A. A.Telitsyn,
I. A. Delektorskaya

Specifics of Forming a Self-twisted Product in Asymmetrical Torsion Device

Kostroma State Technological University,
Mechanical Faculty,
Department of Theory of Mechanisms
and Machines, Machine Parts,
and Production Machines Design
Dzerzhinskogo Street, 17, Kostroma 156005, Russia
E-mail: niskstu@yandex.ru

Abstract
The authors of the article offer an asymmetrical arrangement of air-jet nozzles in the aerodynamic torsion device (ATD). They show the practicability of using such an ATD for the formation of a self-twisted structure of the yarn, including those containing pre-stretched elastomer. The authors calculated the levels of twist of the left-hand and right-hand components, taking into account tolerances used for the mechanical torsion device, constructed according to the asymmetric design.

Key words: *self-twisting (ST) method, yarn formation, aerodynamic torsion device (ATD), mechanical torsion device (MTD), air-jet nozzle, longitudinal force, untwisting moment, single components twisting, composite yarn, elastomer.*

Introduction

The self-twisting spinning process was developed by the Australian engineer D. E. Henshaw [1, 2]. In practice the self-twisting aerodynamic method (ST) is applied to form self-twisted yarn from two yarn components formed by drawing the feeding product (roving or sliver) in the drawing mechanism [3] .

The well-known aerodynamic torsion device is shown in ***Figure 1***. A unit of the vortex chambers includes ejectors (1), working torsion chambers (2), and a junction chamber (3) (active yarn connector). The ejectors are intended to carry over components pulled out of roving through the chambers when loading. The working torsion chambers (2) have two tangential nozzle channels (4) each. Compressed air is alternately supplied to the first and second channel. In this way, the components receive an alternative twist.

After that, the two components pulled out of roving, which have an alternative twist, enter the junction chamber (3), interlock and start self-twisting against each other. In order to intensify this process, alternating pulses of compressed air can be directed to the nozzle channels (4) of the junction chamber.

However, the ST method may also be used to form a self-twisted structure of components which represent finished yarn [4]. Experiments carried out by the authors on the machine (ПСК-225-ШГ2) (PSK-225-ShG2) equipped with licensed aerodynamic torsion devices (ATD) showed that such a process is possible. However, it was found that the ST structure obtained by this method, illustrated in ***Figure 2***, is characterised by an extended length of "zero zones", separating sectors S - twist and Z – twist.

Of particular interest is the technology of forming composite yarn containing pre-stretched elastomer by the ST-method. The technology of using an air stream for the formation of yarn containing elastomer is already known [5, 6].

The formation of such yarn namely by the ST method is appropriate for one more reason. It is known that by sewing fabrics in which yarn with elastomer of dense structure and strong friction bonding between the components are used as weft thread, there is a problem of damaging fabric with a sewing needle [7]. The structure of ST – yarn is quite loose (***Figure 2***) and this problem can be avoided. And, at last, fabrics of the "stretch" type containing, elastomer fit the shape and give people a sense of comfort. However, more preferable is composite yarn of natural fibres [8]. Laboratory experiments conducted by the authors showed the possibility of connecting pre-stretched elastomer by the ST-method even with linen yarn or modified linen yarn. Other cost-effective methods of connecting such components are not known so far.

The purpose of this research is to adapt an aerodynamic torsion device to implement the process of the formation of the ST-structure from finished yarn.

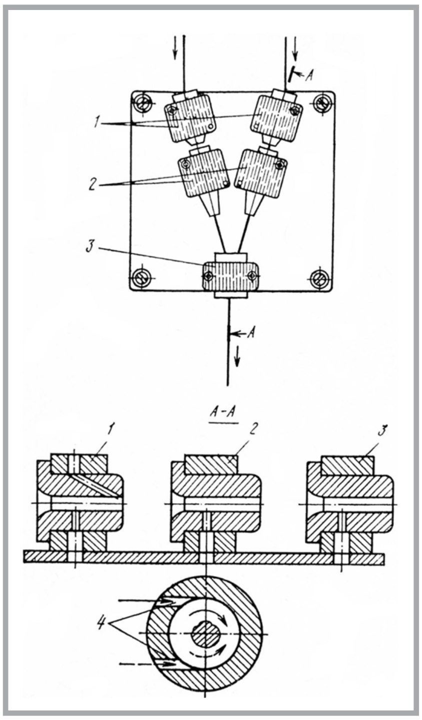

Figure 1. *Aerodynamic torsion device [3].*

Influence of the angle between connected components

Figure 3 illustrates the simplest diagram of double ST-product formation with just one aerodynamic air-jet nozzle. Let us consider the balance of longitudinal forces resulting in the product (double or single) under the influence of twisting

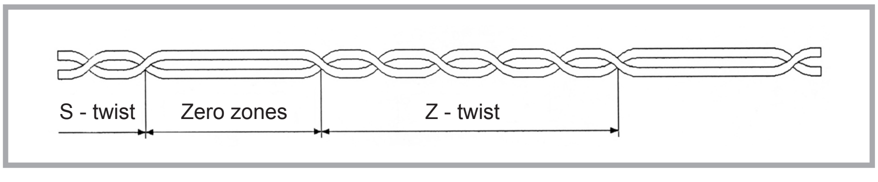

Figure 2. *Yarn of self-twisted structure; (Authors - A.A.Telitsyn, I.A. Delektorskaya).*

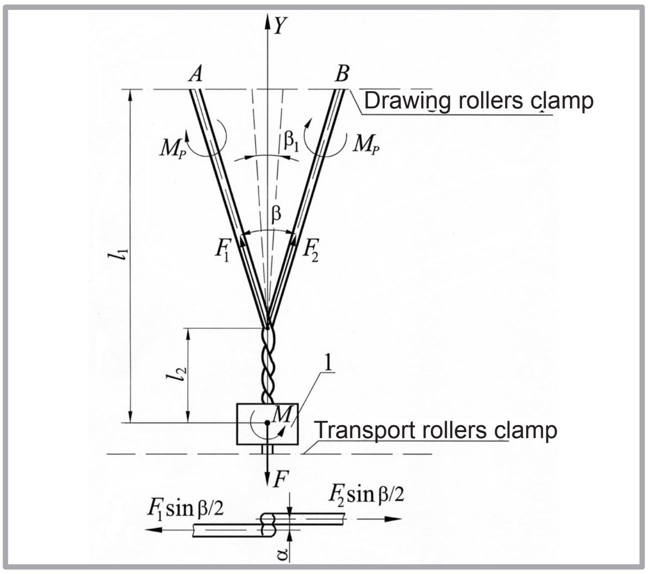

Figure 3. *Simplest diagram of ST-product formation (Authors - A. A.Telitsyn, I. A. Delektorskaya).*

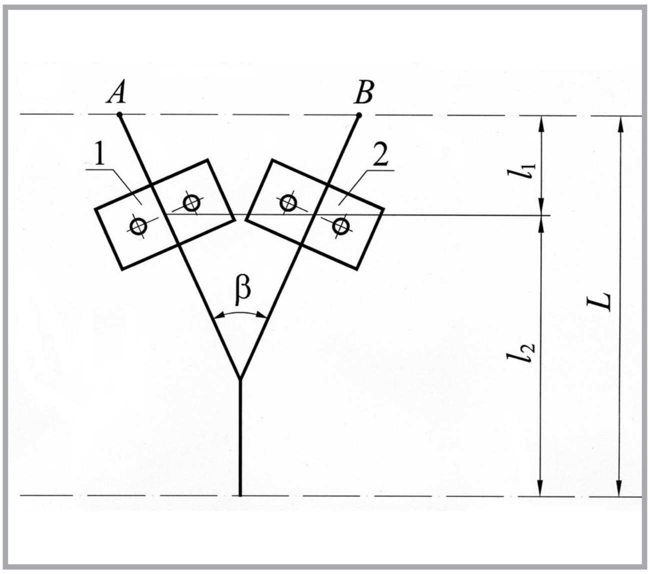

Figure 4. *Arrangement of air-jet nozzles of the primary twist in the ПСК-225-ШГ2 (PSK-225-ShG2) machine (Authors - A.A.Telitsyn, I.A. Delektorskaya).*

in the process of torsion during one half period. Let F-be a longitudinal force generated in a double product, and F_1 and F_2 – longitudinal forces in single components. Then the balance of forces of the condition $\sum F_y = 0$ can be written as $F = F_1 \cos(\beta/2) + F_2 \cos(\beta/2)$

On condition that components A and B are equal:

$$F_1 = F_2 = \frac{F}{2\cos(\beta/2)} \quad (1)$$

From expression (1) it is evident that the reduction of angle *β* between the connected components allows to reduce the longitudinal force in the single component. Note that the value of angle *β* in the ATD of the machine (ПСК-225-ШГ2) (PSK-225-ShG2) is about 60 degrees.

Furthermore we will use the method proposed by B. Schwabe [9] for analysis of the self-twisted method. In our case, the twisting of a single component and a double structure is carried out by an air-jet nozzle, imparting the product with alternating sign-changing torque. We assume that the switching of the air- jet nozzle is instantaneous, and the twisting period is the time between the two nearest switchings, to impart the product with one sign torque. Herewith the twist extends upwards during the half period and at the point of the junction of the components, there is the balance of moments of forces, influencing both the single components as well as the double structure. The condition of the equilibrium of the system with equal components A and B:

$$\Sigma M_y = 0 \quad (2)$$

$$M_y - 2M_{Py}\cos(\beta/2) + - 2F_1(d/2)\sin(\beta/2) = 0$$

Here:

M_y - torque influencing the double structure from the side of the air-jet nozzle 1;

M_{Py} - reactive moment created by the twisted single component above the point of junction.

The last component $2F_1(d/2)\sin(\beta/2)$ represents the moment of forces $F_1 = F_2$ action “untwisting” the double structure. Here *d* is the diameter of the single component.

The analysis of expression (1) and (2) shows that due to the reduction of angle *β*, e.g. from 60° to 10°, the second component increases 1.15 times, and the third, decreases by 6.5 times. This allows to increase the twisting capacity of the air- jet nozzle and reduce the length of the zero zones in the self-twisted product formed.

Analysis of versions of air-jet nozzles arrangement

Shown in ***Figure 3***, the simplest graph of double ST-product formation is used only for understanding the process itself. It is not used in practice due to the fact that the excessively large distance between the air-jet nozzle and the clamp of drawing rollers results in an insufficiently high level of preliminary twisting in single components. That is why in the actual operating ATD air-jet nozzles of the preliminary twists 1 and 2, shown in ***Figure 4***, are placed in close proximity to the drawing rollers. Here 1 and 2 are air-jet nozzles of sign alternating twisting within the two nozzle channels;

$L = \ell_1 + \ell_2$ - distance between the clamps of the drawing rollers and transport rollers ”cylinder-pressure roller”, defined as the total length of the twisting and
forming zones;

ℓ_1 - length of the first zone of twisting of the single component (A or B);

ℓ_2 - length of the second zone of twisting of the single component.

Figure 4 shows that it is the geometric dimensions of the air-jet nozzles of the primary twist that determine the value of angle *β* between the connected components. Obtaining a reduction in angle *β* is possible by shifting air- jet nozzles of the primary twisting along the direction of product movement.

The aerodynamic device, which was got by this method, was called by the authors asymmetrical.

Let us consider the chart of self-twisted structure formation in the asymmetrical torsion device shown in ***Figure 5***.

For maximum visualisation, let us describe the process for the case where the

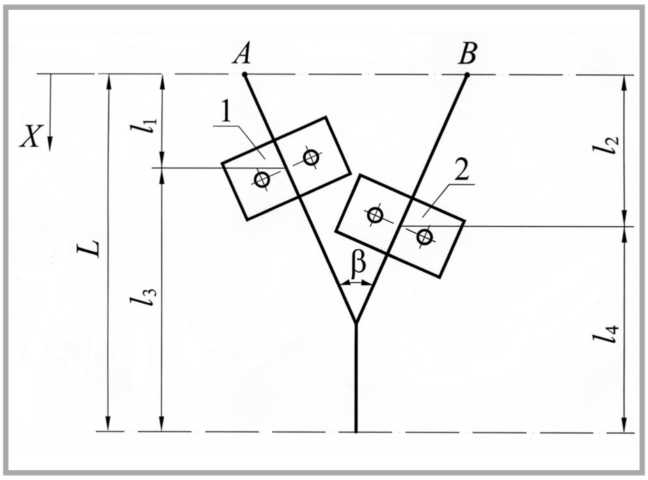

***Figure 5.** Chart of the asymmetric torsion device (Authors - A.A.Telitsyn, I.A. Delektorskaya).*

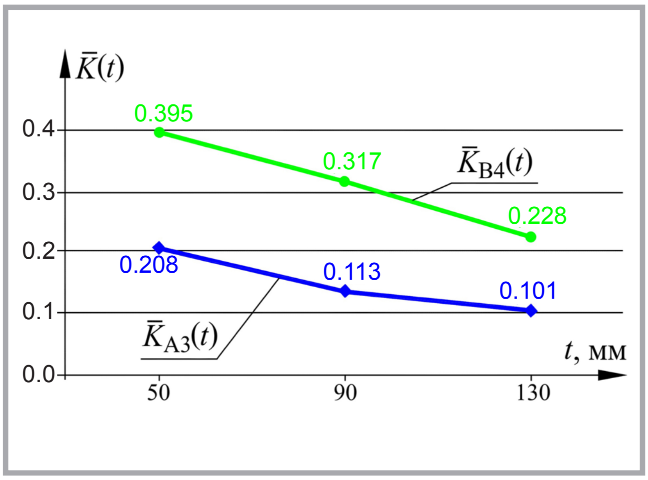

***Figure 6.** Values of the normalised twisting of single components (Authors - A.A.Telitsyn, I.A. Delektorskaya)*

twisting rate does not depend on the level of twisting already given to the component, which corresponds to twisting in the mechanical torsion device (MTD).

Taking into account the assumptions adopted for MTD in [3], equations of the balance of the number of twists of components A and B in zones with lengths ℓ_1, ℓ_2, ℓ_3, ℓ_4 will be written as follows:

For component A:

$$\ell_1 \cdot \frac{dK_{A1}(x)}{dx} + K_{A1}(x) = \frac{n(x)}{V} \qquad (3)$$

$$\ell_3 \cdot \frac{dK_{A3}(x)}{dx} + K_{A3}(x) = -\frac{n(x)}{V} + K_{A1}(x) \qquad (4)$$

For component B:

$$\ell_2 \cdot \frac{dK_{B2}(x)}{dx} + K_{B2}(x) = \frac{n(x)}{V} \qquad (5)$$

$$\ell_4 \cdot \frac{dK_{B4}(x)}{dx} + K_{B4}(x) = -\frac{n(x)}{V} + K_{B2}(x) \qquad (6)$$

where:

n - intensity of twisting components by air-jet nozzles

V - linear velocity of components' movement

The results of calculations performed for the actual dimensions of the asymmetric ATD installed on the (ПСК-225-ШГ2) (PSK-225-ShG2) machine are shown in graphical form in ***Figure 6***.

Values $K_{A3}(\bar{t})$ and $K_{B4}(\bar{t})$ represent the normalised values of twists of components A and B, respectively, in zones with lengths ℓ_3 and ℓ_4.

From their size it is possible to judge the relative level of twisting of the real product in these zones. Herewith the length of the half period of twisting $\bar{t} = t_k$ (the sum of the length of the zero zone and that of zone S or Z of the twist) was assumed to be 50, 90 and 130 mm, of which the value equal to 90 mm is, practically, the one most frequently used.

The calculations show that due to the asymmetric arrangement of the air - jet nozzles, ratio $\left|\frac{\overline{K}_{B4}(t)}{\overline{\hat{E}}_{\grave{A}3}(t)}\right|$ is:

1.90 at t_k = 50 mm
2.22 at t_k = 90 mm
2.19 at t_k = 130 mm (view ***Figure 6***)

Practical application of this result is that component B can be a yarn or filament of greater torsional stiffness than component A.

Conclusions

Thus the application of the torsion device made by asymmetric arrangement allows not only to reduce the angle between the connected components but also to very significantly affect the twisting ability of the left and right air-jet nozzles by adjusting the lengths of the first and second zones of twisting.

This may occur to be useful if component B has larger torsional stiffness than component A. A particular case of this is the technology developed by the authors, in which component B has as an integral part a pre-stretched elastomer (SPANDEX thread), limiting the ability of component B to torsion [10].

References

1. Henshaw DE. *Self-twist yarn*. Merraw Publishing Co, Ltd, Watford, Herts, England, 1971.
2. Henshaw DE. A model for self- twist yarn. *Journal of the Textile Institute* 1970; 61, 3: 97-107.
3. Movshovich PM. *Self-twisted spinning*. Lengpromizdat,1985, p. 248.
4. Telitsyn AA, Mindovsky SK, Filatova NI. A new concept of self-twisted spinning development. News of establishments of higher education. *Technology of the textile industry* 1995; 4: 116.
5. Ortlek HG. Influence of Selected Process Variables on the Mechanical Properties of Core-Spun Vortex Yarns Containing Elastane. *Fibres & Textiles in Eastern Europe* 2006; 3, 57: 42–44.
6. Elastic yarn technologies. *Melliand International* 2004; 10: 14-15.
7. Guranda A, Meric B. The Effects of Elastane Type and Fabric Density of Sewing Needle Penetration Forces and Seam Damage of PET/Elastane Woven Fabrics. *Fibres & Textiles in Eastern Europe* 2007; 4, 63: 73–76.
8. Zimniewska M, Huber J, Krucińska I, Torlińska T, Kozłowski R. The Influence of Clothes Made from Natural and Synthetic Fibres on the Activity of the Motor Units in Selected Muscles in the Forearm-Preliminary Studies. *Fibres and Textiles in Eastern Europe* 2002; 10, 4: 55-59.
9. Schwabe B. Probleme der Fadendrehungen und Mechanik von V – Garnen. *Textiltechnik* 1975; 416-420.
10. Patent of RF No. 2228397. A machine for forming composite yarns by the aerodynamic technique. Telitsyn AA, Delektorskaya IA, Korolyov MV.

Received 03.07.2013 Reviewed 13.12.2013