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A STUDY ON SPINNING LIMITS AND YARN PROPERTIES WITH PROGRESSIVE CHANGE IN YARN COUNT IN FRICTION SPINNING

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Abstract:

The spinning limit for three different fibres (cotton, viscose rayon and polyester) on a Dref-3 friction spinning machine has been investigated. The change in yarn properties with progressive change in count has also been reported. The count range has been seen to be dependent on fibre type. As one progresses from very coarse to fine counts, the yarn tensile property remain fairly unaltered for cotton, but changes for polyester and viscose yarns.

Key words:

spinning limit, Dref-3, friction spinning, yarn property, twist

Introduction

Every spinning system produces yarn over a certain count range, and the limit of this range varies from system to system. As an example, in ring spinning the technologically possible range is 295 tex (2^s N_e) to 3 tex (200^s N_e) and for rotor spinning 590 tex (1^s N_e) to 10 tex (60^s N_e). However, the technologically possible count range differs from the economic or commercially viable count ranges. The commercial count range is usually narrower, and is limited by quality and cost considerations. The range of count that can be successfully spun and the type of fibres that can be processed testifies to the capability of the spinning system and possibilities of its commercial success. Modern machine manufacturers constantly aim to extend this count range so that it overlaps the medium count range (between 20^s Ne and 30^s Ne) where maximum production takes place for better market penetration. The following figure shows the economic count ranges of different spinning systems [5]:

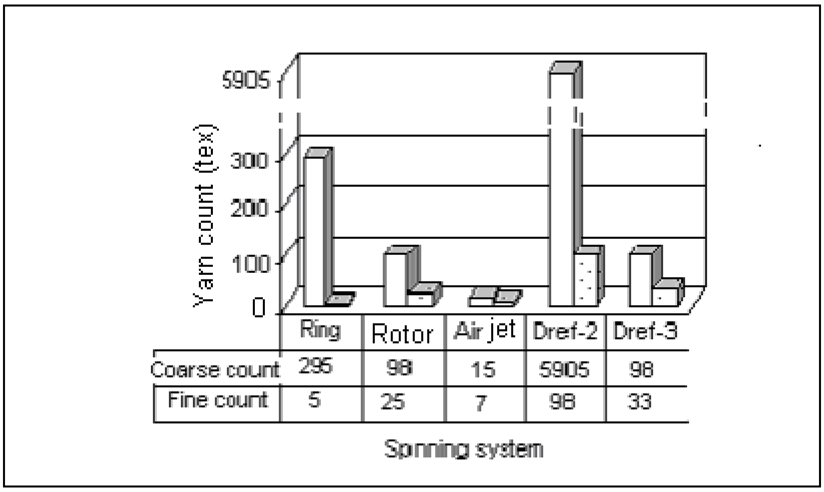

Fig.1 Economic count ranges of different spinning systems

The spinning limit usually refers to the production of the finest yarn count from a given fibre with acceptable qualities and an end breakage rate below a tolerable threshold. The commercial value of a fibre depends upon its spinning limit. It is important to know why a system fails to spin beyond a certain count on both the coarser and finer sides. A clear understanding of the mechanism of yarn formation and the way the fibre parameters interact with the spinning process can lead to further improvement in the machine design with a view to widening the count range. Many people have worked on spinning limits for ring and rotor spinning [2-4,6,7,10,13]. had The focus of their studies has been to determine the spinning limits and the influence of process and fibre parameters on spinning limits. Similar work on friction spinning is limited [1].

According to the manufacturer [11,12], friction spinning (both Dref-2 & Dref-3), can produce yarn within the following count range:

Dref-2:	5905 tex - 98 tex	(0.1^s N_e – 6^s N_e)
Dref-3:	98 tex - 33 tex	(6^s N_e – 18^s N_e)

It appears that Dref-2 is intended for coarse count and Dref-3 for coarse to medium count yarns. However, no report exists which states the technologically possible count range or its dependence on type of fibre. How do the yarn properties deteriorate as the count becomes finer? The aim of the present work is to investigate the technologically possible spinning limits and to understand what restricts the count range.

Materials and methods

In the present study, three types of fibres, polyester (1.2 den, 44 mm), viscose (1.3 den, 51 mm) and cotton (4.1 micronaire, i.e.1.57 denier, 28 mm), were used to produce yarns on a Dref-3 friction spinning machine using the Dref-3 mode. The drum and delivery speed were kept constant at 3000 rpm and 130 m/min respectively. The core/sheath ratio was kept constant at 70:30. For the production of the yarns, one sliver was fed through drafting system 1 and an appropriate number of slivers were fed through drafting system 2.

Determination of spinning limit

The machine was started, maintaining the feed rate at an arbitrary level so that a yarn can be produced successfully for a period of at least 10 minutes without encountering breaks. The yarn was collected and the count determined. Next, the feed rate was gradually changed in steps so as to produce yarns which were either coarser or finer than the previously spun yarn count. The process was continued until a count was reached both on the coarser and finer sides when spinning became practically impossible, i.e. when 5 minutes of continuous spinning without any end break was possible. These terminal yarn counts are termed as the spinning limits. In this way both the coarsest and finest count limits were determined. All the yarns spun were collected and count values determined. The yarns counts thus spun are shown below (Table 1):

Table1. Spun yarn counts

Spinning mode	Yarn count (tex)		
	Polyester	Viscose	Cotton
Dref - 3	**148**, 118, 98, 59, 42, 33, 31, 29, 28, 27, **25**.	**197**, 148, 118, 98, 59, 42, 33, 30, **28**.	**311**, 148, 98, 59, 49, 42, 37, **33**

(*The **bold** figures indicate the count limits*)

Yarn evaluation

The yarns spun with the three types of fibres mentioned above were evaluated for their physical and mechanical properties.

Tensile properties

Single-yarn strength and breaking extension were measured on a Zwick universal testing instrument using a 500-mm gauge length and a 150-mm/min extension rate. The tests were performed in the standard atmosphere of 65 $\pm$ 2% R.H. and at $27^0 \pm 2^0$c temperature. A minimum of 35 observations were made for each sample in order to obtain a 5% error of estimation. The tenacity and breaking extension values were recorded, and then the average value and standard deviation were calculated. The results were also tested for significance.

Unevenness

The yarn unevenness was determined on an evenness tester using a test speed of 100 m/min for one minute. Ten readings were taken for each sample, and the average values of U%, thin and thick places and neps were calculated.

Twist

The yarns were evaluated for twist. The twist measurement was carried out following the twist-to-break principle. A yarn of 254 mm length was gripped between the jaws of the twist tester and first twisted in the direction of original twist of the yarn. Twisting was continued until the yarn broke; the number of turns required to break the yarn (N_1) was noted. The test was repeated with twisting in the opposite direction to that of the original twist, and again the number of turns required to break the yarn (N_2) was noted. The yarn twist was then calculated by using the following relationship:

$$twist\ (turns\ /\ m) = (N_2 - N_1) \times 39.37$$

At least 50 observations were made, in order to have a 5% error of estimation. The average of such readings were taken as the twist value.

Result and discussions

Yarn unevenness and imperfection

The unevenness responds differently for the yarns spun from three different fibres. For polyester, it at first reduces, and then increases as the count becomes finer. With viscose, a similar observation can be made, although the rise beyond minimum is not as significant, and for cotton it increases with count. The reason for such behaviour lies with the fibre separation process in drafting unit II, the arrival of the separated fibres on the friction drum, and the irregularity generated in drafting unit I on the fibres which form the core part of the yarn.

When the yarn is too coarse, fibre throughput rate is very high. The individualisation of fibres by the opening rollers becomes difficult. Fibres therefore arrive on the friction drum in agglomerate form, i.e. in clusters.

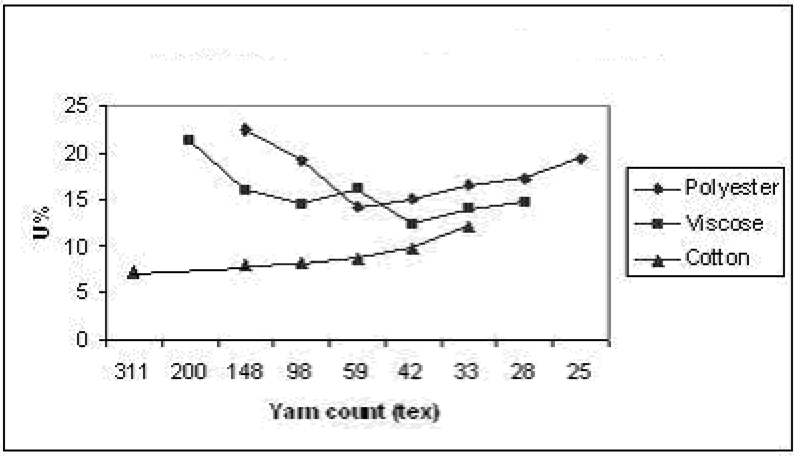

Fig. 3 Variation of unevenness of yarns with count

The individualisation action by the opening rollers will also be fibre-dependent. Polyester and viscose, which are long and fine, are more difficult to separate than cotton, which is relatively short and contains many short fibres. The kidney bean-type cross section in cotton prohibits close contact between the fibres, and so resistance to opening becomes less. Between polyester and viscose, polyester would be more difficult to open, as the frictional drag between polyester fibres can be expected to be greater than that of viscose. The round cross-sectional shape of polyester facilitates adherence among the fibres, resulting in increased frictional resistance to opening. Hence in the case of polyester, clusters of unopened fibres are likely to land on the friction drum, especially when the count is very coarse. The long length of polyester and viscose would cause them to land on the friction drum in more deformed forms. This is why the very coarse polyester and viscose yarns are highly uneven (Figure 3). The core part of the yarn will become progressively more irregular as the yarn becomes finer, as more and more drafts will act on the fibres in drafting unit I. The influences of the two factors of individualisation and drafting irregularity thus seem to counteract each other, and a minimum is observed for polyester and viscose yarns. As cotton is easy to individualise, the coarse

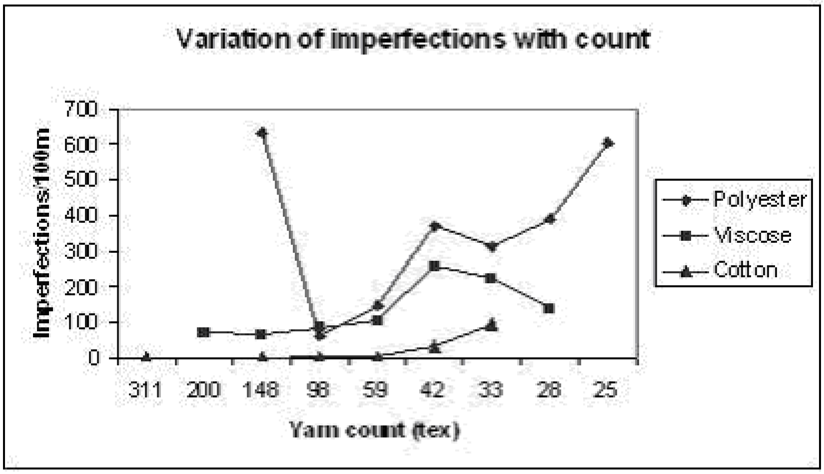

Fig. 4 Variation of imperfections in yarns with count

count yarns are not irregular, and the irregularity generated by drafting unit I dominates the overall irregularity of the yarn.

In general, the imperfection level is found to increase with yarn fineness (Figure 4), which is primarily due to the increase in neps. The exceptionally high value of neps for the coarsest polyester yarn may be due to extremely poor fibre individualisation, which also makes the yarn very irregular. However, this is not seen for viscose yarn. As the yarn becomes more and more irregular, the imperfection level increases.

Twist

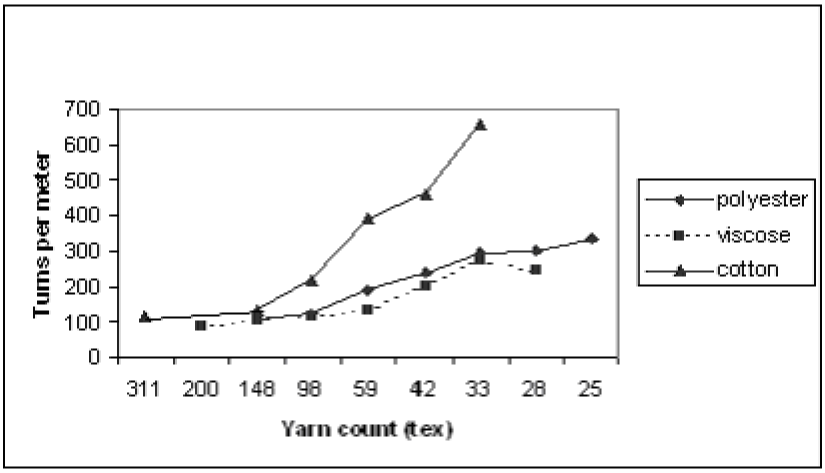

Fig. 5 Variation of twist in yarns with count

The twist is seen to increase with yarn fineness (Figure 5) for all the fibres, and a similar observation can be made with respect to twist multiplier (Table-2). The increase in twist with the increase in yarn fineness is due to the progressive increase in the ratio of the yarn tail to the friction drum diameter. For the same count, the twist is maximum in cotton yarn, followed by polyester and viscose yarns. The twist is dependent not only on the diameter of the yarn tail but also on the friction coefficient between the fibres and the drum, as well as the force with which the fibres are pressed against the drum. Since the fibres are not positively gripped between the drums, there is always a chance of slippage between the fibres and the drum surface.

Table 2. Values of twist multiplier for different yarns

Yarn count (tex)	Twist multiplier (tpcm tex ½)		
	Polyester yarn	Viscose yarn	Cotton yarn
311	-	-	19.8
200	-	12	-
148	13.3	12.9	16.4
98	12.5	11.1	21.9
59	14.8	10.1	30
42	15.5	13.0	30.1
33	16.9	15.9	37.7
28	15.9	12.9	-
25	16.6	-	-

For the same mass of fibres, the cotton with the highest density (1.54 g/cc) will occupy the minimum volume, and therefore the diameter of the yarn tail will be minimum, resulting in the highest twist. As the viscose fibres are too long and flexible in comparison to cotton, most of the sheath fibres will be highly deformed, and the overall diameter of yarn tail on the friction drum will be larger than that of cotton. Hence viscose yarns show lesser twist than cotton. Polyester will occupy the maximum volume as the density is minimum (1.38 g/cc), and should have minimum twist. However, the spin finish on polyester usually leads to very high friction against the friction drum which probably causes less slippage of the yarn tail on the friction drum, and hence the twist observed in it is greater than that of viscose.

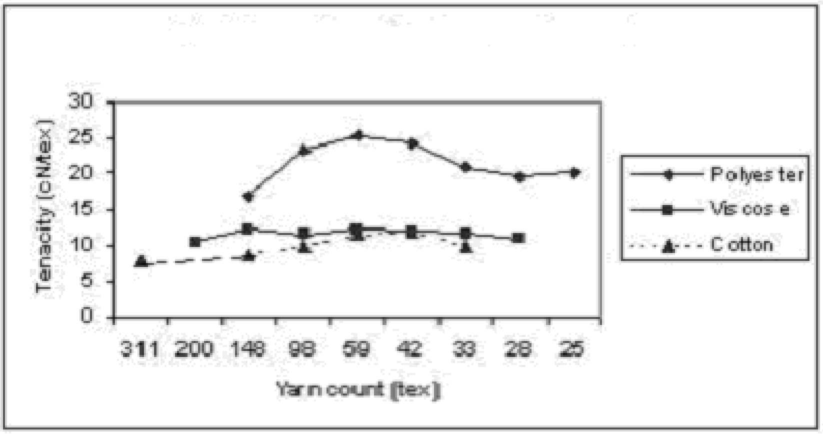

Fig. 6 variation of tenacity of yarns with count

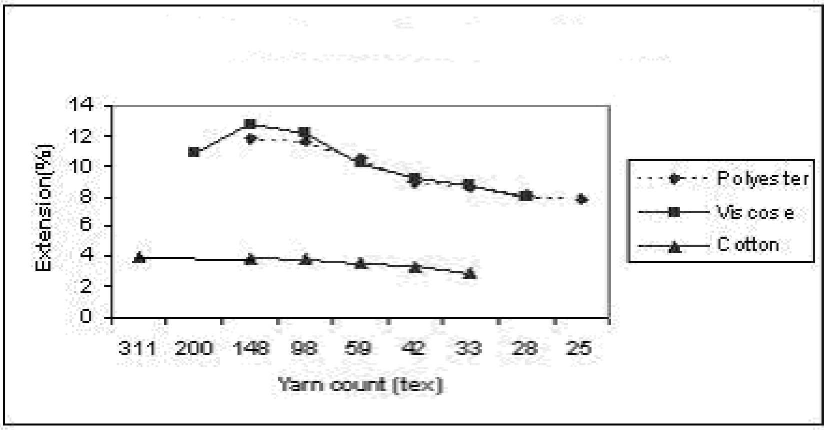

Fig.7 Variation of extension of yarns with count

Tensile property

The tensile properties of any spun yarn depend upon the properties of its constituent fibres, the arrangements of these fibres within the yarn (i.e. on the yarn structure), and the mass distribution of yarn along its length. The structure is primarily decided by the yarn formation mechanism and the process parameters. Dref-3 yarn has a core-sheath type structure. The core, consisting of straight and parallel fibres, is false-twisted between the friction drums and the sheath fibres are wrapped around it. Part of the false twist in the core remains trapped by the sheath fibres. The proportion of core fibres, tightness and density of sheath fibre wrapping and its proportion play a decisive role on the overall strength and extension of the yarn.

The change in tensile properties with count for polyester, viscose and cotton yarns spun is shown in Figures 6 and 7. The three fibres can be seen to respond in different ways. For polyester yarns, the tenacity initially rises and then reduces as the count becomes finer. The optimum for the present polyester fibre is seen to be around 60 tex (i.e. 10s Ne). For viscose fibre, the tenacity remains constant over the range of counts produced; and for cotton, a slow steady rise in yarn fineness can be observed. The breaking extension for polyester and viscose yarns decrease significantly with yarn fineness (from 12% to 8%), and the maximum value is observed at 148 tex (4 Ne). However, the coarsest polyester yarn showed a reduction in extension in comparison to 148 tex yarn. Nevertheless, for cotton, a marginal decrease in extension with fineness is observed.

Therefore, one can broadly state that in the cases of cotton and viscose, the tenacity is not affected much as continuously finer yarns are made. But for polyester, there is an optimum count where tenacity reaches the maximum. The breaking extension remains fairly similar for cotton, but for polyester and viscose it gradually reduces with fineness.

It has been reported that the individualisation action accomplished by the opening roller teeth causes fibre damage, and thus a loss in fibre tenacity and elongation [8,9] due to the vigorous abrasive action of its teeth on the fibres. It has been found that the loss of tenacity and extension is maximum for cotton (7.6% and 8.1% respectively). The extension loss is significant for viscose rayon. A similar loss in breaking extension and tenacity was also reported by researchers [8]. Inadequate opening and long fibre length can considerably reduce the sheath fibre‘s extent on the drum surface, which makes it difficult for the friction drum to wrap the core with sheath fibres effectively.

For a yarn spun from a given fibre, an increase in tenacity is usually associated with an increase in breaking extension, that is, the tenacity and extension are expected to respond together in a similar fashion. This is observed for polyester yarn. The initial rise in tenacity with count can be ascribed to better yarn formation due to the reduced number of fibres in the yarn formation zone and the arrival of increasingly well-individualised fibres to form the sheath. This is also reflected by the reduction of unevenness values of the yarns. Besides, more wrapping twist will also have a beneficial effect on tenacity. The fall in tenacity beyond the optimum count for polyester could be due to the increased unevenness of the polyester yarn.

Viscose yarns should behave like polyester yarn, but too long a length (51 mm) of viscose fibres and its low modulus might caused the sheath fibres to descend on the friction drum in a more deformed state. As a result, the sheath fibres become wrapped in a deformed state restricting the reinforcing effect. Thus the tenacity does not rise, even though the yarn becomes regular and twist increases. The reduction in yarn extension with yarn fineness may be due to progressively greater loss in extension in fibres due to the reduced throughput in the finer yarns.

Although the cotton yarn becomes more irregular as the count becomes finer, the tenacity does not decrease because the concomitant increases in twist multiplier (see Table 2) compensate the loss, and cause a slow but steady increase in tenacity. However, the increased twist multiplier does not increase the breaking extension as the possibility of fibre damage due to the opening action increases with fewer throughputs for finer yarns. Hence the breaking extension of cotton yarn reduces with fineness.

Spinning limit

The range of yarn counts which were successfully produced under identical process conditions from three different fibres are shown in Figure 2. A strict comparison between three fibres is not possible as they are not exactly identical in their physical parameters, i.e, length and fineness. Cotton has the widest possible count range, followed by viscose rayon and polyester.

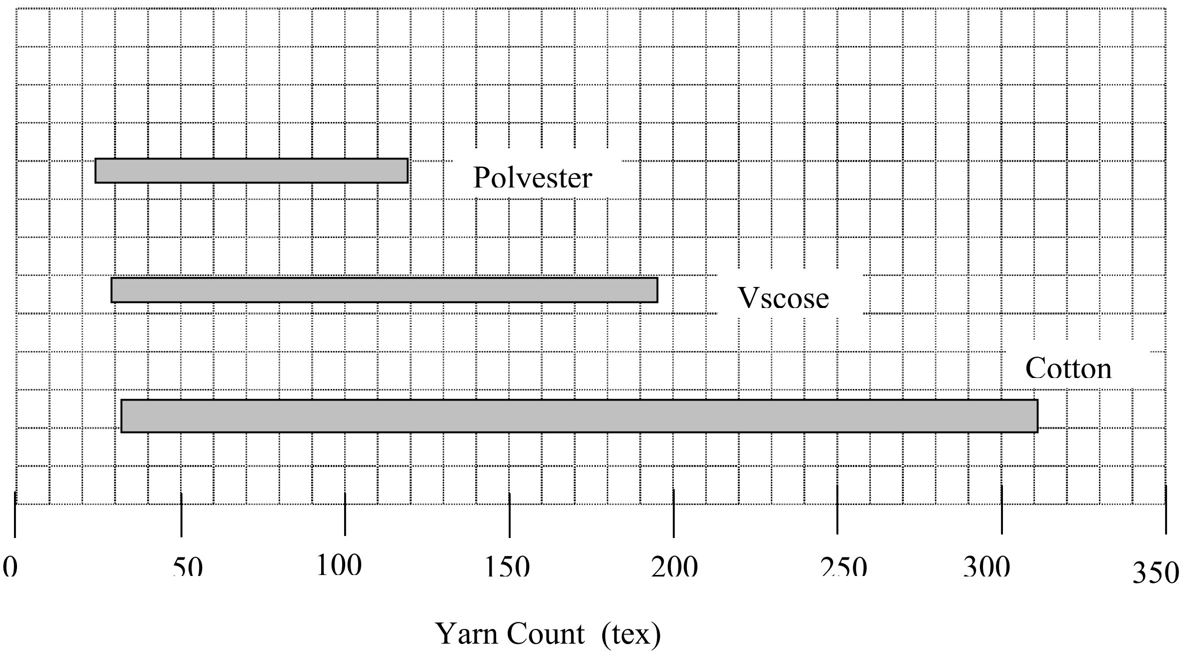

Figure 2. Representation of possible yarn counts produced

The coarse count limit is different for the three fibres. For cotton it is around 300 tex, and for viscose rayon & polyester they are 197 tex and 118 tex respectively. The fine count limits are close to each other for all the yarns (i.e. around 30 tex).

As already stated, when we go to produce coarser yarns, the fibre throughput rate increases. which causes fibre separation to suffer. This will be manifested more for long and fine fibres, as well as fibres with higher coefficient of friction since frictional resistance to opening will increase. Long fibres are likely to deform more as they land on the drum and experience sudden deceleration. As a result the sheath fibre extent reduces. It is more difficult to have effective wrapping by deformed unopened fibres. Cotton, which is easier to open and has many shorter length fibres (which causes them to deform less), can continue to produce yarn up to the count of 300 tex. Polyester and viscose in comparison suffer, due to their insufficient opening and more deformation.

It appears that the number of fibres in the yarn cross-section plays a dominant role in deciding the fine count spinning limit. Once the total number falls below a critical value (200), spinning becomes impossible due to a lack of adequate cohesion between the core fibres and effective wrapping by a few sheath fibres (60) .

The finer count spinning limit for all the fibres is relatively low, as much finer yarns can be produced from the same fibres on a ring spinning system. The presence of deformed fibre shapes, wrapping under low spinning tension and insufficient interlayer migration do not allow a friction yarn to be spun as fine as ring yarn. The possibility of the accumulated fibre mass passing through the nip aperture of the two drums and the low twist efficiency may also limit the finest spinnable count. On the coarser side, too much accumulation of fibres in the nip area may cause suction force to be ineffective on many fibres, as many of them would be away from the suction slot position. This will make consolidation and wrapping or twisting action difficult. Therefore furthering the coarse count limit may also be difficult.

Conclusions

From the study the following conclusions can be drawn:

1. For polyester and viscose fibres, there is an optimum count range where most uniform yarn can be produced. For cotton, however, coarser yarns are more regular.
2. Imperfections usually increase as the yarn becomes finer.
3. Twist values increase with yarn fineness.
4. The response of tenacity to change in count is little for cotton and viscose yarn, but for polyester an optimum count is observed where the tenacity maximises.
5. Spinning limit is widest for cotton followed by viscose and polyester yarn.
6. Fine count limits are fairly similar. However, the coarse count limits differ from each other.

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