DEFINITION OF AREA EXTENSION AND FIBRE MICROSLIP IN CROSS-SECTION OF YARN AND EVALUATION OF STRENGTH DURING TWISTING

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ABSTRACT: *The aim of this paper is to analyze the impact of twist on the strength characteristics of the yarn. In previous studies it is noticed that while twisting and stretching, the cross section of yarn, depends on the fibers located in two zones (stretching and slipping). However, it was unclear that why the quantity of loading fibres vary in between these zones. This research focuses on the important factors such as twist angle which can affect size of stretching and slipping zones and defines the relation of strength with angle of twist.*

Keywords: Strength, twist angle, axial and radial stress, slippage of fibres

INTRODUCTION

The strength of yarn is considered one of the most important parameter of yarn quality. This parameter decides the performance of post spinning processes; warping, weaving, knitting and the properties of end product. Shao [1-2] has defined the modeling of deformation properties of a yarn of low twist where the modeling characterize the value of twist. In studies of the mechanics of yarn, greater attention is paid to assessing the impact of the elastic properties of fibres during spinning [3-9]. Therefore, it has been reported that the breakage and slippage of fibres in the cross-section of yarn varies due to angle of twisting in yarn which mainly affect the strength of yarn.

The twisting of drafted material particularly during yarn manufacturing process is a complex process which leads to reduction of cross-section of product and increase the tensile strength. Following this phenomenon, the strength values reached to certain level where starts decreasing the growth of twisting. In contrast to [10], the aim of this study is to establish the range in which the strength of yarn reaches the appropriate measure of technological capabilities of equipment.

CHARACTERIZATION OF THE YARN STRENGTH

In previous study, the influence of rotor speed on mechanical properties of yarn has been analyzed to investigate the effect of spinning speed. The results showed that the strength improves with an increase of spinning speed. In addition, the orientation of fibres in the yarn cross-section increases, thus improves the elastic properties of yarn [11]. Jumaneyazov et al [12] reported in his findings that rotor diameter also plays a key role to improve the properties of yarn; for example, breaking load of yarn increase with reduction of rotor diameter, however the yarn elongation improves with higher diameter of rotor. This phenomenon is probably related with yarn structure, in particular, character of an arrangement of individual fibres in cross-section section of a yarn. Jumaniyazov and Gafurov found that twist growth in rotor is limited to certain level, after which there will not be any change into yarn structure even by increasing twist level. Spindle speed of ring spinning also influences the structure and properties of yarn [14], particularly breaking load increases with an increase of spindle speed.

THEORETICAL APPROACH TO CHARACTERIZE THE YARN STRENGTH AND FIBRE SLIPPAGE

It is generally accepted, that the cross-section of yarn decreases during twisting and causes an internal radial stress (stress between fibres) [1].

$$\sigma = \sigma_f \cos^2 \frac{(1-\frac{\rho^2}{R^2})\sin^2}{2\left[\left(\frac{\rho}{R}\right)^2 \sin^2 + \cos^2\right]} \qquad (1)$$

Where, b - twist angle, $\sigma_f = E_f\ \varepsilon_f$ - a stress at stretching of fibres, p - distance between fibre and the axis of yarn, R - radius of yarn, E_f – Modulus of fibre, ε_f – fibre elongation. Further, the tensile force of single fibre and friction between fibres are determined according to following equations [1].

$$F_{str} = \pi r_0^2 E_f \varepsilon_f\,, \qquad F_{fr} = \mu \sigma l \cdot L_b \qquad (2)$$

Where, μ - coefficient of friction between fibres, l - length of a fibre $L_b = 2\pi r_0$, r_0 - the reduced radius of a fibre. If tensile force becomes equal to the force Ffr then the process of slippage occurs and leads to straightening of fibres which may be determined as follows.

$$F_{str} \geq F_{sl} \qquad (3)$$

By combing equations (1) and (3), we get;

$$\frac{\sigma}{E_f \varepsilon_f} \leq a = cos^2 \frac{\left(1-r_*^2\right)\sin^2}{2(r_*^2 \sin^2 + \cos^2)} \qquad (4)$$

Here $a = \frac{\pi r_0^2}{\mu l \cdot L_b}$, $r_* = \frac{\rho_*}{R}$,

In above equation, ρ_* is radius yarn which limits the area of stretching zone of stretching from a slippage zone sliding. In this regard, equation (4) defines the borders of these zones. Thus, fibres can be straightened during stretching; however it depends upon values of β and $a = \frac{\pi r_0^2}{\mu l \cdot L_в}$ in yarn.

Figure 1 presents the ratio of equation $r^* = r_* / R = r^*(\ ,a)$ and twist angle at various values of parameter a. In order to

calculate the interval of twist angle it may be defined as $_l(a) < \quad < 45^0$.

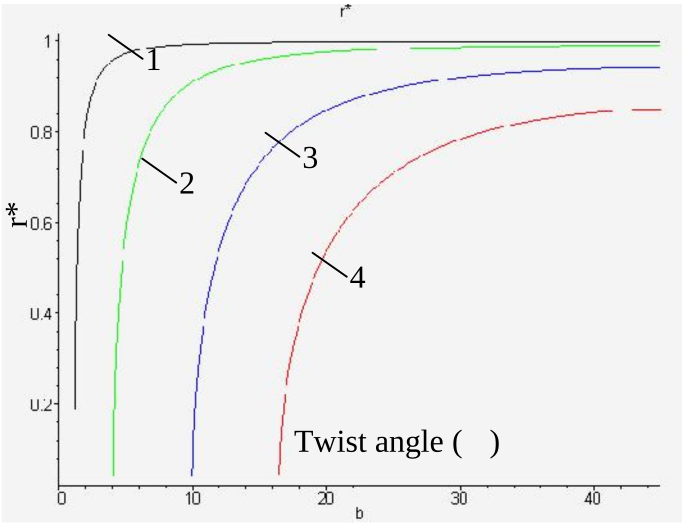


Fig.1: Graphical representation of the ratio of $r^* = r_* / R$ and twist

a: $1 - a = 0.0002$, $2 - a = 0.0025$, $3 - a = 0.015$, $4 - a = 0.04$

The stretching zone of yarn consists two sections, are of rectangular $0 < \quad < \ _l(a)$, $r = 1$ and curvilinear area: $_l(a) < \quad < 45^0$ $r^*(\ ) < r < 1$. It is observed from results that there will not be stretching zone, if $a = 0$ (for example, at « $\to \infty$). However, if a increases, it may lead to reduction of co-efficient of friction with the condition of r_0 / l and the stretching zone starts extending. In interval of twist angle at $a = 0.225$, all fibres in the yarn are completely stretched.

The axial and radial stresses (Fig. 2) in stretching zone of yarn are defined as under;

$$\pm_f = E_f £_f, \quad \pm = \pm_f \cos^2 \quad \frac{(1 - \frac{\circ^2}{R^2})\sin^2}{2\left[\left(\frac{\circ}{R}\right)^2 \sin^2 \quad + \cos^2 \quad\right]}$$

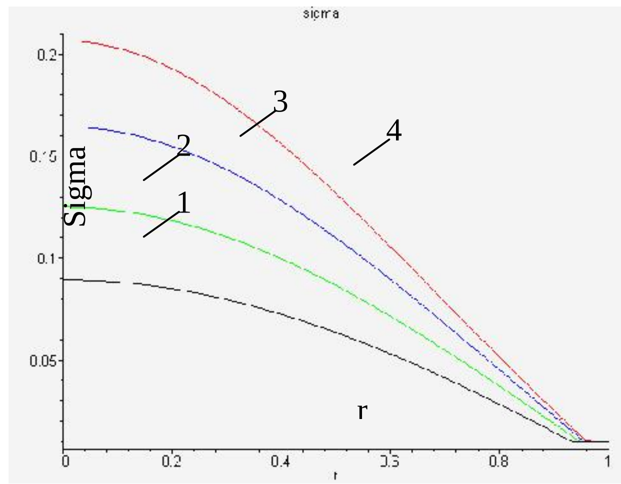
Above calculation can only be applicable in the region defined below;

$$_l(a) < \quad < 45^0, \quad 0 < r < r^*(\ ) \quad (5)$$

However, for regions of $0 < \quad < \ _l(a)$, $r = 1$ and $_l(a) < \quad < 45^0$, $r^*(\ ) < r < 1$ following equation may be used respectively.

$$\pm_f = E_f £_f, \qquad \pm = aE_f £_f \quad (6)$$

$a = 0.01$



$a = 0.08$

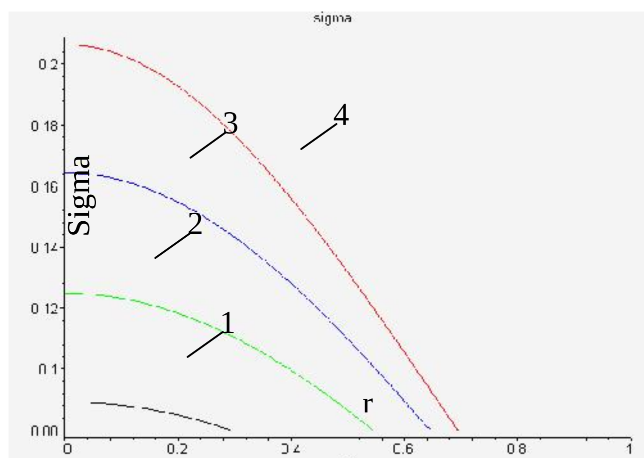


Fig.2. Curves of radial stress distributions $sigma = \pm / E_f £_f$ along radius of yarn

: $1 - \quad = 25^0$, $2 - \quad = 30^0$., $3 - \quad = 35^0$, $4 - \quad = 40^0$

Figure 3 shows the curves distribution of radial stresses ± (referred to value $E_f £_f$) for radius $r = \circ / R$ for $a = 0.01$, $a = 0.08$ and different values of twist angle . The calculations show that the stretching zone expends with an increase of twist angle and radial stresses. However, the internal radius of stretching zone decreases as parameter a increases. The determination of boundary of stretching zone requires further fibres information within boundary such as the condition of preservation of fibre bunch strength according to criteria of strength. The yarn uses four stages to resist the stresses when the stresses reaches certain limit, the bunch of fibres uses fourth resistant that value associates with a breaking strength of yarn. This intensity of stresses leads to following equation.

$$\pm_i = \frac{1}{\sqrt{2}}\sqrt{\pm^2 + (\pm - \pm_f)^2 + \pm_f^2}$$

(7)

Using equations (for ±) (5) and (6) we integrate equeation (7) on area of cross-section section of a yarn.

$$G_i = 2® \int_0^R r\pm_i dr = \frac{1}{\sqrt{2}} ®R^2 E_f £_f \sqrt{a^2 + (1-a)^2 + 1}$$

at $0 < \quad < \quad _l(a)$,

$$G_i = 2® \int_0^R r\pm_i dr$$

$$= \frac{1}{\sqrt{2}} ®E_f £_f \sqrt{a^2 + 1 + (1-a)^2}[R - r_*(\quad)]^2 \text{ at}$$

$$_l(a) < \quad < 45^0$$

The Figure 3 explains the curves of the ratio of $G_i^* = G(\quad, a) = G_i / ®R^2 \pm_f$ and twist angle at different values of parameter a. It is noted that all curves have two sections; the first section corresponds to the value G_i calculated for bunch of fibres in stretching zone. All curves of both sections have the maximal and minimal values, attainable at $= 0$ and $= \quad _* \ (\quad _l < \quad _* < 45^0)$. The second section $_* < \quad < 45^0$, where the yarn is not stretched. If the stress $\pm_f$ and value $\pm_0$ satisfy to an inequality $\pm_0 / \pm_f \le G(\quad _*, a)$ then all curves $G_i^* = G(\quad, a)$ accept values more than $G(\quad _*, a)$, i.e. the inequality $G(\quad, a) \ge \pm_0 / \pm_f$ takes place that the criteria of strength of yarn irrespective of presence of a stretching zone. At $G(\quad, a) < \pm_0 / \pm_f$ the first section $G_i^* = G(\quad, a)$ physically is not realized, as in an interval twist angle $0 < \quad < \quad _*$ all fibres are stretched, therefore the zone will be weakened and consequently the criterion of strength here, will not be carried out. Thus, for verification of strength criterion, it is necessary to check the second section curves $G_i^* = G(\quad, a)$.

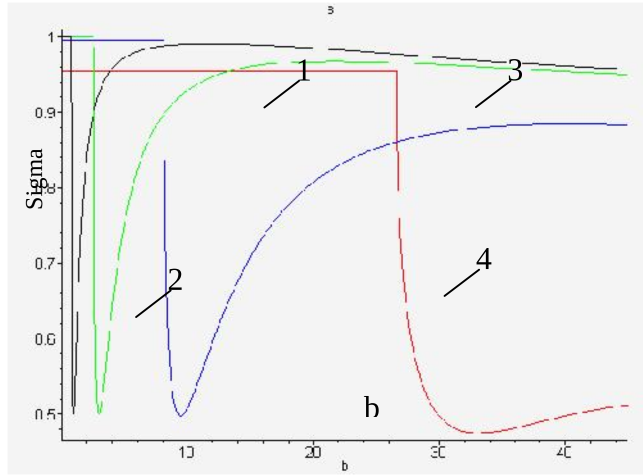


Fig. 3: Relationship of $G_i^* = G(\quad, a)$ and twist angle $b =$ (in degrees) at different values of parameter a :

$1 - a = 0.0001$, $2 - a = 0.001$, $3 - a = 0.01$, $4 - a = 0.1$

On the set values $\pm_0$ and $\pm_f$ on this defined section in Fig. 3, the curve $\pm_f = \pm_0 \cdot G(\quad, a)$ may decide the twist angle which helps to regulate and manage the parameters of machine. It is believed that $r_0 = 0.02$ мм $l = 33$ мм $« = 0.03$, then we have $a = \frac{r_0}{«l} = 0.01$ $\quad _l(0.03) = 8.13^0$, $\quad _* = 9.5^0$. If we consider the sections of a bundle of fibres $9.5^0 < \quad < 45^0$ $r^*(\quad) < r < 1$, with regard to curve of second section $G_i^* = G(\quad, a)$, where fibres are not slipping with each other (In Fig.3, the curve - 3). At the set value $\pm_0$ shall vary a longitudinal stress $\pm_f$. If value of this stress satisfies to inequality $\pm_f > 2.01\pm_0$, the condition of strength is broken for all values and the bundle of fibres cannot resist in such stress. If we assume $\pm_f < 1.33\pm_0$, the strength of a bundle is preserved for all values of twist angle . For the values of $\pm_f$, satisfying to inequality $1.133\pm_0 < \pm_f < 2.01\pm_0$, the criterion of strength will be carried out in interval $_1 < \quad < 45^0$, where $_1$ is the root of the equation $G(\quad _1, a) = \pm_0 / \pm_f$

CONCLUSION

Generally, the open-end yarn has weaker structure due to poor load distribution, less fiber migration and fiber tension during spinning. This paper mainly discussed the issues related with weak structure of open end yarn and developed the mathematic model for width of fibrous ribbon in order to provide tight structure of open-end yarn. The resultant data has been plotted using mathematical model successfully. Experimental results shows that rotor speed directly affect the yarn properties. It is further observed that the cross section area of yarn decrease with an increase of the rotor speed, however specific weight increases which affect the width of fibrous ribbon. As a result, the increase in rotor speed provides the tight structure of yarn.

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