Danuta Cyniak,
Jerzy Czekalski,
Tadeusz Jackowski

Department of Spinning Technology
and Yarn Structure Faculty of Material Technologies
and Textile Design Technical University of Łódź
ul. Żeromskiego 116, 90-543 Łódź, Poland
E-mail: s-k44-@sir.p.lodz.pl

Influence of the Thermal Stabilization Process on the Quality Parameters of Cotton-Type Yarns

Abstract
Up to the present, the process of thermal stabilization has most commonly been used for wool-type yarns. The investigation presented concerns the application of the thermal stabilization process to cotton yarns and cotton-type blended yarns. The yarns used were manufactured on ring and rotor-spinning machines from cotton and blends of cotton with chemical fibres. The quality parameters of the yarns obtained were analysed with special attention given to the yarn twist stabilization, tenacity, elongation at break and hairiness. Statistical analyses were used for the evaluation of the investigation results. It was indicated that thermal stabilization improves the twist unbalance of yarns.

Key words: *cotton-type yarns, blended yarns, thermal stabilization, twist unbalance, quality parameters.*

Introduction

Yarns of the highest quality are characterized by low unevenness of linear density, high tensile strength, a low number of faults, high elasticity, softness and small unbalance of twist.

Manufacturing cotton yarns with a balanced twist is at present the latest, modern world trend in spinning technologies. The unbalance of twist is eliminated by special selection of the fibre parameters, including twist, as well as thermal and mechanical stabilization [1, 2, 6, 9].

The twist is one of the main parameters that are decisive in the unbalance of twist [2]. The twisting moment has a great influence on the following parameters: yarn hairiness, tensile strength of the single yarn, the ability to wrap of knitted fabrics, the ability to twist and wrap of woven fabrics, and final products, as well as the drapability of woven and knitted fabrics [7, 10].

Manufacturing yarns with an optimal and stable twist would allow their further processing without disruption into yarns of improved quality, as well as into knitted and woven final products.

An attempt was undertaken in this work to eliminate or decrease the unbalance of twist of cotton yarns and yarns blended with a content of chemical fibres due to thermal stabilization.

Single as well as double yarns, which were twisted, have a tendency to untwist after unwinding from a bobbin. This is caused by tensions that were created in the fibres and in the yarn as a result of the twist. The aim of the stabilization process (also called steaming) is balancing the tensions that are responsible for untwisting the yarn. Yarns that are not stabilized make their further processing difficult as they form loops during breaking and when the yarn tension decreases. The process of twist stabilization is carried out by the impact on the yarn of an appropriate high temperature, depending on the kind of yarn [1, 3, 4, 9]. The stabilization can be performed in a steaming chamber, ager, boiler, vacuum steamer and an autoclave. Twist fixation by the stabilization method has been carried out for the majority of yarns manufactured. Windings with yarns prepared to be stabilized can be placed in containers and baskets, as well as on runners, and next transported into the steamer's chamber.

Steamers are devices in the form of a closed container in which yarns and other intermediate products are influenced for a certain period by the action of high temperature in the medium of steam; this process is called thermal stabilization.

Twist fixation is performed in order to obtain a stabilization of the yarn twist or contraction of fibres forming a roving or yarn. Therefore, steamers used to stabilize the twist are called stabilizers whereas steamers dedicated to contraction are called contractors.

Modern steamers are characterized by the following features:
- they give the possibility to achieve temperatures of over 100 °C;
- they are equipped with devices that enable a vacuum to be obtained in order to achieve better penetration by steam of the internal parts of the yarn, thanks to which a more rapid and accurate steaming can be achieved;
- they are highly automated, which enables easy adaption of the steamer to the required conditions that are necessary for the process;
- the operations of loading and unloading the steamer of raw material do not require great effort, as they are partially or even totally automated.

Aim of the investigation and the research plan

The aim of our investigation was to determine what influence the thermal stabilization process has on the final product, which is cotton yarns and blended yarns containing cotton and polyester fibres. The influence of a multi-stabilization process of the yarns was also analysed. In our investigation, we accepted from one to five thermal stabilizations for one kind of yarn.

In the first stage of the investigation, in which we established the number of stabilizations for each kind of yarn, the following knitting yarns with a linear density of 20 tex were used:
- W_2 – cotton yarn, classical (ring-spun) combed;

- W_3 – cotton yarn classical (ring-spun) carded;
- W_4 – rotor cotton yarn.

In the second stage of the investigation, the following yarns with a linear density of 20 tex stabilized by a single stabilization were analysed:

A. 20 tex yarn, 100% carded, viscose fibres, classical, ring spun on a G33 ring-spinning frame.
B. 20 tex yarn, 33% cotton, 67% polyester fibres, carded, classical, G33 ring-spinning frame.
C. 20 tex yarn, 50% cotton, 50% polyester fibres, carded, classical, 211B Textima ring-spinning frame.
D. 20 tex yarn, 67% cotton, 33% polyester yarn, carded, classical, 211B Textima ring-spinning frame.
E. 20 tex yarn, 67% cotton, 33% polyester fibres, combed, classical, 211B Textima ring-spinning frame.
F. 20 tex yarn, 92% cotton, 8% polyester fibres, combed, Autocoro 240 rotor-spinning frame.
G. 20 tex yarn, 95% cotton, 5% polyester fibres, carded, classical, G33 ring-spinning frame.
H. 20 tex yarn, 95% cotton, 5% polyester fibres, carded, Autocoro 240 rotor-spinning frame.
I. 20 tex yarn, 100% cotton combed, classical, G33 ring-spinning frame.
J. 20 tex yarn, 100% cotton, carded, R1 rotor-spinning frame.

From the whole group of variants mentioned above (A-J), the following subgroups can be distinguished for further analysis:

- yarns of variants B, C, D and G – classical carded yarns with an increased content of cotton in the blend from 33% to 95%;
- yarns with the same content of fibres in the blend (67% of cotton and 33% of polyester fibres carded – variant D, and combed – variant E);
- carded yarns with a content of 95% cotton and 5% polyester fibres – spun on a classical ring-spinning frame – variant G yarn carded, rotor-spinning frame – variant H;
- combed yarns: classical blend – variant E, rotor blend – variant F and 100% cotton classical spun – variant I;
- rotor yarns: combed, blend – variant F, carded, blend – variant H, 100% cotton carded – variant J;
- homogenous yarns including viscose fibres (variant A) and cotton fibres (variants I and J).

The yarns listed above were **thermal stabilized**. All stabilization tests were carried out with a CONTEXXOR Compact steamer made by XORELLA AG, Switzerland. This type of stabilizer can be used for contraction as well as fibre relaxation, and as a real steamer. The model used is characterized by an "ECO" system, which enables energy saving of the process conducted, and is equipped with a totally integrated memory system that also allows a better recognition rise in working errors occurring during the process. The stabilization of the yarns used for our investigation was carried out by a two-stage programme, called a tricot programme. Over the first stage (cycle) of the process, the pressure (vacuum) in the steamer was decreased down to 150 mbar, and next the temperature was increased up to 56 °C. The time period of this cycle was 5 min. Over the second stage (cycle), the pressure in the steamer was further held on the level of 150 mbar, but the temperature in the steamer increased up to 58 °C. The time period of the second cycle was 20 min. After both cycles, a decompression of the steamer to atmospheric pressure was performed.

The assessment of the yarns' **linear density** was carried out with the use of an Autosorter III electronic balance. The measurements were performed in accordance with standard PN-EN-ISO 2026. Twenty yarn skeins for each yarn variant were wound and then weighed in order to assess the yarns' linear density and the parameters of measurement scattering in relation to the average value.

The **unevenness of the yarn's linear density** was determined with the use of an Uster Tester 3 apparatus. The yarn displacement speed was set at 400 m/min and the measurement time at 5 min. A total of 10 measurements of the coefficient on unevenness of the linear density CV were performed for each of the yarns. The measurements were performed for the following conditions and yarn lengths: CVm, CVm (1 m), CVm (3 m), CVm (10 m), CVm (500 m), CVm (100 m), CVm (Inert), CVm (1/2 In) and Index. At the same time, the yarn hairiness H and the value of the coefficient of its variation (sh) were determined with the use of the Uster apparatus.

The yarn **faults**, such as **thin places**, **thick places and neps**, were determined by the Uster Tester 3 apparatus, which recalculated the numbers of faults in 1000 m of yarn.

The **tensile strength parameters** and **elongation at break** were determined with the use of a Zwick tensile tester with a clamp distance of 500 mm, preliminary tension of 0.5 c/tex and a testing speed of 500 mm/min. For each of the yarn variants, 50 measurements were carried out. The measurements were performed in accordance with Polish standard PN-ISO 2062. The results included the particular and average values of the breaking force, the absolute and relative elongation at break, the standard deviations and the coefficients of variation of these quantities, as well as the tenacity and the work to break of the yarn.

The **twist measurements** were carried out with the use of a semi-automatic computerized D315 Twist Tester made by Zweigle, linked to a computer. Five different twist measurement methods can be applied with the use of this twist meter. The yarn test samples were fastened by hand. The distance between the clamps could be changed within the range of 0-500 mm. The '5th measurement method' recommended by the producer of the apparatus was applied for testing the rotor-spun yarns, whereas for the classical ring spun yarns, the '1st measurement method' was applied. For each of the yarn variants, 30 twist measurements were carried out. The '1st method' applied to the ring-spun yarn was the so-called 'opposite twist' method in accordance with standard PN-84/P 04652, whereas the 5th method applied to the rotor yarns was based on carrying out the 1st method 3 times.

The **twist unbalance** was investigated by the direct method with the use of the semi-automatic twist meter, the same as the meter used for the twist measurement. A yarn segment with a length of 1 m was unwindedfrom a bobbin. At the middle of the segment, a preliminary load was suspended. The twisted and loaded yarn segment was horizontally placed between the twist meter's clamps. The distance between the clamps was 500 mm. The tested yarn was untwisted with the use of a preparatory needle by displacing the snarls formed in the direction opposite to the direction of these snarls. After setting the twist meter into operation, the yarn was untwisted up to the moment that the loop arms would be placed parallel to each other. The number of twists recalculated per 1 m was projected on the monitor on the twist meter.

Figure 1 presents bar charts of the twist unbalance of cotton yarns with a linear density of 20 tex before and after the subsequent thermal stabilizations.

On the basis of the unbalance tests carried out, a significant decrease in the 20 tex yarn twist unbalance was stated after the first stabilization. However, it is difficult to identify explicitly an increase or decrease trend in the twist unbalance of yarns with a linear density of 20 tex with a subsequent increase in the number of stabilizations.

On the other hand, applying the subsequent thermal stabilization (from two to five times) caused an increase in the tensile strength and elongation at break, which improve the yarn quality but also increase the unevenness of linear density (CVm), the number of neps and yarn hairiness, which all worsen the yarn quality. Significant differences between the variances, estimated by the F-test, were obtained for the elongation at break and tenacity of the yarns tested. It is difficult to evaluate the influence of the number of thermal stabilizations on the remaining yarn parameters, such as the coefficients of variation of the linear density, the number of thin and thick places and the number of twists. The number of thermal stabilizations also influences the value of the yarn linear density. The linear density of yarns increases with an increase in the number of thermal stabilizations. This is caused by an increase in the yarn shrinkage and swelling of cotton, which results in an increase in the mass per length of yarns with a great cotton content.

Taking into account the economical factors, as well as the quality of the yarns manufactured, the application of one thermal stabilization should be recommended.

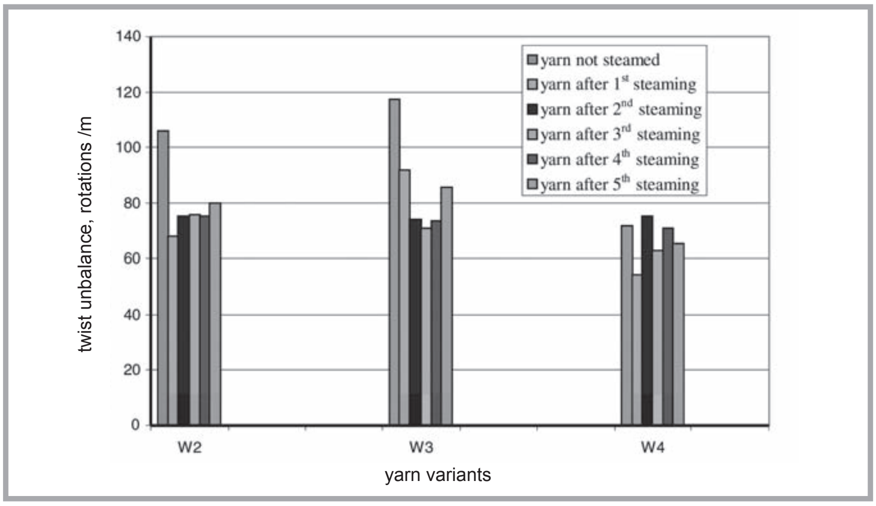

Figure 1. *Twist unbalance of cotton yarns of 20 tex before and after the subsequent thermal stabilization W_2 – 20 tex cotton yarn classical (ring spun), combed, tricot; W_3 – 20 tex cotton yarn classical (ring spun) carded, tricot; W_4 –20 tex cotton yarn rotor spun, tricot.*

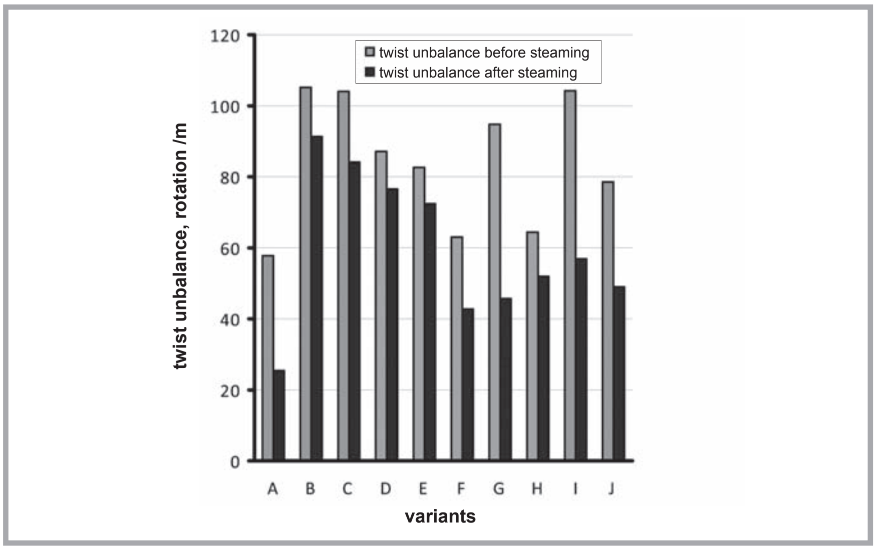

Figure 2. *Unbalance of yarn twist before and after steaming.*

Analysis of the parameters of thermally stabilized yarns

Figure 2 presents bar charts of twist unbalance before and after the process of steaming for 10 different variants of yarn with a linear density of 20 tex.

A – yarn 20 tex, 100% viscose fibres carded, classical, G 33 ring-spinning frame; B – yarn 20 tex, 33% cotton, 67% polyester fibres, carded, classical, G 33 ring-spinning frame; C – yarn 20 tex, 50% cotton, 50% polyester fibres, carded, classical, Textima 211 B ring-spinning frame; D – yarn 20 tex, 67% cotton, 33% polyester fibres, carded, classical Textima 211 B ring-spinning frame; E – yarn 20 tex, 67% cotton, 33% polyester fibres, combed, classical Textima 211 B ring-spinning frame; F – yarn 20 tex, 92% cotton, 8% polyester fibres, combed, rotor-spun, Autocoro 240 rotor-spinning frame; G – yarn 20 tex, 95% cotton, 55 polyester fibres, carded, classical G 33 ring-spinning frame; H – yarn 20 tex, 95% cotton, 5% polyester fibres, carded, rotor-spun, Autucoro 240 rotor-spinning frame; I – yarn 20 tex, 100% cotton, combed, classical, G 33 ring spinning frame; J – yarn 20 tex, 100% cotton, carded, rotor-spun, R1 rotor-spinning frame.

All the yarns that were steamed were characterized by a smaller twist unbalance. This means that the yarns had a lower tendency to form snarls. The investigation results presented indicate that the highest decrease of the twist unbalance after steaming is visible for yarns manufactured on the G 33 ring-spinning frame and the R1 rotor-spinning frame (variants A, G, I and J). The above-mentioned variants A, I and J are homogenous yarns manufactured from 100% cotton or viscose yarns. The content of polyester fibres in the yarn of variant G was only 5%. Taking into account the thermal conditions (temperature of 58 °C) of the stabilization applied, we obtained a lower decrease of the twist unbalance for blended yarns with a higher content of polyester fibres.

For the majority of the yarns tested, the process of thermal stabilization caused an increase in the elongation at break and the tensile strength parameters, such as tenacity and work to break (***Figures 4,***

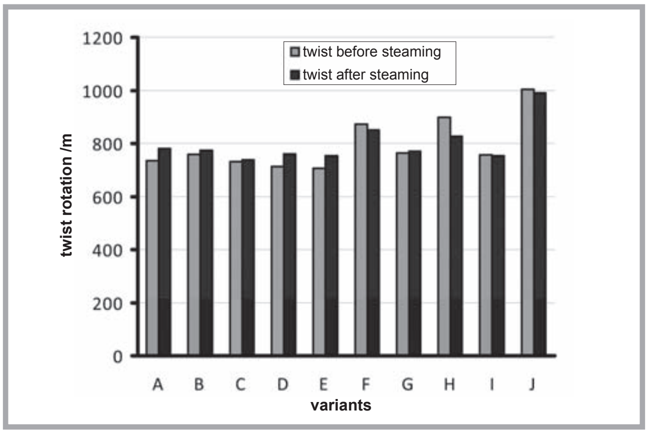

Figure 3. Yarn twist before and after steaming.

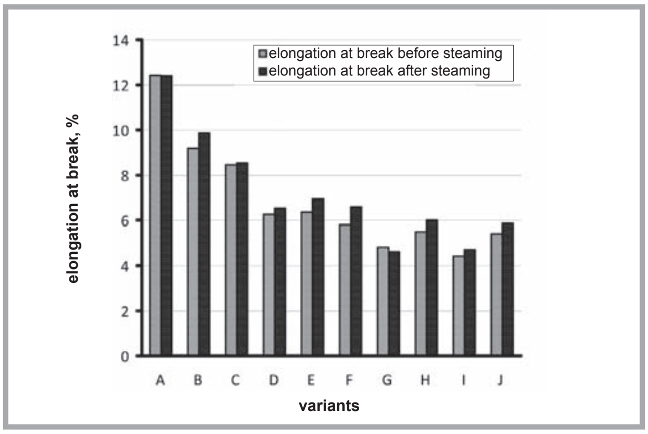

Figure 4. Elongation at break before and after steaming.

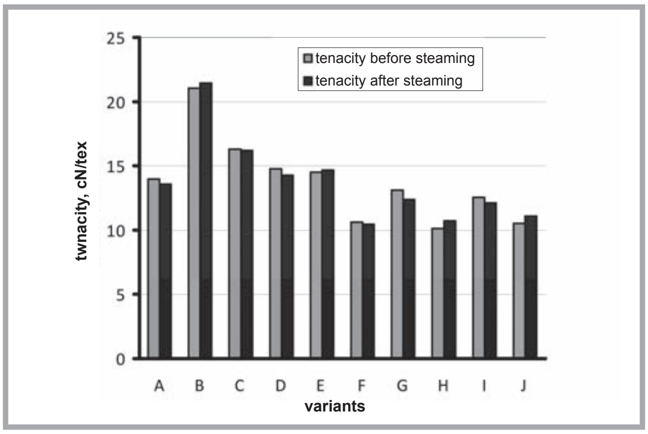

Figure 5. Yarn tenacity before and after steaming.

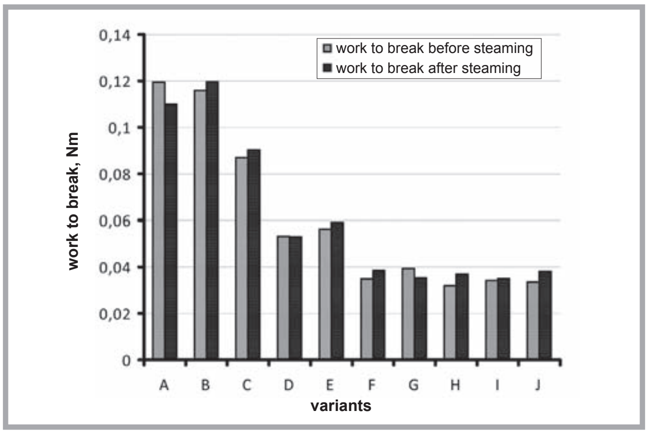

Figure 6. Work to break of the yarn before and after steaming.

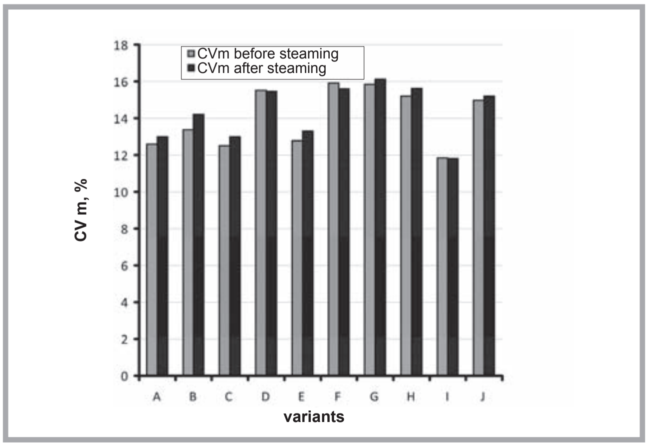

Figure 7. Coefficient of unevenness of linear density CV_m of yarns before and after steaming.

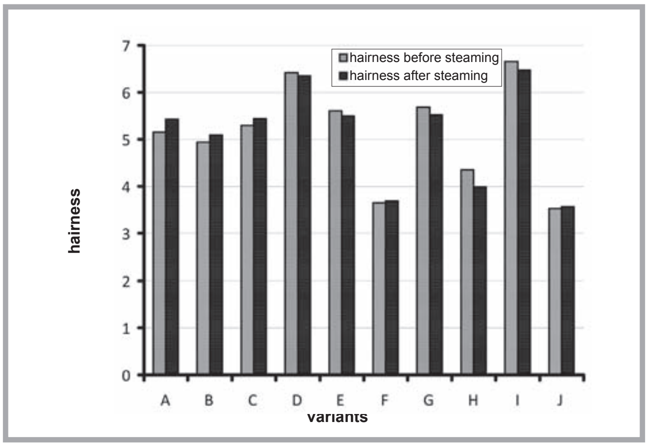

Figure 8. Yarn hairiness before and after steaming.

5 and **6**). The elongation at break of the yarns decreases with an increase in the content of cotton in the blended yarns (variants B, C, D, G and H); the yarn manufactured from viscose fibres variant A were characterized by the greatest elongations at break. The tenacity decreases with an increase in the content of cotton in the yarn blended with polyester fibres (variants B, C, D and G). We also stated that the combing process does not influence the tenacity (variants D and E). The classical yarns had a greater tenacity than the rotor yarns (variants G and H), which is a common rule.

Any significant differences between the variances for twist and the unevenness of twist were indicated for yarns before and after the thermal stabilization. Significant differences were noted between variances estimated by the F-test for the majority of variants for the elongation at break and yarn tenacity.

The thermal stabilization caused an insignificant increase in the coefficient of linear density CVm (***Figure 7***). An analysis of the results of twist measurement (***Figure 3***) and yarn hairiness (***Figure 8***) did not indicate any influence of the process of thermal stabilization on the values of these yarn parameters.

In order to estimate the influence of the process of thermal stabilization on the twist unbalance for all the variants of the yarn tested, the Fischer Snedecor test, also called the F-test, was performed. It was applied for the estimation of the significance of the divergences between the variances s_1^2 and s_2^2 obtained from two tests of equal size. Any significant divergences were stated between the variances for all the variants tested. In order to estimate the influence of steaming on the twist unbalance, the T-Student test was applied for the difference of two averages in the case of equal variances and equal size of the tests. Significant differences from the statistical point of view were obtained for the following yarn variants: A – 20 tex, 100% viscose fibres, carded, classical, G 33 ring-spinning frame; G – 20 tex, 95% cotton, 5% polyester fibres, carded, classical, G33 ring-spinning frame; H – 20 tex, 95% cotton, 5% polyester fibres, carded, Autocoro 240 rotor-spinning frame; I – 20 tex, 100% cotton, combed, classical, G33 ring-spinning frame; J – 20 tex 100% cotton carded, R1 rotor-spinning frame.

The differences between the average values of the twist unbalance from the statistical point of view were insignificant for all the remaining yarn variants (B, C, D, E and F).

Conclusions

1. The thermal stabilization influences advantageously the twist unbalance of yarns, causing its decrease, which is decisive for a significant improvement in the yarns' quality parameters and the conditions of their processing in further technological operations.

2. Homogeneous yarns composed from cotton and viscose fibres have a smaller twist unbalance after steaming than blended yarns.

3. The elongation at break and tenacity of yarns increase as a result of thermal stabilization.

4. The thermal stabilization causes worsening of such yarn parameters as the coefficient of unevenness of yarn linear density CVn (according to Uster) and the number of neps.

5. A significant decrease in the twist unbalance of yarns with a linear density of 20 tex was indicated after the process of thermal stabilization. It is difficult to determine explicitly a decreasing trend of the twist unbalance of yarns with a linear density of 20 tex with the application of subsequent (from 2 to 5) thermal stabilizations.

6. Taking into account on one hand the economical factors, and on the other hand the yarn quality, we can recommend applying only one thermal stabilization.

❑

Acknowledgement

This research work has been financially sponsored by the resources of the Polish Ministry of Science and Higher Education over the years 2007–2009 as part of research project F08 005 02.

References

1. *Ceven E.K., Ozdemir O.: Fibres & Textiles in Eastern Europe, Vol. 16, No. 2, p. 35-40, 2008,*
2. *Jackowski T., Chylewska B.: Przędzalnictwo-budowa i technologia przędz, ed. Technical University of Łódz, Łódz, 1999.*
3. *Domagała M., Chylewska B.: Laboratorium z Przędzalnictwa wełny i włókien Wełnopodobnych, ed. Technical University of Łódz, Łódź, 1994.*
4. *Service Manual of the XORELLA AG Steamer.*
5. *Jabłoński W.: Przędze Modyfikowane – metody teksturowania przędz puszystych, ed. WNT, Warszawa, 1972.*
6. *Korczak A.: 'Influence of the Thermal Stabilization on the Quality Parameters of Yarns Manufactured with the Use of Different Spinning Techniques' (in Polish), M.Sc. thesis, Department of Spinning Technologies of Yarn Structures, Technical University of Łódż, Łódż, 2008.*
7. *Korliński W.: Podstawy dziewiarstwa, ed. WNT, Warszawa, 1976.*
8. *Philips D.G.: Textile Research Journal, Vol. 78, No. 8, pp. 671-681, 2008.*
9. *Recelj P., Gorensek M., Zigon M.: Textile Research Journal, Vol. 76, No. 4, pp. 322-327, 2006.*
10. *Szosland J.: Podstawy budowy i technologii tkanin, 2nd ed., ed. WNT, Warszawa, 1972.*
11. *Zylinski T.: Metrologia włókiennicza, part 2, ed. WPLiS, Warszawa, 1978.*

❑ ***Received 6.12.2007 Reviewed 11.12.2008***