

Review Article

Impact of different stages of spinning process on fibre orientation and properties of ring, rotor and air-jet yarns: Part 1– Measurements of fibre orientation parameters and effect of preparatory processes on fibre orientation and properties

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The economic situation of the textile industry and the extremely sharp worldwide competition have forced the textile mills to use all possibilities of cutting costs. In this context, the question of higher production at each spinning sequence of machine gains importance. This demands a detailed study on the effect of spinning process variables on fibre orientation and properties of products produced out of these machines. This paper reports a glimpse on the different measurement techniques of fibre orientation parameters and impact of various preparatory processes on fibre orientation and properties.

Keywords: Drafting wave, Fibre extent, Fibre orientation, Fibrogram, Lindsley technique

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1 Introduction

Since last 60 years, numerous concepts have been introduced to characterize fibre orientation, namely straightness, fibre extent, helix angle, coefficient of relative fibre parallelization, proportion of curved fibre ends, migration parameters, etc. Several methods of investigating fibre orientation have been developed, such as the direct method¹ in which tracer fibres are viewed through a projection microscope and the indirect method²⁻⁴, such as Lindsley² and modified Lindsley³ method in which the orientation and parallelization in sliver and roving are quantified in terms of weight ratios. The orientation parameters measured with the direct method take into account the behaviour of a single fibre and extrapolate the characteristics of sliver or roving or yarn from it, which is, infact, not a realistic measure. This is due to the fact that the fibrous assembly contains a larger number of fibres whose laying and overlapping each other is of greater significance. Furthermore, both

these methods are quite old and need a thorough review or modifications. This paper reports different measurement techniques of fibre orientation parameters and impact of various preparatory processes on fibre orientation and properties.

2 Measurement of Fibre Orientation

The earliest method for the study of fibre orientation was direct method, which was based on the use of optical tracer fibre technique and ultraviolet rays for the study of hooks. In optical tracer fibre technique^{1,5}, 0.1–0.3% of tracer fibres are dyed with any dark colour dye. These tracer fibres are further mixed with parent fibres preferably during fibre mixing just before blowroom opening. Further, in optical tracer fibre technique the sliver, roving or yarn is immersed in a solution, which is having same refractive index as of parent fibres. This makes the grey parent fibres to optically dissolve while profile of coloured tracer fibres can easily be seen under a microscope. The optical tracer fibre technique can be used for the measurement of fibre orientation parameters, like fibre extent, type of hooks and hook

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extent in sliver, roving and yarn. The schematic view of a fibre seen under microscope for the extent study is shown in Fig. 1. But, this technique is very tedious and time consuming. As the parameters like fibre extent and hook extent are dependent on the length of fibre used, these parameters cannot be compared in different samples prepared from different fibre lengths.

Further, the study of fibre overlap is a recent approach to investigate the longitudinal behaviour of fibre in yarn. It was measured in terms of two newly proposed parameters, viz. fibre-overlap index (FOI) and fibre-pair-overlap length (FPO). The objective of measuring fibre-overlap indices was to get a direct interpretation of total contact length between the fibres which has earlier been interpreted from the fibre extent.⁶

However, in the UV tracer fibre technique the fibres are dyed with any commercial fluorescent dye and this technique can only be used to study the fibre orientation in the web delivered by the card, drawframe and intermediate frame after collecting the web on the black boards. In both of the above techniques, the dyeing of fibres changes the surface characteristics of the fibres. These fibres are thus expected to behave differently during processing in the spinning process. Further, both of them are quite old. Recently, a new index named fibre straightness index (FSI), which can give information about fibre straightness and is comparable for different samples made from different fibre types and lengths, is also being used. FSI is a ratio of total axial projected length of a fibre to the actual length of that fibre in a section of length observed directly with the microscope.⁶ The actual photograph of fibre used for FSI study is shown in Fig. 2. The FSI can be obtained using the following relationship:

$$FSI = n \times P / (L_1 + L_2 + L_3 + \dots + L_n)$$

where n is the no. of fibres; and P and L_1, L_2 are the fibre extent and actual length of the fibre in the section observed.

Further, this tracer fibre technique in yarn is also used to study the fibre migration in the yarn in terms of few mathematical formulae. These formulae specify overall tendency of a fibre to be near the centre or surface of the yarn, termed as mean fibre position (MFP); the rate of change of radial position, termed as mean migration intensity (MMI); and the magnitude of the deviations from the mean position or

the amplitude of the migration, termed as root mean square deviation (RMSD). The schematic view of a fibre seen under microscope for fibre migration study in yarn is shown in Fig. 3. The following formulae as provided by Hearle *et. al.*^{7,8} were used for the calculation of the migration parameters :

$$\text{Mean fibre position } (Y) = 1 / Z_n \int_0^{Z_n} y \cdot dz = (\sum_{i=1}^n y_i) / n$$

where n observations of Y were made over a length Z_n .

Mean migration intensity

$$(I) = [1 / Z_n \int_0^{Z_n} (dY / dz)^2 dz]^{1/2}$$

$$= \{ [\sum_{i=2}^n (y_i - y_{i-1})^2 / (z_i - z_{i-1})^2] / n \}^{1/2}$$

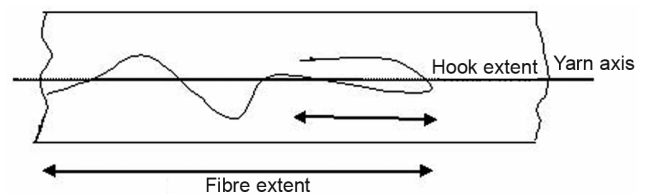


Fig. 1— Outline of a hooked tracer fibre seen under microscope

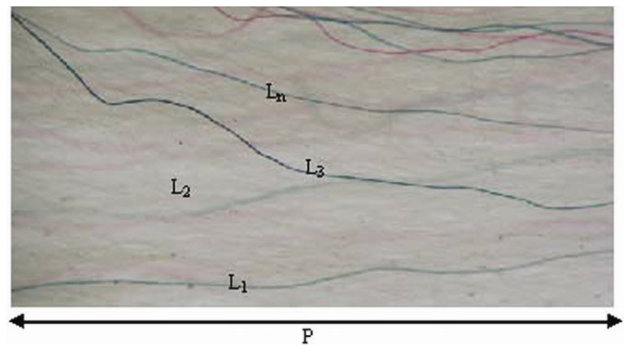


Fig. 2—Section of sliver seen under stereomicroscope at $\times 20$ magnification

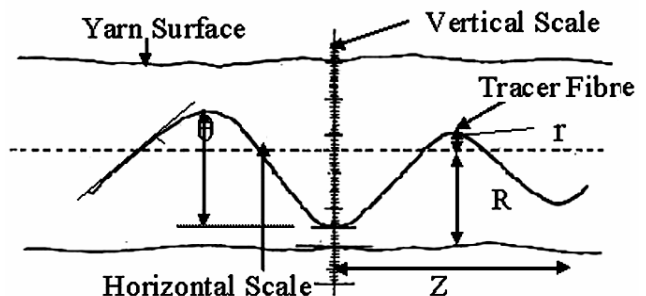


Fig. 3 — Schematic view of a tracer fibre seen under projection microscope

Root mean square deviation

$$(T) = [1 / Z_n \int_0^{Z_n} (y - Y)^2 dz]^{1/2} = \{ \sum_{i=1}^n (y_i - Y)^2 / n \}^{1/2}$$

where R_i & r_i are the i th value of yarn radius and helix radius; z_i , the corresponding values of length along the

yarn; and $y_i = \left(\frac{r_i}{R_i} \right)^2$.

Later on, indirect methods, like Lindsley and modified Lindsley, were used which gave an indirect measure of fibre orientation in terms of few coefficients in the sliver and roving. Initially, three indices were used to measure fibre orientation in sliver and roving. These were cutting ratio, combing ratio and orientation index. But, these indices failed to supply an explanation of the physical sense of these coefficients. Therefore, Lindsley's coefficients were replaced by Leon'teva by two new coefficients known as proportion of curved fibre ends 'ρ' and coefficient of relative fibre parallelization 'K_{rp}'. Here, 'ρ' indicates curved fibre ends as well as their length and 'K_{rp}' represents degree of fibre parallelization and straightening in sliver/roving. Very recently, the equation of 'K_{rp}' is being modified to 'K_{rpm}' for better measure of fibre parallelization and straightness in the sliver and roving.⁶ The schematic view of the instrument used for the study of fibre orientation by indirect method is shown in Fig. 4.

However, it has been stated that the above indices are relative measures of fibre hooks and dependent on the width of the plate used for the measurement and on the fibre length distributions of the material being measured. The projected mean length measured with a special clamping technique similar to the modified

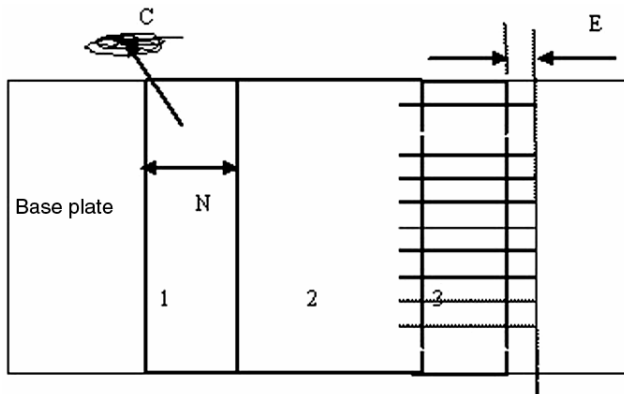


Fig. 4 — Schematic view of instrument for indirect method of study of fibre Orientation

Lindsley apparatus was found to be a good absolute measure of fibre parallelization.⁹ The various coefficients used by several previous researchers for the study of indirect method of fibre orientation in sliver and roving are given in Table 1.

Overall, the indirect method of measuring fibre orientation involves lot of manual operations on fibres which alter the actual state of fibres in tested sample and give only an approximate measure of fibre orientation. The direct methods can be used for the study of fibre orientation in sliver, roving and yarn, whereas indirect methods are mainly used for the study of fibre orientation in sliver and roving only. Furthermore, few researchers have also tried to measure fibre orientation in the sliver and roving by classical fibrogram analysis with the use of specially designed clamp. The fibrogram measure of span lengths and mean lengths are shown in Fig. 5. The beards in majority and minority hooks directions were scanned and measurements were taken for 66.7%, 50%, 5.5% and 2.5% span lengths. It was concluded that the fibrograph technique is faster than other techniques and as it also gives measure of fibre configuration comparable with the spinning process, this technique can be used to determine the fibre configuration in a sliver.⁴

Further, when 2.5%, 50%, and 66.7% span lengths were measured in the direction of majority and minority hooks in the sliver, the span length readings

Table 1—Coefficient used to measure fibre orientation in sliver and roving indirectly

Orientation parameter	Formula
Cutting ratio	E/N
Combing ratio	$C/(E+N)$
Proportion of curved fibre ends (ρ)	$E / (E+N) \times 100 \%$
Orientation index	$(1-E/N) \times 100 \%$
Coefficient of relative fibre parallelization (K _{rp})	$[1-C/(C+N+E)] \times 100 \%$
Modified coefficient of relative fibre parallelization (K _{rpm})	$\{1-(C+E)/(C+N+E)\} \times 100 \%$
Projected mean length (PML), inch	$2 \times (W_f + W_r) / (C_f + C_r + N_f + N_r + E_f + E_r) + M$

C = weight of the combed out portion under the side plates (1 and 3), E = weight of projected portion from the edge of the side plate after combing, N = weight of the material after combing and cutting under the side plates, M = weight of the material under the middle plate, W = weight of the material clamped by the edge plate after initial combing, and t = width of the clamp in inch (2").

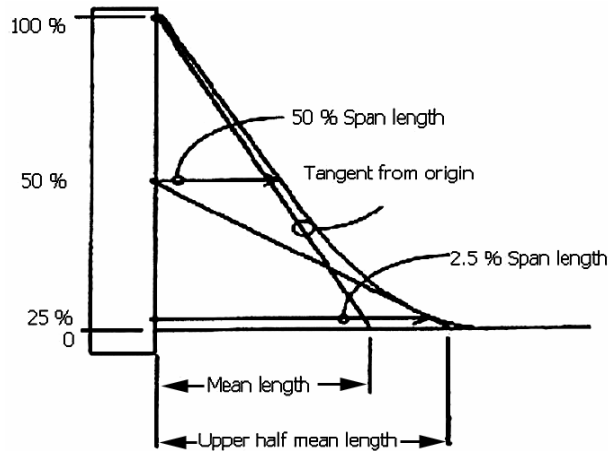


Fig. 5 — Fibrograph length measurement in terms of mean lengths and span lengths

from majority hook beards were greater than that from minority hook beards. The excess span length from majority hook beards over span length from minority hook beards was more clearly shown for the 50% and 66.7% span lengths than for the 2.5% span length.¹⁰ For constant staple length material and for fibres with low length variability the maximum span length difference between the fibrograms in the two directions becomes equal to the differential hook extent in the sliver. Also, the shape of the fibrogram is dependent upon the number and extent of hooks in reverse and forward directions. When length variability is more, the maximum span length difference is found to be different but is still closely related to the differential hook extent.¹¹

A study was conducted by Iyer *et al.*⁴ for comparing different methods of measuring fibre orientation during the processing of six selected varieties of cottons. The classical optical tracer fibre technique, UV tracer fibre technique, modified Lindsley technique, and digital fibrograph clamp technique were compared by using card and drawframe slivers and rovings both in forward and reverse directions. These methods were found to be closely related with one another, inspite of differences in the concepts of measurement of fibre hooking and orientation.⁴ A similar comparison revealed that the multiple correlation of %E, %C, %N with % hooks by visual method is 0.9534 (ref.12). It was also proved by the conclusion based on the evidence of combing ratio's that the quality of yarn is better when the majority of hooks fed to ring frame are trailing as brought out distinctly by the data on the hooks measured by tracer fibre technique.¹³

The yarn cross-sectional study was also done by several researchers.¹⁴⁻¹⁶ Hearle *et al.*⁸ derived a formula to calculate yarn specific volume based on the yarn twist and count which was further used to calculate the packing density of the yarn. The formula is given below:

Packing coefficient = Fibre specific volume(v_f)/Yarn specific volume(v_y)

$$\frac{v_f}{v_y} = v_f / (\tan^2 \alpha / 4\pi.C.T^2 \times 10^5)$$

where α is the twist angle; T , the number of turns /cm; and C , the yarn count in tex.

However, in similar context, Ishtiaque¹⁷ proposed a formula to calculate packing density of the yarn, which is more realistic and based on the helix angle, actual number of fibres in yarn cross-section and helix twist. The formula is as given below:

Packing density

$$\text{of yarn } (\mu) = 2\pi nFZ^2 / (\sqrt{1 + (\pi DZ)^2} - 1)$$

where D ($2R$) is the yarn diameter in mm; d ($2r$), the helix diameter in mm; θ , the helix angle in degree which is equal to $\tan^{-1} (\pi d Z / 25.4)$; F , the cross-sectional area of fibre (mm^2); Z , the number of turns/inch in fibre helix [Z (per mm) = Z (per inch)/25.4]; and n , the actual number of fibres in the yarn cross-section obtained by multiplying theoretical number of fibres by cosine of helix angle (θ). The theoretical number of fibres in yarn cross-section was calculated by $[5315 / (\text{yarn count (Ne)} \times \text{fibre denier})]$.

One can conclude from the above discussion that although there are number of ways to measure fibre orientation in sliver, roving and yarn, the data generated in each technique is unique. The selection of technique is entirely dependent on the objective of the study that needs to be carried out.

3 Effect of Different Spinning Stages on Fibre Orientation and Quality of Sliver and Roving

To understand the role of different spinning stages on fibre orientation and quality parameters, a significant research work has already been carried out by several researchers. In subsequent sections a brief account of those contributions has been discussed.

3.1 Effect of Blowroom Process

In cotton fibre, the purpose of the blowroom is to open the hard pressed bales into small tufts which

provide new surface for cleaning the material. However in man-mades, the blowroom is mainly responsible for the efficient opening of compact fibre mass in the bale form so that it can be processed smoothly on subsequent process stages. The efficient opening at blowroom stage not only improves fibre cleaning but also improves yarn properties, like yarn tenacity and total imperfections. However, with excessive fibre openness these parameters deteriorate sharply. The increase in imperfections at higher openness is due to over beating than that which is necessary, the fibres are stressed and damaged which then buckle and tend to form neps. The changes in fibre openness at blowroom do not appreciably influence the yarn irregularity. The yarn hairiness remains almost unchanged initially with the increase in openness at blowroom, but at higher level of openness it increases sharply. This is attributed to the overstressing of fibres at high values of openness with staple shortening and generation of short fibres. These short fibres could be the cause of increase in hairiness in yarn.¹⁸⁻²⁰ However, in a normal range of blowroom treatment the degree of opening in the blowroom greatly affects the cleaning and lint loss at carding. But it does not appear to have a significant effect on yarn quality and, in particular, on yarn strength, evenness and performance.²¹ A high degree of opening out in the blowroom reduces shortening of staple at the cards.²² Furthermore, the opening of fibres in the blowroom is essential to properly carry out the subsequent process of carding for fibre individualization, which, in turn, is essential for smooth drafting at the drawframe, roving frame and ring frame. Thorough opening of fibres is also essential for achieving a homogenous blend at the yarn stage.²³ Also, the operation of blowroom needs to be controlled depending upon the quality characteristics desired in yarn. Further, the consistency in yarn count depends on the degree of mixing or uniformity of the lap or batt produced.²⁰

The opening at blowroom is primarily dependent on linear density of the lap processed. The reduction in throughput rate/or thickness of the feed material to any machines improves the opening capability of that machine.²⁰ The heavier lap causes excessive beating at the card causing lap-ups in the card cylinder and formation of too many neps.²³ However, a good quality of sliver can be produced from a heavy lap by using high draft at card.²⁴ Further, the fibre parallelization is always high, initially when the

heavier lap is fed to the card. This is due to more carding force generated on the heavy fibre layer present on the cylinder. But, final yarn quality in terms of evenness and hairiness deteriorates.⁶

Overall the blowroom machine has influence on the opening, blending, cleaning, parallelization and distribution of the mass in the subsequent products, like sliver, roving and yarn, which, in turn, influences the quality of the final yarn also.^{25,26}

3.2 Effect of Carding Process

Carding is the most important process responsible for fibre individualization and straightness, which, in turn, affects the fibre orientation in sliver, roving and yarn. Several researchers have studied the effect of carding process parameters on fibre orientation and quality of sliver, roving and yarn. Carding is the first process where fibre hooks are formed. The type of hooks and their amount play a vital role in deciding the fibre orientation and properties of sliver, roving and yarn and their properties. The majority of fibres are hooked at one or both ends in the card sliver, and fibres having their trailing end hooked are dominant. The leading hooks are not only fewer in number than the trailing hooks, but also they are appreciably smaller.⁵ Initially, the configurations of fibres are classified in five groups, namely (i) fibres whose leading ends are hooked, (ii) fibres whose trailing ends are hooked, (iii) fibres with both ends are hooked, (iv) fibres of which neither end is hooked but are not necessarily straight, and (v) fibres which assumed any other shape unclassifiable under the groups (i)-(iv), i.e. knotted fibres, looped fibres, etc.¹

Further, the mechanism of these different types of hook formation was classified accordingly. Basically, the fibres on the cylinder remain in two positions, namely (a) those which are held in the position by their leading end being hooked round the cylinder wires, and (b) those which are not hooked around the cylinder wires but held in position with the contact and entanglement with the hooked fibres. Further when type (a) reaches the doffer, transfer takes place with relatively straight trailing ends lashed into the doffer wire point more firmly than the hooked end is held by the cylinder. Otherwise, the fibres would be drawn past the doffer, merely having their tails brushed once again. The probability of such effective lashing into the doffer wire, however, seems to be very remote. The class (b) type of fibres on reaching the doffer will be arrested at its projecting part most probably by actual contact with a doffer wire. The rest

of its length will immediately swept downwards by the rapidly rotating cylinder forming a trailing hook by carding its leading end. Thus, the above two types of fibre transfer in carding lead to majority of hooks in carding sliver as a trailing hook. The third group of the hooks may be formed in card sliver possibly due to three mechanisms. Firstly, the downward trailing ends of the fibre immediately below the doffer setting point may have their extremities slipped in to the form of a hook by the rapid passage of the cylinder wires. Second possibility is that the hooking of the leading ends is accomplished at the doffer comb. The majority of the fibres on the doffer may approach the doffer comb with relatively straightened ends projecting forward and with its downward stroke be bent forward to form hook. Thirdly, the leading hooked ends at cylinder immediately after leaving the flats, if they are held loosely on cylinder surface, may dislodge from the cylinder under the influence of air current especially below the bottom edge of the front plate. These fibres after dislodging from the cylinder approaches to the doffer with hooked ends leading and lying close to the cylinder surface though detached from it. Such leading ends conceivably passed intact through cylinder and doffer.¹ Overall, it was observed that the majority of fibres change their configuration during transfer. Hooks are formed and previously formed hooks are removed. Transfer of fibres takes place both with and without reversal of ends. The fibres that are transferred without reversal change their configurations more. Thus, the number or the percentage of leading and trailing hooks in the web depends on the balance of three factors, namely (a) number of fibres with hooks transferred from the cylinder to the doffer with or without reversal; (b) number of straight ends hooked during transfer and then transferred with or without reversal; and (c) number of hooked ends straightened out due to carding action between the cylinder and the doffer. Further, the magnitudes of (a), (b) and (c) factors and hence the number of hooks are likely to be influenced by fibre, process and machine factors.

Further, an increase in load on the operational layer of the cylinder would decrease the magnitude of positive control that cylinder wires have over individual fibres. In such a state, fibre transfer will take place more easily without reversal, leaving the leading hooks as leading hooks on the doffer surface. It was also postulated that the formation of a leading hook on the doffer during transference is caused by

buckling of the front end of a fibre. When the front end of a fibre moving with the velocity of the cylinder comes in contact with the relatively slower moving doffer surface, it buckles, and if the fibre is loosely held by the cylinder, it gets transferred without reversal. When conditions for buckling of front ends are satisfied, the probability of a fibre transferring from the cylinder to the doffer without reversal of ends would depend largely on the nature and extent of positive control exercised by the cylinder on the rest of the fibre.²⁷ Quantitatively, in card sliver 50% are trailing hooks, about 15% are leading hooks, about 15% are double hooks, and less than 20% of fibres are not hooked at all.²²

Further, several researchers have studied the effect of carding process parameters on fibre orientation and quality of sliver, roving and yarn. There are various processing factors affecting the quality of carding operation. The effects of these factors are described briefly in next few sections.

3.2.1 Influence of Card Sliver Weight

The sliver weight is changed either by changing linear density of lap feed for constant card draft or by changing card draft for a constant linear density of lap. The nature of change in the orientation of fibres in sliver shows that the increase in sliver weight, either through lap hank or through card draft, decreases the proportion of curved fibre ends and increases relative coefficient of fibre parallelization and projected mean length. This was explained on the basis of deposition of operational layers over cylinder. As coarse lap is fed or card draft is reduced, the operational layers on the cylinder increases, which results in increase in the carding force due to the increased inter-fibre friction. This ultimately increases the fibre straightening and decreases the proportion of curved fibre ends.²⁴

Furthermore, the cylinder-to-doffer fibre transfer decreases and cylinder load increases as sliver weight is decreased. At low carding rate, increased sliver weight caused smaller increase in majority hooks (trailing) but definite decrease in minority hooks (leading). Overall projected mean length decreases with the increase in sliver weight. Card web neps and yarn imperfections increase with the increase in carding rate. At lower carding rate, sliver weight has little effect on card web neps. However, at higher carding rate the coarse sliver appears to have fewer neps. Although the trend was not consistent, this could indicate a direct relationship between neps and

minority hooks. Since the heavy weight sliver had fewer minority hooks than the light weight sliver at high carding rate, the yarn imperfections increase with the increase in sliver weight. Also, the increased draft necessary to process a heavy weight sliver relative to the light weight sliver into the same size yarn caused yarn imperfections to increase. The higher carding rates also improve fibre orientation, which offset the increased short term variability of the card sliver and improves drafting, resulting in a more uniform second drawing sliver. Sliver weight and carding rate had little effect on the yarn uniformity. Overall, as the carding rate increases the strength and elongation decrease marginally. Also, yarn grade deteriorates with the increase in sliver weight and carding rate.^{24, 28-31} End breakage rates may increase with the increase in sliver weight.³¹

Furthermore, it was also reported that both fibre parallelization and fibre hooks decrease as card sliver weight increases, indicating that there are less total hooks in the heavy weight sliver than in the light weight sliver, even though the fibres in the former are less parallel than in the later.³²

3.2.2 Influence of Doffer Speed

A study conducted in Japan shows that at higher card production rate the leading fibre hooks in the sliver increase and the fibre arrangements in sliver change. A distinct rise in the number of leading hooks at higher production rates can be seen, because of the reduced peripheral speed ratio of cylinder and doffer. The number of reverse hooks decreases as the production rate increases, because of the higher tension drafts. Thus, high performance carding affects not only the carding quality but also the yarn quality.³³

Similarly, bad carding, where cylinder speed is reduced and doffer speed is increased from the normal, gives better parallelization, but the rate of improvement in parallelization in the subsequent processes is better with good carding, probably due to better fibre separation. Fibre separation seems to influence carding quality more than the fibre parallelization. Open end spinning has been found to be more sensitive to carding condition both for performance and yarn quality as compared to ring spinning. The measurement of hooks and fibre parallelization in card, drawing slivers and roving showed that the projected mean length (PML) of fibres in sliver and roving, which measure the degree

of parallelization of fibres, was higher under bad carding condition at all the stages. The values of PML with bad carding were much higher than those with good carding at card stage and subsequently as the sliver was processed through drawing and roving. This difference in PML at card stage due to carding condition gets narrowed down as the rate of improvement of parallelization in the subsequent process was high with good carding, possibly due to better fibre-to-fibre separation and degree of parallelization obtained with good carding. However, the difference in PML never vanishes completely even up to roving.³⁴ Furthermore, with the bad carding conditions the effect of increased relative speed of doffer causes reduction in majority hooks and increase in minority hooks at the card stage. Majority hooks are more under good carding at the card stage and this trend continues up to first and second drawing stages. Similarly, minority hooks are more under bad carding than with good carding condition at card stage and this trend continues up to first and second drawing. This indicates that the rate of unhooking the hooked fibre during drafting at drawing remains same, irrespective of the carding condition under which hooks are formed.³⁴

Further, the removal of neps at carding stage significantly improves with the reduction in card production rate because of the intensive carding action. At higher card production rate, neps level tends to increase further at the drawing. Inferior quality of carding at the higher card production rate may be responsible for the generation of neps at drawing. Better carding quality at lower card production rate improves the yarn tenacity.³⁵

However, an increase in card production rate increases the neps in the sliver mainly due to inferior carding quality at higher production rate. But, the number of drawframe passage after carding does not influence neps generation. Thick places and neps in ring yarn increase with the increase in card production rate. The yarn unevenness (U %), however, increases marginally with the increase in card production rate.³⁶

The above discussion reveals that the decrease in the card draft and production rate not necessarily improves fibre orientation parameters in the sliver but definitely improves the yarn properties. Apart from deciding the quality parameters at various subsequent stages the carding process also significantly affects the fibre orientation in sliver and roving.

3.2.3 Carding Force

In carding operation, the force required to individualize a tuft at cylinder-flat zone is called carding force. Increase in the load on the operational layer of the cylinder at a constant cylinder speed linearly increases the carding force. Increase in the tuft size increases the carding force due to increase in the pressure of the tuft during carding. When the fibre stock is not well opened, the increase in the coefficient of inter-fibre friction increases the carding force. When the fibres are thoroughly opened and disentangled, the carding force is influenced by the coefficient of fibre-metal friction and not by the inter-fibre friction. The changes in the carding parameters leading to an increase in the load on the operational layer of the cylinder are detrimental to the quality of carded sliver with regard to neps and regularity. The ratio between the mean carding force and the load on the operational layer of the cylinder or the mean carding force per unit load of fibre on the operational layer is a reliable index of carding quality. Increase in carding force per unit load decreases both the neps content and the U % of the sliver.³⁷⁻³⁹

3.2.4 Influence of Carding Process on Yarn Characteristics

Overall, the carding process is expected to influence the characteristics of the preparatory products and yarn quality to a considerable extent. Increase in openness by altering carding process parameters improves yarn regularity and tenacity up to a certain extent then deteriorate. Intensive opening generates short fibres, leading to uncontrolled drafting and thus rendering the yarn uneven and weak. The increase in openness of card web at lower level does not affect the yarn hairiness but at higher level of openness the hairiness increases with the increase in openness. This can be attributed to generation of short fibres.⁴⁰

Further, in case of man-made fibres, the finer and longer fibres tend to produce more neps in the yarn. Excessive beating of fibres in the blowroom, loading of licker-in or cylinder at the card, blunt wire points on various carding elements and excessive lap weight are some of the major contributory factors. The unopened fibrous neps are not only formed during opening and carding but also at all subsequent processes like drawing, roving and spinning with neps produced in blowroom and the card providing a nucleus. These neps are not only predominant but are largest among the different types of neps. These neps show a large increase as the fibre length is increased.

Further, the lack of fibre individualization and drafting irregularities are two distinct causes of slubs, thick places and neps in yarns. Inadequate number of doublings and/or unevenness of blending lead to clustering of similar fibre and results in thick faults.²³

Further, an insufficient degree of orientation, entanglement of fibres, hairiness and presence of fibre hooks facilitate the formation of neps. Breaking of fibre hooks may also cause the formation of neps during drafting. Generally, the unopened fibrous neps are progressively being reduced by blowroom and carding processes. But, after the blowroom and carding processes the new neps are formed because some unopened or entangled mass of fibres are still left in the material.¹⁹

Hence, it can be concluded from the above discussion that the process of carding drastically changes the arrangement of fibres in sliver, roving and yarn. The effectiveness of carding operation is primarily dependent on the amount of material present in operational layer on cylinder. Increasing the weight of operation layer (either by feeding heavier lap or reducing card draft) sometimes improves the fibre orientation by increasing the carding force but impairs the quality of sliver and final yarn. Further, decreasing the weight of operational layer by increasing the doffer speed increases the neps in the sliver. Also, the process of carding generates lot of hooks, majority of which are trailing followed by leading and double hooks. The magnitude of these hooks decides the amount of fibre parallelization that can be achieved in subsequent processes and, in turn, the quality of sliver, roving and yarn produced. The amounts of hooks are also dependent on weight of operational layer on cylinder.

3.3 Effect of Drawing Process

Drafting arrangement, in particular, increases unevenness very considerably. In order to achieve usable yarn characteristics, the process must include operations which give an equalizing effect. This can be doubling or leveling (drawing while simultaneously imparting twist). Doubling is still the most widely used, but leveling is becoming gradually more significant in woolen spinning mill only. Doubling is in fact a process of equalizing. Several products are fed in together in sliver drafting arrangement, where the thick places generally tend to distribute and compensate each other. In principle, every doubling is a transverse doubling also because the feeds are united side-by-side.⁴¹

3.3.1 Influence of Drawframe on Fibre Straightening and Hook Removal

It is well known that the drafting process, in general, improves the fibre parallelization, and straightens the hooks present in the card sliver. But sometime due to excessive parallelization, fibres in subsequent drawing process start relaxing. This can be observed in Fig. 6. In the drafting arrangement the fibre hooks may be embedded in the body of fibres either as leading or as trailing hooks. A trailing hook for a certain period moves with remainder of the fibre strand at the speed of back roller towards the front roller. If the fibre tip passes into the nip region of the drawing roller, the fibre is accelerated. However, since the trailing end is moving with a relatively thick body of slowly moving fibres, the fibre is straightened before the whole fibre can reach the drawing speed and the hook is eliminated. The straightening of trailing hooks at the drawframe is shown in Fig. 7. On the other hand, leading hooks are immediately caught bodily by the front roller and carried along unchanged.^{41,42} The process of straightening is improved and accelerated when the amount of draft is increased.⁴³

However, it was also postulated that the hooks can be removed in the drafting process only through frictional contact with other fibres moving at a speed different from that of the hooked fibre. The hook removal is greater when (i) the number of such contacts is larger at any instant and (ii) the entanglement and cohesion with neighbouring fibres moving at different speeds are greater. It was assumed that a hook is removed only if the other end of the fibre is positively gripped by a nip and that the floating fibres do not take any part in removing hooks. Finally, it was concluded that the probability of removal of leading or trailing hook is same. It is probably because the total number of effective

contacts from other fibres is the density of the effective fibre fringe which brushes past a hook or through which the hook brushes. This is more at any instant for the trailing hook, which therefore is removed easily. However, the leading hooks are acted on by the fast moving fibres in the region of drafting zone (i.e. nearer the back nip) where fibre density, inter-fibre friction, and fibre entanglements are higher as most of the fibres in this region are fast moving and cannot therefore exercise an effective hook-removing action on the slow moving leading hooks.¹³

Further, fibre parallelization decreases as sliver weight increases, regardless of the processing stage. The improvement in fibre parallelization from card to the first drawing sliver average more than from first to second drawing, about a 3:1 ratio. This indicates that the first drawing process is more critical than second drawing, since most of the fibre parallelization and reduction in hooks take place at this process. It was shown that the maximum fibre parallelization and hooks reduction could be obtained at first drawing by drafting the majority hooks in the trailing direction. This may be accomplished through use of unit carding system.¹³ Also, at first drawing, the trailing (minority) hooks were reduced more than the leading (majority) hooks. At second drawing, the trailing (majority) hooks were reduced more than the leading (minority) hooks. Sliver weight had no effect on hook removal for either the majority or minority hooks in few cases.³²

Further, the proportion of curved fibre ends (ρ) decreases and relative fibre parallelization (K_{rp}) and PML increase as the number of drawframe passage increases. It is interesting to note that the decrease in the value of ' ρ ' and the increase in the value of ' K_{rp} ' and PML are more up to the first drawframe passage as compared to the second drawframe passage for both the cases. But in values of degree of

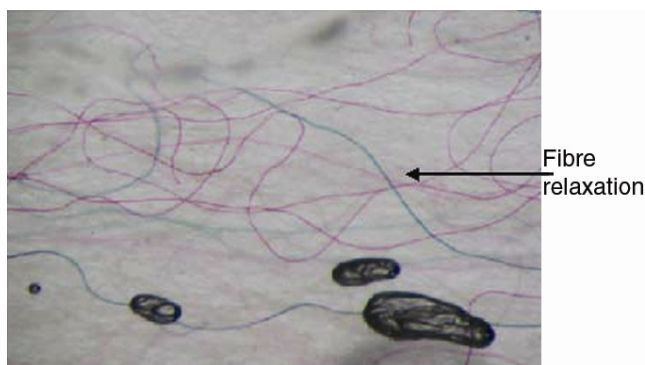


Fig. 6 — Fibre configuration in finisher sliver

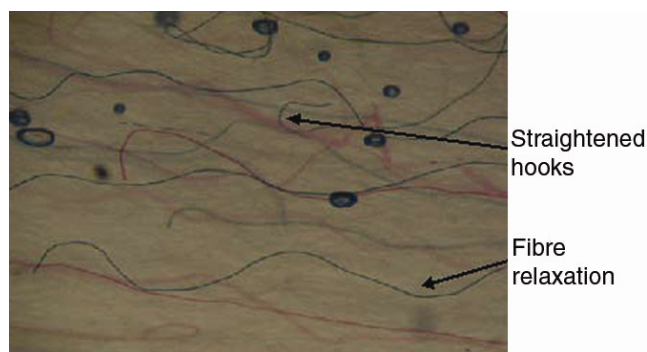


Fig. 7 — Straightening of hooks in the draw frame sliver

straightening of curved fibre ends ($E\rho$ and $E\kappa$), it is observed that the value of ' $E\rho$ ' is more between the first and the second drawframe passages. This may be due to the feeding majority of trailing hooks as trailing to the drafting system of second drawframe, which straightens out the trailing hooks during drafting.^{6,24}

Further, with the constant carding conditions, the ratio of majority hooks to minority hooks is constant for a wide range of fibre mean length and a moderate range of fibre fineness. During processing when majority hooks trails in first and second drawing, the increase in fibre parallelization over the conventional drafting direction is independent of mean fibre length.⁴⁴ Furthermore, the fibres in the sliver exhibit grouping behaviour during drafting. The grouping behaviour is directly related to the drafting performance with optimum roller setting leading to lower grouping tendencies. Fibre orientation, fibre type and the performance of earlier processes are expected to be the major factors influencing the grouping. This grouping behaviour is responsible for the use of wider settings earlier in the process line. On comparing for breaker and finisher drawings, there appears to be longer fibre groups in the finisher drawing. The longer group sizes are attributed to the drafting process orienting the fibre groups along the axis of the strand. Effects of fibre hooks and their opening in the finisher drawing also play a part in the longer group lengths observed.⁴⁵

Significant improvements in the regularity of the roving and the yarn result from the incorporation of two additional drawings. The extent of improvement varies with the type of material processed. It is interesting to note that the improvements in the evenness are not reflected in the strength of the yarn, which is nearly unaffected by the use of additional drawing. This is contrary to the earlier findings on direct sliver-to-yarn spinning frame where improved parallelization leads to better yarn strength. The results have clearly demonstrated that the improved parallelization in the ingoing (feed) material contributes to better drafting at both speed and ring frames. The use of additional drawings thus offers a convenient means of upgrading the evenness of carded cotton and man-made staple fibre yarns. When additional drawings are used with short staple material, it may be necessary to maintain the sliver hank on coarser side in order to minimize the incidence of stretch and sliver breaks at the creel of the speed frame.⁴³

Further, the rotor yarn strength increases with the increase in drawframe passages. This is mainly due to better orientation of fibre and improvement in mean fibre length at rotor groove with the increase in drawframe passages, which is due to better fibre extent in the yarn. Yarn uniformity could be improved with the increase in number of drawframe passages. Neps and thin places do not show any trend, but thick places increase with the introduction of drawframe passages.⁴⁶

3.3.2 Influence of Draft and Doublings

Apart from number of drawframes used, the amount of draft and doublings at drawframe also plays a crucial role in deciding the quality of sliver, roving and yarn. Increase in draft and doublings improve fibre parallelization, but decrease sliver uniformity. The increase in fibre parallelization over shadowed the decrease in sliver uniformity, resulting in a decrease in spinning end breakage. Total draft and doublings had no measurable effect on percentage of hook reduction. There was a slight increase in fibre parallelization and decrease in sliver uniformity with increased draft and doublings, indicating that the fibre parallelization and sliver uniformity were not directly related.³²

Furthermore, the sliver irregularity can be evened by doubling slivers together at the drawframe; however, this evening action becomes ineffective as the wavelength of the irregularity increases.⁴⁷ An 8-fold doubling in comparison to the 6-fold doubling does not cause any improvement on drafted sliver and roving unevenness % and no significant difference in the number of hooks in sliver. However, the reduction in number of hooks at roving is more in case of 8-doubling sliver. The increase in number of doublings at drawframe does not cause any improvement in mass unevenness in the ring and rotor yarns. The tensile strength clearly increases in ring yarn with the increase in number of drawframe passage because of better parallelization of the fibres, and the related increase in fibre-fibre friction. The increase in doublings also increases the tensile strength. In rotor-spun yarn, the tensile strength of the yarn produced directly from the card sliver is even higher than that of the yarn produced from drafted sliver. This proves that the parallelization of the fibres deteriorates in rotor spinning. The increase in number of doublings decreases the breaking elongation in ring yarn but the values are unaffected in the rotor yarn. An 8-fold doubling on the drawing frame leads, for both yarn

types, no detectable reduction in number of thick places.⁴⁸ However, the increased number of doublings not only improves the irregularity but also the mixing in the sliver. The best strength was achieved with a draft of eight and eight doublings, which gave only slight changes in yarn evenness and imperfections.³¹ It was also found that on drawing frame, the best overall results are obtained by using light weight slivers and a draft of eight and eight doublings.⁴⁹

In general, it can be said from the above discussion that the increase in number of draw frame passages or number of doublings improves the properties of yarn. Apart from the above two factors there are other drawing parameters, which decide the fibre orientation in sliver and hence affect the quality of yarn. These factors are discussed briefly in subsequent sections.

3.3.3 Influence of Direction of Hooks in Sliver

In general, feeding majority hooks in the leading direction contributed to more irregularities and the size of the effect was not dependent upon the draft or the count spun. Direction of feed of the hooks had no significant effect on irregularities at the can-fed speed frame under normal conditions.

Feeding the leading hooks contributes to more yarn irregularity and poorer strength, but the magnitude of the effect was nearly of the same order, with the second and third passage slivers as regards irregularity and slightly more marked with second passage sliver as regards strength. Apart from improving the fibre parallelization, the use of additional drawing also introduces a reversal in the direction of drafting of the hooked ends at the subsequent stage, and to evaluate the effect of parallelization alone, the spinning with the same feed directions must be compared. When this is done, parallelization found to contribute towards better drafting, as indicated by lesser number of irregularities and higher strengths and the improvement obtained seems to be of the same order for both the feed directions of the majority hooks at the ring frame. Favourable feed direction (obtained by reversal) has, in general, greater effects on drafting quality than parallelization (achieved through additional drawing). The difference in drafting irregularities due to fibre disorder and feed direction does not vary much with the draft. Further, the draft ratio has no effect on irregularity, a lower draft at the front zone leads to slightly better yarn strength for all input slivers. The relation between relative variance

and count shows that the effect of fibre arrangements in the input sliver on drafting irregularities is not sensitive to the count spun.⁴³

Two passages of drawing followed by can-fed speed frame are a standard processing sequence for carded counts in a modern spinning layout. This is because of the favourable drafting direction at the ring frame and the minimum processing costs associated with this system.⁴³ In general, the trailing hook must be presented to the ring spinning machine. Thus, there should be an odd number of passages between the card and the ring spinning machine.⁴¹

3.3.4 Influence of Drafting Force

The resistance met by the drafting roller when drawing a sliver is called the drafting force.⁵⁰ Basically, drafting takes place in three operating stages, namely straightening of the fibre, elongation of the fibres and sliding of the fibres out of the surrounding fibre strand. So, the force acting on the fibre called drafting force, which enables to move the fibre by pulling it from the restraining force due to relatively slow moving fibres in the back roller grip, first increases sharply. This causes straightening and extending of the fibres. Once the fibres start sliding, drafting force drops down drastically. Overall drafting force decreases as the draft increases, since a higher degree of draft implies fewer fibres in the cross-section. Besides this, drafting force is also dependent on the arrangement of the fibre in the strand (parallel or crossed), cohesion between the fibres (surface structure, crimp and finish), fibre length and nip spacing.⁴¹

Further, for a constant weight of sliver entering the drafting zone, the drafting force in one zone is inversely proportional to the draft and thus directly proportional to the number of fibres being withdrawn by the front rollers of the zone. When this number is changed by feeding a heavier sliver, the force increases more than in proportion to the weight. This is because heavier slivers are more compact. But, considering the forces in the different zones of drawframe, it is proportional to the number of fibres under the front rollers of a zone.⁵¹ However, for very low drafts, the drafting force increases first to a peak as the draft increases and then decreases.⁵² Furthermore, particularly for short fibres, a high ratio of the number of fibres in front roller nip to the number of fibres being delivered by the back roller at any instant will cause an increase in pulling force exerted by the faster fibres. But for apron drafting

systems, this ratio can be kept low enough to prevent the bunching of the fibres dragged into the front roller nip.⁵³

However, there is no relationship between the inter-fibre friction as a measure of drafting force and drafting irregularity. This is because the overall change in the inter-fibre friction would not affect the motion of the floating fibre; to do this it would be necessary to increase considerably the difference between static and kinetic frictions.⁵⁴

3.3.5 Drafting Wave

During the roller drafting of cotton, the rollers cannot set much closer than the length of the longest fibre and consequently most of the fibres are, for a time, out of the control of the rollers. These fibres are called floating fibres. The undue movement of these floating fibres is responsible for the generation of a periodic irregularity called drafting wave in the material.⁵⁵

The drafting wave is basically caused by the position of the change point depending on the number of fibres held by the front rollers. The thickness of drafted sliver then tends to vary periodically. The drafting waves in different length-wise strips of the sliver are formed more or less independently. Further, according to theory of drafting wave all the floating fibres in the part of the drafting zone just behind the front rollers are dragged rapidly forward by the fibres held by front rollers, so that a gap free of floating fibres is left in the sub-sliver. The fibres that are held by the back rollers and then move forward with back roller speed until the gap has passed into the drafted sliver. The snatching process is then repeated and caused a periodic irregularity, called drafting wave in the material.⁵⁶⁻⁵⁹ However, in apron drafting, it is considered that the irregularity due to the drafting wave is at a low level because of the control affected by the apron. However, the drafting wave is mainly caused by the varying acceleration of floating fibres.⁵⁷

Further, when high drafts are used without the employment of a special drafting system the resulting yarn is usually more irregular due to increase of drafting wave amplitude.⁵⁵ Overall, relative variance of the sliver or roving also increases steadily as the draft is increased. Further, there are two reasons why the straightness and parallelism of the fibres affect the amplitude of the drafting wave. In the first place, the greater entanglement, which occurs when the fibres are not parallel, prevents the smooth sliding of the fibres past one another and so increases the tendency

of the fibres to go forward in clumps. Secondly, in drafting, the fibres move in subgroup and the independent drafting of the length-wise strips of the sliver is more marked when the fibres are more nearly parallel. The number of sub-slivers is therefore greater, and the coefficient of variation of the drafting wave is less. For the same cotton the irregularity of the yarn is greater with the higher count; for the same count the irregularity is less when the fibres are finer.⁵⁶ Overall increase in amplitude of drafting wave impairs the quality of sliver and thus yarns.⁵⁹

3.3.6 Sliver Strength

The force required to slide past the fibres in a sliver is termed as sliver strength. The sliver strength can also be used as a measure of fibre alignment in top-making. The fibre alignment and sliver strength increase during the first and second gillings, but only a small increase during the third gilling. The principal factors determining sliver strength are: (i) fibre length and its variability, (ii) intrinsic fibre strength, (iii) fibre-alignment, (iv) fibre-straightness and (v) sliver tension during testing. But in gilling, the major changes are those of fibre alignment along the axis of the sliver and a reduction of fibre hooks.⁶⁰

However, in cotton sliver, the fibre configuration mainly affects the sliver strength. As the fibre parallelization improves with the successive passages of drawing, the sliver strength drops. In the card sliver, the inter-fibre friction and sliver strength show a positive correlation. But, as the fibre parallelization improves with the successive passages of drawing, the sliver strength drops and the difference in the strength of the sliver having different frictional values narrows. Thus, fibre orientation affects sliver strength much more than the values of inter-fibre friction.⁶¹

Further, the cotton slivers possess very lower strength and are liable to unexpected drafting and breakages during processing. If the sliver strength is not appropriately controlled, sliver and roving become uneven and frequent end breaks may occur. The carded sliver tenacity is halved after the two drawing passages. This is attributed to fibre-straightening and fibre parallelization activity in the card slivers. Further, the fibres became more straightened and parallelized, and more intimately packed in the sliver, leading to higher sliver density or lower sliver bulk. This means that the sliver bulkiness reflects the fibre straightening and fibre parallelization in the sliver. Increase in number of drawing process leads to decrease in sliver bulk and further reduction in sliver

strength along with an increase in fibre straightening and fibre parallelization. The number of drawing passages has more influence on the sliver strength than the total draft and doublings experienced by the slivers. This was probably due to the reversal of the sliver processing direction at each drawing passage that played an important role in the straightening and parallelization of the fibres. Increase in draft/doublings at the I drawframe passage increases the strength of the sliver. This effect is diminished at the II drawframe passage. The increase in number of doublings at constant drawframe draft increases the tenacity and evenness. The increase in tenacity is due to reduced improvement in terms of fibre straightening and fibre parallelization. It can be deduced from the above discussion that the sliver strength is affected by drafting conditions and fibre orientation in sliver.⁶² Further, in viscose fibre, the tenacity of I drawframe sliver is higher than card sliver, whereas II drawframe sliver is having the lowest value of tenacity.⁶ The increase in value of ' K_{rpm} ' increases the tenacity of carding and I stage of drawframe sliver, whereas trend reverses in finisher sliver due to fibre relaxation as shown in Fig. 7.

Overall, the literature on drawing process reveals that the process of drafting adds to irregularity by generation of drafting wave in the drafted material. However, the number of doublings given on drawframe reduces the amplitude of irregularity by equalizing effect. Further, fibre straightness and parallelization improve with the amount of draft but deteriorate with the increase in number of doublings given at draw frame. The fibre parallelization and straightness and added irregularity in the sliver are also dependent on feed direction of the sliver to the drawframe. Thus, the properties of sliver are governed by counteracting effect of drafting and doublings, which, in turn, affects the quality of final yarn.

3.4 Effect of Roving Process

It is well known that the drafting of cotton sliver and roving is accompanied by the increase in irregularity. Though in the drawframe this increase is not apparent as it is compensated by doubling, in the speed and spinning frames the irregularity increases at each machine until the yarn is many times more irregular than the sliver from which it was made. Further, the relation between the variance and the draft is linear and the slope of the line increases sharply as the hank feed is finer.⁵⁶

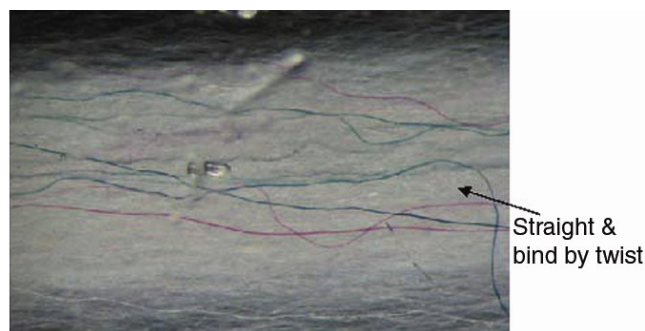


Fig. 8 —Fibre configuration in roving

However, for the best results from apron drafting, adequate parallelization of fibres must be obtained in the ingoing (feed) sliver. This is the reason why concepts of apron drafting failed in the case of drawframe. The fibres become more parallel and straighten in comparison to the drawframe sliver and do not get much chance to relax after drafting system due to the presence of twist.⁶ The state of fibres in the drafted roving is shown in Fig. 8. Further, in general the irregularities added at the speed frame are not influenced by the feed direction of the hooks in the feed sliver especially for coarse roving. But it acquires significant importance as the roving is made finer. Feeding the hooks as leading results in more irregularities in the case of finer roving.⁴³

Furthermore, the products drafted on apron drafting systems also exhibit drafting waves like roller drafting. This suggests that the drafting wave is a feature of drafting process and could originate from factors other than uncontrolled acceleration of short fibres. With cut staple fibre in particular the drafting wave could result from acceleration of leading hooked portion of the fibre which results in too early a feed for some of the fibres or from elastic movement of fibre assembly in the drafting zone. Finally, it appears that the drafting waves introduced at the speed frame are of low amplitude compared to other irregularities, and reversal and drafting at the ring frame reduce the amplitude further so that they are not seen in the yarn. Further, the yarn produced from the roller drafting is more irregular and weaker than that from apron drafting, the difference in uniformity is more pronounced than that in strength.⁶³

3.4.1 Effect of Speed Frame Draft

Draft given at the speed frame is a crucial factor affecting quality of roving and yarn. The increase in the irregularity of a fibrous product during drafting is the result of irregular fibre movements arising from the following principal factors: (i) the irregularity of

the product entering the drafting system, (ii) an unsatisfactory technical condition of elements of the drafting system, (iii) faults in its design and (iv) structural unevenness i.e. uneven distribution of fibres of different lengths in cross-section of the product. The irregular movement increases with the draft and with the difference in the lengths of the fibres in the roving. It follows that the irregular movements occur at any draft and in any drafting field and that their magnitude increases with the draft.⁶⁴

However, on speed frame drafting, the irregularity added is relatively low and nearly independent of draft.⁶³ Contrary to the above, greater the draft at speed frame, the higher will be the level of parallelism in the roving.^{6,65} The higher roving draft required for the heavy sliver influences parallelization more effectively than roving evenness.⁴⁹ In turn, the increase in draft at speed frame improves the properties of relatively poor carded material in ring and rotor yarns.⁶

Apart from the amount of draft given at speed frame, there are some other factors, which decide the quality of roving produced. These factors are described in forthcoming sections.

3.4.2 Drafting Force

In a double apron drafting system, the drafting force increased with the size of the front beard, i.e. with total draft, fibre length and speed of drafting. The drafting force is decreased as break draft and apron-to-apron spacing increased. There was a difference in the force when the roving was fed in the normal direction and then in the reverse, thus showing that the effect of fibre hooking originated at the card still persists at the spinning frame. For good spin, a certain amount of fibre tension is necessary at the front draft zone. But an excessive tension of the front beard will not always lead to optimum conditions. Further by measuring the drafting force at the front draft zone, it was possible to detect the effect of fibre hooking originated at the card. The force was higher when the majority of hooks were trailing. Further a certain amount of fibre tension is necessary in apron zone for optimum yarn properties. Generally, high values of drafting force are associated with the best properties of the spun yarn, but too high a fibre tension may lead to deterioration in yarn properties.⁶⁶

3.4.3 Behaviour of Hooks in Roving Process

The relationship between the total amount of hooks in sliver and roving for cotton is linear. Therefore, it is sufficient to analyze hooks in sliver prior to roving

as a basis for evaluating the effects on yarn properties and spinning end breakage. While converting sliver into roving, the draft (approximately 8) should reduce the amount of hooks. However, while measuring hooks by the Lindsley technique, the twist in the roving is not removed, and this hides or masks the true reduction in the amount of hooks caused by the roving draft.⁴⁴

3.4.4 Roving Strength

Apart from the parameters, which decide sliver strength, the roving strength is additionally dependent on the amount of twist inserted in the roving. The inter-dependence of twist and strength in roving may be explained by two effects. Either the fibres slip or they hold until the tension becomes too high and then break. The amount of twist determines which of these effects will occur. For small twist, parting is by fibre slippage at a low tension. As the twist increases, the strength also increases, but parting is still by slippage up to the point where the strength is equal to the combined breaking strength of all the fibres in the cross-section. This is the maximum strength; further increase in twist beyond this value means that the parting is by fibre breakage, but the strength does not increase and ultimately diminishes because of the increased angle at which fibres are inclined to the axis.⁶⁷ Further, stronger finisher sliver produces stronger roving.⁶

3.4.5 Effect of Roving Twist and Ring Frame Break Draft

The main objective of break draft is to straighten and redistribute the roving twist to a greater length before the main draft. Further, the higher twist in the roving may exert some control over the short fibres and so reduces the amplitude of the drafting wave.⁶⁸

Also, on evaluation of the irregularity of drafting roving by its performance on the ring frame, it was revealed that as the break draft is too low, the twisted roving cannot be properly drafted, resulting in increase in thick places in yarn. But as the draft ratio increases the drafting force increases and the fibre crimps and hooks are straightened, which is beneficial to improve uniformity of the drafted roving. Later, fibres slip partially but the static friction has not yet been overcome. In this zone, the drafting force reaches a maximum value with increasing fluctuations, which results in unsteady draft behaviour and thus worsens the uniformity of the drafted roving. When passing over the peak region, the fibres begin to slip before the roving is completely drafted. In this

dynamic friction behaviour, both the force and its fluctuation decrease. But it frequently causes a drafting wave in the drafted roving because of the higher draft ratio. This drafting wave remains in the yarn and tends to cause serious thick and thin places in the spun yarn. Higher break draft ratios increase the U % of drafted roving and lower the yarn quality.⁶⁹ Further, the migration of the fibres in the cross-section of the roving impairs the mixing uniformity achieved in the proceeding operations of the spinning section. This migration generally increases with the increase in twist in the roving.⁷⁰

Also, as the break draft increases there is an increase in the drafting tenacity (force required to slide past the fibres in dynamic condition) up to a maximum. This is followed by a decrease in the tenacity for further increase in break draft. This is because at lower break draft in the neighborhood of 1, the fibre density in the cross-section of roving, i.e. the fibre-to-fibre contact has not reached its maximum value. But as the break draft increases so does fibre density at back roller, until a maximum is reached, after which fibre slippage begins. On reaching this point, further increase in break draft entails a decrease in fibre contact and drafting tenacity starts to decay.⁷¹

Furthermore, tenacity increases with the increase in roving twist multiplier. However, this characteristic of roving does not always lead to the expected increase in yarn strength.⁷² Infact, the yarn tenacity increases to a maximum value then decreases as the roving twist multiplier (TM) increases. However, the yarn uniformity first increases and then decreases with the increase in roving TM in majority of the cases. This is because the increase in roving TM increases the inter-fibre friction due to more contact area, which creates problem during drafting and ultimately deteriorates the yarn quality. The imperfections in yarn do not show any regular trend.²⁹ For a given yarn count the yarn property is superior with the medium hank (about 2s Ne hank roving). Hence, the optimum draft distribution is observed which exists between speed and spinning frames from the point of view of regularity and strength.⁶³

Overall, the process of drafting at roving frame adds irregularity in roving but the amplitude of drafting wave is contained to an extent by apron drafting. Further, an increase in draft at speed frame improves yarn properties by reducing the draft required at the ring frame. High strength roving, produced with higher twist, produces higher tenacity

yarn due to less spreading of fibres in the drafting zone. However, higher drafting force is required to draft the high strength roving which may add to the irregularity in the yarn. The increase in draft at the speed frame increases fibre parallelization and reduces number of hooks due to increased drafting force acting on the fibre.

Thus, draft given at every stage of spinning preparatory plays an important role in deciding quality of the product produced on subsequent machines and ultimately the properties of the yarn.

4 Conclusions

The method of measuring fibre orientation parameters at various stages in the spinning was started in 1950s and still persisting. The modifications in various measuring techniques were done but principally the concept was almost similar. The orientation parameters have a very good correlation with the properties of sliver, roving and yarns and are useful in explaining the effect of spinning process parameters on properties.

It has been revealed that the carding is the most important process stage, which affects the properties of sliver, roving and ring, rotor and air-jet yarns. The effect of drawing and doublings at subsequent stages also plays a significant role in deciding the quality of intermediate products and yarn quality. Speed frame is also crucial process which decides the final quality of yarn. The negative effect of preceding spinning machine can be overcome by proper selection of parameters at the speed frame. Finally, the draft distribution and roving twist affect the quality of yarn and should be decided judiciously by proper optimization.

References

- 1 Morton W E & Summers R J, Fibre arrangement in card sliver, *J Text Inst*, 40 (1949) 106.
- 2 Lindsley C H, Measurement of fibre orientation, *Text Res J*, 21(1951)39-46.
- 3 Leont'eva I S, Problem of fibre straightening during sliver preparation, *Tech Text Ind USSR*, (2) (1964)57-63.
- 4 Iyer I K P, Parathasarthi M S & Sundram V, Study on different methods of measuring fibre configuration, *Resume of Papers, Twenty First Joint Technological Conference of ATIRA, BTRA, and SITRA* (Bombay Textile Research Association, Bombay, India), 1980, 12-15.
- 5 Morton W E & Yen K C, The arrangement of fibres in fibro yarns, *J Text Inst*, 43(1952) T463-T472.
- 6 Kumar A, *Effect of drafts at different stages of spinning process on fibre orientation and yarn properties*, Ph D thesis, Indian Institute of Technology, New Delhi, India, 2004.

- 7 Hearle J W S & Gupta B S, Migration of fibres in yarns: Part III-A study of migration in staple fiber rayon yarn, *Text Res J*, 35 (1965)788.
- 8 Hearle J W S, Grosberg P & Backer S, *Structural Mechanics of Fibres, Yarns, and Fabrics* (Wiley-Interscience of John Wiley & Sons, New York), 1969, 88.
- 9 Simpson J & Patureau M A, A method and instrument for measuring fiber hooks and parallelization, *Text Res J*, 40(1970)956-957.
- 10 Audivert R, The effect of fiber hooks on the digital fibrograph readings from clamped beards, *Text Res J*, 41(1971)365-366.
- 11 Balasubramanian N, Supanekar S D & Nerurkar S K, Estimation of differential fiber hooking by fibrograph, *Text Res J*, 45 (1975)296-302.
- 12 Deluca L B, An evaluation of hooked fibres in cotton sliver on a relative basis, *Text Res J*, 35(1965)858- 861.
- 13 Garde A R, Wakankar V A & Bhaduri S N, Fibre configuration in sliver and rovings and its effect on yarn quality, *Text Res J*, 31(1961)1026-1036.
- 14 Ishtiaque S M, Distribution of fibres in cross-section of rotor- and ring- spun yarns and their strength, *Indian J Text Res*, 11(1986)215.
- 15 Punj S K, Debnath S & Chowdhury A, Fibre distribution in air-jet and ring yarns, *Indian J Fibre Text Res*, 26 (2001)251-254.
- 16 Punj S K, Debnath S & Chowdhury A, Radial packing density of MJS yarns, *Indian J Fibre Text Res*, 23(1998)229-232.
- 17 Ishtiaque S M, *Selected problems of internal structure of rotor-spun yarn*, Ph.D thesis, University of Mechanical and Textile Engineering, Liberec, Czechoslovakia, 1983.
- 18 Ishtiaque S M, Chaudhuri S & Das A, Influence of fibre openness on processibility of cotton and yarn quality: Part I – Effect of blow room parameters, *Indian J Text Res*, 28(2003)399-404.
- 19 Ishtiaque S M, Influence of man-made fibres on configuration of neps, *Asian Text J*, November (1993)13-15.
- 20 Chattopadhyay R, Quality considerations in blowroom, *Advances in Technology of Yarn Production*, edited by R Chattopadhyay (NCUTE, IIT-Delhi, India), 2002, 9-16.
- 21 Bhaduri S N, Effect of openness of cotton on subsequent processing, *Resume of Papers First Technological Conference of ATIRA, BTRA, and SITRA* (Bombay Textile Research Association, Bombay, India), 1959.
- 22 Klein W, A short staple spinning series, *A Practical Guide to Opening and Carding* (The Textile Institute), 1987.
- 23 Salhotra K R, *Spinning of Manmades and Blends on Cotton Systems* (Textile Association India), 1989.
- 24 Ishtiaque S M & Vijay A, Optimization of ring frame parameters for coarser preparatory, *Indian J Fibre Text Res*, 19(1994)239-246.
- 25 Ishtiaque S M, Present blowroom practices: Scope of improvement, *Advances in Technology of Yarn Production*, edited by R Chattopadhyay (NCUTE, IIT-Delhi, India), 2002, 23-41.
- 26 Salhotra K R, Significance of modern developments in blowroom, *Advances in Technology of Yarn Production*, edited by R Chattopadhyay (NCUTE, IIT-Delhi, India), 2002, 50-57.
- 27 Sengupta A K & Chatopadhyay R, Change in configuration of fibres during transfer from cylinder to doffer in a card, *Text Res J*, 52(1982)178-181.
- 28 Simpson J & Fiori L A, Effect of mixing cottons differing in micronaire reading and carding variables on cotton sliver quality, yarn properties, and end breakage, *Text Res J*, 44(1974)327-331.
- 29 Basu A, Effect of carding on the imperfections of cotton yarns, *Asian Text J*, April(2002)74-78.
- 30 Simpson J, Relation between minority hooks and neps in the card web, *Text Res J*, 42(1972)590-591.
- 31 Sands J E, Little H W & Fiori L A, Yarn production and properties, *Text Prog*, 3(1971)34.
- 32 Simpson J, Sands J E & Fiori L A, The effect of drawing frame variables on fibre hooks and parallelization and processing performance, *Text Res J*, 40(1970)42-47.
- 33 Wolfgang T, High production carding and the quality of combed cotton yarns, *Melliand Textilber*, 65(1984)E211-E215.
- 34 Nerurkar S K, Detailed analysis of carding quality and its influence on processing and yarn properties, *Indian J Text Res*, 4(1979)63-70.
- 35 Rakshit A K & Balasubramanian N, Influence of carding conditions on rotor spinning performance and yarn quality, *Indian J Text Res*, 10(1985)158-162.
- 36 Rakshit A K & Balasubramanian N, Nep generation with polynosic fibres in relation to surface characteristics of fibre, *Indian J Text Res*, 8(1983)95-100.
- 37 Sengupta A K, Vijayaraghavan N & Singh A, Studies on carding force between cylinder and flats in a card: Part I – Effect of machine variables on carding force, *Indian J Text Res*, 8 (1983)59.
- 38 Sengupta A K, Vijayaraghavan N & Singh A, Studies on carding force between cylinder and flats in a card: Part II – Effect of fibre and process factors, *Indian J Text Res*, 8(1983)64.
- 39 Sengupta A K, Vijayaraghavan N & Singh A, Studies on carding force between cylinder and flats in a card: Part III – Carding parameters, sliver quality and carding force, *Indian J Text Res*, 8 (1983)68.
- 40 Ishtiaque S M, Chaudhuri S & Das A, Influence of fibre openness on processibility of cotton and yarn quality: Part II –Effect of carding parameters, *Indian J Text Res*, 28 (2003) 405-410.
- 41 Klein W, *A short staple spinning series, The Technology of Short- Staple Spinning* (The Textile Institute, UK), 1987.
- 42 Dzhokharidze G V, The straightening of fibre hooks on the card, *Tech Text Ind USSR*, (4) (1966)43-48.
- 43 Balasubramanian N & Bhatnagar V K, The effect of disorientation of hooks in the input sliver on drafting irregularities and yarn quality, *Text Res J*, 41(1971)750-759.
- 44 Deluca L B, Simpson J & Fiori L A, An evaluation of fibre parallelization and drafting tenacity of cotton silver, *Text Res J*, 38(1968)817- 823.
- 45 Grover G & Lord P R, The measurement of sliver properties on the draw frame, *J Text Inst*, 83(1992)560-572.
- 46 Ishtiaque S M & Saxena A, Effect of sliver preparation on fibre disorder at rotor groove, *Indian J Text Res*, 16 (1991) 233-235.
- 47 Bowles A H & Davies I, The influence of drawing and doubling processes on the evenness of spun yarns: Part IV-

- Extremely long-term variations, *Text Inst and Ind* January (1979) 38-40.
- 48 Iyer C & Mavely J, Influence of doubling number on longitudinal and transverse scattering of the yarn, optimum doubling number in modern 3-cylinder spinning processes, *Melliand Textilber* (Eng Edition), 57(1976)279-287.
- 49 Sands J E & Fiori L A, Yarn production and properties, *Text Prog*, 3(1971)35.
- 50 Anbinder S U, Fibre straightening in the drafting field, *Tech Text Ind USSR*, (4)(1969)43-47.
- 51 Foster G A R, Roller slip and the irregularity of cotton and rayon-staple drawframe slivers: Part II— The nature of roller slip and the theory of draft distribution, *J Text Inst*, 44(1953)T570-T572.
- 52 El-Sharkawy A F, Audivert R & Castellar D D, The relation between the drafting force, draft, and setting in the roller-drafting of staple-fibre slivers, *J Text Inst*, 64(1973)325-327.
- 53 Sengupta A K & Kapoor I M, Yarn evenness, *Text Prog*, 14 (1985)19.
- 54 Cavaney B & Foster GAR, Some observations on the drafting forces of cotton and rayon-staple slivers, *J Text Inst*, 45(1954)T390-T404.
- 55 Foster G A R, Fibre motion in roller drafting, *J Text Inst*, 42 (1951) T335-T374.
- 56 Cavaney B & Foster G A R, The irregularity of materials drafted on cotton spinning machinery and its dependence on draft, doubling and roller setting: Part I—The speed frames, *J Text Inst*, 45(1954) T529-T549.
- 57 Fujino K, Shimotsuma Y & Fuji T, A study on apron-drafting: Part I—Experimental studies, *J Text Inst*, 68 (1977) 131-140.
- 58 Slater K, Yarn evenness, *Text Prog*, 14 (1985) 17.
- 59 Bakhar M I, Yarn evenness. *Text Prog*, 14 (1985) 17.
- 60 Ross D A, Bratt R L & Story L F, Sliver strength as a measure of fibre-alignment in topmaking, *J Text Inst*, 53(1962) 185.
- 61 Mehta I H & Nanal S Y, The effect of varying interfibre friction on hook removal during drawing, *Text Res J*, 40(1970)1131-1132.
- 62 Miao M, Ning F & How Y, Cotton sliver strength and withdrawal speed limit, *J Text Inst*, 89(1998)468-479.
- 63 Balasubramanian N, A study of the irregularities added in apron drafting, *Text Res J*, 39(1969)155-165.
- 64 Nemzer G M, Reducing irregularity in sliver, roving and yarn, *Tech Text Ind USSR*, (2)(1961)66-73.
- 65 Sippel A, The relationship between minimum twist of cohesion and cutting ratio in cotton rovings, *Text Res J*, 35(1965)283-288.
- 66 Audivert R, Villaronga M & Coscolla R, Drafting force in the front zone of a double apron drafting system, *Text Res J*, 37(1967)1-10.
- 67 Hannah M, The theory of high drafting, *J Text Inst*, 41 (1950) T57-T89.
- 68 Anderson S L & Foster G A R, The irregularity of materials drafted on cotton spinning machinery and its dependence on draft, doubling and roller setting: Part II—The spinning frame, *J Text Inst*, 46(1955)T551-T564.
- 69 Su C I, Evaluating uniformity of drafted roving, *Text Res J*, 69(1999)630-634.
- 70 Tikhomirova A I, Investigation of transverse sections of roving and yarn, *Tech Text Ind USSR*, (3)(1970)43-46.
- 71 Audivert R, ABC's of drafting tenacity, *Text Ind*, 133(1969)125-189.
- 72 Barella A & Sust A, Cohesion phenomena in rovings and yarns: Part IV- Cohesion of twisted rovings, its effect on yarn properties, *Text Res J*, 35(1965)491-496.