A COMPARISON OF THE PROPERTIES OF RING-SPUN AND ROTOR-SPUN YARNS

BY

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DEDICATION

This research project is dedicated

to my mother, Eunice .... !

"you are really motherly",

and my fiancee,

CERTIFICATION

This dissertation entitled "A COMPARISON OF THE PROPERTIES OF RING SPUN AND ROTOR SPUN YARNS" by John Abdullahi Braimah meets the regulations governing the award of the degree of Master of Science in Textile Science and Technology of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Ring and rotor yarns were spun from a blend of cotton fibres using a range of almost similar twist factors. A study was carried out to assess the influence of twist on the physical properties of the two types of yarn, and to use these results to draw a comparison of the properties of the rotor-spun yarns against those of the equivalent ring-spun yarns.

From the results obtained it is clear that in addition to the influence of twist, other factors such as fibre properties and machine design also have an influence on the properties of the respective yarns. It is shown that slight changes in twist level influence yarn strength more than yarn breaking extension. Furthermore, the uniformity and linear density of the ring-spun yarns are appreciably influenced by twist level, whereas the rotor-spun yarn is relatively unaffected. Yarn faults and imperfections tend to increase with twist and it is evident that ring-spun yarn displays superiority in terms of strength compared to its rotor-spun equivalent. Finally, the coefficient of twist variation in rotor spun yarns is shown to be higher than that of the equivalent ring-spun.

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CHAPTER 1

Introduction

Undisputedly, the advent of open-end spinning gave a fresh impetus to spinning technology as well as to fabric design. After nearly two decades since its commercial debut, open-end spinning has shown steady development to the point where, in 1981, rotor represented some 70% of the world's total short staple spinning capacity (expressed on a yarn weight basis).[1]

The main areas of development have been primarily improvement in productivity, yarn quality and the range of application of rotor yarns. The range of counts and types of fibre that can be processed has been extended. . Each fibre type tends to present its own problems during processing, and the parameters within each process and the subsequent yarn properties are to a great extent dependent on the properties of the fibres themselves.

While it is true that perfectly uniform yarns have always been a spinner's dream, and regular (good quality) yarns remain fabric manufacturers' anticipation, the efforts of textile engineers and machinery experts have always been geared towards the satisfaction of these extremes.

It is evident that there has been considerable research carried out on the conventional method of spinning, and open-end spinning in terms of economic gains on the one hand, and the properties of their respective yarns on the other. Whilst ring spinning is still regarded as the most efficient method of spinning a yarn, it is still the most costly process of any in yarn production. It is generally agreed that open-end spinning offers significant economic advantages over

ring spinning for the following reasons:

(i) higher speed
(ii) lower power costs
(iii) lower labour costs.

It is also agreed that rotor-spun yarns are more even, have fewer imperfections and faults, have higher extensions, have lower variations in strength, are less hairy and have better abrasion-resistance than carded ring-spun yarns. However, a rotor-spun yarn is weaker and harsher than an equivalent ring-spun yarn. The advantages of rotor spinning are, however, not always realised since the properties of rotor-spun yarns are greatly influenced by small changes in spinning conditions such as rotor speed and doffing tube characteristics, and small differences in processing conditions which, together, probably explain the many contradictions that appear in literature concerning rotor-spun yarn properties vis-a-vis ring-spun yarn properties.

Furthermore, it has been suggested[2,3,8] that open-end rotor-spun yarns should not always be compared with ring-spun yarns, but should instead be considered as different types of yarns that are suitable for certain types of fabric with a character of their own. This has been said to be so because of the differences prevalent in methods of production and in their ultimate physical structure. Nevertheless, experiments have confirmed[2,3] that cotton needs up to 20%, polyacrylic fibres 100%, and polyester/cotton up to 50% or more twist in open-end spinning than in ring-spinning. On the other hand, rayon could be produced with about the same twist as ring-spun.

It is proposed in this project to produce from cotton a range of ring- and rotor-spun yarns with similar linear densities, but different twist factors, and to assess their spinning performance.

After this has been achieved, it is then intended to study fully the influence of twist on some yarn properties such as imperfection, count, structure, regularity, strength and extension. Furthermore, a critical survey of those areas of literature which are of immediate relevance to the project is carried out, so that in the long run a comparative analysis of the effect of twist on the properties of ring-spun yarns vis-a-vis those of rotor-spun yarns is made and discussed in the light of other existing evidence concerning this area of study.

It is also intended to study the weaving characteristics of the range of yarns assessed in this dissertation and to assess various fabric properties. This part of the work is being undertaken by my colleague, Mallam H.D. Ibrahim.[72]

CHAPTER 2

Literature Review

2.1 The fundamentals of ring and open-end spinning

In this section a brief review of the techniques of both ring- and open-end spinning is given.

2.1.1 Ring spinning

Ring spinning is a process by which non-conventional yarns are made.[4,5,6] It generally entails the passing of a roving between a succession of drafting rollers, so that eventually the number of fibres in a unit cross-sectional area is reduced to the desired number to give the required count. As the fibrous strand leaves the nip of the front roller, twist is inserted through a revolving traveller driven by the action of the yarn and a rotating spindle. The traveller is pulled round the ring by the yarn at a speed which is automatically lower than that of the bobbin by whatever amount is necessary to wind-on the yarn that is delivered. After spinning the yarn is normally re-wound onto a bigger package for convenience in further processing. In Fig. 2.1 is shown an example of the ring-spinning process.

The use of very high speeds in ring spinning is said[6] to be limited by the following factors:

(a) yarn delivery rate
(b) yarn ballooning
(c) end-breakage rate
(d) yarn strength
(e) traveller speed.

It has been stated[7] that the maximum spindle speed on a ring

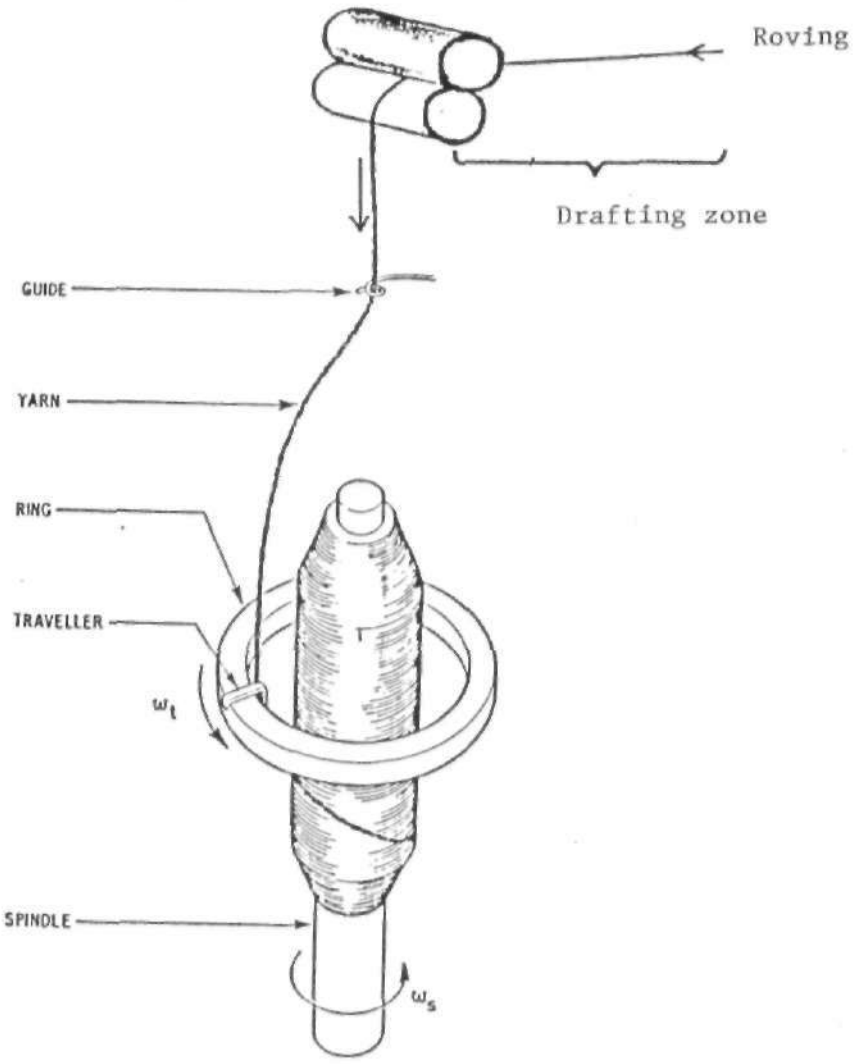


Figure 2.1 The Ring Spinning Process

frame rarely exceeds 16,000 rpm (and is commonly at 10,000 rpm), since the power consumed in rotating even a small yarn package makes it uneconomic to use speeds above this figure. It was further stated that the ring frame has virtually assumed its development peak as a result of this limitation.

2.1.2 Open-end spinning

The Shirley Institute[7] classified the different "break-spinning" devices into four groups, the classification being based on the nature of the fibre assembly in each device and these were:

(a) vortex assembly system
(b) axial assembly system
(c) discontinuous assembly system
(d) continuous circumferential assembly system.

Generally, the basic principle behind open-end spinning is the addition of fibres to a point in the material being spun where a break or an open-end has been introduced. Because of the open end it is possible to insert twist by rotating the yarn end at the "break".

The phases in an open-end spinning operation generally comprise:

(a) drafting
(b) fibre transport
(c) fibre condensation
(d) twist insertion
(e) yarn removal
(f) winding of the yarn.

By virtue of the isolation of the twist insertion phase from the yarn winding phase (which is not the case in ring-spinning), twist insertion has been made possible merely by rotation of the open end, and because of this, speeds as high as 30,000 rpm to more than

80,000 rpm have been achieved in rotor spinning. This represents about 3- to more than 8-times the linear production speed of a conventional ring-spinning machine.

In the literature it is reported[1] that the intensive development phase of open-end rotor spinning which characterised the 1970's has reached a plateau now. The physics and engineering of the rotating mass of the rotor and the effects of the centrifugal force on yarn tension would probably limit further substantial speed increases.

A schematic diagram of the open-end rotor spinning technique is shown in Fig. 2.2.

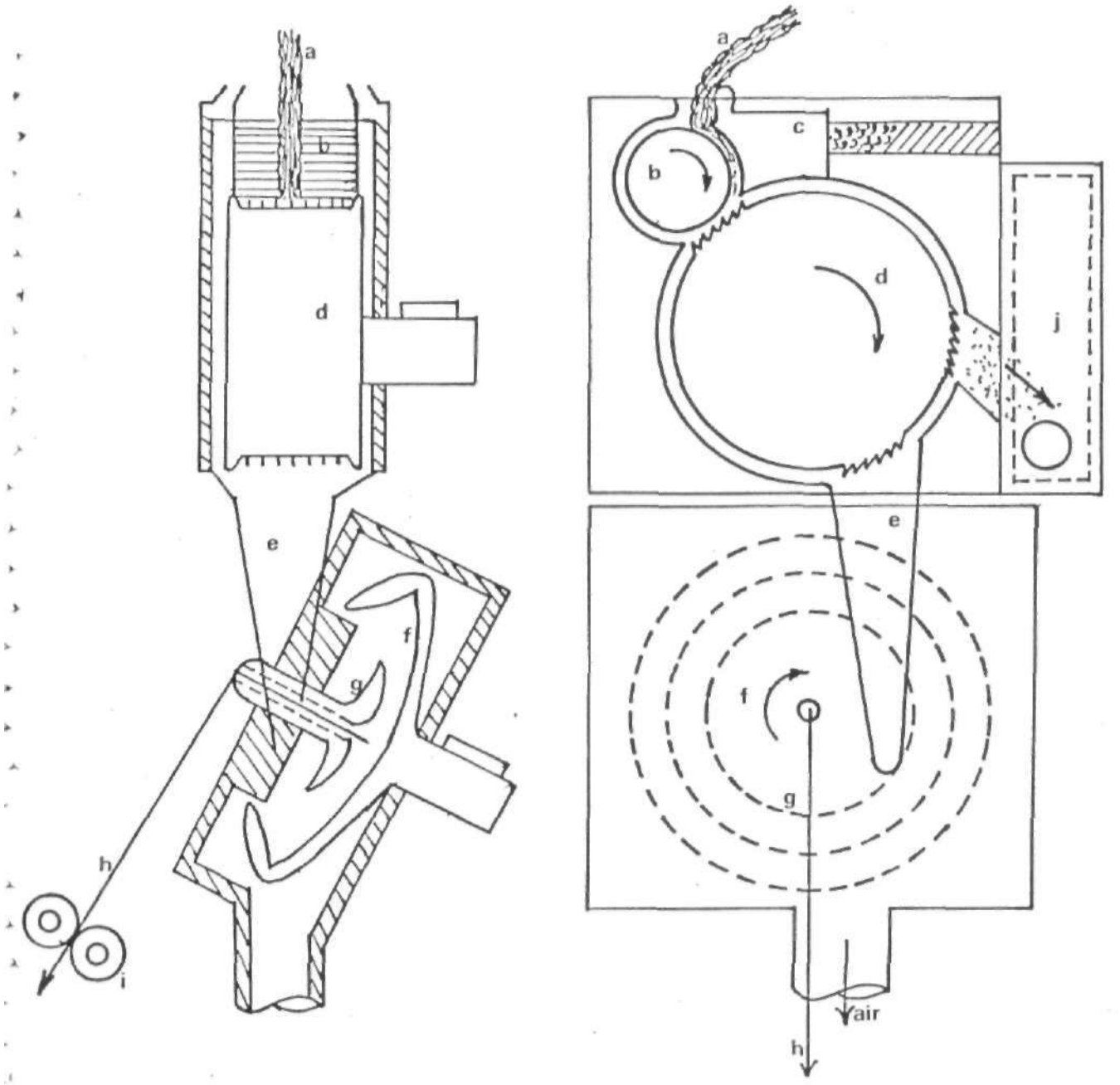
2.2 Yarn properties

This section reviews the major properties of the two types of yarn.

2.2.1 Yarn "character"

Stereoscan photographs of ring and rotor yarns have confirmed the fundamental and characteristic differences in yarn structure and appearance.[9] It is reported that fibres in a rotor-spun yarn are not as uniformly packed as is the case in a ring-spun yarn. These peculiarities are said to be also reflected in blackboard wrappings as well as in the surface appearance of their respective fabrics.[9]

In conventional ring-spun yarns, the fibres are largely arranged in parallel positions and twisted together, while a rotor-yarn consists of a core and a sheath. The twist of the two types of yarn are therefore different, with twist variation from one radius to another



a. Sliver
b. Feed roller
c. Feed pedal
d. Beater
e. Feed tube
f. Rotor
g. Doffing tube
h. Yarn
i. Delivery rollers
j. Trash box

FIG. 2.2 CROSS-SECTION THROUGH THE SPINNING UNIT OF PLATT ROTOSPIN.

in a break-spun yarn.[10] The sheath fibres in a break-spun yarn are usually termed wrapper fibres and said to be firmly bound. As a result, fibre migration does not exist in the same way as in ring-spun yarns. All these have been attributed to the weakness and increase in bulk of the rotor-spun yarns. Increased bulkiness was also suggested to be responsible for reduction in inter-fibre contact forces, and it is for this reason, therefore, that higher twist factors are usually required for optimum results. Kasparek[11] has shown that the core of the BD200 yarn contained between 75% and 87% of all the fibres (i.e. the outer sheath varied from 13% - 25% of the total composition of the yarn).

It has been demonstrated by various people[7,12,13] that variations in the design and dimensions of rotors greatly influence fibres behaviour in spinning and ultimately yarn structure.

2.2.2 Yarn strength and elongation

Experiments have generally confirmed[3,14,16] that open-end yarns are weak when compared to ring-spun yarns. For example, Cormack[15] showed that with the same linear density, open-end yarns were some 30% weaker than ring-spun yarns up to the optimum twist factors. In most publications, the deficiency in strength of the open-end yarns has been elucidated in terms of the difference in their structure. In the rotor-spun yarn there is a lower degree of orientation (alignment) of the fibres[26] and there are thus fewer fibres (in the yarn cross-section) able to take their full store of tensile load.[9]

The reduction in strength of rotor-spun yarns compared with those of ring-spun yarns has been explained by the non-simultaneous rupture of the whole cross-section of the yarn as a result of non-uniformity

of the loading of the fibres.[19] The reduced tenacity of open-end yarn is also claimed to be dependent on type of material, blend proportions and twist level.[9] It is, however, generally agreed that the coefficient of variation of tenacity of the open-end yarn is much lower.

With reference to extension, rotor-spun yarns have been characterised as having a higher elongation at break,[10,13,14] but Cygan[9] has reported some lower values in the case of man-made fibres, while for blends they were about the same. Nevertheless, the higher elongation of rotor-spun yarns compared with ring-spun yarns was explained in terms of the folded and entangled nature of the fibres which act as extensible components of the system.[17,18]

2.2.3 Yarn evenness and imperfection

In almost every case, open-end rotor-spun yarns have been reported[7,9,19,20] to be more regular than the corresponding ring-spun yarns. For example, yarn evenness using the Uster Evenness Tester was found to be about 5 - 10% better for rotor yarns, depending on the form of the rotor groove. Cotton rotor yarns are superior in short term regularity to carded ring-spun yarn.[21] This has been attributed to the unique self-doubling effect inside the rotor and its advantage in suppressing the drafting waves is separately stressed by Lord,[24] Kojima et al,[22] and Krause and Soliman.[23] However, long term irregularity is found in many open-end rotor yarns and is attributed mainly to the reduction in the pre-spinning stages.

In addition to being more regular than ring-spun yarns, rotor yarns are, generally, almost completely free from visible neps, as

the neps tend to be embedded in the yarns and, therefore, are rarely visible.[25,26,27] It was also reported that the presence of surface wrappings can be detrimental to yarn appearance since they can slide on the surface to produce a slub-like appearance, and these are sometimes detected by imperfection indicators as neps. In addition, imperfection indicators have been used to confirm that the number of thin and thick places in rotor-spun yarns is much lower.[28,29,30] Furthermore,[19] cotton rotor yarns were reported to have far fewer short faults (classimat), but far more long faults than carded ring-spun yarns.

The values given by a Pilosimeter for the hairiness of rotor yarns are about 50% lower than for ring-spun.[8,32] Barella and Vigo[31] have explained that this is due to differences in the distribution of the protruding fibre ends, with a predominance of shorter ends in the open-end yarns. Ibrahim[13] went further to explain that yarn hairiness is influenced by spinning conditions and fibre properties.

2.2.4 Abrasion resistance and other properties

It is widely claimed[33,34] that rotor-spun yarns exhibit a distinctly higher abrasion resistance compared to ring-spun yarns, and this was mainly due to structural differences. In one study, Barella and Vigo[35] reported that abrasion resistance is dependent on testing technique, because instruments utilising higher yarn tension have shown lower abrasion resistance for open-end yarn. In a separate study, Ibrahim[13] showed that abrasion resistance of open-end yarns and fabrics changes with several factors such as fibre type, rotor diameter and twist factor, and that these results may be explained

in terms of wrapper fibres. He[13] concluded that in terms of fabric abrasion it is difficult to clearly state which yarn type is superior, as this is dependent on testing conditions and yarn processing parameters.

The specific volume of rotor-spun yarns is something in the neighbourhood of 5 - 10% greater than ring-spun yarns.[34] This increased bulkiness gives the fabrics of these yarns better cover factor, better thermal insulation and better dye and size uptake.

2.3 Influence of cotton fibre properties on yarn properties

Numerous attempts have been made to correlate fibre properties with yarn properties. In this section, therefore, it is intended to review some aspects of literature related to this area, as it is thought that this may help in explaining some of the observations expected in the course of the present research.

2.3.1 Fibre length

Booth[36] has discussed the definitions and various apparatus used for the determination of the various attributes used to denote the length characteristics of cotton fibres.

Short fibre content is reported to be very important for process efficiency, but simple definitions such as the proportion of fibres less than 12 mm long are reported to be inadequate.[37] "Floating Fibre Index" has been claimed[38] to be a better indicator for processability and ultimate yarn quality.

In consequence of the complex structure of rotor-spun yarns it is difficult to exploit the technique developed for assessing

the structure and properties of ring-spun yarns. Kasparek[11] introduced a system for obtaining data relating to the yarn tensile properties. He then related the process conditions, fibre configuration and length to yarn properties using concepts such as mean fibre extent and spinning-in coefficient.

Many workers[39-43] have shown that there is a great correlation between yarn strength and fibre length. At the same time, some differences appear to exist as to which of the different length attributes have the most significant effect when related to yarn properties.

Research at the Texas Textile Research Centre has shown that the influence of fibre length on yarn tensile properties depends on which measuring technique is adopted.[40] In earlier studies[39] it was shown that with regard to yarn strength, length uniformity is the least important, followed by 2.5% span length.

However, in more recent investigations[40] using High Volume Index (HVI) data, the uniformity ratio and the Upper Half Mean (UHM) length were found to be of great importance. The situation is further complicated by the resultant yarn count, since it is also claimed[40] that 2.5% span length is important when considering the strength of fine yarns.

Ramey et al[42] have emphasised the importance of fibre length and strength, and for yarn strength prediction equations, the use of mean fibre length was found to be better than the Upper Half Mean (UHM) length. Louis[41] has mentioned a positive correlation of fibre length and strength with yarn strength. He claimed that fibre length is less significant for yarn strength.

Recently two separate conclusions concerning fibre length were

arrived at. Firstly, Ethridge et al[30] concluded that fibre length has no significant effect on yarn properties, and secondly, Hunter and Gee[43] found fibre length to be more significant for yarn tensile properties. The second conclusion by Hunter and Gee[43] held the view that an increase in 50% span length increases yarn strength and extension, but decreases yarn irregularity. In agreement with this is the work of Vough and Rhodes[44] which considered fibre length to be the most important parameter controlling yarn properties, but discovered that yarns from shorter fibres are stronger and more even than those from long fibres. This is rather astonishing. However, medium length fibres gave yarns with higher elongation.

Kasparek[11] used the spinning-in coefficient to represent the fibres in the yarn body after reporting fibre length exploitation in open-end spun yarns to be about 50%, and found a substantial correlation between the spinning coefficient and yarn strength. Neild and Ali[45] used the Mean Fibre Extent (MFE) and reported a significant correlation between this and yarn properties; increasing the mean fibre extent led to higher tenacity, lower coefficient of variation of breaking load, greater elongation at break and better regularity.

Krause[46] asserted that neither yarn strength nor irregularity is greatly influenced by short fibre content. When investigating the effect of blend proportion on the properties of rotor-spun yarns, Towery[47] found that length differences in blended components were relatively unimportant. It is, however, reported elsewhere[41] that the blend composition was more significant for yarn strength than changes in rotor speed. Furthermore, as yarns become finer, yarn strength reduction is greater for cotton containing more short and weak fibres than cotton containing more long and strong fibres.[41]

2.3.2 Fibre strength

A group of workers[39,40,43,48-52] have shown that fibre strength and yarn strength are substantially related.

Ramey et al[42] have attributed a substantial portion of the variation in yarn strength to variation in fibre strength and length. Louis[41] has stressed the importance of those two parameters, but concluded that the effect of fibre strength is much greater than fibre length. Whilst on the other extreme Simpson and Murray[48] shared the view that fibre strength is less important for rotor yarns than ring yarns, as a result of the poorer parallelization in the former.

Ethridge et al[30] have shown that the relationship betwen fibre strength and yarn strength is non-linear. Furthermore, the correlation between fibre strength and yarn strength was found to be superior to any compound relationship involving fibre length or micronaire.[49]

It has been pointed out[50] that for different count numbers and different types of spinning machine, the stronger fibres always gave stronger yarns, and in general for both rotor- and ring-spun yarns, yarn strength increased as the percentage of high strength and fine cotton in a blend increased, while the percentage coefficient of variation decreased.[48] Kasparek[11] attributed the contribution of fibre strength to yarn strength to fibre length exploitations, and found a very high correlation between fibre strength exploitation and fibre spinning-in coefficient.

2.3.3 Fibre fineness

The importance of fineness in spinning has been stressed by several workers.[30,36,47,48] In most of the researches, fibre fine-

ness is reported to have a significant effect on yarn strength, but Ramey et al[42] have found no correlation between those two at all.

It has been reported[48] that coefficient of variation of rotor-spun yarns decreases with fine cottons, and this view was supported by Hunter and Gee[43] who showed that an increase in micronaire would lead to an increase in yarn strength variation but with a reduction in yarn extension, while an increase in maturity ratio brings about an increase in yarn irregularity.

2.4 Expected effect of twist and wrapper fibre concept

Twist, as defined by Skinkle,[52] is a measure of the spiral turns given to a yarn in order to hold the constituent fibres or threads together. Up to a certain point an increase in twist implies an increase in yarn strength, but above this point any additional twist adds strain to the fibres which results in a weaker yarn. Hence there is an optimum twist level desirable. This is very typical of the behaviour of the ring-spun yarn. A similar effect is revealed in the breaking extension of the yarn. Open-end rotor yarns are expected to show these trends, but as a result of the method adopted in fibre assembly and twist insertion in open-end rotor spinning, the influence of twist on yarn strength is slightly complicated.

Because of the core and sheath structure of rotor-spun yarns[9,10,11] (which is brought about by the presence on the yarn body of bridging and so-called wrapper fibres), a lowering of the yarn breaking strength is to be expected. Further work[8,41] has shown that the higher the percentage of such fibres on the yarn, the lower the breaking strength becomes, but Eljack[65] and others[66] have found that yarn strength may

increase with the number of wrapper fibres.

The bridging fibres[53] are formed when, during spinning, any fibre is laid on the fibre ribbon (or becomes attached into the fibre ribbon which is about to be twisted, whilst its length lies along the Peripheral Twist Extent (PTE) or across the gap behind the peeling point where the yarn has just been removed. This fibre becomes forced to rotate with the yarn as it rolls inside the rotor groove and thus becomes wrapped around the formed yarn. Lord[54] reported that the chance of any fibre, laid in this way, bridging the gap depends on the ratio of the fibre length to the rotor circumference. The percentage of the bridging fibres will, therefore, be equal to

$$\frac{100L}{D},$$

where, L is the mean fibre length, and
D is the rotor diameter.

Cormack[15] has shown that the PTE increases proportionally with twist. During spinning, therefore, the fraction of fibre which will be wrapped round the yarn equals:

$$\frac{(PTE + d)}{2\pi R}, \quad \text{where d is the yarn diameter.}$$

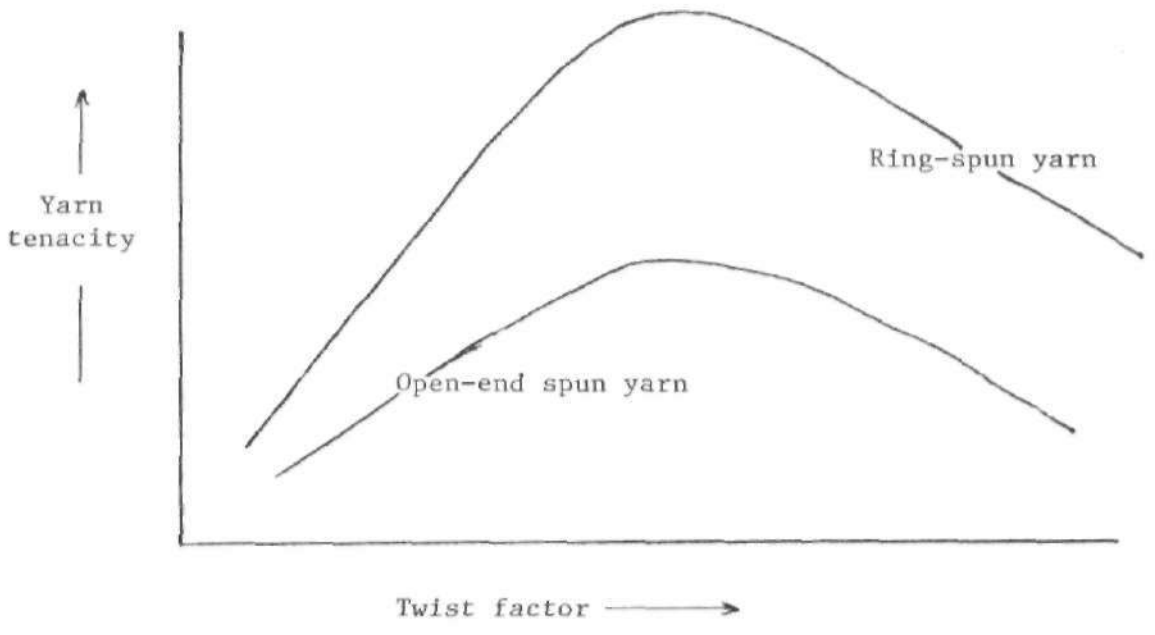
Since PTE increases with twist, the fraction of wrapper fibres formed should also increase with twist. Ho's investigation[55] is in agreement with this. Cormack[15] went further to state that as the number of wrapper fibres increase, the percentage of fibres constituting the core decreases. Hence the breaking strength of a rotor-spun yarn would be expected to be lower since it is the core fibres that support the bulk of the tensile load which is brought to bear upon the yarn.

Supposedly, twist in yarn is necessary to give strength and coherence by reducing fibre slippage, but this effect is partly offset by the presence of wrapper fibres. From the foregoing it follows, therefore, that increase in yarn strength with twist up to a maximum would be expected not to be as rapid as it is with ring-spun yarns. Instead, after the optimum twist, due to the combined effect of fibre obliquity and wrapper fibres, a rapid reduction in strength with twist would be obvious. Thus the difference in strength between a ring-spun yarn and a rotor-spun yarn would be bigger at higher twist factors. Since this is the case, the percentage strength of an open-end rotor-spun yarn would be expected to be higher at low twist factors and to decrease with increase in twist factor.

A plot of yarn tenacity versus twist factor is expected to give the curves shown in Fig. 2.3.[36]

Figure 2.3

Expected curves of yarn tenacity vs. twist factor



the yarn at the take-off navel, because of high yarn tension.

From an engineering standpoint, open-end rotor spinning machines can be operated at high speeds, but most studies show that high speeds damage yarn quality. Grosberg and Mansour[62] using a single 46 mm diameter rotor, studied the effects of increased speed on yarn properties. They found that strength generally increased but elongation at break decreased, and that weight per-unit-length variability increased.

It has been shown[63] that the use of grooved doffing tubes increase wrapper fibres due to an increased false-twist action, resulting in an elongated Peripheral Twist Extent (PTE).

CHAPTER 3

Experimental

3.1 Equipment

The spinning machines used in this research were the "Platts Type 800 Super Spinner" (ring-frame) and "Platts Rotospin Type 883" (rotor spinner). The principles of these types of machine are well known and have been described elsewhere, but for completeness a brief summary of the essential features of the machines used is given below.

3.1.1 Brief description of the "Platts Type 800 Super Spinner"

The Super Spinner is an all-count general purpose ring-frame of compact design and is claimed to provide maximum production and highest yarn quality. The features of the machine include balloon control rings, a range of drafting systems (with long bottom aprons) to cover all process requirements, completely new cam-operated building motion, etc. (from the manual of the machine).

The draft gearing of the Super Spinner caters for a range of drafts from 5 to 55 and the twist range of the machine is 8 to 40 turns per inch. The machine is driven by a specially designed and dimensioned motor on a sliding baseplate located under the spindle rail at the off-end, and motion is transmitted to the spindle driving shaft by Spacesaver wedge belts. Further information on the machine may be obtained from its manual.

3.1.2 Brief description of the "Platt Rotospin Type 883"

The Rotospin machine is designed to produce rotor yarns in the count range of 14 to 200 tex from all commercial grades of cotton,

man-made fibres, or blends of fibres in the staple length range up to 40 mm. Best results for optimum yarn strength and uniformity are achieved by spinning from second passage drawframe slivers.

The complete physical draft range of the machine is 29 to 424, and the twist range of the machine is 10 to 55 turns per inch. The machine is single-sided and is equipped with three drive motors which drive the rotor, the feed and beater rollers. The frame is comprised of a gearing end-unit and an out-end unit which houses the control panel, the drive motors and a 20-head spinning position. A fuller description of this machine is given in its manual and elsewhere.[51]

3.1.3 Mechanics of twist insertion in open-end spinning

The technique of twist insertion in open-end spinning has been described exhaustively by several authors.[6,7,11,26] Fig. 3.1 shows a schematic diagram of the principles of yarn formation in a typical open-end rotor system. The fibre flow from the opening device is accumulated inside the rotor collecting surface, which revolves at a relatively high speed and is normally subjected to external air suction. The removal of the fibre band and its conversion to yarn is effected by the introduction of a "seed yarn" through the yarn withdrawal tube (navel) situated at the axis of the rotor.

Due to the revolution of the rotor and the air inside it, the free end of the seed yarn is also caused to revolve in the same direction and at approximately the same speed. Centrifugal forces throw the end of the seed yarn against the inner peripheral surface of the rotor where it makes contact with the fibre ring on the collecting surface. Twist is generated as a result of the rotation of the

yarn crank, while the rotation of the yarn crank about its own axis causes the fibres at the end of the crank (point B in Fig. 3.1) to be entangled with the fibre ring, which causes some twist to be pushed beyond point B into the peripheral fibre ring.

The integrated yarn leaves practically no fibres at the peeling point B, and this creates an open-end or a gap in the fibre ring which rotates with the peeling point giving a tail-like appearance to the fibre ring in the rotor at steady speed conditions (Fig. 3.1).

The extension of twist beyond the peeling point B into the fibre band is called the Peripheral Twist Extent (PTE)[14] or tying-in zone.[6] It is defined by Cormack[15] as "that length of the fibre band which contains twist and is in contact with the walls of the fibre collecting groove". Its dimensions may be obtained by measuring the distance from the mid-point of the transitional zone to the point where the yarn path diverges from the collecting groove, i.e. the peeling point, in Fig. 3.1, thus:

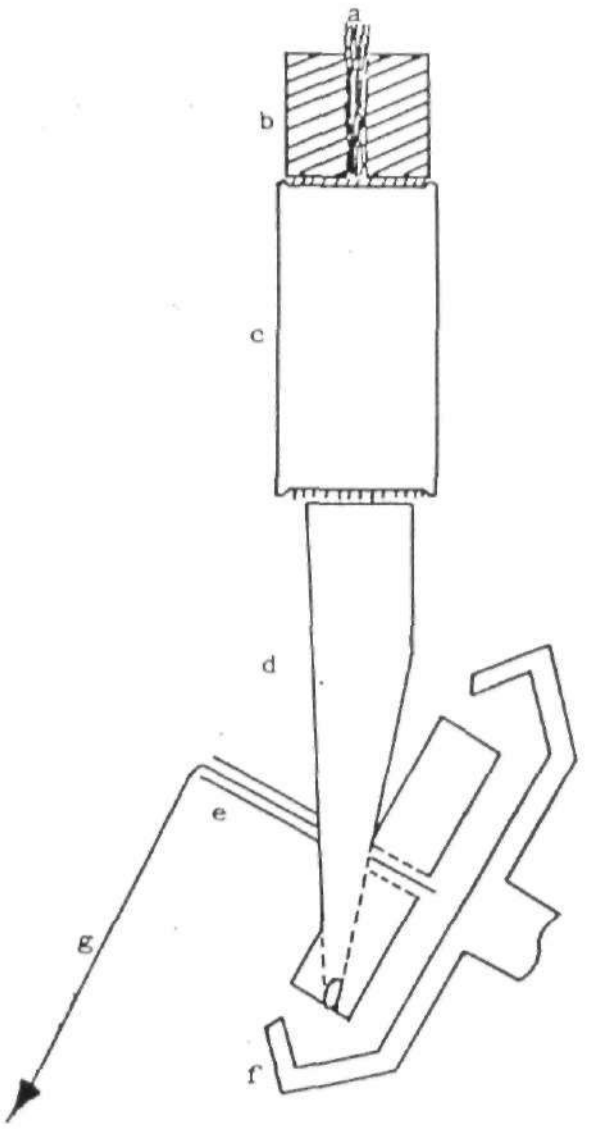
$$PTE = (BC + \frac{CD}{2}).$$

3.2 Production of yarn samples

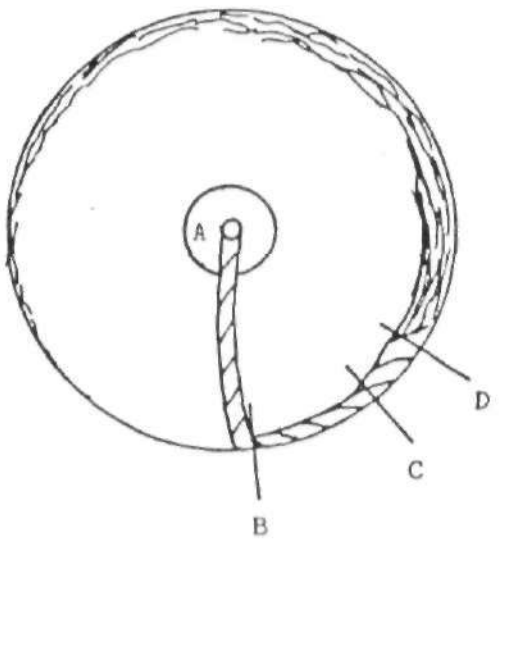
3.2.1 Material used

The material that was used for the current project was a commercial blend of cotton fibres with staple length 1 $^{3}/_{16}$ inches. The blend was comprised of a mix of short staple Nigerian, Californian and Australian cotton fibres. This blend was claimed to be very suitable for spinning yarns to weave quality sheetings when in the correct blend proportion with polyester fibres.

FIG. 3.1: Principle of yarn formation in O.E. rotor spinning



a = Sliver
b = Feed roller
c = Opening roller
d = Feed tube
e = Doffing tube
f = Rotor
g = Yarn



A = Doffing tube

$PTE = (BC + \frac{CD}{2})$

After the cotton fibre blend was processed, slivers and rovings of the requisite linear densities (3 ktex and 300 tex) were made and used as raw materials for spinning yarns on the rotor spinner and ring frame respectively.

3.3 Procedure

36 tex ring and rotor yarns were produced, each with a range of 5 twist factors giving ten samples in all (five for each spinning system). After spinning these were stored in atmospheric conditions of 65% r.h. ± 2%, and 20 ± 2°C for at least 48 hours before testing.

Prior to commencing the production of the yarn samples, a series of preliminary trials were carried out to determine the possible range of twist factors to which both the ring-spun and rotor-spun yarns could be made. Having established this common range, the yarns were produced with almost identical twists on both the ring and rotor machines, the slight variation between ring and rotor being the limitations imposed by the available change gears.

3.3.1 Production of ring yarns

Ring-spun yarns with different twist levels were made on the Platt Type 800 Superspinner. The linear density of the roving is 300 tex, and that of the yarn to be spun is 36 tex. Hence the required draft is 8.33. By dividing the draft constant of the machine by this value, the draft change wheel was found. Since only 36 tex yarns were being spun, once the correct draft change wheel was fixed, no further alteration was made.

Yarns of different twist factors were spun by using corresponding

twist change wheels which were calculated from the required values of turns per centimetre and the twist constant of the machine (see Appendix for details).

3.3.2 Production of rotor yarns

In order to produce rotor yarns at different twist levels, the rotor speed was kept constant whilst the yarn twist was varied by altering the delivery roller speed as required. However, a change in the delivery roller speed would bring about a variation in the linear density of the yarn being spun. Therefore, in order to keep the yarn linear density constant, whenever the twist was changed the feed roller speed had to be altered in accordance with that of the delivery roller.

During spinning, the sliver was fed into the drafting system, following which the fibres were deposited in the V-shaped groove of the rotor running at a pre-selected speed of 45,000 rev/min. As soon as this was done, a seed yarn was fed to the rotor via the yarn outlet tube to initiate spinning. The seed yarn was sucked in by air current, and the end inside the rotor peeled off the deposited fibres from the collecting surface and twisted them together to form a continuous yarn which was later drawn out and wound onto a yarn package (see Fig. 2.2 and Appendix).

3.4 Yarn testing

Testing was carried out in a conditioned laboratory (at 65% r.h. ± 2%, and 20°C ± 2°C) after the yarns had been stored for at least 48 hours in the atmosphere of the room.

The yarn samples were tested for twist, count, irregularity, faults (imperfections) and strength and elongation. The equipment used for the various tests was as follows:

(a) a twist tester
(b) wrap reel and electronic balance
(c) Uster evenness tester
(d) Uster Classimat installation
(e) Uster single-thread tester.

3.4.1 Measurement of twist

As a result of the presence in rotor yarns of wrapper fibres, a single measurement of twist is insufficient for typifying rotor yarns, since the twist (t.p.cm) of the fibres comprising the yarn core is different from those comprising the outer sheath, and both are usually lower than the machine value. The presence of wrapper fibres also makes yarn-untwisting impossible, thus making laboratory twist measurements for rotor yarns very unreliable as the results could be misleading. Despite this, twist measurement for the rotor spun yarns was carried out using the Barker Twist Contraction method[68] which is based on the untwist/reverse twist principle. It has been suggested by Singh[69] that the twist in rotor-spun yarns may be assumed to be equivalent to the machine twist. For this reason, and to avoid errors in interpreting the results which may arise due to defects in twist testing, the various properties of the yarn are compared with the machine twist.

The twist level of ring-spun yarns was assessed by twisting one-inch lengths of yarn on a standard twister according to BS 2085, 1973. With the ring yarn, the untwisting process was fairly simple. In view

of the well-aligned nature of the fibres in the yarn, the end point of the test when all fibres had become straightened out was detected easily with the aid of a dissecting needle. The number of turns removed was read from the revolution counter and recorded. For each yarn sample, fifty tests were carried out and the mean obtained. The results are given in Table 4.2.

3.4.2 Yarn count measurement

The procedure for yarn count measurement was followed according to BS 2010, 1953, and ten readings were obtained for each sample. Their means were then calculated. The following formula was used to calculate the count after 100 revolutions of the wrap reel:

$$\text{Linear density (tex)} = \frac{W \times 1000}{100\ L},$$

where, W = Oven-dry weight of the yarn hank or skein
L = the girth of the wrap reel.

The results of these tests are presented in Tables 4.4 and 4.5.

3.4.3 Yarn irregularity tests

The Uster evenness tester was used to measure the irregularity in the two types of yarn, and the results of these tests were expressed in terms of the linear Uster irregularity U%. A speed of 25 yds/min, recommended for yarns, was used to test the yarns and the variation in the yarn mass per unit length was recorded as U% (integrated percentage mean deviation) from the integrator after every three minutes of running. For each yarn sample, ten U% readings were recorded. All tests were carried out under a standard atmospheric condition of 65% r.h. ± 2% and 20°C ± 2°C. Tables 4.6 and 4.7 show the means of

the ten U% readings for each yarn sample from ring and rotor spinning.

3.4.4 Single thread strength and elongation test

The Uster single thread strength testing machine used for this research is a fully automatic instrument operating on a constant rate of loading and has a fixed test length of 50 cm. The equipment has a variable speed control which enables the rate of loading to be adjusted to give a time of 20 sec ± 3 sec to break a speciment of yarn. The load ranges of the machine may be varied from 0 to 2000 gm, and for measuring the elongation, there are 3 measuring ranges allowing a maximum elongation of 40%. The number of breaks may be set on the machine at will, between 1 and 999. A buzzing tone indicates the end of a pre-selected test series. For further information on the equipment, its manual may be consulted.

For the present research, the carriage weight used ranged from 600 gm to 1500 gm according to the behaviour of the yarns.

Fifty tests were carried out for each yarn sample and values of total load and total elongation were obtained. The mean elongation, mean load and mean tenacity were calculated from these values, using the following formulae as given in the manual of the equipment:

$$\text{Elongation \%} = \left(\frac{\text{Total Elongation}}{\text{Number of breaks}} \times 10\right) + 0.3$$

$$\text{Load \%} = \left(\frac{\text{Total Load}}{\text{Number of breaks}} \times 10\right) + 2.3$$

$$\text{Breaking load} = \frac{\text{Load \%}}{100} \times \text{Load Range (grammes)}$$

Tables 4.8 and 4.9 represent the results of the tests.

3.4.5 Yarn physical appearance

A visual examination of the spun yarns was carried out in order to assess the hairiness and bulkiness of the two types of yarn. This was done by placing side-by-side a ring-spun yarn and an equivalent rotor-spun yarn on a blackboard and then assessing them. In addition to this, stereoscan photographs of the yarns were taken and assessed accordingly. The photographs are represented on Plates 1, 2 and 3. They represent the lowest, medium and highest twist factors from the range of twist factors used for spinning the ring and rotor yarns.

3.4.6 Imperfection test (Classimat)

The detection of faults in the spun yarns was carried out with the aid of the Uster Classimat Yarn Fault Classifying Installation. The instrument makes possible in one operation an automatic, objective, exact and rapid definition measurement classification and counting of the faults in spun yarns.

In measuring imperfections and faults present in the ring-spun and rotor-spun yarns, the Uster instrument was set for the type, count and speed of the material to be tested as outlined in its manual. As soon as all these were set, the Uster installation then classified the yarn faults automatically and provided a complete reference to the number of faults in each of the various classes. The counter results from the Classimat classifying installation were entered into special spaces provided on the Classimat Test Results sheet, and were assessed accordingly. The results are further represented in Tables 4.1 (a-e).

The Classimat grades show 16 fault classes, i.e. A1 to D4.

Horizontally

Length class	A	shorter than 1 cm
Length class	B	1 cm to 2 cm
Length class	C	2 cm to 4 cm
Length class	D	4 cm and longer

Vertically

Cross-sectional class	1	+ 100% to + 150%
Cross-sectional class	2	+ 150% to + 250%
Cross-sectional class	3	+ 250% to + 400%
Cross-sectional class	4	+ 400% and larger

Each fault class is determined by 4 fault groups which represent the limiting values. Each of the four fault groups of one class shows 3 to 5 faults, whereby the faults within each group are the same according to their length and cross-sectional size, but can vary slightly in appearance. A fault can, for example, seem to be more hairy or more voluminous than its neighbour, but in every case such faults would be of the same size.

CHAPTER 4

Results and Discussion

4.1 Discussion

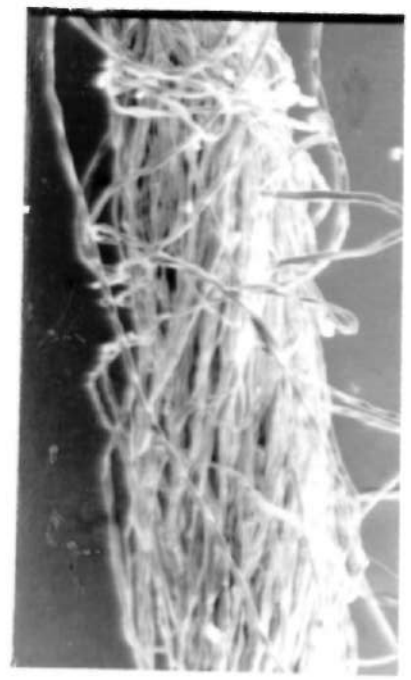
This research work which was carried out over a period of six months, has studied carefully some of the expected effects of twist level in spinning on the properties of both ring and rotor yarns. The discussions which follow, therefore, are made in the light of the results obtained in the course of the present study.

4.1.1 Assessment of yarn appearance

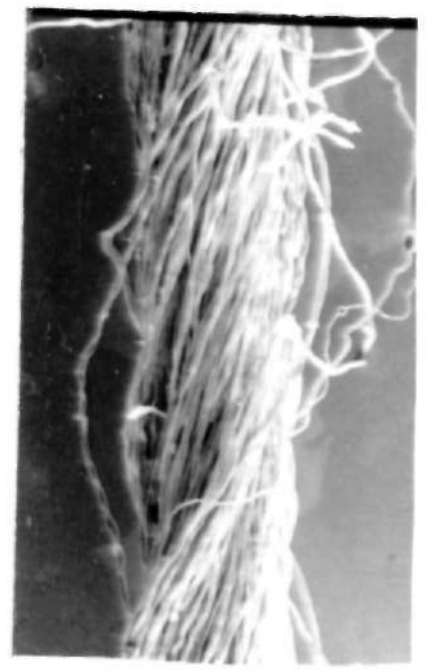
The visual assessment of yarn which was carried out showed that a ring-spun yarn was more hairy than a corresponding rotor-spun yarn, and it was also very obvious that the ring yarns had more shorter protruding fibre ends, whilst in a rotor yarn there were fewer but longer fibre ends. It also appeared that hairiness tended to reduce with twist in both types of yarn.

In terms of bulkiness, rotor-spun yarns appeared more bulkier than their ring-spun equivalents, which were thinner and finer in appearance. Yarn bulkiness was observed to follow a similar trend to hairiness, in that yarn bulk decreased with an increase in twist factor. The stereoscan photographs of the yarns displayed on plates 1,2,3 reveal quite clearly these observations. The photographs further reveal the presence of wrapper fibres on the surface of the rotor-spun yarns.

From the assessment made, it may be concluded that the lower hairiness of the rotor-spun yarns is probably due to the formation of more lightly wrapped fibres (or belts) which inevitably conceal fibre ends.



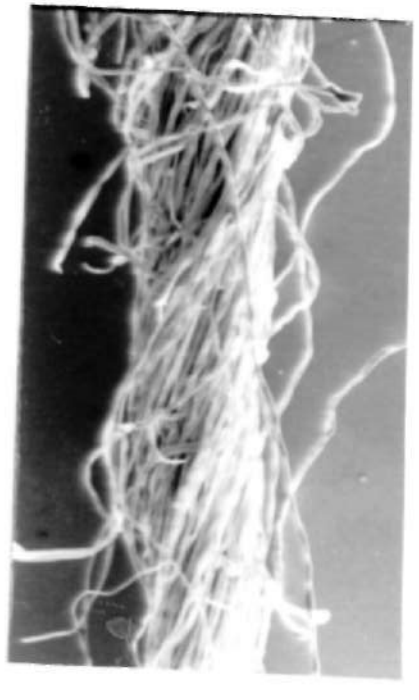
Rotor Spun Yarn



Ring Spun Yarn

Plate 1: Stereoscan photographs of:

Ring spun yarn 31.57)
Rotor spun yarn 32.53) lowest twist factor



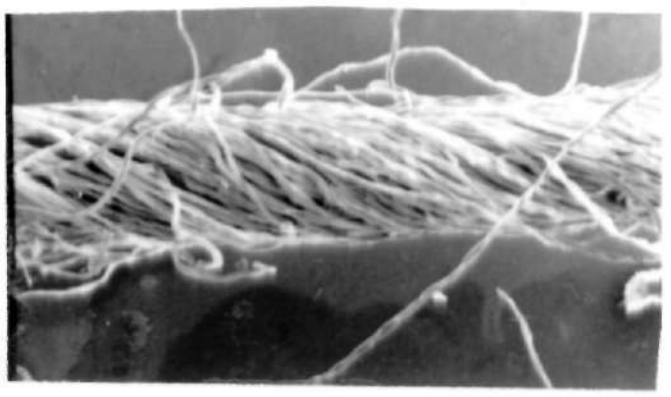
Rotor Spun Yarn



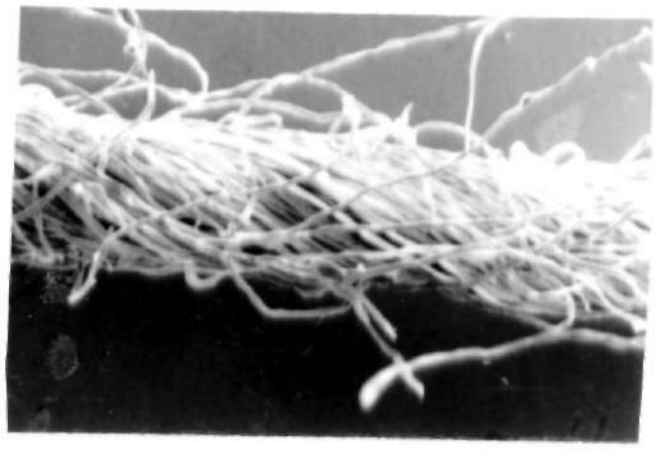
Ring Spun Yarn

Plate 2: Stereoscan photographs of:

Ring spun yarn 38.27)
Rotor spun yarn 39.22) Medium twist factor



Ring Spun Yarn



Rotor Spun Yarn

Plate 3: Stereoscan photographs of:
Ring spun yarn (45.92 - highest twist factor
Rotor spun yarn

4.1.2 Classimat Test

Tables 4.1(i - v) show the level of faults contained in the ring-spun and rotor-spun yarns. It should be noted that whilst different sample lengths were tested, the figures reported are based on faults per 100,000 metres. In Fig. 4.1 is shown a plot of the total number of faults in the two types of yarn against twist factor. The tables and the plots show surprisingly that the fault level in rotor-spun yarns increases with increase in twist factor and showed no tendency to reduce, whilst in the ring-spun yarn, the number of faults increases to an optimum value after which there is a sharp reduction in the number of faults at the highest twist factor in which no fault was recorded by the Uster device for the length of yarn tested. The rotor-spun yarn with the lowest twist factor was unable to be tested because it would not wind.

In general, the total number of faults or the number of faults in a rotor-spun yarn compared with that in an equivalent ring-spun yarn is lower, and the increase in this number for rotor yarns with increase in twist factor is likely to be due to the increase in the number of wrapper fibres with twist, which probably led to the increase in the number of thick places. It is thought that the increase in the number of faults in the ring-spun yarns is as a result of fibre obliquity and a probable escape of twist to thin and thick places in the yarn. Furthermore, in the ring-spun yarn the number of faults tends to level off with twist, then to an optimum value at a twist factor of 41.14.

Finally, it is to be noted that loose or spun-in fly and piecings (which lead to the formation of slubs and neps) may account for a substantial percentage of all the yarn faults recorded by the Uster device.

Since no satisfactory explanation could be put forward to elucidate the observed increase in fault level with twist in the two types of yarn, it is therefore suggested that more studies be done to substantiate this finding.

TABLE 4.1

Uster Classimat Fault Rate Comparison of 36 tex
Rotor and Ring-spun Yarns

(a) Twist Factor: Ring spun - 31.57 α_{tex}
Rotor spun - 32.53 α_{tex}

Cross-sectional class \ Length class	A		B		C		D	
	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor
4	0	-	0	-	0	-	0	-
3	0	-	0	-	0	-	0	-
2	67	-	67	-	0	-	0	-
1	67	-	67	-	0	-	0	-

(Non-cumulative)

Totals: Rotor yarn - Unable to test
Ring yarn - 268 faults/100,000 metres

(b) Twist Factor: Ring spun - 34.44 α_{tex}
Rotor spun - 36.35 α_{tex}

Length class / Cross-sectional class	A		B		C		D	
	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor
4	0	100	0	0	0	0	0	0
3	0	300	0	0	0	0	67	0
2	67	300	0	0	0	0	67	0
1	670	400	134	-	67	-	134	-

Totals: Rotor yarn - 1,100 faults/100,000 metres
Ring yarn - 1,206 faults/100,000 metres

(c) Twist Factor: Ring spun - 38.27 α_{tex}
Rotor spun - 39.22 α_{tex}

Length class / Cross-sectional class	A		B		C		D	
	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor
4	0	0	0	0	0	0	0	100
3	67	0	0	0	0	0	0	100
2	268	327	0	0	0	0	0	100
1	737	400	67	0	67	0	0	100

Totals: Rotor yarn - 1,127 faults/100,000 metres
Ring yarn - 1,206 faults/100,000 metres

(d) Twist Factor: Ring spun) 41.14 α_{tex}
Rotor spun)

Length class / Cross-sectional class	A		B		C		D	
	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor
4	0	200	0	0	0	0	0	0
3	250	200	0	0	0	0	0	0
2	500	310	0	0	0	0	0	0
1	625	400	0	0	0	0	0	0

Totals: Rotor yarn - 1,210 faults/100,000 metres
Ring yarn - 1,375 faults/100,000 metres

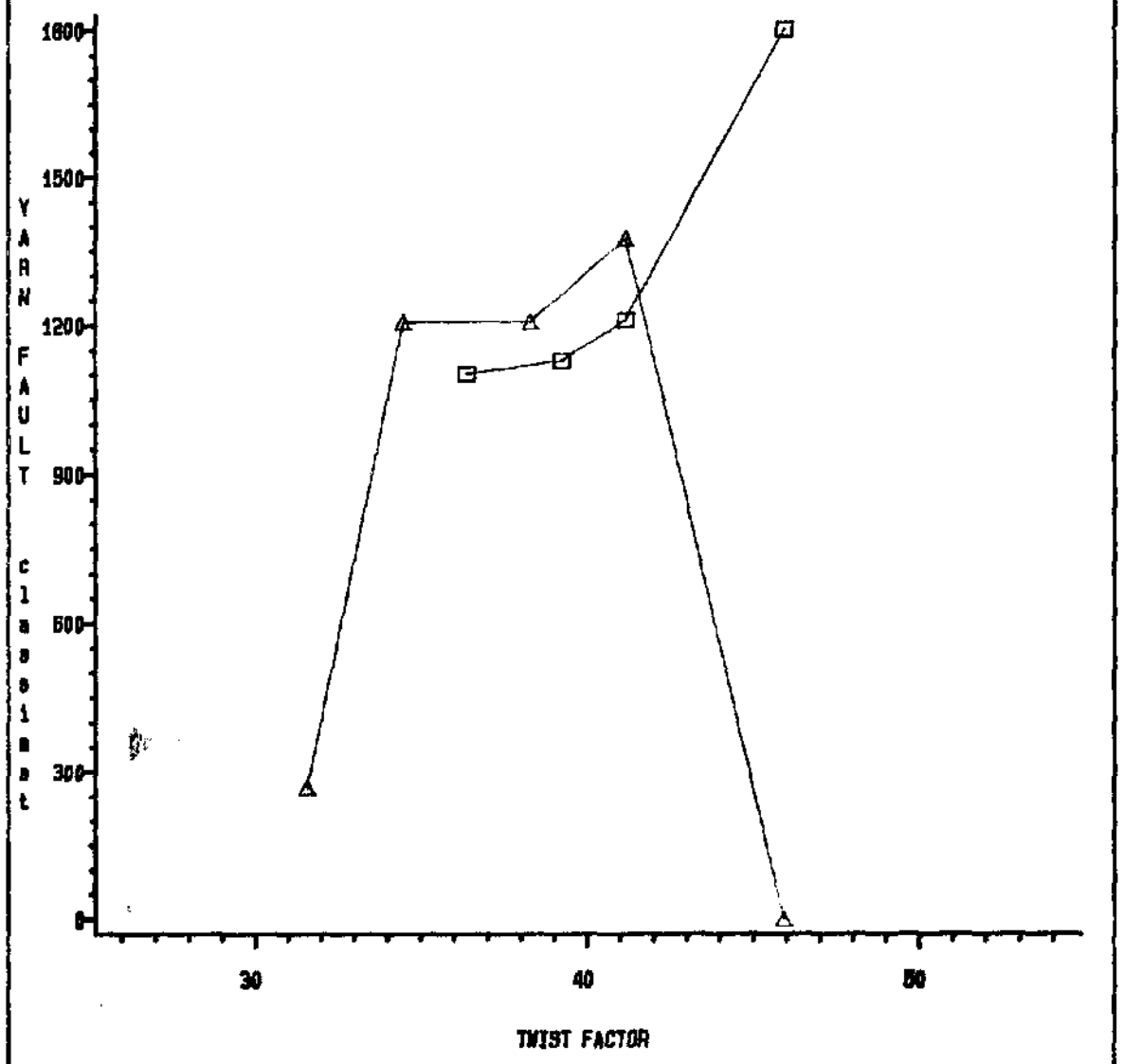
(e) Twist Factor: Ring spun) 45.92 α_{tex}
Rotor spun)

Length class / Cross-sectional class	A		B		C		D	
	Ring	Rotor	Ring	Rotor	Ring	Rotor	Ring	Rotor
4	0	0	0	0	0	0	0	0
3	0	200	0	0	0	0	0	0
2	0	600	0	0	0	0	0	0
1	0	1000	0	0	0	0	0	0

Totals: Rotor yarn - 1,800 faults/100,000 metres
Ring yarn - 0

Fig 4.1

TWIST FACTOR Vs YARN FAULT



RING SPUN YARN

ROTOR SPUN YARN

4.1.3 Assessment of twist

Tables 4.2 and 4.3 show the obvious effects that as twist factor increases the amount of twist in both ring-spun and rotor-spun yarns increases. A "twist efficiency" was calculated based on the ratio of measured yarn twist to the machine twist (i.e. the twist which should have been present in the yarn for the particular conditions used). It may be observed further from Tables 4.2 and 4.3 that the average twist efficiency of ring-spinning and rotor-spinning for the present research lies approximately in the neighbourhood of 97% to 101%, and 92% to 104% respectively. It could be argued that these results imply that under certain conditions some of the machine twist has been lost. In respect of ring-spinning, the "loss in twist" may have been brought about by the slight changes in spindle speed which could have been due to driving belt slippage or by changes in the package size which would result in changes in the traveller speed (and hence twist). A further possible reason for "twist loss" in ring-spinning could result from the method of measuring the yarn twist since the packages were unwound sideways, and this is known[5] to give variations in yarn twist level.

Owing to the difficulties in twist measurement, it is becoming the practice with open-end yarns (e.g. rotor spun yarns) to quote the machine twist calculated from the relevant twist gear and machine constant.[70] This, it was stated, ignores fibre slippage which takes place at the yarn formation point within the rotor. "This slippage enables the differential twist pattern to occur and is likely to cause the machine twist to be greater than the actual mean twist". From this, therefore, it is obvious that twist loss in rotor-spinning is

TABLE 4.2

Twist Measurement of Ring-spun Yarns

Twist factor α_{tex}	Nominal Twist (t.p.cm)	Actual Twist (t.p.cm)	Standard Deviation (t.p.cm)	Coeff.of Variation (CV%)	Twist Efficiency (%)
31.57	5.26	5.17	0.2951	5.71	98.30
34.44	5.74	5.61	0.3128	5.57	97.74
38.27	6.38	6.36	0.2686	4.22	99.70
41.14	6.86	6.73	0.5758	8.55	98.10
45.92	7.65	7.74	0.3728	4.82	101.18

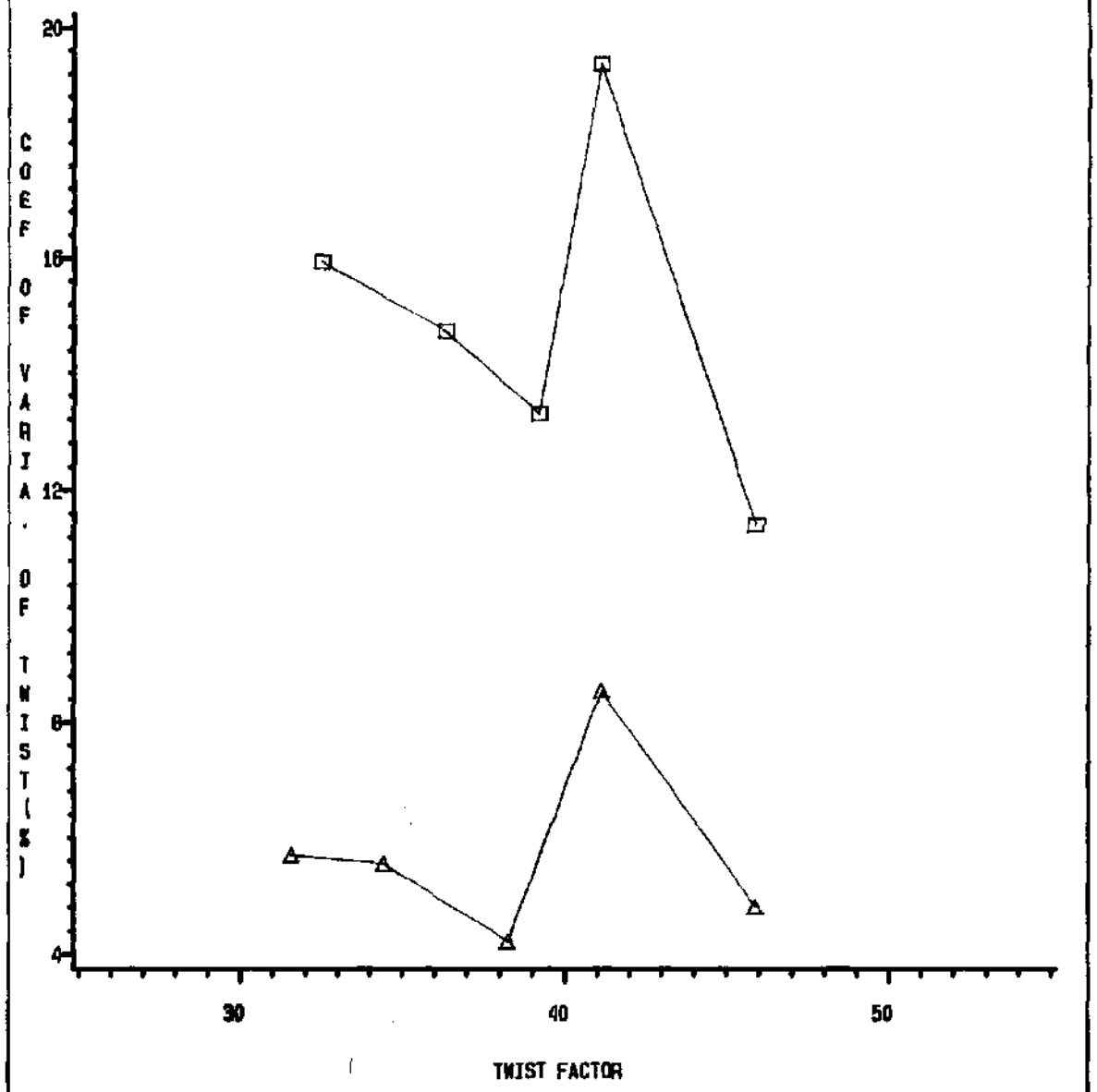
TABLE 4.3

Twist Measurement of Rotor-spun Yarns

Twist factor α_{tex}	Nominal Twist (t.p.cm)	Actual Twist (t.p.cm)	Standard Deviation (t.p.cm)	Coeff.of Variation (CV%)	Twist Efficiency (%)
32.53	5.42	5.08	0.81	15.94	93.70
36.35	6.00	6.25	0.92	14.72	104.20
39.22	6.53	6.03	0.80	13.27	92.30
41.14	6.86	6.30	1.22	19.36	92.00
45.92	7.68	7.98	0.91	11.40	104.30

Fig 4.2

INFLUENCE OF TWIST FACTOR ON CV% OF TWIST



mostly due to the occurrence of slippage inside the rotor.

The most probable cause of the apparent increase in "twist efficiency" with increasing twist factor is twist contraction, which is reported[64] as a factor influencing twist during spinning. When twist is inserted in a yarn it contracts (due to fibre obliquity) and this results in an increase of turns per unit length. This effect is relatively small at low twist levels, but the effect becomes marked as the twist level is increased. This explains the current increase of about 1% for ring-spinning and 4% for rotor-spinning in "twist efficiency" as twist factor is increased in the current investigation.

The existence of "twist loss" in rotor-spinning is still the subject of debate and whilst some researchers[56,57,70] have postulated reasons for the twist loss, Singh[69] doubts its existence. From his[69] analysis of various techniques of assessing twist, he claims that the "twist loss" is not due to a loss in the inserted twist but merely an inherent defect in current techniques for assessing twist.

Coefficient of variation of twist data from Tables 4.2 and 4.3 indicate that both ring-spun and rotor-spun yarns with a twist factor of 41.14 have a C.V.% much higher than C.V.% for other yarns. This, to some extent, suggests a critical point in spinning, although no satisfactory explanation could be found for the higher figures. Whilst it could be agreed that this variation is due to irregularities in the yarn, as reflected by the Classimat results for the ring-spun yarns, data on the U% of the yarn (Table 4.6) does not support this argument, and in the case of the rotor-spun yarn the variation may be said to be reflected in the U% data (Table 4.7), whereas the Classimat results do not confirm this. A plot of C.V.% of twist versus twist

factor in Fig. 4.2 indicates how C.V.% of twist for both ring-spun and rotor-spuns fall and rise to a point where it was highest at a twist factor of 41.14.

4.1.4 Assessment of yarn count

It may be observed from Table 4.4 and Fig. 4.3 that as twist factor is increased, the count of the ring-spun yarn rises and gradually levels off. A similar trend may also be observed from Table 4.5 for rotor-spun yarns, only that at the highest twist factor the count was rather low. With respect to the coefficient of variation of yarn count (linear density) lower values of CV% may be noted from Table 4.5 for rotor-spun yarns compared with those for the ring-spun yarns in Table 4.4. A noteworthy point is the fact that the CV% of count in rotor yarns is fairly constant and about half the magnitude of the ring-spun yarns except for the CV% at the lowest twist factor which is nearly the same as for the ring-spun yarn. This, to an extent, depicts some uniformity in yarn count within individual packages and from package to package for the rotor yarns. This observation may be due to the generally better regularity of rotor yarns which, in turn, may be due to the large number of doublings occurring inside the rotor during spinning as fibres are laid and re-assembled.

The reason for the higher variation in yarn count for ring-spun yarns may be associated with the type of drafting systems used on both the ring frame and roving frame. On no occasion did yarn count measurement exceed the theoretical value of 36 tex for the two types of yarn. Furthermore, a plot of the CV% of linear density in Fig.4.4

TABLE 4.4

Twist Influence on Ring-spun Yarn Linear Density

Twist Factor α_{tex}	Linear Density (Tex)	CV%
31.57	34.00	0.94
34.44	35.40	2.25
38.27	35.22	1.24
41.14	35.35	1.95
45.92	35.29	1.71
Mean total coefficient of variation value for count variation (CVT)		1.62

TABLE 4.5

Twist Influence on Rotor-spun Yarn Linear Density

Twist Factor α_{tex}	Linear Density (Tex)	CV%
32.53	34.69	0.855
36.35	35.36	0.824
39.22	35.01	0.895
41.14	35.12	0.996
45.92	34.64	0.758
Mean total coefficient of variation value for count variation (CVT)		0.865

Fig 4.3

TWIST FACTOR INFLUENCE ON YARN LINEAR DENSITY

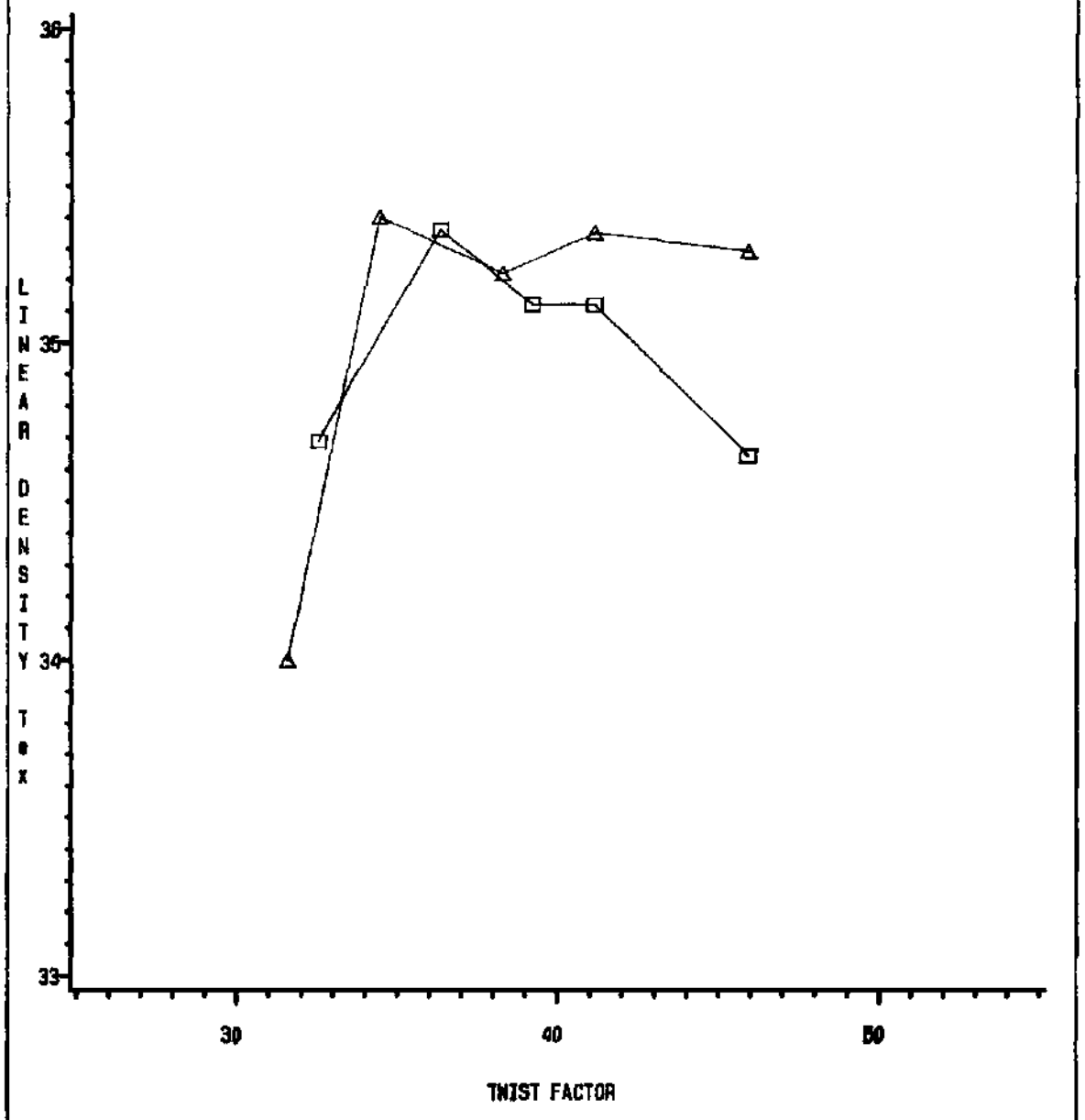
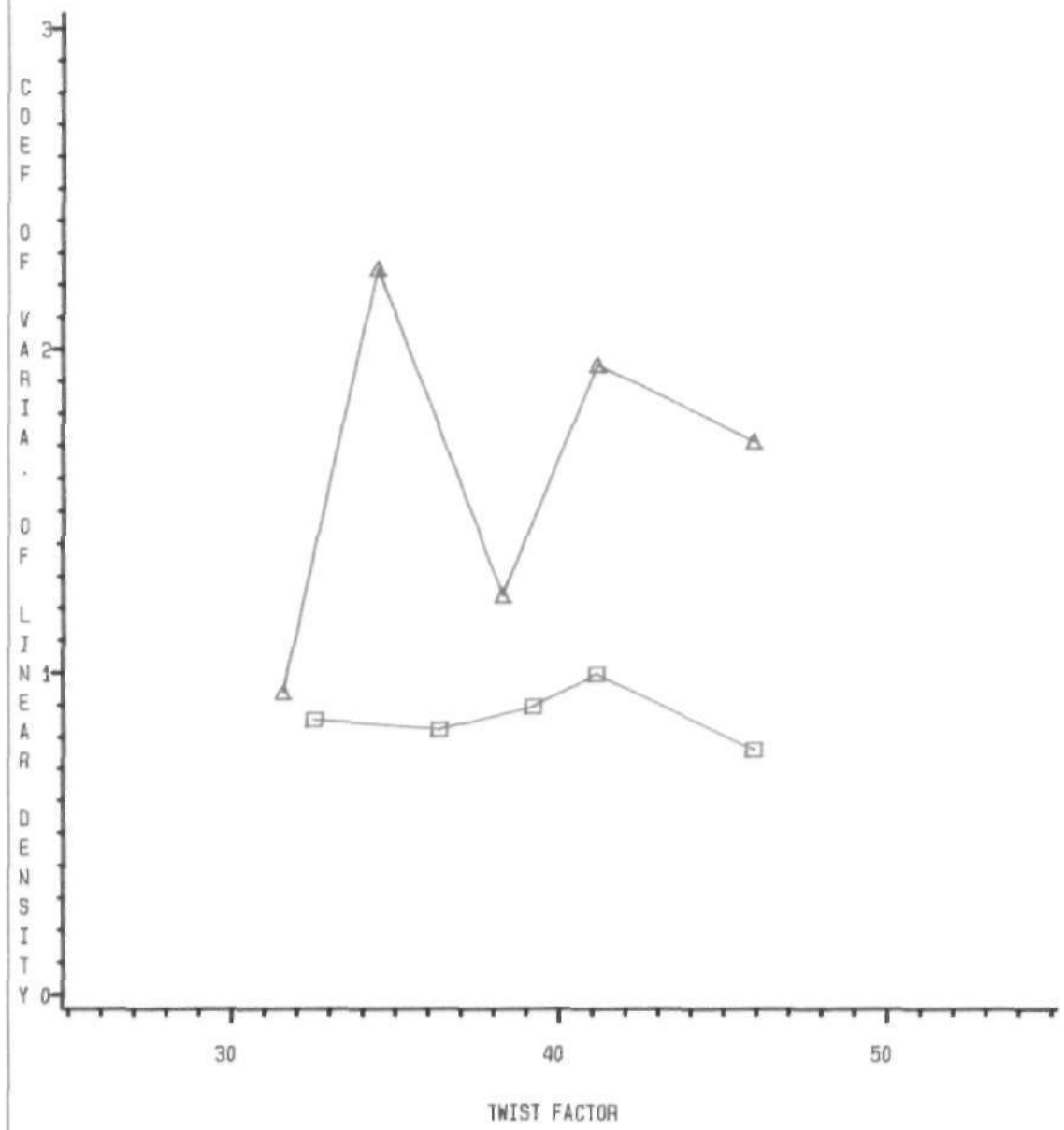


Fig 4.4

TWIST FACTOR Vs COEFFICIENT OF VARIATION OF LINEAR DENSITY



RING SPUN YARN

ROTOR SPUN YARN

describes how count varies with twist for the two types of yarn.

It is reported[71] that the spinning of a constant yarn count and the reduction of variation between yarn packages is determined, to a large extent, by the count constancy (long-term variation) of the products prior to spinning. It is further reported[71] (Uster News Bulletin) that for commercial yarns a value of 2.03% for the mean total coefficient of variation for count variation (CVT) is very reasonable. It is clear from Tables 4.4 and 4.5 that the values of CVT for both ring and rotor yarns are 1.62% and 0.865% respectively and these indicate that the coefficient of variation of count, in individual yarns, is very reasonable.

On the whole, it is inferred that increases in twist did only marginally influence the measured yarn count in both ring and rotor yarns, and a notably higher CV% of count was found for ring-spun when compared to rotor-spun.

4.1.5 Assessment of yarn irregularity

The value of U% obtained using the Uster Evenness tester depicts how irregular or regular a yarn is. Results of irregularity measurement from Tables 4.6 and 4.7 for ring and rotor yarns respectively show that rotor yarns are generally more regular than ring-spun yarns, since the U% of irregularity for each rotor yarn is low compared to that for a corresponding ring yarn. This is in agreement with literature reports,[19,20] though the differences found between the two in the current experiment are quite small. This might be due to the very close similarities in twist levels of the two types of yarn. Cotton rotor yarns are reported[21] to be superior in short-term

TABLE 4.6

Twist Influence on Ring-spun Yarn Evenness
(Irregularity)

Twist Factor α_{tex}	U%
31.57	11.48
34.44	11.79
38.27	12.10
41.14	11.76
45.92	11.59

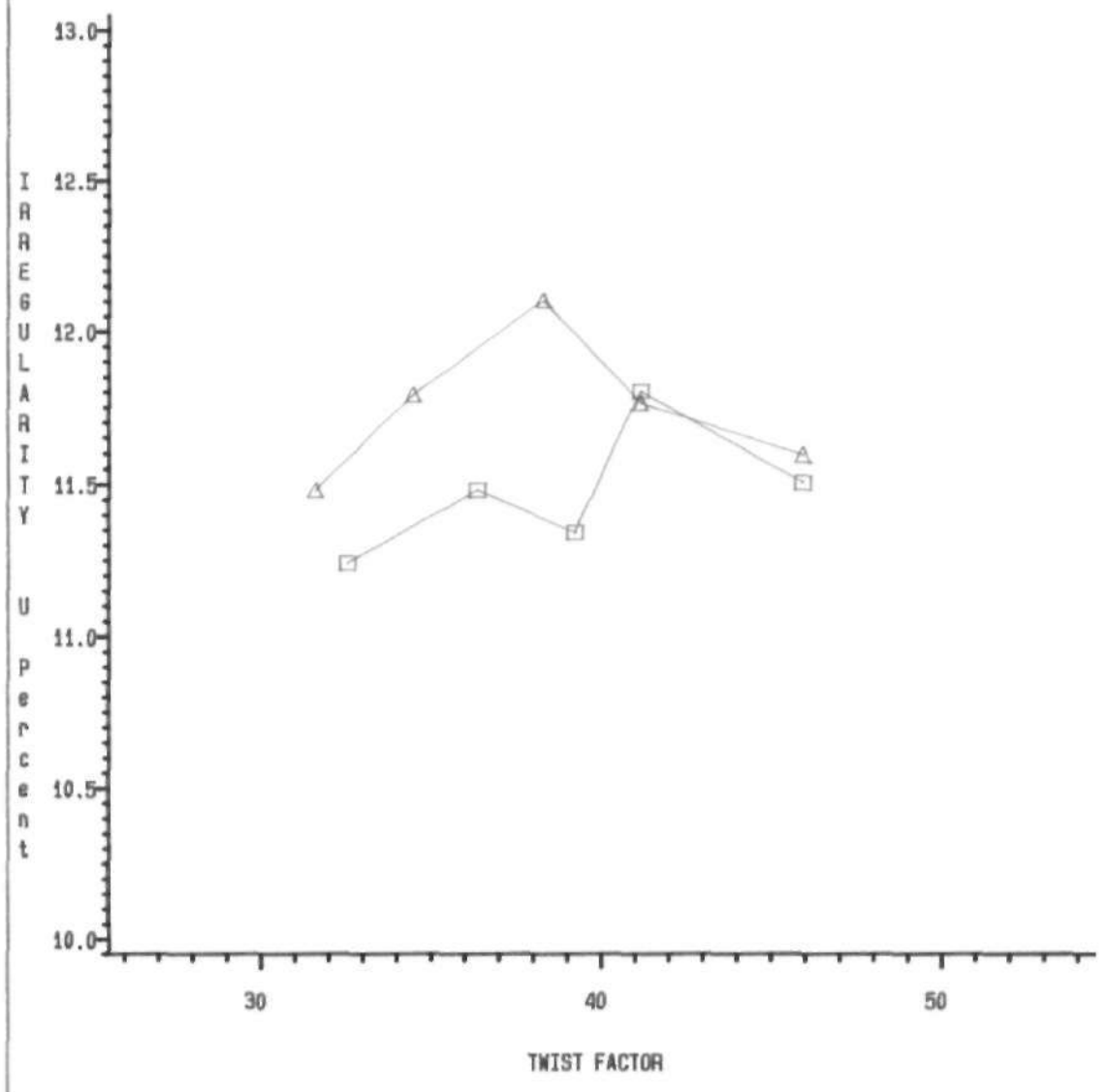
TABLE 4.7

Twist Influence on Rotor-spun Yarn Evenness
(Irregularity)

Twist Factor α_{tex}	U%
32.53	11.24
36.35	11.48
39.22	11.34
41.14	11.80
45.92	11.50

Fig 4.5

TWIST FACTOR Vs IRREGULARITY



RING SPUN YARN

ROTOR SPUN YARN

regularity to carded ring-spun yarns. The unique self-doubling effect inside the rotor and its advantages in suppressing prevalent drafting waves is thought to be responsible for this lower short-term irregularity. Louis[41] separately stressed that, in general, yarn uniformity and wrapper fibres are inversely related for a given cotton except for fine yarns spun at high speeds from long, strong cotton. In essence, it implies that as the number of wrapper fibres increases, the more irregular the yarn becomes. The results of the present study follow this trend but not exactly, because as twist factor is raised (wrapper fibres increase), the U% rose and fell as indicated by the plot of twist factor versus U% in Fig. 4.5. The situation is quite different with ring-spun yarns in which case a gradual increase in irregularity is seen as twist level is raised slightly to a point where it starts to fall as further increase in twist factor takes place. In general, therefore, it may be concluded that in the current trials the difference in irregularity between a ring and a rotor yarn spun at very similar twist levels is slight, and not as remarkable as might be thought.

4.1.6 Assessment of yarn tenacity and elongation at break

Measurement of strength and extension at break for ring-spun and rotor-spun yarns (as shown in Tables 4.8 and 4.9) were obtained using the Uster single thread tester under conditions specified earlier in Section 3.3.4 of Chapter 3.

The results in Tables 4.8 and 4.9 confirm the generally held view that ring-spun yarns are stronger than the equivalent open-end yarns.[3,14,16] Tenacity is seen to increase with twist factor in

TABLE 4.8

Twist Influence on Ring-spun Yarn Tenacity

Twist Factor α_{tex}	Actual Count (tex)	Breaking Load (gm)	Tenacity (g/tex)	Strength (CV%)	Breaking Extension (%)
31.57	34.00	511.00	15.03	8.02	7.9
34.44	35.40	573.00	16.19	5.32	8.6
38.27	35.22	615.00	17.46	6.18	8.7
41.14	35.35	568.50	16.08	29.16	8.7
45.92	35.29	640.50	18.15	6.67	7.7

TABLE 4.9

Twist Influence on the Tenacity of Rotor-spun Yarns

Twist Factor α_{tex}	Actual Count (tex)	Breaking Load (gm)	Tenacity (g/tex)	Strength (CV%)	Breaking Extension (%)
32.53	34.69	219.00	6.31	44.73	5.10
36.35	35.36	378.00	10.69	7.14	7.80
39.22	35.01	413.00	11.80	5.93	7.90
41.14	35.12	413.00	11.76	13.65	7.90
45.92	34.64	451.50	13.03	7.48	8.50

TABLE 4.10

Strength Ratio of Yarns at Different Twist Factors

Twist Factor α_{tex}	Rotor Yarn Tenacity/Ring Yarn Tenacity	
	Ratio	(%)
32.53	0.420	42.0
36.35	0.660	66.0
39.22	0.676	67.6
41.14	0.731	73.1
45.92	0.718	71.8

the two types of yarn, but the effect is much more pronounced in ring yarns than in rotor yarns.

In order to compare the relative effects of twist factor on the breaking strength of the two types of yarn, their tenacities were plotted against twist factor as shown in Fig. 4.6. Yarn tenacity is seen first to rise gradually to a high value at a twist factor of 38.27 and then to fall at 41.14, after which it rises rapidly to a higher value at the highest twist factor for ring-spun yarns. A similar behaviour is observed in the rotor-spun yarns, but this time initial rise in tenacity is rather instantaneous and rapid with twist. This is followed by a slightly sharp increase, then a small fall at a twist factor of 41.14, after which an increase is noticed at the highest twist factor.

Ideally, it is expected that yarn tenacity should be at its highest at an optimum twist factor or twist level, after which it should fall as further increases in twist take place. The yarns in the present study have not completely met up with this expectation. This might be because an optimum twist level was not reached, and that the twist factors selected were rather small or too close to impose any substantial behaviour on the yarns. Since the plots obtained described a steady increase in tenacity with twist factor, then any further rises in twist beyond an optimum point would be expected to bring about a gradual reduction in yarn tenacity for the two types of yarn.

The low strength of the ring yarn spun at the lowest twist level is probably due to the fact that there are only a few fibre contacts and the build-up of lateral pressure is too small to provide any

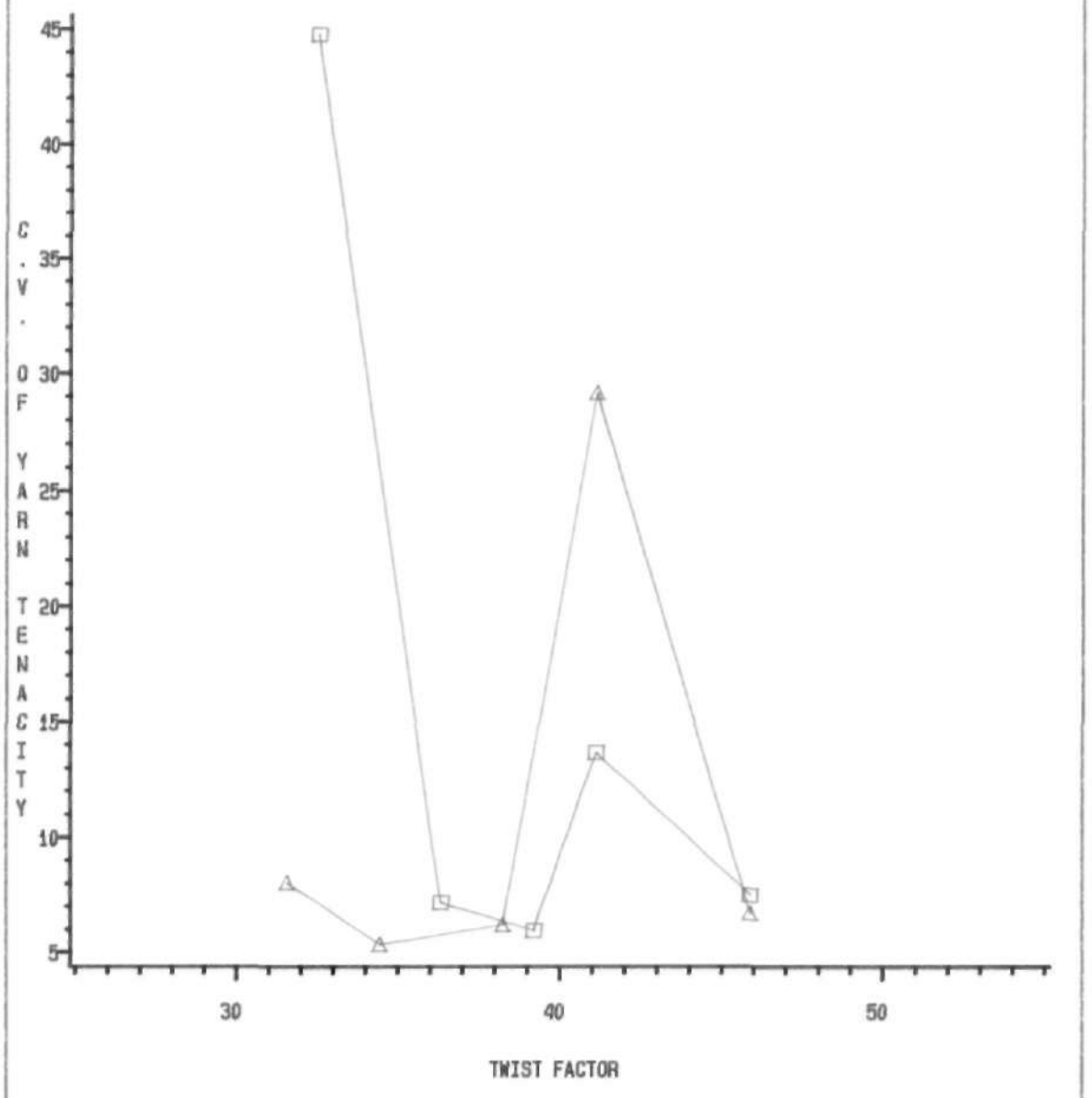
appreciable strength. During axial loading, therefore, the slight tension which is transmitted from fibre to fibre by friction is sufficient to cause slippage, but not high enough to cause fibre breakage, thus re-arrangement of fibre tension and fibre position occurs. As soon as this happens the self-locking features of the yarn are lost, fibre slippage then becomes dominant and the fibre cannot maintain any elastic deformation. Hence at low twist levels it is impossible to build up the tensions needed to generate the transverse force which, in turn, cause the fibres to be gripped and so allow the tension to build up. Thus fibre slippage causes the tension to fall to a very small value determined by the fibre cohesion and which equals the force required to draft the yarn.

The observed increase in tenacity of open-end rotor yarns is thought to be due to the increase in the number of wrapper fibres and increase in the frictional gripping force between the fibres (core and sheath) as twist factor is increased. Eljack[65] has found cotton O.E. rotor yarn tenacity to increase with twist factor. Sengupta et al[66] reported that improvement in yarn strength of O.E. rotor yarns is due to the reinforcement of yarn matrix through belts (wrapper fibres). They[66] went further to stress that these long belts extend during tensile straining of the yarns and thereby increase the lateral compression in the yarn matrix and hence restrict fibre slippage. Effectively, the incidence of fibre slippage is, therefore, likely to be greater at low twist factor.

From Fig. 4.6, it is clear that rotor yarn with the least twist factor (32.53) is the weakest. This is probably due to the very high coefficient of variation of tenacity as Fig. 4.9 indicates.

Fig 4.7

TWIST FACTOR Vs C.V. OF YARN TENACITY

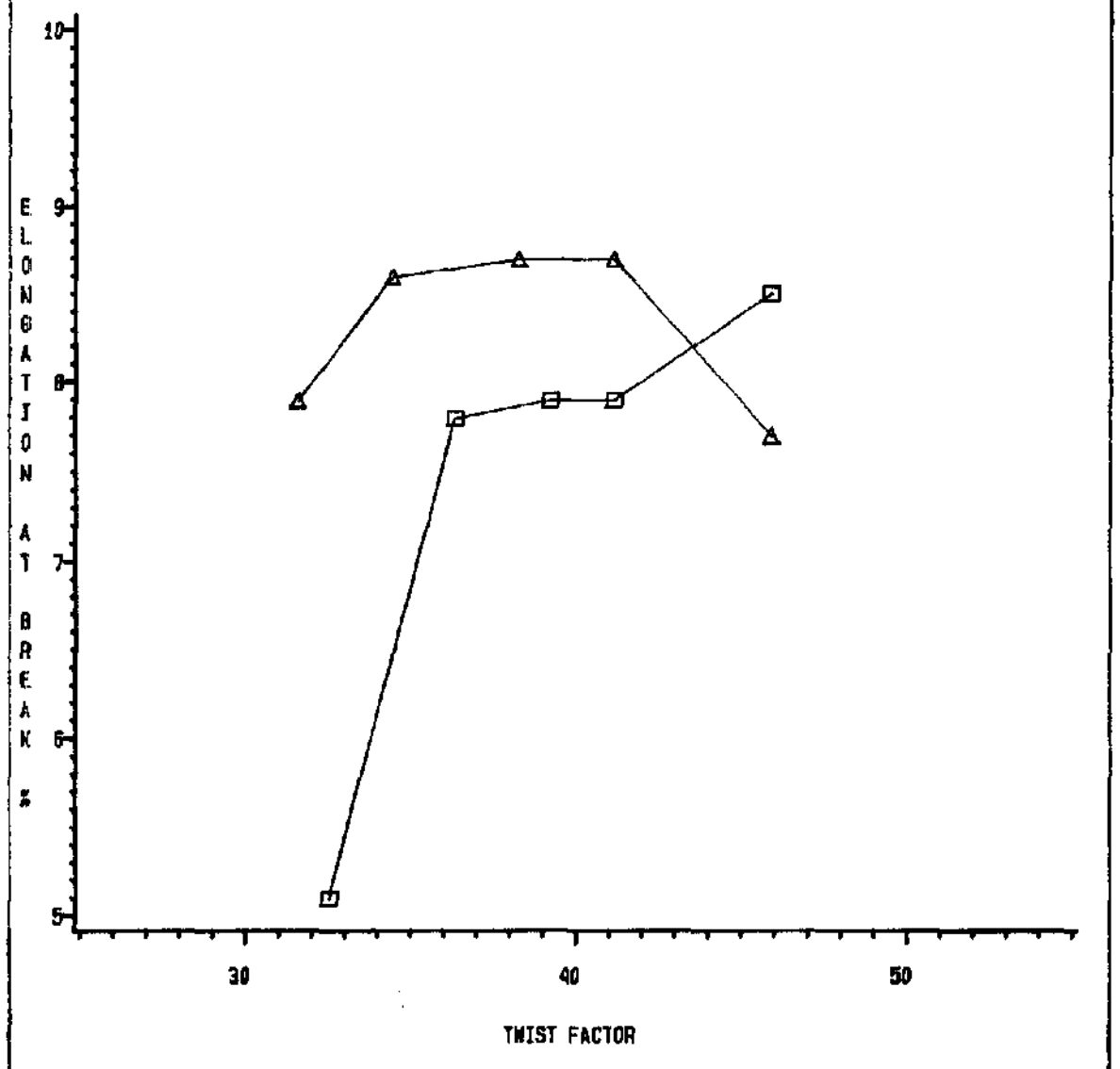


At a twist factor of 41.14 for both ring-spun and rotor-spun yarns, a fall in tenacity as seen in Fig. 4.6 is due, presumably, to their relatively high coefficients of variation tenacity. For the ring-spun yarn this behaviour may be attributed to the high CV% of twist (Fig. 4.2) or its high U% (Fig. 4.5) and higher CV% of linear density values (Fig. 4.4), while for the rotor-spun yarn, it may be attributed to its slightly high U% and CV% of linear density values. It is, therefore, not surprising that count variation was reported[71] to be one of the most important yarn quality characteristics which influences the variation in yarn breaking strength. It may be further seen that the plots of CV% of tenacity for the two types of yarn are almost similar with a reduction in CV% at the highest twist factor, Fig. 4.7.

Because of the similarities in twist factors, the ratio of rotor-spun yarn tenacity to ring-spun yarn tenacity was calculated and expressed as a percentage. The results are given in Table 4.10 and a plot of these values against twist factors is shown in Fig. 4.9. The ratio is seen to be low at the lowest twist factor and to rise sharply as soon as twist factor was increased. This is followed by a very slight rise at a twist factor of 39.22 following which a further increase in the ratio occurred at a twist factor of 41.14 and a slight reduction at the highest twist factor. There is a possibility that the ratio may increase further as the twist factor is further increased, but this would only be to a limited extent since the optimum twist value would be exceeded. The ratios clearly confirm that rotor yarns are weaker compared to ring-spun yarns. A possible explanation for the initial but sudden rise in strength of the rotor-spun yarn from a twist factor of 32.53 to 36.35 may be associated with a change in

Fig 4.8

TWIST FACTOR Vs ELONGATION AT BREAK



RING SPUN YARN

ROTOR SPUN YARN

the structure of the yarn which promotes fibre locking and hence higher strength. The role played by the formation of wrapper fibres may be of some significance but the evidence for the influence of wrapper fibres on yarn strength is contentious, since whilst some workers propose that wrapper fibres enhance yarn strength[65,66] others claim that wrapper fibres detract from the tensile properties of the yarn.[6]

From the foregoing, it is possible to conclude that: (i) yarn strength increases with twist factor for both ring-spun and rotor-spun yarns; (ii) ring-spun yarns are much stronger than rotor yarns at very similar twist levels. In addition, the general weakness of rotor-spun yarns may be explained in terms of their poor fibre extent and fibre migration within the entire yarn body, and it is reported[67] that the effective length of fibres in rotor-spun yarns is less than that of fibres in ring-spun yarns. The opening roller of the rotor spinner, it is said, changes a rectangular fibre array into a triangular one, and when folded back, the fibre ends behave like short fibres, contributing little to the yarn strength but improving its bulkiness.

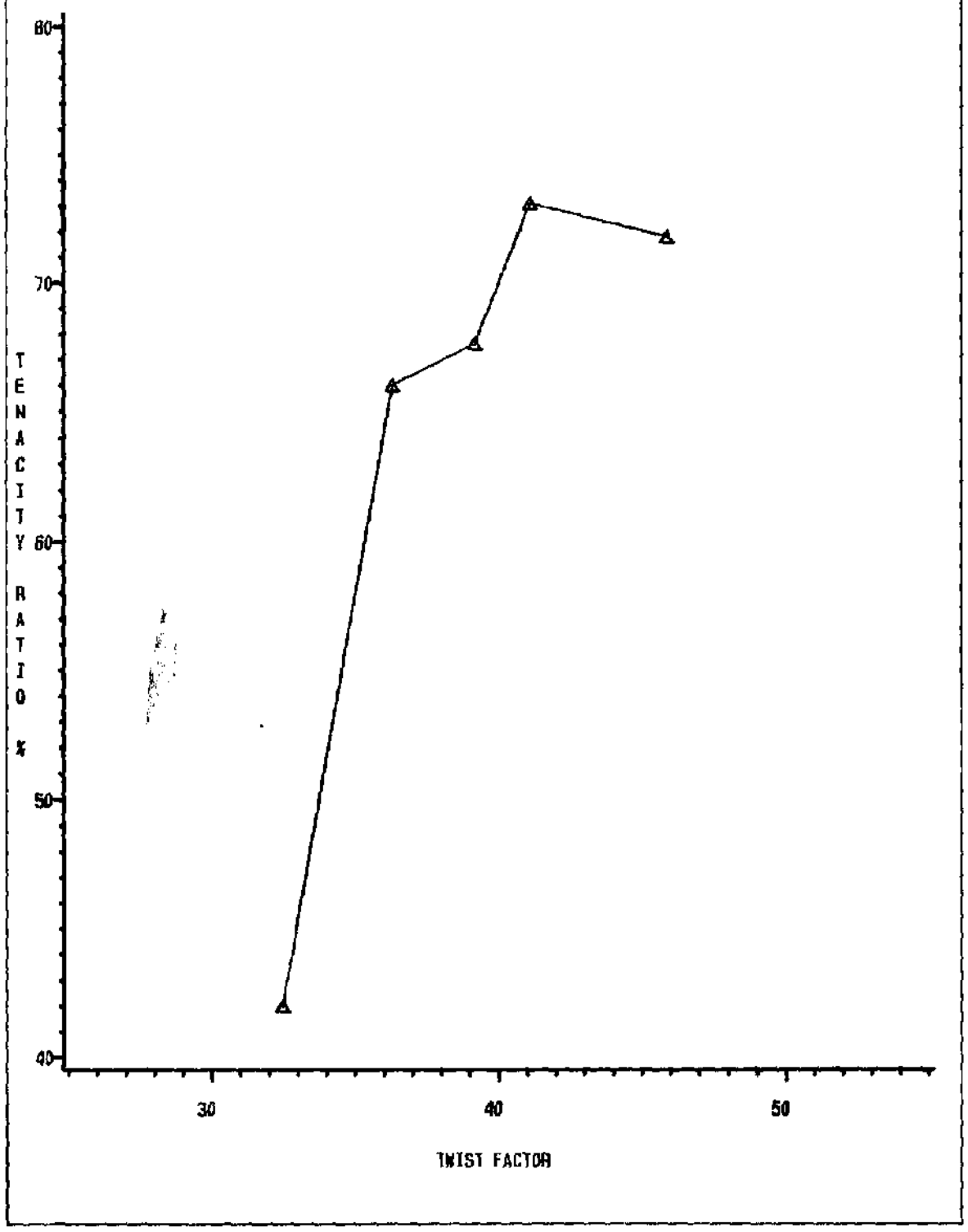
4.1.7 Yarn extension at break

The experimental results of elongation at break of ring-spun and rotor-spun yarns are listed in Tables 4.8 and 4.9 respectively. The results show the effects of twist factor on elongation at break. In Fig. 4.8 the breaking extensions of the two types of yarn are plotted against twist factor.

An analysis of both Tables 4.8 and 4.9 and Fig. 4.8 indicates,

Fig 4.9

TWIST FACTOR Vs ROTOR SPUN YARN PERCENTAGE STRENGTH



first of all, that values of elongation at break for ring-spun yarns are greater than those for the rotor-spun up to a certain twist factor. Secondly, it reveals that elongation at break increased initially for both yarns, but the increase is sharp in the case of rotor-spun yarns. Thirdly, upon further increase of twist, not much change in extension at break may be seen in both yarns. After that stage, the two types of yarn exhibit difference in extension at break since it can be seen that the ring-spun yarn extension at break drops whereas in the rotor-spun yarn an increase in extension at break results.

The low breaking extension at low twist for ring-spun yarns which increases to an optimum value and falls as twist factor is increased, is as expected and it is in agreement with the results obtained by Ibrahim[13] who carried out experiments at much higher twist factors (and used two different rotor diameters).

Generally, rotor-spun yarns are characterised as having higher elongation at break than ring-spun yarns,[10,13,14] and this has been attributed to the presence of some folded and entangled fibres (belts or wrapper fibres) in the rotor yarn which coupled with its more open structure, would bring about fibre straightening and slippage which, in turn, gives rise to a higher breaking extension than that obtained by fibre extension alone, as in a ring-spun yarn.[17,18]

No satisfactory explanation could be found for the generally low breaking extension values for rotor-spun yarns in the present study. It should, however, be stressed that previous reports on the higher extension of rotor yarns have usually been related to "commercial" yarns which would be spun at a significantly higher

twist level than their ring-spun equivalents. In the current analysis, this was not so and the yarns compared had almost identical twist factors. In addition, the extension at break for the rotor-spun yarn was low, probably because too high a winding tension was employed in getting the spun yarn on to the package.

Finally, it would be objective to draw from the discussion so far that, with the two types of yarn, breaking extension increases first with twist and then tends to level off. Increase in twist factor has had a much greater effect on yarn strength than it has had on yarn extension at break.

CHAPTER 5

Summary and Conclusion

5.1 Summary

The objective of the current project was the assessment of the effects of twist on the properties of both ring-spun and rotor-spun yarns. This included an appraisal of the spinning of a blend of cotton fibres to produce ring and rotor yarns at a range of similar twist factors using standard spinning machinery in the Department of Textile Industries at the University of Leeds. The spun yarns were stored in the testing laboratory under specified standard atmospheric conditions, following which they were subjected to various physical tests in order to assess how twist influences their physical properties. The yarns were tested for such physical properties as twist variation, linear density, fault level (Classimat), irregularity and single thread strength and breaking elongation. In addition, stereoscan photographs of some of the yarns were made in order to present a true picture of the yarns and more especially to show the wrapper fibres in the rotor spun yarns.

5.2 Conclusion

5.2.1 Yarn appearance and faults (Classimat)

Visual examination of the spun yarns confirmed that rotor-spun yarns are less hairy but bulkier than ring-spun yarns. It was observed that both hairiness and bulkiness tended to reduce with twist for both types of yarn, and it is thus obvious that twist factor is a critical feature in the modification of these particular properties.

With reference to imperfections and faults, results obtained

have confirmed the generally held view that rotor-spun yarns have fewer faults and imperfections compared to ring-spun yarns. Results further indicated that faults in both types of yarn tend to increase with twist. Whilst the trend of findings can be readily justified it should be emphasised that the results may only be applicable to the particular fibres and machinery used in the current experiment. Indeed, if the fibres had received different preparation (i.e. more cleaning) or a different type of spinning machine had been used, then different values may have arisen. It is suggested that further work should be carried out to substantiate these predictions.

5.2.2 Twist variation

The measured values of twist for both ring-spun and rotor-spun yarns are generally lower than the machine twist; however, the differences between the two are fairly small. From the coefficient of variation of twist data, it is concluded that the distribution of twist in the rotor-spun yarn is slightly less uniform than it is in the ring-spun yarn. The most probable reason for this is believed to be due to the inadequacy of current techniques for measuring the twist in open-end spun yarns.

5.2.3 Yarn count

Yarn count measurements for both ring and rotor yarns reveal fairly low values compared with the theoretical value of 36 tex. The results also reveal a non-linear relationship between yarn count and twist factor and, in addition, the CV% of yarn count indicates lower values for rotor-spun yarns compared with ring-spun yarns.

From this it is concluded that count variation for rotor-spun yarns is fairly constant as twist factor is increased from its lowest to its highest value, and to some extent this indicates some uniformity of the rotor-spun yarn. It is also concluded that increase in twist level during spinning tends to vary or influence significantly the linear density of ring-spun yarns.

5.2.4 Yarn irregularity

The yarn irregularity results of the present study showed that rotor-spun yarns have in general lower irregularity (U%) values compared to the equivalent ring-spun yarns. This is in agreement with reported evidence on yarn uniformity. Furthermore, it is clear from these results and the discussions that followed that increase in twist factor influences ring-spun yarn regularity much more than it does rotor spun yarns. Also, the difference in U% value between a rotor-spun yarn and a ring-spun yarn is not as distinct as would completely merit the conclusion that rotor-spun yarns are remarkably more regular than their ring-spun equivalents. The fairly small difference in U% value between a rotor and a ring yarn might have arisen from the similarities in twist factors. In addition, the Classimat test results obtained may, to some extent, be used to explain the better regularity of rotor-spun yarns.

In rotor-spun yarns, wrapper fibres are known to increase with twist, but results have indicated that yarn irregularity may either increase or decrease with twist. It is thus difficult to conclude whether irregularity in rotor yarns increases or decreases with twist or with the incidence of wrapper fibres. It is obvious, in the light

of the results obtained, and on the evidence of earlier workers[13] that considerable more work is needed to investigate the influence of twist on rotor-spun yarn structure and regularity.

5.2.5 Single thread strength

Experimental results have confirmed that the tenacities of both ring and rotor yarns are influenced by twist. It was found that in the current investigation the strength of rotor-spun yarns were more sensitive to changes in the spinning twist. The results further confirmed that ring-spun yarns are higher in strength compared to rotor-spun yarns and the strength of a rotor-spun yarn is about 42 to 72% that of an equivalent ring-spun yarn, depending on the twist factor. The percentage strength of the rotor-spun yarn (i.e. rotor yarn tenacity/ring yarn tenacity %) is shown to be influenced by the twist factor, higher values being attained at higher twist levels. This is believed to be associated with the high variation in strength which was evident in the rotor-spun yarn produced at low twist level.

It has been suggested[58] that the presence of wrapper fibres may be of benefit to the yarn tenacity due to these increasing fibre/fibre frictions in the yarn core. It is well known that the number of wrapper fibres increases with the spinning twist, and if wrapper fibres did influence tenacity, a sharp rise in tenacity with twist would be expected. The current results do not confirm this and thus the role of wrapper fibres on yarn tenacity must be questioned.

5.2.6 Yarn breaking extension

Results of the current research have generally shown that twist

influenced yarn strength much more than it affects yarn breaking extension. The results have also surprisingly shown that, in general, ring-spun yarns have higher breaking extension than rotor-spun yarns. These results are unexpected since it is generally acknowledged that the breaking extension of a rotor-spun yarn would normally be expected to be higher than that of an equivalent ring-spun yarn. It may be observed that the breaking extension of the rotor-spun yarn rises suddenly to a high value at the highest twist factor.

5.3 Comments and recommendations

In its entirety, the current research has employed empirical evidence to study the role twist plays in influencing various yarn properties. In view of what has already been inferred from the series of tests carried out, it is generally concluded that very slight changes in twist would have little effect on the properties of cotton rotor-spun yarns (though the changes may, to some extent, influence end-breakage and production rates), whilst with the ring-spun yarns, the effects would be rather more. Furthermore, the trends already exhibited by the ring and rotor yarns may not necessarily be reflected in their woven forms. This, perhaps, is due to the fact that in the woven structure all the yarns from which the structure is made act collectively in characterising its properties. Hence, it would not be surprising if, for example, the tenacity or strength of a ring-spun yarn woven fabric is observed to be lower than that of an equivalent rotor-spun yarn woven fabric, whilst the strength of a single ring-spun yarn is known to be higher than that

of the equivalent rotor-spun yarn. Though it is realised that the properties of a given yarn type may not always be reflected in those of the fabric, it is still possible to predict fabric properties from those of the yarns.

The presence of wrapper fibres (or belts) in open-end rotor-spun yarns should not be viewed as a defect, because by their mere presence they give to rotor-spun yarns a distinctive feature. They undoubtedly play some role in most of the properties of the rotor-spun yarns, though there may be instances where their presence could be objectionable.

Yarn clearing after spinning to detect and remove faults is a very important process from a quality control point of view, as their continued presence could greatly influence the various properties of a yarn and inadvertently result in poor quality fabrics.

There are probably other factors (external) as well as twist which may have been responsible for most of the unexpected trends observed in the two types of yarn. In ring spinning, for example, the type or character of the traveller used is likely to influence yarn hairiness and the winding tension of the yarn, and hence the yarn strength, whilst in rotor spinning the use of notched or grooved doffing tubes, for instance, are known to increase wrapper fibres due to an increased false-twist action resulting in an elongated PTE. It should thus be re-emphasised that the results reported are for the specific combinations of fibres and machinery used throughout the current investigation. It is obvious that slightly different yarn properties could be achieved by minor changes in both the fibre type and the processing conditions utilised.

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APPENDIX I

Details of Processing Machinery:

A. Roving Frame: PLATTS MS2 Speedframe

Flyer Speed	880 rpm
Roving Count	300 tex

B. Ring Frame: PLATT TYPE 800 Superspinner

Roller Diameters:

Front roller	2.9 cm
Apron roller	2.9 cm
Back roller	2.9 cm

Roller Settings:

Front zone	13.3 cm
Back zone	13.3 cm

Ring Diameter	5.1 cm
Spindle Speed	10,000 rpm
Draft Constant	516.67
Required Draft	8.33
Draft Change Wheel	62
Twist Constant	920
Yarn Count	36 tex

Twist Change Wheels:

Twist Factor α_{tex}	Turns per cm	Twist Change Wheel
31.57	5.26	66
34.44	5.74	60/61
38.27	6.38	55
41.14	6.86	50
45.92	7.65	45

$$\text{Twist Change Wheel} = \frac{\text{Twist Constant}}{2.54 \text{ cm}} \times \frac{1}{\text{Turns/cm}}$$

C. O.E. Rotor Spinner: PLATTS ROTOSPIN TYPE 883 (Sidefeed)

Rotor type	A
Rotor diameter	40 mm
Rotor speed	45,000 rpm
Opening Roller type	Pinned standard
Opening roller speed	6,500 rpm
Feed roller diameter	2.54 cm
Delivery roller diameter	3.81 cm
Sliver count	3 ktex
Yarn count	36 tex
Twist Factor (α_{tex})	32.53, 36.35, 39.22, 41.14, 45.92
Turns per cm (twist)	5.42, 6.00, 6.53, 6.86, 7.65
Required Draft	83.3
Navel type	16 grooves (coined)

The twist wheels required to give the draft and twist levels were obtained from specially prepared tables supplied in the manual of the machine.

The basic formulae for calculating the different parameters were as follows:-

$$\text{Draft} = \frac{\text{Sliver count (tex)}}{\text{Yarn count (tex)}}$$

$$\text{Twist (tpm)} = \frac{\text{Twist Factor}}{\sqrt{\text{tex}}} \times 100$$

$$\text{Delivery rate (m/min)} = \frac{\text{Rotor speed}}{\text{Twist (tpm)}}$$

$$\text{Delivery speed (rpm)} = \frac{\text{Delivery rate}}{\text{x Delivery roller diameter}}$$

$$\text{Feed rate (m/min)} = \frac{\text{Delivery rate}}{\text{Draft}}$$

$$\text{Feed speed (rpm)} = \frac{\text{Feed rate}}{\text{x Feed roller diameter}}$$

Details of the different calculations are shown below:-

Twist Factor α_{tex}	Twist (t/m)	Delivery Rate (m/min)	Delivery Speed (rpm)	Feed Rate (m/min)	Feed Speed (rpm)
32.53	542	83.0	693.2	1.00	12.5
36.35	600	75.0	626.3	0.90	11.3
39.22	653	69.0	576.2	0.83	10.4
41.14	686	65.6	547.8	0.79	9.9
45.92	765	58.8	491.2	0.71	8.9