Design of a navel and its influence on yarn structure

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key-words
Navel; geometry, yarn quality, grooves OE-rotors spinning, productivity

The texture of a yarn describes the orientation of individual fibers in a yarn group. This yarn structure is determined by the application. The OE-rotor spinning system is a very flexible solution among staple fiber spinning processes, since it allows yarn manipulation through the use of various spinning elements. For example, the design of the navel has a significant influence on the yarn structure. The opening roller and rotor are responsible for a large proportion of the measured number of imperfections, the yarn uniformity, and damage to the fibers. The principal item however, the navel, is able to broadly manipulate yarn volume and hairiness, without necessarily having a negative effect on processing parameters, such as tenacity and elongation.
The two characteristics, volume and hairiness determine the optical appearance and the feel of a fabric. The character of a textile product can therefore be predominantly controlled by the navel.

Introduction

Each of the three established staple fiber spinning techniques - ring -, OE rotor or air jet spinning - have specific pros and cons. Characteristics of each technique show up in the yarn. Comparing the yarn structures optically, the yarn density (compact or open) is usually determined by fiber migration and fiber alignment (parallel or uneven). Usually, in addition the listing of the Uster CV value, the IPI values, and the mechanical characteristics follow such as strength and elongation. Finally decisive is in the long run the look and feel of the final textile product.

Within the further development of OE-rotor spinning we see three directions of developments:
1) the yarns are to become more similar to ring yarn or compact yarn (motivation are here in particular technical applications. The desire comes however also strongly from the conservatives),
2) the range of spinnable yarns is to become larger (motivation here is essentially fashion),
3) the processing behavior in the following process stages should be improved (motivation are among other things less abrasion and fly generation in weaving and knitting, and reduced energy consumption for example in air jet weaving).

A former report emphasized the influence of navel surfaces as a quality instrument [1]. This article deals primarily with the possibilities of yarn manipulation by means of geometry of the navel.

Within yarn fineness and fiber type, substantial possibilities of manipulation of the yarn structure exist in the variation of the yarn twist coefficient α, the rotational speed of opening roller and rotor, the choice of the rotor groove, the navel and the torque stop. The schematic result of the manipulation is represented in Fig. 1. Mainly it is volume and hairiness, which can be influenced independently by each other.

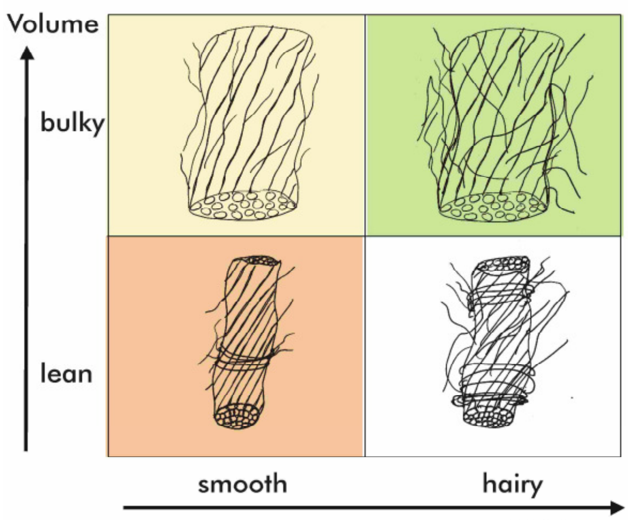

Fig 1: Independent parameters hairiness and yarn volume

Structure of the OE rotor yarns

With OE-spinning yarn formation spreads out from the core to the yarn surface. The OE yarn has therefore a high fiber density and twist in the core, which gradually decreases toward the outside of the yarn. The core twist is a consequence of the twist propagation into the rotor groove. The surface of the rotor yarn is loose and less strongly twisted compared to a ring spun yarn.

The characteristics of local wrapper fibers always sit at the surface and can not be found in the core of the yarn. While the core twist is affected mainly through the design of the rotor groove, the yarn surface and thus the IPI values, the optical characteristics and the feel, like cover and hand, are steered through the navel.

Impact of navel

The navel in conjunction with the rotor, is the central spinning unit. It is twist blocker and false twister element in one. It turns the yarn more or less gently twice around a solid angle of 90°. Its design affects the local air compression in the rotor and arranges the yarn structure and the yarn topography substantially (Fig. 2).

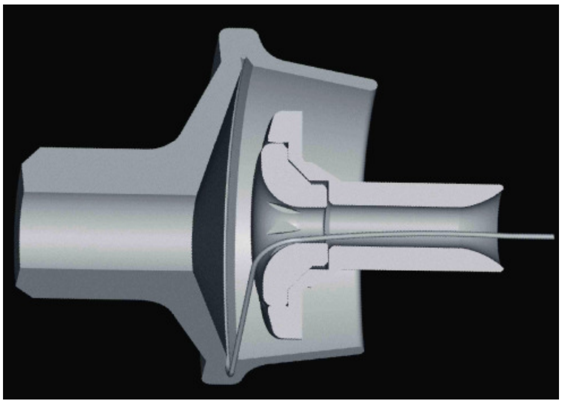

Fig 2: Arrangement of yarn, navel and rotor in OE rotor spinning

With the rotor rotating in the same direction as the yarn crank each rotor revolution induces one turn into the yarn. To this real twist a certain amount of false twist adds itself due to slip-affected rotation of the yarn. This local and temporary limited twist increase has an important influence on spinning stability and piecing-up behavior. Besides it protects the yarn formation against the high loads in the spin zone. The false twist is considerably affected by the design of the navel and by the spin parameters.

A maximum of the rolling friction between shell of the navel and yarn would be desirable, as slippage results in shear stress, abrasion and strong thermal damages. To reach this however, the navel would have to be made in a very small dimension. Contrary to this would be the sharp bending of the yarn and the necessary high rotor speed of at least 150,000 rpm.
Finally there are the dynamic contact conditions between yarn and navel, which influence the twist insertion and the loads exerted by it on the surface of the yarn and the navel (Fig. 3).

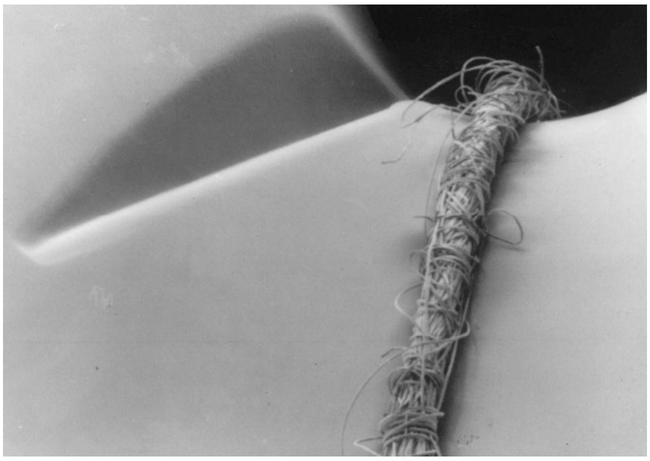

Fig. 3: SEM-picture showing part of contact yarn/navel

Factors of Influence

It is a well-known fact, that the condition of the navel, its geometry, as well as spatial position to the rotor affects the yarn quality and its performance in the subsequent processes. On the shell of the navel, the yarn speed changes permanently and with high frequency in time and place. With a rotor speed of i.e.120,000 rpm within ten thousandths of a second, the elongation of the yarn will be determined. A main reason for this is, that the yarn is activated with frequencies, which lie in the ultrasonic range. Our investigations show that periodic frequencies of over 50 kHz arise (Fig. 4). This corresponds to a longitudinal wavelength in the yarn, which is still larger than the length of the curvature of the navel! In these frequencies friction conditions result, which do not have anything to do with the everyday experiences from sliding and rolling friction. Due to these yarn oscillations the sliding friction measured is significantly smaller than those measured by a friction simulated with a fixed loop method. Depending upon the frequency, the yarn "sees" the navel as a dampening element or as an agitator.

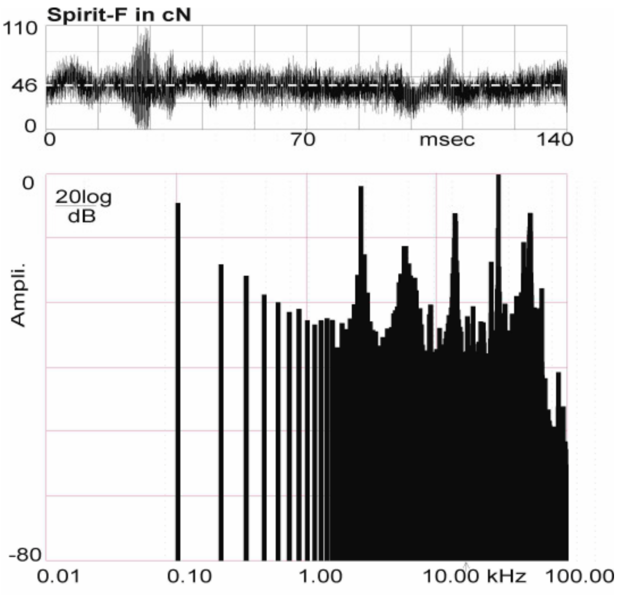

Fig. 4: Frequency analysis of the yarn tension under typical spinning conditions

The stress on the yarn can be reduced considerably with the knowledge of these relationships, since the yarn shows other viscoelastic qualities in this dynamic area. These very dynamic friction events can be partly recognized at the wear picture of the shell of the navel. For these reasons, the fiber formation, the number of wrapper fibers and the mechanical qualities of the yarn are influenced [2].
At present we know of more than 40 geometrical factors, their influence on the spun yarn and the effects on spinning characteristics. Some are to be introduced here briefly. The substantial geometrical manipulations in the shell of the navel are: height of collar, overall height, outside diameter, radius of curvature and diameter of the bore. If the navel possesses grooves, then there are: number of the grooves, design of the groove, axial and radial position as well as depth.

Some the parameters mentioned, result based on the construction, others are freely selectable. Additional elements as roughing devices and torque stops later roughen-up the finished yarn at the surface and can serve for stabilization of the spinning process.

For a certain spin condition the following diagram (Fig. 5) gives an impression of the adjustable range on yarn quality merely through the geometry of the navel. Illustrated are the standardized values of the linked mechanical characteristics elongation and strength over the standardized values of the IPI-values (thicks, thins, neps)for the indicated, constant spinning conditions. Values smaller than 1 are worse, values exceeding 1 are better in the appropriate yarn characteristics. The four grooved classical K4 navel represents the reference and was to date the favorite. The diagram shows only those navels, which show a high effectiveness. The BROELL navels SPIRIT-type B, D, E, K and L, possess 5 grooves. The A-type has 6 grooves. The radius of the curvature, are the same for D, K and L as well as for B and E. The SPIRIT-A lies in between. On the basis of this representation it becomes evident that the influencing factors like number of grooves and radius of the curvature are not sufficient, to clarify the causal relationships.

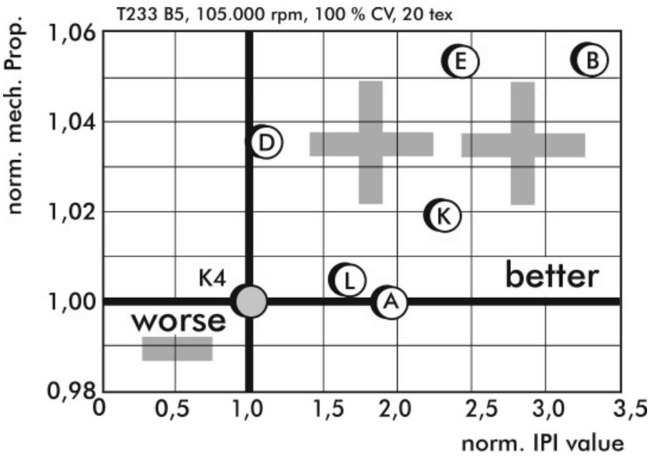

Fig 5: Change of the yarn characteristics with different navel geometries

Influence of radius of curvature

The radius of the curvature of the navel, other than number of grooves, is the most obvious design criterion. With it the area of the shell increases or decreases. By this means the length of the yarn guidance on the navel, the friction path and the yarn tension will be manipulated. It is a far too common mistake to think that a reduction of the radius of the curvature is compellingly linked with a decrease in yarn tension. One has to distinguish clearly between average yarn tension and real yarn tension peaks. Through the changing effects of false twist and twist contraction, the formation of wrapper fibers changes apart from the changing oscillation characteristics of the yarn on the shell. This can lead to the fact that a navel with a smaller radius of curvature and reduced mean values in yarn tension, but higher tension peaks, clearly generates lower yarn elongation values due to the higher yarn tension peaks. A combination of different design parameters however can compensate this effect favourably. Systematic investigations confirm that a smaller radius of the

curvature increases the back twist in the yarn: as a result the yarn possesses fewer wrapper fibers and feels softer. By the accompanying decrease of the contact area the yarn volume is also usually reduced - if not countered by other measures.
With given spinning conditions and yarn twist coefficient, and only varying rotor speed, we state that a good navel has a speed range of approx. 30,000 to 40,000 rpm in which a secured production is possible. The optimal operating point depends however strongly on the navel.

Influence of the groove
The depth of the groove substantially affects the retention time of the yarn in the groove and with it spin stability. The past experience documented an increase of the hairiness at the same time. We know today that this is not compelling, but can be compensated by a skillful design of the navel. The groove as vibration agitator can reduce the average frictional force between yarn and spin element, and improves the propagation of false twist into the rotor groove. We found that there is a fiber-specific optimal average yarn tension, where end breaks reach a minimum. Besides we know today that an asymmetrical groove design has a higher flexibility regarding the range of fineness of the spun yarns and system-dependent will not fill up with fiber fragments and wear debris as it is self-cleaning.

The following diagram shows a relatively complex comparison between two different navels (Fig. 6). Under increase of the rotor speed from 60,000 rpm to 120,000 rpm, in steps of 15,000 rpm, the end breaks and the yarn tension were measured. The representation permits the statement that under the given conditions the optimal operating point of a SPIRIT-A with 6 asymmetrical grooves has the same average yarn tension as a K4, except that the SPIRIT-A should be used with clearly higher rotor speeds. With this navel type the spinner should increase the rotor speed by approx. 15 % in order to obtain a lowest possible end breakage rate. The yarn values justified from the patented design of the navel are nevertheless more favorable than with a K4.

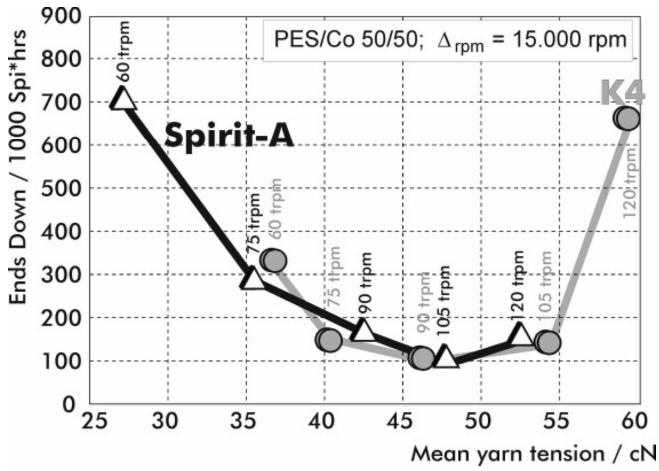

Fig. 6: Yarn tension and end breakage rate of two navel geometries under variation of rotor speed

In the groove design, small changes in angles and radii lead to strong changes in the yarn quality and spin stability. The wear of the navel begins preferentially at these radii. The fiber fly in the spin box and a reduction of the machine efficiency are therefore often explained with the geometrical drift of the groove. With a steel navel, these effects partly arise within a few weeks. Ceramic navels made of BCA1 have due to material and production clearly higher precision, from groove to groove, and a service life which exceeds the metallic navels multiple times over.

Selection of navel
The yarn spinner is anxious to obtain a highest possible productivity during lowest possible fiber damage. However, the increasing market pressure requires that the spinners look beyond that to optimization of the further processing conditions of fabric formation and finishing. When weaving or knitting, effects generated by snarling tendency, rare weak points or fiber fly can appear in such a manner that the acceptance of a slight reduction of the efficiency in OE-spinning in favor of the yarn process characteristics would show up extremely profitably in the subsequent downstream processes.
A possible reduction of the yarn twist coefficient by 5% yields a reduction of the production costs by approx. 4.5%. For example, an increase of delivery speed of 10% saves manufacturing costs by approx. 10% per kg yarn (applies to 20 to 36 tex). An increase of the end breakage rate of around 10% however increases the manufacturing costs just over approx. 1%.

At the latest in the dyeing operation fiber damages from the spinning process show up as nonhomogenous dyeing in connection with partially shiny and matte shades. Many yarn spinners do not change the spinning conditions with new navel types, but look primarily on the end breakage rate - a questionable procedure considering the given potentials.

On the basis of extensive and comparative investigations with navels by our company – regardless if they are our own developments of the SPIRIT series or traditional navels (KG, K3, K4, K8), we are now in a position to provide assistance considering both, the aspects of productivity, as well as appearance of the yarn. The assistance is put on as selection diagram (Fig. 7). The abscissa runs from low to high yarn twist coefficient, the ordinate over the type of fiber, from the man-made fibers (MMF) up to cotton (Co), and blends in between.

Implemented into the diagram is the preceding Fig. 1 stretched in hairiness and volume. The white area is blank since yarns are not usually desired with compact, hairy yarn characteristics. Within the colored areas, in each case two navel types are indicated: the upper line is more suited for finer yarns, the navel below rather is recommended for coarser yarns. A very open, short-haired yarn structure results from the SPIRIT-K. Compared with to a navel with a roughing device, no roughing of the yarn occurs with the SPIRIT-K.

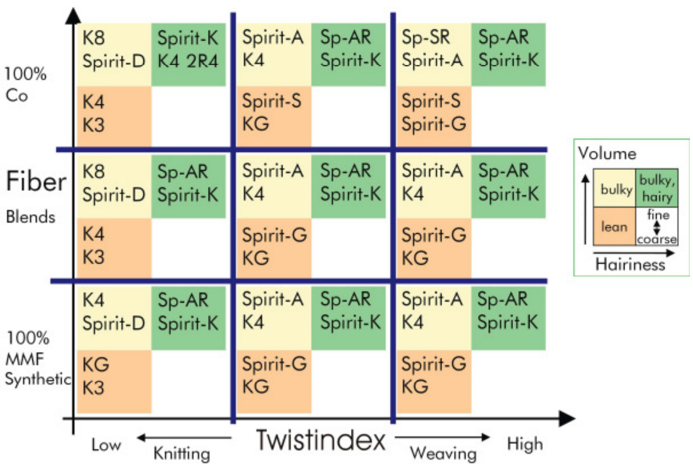

Fig. 7: Selection diagram: Optimal navels as a function of twist coefficient and fiber type

BROELL-navels of the new generation are suited for increasingly high rotor speeds. Their precise tuning of geometry and surface permits the apparent contradiction, to spin with reduced twist coefficient if the contact pressure of the yarn on the navel shell and thus the rotor speed or the rotor diameter to be increased at the same time. This is possible only due to the gentle fiber integration, fiber guidance and insertion of false twist of the SPIRIT navels.

Beside the classical navels Emil BROELL GmbH & CO developed also navels and rotors for the highly-fashionable range, which are needed to meet a certain yarn structure. The potential of the navels is by far not yet exhausted.

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