VORTEX YARN STRUCTURE CHARACTERIZATION

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Abstract

The yarn geometry is generally characterized by fineness and twist. These parameters together with fiber properties and technology conditions are responsible for yarn internal structure (arrangement of fibers). Fiber arrangement can be characterized by packing density and orientation factor. For compact, ring and rotor yarns it is possible to create some models by using above mentioned parameters and predict their properties as diameter, hairiness, strength, etc. Machine twist for these yarns is based on technological conditions as is spindle or rotor rpm and yarn delivery speed. Twisting of fibers during creation of Vortex yarn is based on air pressure and it is not possible to define twist by standard way. Vortex yarn is created from mostly parallel arranged fibers, part of which forms the bearing part of the yarn (core) and some are twisted around the core (cover). The level of twisted fibers is mainly influenced by technological conditions, i.e. the speed of the yarn passing through a nozzle, the air pressure in the nozzle and nozzle design. Standard assumption is that the cover layer consists of flat fiber ribbon with a helical trajectory. Ribbon wraps the core in the regular intervals and the number of turns per unit length is expressing ribbon twist. The main aim of this work is to show influence of Vortex yarn technological parameters on the ribbon twist and influence of the ribbon twist on the yarn parameters. Influence of ribbon twist (ribbon twist coefficient) on the Vortex yarn properties are compared with the influence of standard yarn twist on the yarn properties.

Introduction

In the Vortex system, sliver passes through the drawing mechanism and the fiber strand is delivered to the spinning unit with needle and spindle. Air stream from three nozzles is twisting fibers mainly on the yarn surface. Fibers shorter than 12 mm are removed by air stream. Longer fibers migrate to the yarn core and shorter fibers go to the surface layers (Basal 2003). Because fibers are migrating from the yarn core to the surface, the surface layers of MVS (Murata Vortex Spinner) yarn contain higher amount of fibers in comparison with MJS (Murata Jet Spinner) yarn (Murata Machinery Ltd. 2006). Fibers situated in surface layers create the permanent twist. In Vortex system, the core is composed from parallel fibers bundles and their cohesion is ensured by cover composed from twisted fibrous layers. Between drawing mechanism and point of yarn formation are fibers approximately in parallel position. In the hollow spindle, the fibers ends are casted on the outer surface of hollow spindle by air stream and twist of cover fiber layers is created. This leads to the increasing of surface fibers portion to 20% - 30% and it is positive from point of view of yarn strength (Yonenaga 2003). According to (http://www.muratec-vortex.com.) and (*Oxenham 2011)* in Vortex yarn, just one fiber end is in the yarn core and second one is wrapped in surface layer. Ring spun yarns have constant fiber twist. Rotor yarns are due to lower strength usually spun with higher twist and typical wrapped fibers are on the surface. A vortex yarn has zero twist in yarn core and in direction to surface, twist is increasing.

Vortex yarns have less hairiness among all the types of spun yarns. Vortex yarn woven fabrics have better resistance to pilling, lower dustiness, better abrasion resistance, washing resistance and moisture absorption (http://www.muratec-vortex.com.). Influence of technological parameters as is draft ratio, nozzle angle, nozzle air pressure, spindle diameter, yarn delivery speed and distance between front roller and the spindle, on the structure and properties of 100% cotton Vortex yarn with fineness 20 tex is described in work (Basal, Oxenham 2006), (Erdumlu, Ozipek, Oxenham 2012), (Zou 2012). It was found, that with shortening distance between front roller and the spindle it is improving yarn evenness, decreasing number of imperfections and hairiness. Improving yarn evenness and decreasing yarn hairiness is caused by higher nozzle angle, too. Combination of high nozzle angle and short distance between front roller and the spindle leads to better yarn evenness. Nozzle air pressure and nozzle diameter affect hairiness. Higher number of thick places and lower hairiness is result of low delivery speed. Suitable combinations of yarn delivery speed and nozzle angle have significant influence on the yarn hairiness. Higher nozzle angle, higher air pressure and lower yarn delivery speed lead to higher fiber migration. Nozzle angle, air pressure and yarn delivery speed have no significant influence on the yarn mechanical properties. The effect of the interaction of the intermediate draft and total draft in combination with yarn delivery speed on the Vortex yarn properties is described in (Erdumlu, Ozipek 2010).

The main parameters affecting all yarn types structure and properties are fiber type, type of spinning technology and its conditions, yarn fineness and twist. Influence of these parameters on structural yarn parameters as packing density, orientation factor, etc. was already studied. The influence of structural parameters on yarn properties was found and models for prediction were created (Kremenakova, D., Militky, J., Pivonkova, D., Spankova, J. 2011). In this contribution the simple model of Vortex yarn twist is proposed. The influence of spinning conditions on the yarn twist and influence of twist on the yarn structural parameters and other properties is evaluated.

Theoretical part

Assume that the cover layer consists of flat fiber ribbon in a helical trajectory. Ribbon wraps the core in the regular intervals and the number of turns per unit length is expressing ribbon twist *Z*. Ribbon axis form a helix on the cylinder with a diameter corresponding to the diameter of the yarn core D_h see Fig.1. Ribbon thickness is neglected.

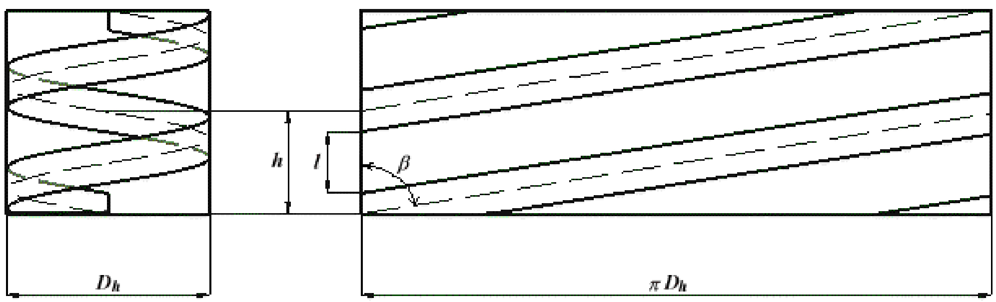


Figure 1. Ribbon twist model.

Helix angle of ribbon is β and helix height is *h*. For ribbon twist *Z* is then valid

$$Z = 1/h \tag{1}$$

The twist intensity tgβ depends on the core diameter D_h and ribbon twist *Z*

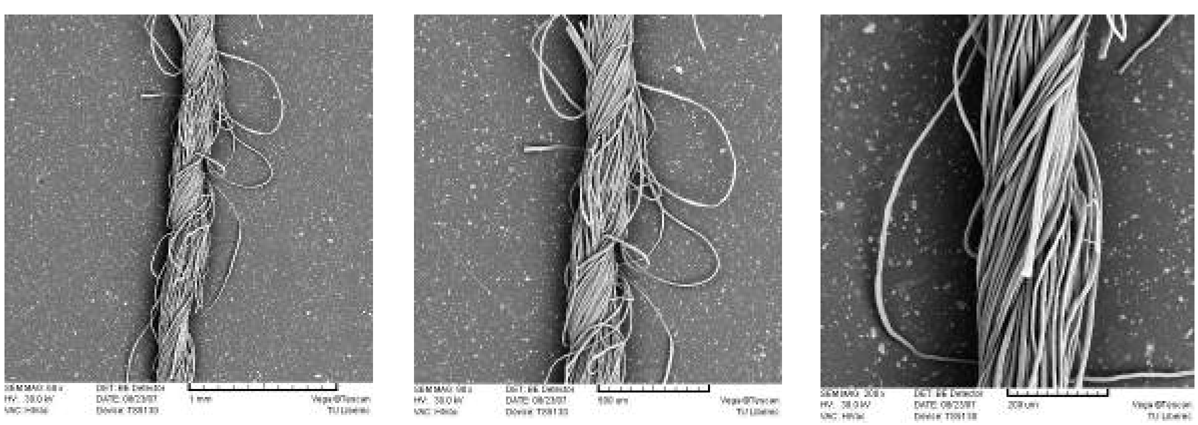
$$tg\beta = \pi D_h Z \tag{2}$$

The core diameter D_h can be calculated from well known relation

$$D = \sqrt{4T/(\pi\mu\rho)} \tag{3}$$

where μ is packing density of yarn core and ρ is fiber mass density. Twist coefficient of ribbon is similar to the ring or rotor yarn and can be defined by Koechlin type relation

$$\alpha = ZT^{(1/2)} \tag{4}$$



a) magnification 60x b) magnification 90x c) magnification 200x

Figure 2. Surface structure of Vortex yarn.

Materials and Methods

Two groups of Vortex yarns from viscose and cotton fibers were spun on the Muratec machine n.861 under different spinning conditions. Viscose yarns (viscose fibers 1.3 dtex, 38 mm) were spun with the same air pressure 0,50 MPa and different fineness (different main draft), spindle diameter and delivery speed - see Table 1. The 100% cotton combed yarns were spun with the same fineness and different air pressure and delivery speed - see Table 2. Structure of Vortex yarn is shown in the Fig.2. The helix height of ribbon and core yarn diameter was measured by using image analysis. Ribbon twist and ribbon twist coefficient were calculated by using eq. (1) and (4). All measurements were repeated 30 times and arithmetic mean and corresponding 95% confidence interval were calculated.

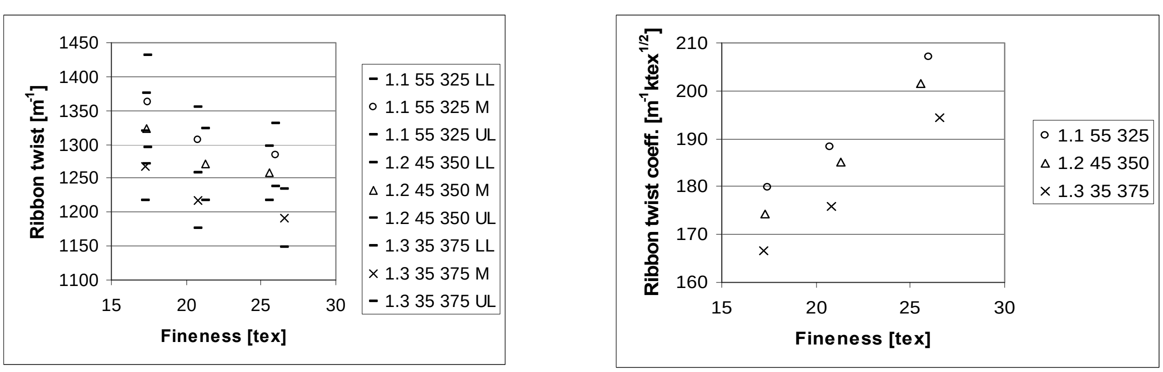
Ribbon twist and ribbon twist coefficient is shown in Fig.3 for Viscose yarns and in Fig.4 for cotton yarns. The influence of ribbon twist coefficient on the Vortex yarns diameter, hairiness, mass unevenness (CV), number of thick places, thin places, neps, strength and deformation at break were measured. Vortex yarn core diameter was measured by using image analysis; see Fig.5a, 5b and by Uster Tester 4 sees Fig. 5b. Yarn hairiness, CV, number of thick places, thin places and neps, were measured on Uster Tester 4, too. Yarns strength and deformation at break were measured on dynamometer Instron 4411. Measurements were realized according to ISO standards.

Table 1. Properties of Viscose yarns.

Yarn number	Yarn fineness [tex]	Delivery speed [m/min]	Spindle diameter [mm]	Main draft
1	16,5	350	1,2	45
2	20	350	1,2	45
3	25	350	1,2	45
4	16,5	325	1,1	55
5	20	325	1,1	55
6	25	325	1,1	55
7	16,5	375	1,3	35
8	20	375	1,3	35
9	25	375	1,3	35

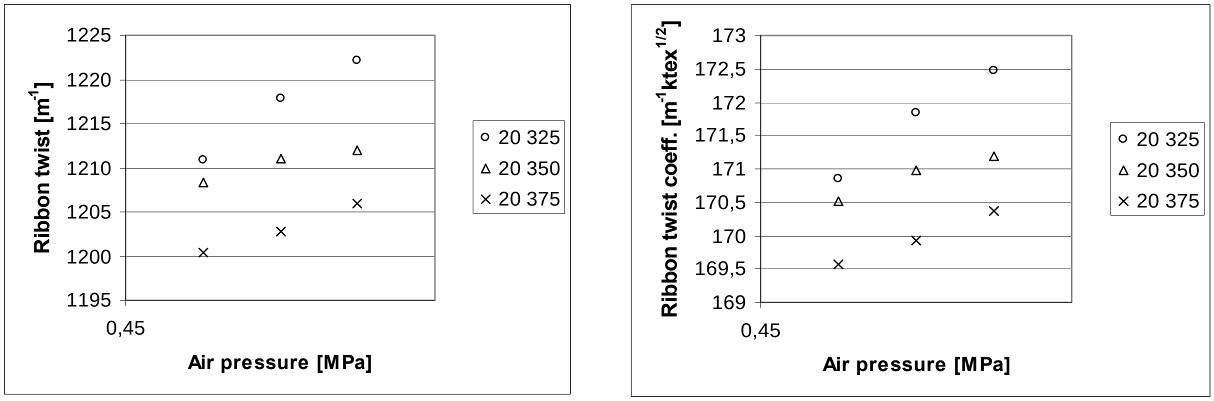
Table 2. Properties of Cotton yarns.

Yarn number	Yarn fineness [tex]	Delivery speed [m/min]	Air pressure [MPa]
1	20	325	0,50
2	20	325	0,55
3	20	325	0,60
4	20	350	0,50
5	20	350	0,55
6	20	350	0,60
7	20	375	0,50
8	20	375	0,55
9	20	375	0,60



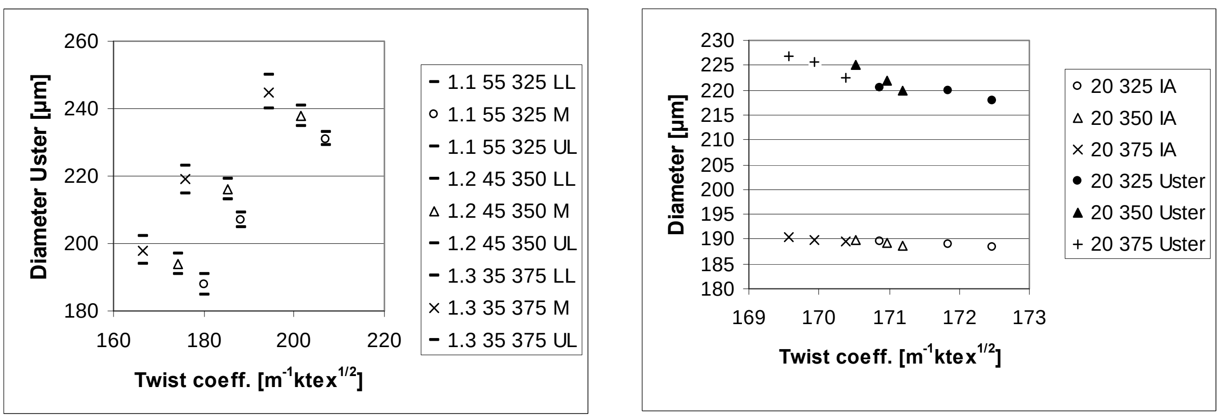
a) b)

Figure 3. Ribbon twist and ribbon twist coefficient of Viscose yarns.



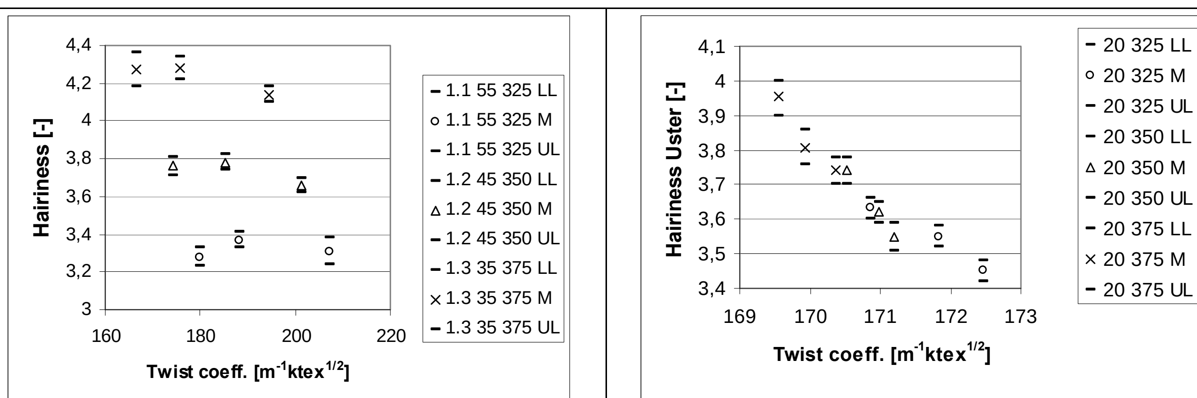
a) b)

Figure 4. Ribbon twist and ribbon twist coefficient of Cotton yarns.



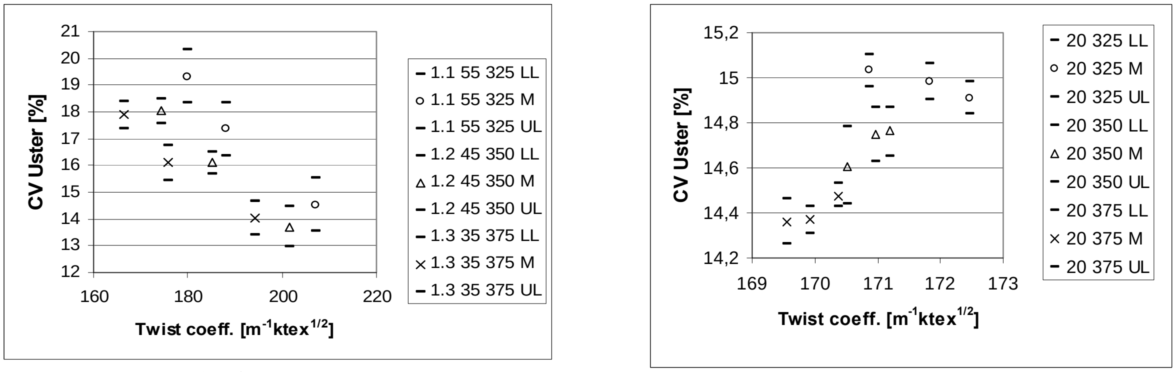
a) Viscose yarns b) Cotton yarns

Figure 5. Influence of ribbon twist coefficient on the Vortex yarn diameter.



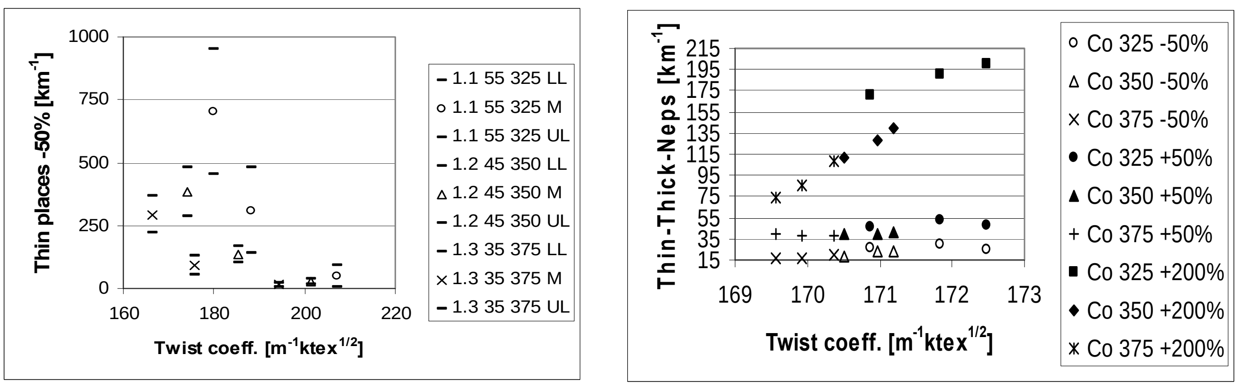
a) Viscose yarns b) Cotton yarns

Figure 6. Influence of ribbon twist coefficient on the Vortex yarn hairiness.



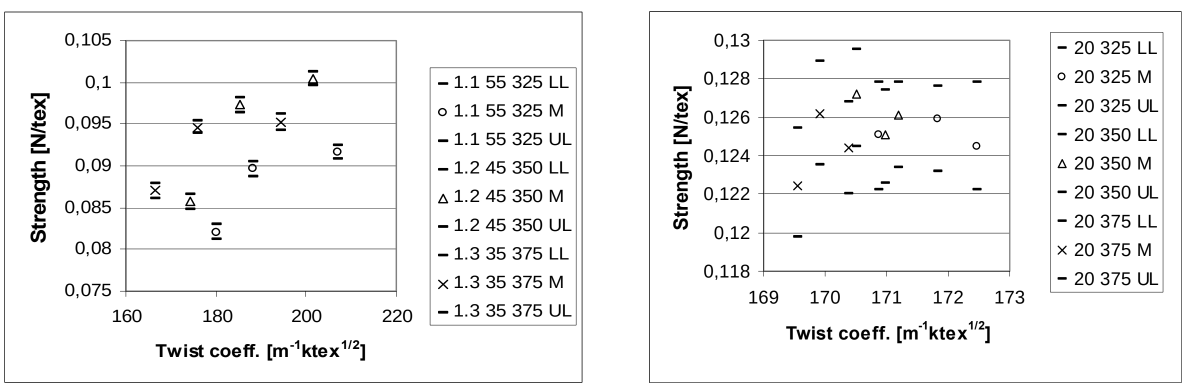
a) Viscose yarns b) Cotton yarns

Figure 7. Influence of ribbon twist coefficient on the Vortex yarn mass unevenness represents by CV Uster.



a) Viscose yarns b) Cotton yarns

Figure 8. Influence of ribbon twist coefficient on the Vortex yarn thin places -50%.



b)

a) Viscose yarns Cotton yarns

Figure 9. Influence of ribbon twist coefficient on the Vortex yarn strength

Results and Discussion

Influence of spinning conditions on the ribbon twist and ribbon twist coefficient

Ribbon twist of viscose (Fig.3a) is increasing with decreasing spindle diameter and decreasing yarn delivery speed. For coarser yarn it is necessary to use lower twist, this is well known rule for standard yarns as well. Coarser yarns have higher amount of fibers in yarn cross-section, slipping forces between fibers are higher and lower twist is sufficient. Ribbon twist of cotton yarns (Fig.4a) with the same fineness is increasing due to increase of air pressure and decreasing due to increase of delivery speed. Opposite trend is obtained for ribbon twist coefficient (RTC) see Fig.3b and Fig.4b.

Influence of ribbon twist and ribbon twist coefficient on the Vortex yarn properties

Ribbon twist coefficient has influence on the yarn diameter. It is approximately the same as for standard yarns. Yarn diameter is increasing due to decreasing RTC (Fig.5a,b). For coarser yarns higher diameters are obtain. These result are obtained by using image analysis measurement and by using of Uster Tester 4, too. Values of both measurements are different. The lower core yarn diameter was obtained from yarn images in comparison with Uster measurements (Křemenáková, Mertová, Kolčavová 2008). The yarn hairiness is decreasing due to increasing RTC (Fig.6a,b).

The CV (Fig.7a,b) and number of thin places, thick places and neps (Fig.8a,b) are slowly increasing with increasing RTC. For fine yarns (16.5 tex) strength is decreasing due to increase of RTC. For coarser yarns (20 tex, 25 tex) strength is increasing to the critical point and after this point is decreasing as for standard yarn. Higher RTC of Vortex yarns leads to lower fiber number in yarn core, and to bigger part of fibers twisted around core.

Summary

The possibility to measure Vortex yarn ribbon twist and ribbon twist coefficient as result of spinning conditions was proved. Similar rules were found for Vortex yarn structure as for standard compact, ring and rotor yarn. These results can be used for optimization of spinning conditions (optimal setting of machines) and obtaining the required yarn properties. It is also possible to find suitable models for prediction of Vortex yarn properties.

Acknowledgements

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