TWISTING OF MULTI-FOLDED YARNS AND THREADS MANUFACTURED BY MEANS OF NEW SPINNING TECHNOLOGIES

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Abstract

This paper includes an analysis of the properties of multi-folded yarns and threads manufactured by means of various spinning technologies, and an analysis of its twisting processes. Considerations related to the influence of twist value of the component fibre streams on the twist value of multi-folded threads, and the influence of the twist value of yarns and multi-folded threads on their processing throughput, are also presented.

Key words:

twist, yarn twist, thread twist, twist modelling, multi-folded thread, doubled thread, doubled yarn, siro-spun yarn, yarn properties, *ring-spinning frame, compact yarn*, *folding, fibre streams*

List of more important designations and their units:

- $\mathbf{R_s}$, m - radius of cross-section of the component fibre stream of a multi-folded thread;
- $\mathbf{S}_p$, m^{-1} - twist of the multi-folded thread;
- $\mathbf{S_s}$, m^{-1} - twist of the component fibre stream;
- $\beta_{\mathbf{n}}$, rad - angle formed by the axis of the component fibre stream with the direction of the multi-folded thread;
- $\mathbf{T}_\infty$, cN - tension of the component fibre streams above the contact point of the component streams;
- $\mathbf{T_0}$, cN - tension of a multi-folded thread below the contact point of the component fibre streams;
- $\mathbf{Q_0}$, Nm - twisting momentum of a multi-folded thread below the streams' contact point;
- $\mathbf{Q}_\infty$, Nm - twisting momentum of the component yarns of a multi-folded thread above the contact point of the component fibre streams;
- **B**, - - coefficient determining the rigidity of bending thin rods;
- **K**, - - coefficient determining the rigidity of twisting thin rods;
- $\alpha_{\mathbf{mp}}$, - - twist multiplier of the multi-folded thread;
- $\alpha_{\mathbf{ms}}$, - - twist multiplier of the component fibre stream of a multi-folded thread.

1. Introduction

The twist of yarns and threads influences their morphology. This feature creates the thread's properties, and at the same time is decisive regarding the processing throughput. A great amount of the literature published hitherto deals with the problem of yarn twisting, but there is a lack of sufficient information related to the twist of multi-folded threads. Technologists in the textile industry set the thread's twist value in their 'spinning planes'. Its actual realisation on the spinning machine and ring-twisting frame is performed by selecting the spindle rotary speed and fibre stream delivery velocity. Yarn plying, i.e. twisting together some component fibre streams, causes a decrease in the linear mass irregularity (thanks to a better fibre packing in the stream), an increase in tenacity, a lowering of the bending stiffness, an increase in the abrasion resistance, and a lowering of the thread's tendency to pilling formation. Owing to these favourable circumstances, twisting positively influences the thread's manufacturing throughput and the barrier ability (e.g. against UV radiation) of the fabrics produced from such a yarn.

2. Aim of work

The aim of our work is to compare the properties of various yarns and multi-folded threads manufactured by means of new spinning technologies, and to analyse their twisting processes.

3. Analysis of the twisting process of multi-folded yarns and threads

The investigations so far carried out in Poland and abroad have focused mainly on the analysis of the process of yarn twisting. The research results have been presented in a monograph [16] in 1971. The theoretical analysis of multi-folded threads has come within the investigation scope of only a few researchers, and its considerations are included in the following works: [4-6, 9, 10, 11, 14-16]. On the basis of an analysis of these considerations, we can state that the twist of the component fibre streams which form the thread depends on their radius $\mathbf{R_s}$, the assumed (set) twist value $\mathbf{S_p}$ of the multi-folded thread, and the coefficient κ, which characterise the material parameters of the component fibre streams. The relation between these parameters is described by the following equation [6, in 1998]:

$$S_s = \frac{S_p}{1+4\pi^2 R_s^{\,2} S_p^{\,2}}\left[1+\frac{(2-\kappa)}{\kappa}4\pi^2 R_s^{\,2} S_p^{\,2}\right] \tag{1}$$

The twist level of multi-folded yarns and threads depends on the properties of the raw material used for their production, including its linear mass, the fibre stiffness, and the structural features of the component fibre streams. The chief point of the problem analysed concerns the selection of appropriate twist values: $\mathbf{S_p}$ of the multi-folded threads, and $\mathbf{S_s}$ of the component fibre streams, which will be decisive in relation to their technological usability, described by the engineering denotation of 'processing throughput'. It is accepted that the twist value $\mathbf{S_s}$ of the component fibre streams is 20% lower than the twist value of the multi-folded thread [3, in 2003]. According to [3]: $\alpha_{ms} = \mathbf{0.55}\alpha_{mp}$, and $\mathbf{S_s = 0.8S_p}$ (for Siro-Spun yarns; see Figure 3a). Twist is also the parameter which can aid the achievement of better protective features against harmful UV radiation of the final product [1, in 2003].

The selection of an appropriate plying direction is an essential problem connected with twisting the component fibre streams with the use of ring-twisting frames. The twist direction of the multi-folded thread can be in accordance, or not, with the twist direction of the component fibre streams. The effect of using twist on twist (S/S, Z/Z) is an increase in the twist values of the component fibre streams below their convergence point. The multi-folded thread shaped in this way is characterised by special stiffness and great ability to form loops.

In contrary, the effect of applying opposite twists (Z/S, S/Z) is the complete or partial elimination of twists of the component fibre streams below their convergence point. The effect of this phenomenon is that the component fibre streams tightly adjoin to each other, and form almost one component fibre stream. The multi-folded thread shaped in this way is softer, has a higher breaking tenacity, and is characterised by a lower ability to form loops.

The users' increasing demands in relation to textile products and the changing fashion trends are forcing yarn manufacturers to permanently improve the yarn quality and broaden the range of assortments. At present, ring-spinning frames equipped with modern technical solutions of the working elements are available on the market. These spinning machines enable the manufacture of new types of yarn and multi-folded threads.

3.1. Yarns manufactured with the use of a compact ring-spinning frame

Spinning with the use of compact ring-spinning frames is a modified version of spinning with the use of classical spinning machines. Compact ring-spinning frames are equipped with compact drafting arrangements [13, in 2003], which enables an improved process of fibre incorporation in the yarn core.

This is possible thanks to a decrease or elimination of the twist triangle, which is characteristic of classical ring spinning.

Yarn manufactured with the use of compact ring-spinning frames is characterised by lower hairiness compared with classical yarn [13]. Thanks to the compaction of the fibre band in the compact drafting arrangement, the fibres are better packed in the yarn, which means that the yarn cross-section includes more fibres. The result is lower linear mass irregularity of the yarn. The yarn is more compact (see Figure 3b), has better tenacity and higher elongation at break. Better structure perfection, better surface smoothness, and a smaller number of protruding fibres cause better properties of the compact yarn compared with classical yarn.

At present, modern spinning machines are manufactured which enable the manufacture of compact core yarns [7]. Such yarns achieve higher tenacity by applying a core consisting of filaments.

3. 2. Multi-folded threads

Figure 1 presents a scheme for twisting a multi-folded thread composed from two component fibre streams; the directions of the tensions $\mathbf{T_0}$ and $\mathbf{T_\infty}$, and the torque momenta $\mathbf{Q_0}$ and $\mathbf{Q_\infty}$, which all affect the streams, are also shown in the picture.

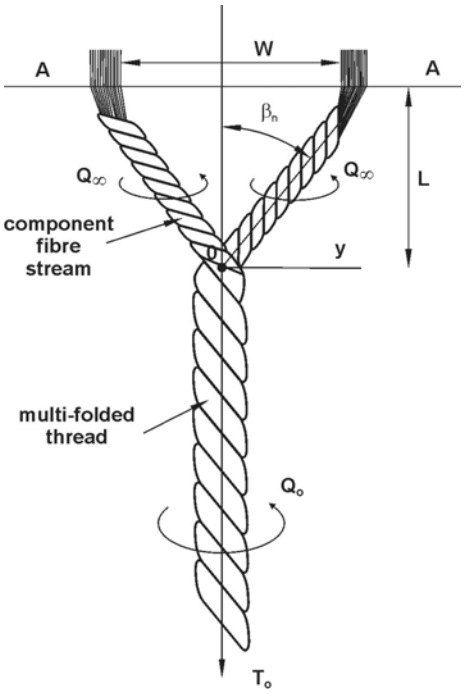

Figure 1. Scheme of a twisted classic multi-folded thread

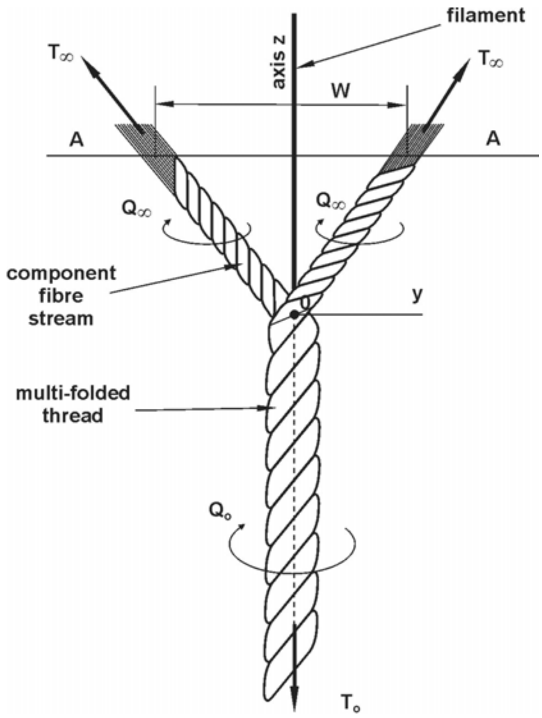

Figure 2. Scheme of a compact multi-folded thread with core [3]

The tension and the torque momentum of the multi-folded thread is described by the following equations:

$$T_0 = 2T_\infty \cos\beta_n + 2(K - B)\cos\beta_n \sin^4\beta_n - \frac{1}{2}\cos\beta_n \sin^2\beta_n \quad (2)$$

$$Q_0 = 2T_\infty \sin\beta_n + 2K\cos^4\beta_n \sin\beta_n + 2B\sin^3\beta_n\left(1+\cos^2\beta_n\right) + \frac{1}{2}\cos^2\beta_n \sin\beta_n \quad (3)$$

$$Q_0 = T_0 \tan\beta_n + 2K\sin\beta_n \cos 2\beta_n + 4B\sin^2\beta_n + \frac{1}{2}\sin\beta_n \quad (4)$$

The dimensions of the twisting triangle depend on the distance of the convergence point **O** from the line **A-A** of the delivery rollers' grip and the distance **W** between the two component fibre streams.

When the convergence point is near the line of the delivery roller grip of the drafting arrangement, the level of the spinning tension is low (the distance **W** between the component fibre streams is small, see Figure 1). Only very small dimensions of the twisting triangle allow small breakage of the multi-folded thread to be achieved.

To achieve higher quality requirements, for example, multi-folded threads are manufactured from compact yarns twisted together. Spinning machines which manufacture compact multi-folded threads are aimed especially at wool spinning, considering the relative low breaking tenacity ??of wool. During condensing, which takes place in the compact drafting arrangement, both component fibre streams near each other and take on a V-shape. The condensation of the component fibre streams takes place at a segment of two skew slots, under the action of negative pressure, by the turn of both streams around their axis. As a result, the phenomenon of fibre protruding from the component fibre streams does not take place, and nor does the twisting angle exist.

With the aim of improving the quality of textile products, it is possible to manufacture compact multi-folded core threads. Figure 2 presents a scheme for spinning a multi-folded thread composed of two component fibre streams and a core. In the figure the directions of the tensions $\mathbf{T_0}$ and $\mathbf{T}_{\propto}$, and the torque momenta $\mathbf{Q_0}$ and $\mathbf{Q}_{\propto}$, acting on the fibre streams, are drawn. By applying a core composed of filaments, the multi-folded thread achieves better strength properties.

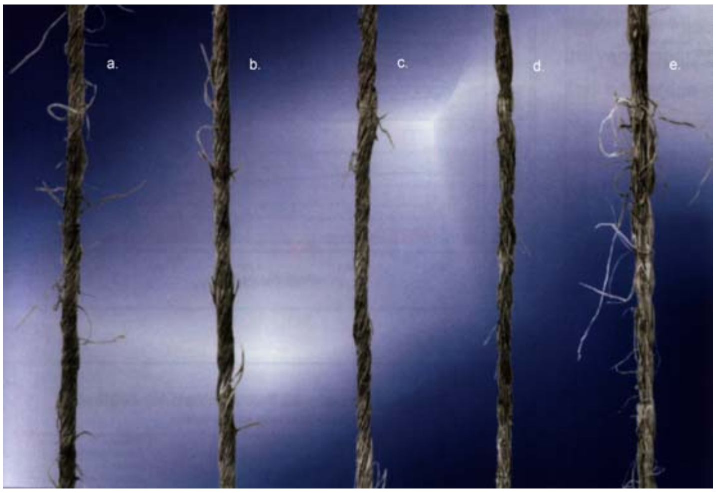

Figure 3. View of yarn manufactured by different spinning systems [3].

Figure 3 image of yarn manufactured using the following spinning systems: a. Siro-spun ring spinning *frame yarn,* ***b.*** *single compact yarn,* ***c.*** *a multi-folded thread - compact yarn,* ***d.*** *a multi-folded thread - twisted compact yarn,* ***e.*** *a multi-folded thread - twisted classic yarn [3, in 2003].*

A multi-folded thread (Figure 3c), according to the literature [3, 8], is described as having the following qualities: very smooth structure, larger gloss, soft hand, high regularity, low hairiness (especially of long fibres – value S3 >3), possibility of spinning with lower twist factor $\alpha_{\mathbf{mp}}$, reduction of twist value $\mathbf{S_p}$ up to 20%, thus keeping strength of thread on the level of classic thread, as well as high abrasion resistance.

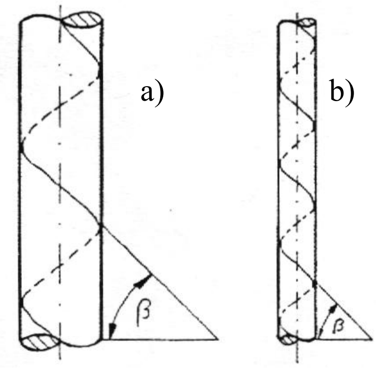

Figure 4. Scheme of rotor yarn with two different linear mass [2]

The above-mentioned considerations concern the component fibre streams obtained with the use of flyer-roving frames and ring spinning frames. A multi-folded thread can also be manufactured from yarns obtained from rotor spinning machines. However, it should be taken into account that these yarns are characterised by a different structure compared with yarns obtained from a classic ring-spinning frame, which results in their diverse properties [2, in 2003]. Thanks to the nature of the process of rotor spinning, the manufactured yarns are distinguished by a sheath, which means that they have fibres wrapped around their surface; this is the reason that rotor yarn should be manufactured with the assumption of a higher $\alpha_{\mathbf{ms}}$ coefficient. Figure 4 schematically presents two rotor yarns which have the same $\alpha_{\mathbf{ms}}$ coefficient and angle β of the fibre inclination in relation to the yarn axis, but which differ by linear mass, a) smaller, and b) greater. According to analysis [2], for example, for ring-spun knitting yarns, the $\alpha_{\mathbf{ms}}$ coefficient is accepted within the range from 60 to 90, while for rotor yarns within the range from 110 to 120. In the case of warp weaving ring-spun yarns, the $\alpha_{\mathbf{ms}}$ coefficient is accepted within the range from 115 to 135, and for rotor yarns from 135 to 155. The use of rotor yarn as a component fibre stream in a multi-folded thread may allow us to lower its twist value, which in turn results in an increase in the spinning machine's efficiency.

4. Summary

Spinning technologists aim to manufacture linear textile products which should meet specified criteria. One of these criteria may be to secure protecting barrier properties against UV radiation. This can be realised by using appropriate raw material in the process of ring spinning (the best thin fibres) and selecting the yarn twist value.

Taking advantage of the qualities of multi-folded compact yarns and threads allows us to create a totally new product with new properties. The advantages which result from manufacturing and applying compact yarns and threads, compared with the classical ones, include a lower breakage number, a decrease in the average percentage of good fibres in waste, lower dustiness of the manufacturing rooms in spinning mills, weaving departments, and knitting plants, low pilling ability of the final products, and higher machine efficiency. In the weaving process, the warp is exposed to different, diversified cyclic destructive loads during its path over the loom. These include repeatedly occurring stretching & bending tensions, impacts, and friction forces. Considering these peculiarities of the weaving process, compact yarns and threads are especially suitable for the production of woven fabrics.

The twist of yarns and threads influences the protective properties of textiles, and during the ring-spinning process, it has a significant effect on the dynamic phenomena which occur in the twisting-and-spinning unit of the spinning machine.

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