	0.954	1.059	1.061	0.950
SD	0.041	0.037	0.069	0.032
CV, %	4.297	3.493	6.503	3.368
c (for 95% confidence level)	0.019	0.017	0.032	0.015
$\bar{k}$ + c	0.973	1.076	1.093	0.965
$\bar{k}$ - c	0.935	1.021	1.029	0.935

higher and sometimes lower than those for component ring-spun yarns.

By using equation (1), projected values of the breaking forces for all the twisted yarns analysed are determined. Therefore, in equations (1) and (2) real values were applied, measured using standard procedures.

In **Figure 4** (see page 45) a correlation of projected and real breaking force values of twisted yarns is shown.

Since the calculated values of the breaking forces of twisted yarns differ from the real ones, a correlation coefficient was introduced, and the equation (1) became:

$$F_{b,tw} = k \cdot F_{b,s} \cdot n \cdot \cos \beta_1 \text{ in cN} \qquad (3)$$

Parameters of equation (3) are defined based on 1000 single measurements of the breaking forces of single and twisted yarns for each analysed. The correction coefficient, **k** is defined depending on the type of twisted yarn, which was statistically processed and is presented in **Table 5**.

By analysing the correction coefficient values, it can be concluded that they are below a value of one with twisted ring spun yarns (lots 1 to 18 and 55 to 72), whereas they are greater than one with twisted rotor spun yarns (lots 37 to 54). They are also above unity with twisted yarns made by combining single ring spun and rotor spun yarns (lots 37 to 54)

■ Conclusions

The breaking characteristics of twisted yarns depend on their structural and construction design, as well as on technological parameters during spinning, winding and twisting processes.

The results obtained confirm that the structural design of selected single yarns determines the characteristics of their more complex structures. Therefore, the equations for projecting the breaking forces of twisted yarns cannot be applied without introducing appropriate correction coefficients that depend on the types of single yarns. Moreover, the results show that the twisting of one ring spun and one rotor spun yarn does not give satisfactory results due to the different structures of these yarn types. Moreover, the results of the investigation indicate a high correlation between projected and real breaking forces, enabling the use of a geometrical model and experimental results to develop equations for predicting the breaking force of twisted ring and rotor spun yarns, through which conditions for the improvement of the technical preparation of yarn production can be realised.

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