STRUCTURE AND PROPERTIES OF OPEN-END FRICTION-SPUN YARNS UNDER DIFFERENT SPINNING CONDITIONS

BY

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ADissertation

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DECLARATION

I hereby declare that the content of this thesis is purely a record of my research findings. No part of this work has been submitted or accepted in any previous application elsewhere. All quotations and literature cited from sources are duly acknowledged.

A.R.B. Ibrahim
November, 1992.

DI[illegible]ED

CERTIFICATION

This thesis titled "Structure and Properties of Open-End Friction-Spun Yarns Under Different Spinning Conditions" by A.R.B. Ibrahim meets the regulation governing the award of the degree of Ph.D in Textile Science and Technology of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

To the cause of Allah.

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ABSTRACT

A laboratory model type of open-end friction-spinning machine (one sided) was used to spin ten different packages of polyester open-end friction-spun yarns and another ten packages of cotton open-end friction-spun yarns. Some packages were spun with back-suction and others without backsuction under different spinning pressures of 1066.8mm, 1219.2mm, 1320.8mm, 1422.4mm and 1498.6mm head of water at a speed of 160m/min. The magnitude and pattern of the suction affected the way in which fibres were assembled on the forming yarn, as well as the torque produced. Likewise, the structure and performance of the yarns are generally very dependent on these factors. The effects of these factors on the spun yarns were studied. The spun yarns were then analysed fully for their characteristics in order to know more about the new spinning technology for commercial exploitation.

The counts spun included the fine range from 20tex to 24.5tex with one percent tracer fibres made of viscose rayon and dyed black.

For twist investigation, optical method based on the tracer fibre technique was used with the expression:

$$t = \frac{\tan \theta}{\pi D}$$

Methylsalicylate solvent was used to isolate polyester fibres while ethylsalicylate solvent was used to isolate cotton fibres for twist analysis. The results of optical method of twist investigation showed that backsuction increases the amount of twists along the length of cotton open-end friction-spun yarns. The differences in twists level between backsuctioned and non-backsuctioned cotton O-E friction-spun yarns contribute to the differences in physical

properties between the packages. Even on the same package big differences in twist level along the length of cotton open-end friction-spun yarns were found. This is one of the causes of the low strength of the yarns. For example, one specimen of a yarn from package 17/1 had 1013.6 t.p.m. and another specimen from the same package had 386.2 t.p.m. a difference of 617.4 t.p.m. which is giving a lot of concern.

These investigations have shown that the yarn spun with backsuction under high spinning pressure (1320.8mm head of water) produced a yarn with more twists along its length. This is demonstrated by packages 17/11 and 17/13 which were both backsuctioned under similar conditions but package 17/13 was spun under higher pressure than package 17/11 and therefore has higher t.p.m. But the results showed by the package 17/15 gave a different trend entirely, since the package was spun under a pressure of 1422.4mm head of water with backsuction and produced a yarn of 759.0 t.p.m. compared with the package 17/13 which was also backsuctioned but spun under a pressure of 1320.8mm head of water and has higher t.p.m. in the order of 982.2 t.p.m. This shows that in open-end friction-spinning system there is probably a maximum spinning pressure under which the yarns are hard twisted, above this pressure the t.p.m. would be reducing hence changes in the structure and properties of the yarns.

Backsuction improves fibre orientation and fibre utilisation in cotton and polyester open-end friction-spun yarns. These investigations showed that backsuction makes the yarns smoother in O-E friction-spinning. The evenness and irregularity characteristic of the yarns is very good and this is improved by backsuction. All the yarns spun with backsuction have higher breaking force, work of rupture, tenacity and lower elongation than those

yarns spun without backsuction for both cotton and polyester yarns. This new spinning system is more promising for polyester yarns than for cotton yarns. The tenacity of cotton and polyester open-end friction-spun yarns increases by increasing the fibre extent but the effect is higher for backsuctioned packages. The tenacity of open-end friction-spun yarns decreases with increase in the number of neps and hairs/metre. These investigations revealed that the fibres are disoriented and the fibre extent is extremely low, these lead to low strength of the yarns. The highest tenacity (14.85 cN/tex) obtained from a backsuctioned package is not good enough. Means of partly straightening portions, at least, of the fibres are required to obtain tenacity needed for full commercial success.

The investigations carried out on the OE rotor spinning machine installed in the Department of Textile Science and Technology, Ahmadu Bello University, Zaria showed that the finnest count that can be obtained from the spinner is 22.0tex. In the spinning process, increase in yarn tex increases the spinning speed possible.

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CHAPTER 1

INTRODUCTION

Machine productivity in yarn manufacture has risen more or less logarithmically over three centuries. The need to have increased production per unit currency invested has been the incentive to design new yarn-production systems. Thus, over the period, the literature records the spinning jenny, mule, ring-spinning, rotor-type open-end spinning, to mention some of the most significant. There have been two major consideration: the achievement of high machine productivity and the production of an acceptably large output-yarn package.

In the case of the ring and traveller, the yarn stresses in spinning are controlled in large part by the size of the yarn balloon and the spindle speed; these considerations imply severe limitations in both productivity and package size. It is possible to improve spindle speeds if the ring size is reduced, but it is not possible to do both concurrently.

The open-end principle permits the severance of the functional connection between productivity and package size. In rotor-spinning, the rotor supports much of the yarn during formation, and the yarn stress in spinning is lower than that for a ring frame for a given twist insertion rate. With small modern rotors, speeds of 100,000 r.p.m. have been achieved, and this has led to a much greater productivity than is possible with a ring spindle. However, the stresses generated in the yarn inside the rotor are relatively high because the "spoke" of yarn inside the rotor moves at a high rotational of the rotor has to be reduced to keep the stresses within bounds. There is a practical limit to speed, and thus to productivity.

In the friction-spinning of staple-fibre yarns which is the major part of this research work torque is applied directly to the surface of the yarn by frictional contact between relatively slow-moving solid surfaces and the yarn itself. The yarn rotates only about its own axis, and the tensile stresses are lower still. Once again it becomes possible to increase the spinning speed by a further considerable margin. As with rotor-spinning, the former restraints on package size are no longer a factor, and large cones or cheeses can be made. The concept of friction-spinning has appeared in the patent literature over the last decade or so but it has not been fully developed(3).

Torque is generated by tangential components of the frictional forces acting on the surface of the yarn. Solid surfaces moving in opposite direction in close proximity create a shear field which acts to produce the required torque. An analogous idea is used in texturing continuous filament yarns, in the course of which the yarn can be made to rotate at over a million r.p.m. Thus it is reasonable to expect that speeds approaching this may become possible in staple-fibre spinning. At present, staple-fibre friction-spinning machines can produce yarn at 200-450m/min, but the yarns have a low tenacity. Friction-spinning machines producing core-spun yarns currently have a limit of about 10s English cotton count (59 tex). Open-end friction-spinning is capable of making yarns of up to about 40s English cotton count (15 tex), and the yarns and fabrics have a good aesthetic appeal.

In fact, friction-spinning of a staple-fibre yarns involves the supply of separated fibres to a torque zone within a shear field and the removal of yarn from it. The shear field is created by the movement of one or more solids of revolutions. Usually, two parallel cylinders rotating in the same direction in close proximity are used to create the desired shear field in the vicinity of the nip line.

At least one of the cylinders is perforated, and air-flow into the cylinder causes force reactions to be generated between the yarn and the cylinders. The solid surfaces move in opposite directions in the vicinity of the yarn, and the drag forces acting on the yarn create a torque.. The magnitude and pattern of the air-flow strongly affect the way in which fibres become assembled on the forming yarns as well as the torque produced. The structure and performance of the yarns are very dependent on these factors.

The yarn from first-generation machines is weak because of poor-fibre structure, and this research work looks into some possibilities of improving the mechanical properties of the yarn.

Objectives of the Work

1. To spin some cotton and polyester packages from open-end friction-spinning machine under different spinning conditions.
2. To observe the effects of backsuction in open-end friction-spinning system and how suction affects the structure and performance of the yarns spun from the spinning system.
3. To study the structure of the yarns spun and to investigate the distribution of twist, fibre, fibre orientation and utilisation in this new spinning system.
4. To study the mechanical properties and the surface characteristics of these yarns and how these properties can be improved for better understanding of the spinning.
5. To compare some yarn properties together and to observe how the structural built-up of these yarns affect these properties.
6. To find out and suggest the best spinning conditions for commercial utilisation of the spinning system.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

To make Open-end friction-spun yarns, it is necessary to introduce fibres to the appropriate shear zones(1), and a popular solution is to make at least one of the moving surfaces a non-flat solid of revolution. This permits a fibre supply channel to be brought close to the torque zone, which helps control the fibre-assembly process. In this case, the torque is generated by the oppositely moving surfaces, and the arriving fibre is carried out into mesh with the yarn by one of those surfaces or by the yarn itself. However, the emerging yarn does not rotate, and only a rotating envelope of fibres at the open end is capable of twisting in the arriving fibres. The direction of arrival of the fibres is said to be more or less opposite to the direction of departure of the yarn. This is called "backwards spinning". However, it is quite possible for the fibres to approach at other angles with respect to the yarn. The best arrangement is yet to be determined, though variations in the angle of approach are not very powerful factors.

Implementing this concept requires that the location of the open end of the yarn remains fixed with relation to the moving surface and that a sufficient normal force be present for twisting. This can be accomplished by sucking the fibres to a limited local surface as they are supplied.

The concept of producing yarns on such principles is to be found in the patent literature of the 60s and 70s. Friction-spinning was first implemented in the 70s by Dr. E. Rehrer, who has developed several machine versions in the meantime. In his first machine design, the DREF 1, opened fibres were sucked against the surface of a perforated cylindrical drum in a narrow area(2).

When the perforated drum/yarn surface ratio is large, the drum speed can be kept relatively low, even if one takes the unavoidable slippage into account. In order to reduce slippage and improve twist efficiency, the DREF 2 machines(2) were equipped with two perforated drums. The yarn is more securely fixed in the nip of two drums, and twist transfer is intensified.

Since the translation ratio of friction drum diameter to yarn diameter increases with the yarn fineness, finer yarns are more intensively twisted, assuming constant drum speed and slippage.

The concept of enclosing the yarn between two friction surfaces is found in all OE-friction spinning methods published in the patent literature(2). Twist can be imparted by friction using two rotation symmetrical bodies. Either outside or inside friction may be used(2) Inside friction offers the advantage of better fixation and nipping of the yarn end, but at the cost of much more difficult yarn feeding and machine operation.

The patent literature shows that rotating bodies between which the open-end yarn structure is formed and twist-consolidated by means of friction may be cylindrical, as in the case of Fehrer, conical or hyperbolic.

DREF 1 and its successor process, DREF 2, are intended for coarse yarns. The process is suitable for producing relatively coarse yarns, because of the yarn structure and fibre orientation resulting from the fibre feed direction, which is perpendicular to the yarn delivery direction. The possibility of producing core yarns by the DREF 2 method, by feeding a filament yarn parallel to the drum axes, for example, led to the DREF 3 process, which attempts to combine the advantages of high spinning speed and an axis-parallel fibre orientation in the yarn. This is intended to improve yarn tenacity and produce relatively finer yarns.

This spinning method utilises two perpendicular fibre streams. The yarn structure, supplied in the direction of the yarn axis and reduced by a draw frame, is merely false-twisted. The fibres of this component, which predominate in the yarn (about 70 - 80%), lie untwisted in the core and are wrapped by a smaller component of fibres fed crosswise.

The DREF 3 process is not an OE-friction method in the above sense. There is no open end, and the yarn is consolidated by wrapping with a relatively small proportion of the fibres.

2.2. General Properties of Open-End Friction-Spun Yarns

2.2.1. Yarn Structure

Visually, the structure of OE friction-spun yarns seems more like ring yarn than an OE yarn (2). This is confirmed by the cross sections. According to present in sights, deviations in dynamometric properties of the OE friction yarns are due to mass fluctuations and shorter fibre utilization lengths, i.e. poorer orientation and extension of the fibres in the yarn.

OE friction yarns do not have the wrapping fibre structure of OE rotor yarns, but (2) their degree of fibre orientation and extension is very low.

OE friction-spun yarns have no systematically formed wrapped fibres (3) but with lower fibre straightened and orientation than with ring and OE rotor yarns. It remains to be seen whether the advantages of the yarn structure considering the restricted application field due to lower strength offer so many economic advantages that a market introduction of the OE-friction technology is justified (4).

2.2.2. Yarn Tenacity and Elongation

The quality and structure of OE-friction spun yarns depend essentially on the arrangements for fibre opening and fibre feeding. It has been shown by many workers that both the tenacity and elongation of OE friction-spun yarns depend to different degrees on the final yarn count(5) and spinning speed. The tenacity of open-end friction-spun is lower than that of the comparable ring and rotor spun yarns(5) while the yarn breaking elongation of OE friction-spun yarns is a bit higher than that of rotor spun yarns but lower than that of comparable ring spun yarns.

Typically, open-end friction-spun yarns have only about 60% of the tenacity of ring-spun yarns or about 90% of that of rotor-spun yarns(1). The tenacity of core-type friction-spun yarns decreases with increase in amount of sheath or as the sheath is made thicker. This suggests that the sheath fibres were disoriented. Furthermore, the tenacity of cotton open-end friction-spun yarns from current machines was quoted in the literature to be about 9gf/tex (88.3mN/tex) when tested at normal gauge lengths. At shorter gauge lengths(1), the tenacity is said to have increased as fibre loops within the test sample became gripped by the clamps of the test machine. At 6mm gauge length, the tenacity of some commercially produced open-end friction-spun yarns rose by 37% as compared with the value at 500mm. For a ring-spun yarn, the comparable rise in strength was given to be only 20%(1). This also suggests that the open-end friction-spun yarns have poor fibre orientation.

2.2.3. Yarn Evenness and Imperfection

Due to the torsion insertion during open-end friction-spinning mass variations in the fibre feeding stream lead unavoidably to changes of the friction conditions and also to stronger twist variation(6) in the yarn. These mass variations can be improved considerably by the quality of the opening device and the guaranty of a very constant fibre system.

A considerable number of fibres in the OE rotor yarns were loosely wrapped around the yarn, with some forming rings or wrappers around the yarn giving a bulky appearance(7). This is found also in open-end friction - spun yarns and a contributing factor to yarn imperfection. Though, OE friction-spun yarns have fewer imperfections than the OE rotor yarns, in some cases the thin places are very pronounced, i.e. there are more thin places with fewer fibres in the yarn cross section than with OE rotor yarn for example(5). This hitherto typical characteristic of OE friction-spun yarns is largely responsible among other things for the strength performance of the friction-spun yarns. Accordingly, measures to improve, i.e. reduce the number of thin places in these yarns are bound to raise the yarn strength substantially. OE friction-spun yarns have good evenness characteristic(1).

As with all spinning systems, the mass irregularity of open-end friction-spun yarns depends on the yarn count(8) with optimum passage of drafting. In most cases, is better for finer counts than coarser yarns. OE friction-spun yarns of the present generation are noted for very short-wave irregularities of approximately 25 to 30mm and short weak spots with a magnitude of 1.5 to 4.0mm(8). It is possible to ensure an acceptable coefficient of variation of mass irregularity using open-end friction-spinning principle(5). It has also been reported that OE friction-spinning system produces more uniform yarn(7) than ring-spinning system.

2.2.4. Yarn Abrasion Resistance and Other Mechanical Properties

The marked hairiness of OE friction-spun yarn and the specific character of the yarn surface make it prone to stripback and abrasion(5). Fabrics made from open-end friction-spun yarns have a good handle but tend to have poor surface durability(1). In spite of deviations in tenacity and elongation(2), open-end friction-spun yarns have tendency to kink in a similar way as ring-spun yarns.

2.2.5. Processing Technology and Performance of Open-End Friction-Spun Yarns

The quality and structure of open-end friction-spun yarn depends essentially on the arrangements for fibre opening and fibre feeding(9). In particular, the regularity of the fibre flow and the degree of fibre stretching and orientation during fibre attachment to the rotating yarn end are of major importance(10) (11). It has been stated that friction-spinning technology was introduced commercially by the Dr. E. Fehrer's company in the form of the "Dref 2" and "Dref 3" machines. However, since the "Dref 2" system principally manufactures yarn of coarser counts for special end-uses(12) (13) (14), and the "Dref 3" system is used to produce multi-component and speciality yarns, there have been various developments aimed at extending OE friction-spinning technology towards the finer yarns range.

In OE friction-spinning, the rapidly incoming fibres impinge on a yarn end rotating at high speed. However, since it is moved only at relatively low speed in the take-off direction, a further improvement in the fibre orientation is not attainable, hence low strength product. For this reason, an attempt has been made to effect a positive influence through the injection of compressed air or a stream of suction air (15).

2.2.6. Application and End-Use of Open-End Friction-Spun Yarns

Open-end friction-spun yarns have not penetrated the yarn market (7), partly because of the comparatively wide range of yarn counts produced by ring spinning and the diversity of fibres it can handle compared to OE friction-spinning and partly due to the low strength of OE friction-spun yarns. Means of straightening the fibres to improve orientation are required to obtain the tenacity needed for full commercial success(1). The new spinning system has been employed for producing relatively fine yarns. For spinning

finer short-staple fibre yarns (finer than 25 tex) the OE friction-spinning appears particularly attractive, because with this technology(16) the speed limitation dictated by physical and technological reasons is much higher than in OE rotor spinning for instance.

A particularly favourable future is being forecast for open-end friction-spinning because of its high production rate, and also for the wide range of application(17) of the alternative spinning techniques at the present time. Well known textile machine manufacturers are competing with each other to apply this spinning principle in order to be in a position to profit from any possible commercial implementation of this technique.

2.3. Effect of Processing Parameters in Open-End Friction-Spinning

2.3.1. Role of Opening Device

The quality and structure of OE friction-spun yarns depend essentially on the arrangements for fibre opening and feeding(9). In particular, the regularity of the fibre flow and the degree of fibre stretching and orientation during fibre attachment to the rotating yarn end are of major importance (10) (11). Opening device is responsible for effective and uniform fibre singling(16) and may be provided with injectors for manipulating the fibres stream. In this way the yarn properties may be varied more than 100% depending on the types of opening and feed units. It has also been stated clearly that (3) the opening cylinders are responsible for an excellent division of the sliver and separation of the fibres.

2.3.1.1. Fibre Presentation to Opening Cylinder

In the sliver feeding in groups, as already known from the Dref-Machines, the fibres are fed vertically to the yarn take-off direction. The doubling, can be regarded as an advantage of this method. In the cross section of the yarn, fibres from different slivers are found which are systematically distributed over the

cross section(3). On the other hand the feeding of the fibres vertically to the yarn take-off direction is connected with a very small length of fibre usage and consequently with a lower tenacity. Thus, this procedure is only suitable for the production of coarser counts, which consist of different fibre materials, especially, however, for those consisting of waste materials. This fact coupled with sliver feeding and fibre feeding led to the opinion, that OE friction-spinning represents a technology of coarse yarns. For the improvement of fibre alignment in the direction of the yarn axis a "Parallelisator" was developed by Fehrer. With the help of this rotating beater blade disk, those fibres flowing in vertically to the yarn axis are meant to be deflected.

A new development is the use of oblique feeding of single slivers which are opened to single fibres with the help of an opening aggregate, several factors of influence are important. A temporarily constant flow of fibres is required by separating the single fibres from one another and having them to flow as well aligned units into the yarn formation area where they are bound into the rotating yarn and parallel to the yarn axis. From this requirements, which can only partly be fulfilled, certain realizations and arrangements of the opening aggregate and the fibre guiding canal are derived. The latter should be sloping between 10 and 45° towards the yarn take off direction(3).

The yarn take off can be effected against (backward spinning) or in the spinning direction of the fibre feeding (forward spinning). The influence of the spinning or yarn take-off direction is again in reciprocal action to other technical spinning measures, so that one or the other variant cannot be generally preferred in respect to spinning performance and result. Certainly the remaining constructive realisation of the machine is an important point for the choice of the yarn take-off direction.

In open-end friction-spinning systems the main reasons for unsatisfactory spinning results can be found in the unfavourable conditions during the fibre accumulation dependent on the procedure(18).

2.3.1.2. Opening Cylinder Parameters

Generally, slivers of the second drawing passage are fed. Although the application of a high-draft drawing system for the attenuation of the sliver is possible. Opening aggregate, as they are known from rotor spinning, have succeeded. These opening cylinders are equipped with needles and/or saw-tooth sets(3). The opening roll of OE rotor-spinning is also to be seen on the Platt Saco Lowell OE friction-spinning machine. In that case, the fibre transport to the collecting surface is via a fibre feed duct. Lawrence et. al.(19) demonstrated how the geometry of the fibre duct, the setting of the air speed and its velocity ratio relative to the opening roll, influence the fibre flux and the fibre orientation. One of the major problems with this basic principle is the free flight of fibres and the consequent elimination of the drafting effect of the drawframe drafting. In other words, the fibres are not fully aligned. Their compression on impingeing on the collecting surface also contracts the drafting, within the result that there is a characteristic random orientation of the fibres. In open-end friction-spinning more favourable conditions apply in the fibre acceleration in the fibre transport sector than the case in rotor-spinning. Due to this, the fibres have to be orientated with other means, usually of aerodynamic nature. In OE friction-spinning, the rapidly incoming fibres impinge on a yarn end rotating at high speed. However, since it is moved only at relatively low speed in the take-off direction, a further improvement in the fibre orientation is not attainable (3) (10) (16).

2.3.1.3. Opening Roller Speed

Opening cylinder speed is very important in getting the desired result in open-end friction-spinning system. Suitable opening roller speed is desirable to improve the degree of opening, fibre velocity, fibre orientation after opening, yarn regularity and dynamometric properties (substance utilization) (16). No optimum opening roller speed has been established because of the complexity of the spinning system.

2.3.2. Opening Efficiency and the State of Order of the Fibres

Fibres opening efficiency in this spinning system is expected to be high for improved quality. The mechanically effective measures taken by Dr. E. Fehrer for the improvement of the fibre alignment with vertical feeding arrangement are commendable. The improvement of the quality of fibre alignment in the stage of fibre feeding and yarn formation, however, is attempted first of all by technical aerodynamic measures.

In OE rotor-spinning, the fibres in the conic fibre guiding canal are speeded up, aligned and stretched under the effect of the vacuum in the rotor housing. The fibres are furthermore aligned and stretched while leaving the rotor rotating with a higher circumferential speed and during their sliding into the rotor groove. The behaviour of fibres in OE friction-spinning is different. Here, fibre stretching and alignment are much smaller. During the connecting phase of the fast flying fibres with the yarn end moving with limited speed in yarn take-off direction but rotating with high speed, no further improvements are to be expected as in rotor-spinning. By means of an injection of compressed air, the position of the fibres in the fibre guiding canal and the process of feeding can be influenced. Another possibility is represented (3) by the application of a suction stream for the alignment of fibres in the accumulation, that is to say yarn formation phase as described by Platt Saco Lowell ( ). The pneumatic measures represent important devices for the control of the OE friction-spinning process

and of the yarn characteristics. They may never however, be seen isolatedly but always in connection with other spinning conditions. As the spinning system stands now, the state of order of the fibres is poor as shown by the results of research work done in this area and supported by many papers done in the past in the area (2) (3) (4).

2.3.2.1. State of the Order of the Fibres in the Torque Zone

The optimum orientation of fibres in the torque zone has not been achieved yet and it is a factor responsible for low tenacity of the yarns from the spinning system. In OE friction-spinning efforts are made to work with feed slivers similar to these in OE rotor-spinning. With the multisliver feed introduced by Fehrer, besides the different doubling conditions the fibre mass distribution also differs from that with a fibres stream fed at an angle (5). The fibre mass distribution in the collecting zone occuring in practice may be simultated by feeding in fibres with the friction element stationery, followed by determination of the mass distribution by cutting and weighing. Much more informative is measuring the pulse density, i.e. the number of fibres at different points with fibre orientation along the fibre duct opening, during the spinning process.

By means of a measuring head developed by the Institute for Textile Technology of the RWTH Aachen (5) which serves also to detect the fibre speed and fibre orientation; the local pulse density is registered - a characteristic proportional to the number of fibres. There are various possibilities of influencing the fibre distribution in the collecting zone with various injector configurations and injector pressures. Generally, the fibres are expected to be stretched out and parallel with yarn axis (in collecting phase) for good yarn characteristics in the torque zone, but unfortunately this condition has not been fully realised (16).

The realisation of this condition will eventually give good yarn structure, improve yarn fineness with better regularity and good dynamometric properties.

2.3.3. Torque Production

The required shear field needed to produce torque may be obtained in a variety of ways, but it is usually required that the lateral movement of the yarn be zero(1). In simple theory, two moving surfaces move at equal and opposite velocities, and the surfaces are kept in contact, with opposite sides of the yarn being twisted. To generate a torque, forces F have to be applied, and the resulting torque is μfd, where d is the diameter of the yarn and μ is the dynamic coefficient of friction. The normal force between the yarn and the moving surfaces has to be produced, in most cases, by a force F, which creates two reactions R_1 and R_2. The tangential forces produce torque:

$$\text{Torque} = (\mu R_1 + (\mu R_2)\ (d/2) \qquad - \quad \backslash \quad - \quad - \quad -$$

It has been fully recognized that the geometry of the system greatly affects the ratios R_1/F and R_2/F for that reason, the separation of the torque rollers (G) and the local yarn diameter (Y) are critical factors. The force F is usually produced by causing air to flow over the yarn, through perforations in one or both torque elements into a suction device. This force is a function of the pressure difference P across the yarn and the projected area of the yarn (SY.dx). The spinning tension and the torque are both functions of F. However, there are other factors that affect them, and these will now be discussed.

In open-end friction-spinning, the yarn end is tapered, fibres are added continuously in the vicinity of the tapered portion, and formed yarn is removed continuously from that section. There is a

mass equilibrium between the arriving fibres and the departing yarn, but the linear density of the fibrous material in the zone is not necessarily constant. The yarn dimension changes along the length of the formation zone, and the local force gradient varies accordingly. At the thin end of the taper, where $Y<G$, the yarn would pass through the gap if the air streamlines were tangetial to both torque rollers. However, the streamlines are controlled by the geometry of the non-rotating suction cylinders inside the torque rollers. The slits in these cylinders are in the vicinity of the nip, with the consequence that the thin end is also held in the vicinity of the nip. Where $Y>G$, the angles of the reactions R_1 and R_2 change along the length of the rest of the tapered position of yarn. This implies that, where Y/G approaches 1.0, the ratio R/F approaches infinity, but F approaches zero, and no torque should be generated by direct contact.

From the above equation, we have:

$$\text{torque} = (Y/2)\ (R_1/F + R_2/F)\ (\mu F)$$

but

$$dF = PY.dx$$

and hence the incremental torque generated is equal to:

$$(R_1/F + R_2/F)\ (P)\ (Y/2)\ (Y.dx)\ (\mu)$$

for each increment of length dx along the yarn between the points where $x = z$ and $x = 1$. As Y approaches G from the thick end, the term R/F increases and the term Y decreases, with the result that the torque distribution along the tapered end of the yarn varies. In practice, the effective diameter in the yarn-formation zone, the coefficients of friction, and the longitidual pressure distribution vary and modify the torque distribution from that described theoretically. However, it seems reasonable to assume a polynomial relationship between torque and length over the fibre assembly zone (1).

2.3.3.1. Role of Torque and Associated Parameters in the Mechanics of Yarn Formation

The twist distribution is determined not only by the torque distribution but also by the changing stiffness of the fibrous material in the assembly zone. Various annular layers of fibre are likely to have different twist levels. The outer layers of fibre are deposited in the vicinity of yarn departure, and the core fibres are deposited at the thinnest portion of the forming yarn tail. There is also a possibility of false-twist level of late-arriving fibres. These late arrivals form a sheath, which defines the surface character of the yarn(1).

For the formation and torsion of the yarn assembly, usually rotating friction elements are used. In all cases the fed fibres are formed to the yarn assembly in the nip of the friction elements used and at the same time strengthened by twisting(3). The importance of torque generation can not be over emphasised in open-end friction-spinning since the consolidation of yarn takes place in the torque zone only.

2.3.3.2. Effect of Spinning Speed on Yarn Properties

The arguments given here under the effect of spinning speed on yarn properties should be regarded only as revealing trends, as the large number of fibre and machine parameters may influence the strength level, for instance, considerably in some cases. Apart from the known influences of fibre type and fineness, the tenacity depends essentially on the spinning speed and the friction ratio(16).

Owing to the worsened doubling, both fineness reduction and speed increases are detrimental to strength. Depending on the friction ratio a twist state optimal for the yarn strength adjusts itself generally as with ring and OE rotor yarns. With constant friction ratio, as expected the elongation increases as the yarn becomes coarser. Finer yarns spun at higher speeds also display

poorer mass irregularity. Neps, thick and thin places show the same qualitative dependence on the spinning speed, yarn fineness and friction ratio. With coarser yarn counts the twist factor increases due to better friction transfer, and may be directly influenced by means of the friction ratio.

2.3.3.3. Spinning Speed

In view of the high spinning speeds attainable and the mass associated with this, an additional airflow in the fibre conveying zone is used. The speed of spinning ranges from 200/min to 450m/min at present of decisive importance to the spinnability of finer yarns with satisfactory properties by the open-end friction-spinning process are firstly the fibre stretch out and orientation(16), secondly, the doubling action of the particular spinning unit. Though the technological possibilities for yarn consolidation, i.e. twist insertion, are numerous, they are of minor importance to the fundamental question of finer yarn spinability because they affect the yarn structure and irregularity less than the influences in the fibre opening, feed and collection zones. The difference between the fibre speed and the yarn take off speed causes in general the bad orientation and stretching of the fibres in the yarn from which the relatively low strength of the OE friction-spun yarns results(18).

In both ring and OE rotor spinning systems, the spinning speed is strictly dependent on count and twist, about 20m/minute for ring and 150m/minute for OE rotor spinning. Whereas, in OE friction-spinning, the spinning speed does not depend on count and twist and is over 200m/minute(3).

2.4. Twist Characteristics in Open-End Friction-Spinning

2.4.1. Mechanics of Twist Insertion in Open-End Friction-Spinning

The tensional yarn drive regarding the open-end friction-spinning system allows spinning speed which promise considerable economical advantages compared to the ring and OE rotor principle. If one disposes for the interlocking working principles (ring and OE rotor) of relatively large lever arms for the creation of the torsion moment, for the OE friction-spinning system only very short lever arms are available for the yarn drive(18). Due to this fact regarding the open-end friction-spinning system considerable forces are necessary to create a torsion moment comparable to ring spinning or OE rotor spinning as only the local yarn radius acts as lever arm. Furthermore, for OE friction-spinning because of the yarn drive by the help of friction forces an increased energy expenditure is required for the reciprocal value of the friction coefficient. This is the reason for the high suction forces which are necessary for OE friction-spinning often incomprehensible for a lay man.

Two elements systems which were at first developed by Dr. Ernst Fehrer(2), which are today state of engineering - cause a pressure of the yarn between two counter-rotating planes, the so called friction elements. The twisting of the yarn depends on the number of revolutions in the spinning zone and can be influenced by different machine parameters. The penetration of the yarn by suction of one element or both elements with underpressure causes a pressure of the yarn on the friction element surfaces. When spinning with two friction elements, the maximum transferable moment and the displacement can be influenced by the friction coefficient because of the use of the adhesive force. Compared with one element system, two element systems offer the advantage, with a high adhesive force necessary for a good spinning stability to allow at the same time an effective force transferability.

The fibre stream profile in the yarn formation zone leads to an increase of the yarn mass which itself causes the growing of the yarn radius. The radius development is additionally dependent on the individual packing density of the built formation and also strongly on the used spinning system(20). In the theoretical case of the interlocking yarn drive the local yarn revolution would behave proportionally to the reciprocal value of the yarn diameter. Due to the increasing yarn torsion moment which reaches its maximum value in the face-off zone of the spinning device, the yarn rotation decreases during the spinning process to zero. Furthermore in the area of the open yarn end the acceleration forces on the landing fibres are too low to attribute to them the maximum yarn rotation. The yarn rotation at the open yarn end is lower than the maximum rotation. The yarn rotation decreases continuously up to the take-off of the friction spinning device. There the complete rotation stand still occurs.

By the help of transparent friction elements (disk or drum) the real spinning process can be documented photographically or with high frequent cinematography (20). Regarding the photographical procedure it is possible to ascertain by the measurement of the local yarn diameter and the outer fibre angles the angular velocity respectively the rotation graph in the spinning area. High speed films of the spinning process will also assist determine the yarn rotation graph by the help of the picture frequency and the yarn take off speed. The direction of the fibre angle of the outer yarn layer changes at a certain point during the motion through the spinning zone. The reason is that the part of the yarn with the maximum revolution number rotates faster than the non-rotating pulled off yarn and the relatively slowly rotating yarn end.

The main drive point, i.e., the position of the maximum revolution number for the fibre configuration and the yarn strengthening during the spinning phase are very important. With a further displacement

of this point in direction of the yarn take off the yarn twist decreases within the spinning zone, i.e. the yarn twist occurs only shortly before leaving the spinning device. If one increases by suitable measures the revolution numbers of the yarn end then a further twist decrease takes place within the spinning zone with a larger displacement of the maximum revolution number. The less twisting appears within the spinning zone the more constant becomes the twist distribution over the yarn cross section as the main twisting occurs only after the complete yarn formation.

2.4.2. Role of Friction Elements in Twist Characteristics

The friction elements are responsible for torque generation which in turn is responsible for twist insertion. The following influencing factors of the drum or disk will affect the amount of twist generation and the amount to be imparted(3).

- diameter of the friction disk.
- condition of the friction disk surface.
- execution of the drum (diameter and length).
- condition of the friction drum surface and perforation.
- number of revolutions of the disk and drum and their coordination.
- rotating direction of disk and drum.
- influence of the rotation and transporting component by variation of the disk position.
- geometry of the nip between the friction elements (drum, disk). Also important here are the finish and adjustment of the suction and the suction itself. All these will have bearings on twist characteristics.

Further factors of influence are represented by the yarn take-off speed and the direction of yarn take-off. The multiple realisation forms of open-end friction-spinning and the multitude of factors of influence illustrate the complexity of this spinning method.

2.4.3. Influence of the Suction on Twist, Strength and Elongation

The influence of the suction in the drum on strength, elongation and twist is very marked. The higher the suction pressure the higher the strength and breaking elongation(3). But, the higher the suction pressure the lower the twist in yarn structure. If drum and disk are the friction elements used, strength and elongation, yarn twisting, snarling tendency and hairiness are strongly influenced by the position of the point of their synchronisation and the consequently changed friction effect. By means of transparent friction elements it is possible, to analyse the yarn formation and fibre binding processes. For this purpose one of the cylindrical friction-drums particularly the friction disk can be made of glass. While short-time recordings in the nano seconds range of high-speed films will allow a thorough analysis of the operations, which serve the purpose of process optimization.

2.4.4. Measurement of Twist in Open-End Friction-Spinning and Wrapper Fibres

Based on the investigation done in this area accurate twist measurement in open-end friction-spun yarns is a problem because of the complexity of the structure. Also, due to the inhomogenity of the structure twist varies over the whole cross-section of open-end friction-spun yarns. This is also complicated by the presence of wrapper fibres on the surface of the structure. These are the fibres which escaped the twist formation mechanism and they were bonded tenaciously to the surface of the yarn. They were not found in the core of the yarn. They do not contribute meaningfully to the strength of the open-end friction-spun yarns.

2.4.4.1. Twist in Open-End Friction-Spun Yarns

The determination of the twist imparted to a yarn by the open-end friction-spinning system is very difficult because twist depends on (a) the relationship between yarn diameter and spinning-drum diameter, (b) the spinning-drum speed or friction ratio, (c) the slippage between the yarn diameter and the spinning drums, which produces a loss of twist, (d) the separation between the spinning drums and (e) the type of air injection and pressure in the spinning drums (21). It is well known that there is no accurate procedure allowing the twist in such yarns to be measured directly (22) (23) (24) (25). Infact, the apparent yarn twist and residual twist in open-end friction-spun yarns (26) (27) can be investigated or determined by means of the untwist/retwist method (28), but the method doesn't evaluate it very well because different results will be obtained by different persons using the method.

By assuming the existence of different twist mechanisms (29), the apparent yarn twist gives an idea of the amount of twist of a conventional type, whose theoretical model is a helicoid existing in the yarns, which it is possible to eliminate by means of the torsiometer. The non-eliminated (or residual) twist depends on the yarn structure and consequently on the spinning system. It is possible to calculate it from the machine twist and the apparent twist (23) (26), and its value is indirectly demonstrated through the yarn strength at a theoretically null twist or residual strength. The theoretically null twist means that obtained by untwisting yarn by an amount equal to the apparent twist. But, for nonconventional spinning system like open-end friction-spinning it is different and the method is not adequate for it. The author used optical and untwist/retwist methods for this research work.

2.4.4.2. The Effect of Twist on Yarn Properties

The twist is very important indeed in open-end friction-spinning because it determines the mechanical properties of the yarns. As was mentioned before open-end friction-spun yarn is usually weak, and the twist needed is usually higher than that needed in ring-spinning. Typically, open-end friction-spun yarns have only about 60% of the tenacity of ring-spun yarns (1). The higher the twist the higher will be the strength until after maximum twists have been inserted. An attempt to increase the twist further will lead to over twisting of the structure, hence lowering the strength. Since there is no specific method yet for twist insertion, friction condition responsible for twist insertion may change (lower or higher) which can lead to undertwisting or over twisting and hence changes in the tensile strength of the yarn. The twist mechanism of open-end friction-spinning is very complex. Theoretically to have uniform twist in open-end friction-spun yarns, there must be uniform friction mechanism with little or no slip at all (16).

2.5. Yarn Tension in Open-End Friction-Spinning

The open-end friction-spinning is characterised by very minor yarn forces, since hardly any centrifugal forces have an effect upon the yarn which rotates about its own axis. The small yarn forces in open-end friction-spinning thus allow very high spinning speeds. Despite the lower yarn tenacity only few yarn breakages occur during spinning.

2.5.1. Theoretical Consideration of Yarn Tension

The yarn tension in open-end friction-spinning is very negligible in comparison to ring-spinning and rotor-spinning systems. Lunenschloss and Brockmanns (3) use a high frequency tensiometer over a long period to compare the yarn tension in open-end friction-spinning to ring and open-end spinning systems. They compared ring spinning at 15,000 r.p.m. with a ring diameter of 50mm and a traveller number of 1/0 with a rotor spinning at 90,000 r.p.m. and a rotor diameter of 40mm as well as with

friction spinning by two sucked drums. In OE rotor spinning the mean yarn tension and its variations can be decreased by the use of smaller rotors. In this comparison the much smaller yarn force and the small yarn force variation in OE friction-spinning becomes obvious, which at an almost fifteen fold rate of production amount to only at about 20% of the yarn tension in ring spinning and at more than two and a half fold production rate only about 14% of the yarn tension in rotor-spinning. In rotor and ring spinning systems, yarn tension increases drastically by increasing the spinning speed, that is to say the number of revolutions of spindle and rotor. In a range of spinning speeds of 100 up to 250m/min. only a small increase of the yarn tension in open-end friction-spinning is obtained. The standard deviation remains unchanged, the level of yarn tension is far below that of ring and rotor spinning. The small yarn tensions in open-end friction-spinning are the reason for the high spinning speeds being attainable and very low number of yarn breakages in spinning. It has to be mentioned, however, that weak places which cause yarn breakages under the influence of the high yarn tensioning in ring and OE-rotor spinning and survive the spinning process in open-end friction-spinning, can be the cause of yarn breakages in the following stages of processing. Still the correlations have not yet been investigated thoroughly enough to formulate a clear statement about the question, whether those weak places surviving the spinning process can impair the further processing of the yarns (3).

At the moment it can only be assumed that the open-end friction-spun yarns available at the moment should preferably be applied where no major strains of the yarn occur. It has also been found out by Lunenschloss and Brockmanns (3) that the kind of the open-end friction-spinning system strongly influences the yarn traction. In this comparison the highest yarn traction forces are given by friction-

spinning with two sucked drums, the lowest with one sucked and one solid respectively perforated supporting drum. Between those two ranges the drum-disk system. The mean yarn tension and the standard deviation of the yarn tension are also affected by the kind of the friction system employed. The type of disk surface in correlation with the spinning speed and the mean friction ratio has some influence. In this connection the friction ratio proves to be an important factor for the influence on the yarn traction force.

2.5.2. Count Range and Material Range in Open-End Friction-Spinning

The open-end friction-spinning system can be employed to spin coarse, medium and fine yarns but at present up to 16 tex. At present cotton and man-made fibres in short fibres form are used. The economic viability of the system is not yet clear. At speeds above 200-250/min. probably more economical than OE rotor-spinning(3).

2.5.2.1. Influences of the Design on Open-End Friction-Spun Yarns

The shape of the drums, length of diameter of the drums, using one or two sucked drums, percentage of perforation in the total surface, finish of the friction producing drum surface, finish and adjustment of the suction cover plates will all have varying effects on the properties of open-end friction-spun yarns.

2.5.2.2. Influences of Adjustment in Open-End Fiction-Spinning

The suction system, diamension and geometry of the nip between the drums, ratio of the drum surface speed and yarn take-off speed, ratio of the rotating speed of the two drums will all have bearings on the spinning system. The rotating direction when using only one sucked drum, fibre feeding device and direction of yarn take-off will also have different effects and affect the spinning procedure and the spinning result partly in reciprocal action. A very high precision and a very true running is demanded of the friction drums.

2.5.2.3. The Advantages and Disadvantages of Open-End Friction-Spinning

The important advantages of the open-end friction-spinning concept include no centrifugal forces and low masses rotating with yarn angular velocity and very low yarn tension. Extremely very high spinning speed is possible and the surface structure of the yarn similar to ring yarn. High flexibility and versatility relative to processing fibre material, possible yarn count range, yarn construction and field of application(3). The noise generation of the machine is very low. While the disadvantages and uncertainties of open-end friction-spinning are to be found in low fibre substance utilization factor in consequence of unstraightened fibres, inhomogeneous twist distribution over the yarn cross-section. Bad reproducibility of the spinning product in consequence of differences between spinning conditions influence of time on the friction conditions at the same spinning position. There is no defined twist possible combined with uncertainty of economical advantages. Production of finer yarns desired, but technologically and economically uncertain.

Literature Review on The Structure and Properties of Open-End Rotor Spun Yarns

2.6. Introduction

Few innovations in the spinning of staple fibres have aroused as much interest in recent years as the emergence of open-end spinning. One factor which is clear from the various papers that have appeared on the subject is that open-end yarns have a structure which is different from that of ordinary ring-spun yarns. Open-end spinning has been one of the major developments in textile industries in this period and its history dated back to about one decade now. In the past two decades great increases in the productivities of the carding and drawing processes were seen but ring spinning experienced only a very moderate increase. Fabric production capabilities also increased rapidly particularly with the greater use of knitted and stitch bonded

fabrics. Hence, yarn production has been a major bottleneck to increased productivity. The advent of textured yarns also created new competitive pressures on staple spun yarns. However, with all these pressures for new methods of spun yarn production, the break through was not so much the emergence of absolutely new principle but the refinement of ideas that date back to the 19th century.

Even though the rotating drum type spinner is a recent commercial development in 1807. Williams patented a system that utilized a rotating comb to doff fibres from a card cylinder and condense them on to the end of a forming yarn. The design of the first commercial machine or the Czechoslovak BD200, is not very complex. It is obviously an inverted aeromechanical system with the fibres being delivered to the yarn forming surface in a more or less tangential manner. The reasons for the break through are both technical and economic, although not always distinguishable in practice. On the technical side, the pure mechanical systems are generally very cumbersome while the fluid and electrostatic systems have been plagued with fibre control problems. Conversely the rotor (or drum) spinner provided a viable simple method which combined the best aspects of a simple mechanical method with fluid (air) as an inexpensive fibre carrier. In addition the technique of placing the fibre on the rotating surface in a tangential mode is the most direct way of obtaining the fibre in a position so that it can easily be formed into a high quality yarn. High speed bearings at low prices and the availability of suitable alloys for the essential parts made the achievement of a practical model of a rotor-type machine possible. Also, the availability of metallic sawtooth wire made the development of the comber roll for high speed drafting possible. These technical developments led to a system that could produce a yarn with a better fault rate and evenness than ring yarn and, although the yarn produced a harsher fabric, methods of fibre lubrication were developed to soften

the products. Thus the basis for acceptance has been established.

The economic reasons for the break through are more complex than the technical aspects. Even though the technical capability to produce a machine with superior productivity and lower labour requirements was established, the problem of raising the necessary capital to produce a commercial machine was enormous. There are many constraints on the introduction of new yarn making machinery. Thus, the reluctance by machinery manufacturers to invest in an entirely new concept is easily understood. Eventually this was overcome only by government participation, namely, the development of the BD200 by the Czechoslovakians. Even large corporations have great difficulty in raising the capital to develop such machines, as evidenced by the consortium formed by Swiss, German and English companies to develop open-end spinning machinery.

Once it became evident that commercial machines were possible and the potential market large, some individual corporations did make large capital outlays to develop OE equipment. However, yarn producers were very reluctant to invest in these new machines even though machine producers launched a strong advertising campaign to emphasize their many "advantages" over ring spinning equipment. Many testing and research efforts clearly indicated that OE spun yarns were very different in character from ring-spun yarns and this, of course, was one of the primary reasons the yarn producers were reluctant to purchase the machines. When a few major purchases were publicised and the demand for staple yarns was currently very strong, the sales of OE equipment soared. Machine producers were suddenly unable to meet the demand. Yarn production capacity, particularly OE yarn increased to meet anticipated demand that suddenly shrank, primarily owing to the recession of 1974-75.

Problems also developed with some of the end products made with OE yarns, and in a slow market the demand for these yarns in marginal areas dropped because of the uncertainties. Doubtless, the recession

has wrung out some of the less efficient ring and OE spinners and has more sharply defined the product areas. The demand for yarn is now beginning to grow again. Several features are common to most (but not all) sorts of OE yarns. Generally, the yarns are weaker, bulkier, less hairy, more even and more extensible than ring yarn but always a qualifying statement has to be added. For example, hairiness is affected by the way in which it is rewound, and it is always possible to produce an OE yarn which is more hairy than a ring yarn. The evenness is better for error wave lengths less than the circumference of the rotor, provided the rotor is clean, but it is also directly effected by the sliver preparation and it is quite possible for the over all coefficient of variation to be worse than ring yarn if an unclean rotor or poor sliver is used. The yarn bulk can be real or illusory according to the type of fabric in which the yarn is used. Perhaps the most important aspect of the character of OE yarn is the way it affects the fabrics made there from. The ultimate market for OE yarns is represented by the finished articles made from the yarn. In the short time, durability, performance in laundering or cleaning, comfort in use, retention of shape, etc. will affect the continuing market. Consequently, the ways in which the yarns interact in particular fabric construction and their reaction to finishing play a significant role in determining the market for the yarn.

OE yarns can be supplied with a variety of structures according to the fibre, twist level, machine and operational conditions used. Since there is a superimposed false-twisting action at the Funnel where the yarn leaves the rotor, the yarn twist inside the rotor can be quite different from that in the delivered product. The yarn twist inside the rotor helps determine the yarn structure as well as the end-breakage rate during spinning. When there is a low twist gradient,

the yarn will be something like a ring yarn but when there is a high twist gradient the yarn will tend to have a harder core than an equivalent ring yarn. The false-twist makes it possible to spin at a lower real twist level than otherwise would be possible and thus one can get the anomaly that a low twist OE yarn can leave a harder core and not behave quite as one would expect with a low twist yarn.

The degree of false-twist is affected by the geometry of the yarn withdrawal tube and the rotor, the speed, twist level, and count of the yarn as well as the physical properties of the fibre. The OE spinning speed is in excess of that of ring-spinning system but OE spinning cannot replace it but only to supplement.

2.7. General Properties of OE Rotor-Yarns

2.7.1. Yarn Structure

The internal arrangement of the fibres in a yarn can best be studied by direct examination of the distribution of single fibres in the body of the yarn and by analysing their migration in the cross-section of the yarn and along their length. The study of fibre shape and the analysis of the exploitation of the geometric properties of fibres in staple yarn are very essential in understanding yarn structure. A textile product is a complex system which cannot be considered structurally as a homogeneous body but rather should be seen as a complex of partial groupings of elementary particles (3). Its general classification will depend on the analytical approach to the problem assumed; thus, for example, in a morphological approach, single fibres could be taken as yarn elements. In non-wovens, the element would be fibres and bounding agents, while in other textile fabrics they might be even spun or filament yarns, etc. In the broader sense of the word, the term "yarn structure" includes not only the geometric properties of the yarn such as bulkiness, twist, hairiness, appearance and irregularity, but also the relations link

between the fibre and yarn properties (30). The interaction between single fibres and their arrangement in the yarn body analysed by means of the sectional distribution of the longitudinal arrangement of the length and fibre shapes, are features of the structure in the narrower sense. The same applies to the other textile forms-semi products and finished products. The characteristics of textile structure can therefore be summarised as follows:

(a) The elements of the structure, i.e. the fibres.

(b) The relationship between the structural elements.

(c) The distribution of elements, i.e. fibres, in the yarn.

(d) The outer form of the yarn.

The structure of OE rotor spun yarns differs from that of ring yarns in the pronounced variation over the yarn length of the helix angle of the outer layers (31) (34). On the other hand the yarn core has a structure similar to that of ring yarns. The core assumes that yarn twist given by the rotor speed and the draw-off rate. The so-called wrapper fibres tied round the core of the rotor yarns can be recognised. The fibres single out by the opening roll or fibre guide are deposited in the upper part of the rotor walls whence they slide into the groove of the rotor. The levels of fibre migration in the structure of open-end yarns are usually lower (35) (36) and there is a cause to believe that the design of the OE machine affects the character of the yarn. Here, most of the fibres form a strand, which becomes the core of the yarn. Odd fibres slide into the tying-zone where they are siezed by the yarn rotating in this zone and initially would round the yarn core with S twist. The longer the tying-zone is and the stronger the yarn rotation is, the greater the number of S twists will be. After lifting-off from the rotor groove, the wrapper fibres are wound round the yarn core with S twist as long as the angle between wrapper fibres and yarn

axis exceeds 90° (31). If the wind-on angle is about 90° for several revolutions, this leads at the turning point to the local concentrations of the wrapping fibre furnishes subsequently, the wrapper fibres reverse their direction and run back into Z twist. They then assume the same twist as the core. The moment the ends of the wrapper fibres leave the rotor groove they are no longer wound round the yarns surface. They perform the same rotation as the yarn and attach themselves to the yarn untwisted. The ends of the wrapper fibres sliding into the still untwisted fibre strand outside the tying-in zone are tied in with Z twists like the yarn core.

A black tracer fibre technique is being used to study the formation of these wrapper fibres. These black fibres were added to white carrier sliver in thousandth parts and spun together. These untwisted fibres are mostly tied in by other wrapping fibres following.

Differences arise in the structure of open-end yarns because of the manner in which the yarn is made (32). Bridging fibres are converted into hooks in the spinning process and this reduces the effective fibre length in the yarn. Fibres migrate in a different way and the fibre-helix wave lengths vary according to radius; also, fibre tensions are lower. Because of these differences, the yarns behave in a different way in subsequent processing, and also the fabrics take on a different character from those normally encountered.

2.7.2. Yarn Tenacity and Elongation

The strength of open-end rotor spun yarns is usually 10-25% lower than that of ring-spun yarns (33). The rate of decline in yarn strength varies with the yarn counts and materials to be spun. With 10 cotton count there is hardly any difference in the rate between ring and rotor yarns; however, there is a considerable difference between the two in the case of fine count yarns and also in yarns which are completely or mainly composed of man-made fibres exceeding

40mm in fibre length. Because of the difference in the coefficient of twist as between ring and open-end rotor yarns, the maximum point of strength of rotor spun yarns occurs at a higher twist coefficient in comparison with that of ring-spun yarns (33). The strength and elongation of open-end spun yarns is dependent on fibre length and fineness, but the effect of these parameters on the yarn strength will vary with fibre types particularly for man-made fibres (37). It has also been found that combing-roll speed has a large effect on yarn tenacity and elongation, but that the combing-roll wire type has little effect (38).

2.7.3. Yarn Evenness and Imperfections

Open-end yarn is said to have a better evenness than ring yarn, but the truth of this statement depends on the error wave length (39). It has been shown that errors are reduced when the error wave length in the yarn is less than the circumference of the collecting surface. In practice the main advantages in open-end spinning as far as evenness is concerned derive from the suppression or avoidance of drafting waves and the manufacture of larger packages. In consequence of the multiple doubling inherent in the layering which occurs in rotor-type open-end spinning, there is usually an improvement in the short-term irregularity of the yarn. However, long-term variations arising from prior processes are not greatly affected (39).

The normal unevenness of a yarn consists of a spectrum of wave lengths, and apart from the obvious effects caused by suppressing the short wave lengths, there is also an effect on transients. Suppression of the short wave lengths tends to smear sudden changes in linear density. It is unlikely that slub-like faults will be produced, and such faults that are produced are likely to have slowly tapered ends, the length of the tapered positions being at least several inches long. Long-and medium-term variations affect the CV of linear density, and the normally

measured CV is the integral of the errors of all wave lengths within the capacity of the measuring device. Thus suppression of only the short-term errors still leaves those of longer wave length. Bridging fibres in spinning are also contributing to long-term variations in rotor spinning. It is clear that to get even yarns it is necessary to take particular care in the prior processes to achieve evenness and cleanlines of the sliver to be used for spinning, and it is also necessary to use appropriate fibres.

Damage to the combing roller can also produce a period effect of several times the wave length mentioned above.

2.7.4. Yarn Abrasion Resistance and Other Mechanical Properties

The outer fibre layer on rotor-spun yarns has a rough surface and this layer is not easily broken by friction against other materials, and the core is not exposed and this is the reason why rotor spun yarns show a rather high performance in abrasion resistance (40). Some helical corrugations deriving from the single structure are found on the surface of rotor-spun yarns, so the peaks of the corrugated helical surface are the first to come unto frictional contact with other materials and thus mass damage of all the fibres on the surface of the yarn can be avoided. Again, the reason why rotor-spun yarns show a good abrasion resistance. The fabrics from the yarns have smooth appearance. Hence, although the yarns are more bulky than an equivalent ring spun yarns before finishing because of the fairly large percentage of hooks and folded fibres, they are not necessarily more bulky after-finishing (32). The hairiness of rotor-spun yarns is higher than that of ring-spun yarns in general terms.

2.7.5. Processing Technology and Performance of Rotor OE Yarns

In open-end spinning, the yarn end is rotated onto which the fibres are fed in forming the yarn. In order to avoid a possible false-twisting effect, it is absolutely necessary to provide a break in the fibre flow which means that continuous fibre entanglement in

the sliver feed must be broken up into independent, individual components (41). The opener and feed roll device supplies fibres, at a steady and constant rate, the fibres are separated further and transferred to the actual spinning unit where the components are collected and reassembled into a more or less twisted configuration. After the break is achieved by high speed, the components are reassembled in the spinning unit to the desired yarn count. This condensing step, sometimes referred to as backdoubling, is equivalent to a draft smaller than 1 (4). It provides for an excellent opportunity to even out short-term irregularities, but under certain conditions it creates problems when the fibres are retarded, leading to fibre-hook or fibre-loop formation in the condensing phase. One of the problems in developing a satisfactory open-end machine is to overcome this difficulty. A preliminary comparison with the ring-spinning machines showed the OE rotor machine to have favourable yarn tension parameters (42). A production-limiting yarn tension range is reached at much higher speeds than in ring-spinning process. The latter reaches such a limit at 15-20 thousand r.p.m., while the OE process can realise speeds of 60-70 thousand r.p.m., although here the problem of beginning the yarn remains to be solved (42). This spinning system therefore permits much higher average yarn tensions than the ring spinning process. This may be attributed to the smoother movement of the yarn spiral in comparison with the yarn balloon.

The development of rotor spinning initially took place in the area of coarse and medium yarn counts. Today, rotor-spinning has been extended to the production of fine yarns, though the economic advantages of the spinning system decrease with finer yarn counts (43). As the rotor-speed increases, the yarn tension rises with the square of the angular speed of the rotor.

2.7.6. Application and End-Use of OE rotor Yarns

OE rotor yarns are predestined for items which are not required primarily to possess very high strength, softer handle and brilliant surface effect, but rather maximum evenness, good covering power and a somewhat firmer handle (44). Fabrics in which rotor yarns are now being used with great success include bed lining, base fabrics for coated surface products, raised articles, decorative fabrics, household textiles, workwear, print cloths, interlacings, denims, heavy poplin coatings and leisure wear (44). Other cloths that can be made successfully from OE rotor yarns are cords, terries and single jerseys, though a certain amount of process know-how is required for these. On the whole, however, it would be more purposeful if the difference between the structures of rotor and ring yarns could be narrowed further. This is not only because ring yarn has superior properties for some applications but above all because the existing standards are based without exception on long experience with ring yarns and modification of these standards can be accomplished on very slowly.

2.8. Effect of Processing Parameters in Rotor OE Yarns

The production advantages of open-end spinning over ring spinning decrease as the yarn becomes finer. Generally, in ring spinning spindle speeds are increased for finer counts, but the trend is the opposite in OE spinning. Also the quality of fine OE yarns deteriorates rapidly at high rotor speeds (38). In a study with a constant rotor speed, but different combing-roll speeds, some workers found that combing-roll speed had a large effect on yarn properties, but that the combing-roll wire type had little effect. The strength of OE rotor yarns reduces at high rotor speeds due to the increase in the twisting torque to the yarn formation point. Such an increase disturbs the fibre orientation and short-term uniformity of the yarn, while the decrease in the fibre orientation of fibres in the rotor,

the greater fibre breakage at the fast combing-roll speeds. Yarn variability increases at high rotor speeds. In OE rotor-spinning, the number of fibres in yarn cross section must be considered as the critical magnitude because it affects the mechanical properties of the yarn (45). Rotors with smaller diameters may require higher coefficients of twist than those with larger diameters, if the running properties of the yarn are to be the same (43) with consequence of high tension hence yarn breakages.

It has also been found out that the strength of open-end rotor yarns is enhanced as the spinning speed increases, probably owing to the increase in the centrifugal force, which presses the fibres into the groove of the rotor and thus straightens them as the spinning speed increases (46). The increase in yarn tension as speed increases will also tend to straighten the fibres. Due to this, the extensibility of the yarn drops sharply. Due to the fact that, at the highest extension, the yarn breaking extension is slightly less than the fibre extension is most probably due to the fact that at these extensions some of the fibres are straight, whereas others still retain some curl (46). The straight fibres will take a large part of the load and will break at an extension that is less than the fibre extension because of the effect of the pressure on these fibres exerted by the outside layers on the core of the yarn.

2.8.1. Role of Opening Device

The opening device is responsible for opening the individual fibre tufts. Most rotor spinners have a wire clothing that snatches fibres from an advancing sliver, although it can be argued that the use of a pinned roller is kinder to the fibres, suffers from less wear and causes less damage and shortening of the fibres. The type of wire used on combing roll will affect the degree of opening. The 0^{o} wire removes less lint while the 30^{o} wire removing more (38).

Lint increased significantly with increased combing roll speed. The wire angle has no effect on yarn variability while yarn variability increases at high rotor speeds. Fibres undergo a first speed change as they are combed from the sliver by the card-wire teeth that cover the rotating combing roller. A high velocity air-stream along a channel further accelerates and removes the fibres from the wire teeth and carries them into the spinning chamber (47). It has been shown that fibre breakage in the fibre presentation area is of prime importance and that fibre breakage effects can be minimised by using a low linear density of sliver, a high speed of sliver input, a slow combing roller speed, and a combing roller with a low wire-point density (47). The choice of combing roller speed can significantly affect yarn properties. Generally, the speed must be increased as the yarn linear density is increased. This contrasts with the recommended fixed speed of 8000 r.p.m. for the spinning of cotton.

2.8.1.1. Fibre Presentation to Opening Roller and Openning Roller Parameters

In order to obtain the individual fibres, the continuity of the fibre stream must be broken up. It is possible to achieve this opening action by means of roller carding or roller drafting followed by air suction (41). The former technique is being used in the Zech machines. Roller carding provides excellent opening action but the optimum card wire and roller speed must be known, while its wire cloth creates fibre hooks. The degree of fibre parallelisation in the sliver feed is disturbed also, and under certain conditions, fibre damage can occur. Due to all these problems, apron drafting system is being employed to open the sliver (41).

A drafting sliver may contain 15,000-30,000 fibres per cross-section, and the ideal opening action requires that each fibre be pulled/cut individually from the sliver. Infact, it is possible to obtain this result by mechanical drafting alone. In practice, the

drafting system will provide a certain portion of the total draft and an adequate air-suction stream will complete the opening action. Being aware of the difficulties at very high draft ratios, say 50-100, which are caused by short (floating) fibres that cannot be kept under sufficient control in an airon drafts system one usually prefers to operate with normal draft ratios of 25-40. It has also been shown that improved fibre flow uniformity results as the number of fibres in the cross-section leaving the front rollers becomes smaller, i.e. when mechanical draft is high.

Also, the opening roller must be supplied with as steady a flow of fibre materials as possible. The order of magnitude of this flow is several thousand fibres per sec (48). A strict condition for this is the exact clamping of the sliver between the pressure plate and the intake roller, so that only those fibres are drawn in that are actually in turn according to their position in the sliver. This condition is not fulfilled with a vertical condenser and pressure plate. Another source of difficulties in the intake section is the roller whose straight grooves may produce cut yarn. The release of the fibre ends from the nipline is smoother if a helical groove arrangement is used.

2.8.1.2. Opening Roller Speed

As has been mentioned before the choice of combing roller speed can significantly affect yarn properties. In general terms, the speed must be increased as the yarn linear density is increased (47). This contrasts with the recommended fixed speed of 8000 r.p.m. for the spinning of cotton. Lunenschlos and Tortosa (49) found that the fibre orientation decreases considerably at extremely high opening roller speeds. This disorientation at the high opening roller sped of 11,500 r.p.m. can be due to the fact that a larger number of fibres are thrown out to the wall at the entry of the fibre duct as a result of the high centrifugal forces. This causes partial compression of the fibres, and any straightening already is lost again.

2.8.2. Opening Efficiency and the State of Order of the Fibres

The state of order of the fibres at the beginning of the fibre duct should be of decisive influence on the degree of opening and orientation of the fibres at the exit of the fibre duct and thus on the properties of the OE rotor-spun yarns (49). Fibres passed to the fibre duct in a bad opened and disoriented state will be separated and orientated only in part. Even a strong drafting of the fibres as they pass from the fibre duct to the inner wall of the rotor will have an only limited effect in compensating for such shortcomings at the entrance of the fibre duct. The prerequisite for a high degree of orientation and opening at the entrance of the fibre duct is, apart from a careful preparation of the sliver, a gentle and uniform separation of the fibres is required.

After the opening process, the fibres are pulled away from the feed roller and will then be accelerated to a velocity approaching that of the airstream. With respect to yarn uniformity and, particularly, to the yarn structure, it is of utmost importance to maintain the fibres in a straight and parallel configuration and not to disturb the fibre flow uniformity during the transfer phase (41). It has also been reported that, while evenness of fibre flow may be maintained, it is rather difficult and, perhaps, impossible to prevent the fibres from curling and crimping during the passage in the air stream (41). This is a major handicap of open-end spinning.

2.8.2.1. State of the Order of the Fibres in the Rotor Groove

If it is assumed that the drafting stage is perfect and that fibres enter the spinning chamber of rotor in a well-separated and oriented condition. These fibres are laid unto the collecting surface of the rotor and are held there by centrifugal force (32). It is possible for the surface speed to be slightly higher than that of the arriving fibre and this can cause a beneficial fibre straightening. A V-shaped fibre-collection surface will also assist in this regard.

The fibres are expected to remain straight and oriented in the rotor groove for better quality of yarns. If we consider the fibres to be straight and laid end to end in P rows on the collecting surface. Also, if there are n fibres in yarn cross-section, the rotor has to turn n/p times to build up sufficient fibre, while the fibres assembly is then peeled off the collecting surface and is carried radially inwards and then out along the rotor axis. Each revolution of the rotor inserts about one turn of twist into this fibre assembly and converts it into yarn.

It has also been reported that both the state of order of the fibres at the end of the fibre duct as well as the yarn properties are affected by the air flow conditions and geometrical data at the entry of the fibre duct which determine the fibre trajectory (49).

2.8.3. Role of Rotor and Associated Parameters

Each revolution of the rotor inserts about one turn of twist into fibre assembly and converts it into yarn. To conserve mass flow, 1 inch of yarn has to be removed for each t revolutions of the rotor, infact when π D inch of yarn has been removed, the peeling point makes one complete traverse of the collecting surface and $\pm$ 1 turn is generated in this way (32). This extra turn is of very little consequence as far as the yarn is concerned, but its presence is vital because of a differential motion which is set up in which the rotor and the yarn tail rotate at slightly different speeds. In consequence of this, the yarn tail is tapered. Fibres can be laid on anywhere around the circle formed by the tapered tail and occasionally some will be laid across the break. These are refered to as bridging fibres. It has to be pointed out that fibres are not in fact laid on an "open end" but are distributed over a tapered tail and which might be some 8 inches long (32). This produces some profound effects on the yarns structure.

Removal of the yarn from the formation zone is likely to remove the bridging fibres, with both ends trailing. This causes them to be assembled into the yarn as hooked or folded fibres, which seriously impairs their ability to carry much load. This is because each limb of the folded fibre tends to act as a separate short fibre. If we consider the fact that the circumference of a normal rotor is only about 8 inches, then the likelihood of a $1\frac{1}{4}$ inches fibre being a bridging one is about 16% and this has been proofed by Smith and Lord (51). If the bridging fibres always become attached to the assembly at the entry to the yarn formation zone, then all bridging fibres will be on the outside surface of the yarn, unless they move inwards due to fibre migration as the yarn is formed. The use of tracer fibres has shown that folded fibres appear more frequently in the outer layers of OE rotor yarns but that some do exist well below the surface of the yarn. A crimpy, rough fibre with a high coefficient of friction being spun in a low-speed, small-diameter drum is likely to lead to a higher percentage of folded fibres than if the converse conditions apply. Lord (32) has reported that the number of bridging fibres is less than $1/\pi D \times 100\%$, where l is the fibre staple length and D is the rotor diameter. This demonstrates that there is a practical limit to the staple length that can be spun in a given rotor, although, this limit cannot be sharply defined without reference to the tolerable limit in the matter of fibre hooks formation. If it is not acceptable to create more than h% of hooked fibres in the spinning process, then $L/D < h\pi/100$. Thus, from this point of view, it is desirable to use large rotors or short fibres or both, but for such solutions each have their own difficulties in the matters of power consumption and yarn strength, respectively.

2.8.3.1. Role of Rotor Associated Parameters in the Mechanics of Yarn Formation

It has been reported that in order for high speeds to be successful, changes are required at the open-end spinning machines. One of the main changes is to use a rotor with a smaller diameter than the one used at low speeds (52). The yarn tension T at the inlet to the doffing tube may be expressed as $T = \frac{N}{2} \cdot S^2 \cdot r^2$

where N = yarn count in tex. S = rotor speed in r.p.m. r = radius of rotor in mm. This equation shows that the spinning tension for staple yarn formation depends on rotor associated parameters as shown in the equation above. Another factor which may be used to determine spinnability is twisting efficiency. Twist efficiency is defined as the ratio of measured yarn twist to machine twist. It has also been reported that twist efficiency is about the same whether one uses a small or large rotor (52), but it decreases as rotor speed increases except in the case for cotton yarns. The popular fibre blend of polyester/cotton and 100% polyester do not have high values of twist efficiency even at low rotor speeds, compare to cotton, which suggests that these fibres and blends are somewhat difficult to spin at high rotor speeds. Although, twist efficiency data may not correlate exactly with the spinnability, but it does give an idea that different fibres twist together at various levels, even when the mechanical conditions may be the same.

2.8.3.2. Effect of Rotor Speed on Yarn Properties

With increasing rotor speed the insertion of false twist increases too, unless counter measures are taken by adapting the rotor diameter and the geometry and surface of the draw-off tube (53). This results in more frequent wrapper fibres and more twisting back of the yarn in the S sense at the draw off tube, causing the yarn sheath to loosen up. This alters the structure of the outer layers

of the yarn, and consequently the yarn properties. As mentioned before, since by increasing rotor speed, the insertion of false twist at the draw-off tube will also lead to higher frictional forces between yarn and draw-off tube, the surface of the latter must be reduced to obtain constant false twist insertion with rising rotor speeds. Due to this, the formation of wrapper fibres and the amount of yarn sheath loosening due to yarn twist back will remain constant even at increasing rotor speeds (53). The strength of coarser rotor yarns is influenced only insignificantly by the rotor speed in the range from 50,000 r.p.m., with rising rotor speeds there is a slight drop in finer yarns. The yarn strength can be raised by optimisation of the draw-off tube surface.

The elongation at break of OE rotor spun yarns decreases of course with rising rotor speed from 50,000 r.p.m. while at the same time, the number of neps and thick places (i.e. stripe backs) increases with the rotor speed. With non-optimized draw-off tube surface the frequency of wrapper fibres turns increases, and the yarn is twisted back more at the draw-off tube, i.e. the yarn sheath is loosened more. The increased yarn faults usually occuring at higher speeds with optimized draw-off tube surface are caused mainly by the higher thread tensile forces. This tensile force can be reduced by using a smaller rotor which will result in fewer yarn faults in the fine counts too. This effect of higher yarn faults with high rotor speeds also depends on whether a person is processing long fibres (e.g. polyester) or short fibres (e.g. cotton). Yarn faults are much lower for long fibres than short ones (53). This may be explained by the better tying-in of the longer (compared with cotton) fibres and the changed fibre-to-fibre friction coefficient, which offers more resistance to pushing back. In addition the proneness to strip back depends on the running

direction of the yarn. The yarn is more likely to strip back when it is taken off in the direction of spinning, i.e. after one rewind. The strip back proneness of yarns spun with constant draw-off tube surface increases with rising rotor speed owing to the more numerous wrapper fibre turns and the greater loosening of the yarn sheath.

2.8.3.3. Rotor Diameter and Speed as Performance Limit for Spinning

The idea of increasing rotor speeds will automatically lead to increase in spinning tension, which will ultimately cause excessive ends-down. The maximum possible speeds will depend on the rotor diameter and on the yarn strength and its variability (46). There is also a limitation due to the difficulty of hand-piecing at higher spinning speeds, and the solution usually adopted is to decrease the rotor speed for piecing. It has also been shown that small rotors should be capable of operating economically at speeds of up to 100,000 r.p.m. in coarse to medium linear density ranges if a cheap and reliable method of supporting the rotor shaft at high speeds can be found. It has also been found that there is a limitation on the range of twist and linear densities that can be spun at different spinning speeds (54). The spinning limit of a fibre material shifts towards coarser count with increasing rotor speed (55). One has to put it in mind also that the attendability of OE rotor machine will as well set certain limits to speed increase, especially with coarse yarns. The rotor speed employed will also depend whether cotton or man-made fibres are under processing. Stalder (55) found out that a 25 tex yarn from dry-spun acrylic showed a very marked increase in end breaks at high rotor speed. At 60,000 r.p.m. he found out that the ends down per kg of yarn were twice as high as at 45,000 r.p.m. In view of the rather fine yarn count this is quite understandable. He found with a low-pill type polyester that things were much more critical, and it could be

spun successfully at no more than 40,000 r.p.m. At 45,000 r.p.m. the end breaks were five times higher, and at 50,000 r.p.m. the condition of end breaks was too bad. In this case the end breaks were due to insufficient resistance of the fibres to the increasing torsion moments in the yarn. The torsion moment M in a piece of yarn under an axial tension P may be determined as $M = cPr\alpha$, where α = twist factor, r = yarn radius and c = constant. Since the axial tension P increases with rising rotor speed, the torsion moment grows commensurately.

2.9. Twist Characteristics in Rotor OE Spinning

The nature of twist in open-end spun yarn is very complex and it is difficult to determine the amount of twist in OE structure. ASTM Standards (56) states that it is difficult, if at all possible, to determine twist by direct counting method in open-end spun yarns, because of their differential twist. It is also stated by ASTM (57) that the untwist-retwist method is not satisfactory for determining the twist in open-end yarns. The presence of wrapper fibres on the structure of rotor open-end spun yarns complicates the issue further. Twist is imparted in a different manner for rotor yarns than for ring yarns, whereby, when using ordinary methods of twist measuring, appreciable differences between normal twist and actual twist of the rotor yarn are found. Generally, actual twist is lower than normal twist (58). Kasparek reported that, for rotor yarns, fibres on the yarn surface posses different twist from fibres in the yarn core, so that twist cannot be reversed, and, on untwisting the strand of fibres, fibres are not untwisted in a regular manner and do not stay parallel to each other, so that the appreciation of methods based on yarn untwisting for twist measurement does not lead to accurate results (59).

2.9.1. Mechanics of Twist Insertion and Twist Efficiency in Rotor Spinning

There are many operations involved in open-end spinning, the first of which involves a drastic drafting to such an extent that the fibres travel either singly or in small groups. These groups are sufficiently separated so that a torque cannot be transmitted upstream and an open-end is created. The fibres or groups of fibres are attached to the end portion of yarn and are twisted into the structure continously. Thus, there are the stages of drafting, fibre transport, condensation at the open-end, twist insertion, and winding (31). These are each separate operations occuring in series.

If it is assumed that the drafting stage is perfect and that fibres enter the spinning chamber of rotor in a well-separated and oriented condition. These fibres are laid onto the collecting surface of the rotor and are held there by centrifugal force. It is possible for the surface speed to be slightly higher than that of the arriving fibre and this can lead to fibre straightening. Concurrently with the laying-on process, the cumulation of fibre has to be removed and converted into yarn. This fibre assembly is then peeled off the collecting surface and is carried radially inwards and then out along the rotor axis. Each revolution of the rotor inserts about one turn of twist into this fibre assembly and converts it into yarn. Has stated before, some fibres slip as they leave the collecting surface, and this implies a twist loss because the slip allows the radial yarn tail to rotate about it own axis to relieve the torque generated by the twist. However, the core fibres do not slip much, and it is assumed that there is little or no twist loss there. In consequence, there is a differential structure in which the helix angle of the outer fibres differs from that of the core (32). Due to this differential structure and because of the unusual fibre strain patterns, it is difficult to measure the twist in the yarn.

It has been reported that the nominal amount of twist inserted into the yarn is equal to the ratio of the spinning-chamber speed to the yarn with-drawal sped (60). However, because of the torsional rigidity of the fibre in the untwisted ribbon, there will be a reaction to the turning moment and the process will not therefore be 100% efficient. To increase the linear density of the yarn being spun without changing the amount of twist, the number of fibres in the cross-section of the ribbon must be increased, and this will increase the reaction to the turning moment. It is therefore to be expected that the twist efficiency will decrease with increasing linear density (60), where the twist efficiency (TE) may be defined by:

$$TE\ (\%) = \frac{\text{actual twist/unit length} \times 100}{\text{nominal twist/unit length}}$$

Similarly, if the twist is increased without change of linear density, then the number of doublings within the chamber increases, and twist efficiency will again fall. It has been reported through experimental work that, twist efficiency decreases with increasing yarn linear density from 90% at 24 tex to 79% at 40 tex. Also, by increasing the nominal twist will lead to the fall of twist efficiency. The losses in twist from the nominal value are quite large and range from about 10 to 30%, dependent on twist level and yarn linear density. Obviously, in machine-setting, these losses must be taken into consideration so that the desired twist level is achieved, and this is particularly important in calculations of machine production, where errors of this order can make large differences in the analysis of yarn-conversion costs.

2.9.2. Measurement of Twist in Rotor OE Spinning

The twist in the tail of yarn inside the rotor in open-end spinning probably differs from that of the yarn being withdrawn from the rotor (61). Many forms of doffing tube have been introduced to alter this difference, which may be assumed to be of

considerable importance in determining the minimum twist factor at which yarns can be spun in rotor-spinning. Cormack, Grosberg and Ho (61) used a method based on stroboscopic-flash photography of the yarn tail inside the rotor, a perspex cover to the rotor being used to measure the twist inside the rotor. In this method, the yarn tail can be brought visually to a stands still by using a Dawes stroboscope and photographed by standard procedures. The most important thing is to highlight the twist so that it could be seen on the photograph for twist analysis. The same workers (61) reported that, the twist level inside the rotor was almost always greater than the value calculated from the rotor speed and yarn-withdrawal speed (this value is called machine twist). It has also been reported that machine twist and twist determined optically by observing tracer fibres in the core of the yarn are in agreement. However, since the outlet tube acts as a false twister increasing the value of the twist in the yarn tail, it would therefore be expected that different designs of outlet tube would have different false-twisting actions hence different levels of twist inside the rotor. A correction factor has to be applied to the results of photographic technique mentioned above. This correction factor is shown to be accurate by using a positive false-twister at the exit of the outlet tube. As a result of the use of this technique, it has been shown that the twist level inside the rotor is always greater than the machine twist (61).

2.9.2.1. Twist in Open-End Yarns

The twists in open-end yarns are higher than the twists in ring yarns as a result of different structures. A single measurement of twist is insufficient to typify open-end yarns because the twist on the fibres comprising the yarn core is different from those comprising the outer sheath, and both are usually lower than the machine value (34).

The differences may be expressed in terms of a twist gradient which is a function of machine design operating conditions and fibre characteristics. It has also been reported that both the yarn twist and count have an influence on the amount of twist gradient produced as a result of the differences. The size and speed of the rotor play a significant part. The critical zone of twist insertion or propagation lies in the rotor groove, at the point of transition from twisted yarn to untwisted fibres (62). To transform the untwisted fibres into a twisted yarn a torque is required - the so-called twisting-in torque. This torque MA serves to overcome the friction forces occuring during twist insertion between the fibres and between these and the rotor wall. These frictional forces are function of rotor diameter among other things, the bigger the rotor diameter the higher these frictional forces, which are due largely to the centrifugal force. It therefore follows that, if twist insertion is to be assured, the torque available in the yarn must be equal to or greater than thatrequired for twist insertion (62).

As mentioned above, the twist-in torque MA is a function of the rotor diameter and this torque depends mainly on the indirect influence of the centrifugal force, it has an approximately linear correlation with the rotor diameter. While the torque available in the yarn also depends on the rotor radius, through the yarn tension. However, the correlation between the axial tension and the rotor diameter is very complicated. The worker reported that with bigger rotors it may be expected that less yarn twist can be used than with small rotors. As regard to the optimal yarn twist, it should be emphasized that in practice the yarn twist is fixed not only by reason of the running behaviour, yarn quality, the strength in particular, plays a part and the type of yarns (natural or man-ade fibre yarns) also plays a part. Man-made fibre yarns usually

react very differently to any alteration of twist. Stalder (62), reported that cotton yarns attain their maximum strength only at a relatively high twist, whereas the minimum twist necessary for the spinning operation is much lower. Hence in cotton spinning the twist is often selected more on account of strength than for optimal running behaviour. For man-made it is usually the reverse, the yarn twist giving optimal strength is lower than the minimum needed for spinning. Man-made fibre yarns ought to be twisted as soft as possible, i.e. as soft as the spinning operation will permit. The same worker reported that the yarn twist and unevenness are practically unaffected by the twist level. The spinning of man-made fibres with larger diameter rotors is reported to be a very attractive proposition. Practically, bigger rotors enable yarns to be spun with much lower twist factors, thus permitting substantially higher production speeds. Secondly, the yarn quality achieved with bigger rotors is virtually equivalent to that from smaller ones. Thirdly, the softer handle of the finished product as a result of low twist is a big advantage in many cases. Since with the same twist the big rotor turns out somewhat lower quality than the small one, it follows that most cotton yarns are best spun with rotors of 45mm diameter. Apart from the production of soft twisted man-made fibre yarns by the use of bigger rotors, there are other areas where bigger rotors offer advantages. These include the spinning of fibres 50 or 60mm long. Fibres of 50mm require a 55 or 65mm rotor, while 60mm fibres can be spun reasonably only with a 65mm rotor. The bigger rotors are also used in the manufacture of coarser counts, e.g. 100tex for both cotton and man-made fibres. Although, sliver comb-out on the opening roller deteriorates with coarser count owing to the higher material throughout. This implies more resistance to twisting-in, and consequently higher minimum twist for spinning.

2.9.2.2. Measurement of Twist in Open-End Yarns

It should be remembered that most methods of twist measurement involve an untwisting phase. The optical method (58) of measuring twist angle as an appropriate technique has been suggested. Though, it is non-industrial one, discarding simple untwisting, and as a practical method, it has been suggested that a method based on the indirect untwisting coupled to a tensioning device, described in a Czech standard be used (63), operating on 250mm test length. The method gives unreliable results. Owing to the difficulties in twist measurement, it is becoming the practice with open-end yarns to quote the machine twist calculated from the relevant twist gear and machine constant. Here, fibres slippage which takes place at the yarn formation point within the rotor is being ignored. 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 (34). Twist is normally used implicitly to describe various attributes which have not always recognized for what they are. A certain amount of twist level implies certain degree of hairiness, covering power (diameter), hand, twist liveliness (torque), bending stiffness, etc. (34). Once the structure of the yarn is changed, the meaning of a given level of twist in terms of any of the implied attributes changes. Each of the various systems of twist measurement is likely to be associated more with certain attributes than others. A typical example, is in the measurement of the surface twist which might be a more dependable measure of hand and appearance than one that measures the mean twist level.

The following methods of twist measurement have been reported (34): (a) Rockbank (64), (b) untwist/reverse twist (65), (c) Torsional equilibrum (66) and (d) machine value designation only. The method (a) utilizes a low power microscope for the observation of the surface fibres. In this method, twist is removed until the

surface fibres become parallel to the axis of the yarn and the twist removed is noted. This method only gives information about the surface twist and not about the internal. However, it is probable that it gives some indication of the tactile and visual character of the yarn. It is also likely to give the low extreme of the various sorts of measurement because the fibres slippage is probably most on the surface of the yarn. The machine value may likely give an indication of the twist in the yarn core and is thus likely to give the other extreme. The difficulty with the Rockbank method used with OE yarns is that an accuracy is likely to suffer because of the disorder in the wrapper fibres (34).

The untwist/reverse twist method works through the medium of twist contraction, here sufficient reverse twist is inserted to restore the original length under a stated tension, and it is assumed that one half the algebraic difference in twist is the amount originally contained in the sample. As was mentioned before, there is a danger of fibre slippage and there is also a probability that the reversed twist contraction rate differs from the untwist extension rate (66), particularly with OE yarns. This is the method commonly used in industry and that is why it is included here.

The torsional equilibrum was specially designed to avoid the defect of structural changes during testing. In fact, the idea involves the use of a short sample length and to measure the number of turns removed to give torsional equilibrum. The method was thought likely to give a value which could be related to the torsional characteristics of the yarn. The method involves a rotatable drum which is attached to the yarn at a distance staple length. At this juncture, the drum would then be released and allowed to find its torsional equilibrum point. The drum contained coded holes which allowed intermittent pulses of light to be transmitted to a transducer.

The electrical coded pulse output of the transducer is then fed to a counter system which uses the coding to sense direction as well as the magnitude of the angular motion (66). Thus, the system could tolerate oscillation of the drum and still read out the net number of turns to equilibrium. The device is so designed to permit rapid testing because the use of such a short gauge length necessitated numerous tests to overcome the length-wise variations inherent in textile yarn.

2.9.2.3. The Effect of Machine Twist on Yarn Properties

As with other spinning systems, the relation between the amount of twist in an open-end spun yarn and the yarn tenacity is important. It has been reported by Dyson (60) that the twist-tenacity relations for both the open-end and ring-spun yarns are very similar but that the open-end spun yarns have tenacities of the order of 30% lower. It has to be borned in mind that, the open-end spun yarns were spun with a combing roller which tends to reduce the yarn tenacity. The same worker reported that in the spinning of vincel fibres, it appears that the optimum yarn tenacity occurs for twist factors below 25. But, in commercial production, the actual spinning twist factor must be such as to give an acceptable end-breakage rate.

Morikawa and Barella (67) reported that the strength of conventional spun yarns is at maximum at twist factor between 150 and 160, the average value being 155, while for open-end spun yarns, however, the twist factor for maximum breaking strength ranged from 173 to 181, the average value being 176. These values are similar to those found by some workers (68). This effect also depends on the fibre characteristics (67). A high twist multiple in OE spinnings is responsible for producing many of the unfavourable aspects of the yarn such as decreased production, poor hand to the fabrics, difficulties due to snarling, poor cover,

etc. (32). Therefore, attention has to be directed towards finding ways to be able to reduce it without loss in strength. In open-end rotor spinning, optimum yarn tenacity occurs at a higher twist multiple than normal and this is because of the structural differences in OE yarns.

2.9.2.4. Yarn Tension in OE Spinning

It has been reported that the principal force on the yarn tail is centrifugal and that the tail is therefore effectively radial, except very close to the periphery of the spinning chamber (60). It has been confirmed by direct observation, by means of photography, that the yarn tail does, in practice adopt this configuration in the BD 200 rotor machine. Dyson (60) reported that the tension generated in the yarn inside the chamber at 250 r.p.m. is 5.8 mN/tex, which is clearly considerably less than the yarn tenacity. As the yarn is removed from the spinning chamber, it passes through two changes of direction, each of almost a right angle, and it is the emergent tension that must be less than yarn tenacity in order that the system may spin. Although, on some open-end spinning machines now being offered commercially, the path of the emergent yarn is such as to avoid two right-angle changed in direction which may probably reduce the tension on the spinning yarn that leads to end-breakages.

Kirschner (42) compared OE and ring spinning systems in terms of tension and showed OE machine to have favourable yarn tension parameters. He mentioned that, a production-limiting yarn tension range is reached at much higher speeds than in the ring spinning process. He supported this by giving a value that the latter reaches such a limit at 15-20 thousand r.p.m., while the open-end process can realise speeds at 60-70 thousand r.p.m., although here the problem of beginning the yarn remains to be solved. The average yarn tensions measured and quoted by the worker in this context ranged up to 200 grammes. This spinning system therefore permits much higher

average tensions than the ring spinning process. This may be attributed to the smoother movement of the yarn spiral in comparison with the yarn balloon.

2.9.2.5. Theoretical Consideration of Yarn Tension

It has been shown that (52) yarn tension T at the inlet to the doffing tube may be expressed as follows:

$T = \frac{N}{2} S^2 . r^2 + c$, where N is the yarn count in tex, S is the rotor speed in r.p.m., r is the radius of rotor and c is the yarn tension at the rotor wall in grammes. From the aboved equation one may see that for a given rotor diameters $T/N \backsimeq S^2$ g/tex. The torque available in the yarn among other things also depends on the rotor radius, through the yarn tension. However the correlation between the axial tension and the rotor diameter is very complicated, windage as well as centrifugal forces being involved (62). Stalder (62) reported that the influence of the centifugal forces on yarn tension is linear, while the influence of windage forces on yarn tension is proportional to the third power of the rotor radius.

2.9.3. Automation in OE Spinning

The most telling argument in favour of automatic devices used to replace manual operations in the textile process is that of avoiding human interference in the quality of the product. Often the action of automatic device is no more rapid than a manual operation, but if properly maintained the automatic equipment will ensure the minimum stopped time of the producing machine and consistent quality of the product. Creeling, doffing, piecing and rotor cleaning may be carried out while the machine is running, therefore automatic devices will improve the machine productivity by a significant degree.

If end break rates and yarn quality remained acceptable at rotor speeds exceeding about 70,000 r.p.m., automatic machinery

would prove necessary in order to give satisfactory and consistent yarn piecings. The case for an automatic piecing device is therefore based on consideration of cost, labour availability and piecing quality (52). At this point it should be dismissed immediately any view that the use of an automatic piecing device will permit higher end break rates and higher processing speeds because: (a) yarn piecings are not desirable and should be kept to a sensible minimum, and (b) end break rates are non-linear with speed, that is small increment in speed results in a disproportionately high end break rate. Today, automatic piecing and clearing devices are reality in open-end spinning field of textile industries.

The current machines are so designed that both the creel and doffing operations are carried out without the need to stop the machine. A winding tail is formed on the new package and therefore the cost elements associated with doffing are: (a) operators time, (b) the cost of the small amount of material run to waste. The latter is completely negligible. A large proportion of the operator's time is taken up with doffing particularly when processing coarse counts and doffing aids which reduce the operator's time or effort, such as conveyor belts, will assume greater importance. If fully automatic doffing and donning is required, it will be essential to retain the automatic tailing facility, which will add to the complexity and cost of the device. Auto-doffing for open-end spinning machine are now becoming part of the machine specification.

CHAPTER 3

3.1. SPINNING CHARACTERISTICS OF OPEN-END FRICTION-SPUN YARNS

3.2. PREPARATION OF YARN PACKAGES

The yarn packages spun include the fine range of counts from 20 tex to 24.5 tex. These counts were chosen to forecast or determine with certainty the limitation of the new spinning system which has not been employed commercially not only because of the poor properties of the yarns obtained from the system but also because the spinning system is very complex. Twenty different spinning packages were spun under different spinning conditions.

3.2.1. Materials and Spinning of the Yarn Packages

For spinning, 100% polyester fibres and 100% cotton fibres were used, while the tracer fibre used for twist investigation was viscose rayon dyed black and obtained from France. The particulars of polyester, cotton and tracer fibres used are shown in Appendix I.

The solvent used to isolate polyester fibres for twist investigation was methylsalicylate while the one used to isolate cotton fibres was ethylsalicylate. All the yarns were spun with one percent tracer fibres at a speed of 160m/minute. The spinning speed could be as high as 450m/minute as mentioned before and thus the major advantage and technologically break through in spinning. Just as with open-end rotor spinning, already formed yarn was introduced into the spinning zone and this formed a tapared tail unto which separated and parallel fibres were fed continuously. The counts spun were obtained by adjustments to the suction system and spinning pressure used since there is no difect method available yet for spinning different counts as found with conventional spinning systems. Hence, some counts were obtained by backsuction and some without backsuction under different spinning pressures. Due to this, reproducibility of product in open-end friction-spinning is extremely poor. For this research work, the feeding

Due to this, reproducibility of product in open-end friction-spinning is extremely poor. For this research work, the feeding of the sliver is perpendicular to the spinning zone. The spinning pressures used are 1219.2mm, 1320.8mm, 1422.4mm, 1498.6mm and 1066.8mm water gauge. Better understanding of the mechanics of open-end friction-spinning is needed for full implementation of the system.

3.3. Twist Characteristics Investigation

The measurement of twist and twist related parameters in open-end friction-spun yarns are very difficult because of the complexity of the structure and also due to the presence of wrapper fibres on the surface of the yarn. The methods used to investigate twist characteristics in conventional yarns cannot be used for this type of yarns structure, if not erroneous results will be given. Due to the reasons mentioned above, a new method entirely was developed for this. This is optical-microscopic method.

3.3.1. Optical-Microscopic Method of Twist Investigation

The twist 't' in a yarn can be expressed in terms of the twist angle 'θ' as:

$$t = \frac{\tan\theta}{\pi D}$$

where D is the yarn diameter. If the twist angle is measured along with corresponding diameter of the yarn with the help of optical microscope, the absolute yarn twist may easily be calculated without actually untwisting the yarn. Thus, the principle is used to measure the absolute twist in the core of open-end friction-spun yarns using the procedure described later.

Apparatus and materials: The materials and apparatus used for this investigation include microscope, camera, video, television, methylsalicylate, ethylsalicylate, cotton yarns and polyester yarns spun.

The long-stem camera was set over the ordinary microscope and the camera was then connected to a video through camera-video cable and the video connected to the television through video-television cable. Both the camera, microscope, television and the video were put on. At this stage, adjustments were made with all the apparatus until a clear focus was obtained on the television screen.

Procedure: Each yarn sample was suitably mounted on glass microslide by wrapping at parallel and length-wise. The yarn ends were fixed at the slide ends with the help of a quick drying adhesive. The yarn wraps at one side of the slides were cut and removed with the help of a razor blade. For optical isolation of tracer fibres in cotton yarns, a few drops of ethylsalicylate solvent were spread evenly on these threads with the help of a cover glass almost the size of the slides. While for polyester yarns, methylsalicylate solvent was used for optical isolation of tracer fibres in its structure as described for cotton yarns above. These slides were mounted on an optical microscope having the provisions of a micrometer scale in the eye-piece for measuring the yarn diameter after the structure has been fully focused on the television screen, while a protractor graduated in degrees was used to measure the angle of twist of the focused tracer fibres on the television screen.

The investigation was carried out with a magnification of X15 for the optical camera and a magnification of X10 for the microscope used having a total of X150 magnification employed. Since it was the angle of twist 'θ' of the tracer fibres in the core of the yarns that was measured with respect to the yarn axis, the diameter corresponding to inflexions of the tracer fibre on the surface of the core in each case was observed on the microscale and was corrected for magnification to provide the values in metre. On the

average, five slides with 8 - 10 yarns on each were prepared for each of the yarn samples to measure the twist by the optical method using the relationship.

$$t = \frac{\tan\theta}{\pi D}$$

All the parameters here have been described above.

3.3.2. Optical Microscopic Method of Twist Investigation Results

From the twenty yarn packages spun only eight of them were used for this twist investigation, two cotton yarn packages and six polyester yarn packages. Since the spinning system is worst for cotton yarns and a bit fair for polyester yarns in terms of tenacity, that is why only two packages were selected from cotton yarn packages for twist investigation in order to save time and materials. One hundred samples were taken and tested for each of the packages. The values of tan θ were given both in degrees and in numerical values for better understanding, while the values of twist were also quoted in both t.p.mm and t.p.m. for quick grasping. The packages used for the investigation were 17/1, 17/2, 17/11, 17/12, 17/13, 17/14, 17/15 and 17/16, the first two packages were cotton packages while the remaining are polyester packages. All the odd number packages were spun with backsuction while the even number packages were spun without backsuction and also spun under different pressures.

The twist characteristics results are shown in Tables 3.1 for cotton yarns and each value in the table is a mean value of at least fifteen observation results from the one hundred results obtained for each yarn package while the overall mean values are also quoted. The twist characteristics results for the polyester yarns are shown in Table 3.6 while the investigation and the method of analysis are the same with that of cotton yarns mentioned above.

Packages	Mean Twist Angle (Tanθ)	Mean Numerical Values of Tan θ	Mean diameter (mm)	Mean Turns/ Milimetre	Mean Turns/ Metre
17/1: back-suctioned: 1219.2mm Water gauge pressure	21.17	0.3897	0.2219	0.6321	632.1
	20.23	0.3705	0.2086	0.5812	581.12
	19.05	0.3463	0.1744	0.6459	645.9
	18.70	0.3390	0.1446	0.7570	757.0
	15.94	0.2724	0.1866	0.5029	502.9
	19.53	0.3605	0.2052	0.5600	560.0
Overall Mean	19.10	0.3464	0.1902	0.6132	613.2
17/2: Not back suctioned: 1219.2 mm water gauge pressure.	18.94	0.3467	0.2019	0.5421	542.1
	21.88	0.4046	0.2078	0.6293	629.3
	22.88	0.4277	0.2387	0.5812	581.2
	17.94	0.3253	0.2062	0.5082	508.2
	17.00	0.3088	0.1670	0.5460	546.0
	21.11	0.3949	0.2070	0.6071	607.1
Overall Mean	19.96	0.3680	0.2048	0.5690	569.0

Table 3.1. Cotton yarn packages twist characteristics.

Twist Parameters Analysis of Cotton Yarns

Package 17/1

Diameter (mm)	Mean Numerical Values of Tan θ	Sample Size (n)	Coefficient of Variation of Tanθ (%)
0.4466	0.2493	1	0
0.3666	0.3443	1	0
0.3333	0.4418	3	26.68
0.3000	0.3640	1	0
0.2800	0.3755	2	26.26
0.2666	0.3839	1	0
0.2600	0.3839	1	0
0.2533	0.3698	4	16.45
0.2400	0.4259	2	20.54
0.2333	0.3923	8	13.74
0.2266	0.7002	1	0
0.2200	0.3941	3	31.78
0.2133	0.4452	1	0
0.2066	0.1944	1	0
0.2000	0.3705	7	15.22
0.1933	0.3866	8	25.34
0.1866	0.3217	4	26.84
0.1733	0.3057	1	0
0.1666	0.3331	8	17.79
0.1600	0.3724	7	27.13
0.1533	0.3105	5	21.99
0.1466	0.3011	7	19.33
0.1400	0.2906	6	19.63
0.1333	0.3353	8	15.20
0.1266	0.2906	6	19.81
0.1200	0.2586	2	5.09
0.1133	0.1763	1	0

Table 3.2. Package 17/1 twist parameters.

Package 17/2

Diameter (mm)	Mean Numerical Value of Tan θ	Sample Size (n)	Coefficient of Variation of Tan θ (%)
0.3266	0.3640	1	0
0.3133	0.5543	1	0
0.2933	0.4805	3	34.92
0.2733	0.5543	2	0
0.2666	0.5010	4	50.53
0.2600	0.4537	3	17.28
0.2533	0.4549	6	31.00
0.2466	0.3839	1	0
0.2400	0.5096	3	4.32
0.2333	0.3832	10	27.53
0.2266	0.3022	4	25.38
0.2200	0.3254	2	16.78
0.2133	0.3954	5	28.45
0.2066	0.3660	5	30.44
0.2000	0.4029	11	22.78
0.1933	0.3809	4	24.28
0.1866	0.3260	4	21.66
0.1800	0.2679	1	0
0.1666	0.3064	9	17.69
0.1600	0.3249	2	0
0.1533	0.2497	2	20.95
0.1466	0.2794	6	34.57
0.1400	0.2541	4	30.42
0.1333	0.2355	5	29.85
0.1266	0.3640	1	0
0.1200	0.2494	1	0

Table 3.3. Package 17/2 twist parameters.

Diameter and Twist Relationships of Cotton Yarns

Package 17/1

Diameter (mm)	Mean Numerical Values of Tan θ	Diameter (mm)	Mean Numerical Values of Tan θ
0.4466	0.2493	0.2066	0.1944
0.3666	0.3443	0.2000	0.3676
0.3333	0.4418	0.1933	0.3866
0.3000	0.3640	0.1866	0.3217
0.2800	0.3755	0.1733	0.3057
0.2666	0.3839	0.1666	0.3331
0.2600	0.3838	0.1600	0.3724
0.2533	0.3698	0.1533	0.3105
0.2400	0.4259	0.1466	0.3011
0.2333	0.3923	0.1400	0.2906
0.2266	0.7000	0.1333	0.3353
0.2200	0.3941	0.1266	0.2906
0.2133	0.4452	0.1200	0.2586
		0.1133	0.1763

Table 3.4. Package 17/1 diameter and twist relationships.

The relationships are shown graphically in Fig. 3.1. The graph and the straight line equation values are given by a computer using the above data. The letter r besides the straight line equation is linear correlation coefficient.

Package 17/2

Diameter (mm)	Mean Numerical Values of Tan θ	Diameter (mm)	Mean Numerical Values of Tan θ
0.3266	0.3640	0.2066	0.3660
0.3133	0.5543	0.2000	0.4029
0.2933	0.4805	0.1933	0.3809
0.2733	0.5543	0.1866	0.3260
0.2666	0.5010	0.1800	0.2679
0.2600	0.4537	0.1666	0.3064
0.2533	0.4549	0.1600	0.3249
0.2466	0.3839	0.1533	0.2487
0.2400	0.5096	0.1466	0.2794
0.2333	0.3832	0.1400	0.2541
0.2266	0.3022	0.1333	0.2355
0.2200	0.3254	0.1266	0.3640
0.2133	0.3954	0.1200	0.2493

Table 3.5. Package 17/2 diameter and twist relationships.

The relationships are shown graphically in Fig. 3.1.

The graph and the straight line equation values are given by a computer using the above data.

A = Package 17/1 (Backsuctioned) y=0.275 + 0.2926; r=0.2281
B = Package 17/2 (Not backsuctioned) : y=1.278 + 0.1026; r=0.7831

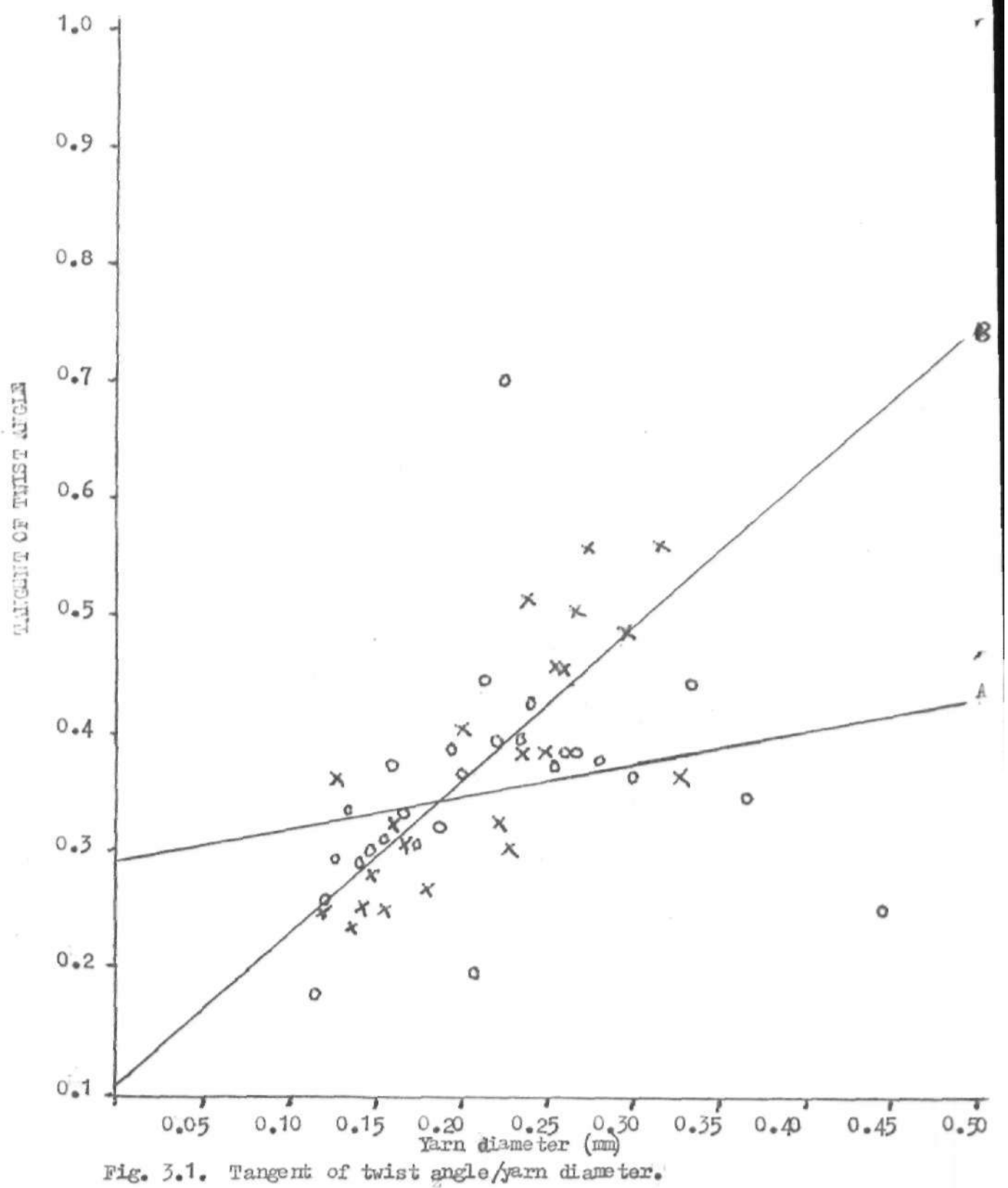


Fig. 3.1. Tangent of twist angle/yarn diameter.

3.4. Twist Characteristics Results of Polyester Yarns

The twist characteristics results of the polyester yarns investigated are shown in Table 3.6 below and each value in the table is a mean value of at least fifteen observation results from the one hundred results obtained for each yarn package while the overall mean values are also quoted.

3.4.1.

Packages	Mean Twist Angle Tan θ	Mean Numerical of Tan θ	Mean Diameter (mm)	Mean Turns/ Milimetre	Mean Turns/ Metre
17/11: Backsuctioned 1219.2mm water gauge pressure.	26.41	0.5048	0.1992	0.1992	822.3
	25.35	0.4830	0.2474	0.6497	649.7
	30.88	0.6239	0.2149	0.9208	920.8
	26.94	0.5201	0.1867	0.8924	892.4
	26.47	0.5022	0.1835	0.9256	925.6
	32.73	0.6444	0.1888	1.1273	1127.3
Overall Mean	28.13	0.5464	0.2034	0.8896	889.6
17/12: Not backsuctioned 1219.2mm water gauge pressure.	27.94	0.5547	0.2266	0.7892	789.2
	31.88	0.6458	0.2419	0.8557	855.7
	24.41	0.4588	0.2274	0.6606	660.6
	23.05	0.4315	0.1701	0.8770	877.0
	27.66	0.5266	0.2257	0.7693	769.3
	31.05	0.6162	0.2160	0.9462	946.2
Overall mean	27.66	0.5389	0.2179	0.8163	816.3

Packages	Mean Twist Angle Tan θ	Mean Numerical of Tan θ	Mean Diameter (mm)	Mean Turns/ Milimetre	Mean Turns/ Metre
17/13: Backsuctioned; 1320.8mm water gauge pressure.	23.82	0.4498	0.1631	0.8886	888.6
	25.70	0.4905	0.1819	0.8931	893.1
	24.94	0.4697	0.1545	1.0832	1083.2
	24.70	0.4855	0.1509	1.0325	1032.5
	23.94	0.4520	0.1357	0.9341	934.1
	22.40	0.4147	0.1658	1.0619	1061.9
Overall Mean	24.25	0.4603	0.1586	0.9822	982.2
17/14: Not backsuctioned; 1320.8mm water gauge pressure.	26.41	0.5021	0.1996	0.8241	824.1
	26.47	0.4772	0.1956	0.8233	823.3
	24.29	0.4555	0.2141	0.6887	688.7
	23.70	0.4417	0.1513	0.9861	986.1
	23.29	0.4359	0.2211	0.6475	647.5
	24.06	0.4479	0.1733	0.8532	853.2
Overall Mean	24.70	0.4600	0.1925	0.8038	803.8

Packages	Mean Twist Angle Tan θ	Mean Numerical of Tan θ	Mean Diameter (mm)	Mean Turns/ Mili-metre	Mean Turns/ Metre
17/15: Backsuctioned; 1422.4mm water gauge pressure.	23.88	0.4471	0.1847	0.7813	781.3
	22.52	0.4170	0.1709	0.7823	782.3
	21.29	0.3913	0.1639	0.7724	772.4
	23.11	0.4358	0.1905	0.7530	753.0
	22.35	0.4133	0.1745	0.7862	786.2
	19.80	0.3642	0.1706	0.6793	679.3
Overall Mean	22.15	0.4114	0.1758	0.7590	759.0
17/16: Not backsuctioned; 1422.4mm water gauge pressure.	19.52	0.3614	0.1741	0.6653	665.3
	21.23	0.3924	0.1968	0.6383	638.3
	23.29	0.4367	0.2043	0.6875	687.5
	21.17	0.3977	0.1957	0.6630	663.0
	20.41	0.3787	0.1956	0.6418	641.8
	24.06	0.4557	0.1902	0.7806	780.6
Overall Mean	21.61	0.4037	0.1927	0.6794	679.4

Table 3.6. Polyester yarn packages twist characteristics.

Twist Parameters Analysis of Polyester Yarns

Package 17/11

Diameter (mm)	Mean Numerical Values of Tan θ	Sample Size (n)	Coefficient of Variation of Tan θ (%)
0.3800	0.3640	1	0
0.3200	0.4245	1	0
0.3133	0.8693	1	0
0.3000	0.3839	1	0
0.2933	0.5492	2	37.38
0.2867	0.8759	3	64.52
0.2800	0.3443	1	0
0.2733	0.5719	3	15.64
0.2667	0.5116	3	17.24
0.2600	0.5774	1	0
0.2533	0.7173	2	18.22
0.2467	0.6728	2	47.82
0.2400	0.5510	5	32.01
0.2333	0.7963	2	7.58
0.2267	0.6505	2	10.79
0.2200	0.4348	2	3.35
0.2133	0.5510	5	23.90
0.2067	0.5584	9	32.12
0.2000	0.5471	7	23.26
0.1933	0.7265	1	0
0.1867	0.5792	6	15.07
0.1800	0.4829	5	22.92
0.1733	0.5668	5	27.13
0.1677	0.4040	1	0
0.1667	0.4358	6	13.05
0.1600	0.4960	6	24.05
0.1533	0.4962	4	20.65
0.1467	0.4402	5	24.19
0.1400	0.5317	2	0
0.1333	0.5815	3	20.73
0.1267	0.3640	1	0
0.1200	0.3443	1	0
0.1067	0.4877	1	0

Table 3.7. Package 17/11 twist parameters.

Package 17/12

Diameter (mm)	Mean Numerical Values of Tan θ	Sample Size (n)	Coefficient of Variation of Tan θ (%)
0.3933	0.3991	1	0
0.3667	0.7813	1	0
0.3333	0.6745	1	0
0.3267	0.6009	1	0
0.3133	0.5706	4	21.59
0.3000	0.7709	3	38.26
0.2933	0.3640	1	0
0.2867	0.9004	1	0
0.2800	0.5461	3	28.95
0.2733	0.6293	3	19.40
0.2667	0.5087	4	29.59
0.2600	0.7573	3	82.37
0.2467	0.3640	2	0
0.2400	0.6116	4	34.77
0.2333	0.5896	7	20.92
0.2267	0.5245	3	6.44
0.2200	0.5226	3	27.87
0.2133	0.5241	5	12.38
0.2067	0.5479	10	32.88
0.2000	0.5471	9	22.24
0.1933	0.5510	4	18.69
0.1867	0.4521	4	16.94
0.1800	0.5269	4	45.62
0.1733	0.4877	1	0
0.1667	0.5095	1	0
0.1600	0.5704	2	25.80
0.1467	0.4806	2	28.46
0.1400	0.3565	5	12.59
0.1333	0.4452	1	0
0.1267	0.3640	1	0
0.1200	0.3155	2	12.90
0.1133	0.2867	1	0
0.0933	0.2493	1	0
0.0867	0.2679	1	0
0.0800	0.5095	1	0

Table 3.8. Package 17/12 twist parameters.

Package 17/13

Diameter (mm)	Mean Numerical Values of Tan θ	Sample Size (n)	Coefficient of Variation of Tan θ (%)
0.3333	0.7002	1	0
0.3000	0.8391	1	0
0.2933	0.5774	1	0
0.2867	0.8393	1	0
0.2667	0.6180	2	24.82
0.2400	0.8093	1	0
0.2333	0.4551	2	23.36
0.2267	0.5219	2	15.04
0.2200	0.2867	1	0
0.2133	0.3839	1	0
0.2067	0.5138	4	23.04
0.2000	0.6913	5	66.29
0.1933	0.5145	2	30.34
0.1867	0.5331	6	11.91
0.1800	0.4778	2	27.77
0.1733	0.5198	4	23.93
0.1667	0.5095	1	0
0.1666	0.3609	5	16.63
0.1600	0.4479	2	26.46
0.1533	0.3058	2	8.83
0.1467	0.4444	3	35.23
0.1400	0.4296	8	20.86
0.1333	0.4097	4	11.06
0.1267	0.4321	7	17.17
0.1200	0.3595	8	11.91
0.1133	0.3721	4	30.18
0.1067	0.3670	3	32.48
0.1000	0.5153	2	72.99
0.0933	0.3626	7	20.27
0.0867	0.3995	4	11.36
0.0800	0.4458	2	13.26

Table 3.9. Package 17/13 twist parameters.

Package 17/14

Diameter (mm)	Mean Numerical Values of Tan θ	Sample Size (n)	Coefficient of Variation of Tan θ (%)
0.3267	0.5550	3	31.02
0.2933	0.7002	1	0
0.2867	0.6009	1	0
0.2866	0.4877	1	0
0.2600	0.5526	5	16.53
0.2533	0.5552	2	11.58
0.2467	0.4742	6	33.36
0.2400	0.3840	2	7.34
0.2333	0.4896	4	16.16
0.2267	0.4520	5	20.55
0.2200	0.3443	1	0
0.2133	0.4770	2	3.16
0.2067	0.5145	2	30.34
0.2000	0.4891	4	14.11
0.1933	0.4806	10	21.12
0.1867	0.4261	11	16.71
0.1800	0.5319	4	25.81
0.1733	0.5097	2	6.10
0.1667	0.3640	1	0
0.1600	0.4626	10	21.14
0.1533	0.3895	7	28.01
0.1467	0.4389	3	11.87
0.1333	0.3931	3	27.70
0.1267	0.2867	1	0
0.1200	0.3640	1	0
0.1133	0.4252	3	12.94
0.1000	0.3249	1	0
0.0933	0.4040	1	0
0.0867	0.3641	2	7.69
0.0667	0.3443	1	0

Table 3.10. Package 17/14 twist parameters.

Package 17/15

Diameter (mm)	Mean Numerical Values of Tan θ	Sample Size (n)	Coefficient of Variation of Tan θ (%)
0.3333	0.4452	1	0
0.2867	0.7536	1	0
0.2733	1.0000	1	0
0.2667	0.5009	2	21.58
0.2600	0.4663	1	0
0.2467	0.4663	1	0
0.2400	0.5113	2	18.27
0.2333	0.4806	2	28.46
0.2267	0.4459	2	13.25
0.2200	0.4616	4	6.91
0.2133	0.5274	3	20.42
0.2067	0.4963	3	14.31
0.2000	0.4454	7	22.74
0.1933	0.4555	5	17.21
0.1867	0.3739	2	3.74
0.1800	0.4104	4	17.49
0.1733	0.3739	2	3.74
0.1667	0.4027	11	21.50
0.1600	0.3500	9	20.34
0.1533	0.3762	11	19.09
0.1467	0.3975	3	7.72
0.1400	0.3514	6	13.09
0.1333	0.3398	4	10.74
0.1267	0.3381	6	10.06
0.1200	0.3640	4	4.42
0.1133	0.3839	1	0
0.1000	0.2867	1	0
0.0933	0.2309	1	0

Table 3.11. Package 17/15 twist parameters.

Package 17/16

Diameter (mm)	Mean Numerical Values of Tan θ	Sample Size (n)	Coefficient of Variation of Tan θ (%)
0.3200	0.4040	1	0
0.2800	0.2309	1	0
0.2667	0.5547	5	21.81
0.2600	0.4245	1	0
0.2533	0.7265	1	0
0.2467	0.4663	1	0
0.2400	0.3839	1	0
0.2333	0.4467	2	19.88
0.2267	0.2964	2	13.59
0.2200	0.3325	6	19.93
0.2133	0.3599	4	17.14
0.2067	0.4212	4	20.18
0.2000	0.4037	15	44.32
0.1933	0.5236	8	41.99
0.1867	0.4184	9	23.69
0.1800	0.3718	8	38.30
0.1733	0.3524	4	23.52
0.1667	0.4496	5	52.62
0.1600	0.4638	5	30.12
0.1533	0.2940	6	22.99
0.1467	0.3691	4	6.77
0.1400	0.3250	2	8.36
0.1333	0.3059	3	12.49
0.1267	0.2962	2	4.52

Table 3.12. Package 17/ 16 twist parameters.

Diameter and Twist Relationships of Polyester Yarns

Package 17/11

Diameter (mm)	Mean Numerical Values of Tan θ	Diameter (mm)	Mean Numerical Values of Tan θ
0.3800	0.3640	0.2133	0.5510
0.3200	0.4245	0.2067	0.5584
0.3133	0.8693	0.2000	0.5471
0.3000	0.3839	0.1933	0.7265
0.2933	0.5492	0.1867	0.5792
0.2867	0.8759	0.1800	0.4829
0.2800	0.3443	0.1733	0.5668
0.2733	0.5719	0.1677	0.4040
0.2667	0.5116	0.1667	0.4358
0.2600	0.5774	0.1600	0.4960
0.2533	0.7173	0.1533	0.4962
0.2467	0.6728	0.1467	0.4492
0.2400	0.5510	0.1400	0.5317
0.2333	0.7963	0.1333	0.5815
0.2267	0.6505	0.1267	0.3640
0.2200	0.4348	0.1200	0.3443
		0.1067	0.4877

Table 3.13. Package 17/11 diameter and twist relationships.

The relationships are shown graphically in Fig. 3.2. The graph and the straight line equation values are given by a computer using the above data. The letter r besides the straight line equations is correlation coefficient.

Package 17/12

Diameter (mm)	Mean Numerical Values of Tan θ	Diameter (mm)	Mean Numerical Values of Tan θ
0.3933	0.8391	0.2133	0.5241
0.3667	0.7813	0.2067	0.5479
0.3333	0.6745	0.2000	0.5471
0.3267	0.6009	0.1900	0.5510
0.3133	0.5706	0.1867	0.4521
0.3000	0.7709	0.1800	0.5269
0.2933	0.3640	0.1733	0.4877
0.2867	0.9004	0.1667	0.5095
0.2800	0.5461	0.1600	0.5704
0.2733	0.6293	0.1467	0.4806
0.2667	0.5087	0.1400	0.3565
0.2600	0.7573	0.1333	0.4452
0.2467	0.3640	0.1267	0.3640
0.2400	0.6116	0.1200	0.3155
0.2333	0.5896	0.1133	0.2867
0.2267	0.5245	0.0933	0.2493
0.2200	0.5226	0.0867	0.2679
		0.0800	0.5095

Table 3.14. Package 17/12 diameter and twist relationships.

The relationships are shown graphically in Fig. 3.2. The graph and the straight line equation values are given by a computer using the above data.

Package 17/13

Diameter (mm)	Mean Numerical Values of Tan θ	Diameter (mm)	Mean Numerical Values of Tan θ
0.3333	0.7002	0.1733	0.5198
0.3000	0.8391	0.1667	0.5095
0.2933	0.5774	0.1666	0.3609
0.2867	0.8693	0.1600	0.4479
0.2667	0.6180	0.1533	0.3058
0.2467	0.5095	0.1467	0.4444
0.2400	0.8093	0.1400	0.4296
0.2333	0.4551	0.1333	0.4097
0.2267	0.5219	0.1267	0.4321
0.2200	0.2867	0.1200	0.3595
0.2133	0.3839	0.1133	0.3721
0.2067	0.5138	0.1067	0.3670
0.2000	0.6913	0.1000	0.5153
0.1933	0.5145	0.0933	0.3626
0.1867	0.5331	0.0867	0.3995
0.1800	0.4778	0.0800	0.4458

Table 3.15. Package 17/13 diameter and twist relationships.

The relationships are shown graphically in Fig. 3.3. The graph and the straight line equation values are given by a computer using the above data.

Package 17/14

Diameter (mm)	Mean Numerical Values of Tan θ	Diameter (mm)	Mean Numerical Values of Tan θ
0.3267	0.5550	0.1867	0.4261
0.2933	0.7002	0.1800	0.5319
0.2867	0.6009	0.1733	0.5097
0.2866	0.4877	0.1667	0.3640
0.2600	0.5526	0.1600	0.4626
0.2533	0.5552	0.1533	0.3895
0.2467	0.4742	0.1467	0.4389
0.2400	0.3840	0.1333	0.3931
0.2333	0.4896	0.1267	0.2867
0.2267	0.4520	0.1200	0.3640
0.2200	0.3443	0.1133	0.4252
0.2133	0.4770	0.1000	0.3249
0.2067	0.5145	0.0933	0.4040
0.2000	0.4806	0.0867	0.3641
0.1933	0.4806	0.0667	0.3443

Table 3.16. Package 17/14 diameter and twist relationships.

The relationships are shown graphically in Fig. 3.3. The graph and the straight line equation values are given by a computer using the aboved data.

Package 17/16

Diameter (mm)	Mean Numerical Values of Tan θ	Diameter (mm)	Mean Numerical Values of Tan θ
0.3200	0.4040	0.2000	0.4037
0.2800	0.2309	0.1933	0.5236
0.2667	0.5547	0.1867	0.4184
0.2600	0.4245	0.1800	0.3718
0.2533	0.7265	0.1733	0.3524
0.2467	0.4663	0.1667	0.4496
0.2400	0.3839	0.1600	0.4638
0.2333	0.4467	0.1533	0.2940
0.2267	0.2964	0.1467	0.3691
0.2200	0.3325	0.1400	0.3250
0.2133	0.3599	0.1333	0.3059
0.2067	0.4212	0.1267	0.2962

Table 3.18. Package 17/16 diameter and twist relationships.

The relationships are shown graphically in Fig. 3.4. The graph and the straight line equation values are given by a computer using the aboved data.

A = Package 17/11 (Backsuctioned) : y=0.4568x + 0.4452; r=0.2200
B = Package 17/12 (Not Backsuctioned) : y=1.4330x + 0.2197; r=0.7500

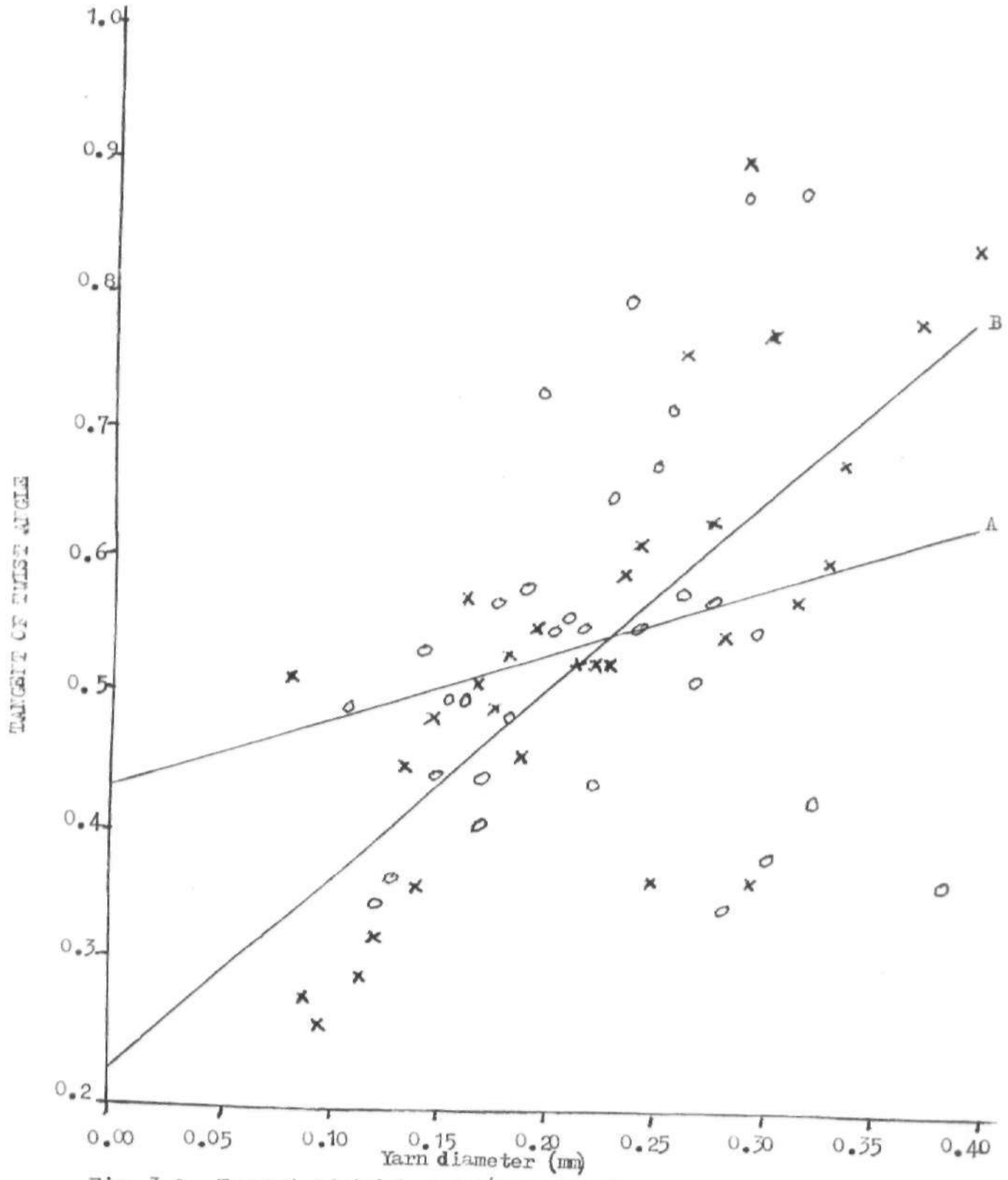


Fig. 3.2. Tangent of twist angle/yarn diameter.

A = Package 17/13 (Backsuctioned) : y=1.5014x + 0.2230; r=0.6878
B = Package 17/14 (Not backsuctioned) : y=0.9908x + 0.2648; r=0.7397

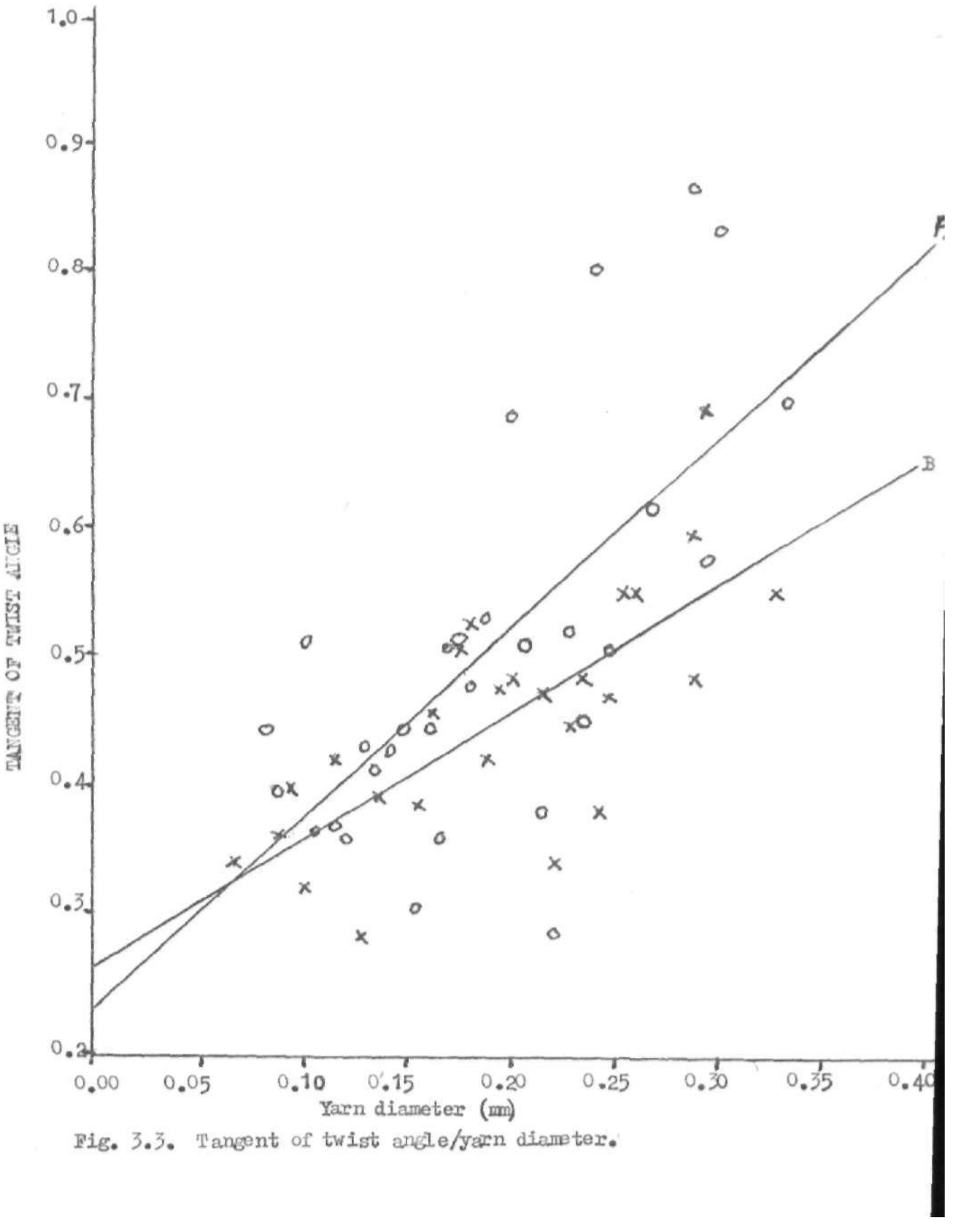


Fig. 3.3. Tangent of twist angle/yarn diameter.

A = Package 17/15 (Backsuctioned) : y=1.6232x + 0.1315; r=0.6874
B = Package 17/16 (Not backsuctioned) : y=0.6206x + 0.2734; r=0.3055

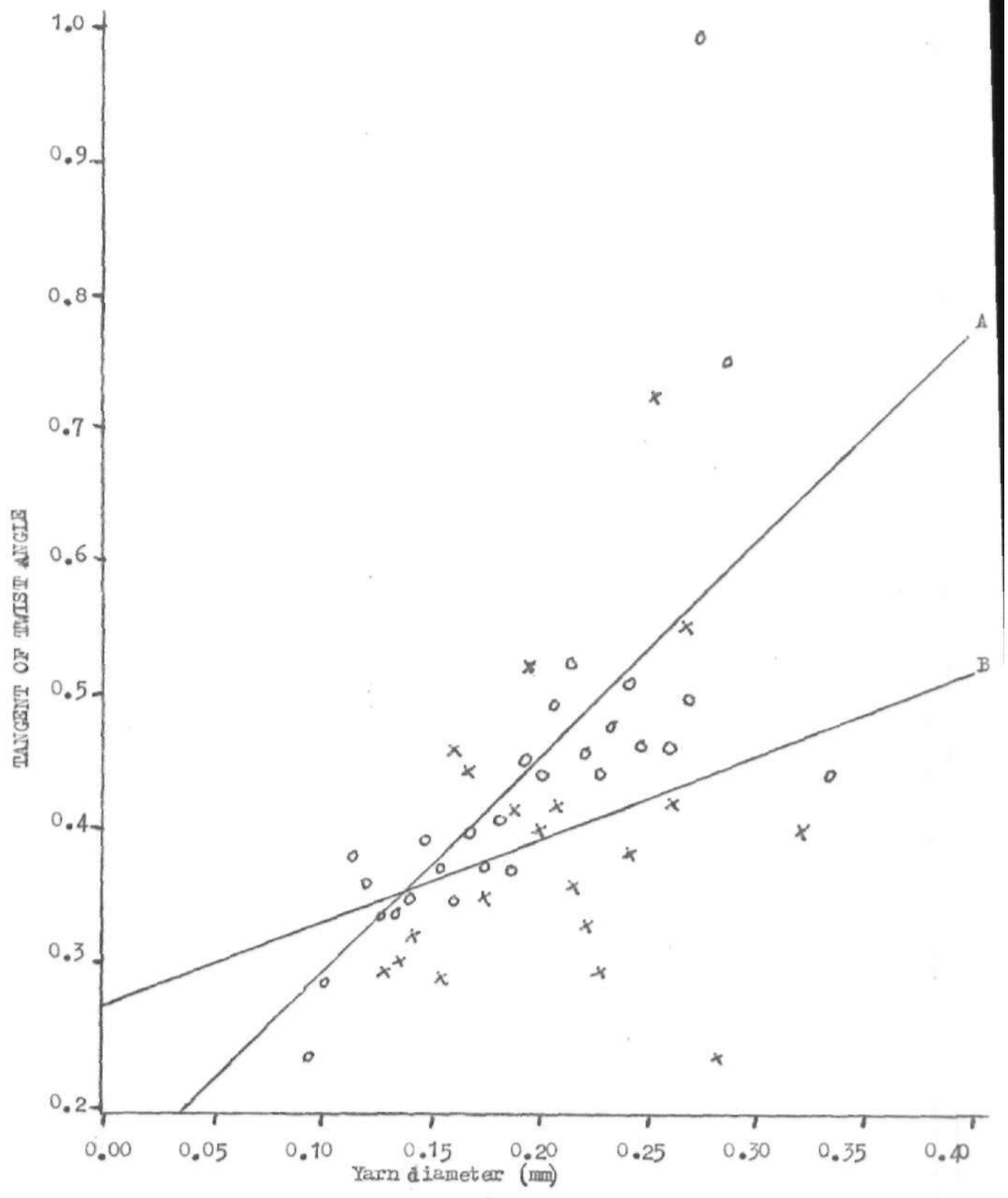


Fig. 3.4. Tangent of twist angle/yarn diameter.

3.5. DISCUSSION

Effect of Backsuction on Twist Characteristics of Cotton Yarns

Yarn packages 17/1 and 17/2 are spun under the same spinning pressure of 1219.2mm head of water but package 17/1 was spun with backsuction while sample 17/2 was spun without backsuction. The results of twist measurements of these yarns showed that package 17/1 gave overall higher average t.p.m. in the order of 613.2 t.p.m. than package 17/2 which has got 569.0 t.p.m. on overall average. The counts of these yarns are very similar with a difference of just 0.1 tex which is not expected to have any significant effect on the twist properties of the yarns. These findings showed that backsuction in open-end friction-spinning increases the amount of twists in yarns appreciably because of the difference of 44.2 t.p.m. is very significant. This high significant value in t.p.m. will also create high differences in both physical and mechanical properties of the two yarns, some of these would be shown in the later sections of this thesis.

If the individual t.p.m. values even for each of the same package are considered we found extremely big differences which are not expected (these are shown in Table 3.1). This suggests that marked twist variations are present with open-end friction-spun yarns which is likely to be one of the causes of low strength of the yarns. For example, one specimen of a yarn from package 17/1 had 1013.6 t.p.m. and another specimen from the same package had 386.2 t.p.m. a difference of 617.4 t.p.m. which is giving a lot of concern. If some parts of the length of a yarn are hardly twisted and some parts are softly twisted, not only that it will lead to problems in processings like spinning and weaving but also the overall texture of the yarn will be affected badly. The presence of wrapper fibres on the surface of

friction-spun yarns may also contribute to the large twist variations along the length of friction spun yarns. This is because wrapper fibres can obstruct the easy and adequate flowing of twists during twist insertion so that places of high wrapper fibres concentration will experience lower t.p.m. while areas of low wrapper fibres concentration will experience higher t.p.m. The formation of these wrapper fibres on the surface of open-end friction-spun yarns must be fully understood in other to find means of reducing their effects on twist insertion.

The overall mean diameter for package 17/1 is 0.1902mm while that of package 17/2 is 0.2048mm with overall mean twist angle of 19.96 degrees compare to 19.10 degrees for package 17/1. One would probably expect package 17/2 which has got higher twist angle to have higher t.p.m. but the reverse is the case which suggests the complexity of these yarns again. Presence of wrapper fibres will influence the magnitude of diameter of these yarns. From the one hundred specimens observed for twist investigation of package 17/1, only one specimen has the highest diameter of 0.466mm compare to the lowest diameter of 0.1133mm found also with one specimen. But, yarn specimens with diameters of 0.2333mm, 0.1933mm and 0.1666mm are more in the one hundred yarn specimens observed in the order of eight each. In other words, yarn specimens with diameters of 0.2333mm, 0.1933mm and 0.1666mm are more in the yarn structure of package 17/1 than other diameters. See Table 3.2. For package 17/2, the highest diameter was 0.3266mm and it was found also with only one yarn specimen as with package 17/1 while the lowest diameter was 0.1200mm. Yarn specimen with a diameter of 0.2000mm was more in the yarn structure and it was in the order of eleven. This is shown in Tables 3.3.

The graphs obtained by plotting tan. of twist angles against yarn diameters for packages 17/1 and 17/2 are shown in Figure 3.1 with their straight line equations. For package 17/1, y = 0.2757 x + 0.2926; r = 0.2281, while for package 17/2, y = 1.2780x + 0.1026; r = 0.7831. The value of correlation coefficient (r) for package 17/1 which is 0.2281 is too low, means that the two parameters used for plotting the graph varied widely from each other and very irregular in the yarn structure. Since we told the computer to draw a best straight line through the points on the graph, the more the straight line moves towards the tan. of twist angle axis the better would be the yarn and the higher would be the value of r. For package 17/2, r is 0.7831 which is higher than that for package 17/1 and the two parameters used for plotting the graph as well as their points of intersections were not as scattered as that of package 17/1. That is why package 17/2 has higher overall twist angle than package 17/1. For a perfect correlation of the two parameters r would be 1.

Effect of Backsuction on Twist Characteristics of Polyester Spun Yarns

This research work has shown that the effect of backsuction on twist characteristics of polyester open-end friction-spun yarns is very marked. This is reflected in the results obtained for packages 17/11 and 17/12 spun under the same pressure but one of them was backsuctioned and the other spun without backsuction. The package 17/11 which was backsuctioned has higher turns per metre (twist factor) in the order of 889.6 as compared to package 17/12 which was spun without backsuction and which has 816.3. The difference in twist characteristics of course would be manifested in the tensile behaviour of these yarns which is a crucial factor in determining the end-uses of the yarns. There are also variations

in twist angles of these yarns package 17/11 has higher overall average twist angle (28.13) than package 17/12 (27.66) which is a contributing factor to twist variations in open-end friction-spun yarns. If the individual value of twist angle and yarn diameter of these yarns are considered even on the same package it would be found that open-end friction-spun yarns vary so much along their structures in these regards. All these may probably account for the low strength of these yarns. Though, the differences in twist angle and yarn diameter of the two packages spun under the same pressure (1219.2mm head of water) are not much but the difference in t.p.m. of the two packages is so great which suggests that something else may be responsible for this in the structure or in the mechanics of yarn consolidation which is not known yet.

Package 17/13 and 17/14 were spun under the same pressure (1320.8mm head of water) but package 17/13 was backsuctioned while package 17/14 was not backsuctioned, it would be seen from the results in Table 3.6 that the package 17/13 has higher t.p.m. (982.2) than the package 17/14 (803.8) and lower twist angle (24.25) than the package 17/14 (24.70) and lower yarn diameter (0.1586mm) than the package 17/14 (0.1925mm). These investigations have shown that the yarn spun with backsuction under higher pressure (1320.8mm head of water) produced a yarn with more twists along its length. For example, packages 17/11 and 17/13 were both backsuctioned under similar conditions but package 17/13 was spun under higher pressure than package 17/11 and therefore has higher t.p.m. But the results showed by the package 17/15 gave a different trend entirely, since the package was spun under a pressure of 1422.4mm head of water with backsuction and produced a yarn of 759.0 t.p.m. compared with the package 17/13 which was also backsuctioned but spun under a pressure of 1320.8mm head of water and has higher t.p.m. in the order of 982.2 t.p.m.

The result shows that in open-end friction-spinning system there is probably a maximum spinning pressure under which the yarns are hard twisted, above this pressure the t.p.m. would be reducing hence changes in the structure and properties of the yarns.

Also, packages 17/15 and 17/16 were spun under the same pressure of 1422.4mm but package 17/15 was backsuctioned while package 17/16 was spun without backsuction. From the results shown in Table 3.6, it would be seen that package 17/15 which was backsuctioned has higher t.p.m. (759.0), higher twist angle (22.15°) and lower diameter (0.1758mm) than package 17/16 which was not backsuctioned and has 679.4 t.p.m., 21.61° twist angle and 0.1927mm diameter. The counts of the two yarns are very similar but with only 0.3 tex difference. This showed that backsuction in open-end friction-spinning has a significant effect in the structure of open-end friction-spun yarns.

Since the counts of the yarns compared together in pairs (17/11 and 17/12, 17/13 and 17/14, 17/15 and 17/16) are very similar to each other then, the effect of count variations on the structure of the yarns will be insignificant. If we consider all the packages spun with backsuction and spun under different pressures, it will be found that package 17/13 which was spun under a pressure of 1320.8mm head of water gave the highest t.p.m. with a value of 982.2 t.p.m. while package 17/15 has the smallest value of 759.0 t.p.m. and spun under a pressure of 1422.4mm head of water.

The use of backsuction in open-end friction-spinning also has tremendous effect on the yarn diameter. The results obtained from the yarn diameter measurements showed that all the yarns spun with backsuction have lower diameter values than those spun without backsuction even under the same spinning pressure. These differences can be observed from Table 3.6. For example, the overall average diameter of package 17/11 (backsuctioned) is 0.2034mm and that of

package 17/12 (spun without backsuction) is 0.2179mm though they were both spun under the same pressure of 1219.2mm head of water. This is the case with all the yarns spun even under the same pressure. If all the yarns spun without backsuction but under different spinning pressures were considered it will be seen from the results that the higher the spinning pressure the lower the yarn diameter generally. Packages 17/12, 17/14 and 17/16 were spun under different spinning pressures of 1219.2, 1320.8mm and 1422.4mm head of water respectively and have their average diameters of 0.2179mm, 0.1925mm and 0.1927mm respectively which suggests that high spinning pressure helps in thinning down the yarns in open-end friction-spinning system without backsuction. But, in the case of yarns spun with backsuction different trends were shown. For example, packages 17/11, 17/13 and 17/15 were all backsuctioned under spinning pressures of 1219.2mm, 1320.8mm and 1422.4mm head of water respectively and have diameters of 0.2034mm, 0.1586mm and 0.1758mm respectively. This observation shows that the effect of spinning pressure on the structure of open-end friction-spun yarns will depend on either the yarns are backsuction or not.

The results of these investigation have shown that yarn diameter in open-end friction-spun yarns are not consistent at all. For package 17/11, yarn diameter ranges from 0.3800mm to 0.1067mm (backsuctioned package) and from 0.3933mm to 0.0800mm for package 17/12 (not backsuctioned package). The same trends apply to the remaining packages as shown in Section 3.4.3. The trends of yarn diameter variations are worst for yarns spun without backsuction hence more structural variations of the yarns spun without backsuction. The graphs obtained by plotting tan. of twist angles against yarn diameters for packages 17/11 and 17/12 are shown in Figure 3.2

with their straight line equations. For package 17/11, y = 0.4568x + 0.4432; r = 0.22, while for package 17/12, y = 1.4330x + 0.2197; r = 0.25. The correlation coefficient (r) value for package 17/11 (0.22) is extremely too low which suggests that the degree of correlation of the two parameters used for the graph is poor and they varied widely from each other and very irregular in the yarn structure. In the case of package 17/12, with higher value of r (0.75), the two yarn parameters used for the graph are still not consistent and vary widely in the structure as shown in the graph. The same thing applies to the remaining four packages spun in pairs. Packages 17/13 and 17/14 have y = 1.5014x + 0.2230; r = 0.69 and y = 0.9908x + 0.2648; r = 0.74 respectively as shown in Figure 3.3. It will be seen from the figure that the two yarn characteristics used for plotting the graphs vary so much and their points of intersections on the graphs are all scatered here and there, suggesting mass variation of the yarns.

Packages 17/15 and 17/16 spun under the same spinning pressure of 1422.4mm head of water having y = 1.6232x + 0.1315; r = 0.69 and y = 0.6206x + 0.2734; r = 0.31 respectively showed something a bit different from packages 17/13 and 17/14 in that the two yarn parameters used for plotting the graphs are more concentrated on certain parts of the graphs than packages 17/13 and 17/14. This is shown in Figure 3.4.

CHAPTER 4

4.0. CHARACTERISATION OF FIBRE AND YARN PROPERTIES

4.1. Introduction

All the eight packages used for twist investigation were also used to study fibre orientation in the yarns. The study of fibre orientation is very important since it determines the contribution of each fibre to the overall strength of any particular yarn. Fibre orientation in a yarn is a study of the state or configurations of fibres in the structure of that particular yarn. After the yarn has been consolidated, the fibres are formed into different shapes inside the structure and these fibres shapes are the building block contributing to the yarn mechanical properties.

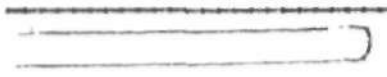
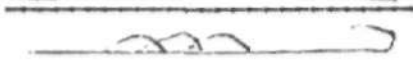
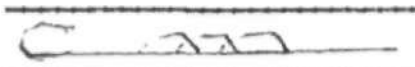
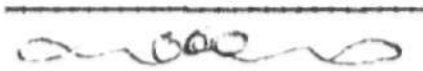
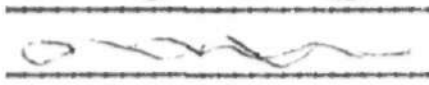
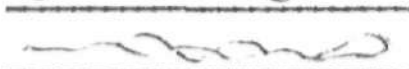
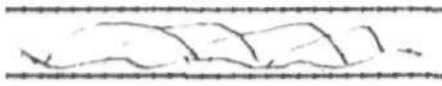
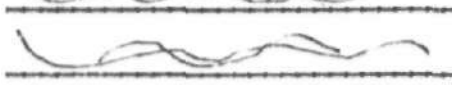
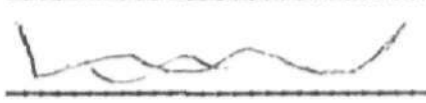
4.2. Measurement of The Fibre Orientation in Open-End Friction-Spun Yarns

The same optical apparatus that was used for twist investigation in chapter three based on tracer fibre technique was also used for this orientation investigation.

When a yarn is focused with its two ends shown on the television screen, the fibre shape or configuration was noted and drawn out and its fibre extent measured in mm on the microscale. For this investigation, one hundred fibres with both two ends shown on the screen were observed for each of the package yarns. All yarns with only one end shown on the screen were discarded and not studied because the two ends of a yarn are required before its correct fibre extent could be measured. The number of each configuration in a structure was obtained with their fibre extent and their mean overall fibre extent calculated from the one hundred results. Some fibres are found to be formed into trailing hooks, leading hooks, entanglement, hooks at both sides, leading folds, trailing folds, folds at both sides, some are straight etc.

4.2.1. Fibre Orientation Results

Package 17/1: Backsuctioned; Pressure (Water gauge): 1219.2mm Cotton Yarn

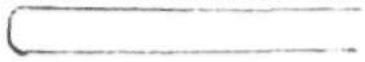
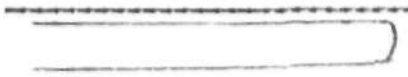
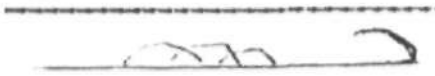
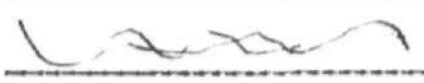
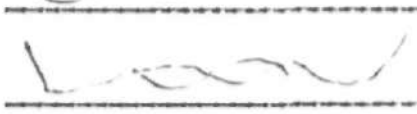
FIBRE CONFIGURATION	NO. OF FIBRES	MEAN FIBRE EXTENT (mm)
	8	30.12
	13	18.85
	5	20.40
	4	14.25
	9	14.57
	6	13.58
	1	19.00
	6	21.00
	5	20.50
	14	15.61
	7	17.29
	9	19.94
	6	14.83
	5	20.40
	2	15.75

Mean Overall Fibre Extent = 19.07mm.

Table 4.1. Package 17/1 Fibre orientation results.

Package 17/2: Without Backsuction; Pressure (Water Gauge):

1219.2mm Cotton Yarn.

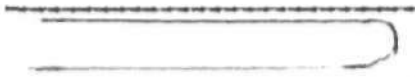
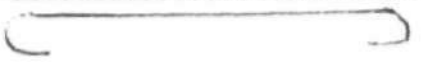
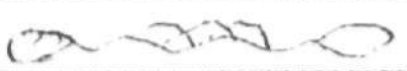
Fibre Configuration	No. of Fibre	Mean Fibre Extent (mm)
	4	30.38
	12	19.12
	6	17.08
	5	17.70
	4	17.25
	10	14.44
	1	10.00
	4	15.50
	4	17.13
	13	16.27
	7	18.36
	12	17.08
	7	13.29
	6	18.25
	5	17.30

Mean Overall Fibre Extent = 17.28mm

Table 4.2. Package 17/2 Fibre orientation results.

Package 17/11: Backsuctioned; Pressure (Water Gauge): 1219.2mm

Polyester Yarn

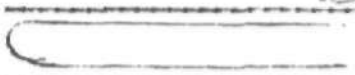
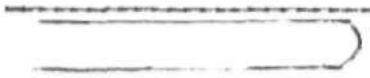
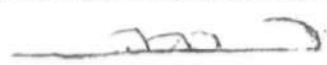
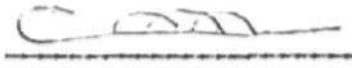
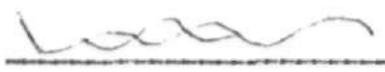
Fibre Configuration	No. of Fibres	Mean Fibre Extent (mm)
	2	26.50
	17	16.18
	1	25.00
	6	11.75
	4	15.25
	4	20.13
	-	-
	2	11.75
	1	5.50
	38	12.50
	12	13.63
	11	14.41
	1	20.00
	1	8.50
	-	-

Mean Overall Fibre Extent = 14.20mm

Table 4.3. Package 17/11 Fibre orientation results.

Package 17/12: Without Backsuctioned; Pressure (Water Gauge):

1219.2mm Polyester Yarn

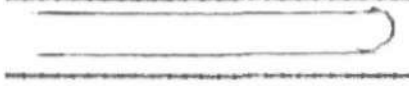
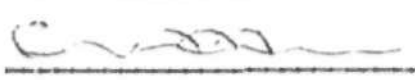
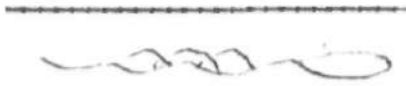
Fibre Configuration	No. of Fibre	Mean Fibre Extent (mm)
	1	24.00
	6	13.58
	4	11.50
	4	10.13
	5	15.50
	3	7.83
	-	-
	7	8.14
	3	11.17
	39	11.55
	12	10.00
	8	12.13
	7	6.86
	1	9.00
	-	-

Mean Overall Fibre Extent = 11.08mm.

Table 4.4. Package 17/12 Fibre orientation results.

Package 17/13: Backsuctioned; Pressure (Water Gauge) : 1320.8mm

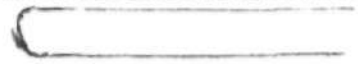
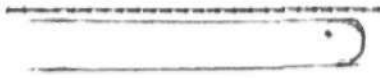
Polyester Yarn

Fibre Configuration	No. of Fibres	Mean Fibre Extent (mm)
	1	32.00
	6	15.92
	8	16.50
	9	10.83
	3	12.67
	4	15.75
	-	-
	3	8.33
	2	16.50
	37	14.07
	15	12.67
	7	14.64
	4	10.52
	1	10.00
	-	-

Mean Overall Fibre Extent = 13.81mm

Table 4.5. Package 17/13 Fibre orientation results.

Package 17/14: Without Backsuctioned; Pressure (Water Gauge) : 1320.8mm Polyester Yarn

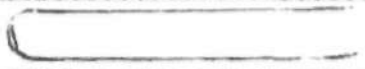
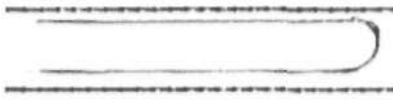
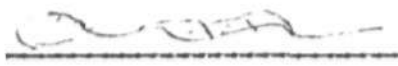
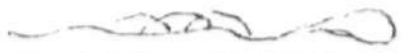
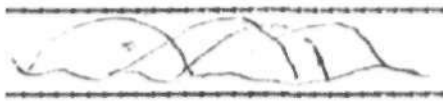
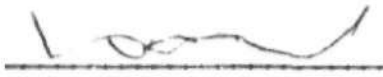
Fibre Configuration	No. of Fibres	Mean Fibre Extent (mm)
	-	-
	6	12.33
	7	11.00
	4	9.38
	7	12.36
	7	14.29
	-	-
	5	12.30
	-	-
	43	13.03
	6	14.25
	7	12.29
	4	11.75
	4	6.75
	-	-

Mean Overall Fibre Extent = 9.42mm

Table 4.6. Package 17/14 Fibre orientation results.

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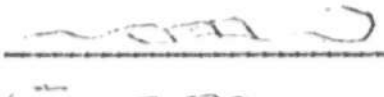
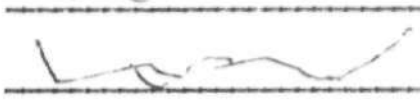
Package 17/15: Backsuctioned; Pressure (Water Gauge): 1422.4mm; Polyester Yarn

Fibre Configuration	No. of Fibres	Mean Fibre Extent (mm)
	1	29.00
	3	9.33
	8	10.69
	4	14.25
	4	17.37
	6	14.92
	-	-
	2	18.50
	-	-
	49	12.56
	8	10.19
	4	18.50
	9	10.67
	2	13.00
	-	-

Mean Overall Fibre Extent = 12.89mm

Table 4.7. Package 17/15 Fibre orientation results.

Package 17/16: Without Backsuctioned; Pressure (Water Gauge) : 1422.4mm; Polyester Yarn

Fibre Configuration	No. of Fibres	Mean Fibre Extent (mm)
	1	28.50
	5	9.90
	3	13.17
	3	19.83
	3	9.00
	4	15.50
	1	29.00
	2	9.75
	2	6.25
	57	12.73
	2	15.00
	5	14.20
	7	8.93
	5	12.90
	-	-

Mean Overall Fibre Extent = 12.81mm

Table 4.8. Package 17/16 Fibre orientation results.

4.3. Determination of Yarn Hairiness of Open-End Friction-Spun Yarns

For the evaluation of hairiness of yarns of open-end friction-spun yarns, additional twelve more packages are spun together with the eight packages used for twist and orientation investigations making a total of twenty packages. Ten of these packages were backsuctioned and the remaining ten were spun without backsuction under different spinning pressures. Packages 1, 2, 11 adn 12 were spun under a spinning pressure of 1066.8mm, packages 3, 4, 13 and 14 were spun under 1219.2mm, packages 5, 6, 15, and 16 were spun under 1320.8mm, packages 7, 8, 17 and 18 were spun under 1422.4mm while packages 9, 10, 19 and 20 were spun under 1498.6mm head of water. All the even numbered packages were spun without backsuction. Ten of the packages are cotton yarns while the remaining ten packages are polyester yarns.

The hairiness of the yarns was evaluated using Shirley Yarn Hairiness Tester. Its working principle is based on electronic capacitance method. Under certain conditions, the effect of introducing a non-conducting material such as a yarn into the space between the plates is to change the capacity of the capacitor, the change being proportional to number of hairs present. If, therefore, the material is drawn through the capacitor continuously, the changes in the capacity will follow the variation in the number of hairs per unit of length of the yarn. The changes in the capacity is detected and translated electronically into a pen recorder which indicates the average hairs/metre, the standard deviation and the coefficient of variation of the hairs/metre(69).

The measurement was done by passing the yarns through the instrument at a speed of 60m/min. followed by taking the readings.

Full Test Parameters.

Speed:	60m/min.
Test Length:	10m
Number of Tests:	10 and 1mm from yarn axis.

Some packages were very difficult to test due to excessive yarn breakages before the test was completed e.g. packages 17/1 and 17/12 proved to be difficult to test. All packages were conditioned in a standard atmosphere for testing textile materials before testing. The results obtained are shown in Table 4.9 while the schematic diagram of the instrument is shown in Appendix IV.

4.3.1. Yarn Hairiness Results

Packages	Mean Hairs Per Metre	Standard Deviation	Coefficient of Variation (%)
17/1*	160.00	8.74	12.04
17/2	242.14	6.38	2.63
17/3*	178.72	10.45	5.85
17/4	185.17	8.42	4.54
17/5*	184.17	5.69	3.09
17/6	158.75	5.22	3.29
17/7*	154.17	12.96	8.41
17/8	160.12	3.95	2.47
17/9*	170.73	6.05	3.54
17/10	152.22	3.98	2.66
17/11*	137.70	3.66	2.66
17/12	139.50	2.97	4.05
17/13*	141.36	7.68	5.44
17/14	143.20	13.78	9.62
17/15*	145.60	4.21	2.89
17/16	144.54	10.53	7.29
17/17*	127.57	10.24	19.23
17/18	140.75	6.25	4.44
17/19*	164.07	7.88	4.81
17/20	158.08	23.12	14.63

Table 4.9. Yarn hairiness results.

*Backsuctioned packages.

Packages 17/1 to 17/10 are cotton yarns while packages 17/11 to 17/20 are polyester yarns.

4.4. Measurement of Yarn Evenness and Irregularity of Open-End Friction-Spun Yarns

All the twenty packages spun and used for yarn hairiness determination were also subjected to yarn evenness and irregularity measurement. The yarns (packages) were conditioned and tested in a standard testing atmosphere for textiles i.e. an atmosphere of relative humidity of 65 ± 2 percent and a temperature of 20 ± 2°C.

The irregularity and evenness of the yarns was determined using Uster Tester 3 with its schematic diagram shown in appendix V. Two oscillators A and B have equal frequencies when there is no material in the measuring capacitor C. When the two frequencies are superimposed the difference in frequency is zero. The presence of material in the capacitor causes its capacity to change and alter the frequency of the oscillator A. There will then be a difference between the two frequencies which varies according to the amount of material between the capacitor plates. Suitable circuits D translate these frequency differences into signals which (a) are indicated on the meter M, (b) drive the pen of the recorder, and (c) are fed into the integrator which indicates the CV (km), CV (3m), index of irregularity (%), thin places (-50%), thick places (+50%) and neps (+200%). The Uster Tester used was the most modern type of irregularity testing machines. The determination was carried out according to the Uster Tester manufacturer's instructions using 200 metres for each test (70). The results are shown in Table 4.10. Some photographs of irregularity spectrum of these yarns are shown in Appendix VI.

4.4.1. Yarn Evenness and Irregularity Results

Packages	CV (km) (%)	CV (1m) (%)	CV (3m) (%)	Index of Irregularity (%)	Thin Places (-50%)	Thick Places (+50%)	Neps (+200%)
17/1*	14.40	3.67	2.97	2.09	8.0	0.0	12.0
17/2	14.83	3.67	2.92	2.11	25.0	2.0	16.0
17/3*	14.29	3.79	2.98	2.08	12.0	0	6.0
17/4	14.64	4.04	3.33	2.09	12.0	3.0	8.0
17/5*	14.52	3.35	2.53	2.11	8.0	1.0	7.0
17/6	14.29	3.84	2.98	2.04	11.0	0	8.0
17/7*	14.19	3.64	2.82	2.04	7.0	1.0	8.0
17/8	14.13	3.47	2.56	2.04	16.0	1.0	6.0
17/9*	14.41	3.86	2.96	2.04	6.0	1.0	13.0
17/10	14.41	4.03	3.39	2.01	11.0	1.0	13.0
17/11*	15.80	3.90	2.97	2.35	26.0	6.0	29.0
17/12	15.37	3.76	3.2	2.34	26.0	4.0	29.0
17/13*	15.76	4.10	3.06	2.47	23.0	5.0	14.0
17/14	15.75	4.24	3.34	2.40	35.0	1.0	22.0
17/15*	16.35	4.31	3.60	2.47	44.0	9.0	23.0
17/16	16.03	3.98	2.94	2.40	47.0	8.0	29.0
17/17*	15.69	3.39	2.19	2.36	27.0	10.0	21.0
17/18	15.78	3.82	2.97	2.37	42.0	2.0	21.0
17/19*	15.57	3.90	3.03	2.32	25.0	5.0	27.0
17/20	15.16	3.27	2.43	2.29	22.0	2.0	47.0

Table 4.10. Yarn evenness and irregularity results.

*Backsuctioned packages.

Packages 17/1 to 17/10 are cotton yarns while packages 17/11 to 17/20 are polyester yarns.

4.5. Single Yarn Strength and Elongation at Break of Open-End Friction-Spun Yarns Determination

The Textechno Stimat M Test machine (a computerised machine) was used to evaluate the strength characteristics of all the 20 packages spun which were the same package used for yarn evenness and irregularity evaluation. This tensile strength tester uses the bonded-wire type of strain gauge combined with a computer. It uses several interchangeable load cells containing the strain gauges e.g. from 2 to 50,000 grammes is possible. The load cell is located centrally in the fixed crosshead while the main controls for load range selection, calibration, etc., are mounted on the front panel below the recording chart. The load cell output is fed by cable to the control cabinet which houses the various electronic circuits and the pen recording equipment. Since the instrument works on the principle of constant rate of extension, so the test specimen will be extended until it finally breaks.

To carry out a test the instrument must be fed with the necessary particulars of the yarns. In fact, the measurement was carried out by feeding the computerised instrument with the packages particulars e.g. yarn count, package reference number, number of tests to be done and the type of yarn under test (cotton or polyester). Each package was made to run through the machine accordingly and the results were printed out automatically. Twenty tests were carried out for each of the packages and the mean results given by the instrument. The test length of the instrument was approximately 500mm. All the packages were conditioned for approximately 24 hours in a standard testing atmosphere for textiles before the test was carried out. Apart from the single yarn strength and elongation at break of the individual yarn given by the computerised instrument, the magnitude of work of rupture and the force required to break the individual yarn were also given by the instrument together with the average force/elongation curves of all the yarn packages.

The tensile strength characteristics results of the yarns are shown in Table 4.11 while the schematic diagram of the instrument is shown in Appendix VII.

4.5.1. The Yarn Tensile Strength Characteristics Results

Packages	Count (tex)	Mean Breaking Force (N)	Mean Work To Rupture (Ncm)	Mean Tenacity (cN/tex)	Mean Elongation (%)
17/1*	20.1	1.75	3.00	8.71	6.80
17/2	20.2	1.32	2.20	6.55	5.99
17/3*	21.1	1.75	3.03	8.29	6.91
17/4	20.3	1.58	2.79	7.77	6.92
17/5*	21.1	1.81	3.19	8.60	6.87
17/6	20.3	1.60	2.83	7.91	6.94
17/7*	20.7	1.74	3.02	9.41	6.91
17/9*	20.0	1.71	2.96	8.55	6.85
17/10	19.5	1.42	2.40	7.30	6.34
17/11*	22.2	2.99	7.40	13.49	10.66
17/12	23.2	2.33	5.45	10.03	9.69
17/13*	24.5	3.64	9.52	14.85	11.30
17/14	23.2	2.57	6.30	11.06	10.47
17/15*	22.8	3.33	8.76	14.60	11.32
17/16	22.5	2.66	6.69	11.81	10.62
17/17*	22.6	3.28	8.30	14.48	11.14
17/18	22.5	2.72	6.43	12.08	9.71
17/19*	22.2	2.76	6.64	12.41	10.62
17/20	22.9	1.50	2.98	6.55	7.42

Table 4.11. Yarn tensile strength characteristics results.

*Bucksuctioned packages.

Packages 17/1 to 17/10 are cotton yarns while packages 17/11 to 17/20 are polyester yarns.

4.6. Graphical Comparison of Some Yarn Properties

4.6.1. Measured Twists

The probable amount of twists inserted onto the twenty packages of yarns spun was measured by an instrument called Zweigle apparatus. This apparatus works on the principles of untwist-retwist method of twist measurement and it is the apparatus designed to determine quickly the amount of twist inserted onto open-end friction-spun yarns. The apparatus has been proved inadequate to measure the amount of twists in open-end friction-spun yarns by this investigation (from optical-microscopic method). Five tests were carried out for each package and the mean of the five tests results was given in Table 4.12. The measured twists experiment was conducted according to the Zweigle apparatus manufacturer's instructions.

4.6.2. Measured Twists Results

Packages	Measured T.P.M.	Packages	Measured T.P.M.
17/1*	917.40	17/11*	803.40
17/2	922.20	17/12	812.80
17/3*	952.40	17/13*	761.60
17/4	932.20	17/14	802.80
17/5*	984.20	17/15*	819.80
17/6	957.20	17/16	838.20
17/7*	996.80	17/17*	825.20
17/8	990.60	17/18	826.20
17/9*	957.80	17/19*	765.20
17/10	953.00	17/20	769.20

Table 4.12. Measured twist results.

*Backsuctioned packages.

Some yarn parameters were compared together graphically. The graphs are shown from Figures 4.1 through 4.11.

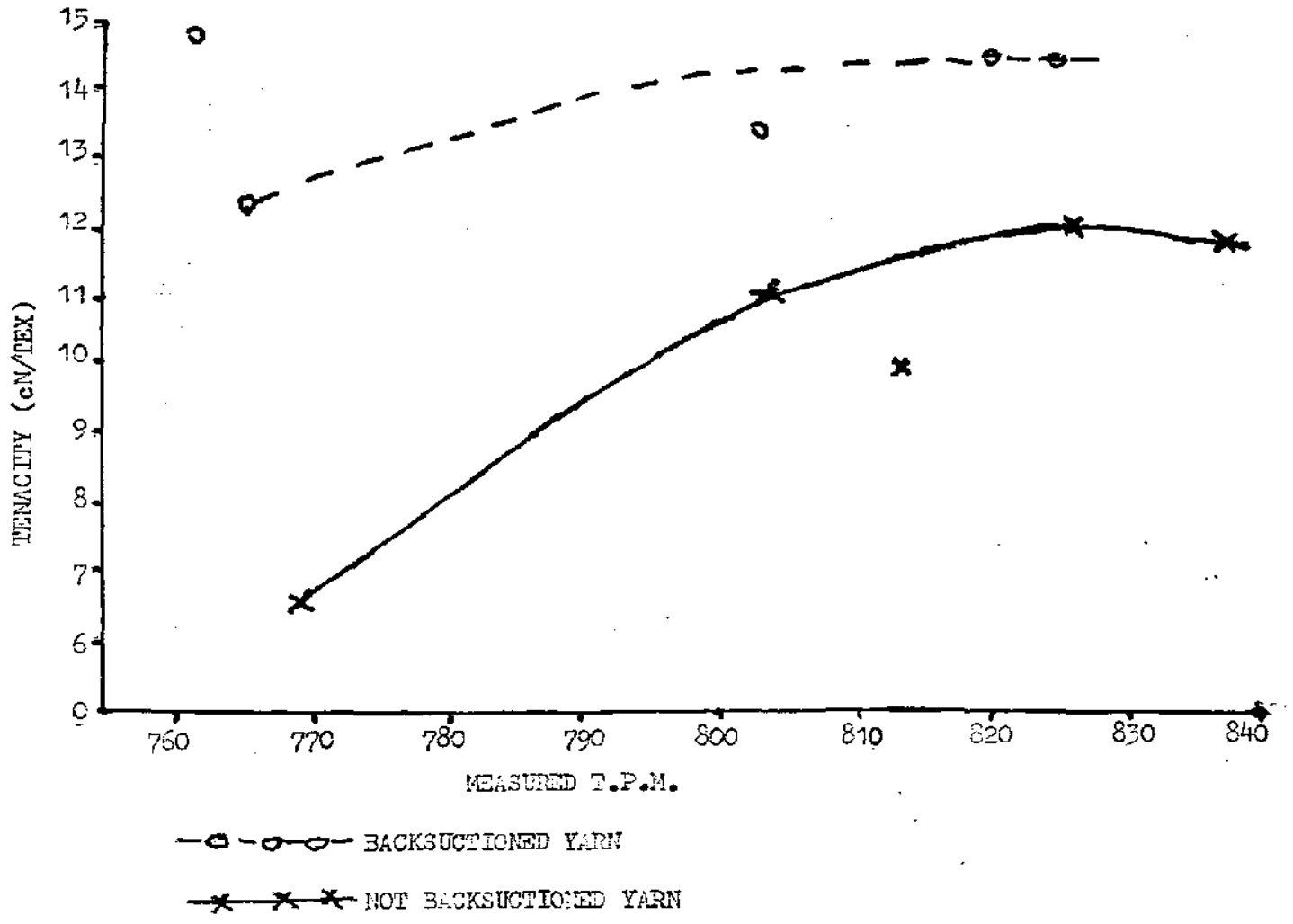


Fig. 4.1 Polyester yarn tenacity/measured t.p.m. relationships

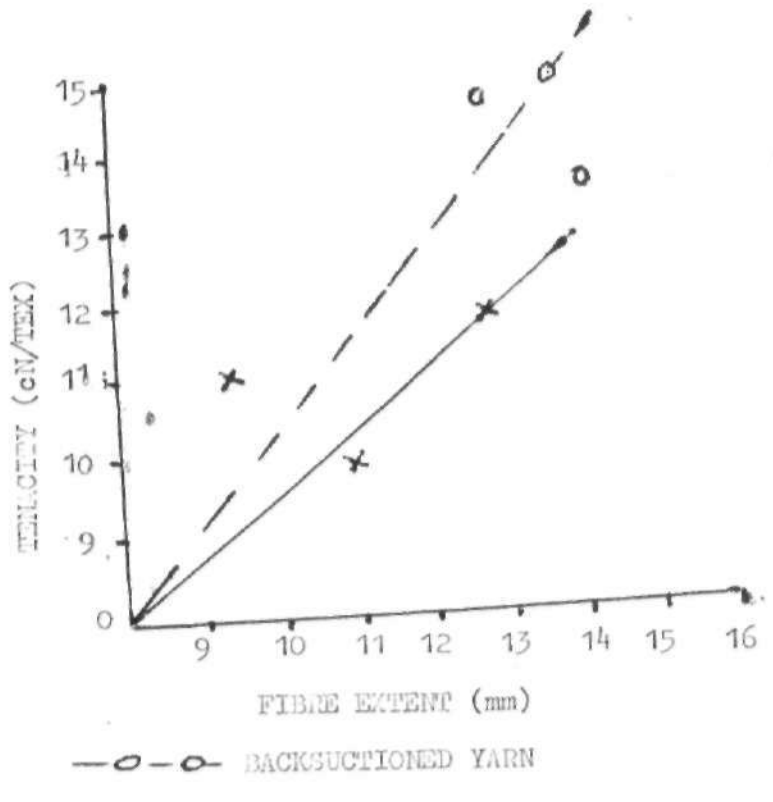


Fig. 4.2 Polyester yarn tenacity/fibre extent relationships

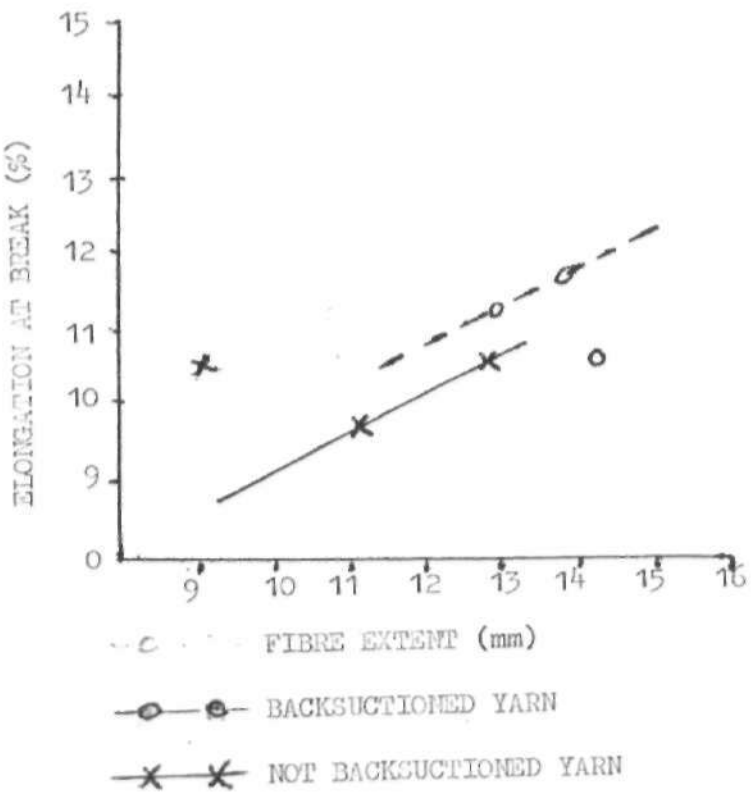


Fig. 4.3 Polyester yarn elongation/fibre extent relationship

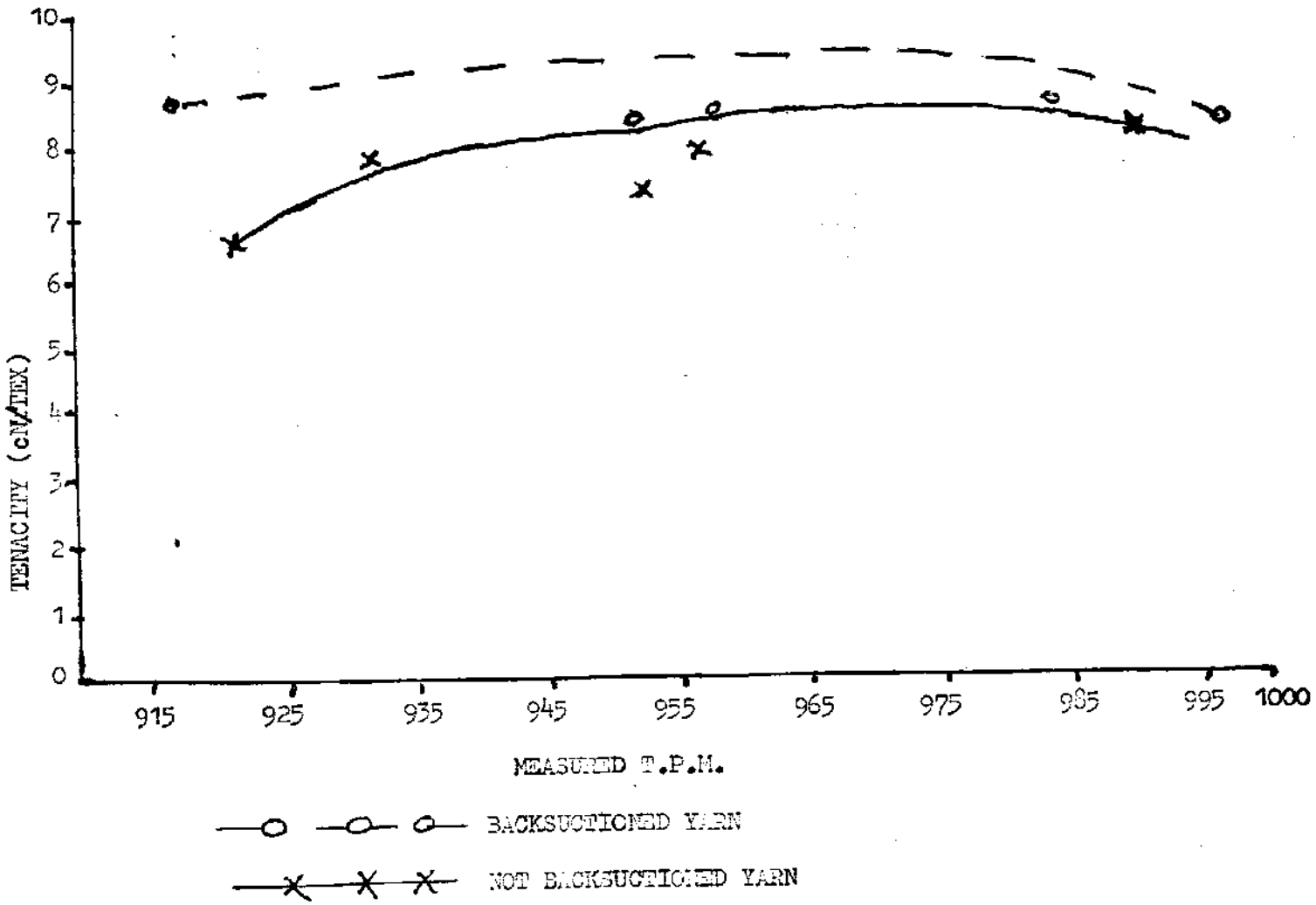


Fig.4.4. Cotton yarn tenacity/measured t.pm. relationships

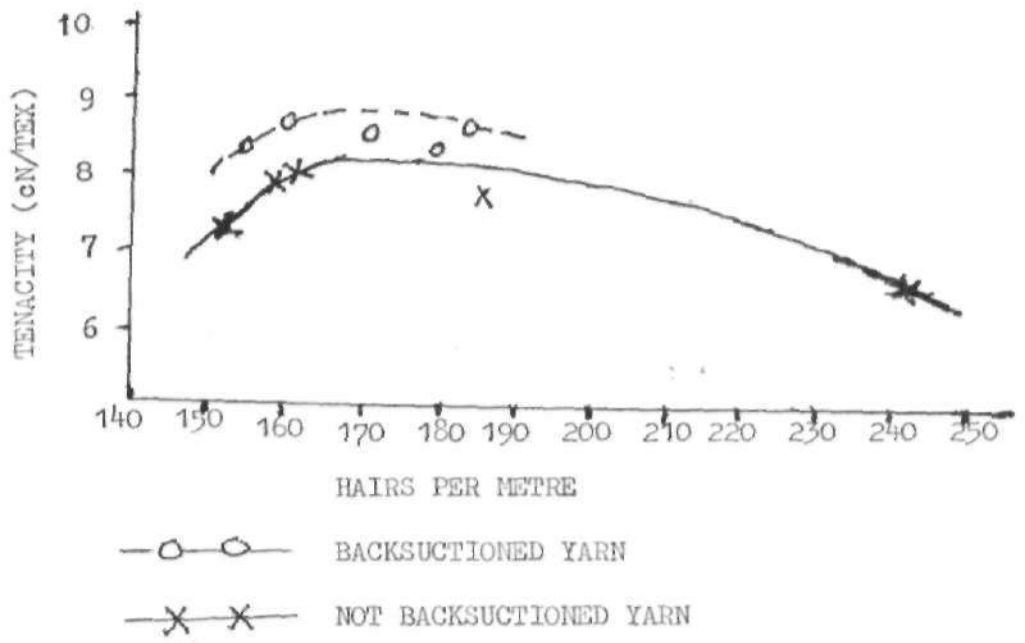


Fig. 4.5 Cotton yarn tenacity/hairs per metre relationships

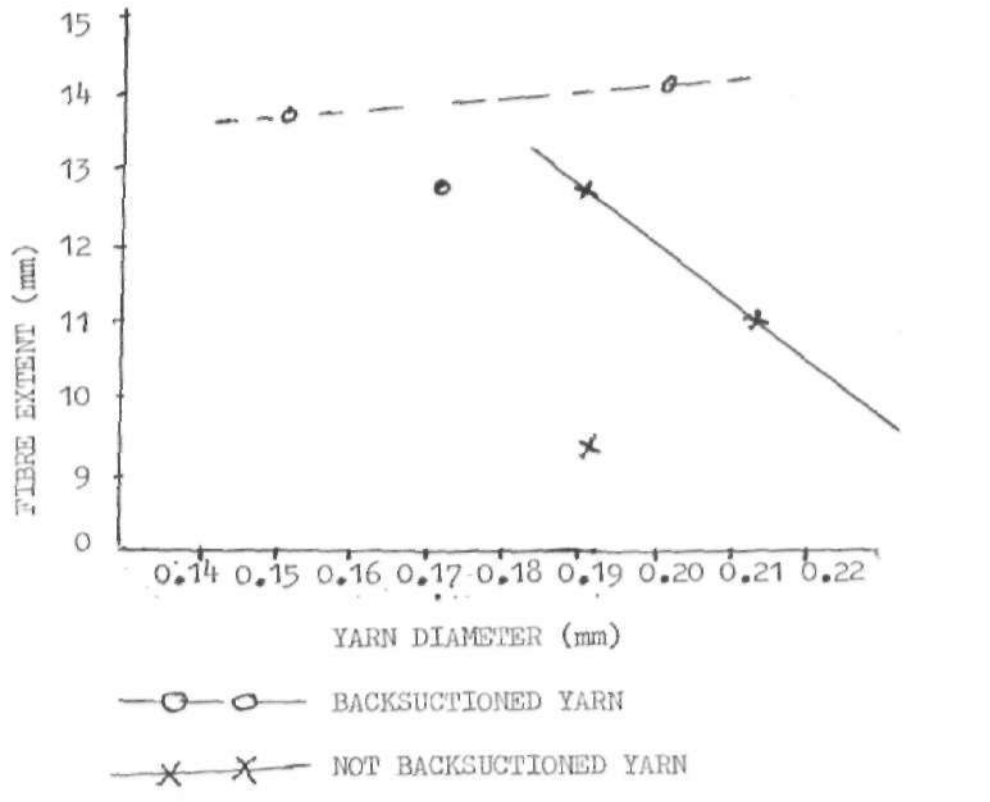


Fig. 4.6 Polyester fibre extent/diameter relationships

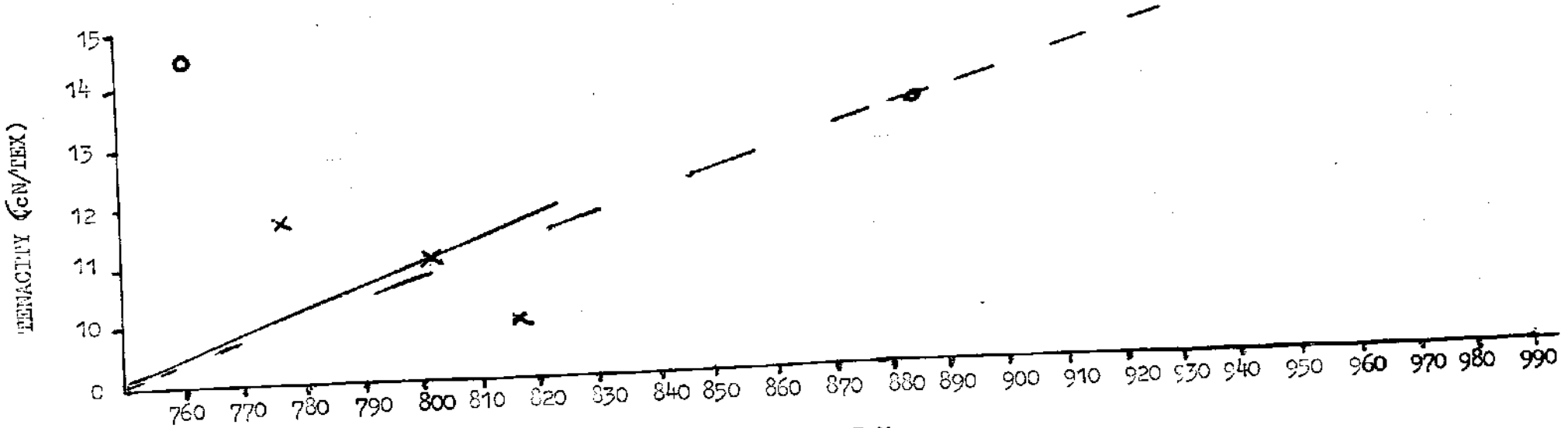


Fig.4.7. Polyester yarn tenacity/calculated t.p.m. relationships

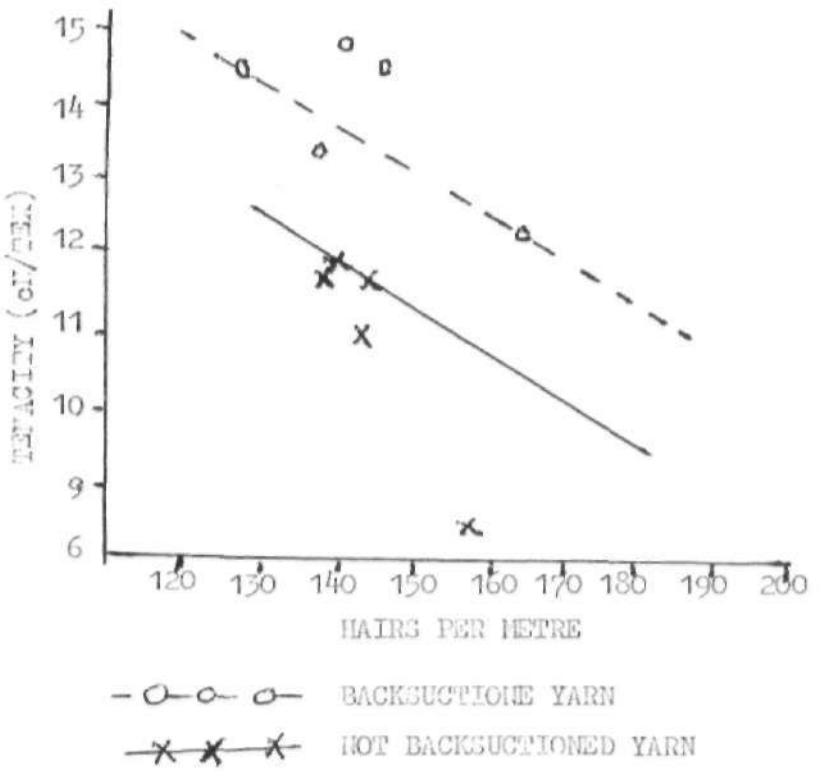


Fig. 4.8. Polyester yarn tenacity/hairs per metre relationships

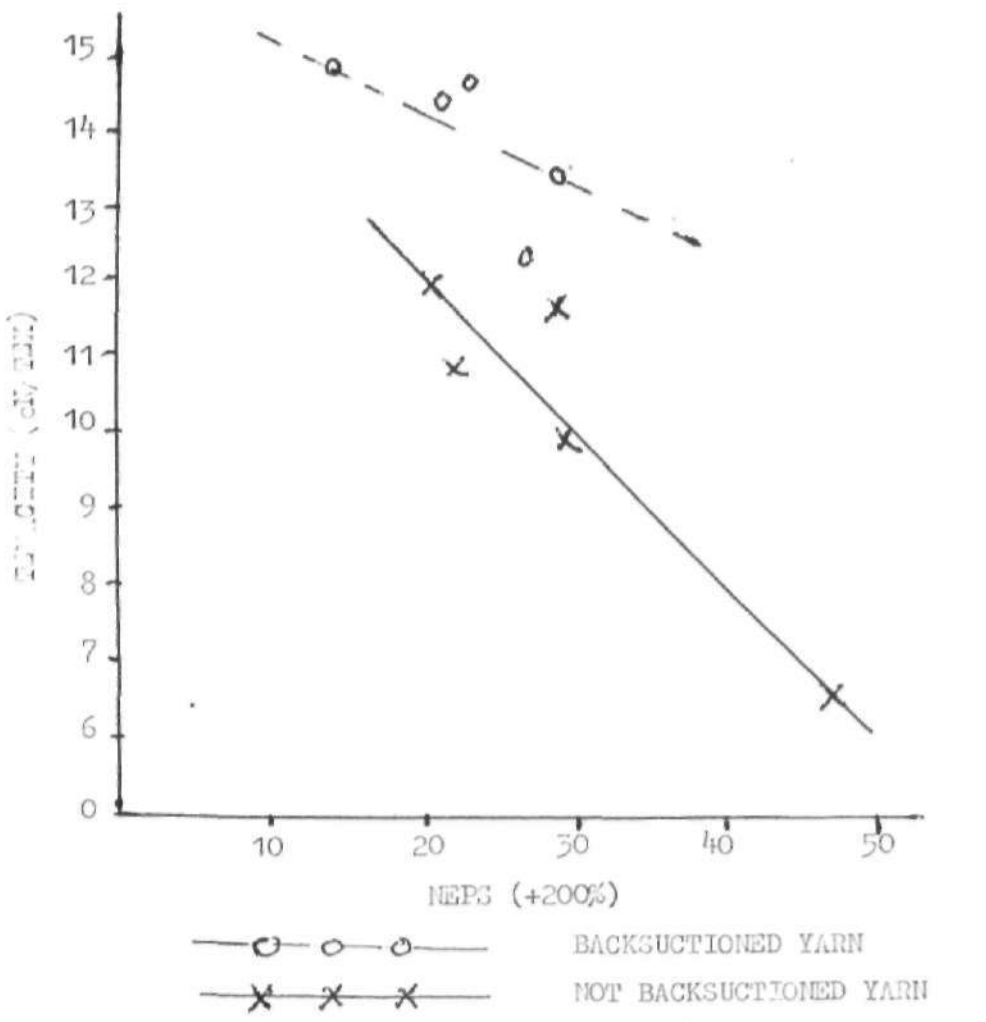


Fig. 4.9. Polyester yarn tenacity/neps relationships

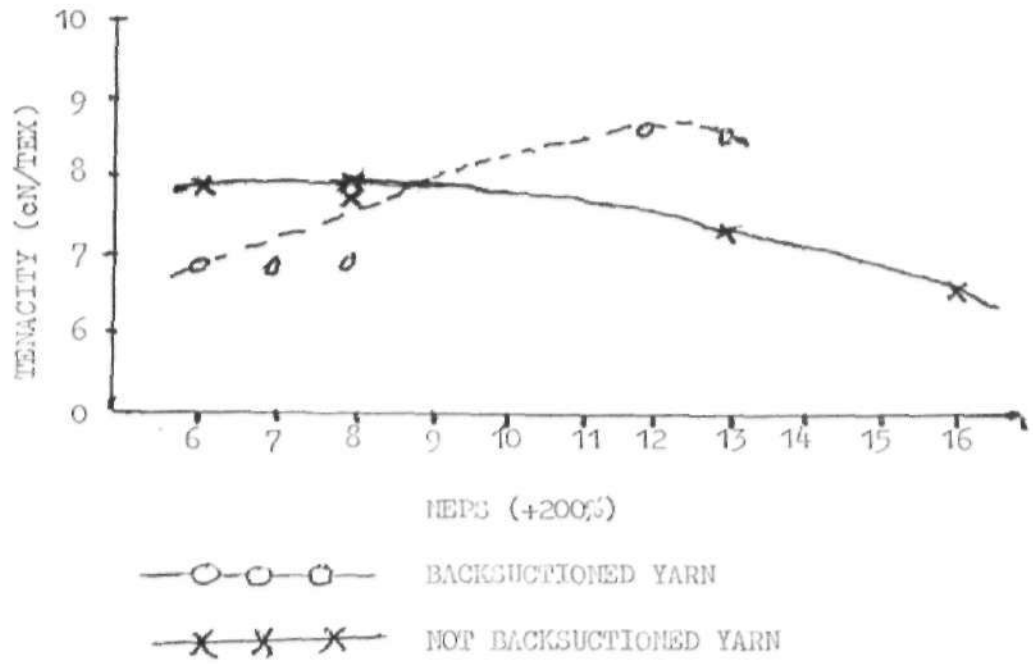


Fig. 4.10 Cotton yarn tenacity/neps relationships

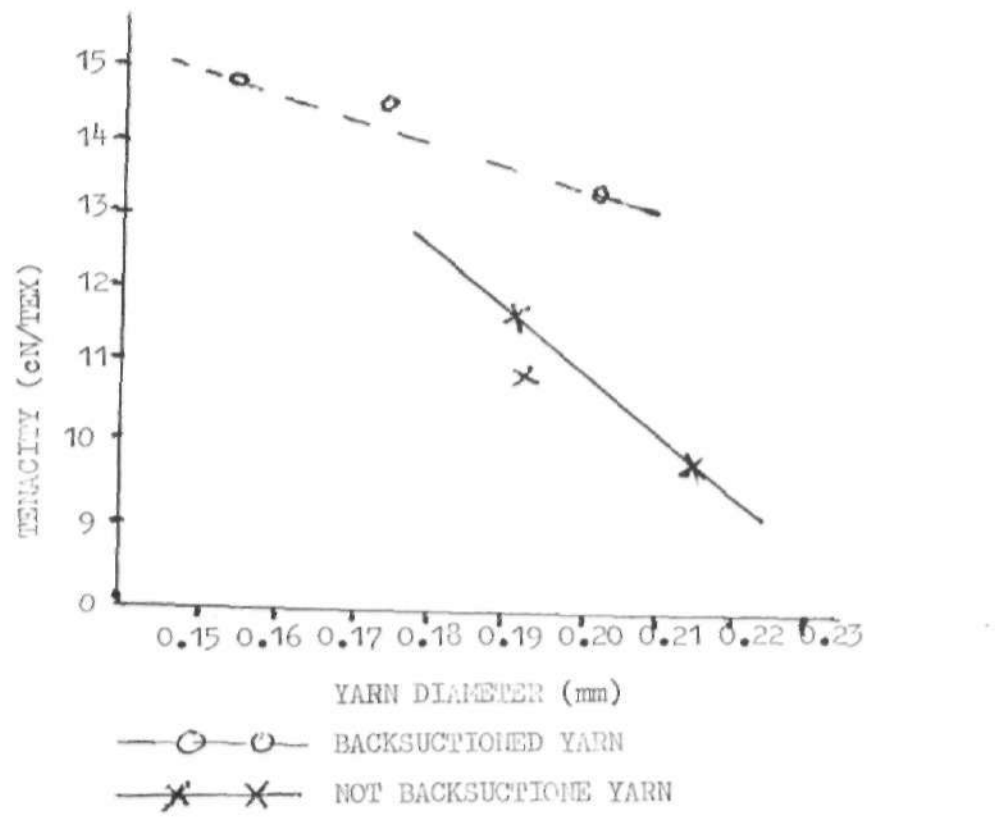


Fig.4.11. Polyester yarn tenacity/diameter relationships.

4.7. Discussion of Results of Fibre Orientation and Some Properties of Open-End Friction-Spun Yarns

For fibre orientation in open-end friction-spun yarn investigations, six packages of polyester yarns and two packages of cotton yarns are used. Only two packages of cotton yarns are used for fibre orientation investigations because the spinning system gives the worst result for cotton yarns hence there was no need for wasting time and materials in investigating more cotton yarn packages. If the results of cotton yarns are considered (Tables 4.1 and 4.2), it would be found that package 17/1 which was backsuctioned had higher overall fibre extent (19.07mm) than package 17/2 which had 17.28mm and which was spun without backsuction. The number of fibres that are found straight in package 17/1 (8) doubled the number that are found straight in package 17/2 which had only 4. Also, the number of fibres that were formed into entanglement in package 17/1 are lower (6) than that found in package 17/2 which is in the order of 7. The results from this orientation investigation showed that backsuction helps in straightening the fibres (hence better orientation) and better fibre utilization. Other fibre configurations and their number are shown in Tables 4.1 and 4.2.

The results of analysis of fibre orientation in the polyester yarns spun showed higher overall fibre extent for all the packages spun with backsuction than those spun without backsuction even under the same spinning pressure. Packages 17/11 and 17/12 were spun under the same spinning pressure but package 17/11 was backsuctioned and had higher number of fibres straightened and lower numbers of entanglement than package 17/12 which was spun without backsuction. These conditions apply for nearly all the yarns spun in pairs under the same spinning pressure and these were

shown in Tables 4.3 through 4.8. Different fibre configurations, their numbers and their fibre extent are also shown in the aboved mentioned tables. The results of this investigation showed that backsuction is also very important in open-end friction-spinning of polyester yarns.

The results of the yarn hairiness for all the cotton yarn packages showed that all packages spun with backsuction with the exception of sample 17/19 have lower number of hairs per metre than their counter part packages spun without backsuction. This is shown in Table 4.9. Similar trends are observed for the polyester yarns also. Those packages that were spun with backsuction have lower number of hairs per metre than the packages spun without backsuction with the exception of packages 17/15 and 17/19 which have approximately 1 and 6 hairs per metre respectively higher than their counterparts spun without backsuction. This is shown in Table 4.9.

The results of the yarn evenness and irregularity shown in Table 4.10 indicates that yarns spun with backsuction are better than the yarns spun without backsuction in terms of thick and thin places present with the yarns. For both cotton and polyester yarns spun with backsuction there are fewer number of neps than the packages spun without backsuction. The coefficient of variations of irregularity of backsuctioned packages are smaller for some packages than those spun without backsuctioned while for some backsuctioned packages the CV % are higher than some packages spun without backsuction. The index of irregularity of some backsuctioned packages are lower and some higher than some packages spun without backsuction.

If the results of yarn tensile strength characteristics shown in Table 4.11 are examined, it would be seen that all the yarns

spun with backsuction have higher breaking force, work to rupture, tenacity and lower elongation than those yarns spun without backsuction for both cotton and polyester yarns. The differences in tenacity, work of rupture and breaking force between backsuctioned packages and packages spun without backsuction are greater in polyester yarns than in cotton yarns. This again shows that the spinning system is more promising for polyester yarns than for cotton yarns.

The results of the measured t.p.m. given by the Zweigle apparatus are not actually the magnitude of twist present with the yarns because the apparatus gave higher value of t.p.m. for some yarns spun without backsuction than those spun with backsuction and in some packages the reverse is the case. This research work has proved the Zweigle apparatus unreliable to measure the amount of twists in open-end friction spun yarns. Typical cases in this regard are seen with packages 17/13 and 17/14 where Zweigle apparatus gave 761.6 t.p.m. and 802.8 t.p.m. respectively for the packages whereas optical method gave 982.2 t.p.m. and 803.8 respectively for the packages. The optical method that was used for twist investigation in this work and which was described in Chapter 3 gave the best results, though is a time consuming process.

The tenacity values of the polyester yarns are plotted against their measured t.p.m. values and it was found that the tenacity increases with increases in measured t.p.m. for both backsuctioned packages and the packages spun without backsuction as shown in Figure 4.1. But the effect is higher for backsuctioned packages than for packages spun without backsuction. Tenacity also increases with increase in fibre extent for both backsuctioned packages and packages spun without backsuction, but the effect is higher for backsuctioned packages as shown in

Figure 4.2 for polyester yarns. In cotton yarns tenacity does not increase by increasing measured t.p.m. values but remains more or less the same from a t.p.m. of 925 as shown in figure 4.4. Elongation at break of polyester yarns for both backsuctioned packages and the packages spun without backsuction increases with increase in fibre extent. The effect is higher for backsuctioned packagesas shown in Figure 4.3.

Figure 4.6 shows that increase in diameter increases the fibre extent of backsuctioned polyester yarns marginally, while the opposite is the case for non-backsuctioned yarns. The tenacity of polyester yarns increases steadily as the calculated t.p.m. increases as expected. This is shown in Figure 4.7 for both backsuctioned packages and the packages spun without backsuction. The tenacity of backsuctioned cotton yarns shows increase initially with increases in the amount of neps and finally drops sharply while the tenacity decreases rapidly with increasing neps for the packages spun without backsuction. The reason for that initial increase in tenacity with neps is not understood probably due to the complexity of the open-end friction-spun yarns. This is shown in Figure 4.10.

For both backsuctioned packages and the packages spun without backsuction of polyester yarns, the tenacity decreases with increase in yarn diameter as shown in Figure 4.11. For both cotton and polyester yarns, tenacity decreases with increase in hairs per metre for both backsuctioned packages and the packages spun without backsuction as shown in Figures 4.5 and 4.8. This is probably due to the fact that the fibres that formed hairs on the surface of the yarns are not tenaciously attached to the rest of the fibres and then reduced the number of fibres participating to the overall strength of the yarns. Also, complexity of these yarns structures may be a contributing factor.

The results of this research work revealed that the tenacity of polyester yarns spun with and without backsuction decreases with increase in number of neps along the yarn length. The effect is worse for the yarns spun without backsuction though the tenacity drops sharply for both backsuctioned yarns and the yarns spun without backsuction as shown in Figure 4.9.

CHAPTER 5

5.0. SINGLE FORCE/ELONGATION CURVE CHARACTERISTICS OF OPEN-END FRICTION-SPUN YARNS

5.1. Introduction

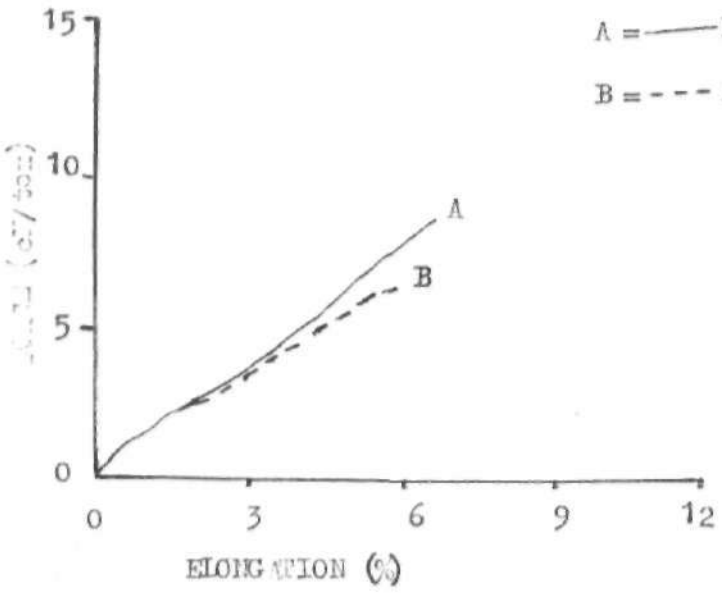
In the analysis of stress/strain curve characteristics of any particular yarn is very important to observe how the yarn will behave in practical use. The stress/strain curve of a yarn gives indication of the performance of that yarn when some loads are applied to the yarn.

5.2. Determination of Single Force/Elongation Curve of Open-End Friction-Spun Yarns

All the twenty packages spun (polyester and cotton) are subjected to stress/strain curve analysis using Textechno Statimat M Test apparatus. On each package, twenty tests werecarried out and the apparatus produced individual curve for each test and super-imposed some curves where necessary and finally gave the force/elongation curve for each package. The histogram for both breaking elongation and breaking force were also produced for each of the packages. It was from the single yarn strength and elongation at break values or data that the curves and the histograms are drawn.

5.2.1. Average Force/Elongation Curves and Histogram Results

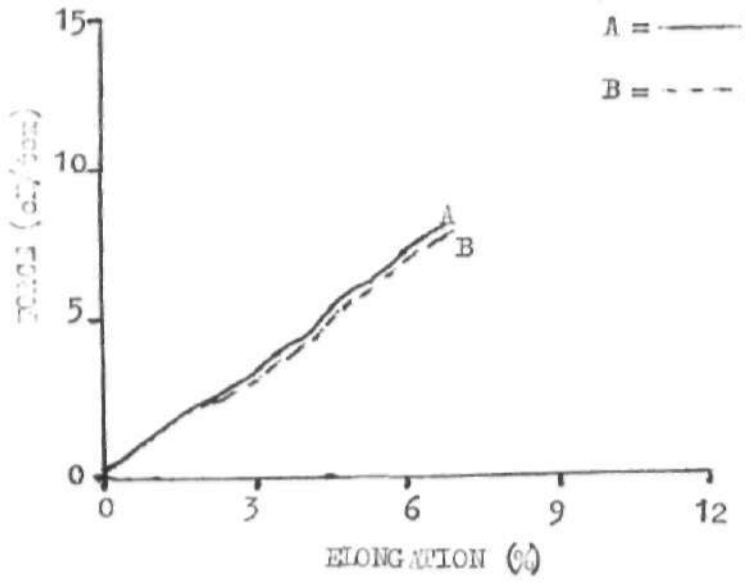
The average force/elongation curves were shown from Figures 5.1 to 5.10. Packages 17/1 to 17/10 are cotton yarns while packages 17/11 to 17/20 are polyester yarns. For both yarns all the odd numbered packages are backsuctioned yarns while all the even numbered packages are the yarns spun without backsuction.



A = ——— Package 17/1 (Backsuctioned)

B = - - - Package 17/2 (Not backsuctioned)

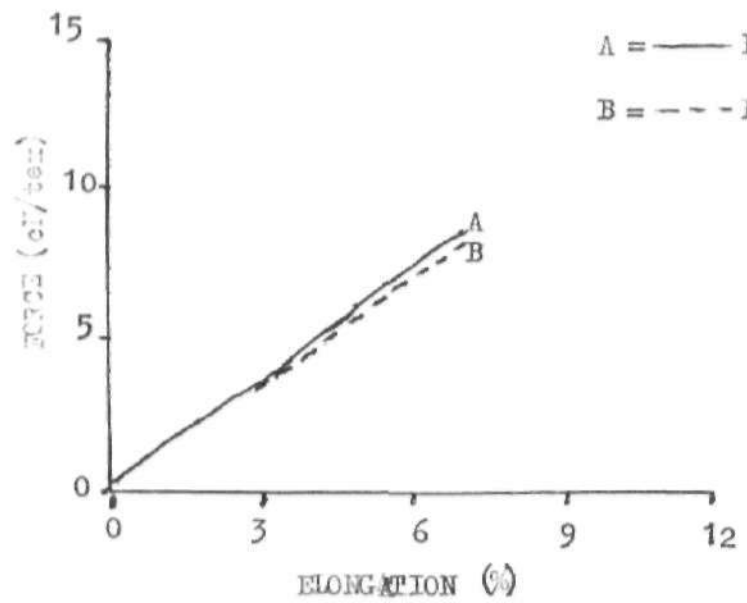
Fig. 5.1. Average Force/Elongation Curve.



A = ——— Package 17/3 (Backsuctioned)

B = - - - Package 17/4 (Not backsuctioned)

Fig. 5.2. Average Force/Elongation Curve



A = ——— Package 17/5 (Backsuctioned)

B = - - - Package 17/6 (Not backsuctioned)

Fig. 5.3. Average Force/Elongation Curve.

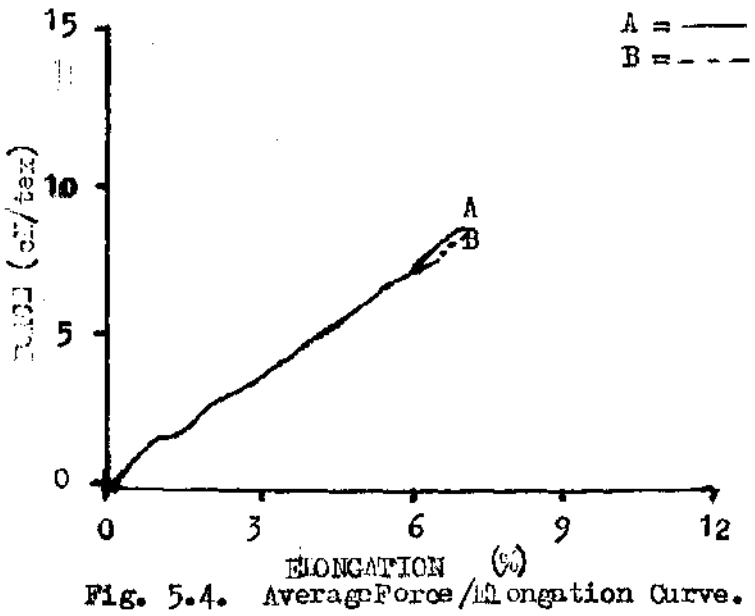


Fig. 5.4. Average Force/Elongation Curve.

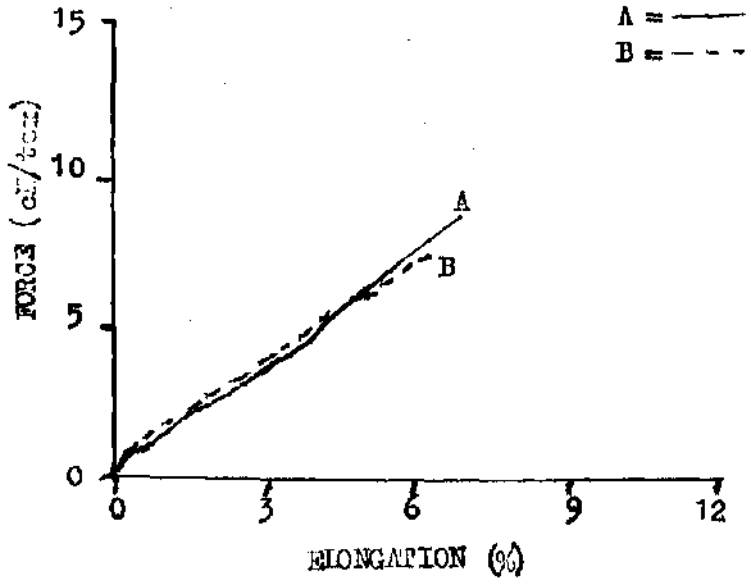


Fig. 5.5. Average Force/Elongation Curve.

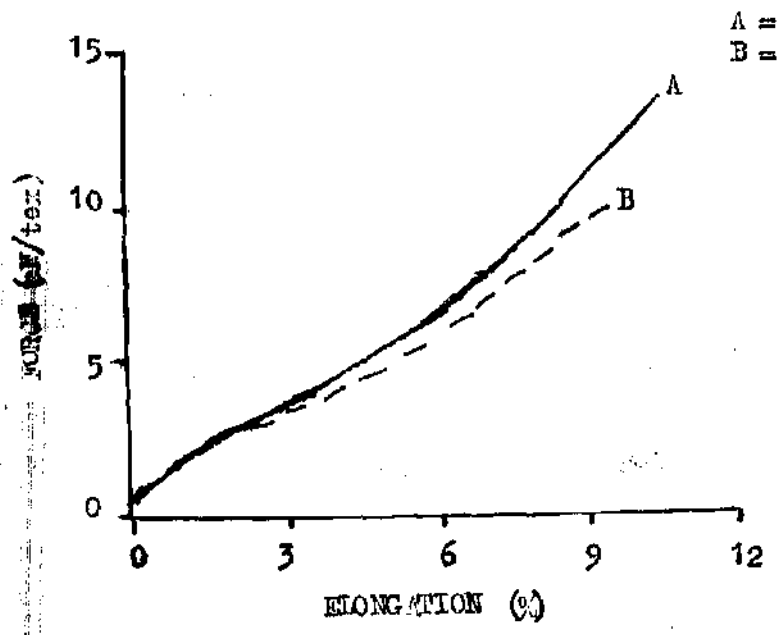


Fig. 5.6. Average Force/Elongation Curve.

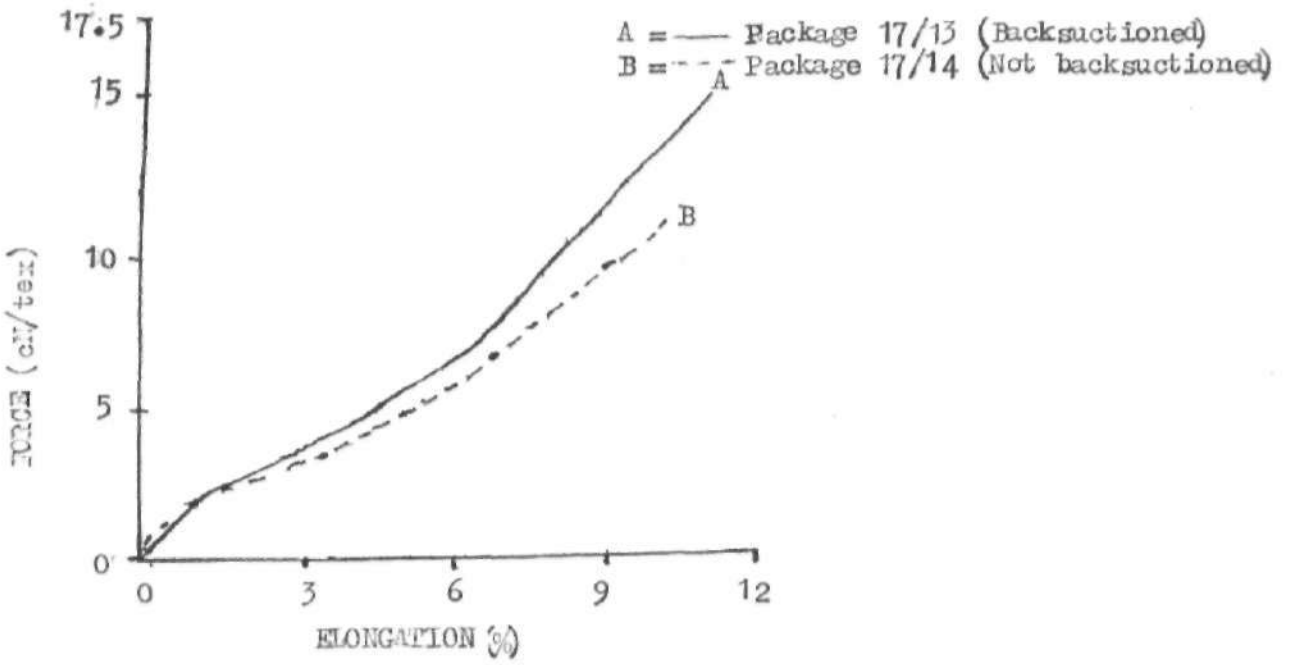


Fig. 5.7. Average Force/Elongation Curve.

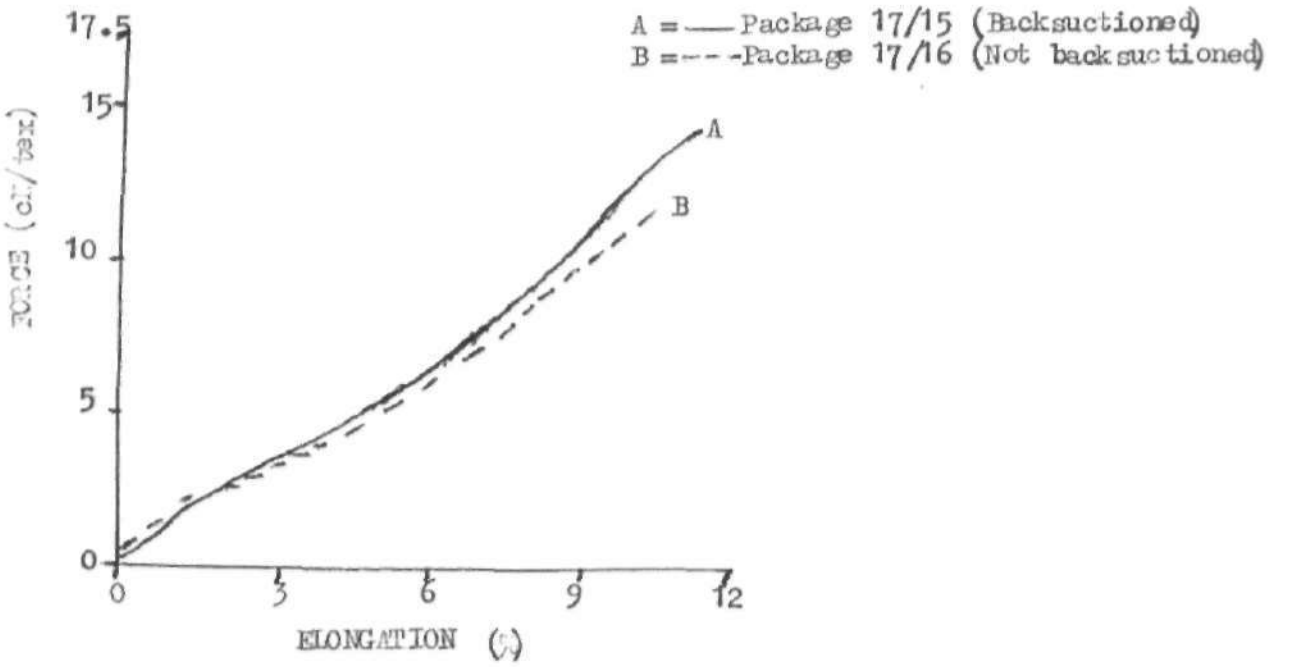


Fig. 5.8. Average Force/Elongation Curve.

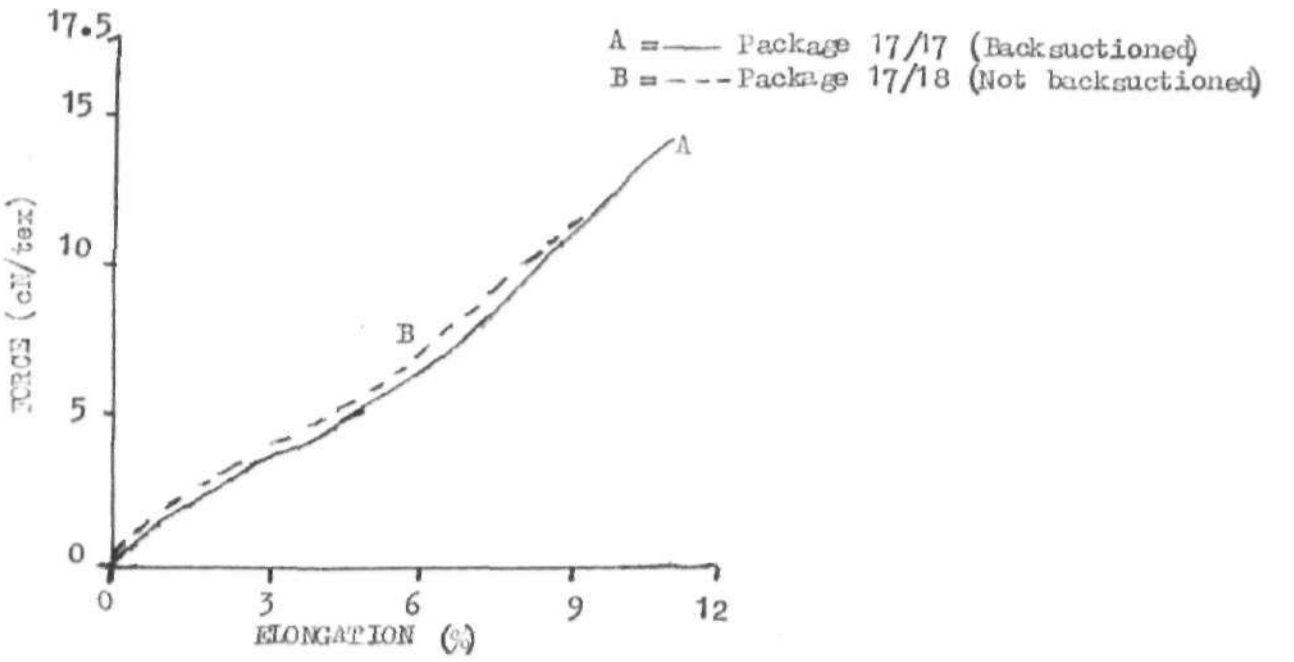


Fig. 5.9. Average Force/Elongation Curve.

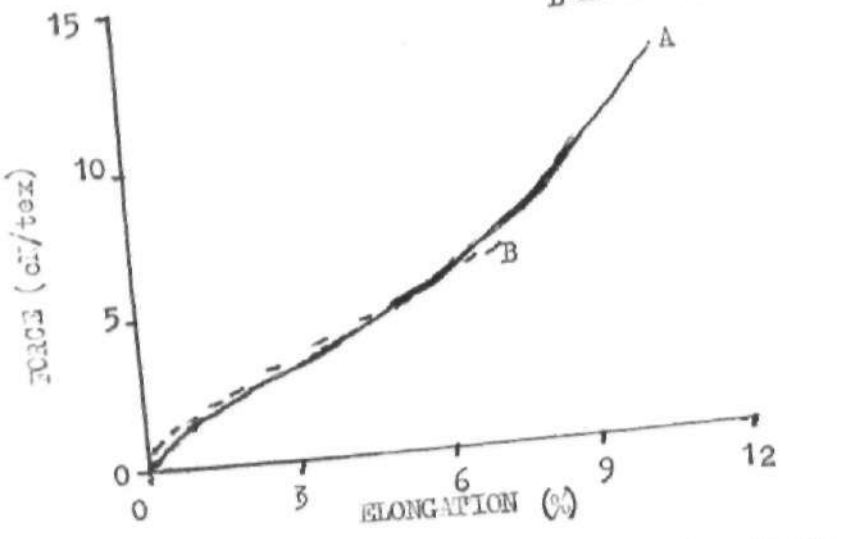


Fig. 5.10. Average Force/Elongation Curve.

5.3. Graphical Representation of Yarn Evenness and Irregularity Results of Open-End Friction-Spun Yarns

The graphs of evenness and irregularity of all the twenty packages spun are given by the Uster Tester 3 used for the analysis of the yarns. Graphical representation of yarn irregularity is very essential to study the variability in spun yarns and to see if the yarn has fulfilled the specification requirements. The test length was 200m. and the mass variation within each test length, the spectrogram of the mass and the variance-length curve of the mass are drawn out and printed by the instrument.

The Uster Spectrograph which is an embodiment of Uster Tester 3 used, is an electromechanical unit which is operated in conjunction with the associated Uster evenness tester; its function is to produce an irregularity spectrum of material tested in the evenness tester. During a test, signals from the evenness tester are fed into the spectrograph and are analysed by a special circuit. The data are stored until, after 5 or 10 minutes testing, a button is pressed and the pen recorder produces the irregularity spectrum or spectrogram of the material. But, in the case of the Uster Tester 3 used everything is done automatically and there is no need for waiting for 5 or 10 minutes after testing before a buttom could be pressed to activate the pen recorder. Inspection of the spectrogram enables the observer to note the presence of wave length and amplitude of periodic variations immediately without the need to analyse charts which are often confusing.

The variance-length curves of the mass as printed by the instrument which could be taken as true representations of irregularity in the yarns are analysed and given in Figures 5.11 through 5.18.

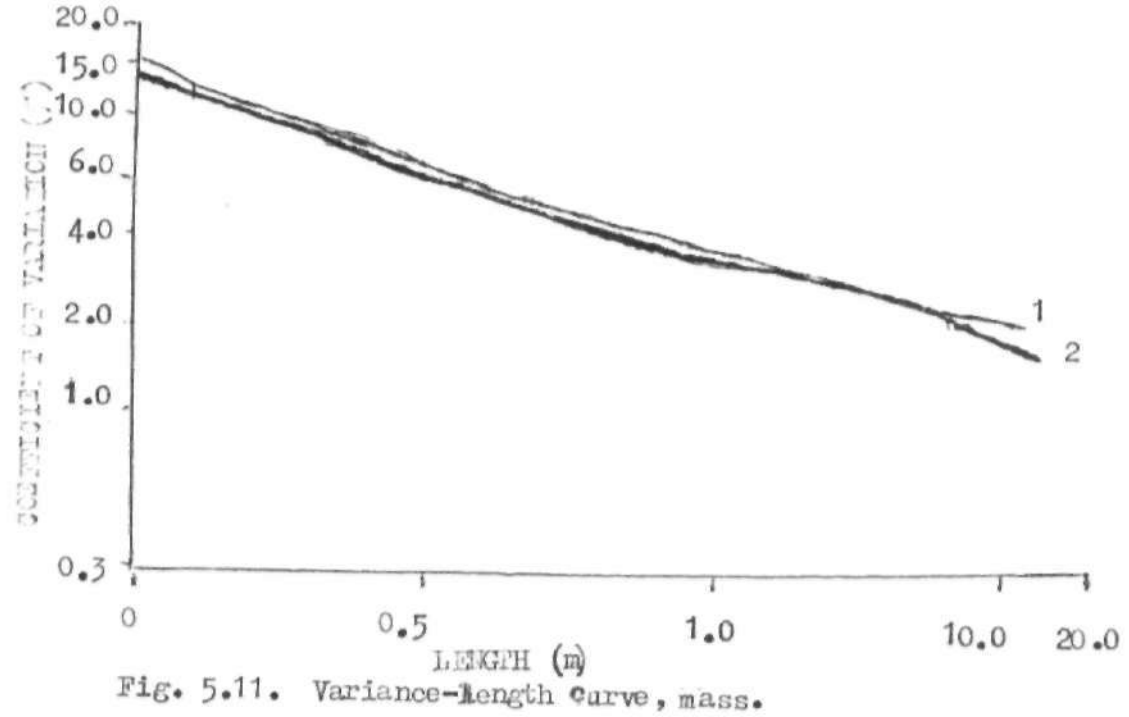


Fig. 5.11. Variance-length curve, mass.

1 = Package 17/1
2 = Package 17/2

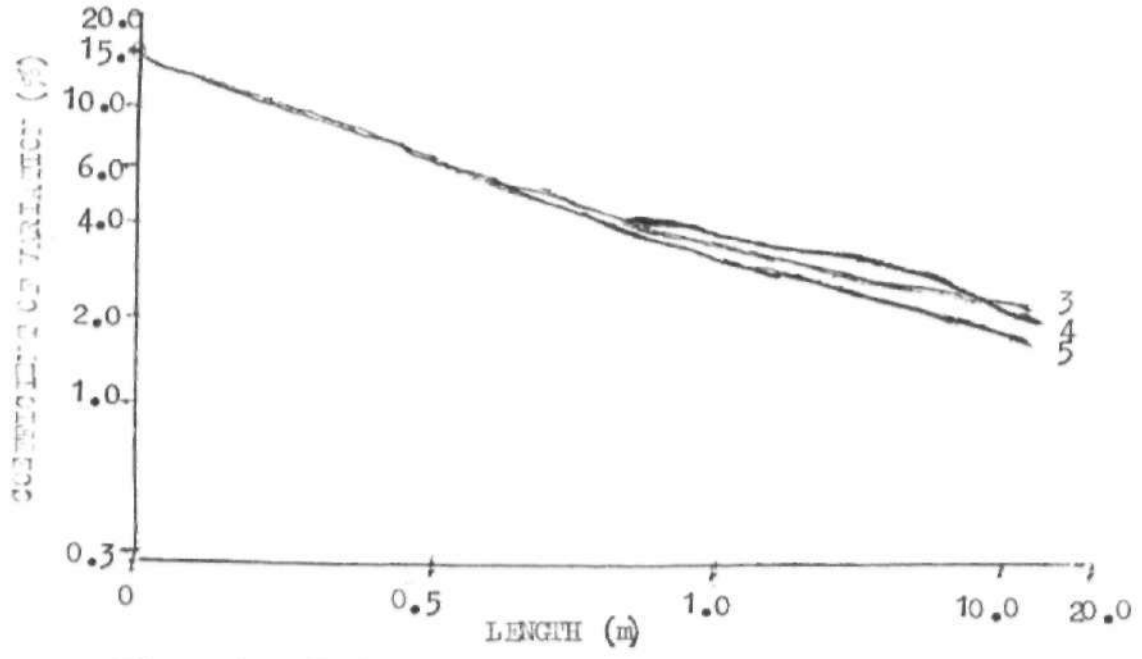


Fig. 5.12. Variance-length curve, mass.

3 = Package 17/3
4 = Package 17/4
5 = Package 17/5

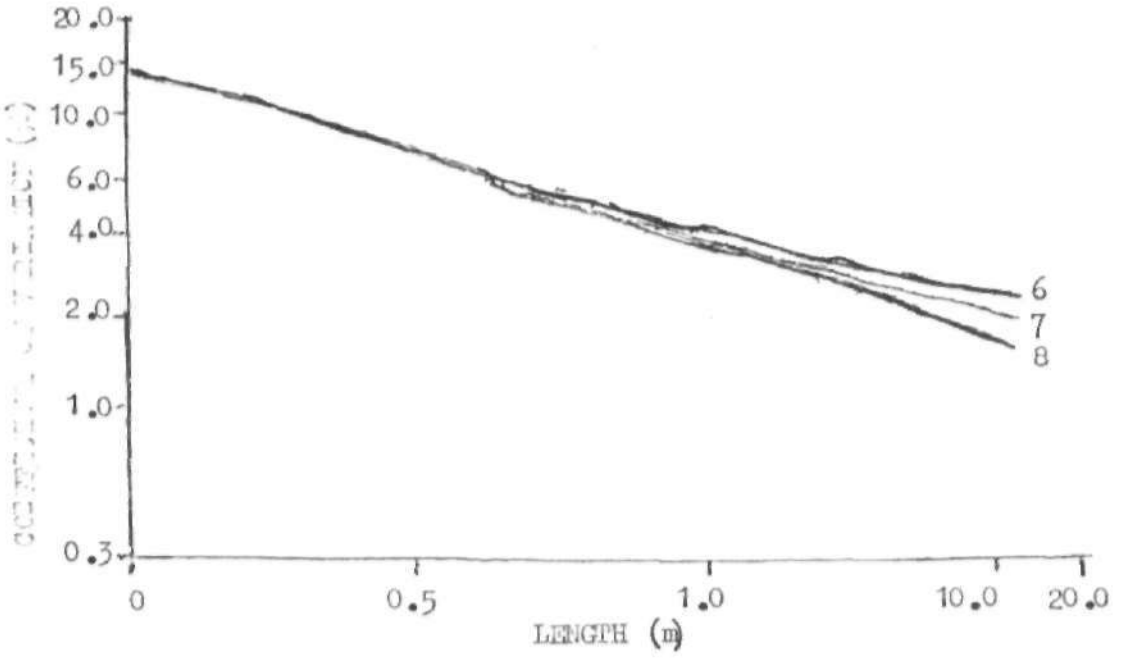


Fig. 5.13. Variance-length curve, mass.

6 = Package 17/6
7 = Package 17/7
8 = Package 17/8

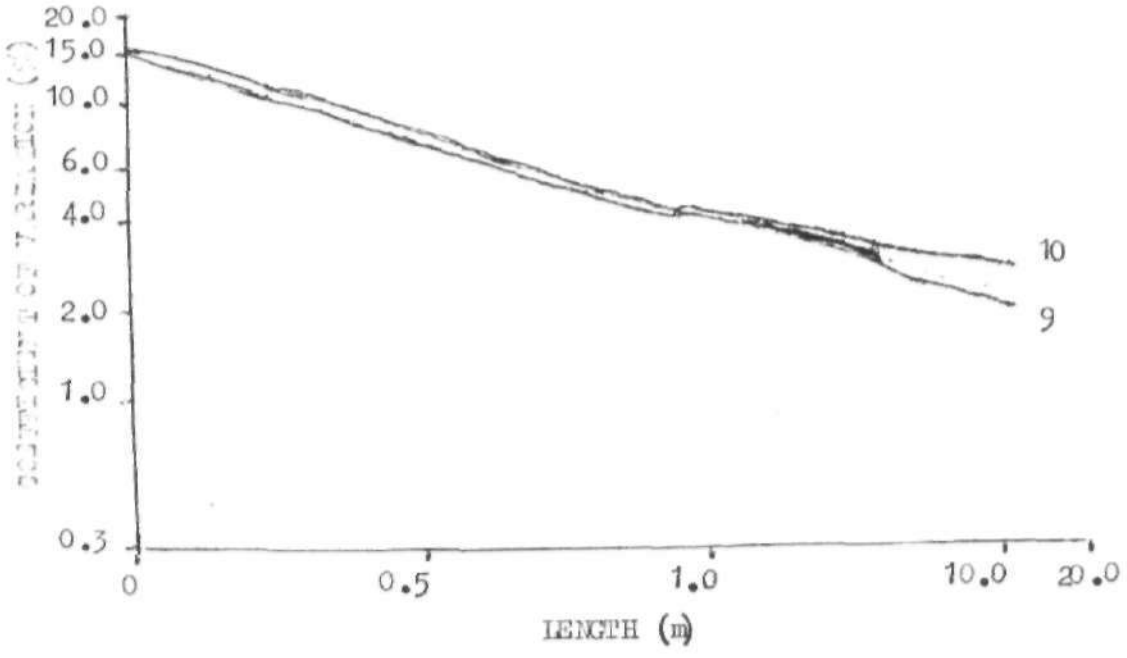


Fig. 5.14. Variance-length curve, mass.

9 = Package 17/9
10 = Package 17/10

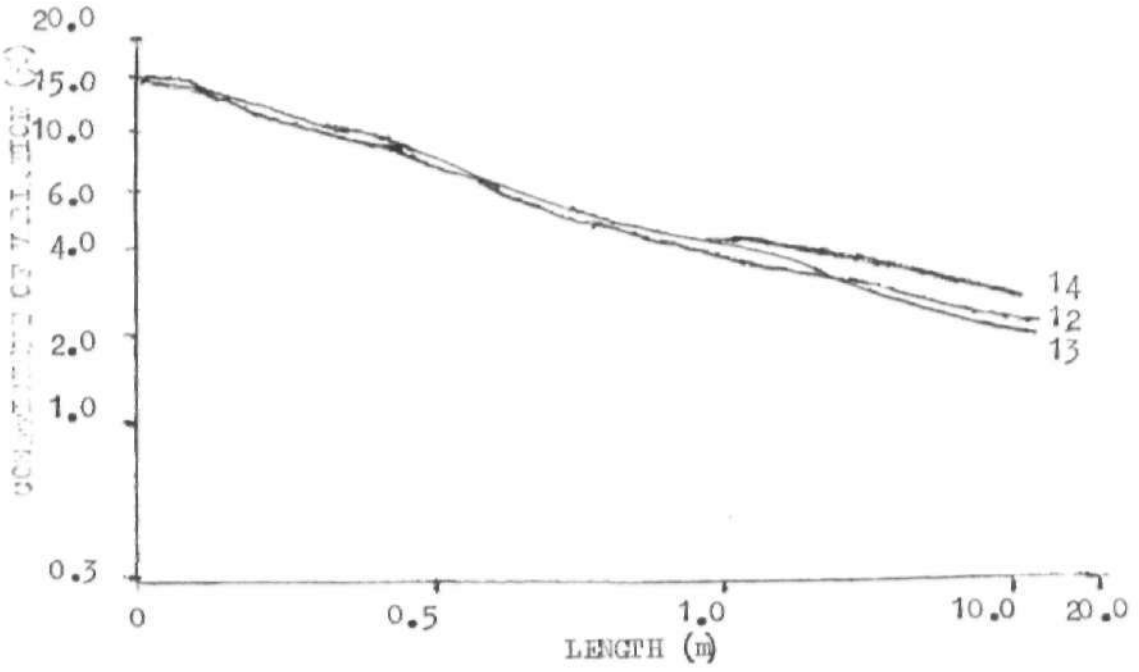


Fig. 5.15. Variance-length curve, mass.

12 = Package 17/12
13 = Package 17/13
14 = Package 17/14

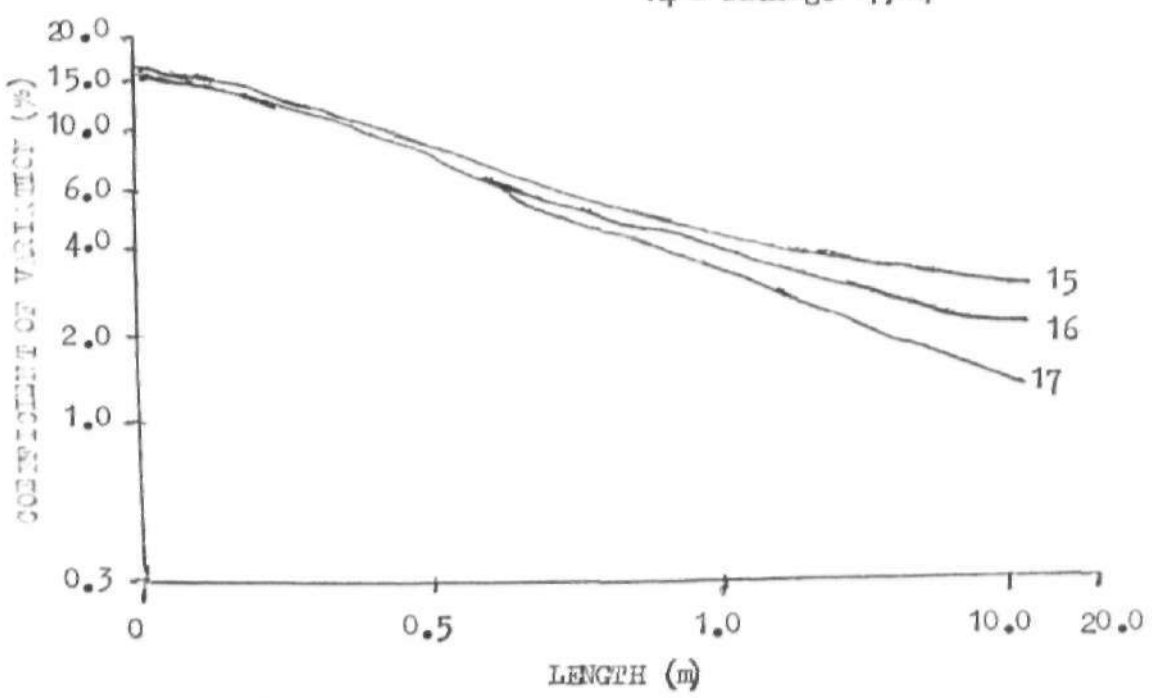


Fig. 5.16. Variance-length curve, mass.

15 = Package 17/15
16 = Package 17/16
17 = Package 17/17

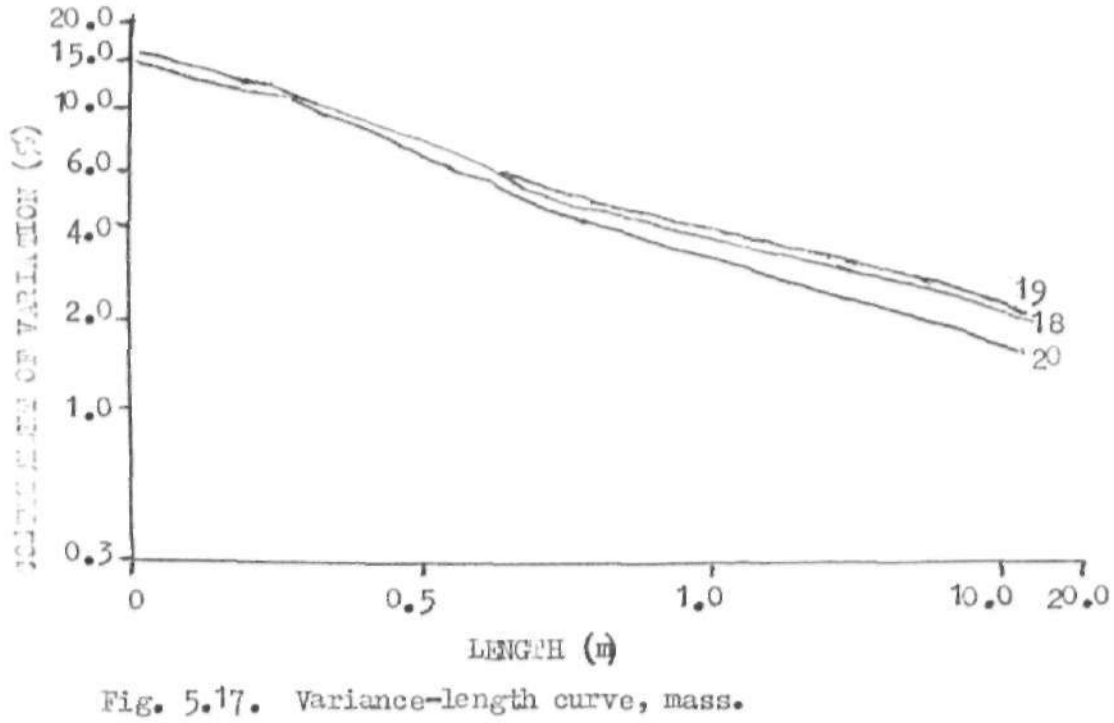


Fig. 5.17. Variance-length curve, mass.

18 = Package 17/18
19 = Package 17/19
20 = Package 17/20

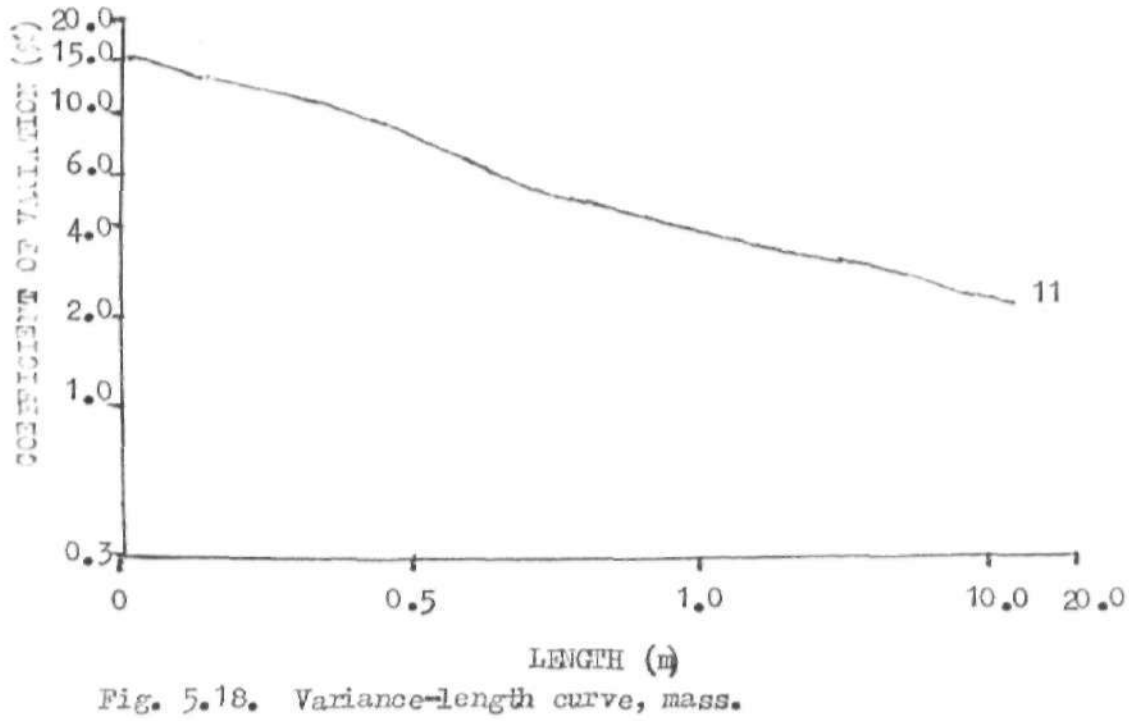


Fig. 5.18. Variance-length curve, mass.

11 = Package 17/11

5.4. Discussion of Results of Average Force/Elongation Curves and Graphical Analysis of Irregularity of Open-End Friction-Spun Yarns

The results for cotton yarns shown from Figures 5.1 through 5.5 showed that open-end friction-spinning system is not adequate yet for the spinning of cotton yarns and the worse results are even given by cotton yarns spun without backsuction. There was a slight improvement in stress/strain behaviour of those cotton yarns spun with backsuction. It is seen from the graphs that the yarns contain a lot of kinks which weaken the yarns. The single force/elongation curves showed the individual stress/strain behaviour of each test length (not shown) while the average force/elongation curves showed the mean stress/strain behaviour of all the test lengths together of a particular package (yarn). The histograms for both the breaking elongation and breaking force also showed or revealed the weakness of these yarns in terms of their mechanical properties.

For the polyester yarns, the stress/strain behaviour performance is better than that of cotton yarns as shown from Figures 5.6 to 5.10. The backsuctioned polyester yarns showed more promising stress/strain behaviour than those packages spun without backsuction. This again has shown one of the effects of backsuction in open-end friction-spinning system. Other things said above under the stress/strain behaviour of cotton yarns also apply to polyester yarns as well.

Now, if the stress/strain characteristics of the yarns spun in pairs are considered fully many things are revealed about the open-end friction-spun yarns. Packages 17/1 and 17/2 are spun under the same spinning pressure but package 17/1 was backsuctioned while package 17/2 was not and this have tremendous effects on both the single force/elongation and the average force/elongation behaviour of the yarns. The stress/strain shape or configuration of package

17/2 contains more kinks and weak places than package 17/1. The histograms of elongation and force of the two packages also revealed the differences in the structures of the yarns with package 17/2 histogram showed more irregular structures than package 17/1. These differences in mass variation of the two packages can be observed also by studying the average force/elongation curves of the yarns shown in Figure 5.1. For package 17/3 and 17/4, the differences in their structural variations can be seen easily from their stress/strain behaviour in Figure 5.2. with package 17/4 that was spun without backsuction contains more weak places and places of low tensions.

For packages 17/5 and 17/6, when the average force/elongation characters of the two yarns are considered, package 17/6 showed more weak places than package 17/5 (backsuctioned package). The differences in the stress/strain behaviours of packages 17/7 and 17/8 are not much as shown in Figure 5.4. Though, package 17/8 that was spun without backsuction contains a little more weak points than package 17/7 (backsuctioned package). The stress/strain behaviours of package 17/9 and 17/10 are shown in Figure 5.5 and it will be seen that package 17/10 behaves so much differently than package 17/9 because of large structural variations existing in package 17/10 than in package 17/9.

The stress/strain configurations and behaviours of polyester open-end friction-spun yarns are virtually different in all aspects from that of cotton open-end friction-spun yarns discussed above. The polyester yarns occupy longer length along the horizontal axis and longer distance along the vertical axis of the stress/strain curves. This means that the polyester yarns have higher breaking elongation and breaking force than the cotton yarns spun. Packages 17/11 and 17/12 were spun under the same spinning pressure but

package 17/11 was backsuctioned while package 17/12 was not, the effect of this can be seen in the stress/strain behaviours of the yarns shown in Figure 5.6 with package 17/12 showed more kink places and places of low tension than package 17/11. Packages 17/13 and 17/14 have their stress/strain behaviours shown in Figure 5.7 with package 17/14 (not backsuctioned) showed more irregular places. The stress/strain behaviour of the remaining polyester yarns investigated i.e. Packages 17/15, 17/16, 17/17, 17/18, 17/19 and 17/20 are shown in Figures 5.8, 5.9 and 5.10 respectively. It will be seen from the stress/strain characters of the yarns that all the backsuctioned packages (odd numbered packages) have lower degree of irregularity than the packages spun without backsuction (even numbered packages).

The Figures 5.11 to 5.14 showed the irregularity variance-length curves of all the cotton yarns spun. From these figures it would be seen that those packages spun without backsuction are more irregular than those packages that are backsuctioned. It has also been shown that those yarns that are not backsuctioned have higher amplitude of irregularity than their counterpart yarns spun with backsuction. Both the spectrogram and the variance-length curves of the yarn mass showed bad results for yarns not backsuctioned than those yarns spun with backsuction. This again demonstrates the importance of backsuction in this type of spinning system.

Figures 5.15 to 5.18 showed the variance-length curves of all the polyester yarns spun. It was observed that the amplitude of the wave length irregularity of the yarns spun without backsuction is higher than their counterpart yarns spun with backsuction. The variability in both cotton and polyester yarns follow the same trend but backsuctioned polyester yarns showed better results than backsuctioned cotton yarns in terms of the amplitude of the wave

length irregularity. Although, on average, the C.V% of cotton yarns in general seems to be lower than that of polyester yarns. From the variance-length curve, it could be seen that some back-suctioned polyester yarns have higher C.V.% than some packages spun without backsuction. This trend was also observed for some cotton yarns as well. The reason for this trend is not known and it may probably be due to the complexity of structure of open-end friction-spun yarns.

The spectrogram analysis of individual yarns shows that irregularity in these yarns are from many sources such as periodic variation, drafting waves and probably variation from random fibre distribution. If the spectrogram of the individual yarn spun in pairs are considered differences in the degree of irregularity exit between the backsuctioned package and the package spun without backsuction. Packages 17/1 and 17/2 are spun under the same spinning pressure but package 17/1 was backsuctioned and 17/2 was not. It was observed that package 17/2 contains more drafting waves than package 17/1. For packages 17/3 and 17/4 spun under the same spinning pressure it was observed that package 17/4 possesses more periodic variations and drafting waves than package 17/3. This can also be seen from their variance-length curves shown in Figure 5.12. For packages 17/5 and 17/6, with package 17/6 which was not backsuctioned shows more irregularity shapes of drafting waves in nature than package 17/5 that was backsuctioned. Package 17/8 contains a lot and more drafting waves than package 17/7 that was backsuctioned. Package 17/10 shows more drafting waves than package 17/9.

Irregularity spectrum or spectrogram of the polyester yarns spun and investigated are better than that of the cotton yarns spun and analysed. For packages 17/11 and 17/12 spun under the same

spinning pressure but with package 17/11 backsuctioned and shows lesser irregularity character than package 17/12. These variations can also be observed in those packages variance-length curves shown in Figures 5.15 and 5.18. The spectrograms of packages 17/13 and 17/14 are similar but package 17/14 seems to contain more drafting waves than package 17/13 spun under the same spinning pressure. Packages 17/15 and 17/16 are spun under the same spinning pressure but package 17/15 was backsuctioned and shows lesser drafting waves and periodic variations than package 17/16. Package 17/18 contains more drafting waves hence more structural changes than package 17/17. Packages 17/19 and 17/20 are spun under the same spinning pressure but package 17/19 was backsuctioned and it has got lower drafting waves and periodic irregularity than package 17/20. The variance-length curves of the two packages are similar as shown in Fig. 5.17.

CHAPTER 6

SOME OF THE STRUCTURE AND PROPERTIES OF OPEN-END ROTOR-SPUN YARNS

CHAPTER 6

6.0. Introduction

This is the second part of these research works and is on some of the structure and properties of open-end rotor-spun yarns. For this investigation 4-Head BD 200 Rotor Spinning Machine was used to spin the yarns analysed. The rotor spinner is based upon four standard heads of the renowned Czechoslovakian BD 200 rotor spinner and developed by Bradford University Research Limited. Operating from a normal domestic-type, single-phase socket, the machine has a total consumption of approximately 1KW.; 250V 50Hz operation is normal. The range of opening roller and rotor speeds, yarn delivery rates and twist and draft are essentially those of the full-scale BD200 machine. The first three of these are instantly adjustable over the full range via continuously variable controls whilst the draft is adjusted by means of small change-wheels.

Sliver in the range of 2200 tex to 4000 tex is drawn from four cans of maximum size of 914.40mm x 304.80mm. Full-sized yarn packages having weights up to approximately 1.5kg are produced at production rates up to 100m/min., or more dependent upon rotor speed and yarn twist. The rotor speed can be set at any value upto 40,000 r.p.m. plus and the opening roller speed up to at least 10,000 r.p.m. While the standard change-wheels enable drafts between 36 and 225 to be employed on the spinner. Modified versions of the machine are now in the market, in corporating such features as digital display of twist or techniques for the determination of minimum twist at which spinning is possible.

6.1. Initial Experimentation

This research work is meant to determine the finnest counts that can be obtained from the 4-Head BD200 rotor spinning machine in our spinning laboratory of the Department of Textile Science and Technology, Ahmadu Bello University, Zaria. Some of the structural built-up of the counts and the yarns properties are studied to forecast the capability and versatility of the rotor spinner. To accomplish this, fifteen different counts are spun from the finest count of 22.0 tex to the highest count of 32.2 tex. The finest count that could be obtained from the machine is 22.0 tex and it could be obtained with difficulties. The yarns are spun under different spinning conditions that can only just allow the counts to be spun.

6.2. Materials for Spinning

The materials used include the 4-Head BD200 rotor spinning machine itself, carded cotton sliver (5.062 Ktex) and a sliver can from where the sliver is withdrawn into the machine. Detailed information about the cotton sliver and cotton fibres used will be seen under Appendix II 100% cotton fibre was used for this studies.

6.2.1. Spinning the Yarn Packages

Each count was spun using 5.062 Ktex sliver from only one sliver can by using appropriate change-wheels in place and adjust the intermediate idler wheel. This is followed by selecting an appropriate rotor speed and an appropriate level of twist expressed in turns/metre. The twist level was divided into the rotor speed to obtain the necessary yarn delivery speed. An appropriate opening roller speed was then set. On this machine, all the three speed controls can be re-set irrespective of whether the machine is running or stationary. At this stage the spinner was switched on and during

the course of spinning re-adjustments to the draft and yarn withdrawal speed were carried out to get the correct yarn count and twist.

Spinning commenced by square the end of the sliver and fed by hand into the plastic condenser or sliver guide at the front of the spinning unit. The yarn detector was moved to the right so that the warning light could be extinguished and the feed roller rotates. To assist the initial feeding of the sliver, the plastic condenser was pressed against its spring loading, and the sliver to be drawn in was allowed for a few seconds and the yarn detector was then released. When a sliver breaks or when the spinning has to take-up finally, the spinning unit was opened by releasing the catch at the top left-hand side of the machine and allowing the unit to open its first position. When the rotor has come to rest, the ring of fibres from the rotor was cleaned using a small paint brush. This can only be done when the rotor has come to rest fully if not the action will damage the rotor. At this stage, the spinning unit was closed and a length of yarn of about 50cm was taken and inserted the end of the yarn into the yarn withdrawal tube at the top of the spinning unit and passed it below the yarn detector wire. The yarn was then allowed to be drawn into the spinning unit by the suction which exists. When the yarn tension was felt to rise indicating that the yarn is being rotated within the rotor, quickly but smoothly allowed a few further centimetres of yarn to enter the rotor. At the same time, the yarn detector was allowed to move over thus starting the feed, and then immediately and smoothly withdraw the yarn at the same time inserting it into the withdrawal rollers and then collecting the yarn in hands. Whilst keeping some tensions on the yarn so as to prevent it lapping around the rollers, the yarn

was then dropped on to the spool, previously placed in the take-up arms and brought into contact with the winding drum. It was then ensured that the yarn started to wind on to the spool and did not lap around the drum.

An alternative technique which could be used also is to use a spool which has had a few metres of yarn wound onto it. This yarn will then be inserted in the winding arm and will be followed by the use of the technique of piecing after an end breakage. The counts spun include 22.0 tex, 23.3tex, 24.5 tex, 24.8 tex, 25.1 tex, 25.5 tex, 27.2 tex, 28.6 tex, 28.7 tex, 29.7 tex, 30.6 tex, 31.5 tex, 31.3 tex, 31.9 tex and 32.2 tex under different spinning conditions shown in Table 6.1. These counts are designed in this experiment in such a way that the preceeding counts are the possible counts next in fineness that can be obtained just before the preceeding counts. For example, since 22.0 tex is the most fineness count that can be spun from the machine while the next fine count possible is 23.3 tex and that is why 23.3 tex followed 22.0 tex and the whole counts spun follow that route.

6.2.2. Spinning Conditions Applied

The different spinning conditions used to spin the counts are shown in Table 6.1 below. In some cases the spinning conditions are similar for some counts while for some counts the spinning conditions are totally different.

Packages	Count (Tex)	Rotor Speed (R.P.M.)	Opening Roller Speed (R.P.M.)	Spinning Speed (M/Min.)	Draft	Upper & Lower Draft Change Wheel	Twist (Turns/ Metre)
1	22.0	22,000	7,000	23.4	228.7	40, 100	941.0
2	23.3	22,000	7,000	24.5	217.3	40, 95	898.0
3	24.5	22,000	7,000	24.3	205.8	40, 90	904.0
4	24.8	22,000	7,000	24.1	203.3	45, 100	913.0
5	25.1	22,000	7,000	23.5	194.4	40, 85	936.0
6	25.5	22,000	7,000	24.7	185.5	45, 95	890.0
7	27.2	25,000	7,000	27.8	182.9	45, 90	899.0
8	28.6	30,000	7,000	34.4	173.9	50, 95	872.0
9	28.7	25,000	6,000	32.5	172.8	45, 85	769.2
10	29.7	25,000	6,000	33.0	164.7	50, 90	757.6
11	30.6	25,000	6,000	33.5	162.6	45, 80	746.0
12	31.3	25,000	6,000	35.0	155.6	55, 85	714.0
13	31.5	25,000	6,000	34.5	158.1	55, 95	725.0
14	31.9	25,000	6,000	35.0	152.5	45, 75	700.0
15	32.2	25,000	6,000	36.0	149.8	55, 90	690.0

Table 6.1. Spinning conditions applied.

6.2.3. The Process of Piecing-Up After an End Breakage

As mentioned above, the most possible fine counts that can be obtained from the rotor spinner are the packages spun. Due to this a lot of end breakages are experienced during the actual spinning operations. In fact, piecing up is effected by opening the spinning unit followed by bringing the rotor to rest and cleaned it with a small brush. At this stage the unit will then be closed and the yarn package raised so that it remains raised and the end of the yarn found and pulled some yarn from the package. It will be found that in many cases the end has a long tapered form (a "taper break"), followed by breaking some 20cms or more from the end. Sufficient yarn was then pulled from the package so that it can be held in the left-hand, well to the left of its normal position, and inserted into the yarn tube as before. The left-hand was then moved to the right and allowed the yarn to be drawn into the rotor as before so that the yarn path is more or less direct from withdrawal tube to package just as the tension rises. As this happened, the yarn package was pull down onto the drum firmly with the right-hand so that withdrawal can start immediately. It frequently happens that spinning restarts without the yarn passing between the withdrawal rollers and it can be guided into position later. The traverse guide should pick up the yarn of its own accord.

In rotor spinning, there are two reasons for unsuccessful attempt at piecing. Firstly, either the yarn was not allowed to be drawn far enough in or it was withdrawn too soon so that the proper contact was never established with the fibre band in the rotor groove. Secondly the yarn was fed in too far or not withdrawn quickly enough, causing over-twisting until the yarn breaks, leaving a short length inside the rotor. In this situation, it is advisable to always open and reclean the rotor after any unsuccessful attempt.

6.3. Testing Techniques

The basic properties of the yarns spun are tested and evaluated to assess the acceptability of the counts.

6.3.1. Measurement of Single Yarn Strength and Extension at Break

To determine these, one type of tensile strength tester was used. This is Goodbrand Tester which works on the principle of pendulum lever.

The Goodbrand Tester which works on the principle of pendulum lever is the type of machine mostly found in textile mills today all over the world and in Nigeria in particular. Here, the tested specimen was clamped in the upper and lower jaws of the instrument. The upper jaw was attached to a steel tape which runs over a small pulley of a certain radius. The lower jaw was given a constant rate of traverse in a downward direction by a screw mechanism. The small pulley was pulled round and in doing so swings the pendulum from the vertical when the machine was started. In doing so, the tested yarn specimen began to extend until when it finally broke and the pendulum stopped moving. The breaking load and breaking extension of the samples are then read off from the dial of the instrument graduated in ounces and inches respectively. These old unit systems were then converted to metric unit systems using conversion factors. The test length for each sample was 500mm and the whole testing procedures are carried out according to the instructions given by the manufacturer of the instrument. Five tests wurecarried out for each sample to conserve yarns while the average mean results and the coefficient of variations of the results quoted for both breaking load and breaking extension. The results are shown in Tables 6.2 and 6.3.

6.3.2. Single Yarn Strength Results

Packages	Count (tex)	Mean Breaking Load (g)	Tenacity (gf/tex)	Coefficient of Variation Breaking Load (%)
1	22.0	85.1	3.87	0
2	23.3	106.7	4.58	11.5
3	24.5	118.0	4.82	12.9
4	24.8	110.7	4.46	3.0
5	25.1	119.2	4.75	15.1
6	25.5	119.2	4.67	19.9
7	27.2	155.5	5.72	15.2
8	28.6	136.2	4.76	13.6
9	28.7	116.9	4.03	12.2
10	29.7	153.2	5.16	16.6
11	30.6	147.6	4.82	13.9
12	31.3	147.6	4.72	16.1
13	31.5	153.2	4.86	16.6
14	31.9	149.8	4.69	22.8
15	32.2	146.4	4.55	29.3

Table 6.2. Single yarn strength results.

Packages	Count (tex)	Mean Breaking Extension (%)	Coefficient of Variation Breaking Extension (%)
1	22.0	5.45	6.37
2	23.3	4.69	7.40
3	24.5	5.24	5.46
4	24.8	5.08	0
5	25.1	4.57	42.12
6	25.5	5.46	6.39
7	27.2	6.09	5.70
8	28.6	5.50	5.71
9	28.7	4.95	5.73
10	29.7	5.71	7.86
11	30.6	5.00	10.97
12	31.3	5.71	8.83
13	31.5	5.71	13.60
14	31.9	5.52	10.00
15	32.2	5.33	6.52

Table 6.3. Single yarn strength results continued.

6.3.3. The Lea Strength Testing

In many sections of the textile industry, especially the older sections of wool, cotton, and flax, the lea or hank test on a pendulum lever tester is the standard method of measuring the strength of the yarn.

Testing Procedure: To carry out the test, a lea of yarn (120 yds), with its starting and finishing ends knotted, was placed over the hooks of a lea tester. The lea tester used was called KIM. As the lower hook descended, a load was imposed on the loops of yarn constituting the hank. At some point one of the threads broke, yet the hank remains intact and capable of sustaining further loading. During this process, the hank suffered a succession of thread breaks and ultimately became unable to sustain any further increase in load. When this happened the pendulum stopped moving and the maximum load was indicated on the dial, the lea strength of that particular hank. At this point one has to note that only a fraction of the total number of threads between the hooks have actually broken. The end-point of the tests is determined by the rate at which the hank unravels as the threads break. At the first few breaks, the rate of unravelling was small. When the rate of unravelling equals the rate of separation of the hooks, the top hook has to be stopped and the maximum load must have been reached. Two samples are tested for each package. The results are shown in Table 6.4.

6.3.4. Lea Strength Results

Packages	Mean Count (C.C.)	Mean Strength (lb)	Mean Weight (Grains)	Mean Count Strength Product (C.C.lb)
1	26.84	35.00	34.00	939.40
2	25.34	36.00	35.00	912.24
3	24.10	38.00	38.00	915.80
4	23.81	42.00	38.50	1000.02
5	23.52	43.00	40.00	1011.36
6	23.15	41.00	40.00	949.15
7	21.70	48.00	42.50	1041.60
8	20.64	47.00	43.00	970.08
9	20.57	46.50	44.25	956.51
10	19.88	50.00	48.00	994.00
11	19.29	48.00	45.00	925.92
12	18.86	48.00	51.50	905.28
13	18.74	51.00	51.00	955.74
14	18.51	51.50	51.00	953.27
15	18.34	52.00	51.50	953.68

Table 6.4. Lea strength results.

6.4. Yarn Evenness and Irregularity Measurement

The evenness and irregularity of the fifteen packages spun were evaluated using Uster evenness tester. The tests are carried out according to the instructions given by the manufacturer of the instrument. The instrument cannot evaluate the number of thick, thin and neps in the yarn properly and therefore gave the U% of the yarns only.

Testing particulars are as follows:

Test length: 25m

Material speed: 25m/min.

Diagram speed: 25m/min.

Evaluation time: 1 minute.

Two samples are tested for each package.

The results obtained are shown in Table 6.5.

6.4.1. Yarn Evenness and Irregularity Results.

Packages	Count (tex)	Moisture Content (%)	Mean U % (%)
1	22.0	5.5	12.72
2	23.3	5.5	12.73
3	24.5	6.0	13.24
4	24.8	5.5	13.22
5	25.1	5.5	12.56
6	25.5	6.0	12.73
7	27.2	6.0	11.43
8	28.6	6.0	12.40
9	28.7	6.0	13.40
10	29.7	6.0	77.86
11	30.6	6.0	10.88
12	31.3	6.0	13.67
13	31.5	6.0	12.56
14	31.9	6.0	12.30
15	32.2	5.5	11.44

Table 6.5. Yarn evenness and irregularity results.

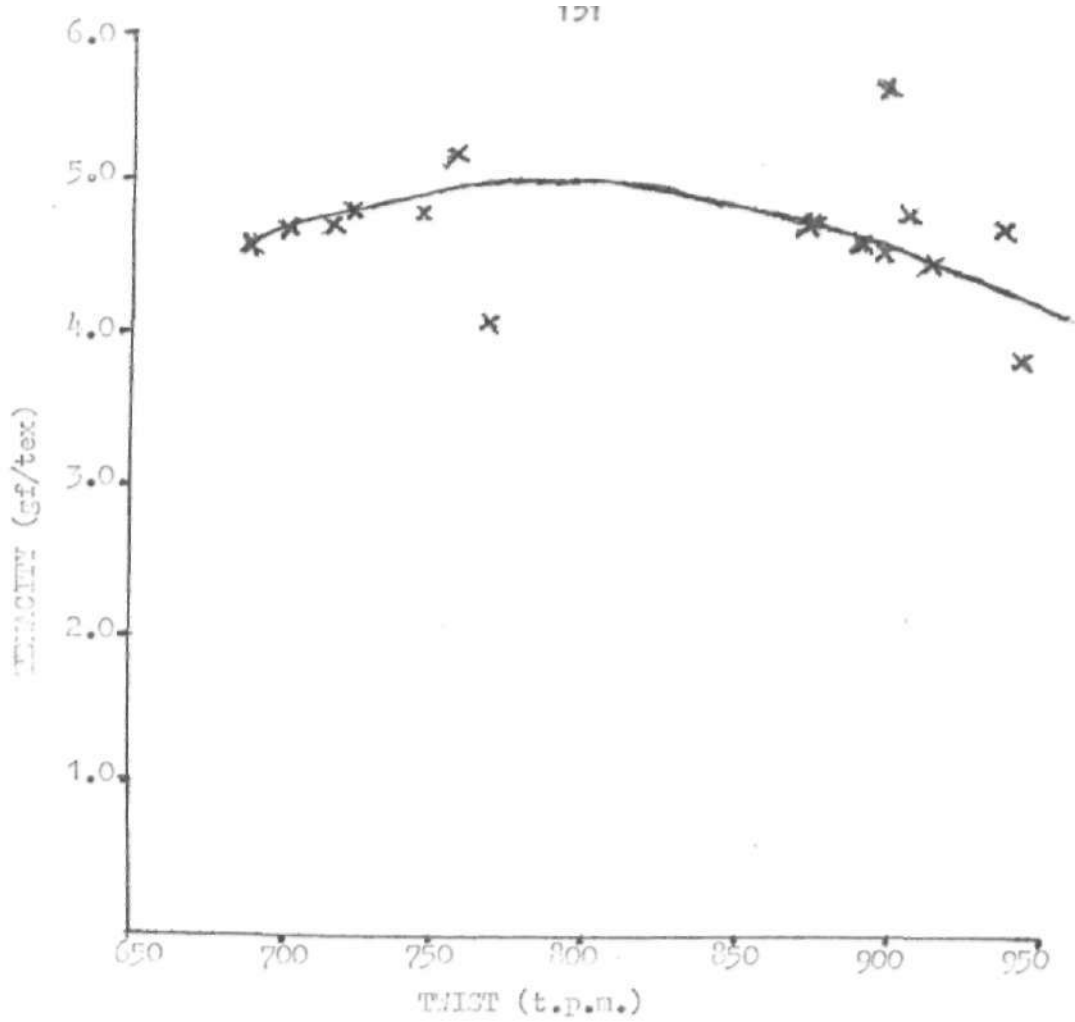


Fig. 6.1 : Tenacity/twist characteristics

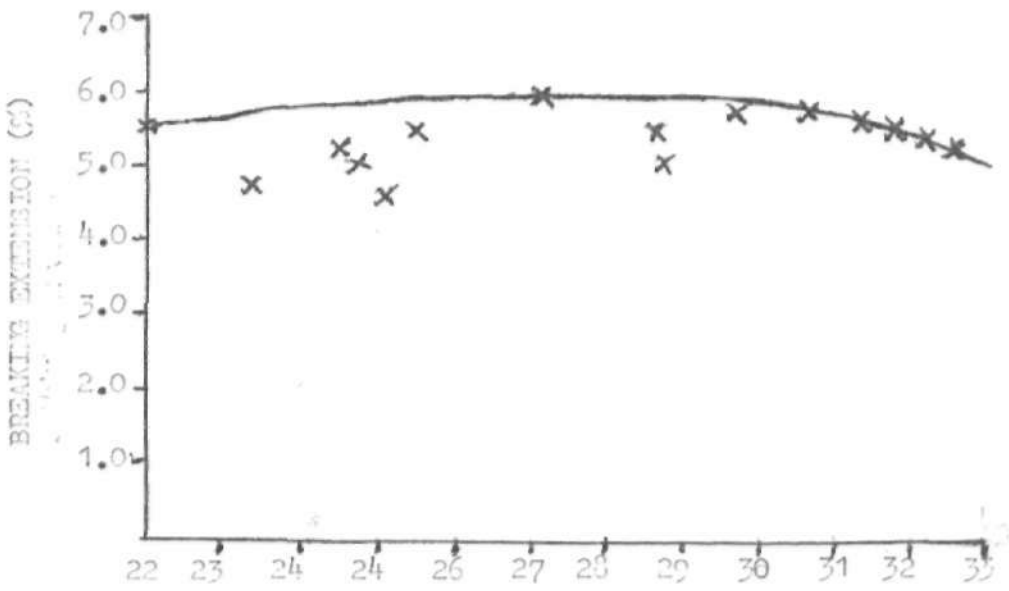


Fig. 6.2 : Breaking extension/count relationships

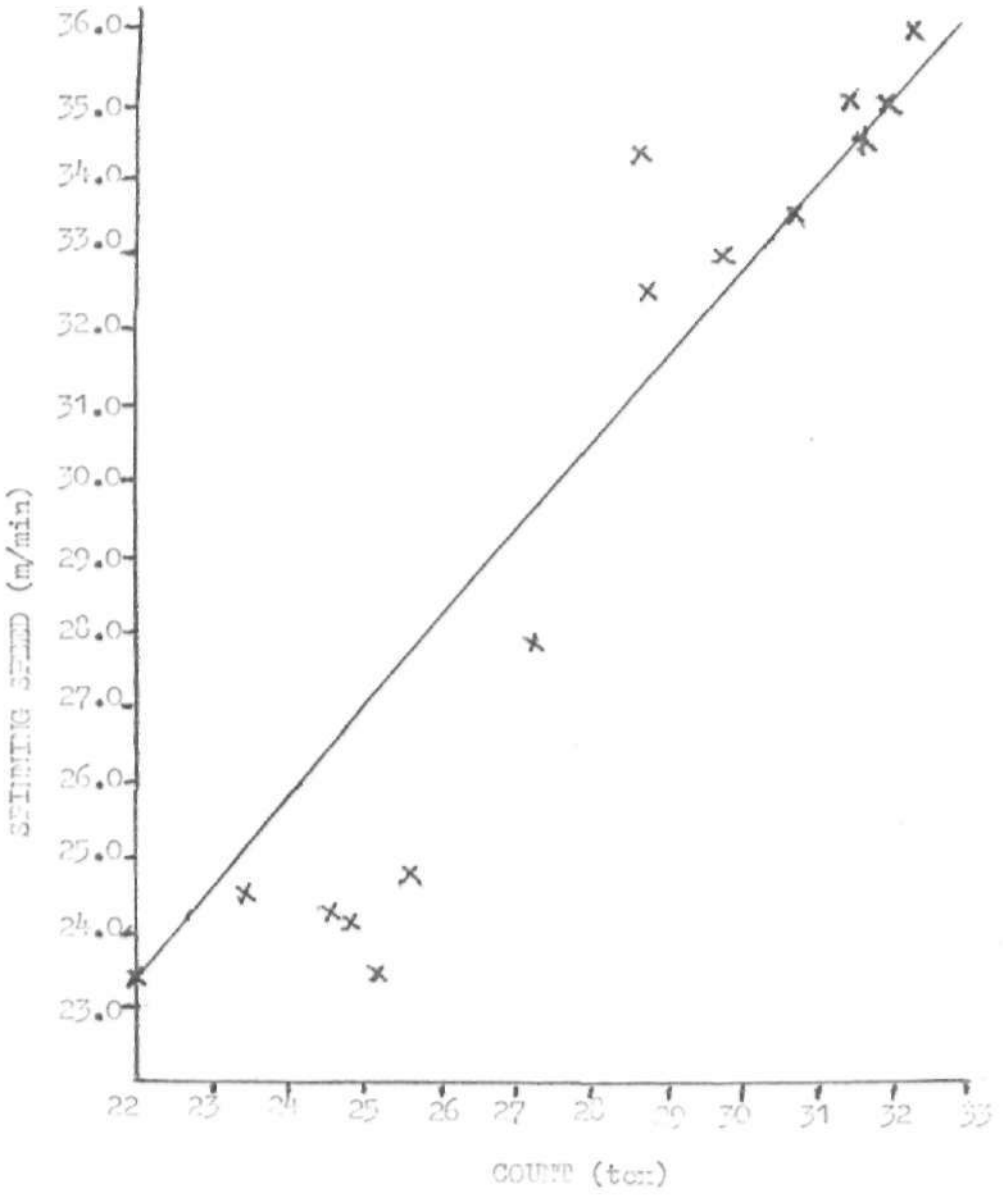


Fig. 6.3 : Spinning speed/count relationships

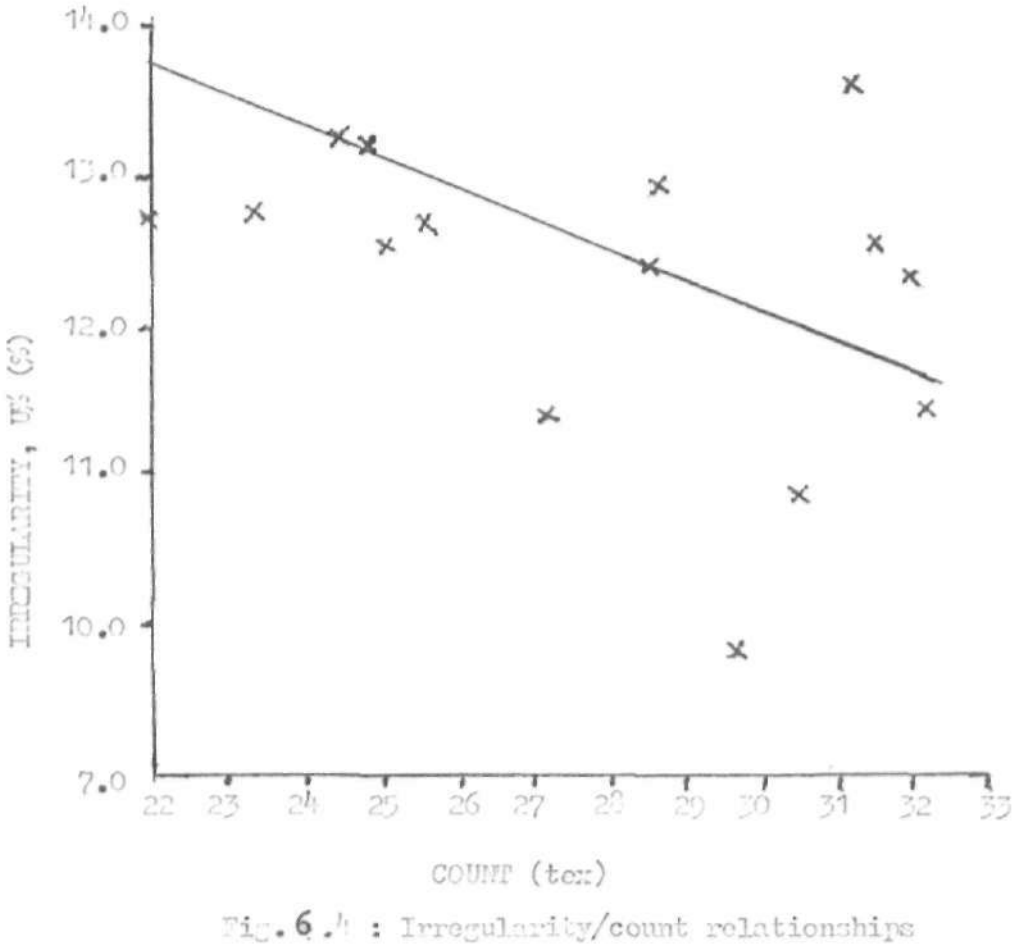


Fig. 6.4 : Irregularity/count relationships

6.5. Discussions of Results of Properties of Open-End Rotor-Spun Yarns

It has to be remembered that the fifteen packages or counts spun and evaluated are used to see how versatile the OE rotor spinning-machine in this spinning laboratory of the Department of Textile Science and Technology, Ahmadu Bello University, Zaria is and may not necessarily be employed for commercial production. If we compared packages 1 and 2 with counts 22.0tex and 23.3tex respectively in terms of strength it was found that package 1 with 22tex has a lower strength of 3.87gf/tex than package 2 of 23.3tex which has got a strength of 4.58gf/tex. It is expected that the finer yarn which has 22tex supposed to have higher tenacity than the 23.3tex. The reason for this may be due to structural variations of the two packages. In the case of packages 3 and 4 which have 24.5tex and 24.8tex respectively showed a different trend in their tenacity with the finer count gave the higher tenacity of 4.82gf/tex than the coarser count which gave 4.46gf/tex as expected. The same trends are shown by packages 5 and 6 whereby package 5 (the finer count) showed higher tenacity in the order of 4.75gf/tex than package 6 which has got 4.67gf/tex.

If the strength of all the packages are considered together it was found that the most finenest count (22tex) has the least strength. This may probably be due to many end breaks encountered during spinning operations of the package. The results also showed that not only the count that will determine the strength of rotor-spun yarns but also the structural properties e.g. twist of the yarns. Since many finer counts are found to have lower tenacity than their coarser counts counterparts. The highest tenacity of 5.72 gf/tex was given by package 7 with a count of 27.2tex. The tenacity of the yarns are not far from each other, suggesting

good spinning operation and this can be observed from Table 6.2.

The highest coefficient of variation (29.3%) of the yarns breaking loads was given by package 15 which has the highest tex value (32.2tex). While the least coefficient of variation (0%) of the yarns breaking loads was given by the most finer count, package 1. Packages 1 the most finest count (22tex) which showed the least tenacity demonstrated high breaking extension in the order of 5.45% when compared to other yarns. The package 7 which gave the highest tenacity also showed the highest breaking extension of 6.09%. This shows that strength magnitude is not a factor that determines the magnitude of yarn breaking extension in OE rotor-spun yarns as usually thought of. Also, if we compare the packages in pairs e.g. packages 1 and 2, 3 and 4 etc. as shown in Table 6.3 it will be found that nearly all the finer packages have higher breaking extension with the least breaking extension given by package 2. The highest coefficient of variation (%) of the packages breaking extension was given by package 5 in the order of 42.12% (too much high), while the least was given by package 4 in the order of zero percent.

In the case of lea strength of the yarns, if, instead of two hooks that are used the yarn had been looped round 80 pairs of frictionless pulleys, then as soon as the first thread broke the whole hank would unravel. In the normal test, therefore, it is the presence of frictional forces between thread and thread, and thread and hook, which restricts the unravelling of the hank. Hence, the indicated strength is a combination of a complex composite specimen test plus a measure of the frictional properties of yarn in hank form and yarn/hook friction. The inter-yarn friction is increased by any twist put into the hank as it is placed over the hooks or if the threads are bunched on the hooks. Personal errors are thus liable to creep in.

Another thing here, is that unequal tensions in the threads of the hank will result in a lowered strength because the tighter threads will break too soon. The frictional forces present in the lea test reduce the sensitivity of the test to the detection of weak places in the yarn. A yarn which is generally weak will, of course, produce a low lea strength, but the presence of an abnormally weak place in one of the threads may escape detection.

It must be understood that there is no simple proportional relation between the hank breaking load and the single-thread strength, a limiting factor in the usefulness of the lea test. Lea strength testing is mainly used for routine testing of yarns and commonly used in industries. The lea test is adequate for routine job because it is sensitive enough to detect a change in the yarn quality. Investigation of the cause of the change may then be made with the aid of more refined testing instruments and techniques.

From the results of these investigations, the package 15 showed the highest lea breaking load whereas package 7 showed the highest breaking load in the single-thread strength testing method. It is surprising that the most coarse yarn gave the highest breaking load in lea strength testing. For most of the counts spun the higher the cotton count the higher the lea breaking load. The yarn package 15 which gave the highest lea breaking load also showed the highest weight (51.5 grains) of all the yarns. All these are shown in Table 6.4. The highest count-strength product was given by package 7 in the order of 1041.60 C.C.lb and it was the same package which gave the highest breaking load in single-yarn strength testing. This means that the two testing techniques showed the actual strength behaviour of the packages. The lea strength was also found to be increasing with the lea

weight as shown in Table 6.4. When assessing the character of cotton yarns, the product of the count and the lea strength is a useful measure of the merit of the yarn from a strength point of view. The count-strength product, C.S.P., enables comparisons to be made between yarns of similar, but not necessarily identical, count.

The concept of the C.S.P. is used in spinning technology to derive an index by which the spinning quality of a cotton yarn is judged or the spinning efficiency of a particular system. In these investigations package 7 showed the highest quality index due to its high count-strength product. But, as the count of a yarn becomes finer the C.S.P. falls, therefore at a certain count the C.S.P. will be equal to the standard. (Standard C.S.P. values have been chosen, 2000 for carded and 2,250 for combed yarns). This count is then termed the highest standard count.

The results of irregularity and evenness measurement of the fifteen packages spun showed that the irregularity magnitudes or values of the yarns are very similar to each other with the exception of package ten which has 7.86% U%. The international accepted U% value (maximum) for cotton open-end spun yarns is 12%. The results showed generally that the higher the tex count of the yarns the lower the irregularity and hence the U%. The highest U% value of 13.67 was given by the package 12 with a count of 31.3tex while the smallest U% value of 7.86% was given by package 10 which has got a count of 29.7tex. The Uster irregularity tester used cannot evaluate the number of neps, thin and thick places in the yarns properly and that is why their magnitudes or values are not quoted.

The values of moisture content of the packages are more or less the same with a highest value of 6.0% given by the majority of the packages while the smallest value of 5.5% was given by the

remaining yarns. The yarn packages are not conditioned for evenness and irregularity testing since we wanted to see how the yarns will behave in practice in terms of appearance and also to see if the yarns meet the international quality of evenness and irregularity of cotton open-end spun yarns.

The Figure 6.1 showed that the yarn tenacity increases with the possible t.p.m. in the structure of the yarns and later falls out. Relationship between breaking extension and yarn counts shown in Figure 6.2 is difficult to interpret since some fine counts showed higher breaking extension than some coarse counts and vice-versa. Spinning speed increases with increase in yarn tex as shown in Figure 6.3. Generally speaking, the U% decreases as the yarn tex increases except only one package which showed the highest U% at a yarn count of 31.3tex as shown in Figure 6.4.

CHAPTER 7

CONCLUSIONS

7.1. Twist in Cotton Open-End Friction-Spun Yarns

From these investigations it can be concluded that in open-end friction spinning of cotton yarns backsuction should be employed to improve the efficiency of twist running along the length of yarns and to increase the amount of t.p.m. in a given yarn. The magnitude of spinning pressure to be used to give high t.p.m. must be investigated through pilot spinning operations because this research has shown that the amount of spinning pressure will probably affect twist multiplier. Generally, t.p.m. in cotton open-end friction-spun yarns varies so much that even on the same package large differences are found. This condition is a contributing factor to the low performance of cotton open-end friction-spun yarns. Some sections in these yarns are hard-twisted while other sections are soft-twisted leading to problems in spinning operations and this affects the overall texture of the yarns.

Presence of wrapper fibres on the surface of cotton open-end friction-spun yarns contributes to the large twist variations along the length of the yarns. Since wrapper fibres can obstruct the easy and adequate flowing of twists during twist insertion so the places of high wrapper fibres concentration will experience lower t.p.m. while areas of low wrapper fibres concentration will experience higher t.p.m. The nature and formation of these wrapper fibres on the surface of open-end friction-spun yarns must be fully understood in other to find means of minimising their effects on twist insertion.

7.1.1. Diameter of Cotton Open-End Friction-Spun Yarns

Backsuction reduces the diameter of cotton open-end friction-spun yarns and makes the yarn finer, though the presence of wrapper fibres on the surface of the yarns will influence this. Large differences exist in yarn diameter between the backsuctioned packages and the packages spun without backsuction. Yarn diameters of 0.2333mm, 0.1933mm and 0.1666mm are more in the structure of backsuctioned cotton yarns investigated. But, in the case of cotton package spun without backsuction a diameter of 0.2000mm was more in the yarn structure. The yarn twist angles and diameter of cotton open-end friction-spun yarns are very irregular in the yarn structures.

7.1.2. Twist in Polyester Open-End Friction-Spun Yarns

Backsuction has tremendous effects on the twist characteristics of polyester open-end friction-spun yarns. The application of backsuction increases the amount of twist in polyester yarns and the magnitude of spinning pressure employed during spinning will also have effects. The twist characteristics of open-end friction-spun yarns determine the physical behaviour of the yarns. These twists vary so much in both backsuctioned and non-backsuctioned packages but the variations are more for non-backsuctioned packages. Backsuctioned polyester open-end friction-spun yarns have higher twist angle than their counterparts spun without backsuction. Backsuction reduces the diameter of the polyester yarns and makes the yarn finer. Both the twist angles and diameters of polyester open-end friction-spun yarns are too much irregular even on the same package and worst for non-backsuctioned packages. The differences in the twist angles and diameters between backsuctioned and non-backsuctioned polyester yarns are lower than the difference in t.p.m. between backsuctioned and non-backsuctioned packages. This is due to the complexity of the structure of open-end friction-

spun yarns and to the complexity of yarn formation mechanics. The magnitude of the spinning pressure used will have bearings on both backsuctioned and non-backsuctioned packages in terms of their t.p.m. but the effect is more on backsuctioned packages.

Open-end friction-spun yarns of extremely high twist levels are produced with backsuction combined with high spinning pressure e.g. 1320.8mm head of water. But, yarns spun under a spinning pressure in excess of 1320.8mm may not show increase in twist level along the length of the yarns. Packages 17/13 and 17/15 showed this. Since the mechanics of twist insertion in open-end friction-spinning system is very complicated, therefore other factors other than higher spinning pressure may be responsible for this. Other contributing factors are not known yet, hence more work is required in these area to understand the mechanics of twist insertion in this new spinning system. From this investigation, we may say that there is probably a maximum spinning pressure at which polyester open-end friction-spun yarns are hard-twisted, above this pressure the t.p.m. would be reducing hence changes in the structure and properties of the yarns. Backsuction and the magnitude of spinning pressure used during spinning operations would have significant effects on the structure of polyester open-end friction-spun yarns.

7.1.3. Diameter of Polyester Open-End Friction-Spun Yarns

Spinning pressure at higher value than 1219.2mm head of water reduces the diameter of polyester yarns and makes the yarns thinner and finner. This can be observed in Table 3.1 with packages 17/12, 17/14 and 17/16 that were spun without backsuction but under different spinning pressures. Backsuction further increases this effect of higher spinning pressure on the diameter or fineness of polyester open-end friction-spun yarns.

The diameters of polyester open-end friction-spun yarns are not consistent at all even on the same package.
The trends of diameter variations of polyester yarns are worst for packages spun without backsuction hence more structural variations of non-backsuctioned packages. The yarn twist angles and diameters showed extremely poor correlation as shown in Figures 3.2 to 3.4 which again showed the magnitude of internal variations existing in polyester open-end friction-spun yarns.

This degree of correlation between the natural tan. of twist angles and yarn diameters is poor for the yarn spun without backsuction. Probably the presence of wrapper fibres on the surface of these yarns may be a contributing factor.

7.1.4. Fibre Utilisation and Fibre Orientation in Cotton Open-End Friction-Spun Yarns

Fibre utilisation and fibre orientation in cotton open-end friction spun yarns are poor and hence the spinning system is poor for the production of cotton yarns. The fibre orientation is worst for the cotton yarns spun without backsuctioned which means that the spinning system is not adequate yet for the spinning of cotton yarns. Fibre utilisation in cotton open-end friction-spinning system is too low but improved a bit with backsuction though still low for commercial utilisation. The straightened fibres in backsuctioned cotton open-end friction-spun yarns are more than those in cotton yarns that are spun without backsuction. Many entangled fibres are found in these yarns and the condition is worst for the packages spun without backsuction.

7.1.5. Fibre Utilisation and Fibre Orientation in Polyester Open-End Friction-Spun Yarns

The conditions of fibre orientation and fibre utilisation in polyester open-end friction-spun yarns are better than those found in cotton open-end friction-spun yarns. Backsuction improves fibre utilisation and fibre orientation in polyester O-E friction-spun yarns. Fibre extent is higher in polyester yarns spun with backsuction than those spun without backsuction. The magnitude of spinning pressure used may probably be a contributing factor to the increase in fibre extent combined with backsuction.

7.1.6. Yarn Hairiness in Open-End Friction-Spun Yarns

This investigation has shown that backsuction in open-end friction-spinning system reduces yarn hairiness and makes the yarn a bit smoother than the yarns spun without backsuction. This is applied to both cotton and polyester yarns investigated with the exception of only two polyester packages which showed the reverse case.

7.1.7. Irregularity in Open-End Friction-Spun Yarns

It may be concluded from the results of these investigations that backsuction reduces the number of thick and thin places present in both cotton and polyester open-end friction spun yarns. The effect is more for polyester yarns spun with backsuction and the magnitude of spinning pressure has no effect on this. Also, there are fewer number of neps on packages spun with backsuction than those spun without backsuction. We may probably say that backsuction minimises the occurence of neps on the surface of open-end friction-spun yarns. The coefficient of variations of irregularity of both the backsuctioned packages and the packages spun without backsuction are difficult to say which one is better than the other. Since higher C.V. percentage values are found for some non-backsuctioned packages than their counterparts spun with backsuction and for some

backsuctioned packages higher C.V. percentage values are observed than for their counterparts spun without backsuction. The study of spectrograms of open-end friction-spun yarns have shown that irregularity in these yarns are from many sources e.g. periodic variation, drafting waves etc. But, generally the yarn evenness is very good. The index of irregularity of both the backsuctioned and non-backsuctioned packages followed similar trends mentioned under the C.V. percentage values written above. The amplitude of wave length irregularity of backsuctioned cotton yarns is lower than those cotton yarns spun without backsuction. Backsuction reduces the amplitude of wave length irregularity of polyester yarns also.

7.1.8. Tensile Properties of Open-End Friction-Spun Yarns

Backsuction improves the tensile characteristics of both cotton and polyester yarns and therefore increases the breaking force, work of rupture and tenacity of the yarns. The effect is higher for polyester yarns. From these findings, it may be said that open-end friction-spinning system is more promising for the production of polyester spun yarns than for cotton yarns. This investigation has proved the Zweigle apparatus unreliable to measure the absolute twists in open-end friction-spun yarns. The optical method gave the true twists in open-end friction-spun yarns. though, it is a time consuming method. The higher the measured t.p.m. the higher the tenacity of the polyester yarns for both the backsuctioned and non-backsuctioned packages. But, the effect is higher for backsuctioned polyester packages. Tenacity also increases with increase in fibre extent for both backsuctioned and non-backsuctioned polyester packages but the effect is higher for backsuctioned packages. In cotton open-end friction-spun yarns tenacity did not increase by increasing measured t.p.m. values but remains more or less the same from a t.p.m. of 925.0.

For polyester yarns, elongation at break increases by increasing the fibre extent and the effect is more pronounce with backsuctioned packages.

Increase in yarn diameter increases the fibre extent marginally for backsuctioned polyester yarns, while the opposite is the case for non-backsuctioned yarns. The tenacity of both backsuctioned and non-backsuctioned polyester yarns increases steadily as the calculated t.p.m. increases as expected. The stress/strain behaviour of cotton O-E friction-spun yarns is not encouraging at all since the yarns contain a lot of kinks along their lengths and these kinks weaken the yarns. The stress/strain behaviours performance of polyester yarns is better than that of cotton yarns. The polyester yarns spun without backsuction contain more kinks and weak places as shown in their stress/strain behaviour graphs than the packages spun with backsuction.

7.1.9. Technological Considerations

Hardly any other spinning system known today offers the wealth of possible variations affecting yarn structure and yarn data as does open-end friction-spinning. Higher spinning speeds are physically and technologically possible compared with conventional systems. If we compare the yarns spun by various routes, it is apparent that O-E friction-spinning is not to be over looked among the innovatory processes. However, every new technical development needs time to mature and this is especially true in view of the complexity of this new spinning system. The evidently impending diversification of spinning technologies is of great consequence for builders and buyers of textile machines alike. When discussing the requirements to be met by the spun product and the respective technological capabilities, special attention must be given to the

high machine development costs and the economics of the new spinning systems for the spinner. In this new spinning systems the fibres are disoriented and the fibre extent is extremely low, these lead to low strength of the yarns. Means of partly straightening portions, at least, of the fibres are required to obtain the tenacity needed for full commercial success. If only the tenacity can be improved, the good handle and evenness of the yarn would provide an acceptable products.

The open-end friction-spinning system will certainly need several more years of development before large-scale industrial adoption becomes possible, so that O-E rotor spinning will retain its undisputed place beside ring-spinning.

7.2. Conclusions on the Structure and Properties of Open-End Rotor-Spun Yarns

It may now be concluded that the practical finnest count that can be obtained or spun from the BD200 rotor spinning machine installed in the spinning laboratory of the Department of Textile Science and Technology, Ahmadu Bello University, Zaria is 22.0tex. This is achieved with many difficulties since it was not easy to spin. From a count of about 25.1tex, the spinning process became easier and no more ends breakage. Spinning from a count of 30.6tex became more easy and smooth while spinning at a count of 32.2tex has no problem. These research works have established the versatility of the spinning machine in terms of the counts that can be spun from it. The amount of twists in the structures of the yarns varies with count, spinning speed and draft and the behaviour of the yarns will depend on these parameters or factors. This is shown in Table 6.1.

The tenacity of some finer counts are lower than some coarser counts probably due to many ends breakage accompanied the production or spinning of finer counts. Due to the presence of these weak

points in the structures of finer counts or yarns, reduction in strength will follow. The highest tenacity was given by package 7 with a count of 27.2tex in the order of 5.72gf/tex. The tenacity of all the fifteen packages are not far from each other suggesting good spinning procedures. The most coarse count or yarn (32.2tex) showed the highest coefficient of variation of the breaking load while the finenest count (22.0tex) showed the least coefficient of variation of the breaking load. The same package 7 which gave the highest tenacity also showed the highest breaking extension in the other of 6.09%. Nearly, all the fine counts or packages with the exception of package 2 showed high breaking extension.

Package 15 showed the highest lea breaking load (52.0lbs) whereas package 7 gave the highest count-strength product in the order of 1041.60C.C. lb and it was the same package which gave the highest tenacity. The package 7 with a count of 27.2tex gave the highest quality index of all the yarns. It may be said that the higher the tex counts of the yarns the lower the irregularity and hence the U% of the yarns. The highest U% (13.67%) was given by a count of 31.3tex and the value is not far from the international standard which is 12%. The tenacity of the yarns increases with t.p.m. to certain point and later on falls down, suggesting that there is probably a maximum t.p.m. above which the strength of the yarns will be reducing. The relationships between breaking extension and yarn counts shown are very complex to interpret but it may probably be said that the finer the yarn count the higher the breaking extension of the yarns.

Increase in yarn tex increases the spinning speed possible and reduces the yarn irregularity in terms of U%.

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APPENDICES

APPENDIX I

Material Details

The details of all the materials used for this research work are given below.

Cotton Fibres

The count of the sliver used for cotton yarn spinning was 3 gm/m, while the number of draw frames was four and the draft was 150. The micronaire value of the material (cotton fineness) was 4.3 with a staple length of 32mm.

Polyester Fibres

The count of the polyester fibre used was 1.3 decitex, while the count of the sliver used was 2.8 gm/m with a total number of draw frame of 4. The number of draft used was 140. The polyester fibres are also in staple form with a staple length of 32mm also.

Tracer Fibre Particulars

The tracer fibre has a count of 1.5 demier and a staple length of 32mm obtained from France. The fibre was made from viscose rayon and dyed black. The amount of tracer fibre used in the bulk material has to be small and it was extremely small in the order of 1%. This amount was adequate for twist investigation to be carried out properly.

APPENDIX II

Rotor and fibre particulars for OE rotor spinning are shown below:

Rotor inner diameter	5.55cm
Rotor outer diameter	7.21cm
Feed roller diameter	2.5cm
Delivery roller diameter	5.33cm
Fibre length	2.700cm
Fibre micronaire reading (finness)	3.82cm
Sliver count	5.12Ktex

APPENDIX III

The straight line equations and linear correlation coefficients (r) for both cotton and polyester packages analysed for twist investigations were shown below.

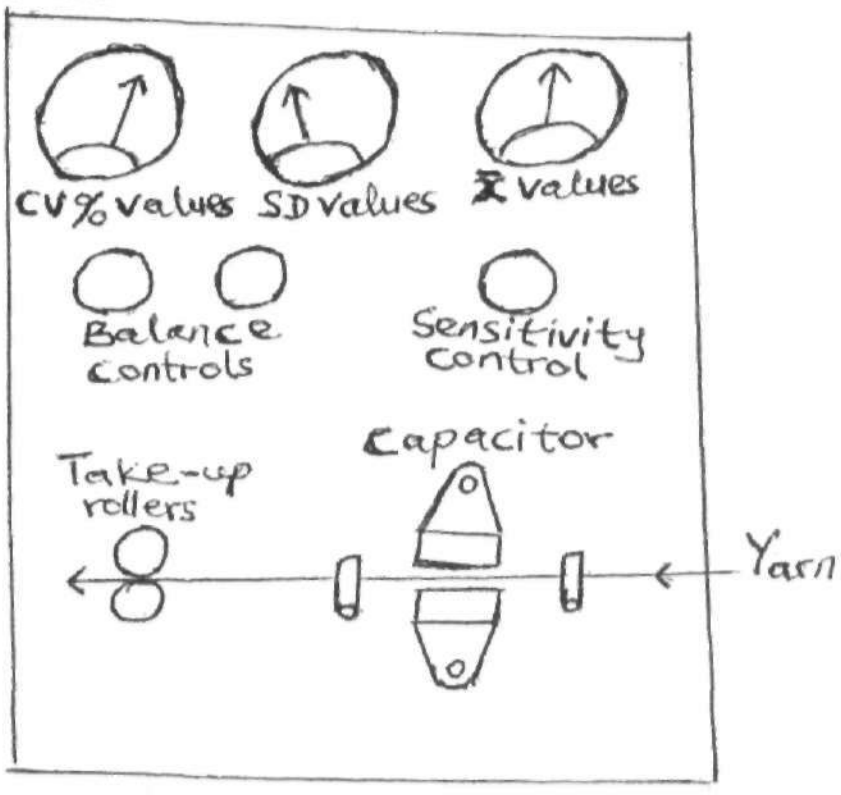
Package	Straight Line Equation	Correlation Coefficient (r)
17/1*	y = 0.275X + 0.2926	0.2281
17/2	y = 1.278X + 0.1026	0.7831
17/11*	y = 0.4568X + 0.4432	0.2200
17/12	y = 1.4330X + 0.2197	0.7500
17/13*	y = 1.5014X + 0.2230	0.6878
17/14	y = 0.9908X + 0.2648	0.7397
17/15*	y = 1.6232X + 0.1315	0.6874
17/16	y = 0.6206X + 0.2734	0.3055

Packages 17/1 and 17/2 were cotton while the remaining packages were polyester.

*Backsuctioned packages.

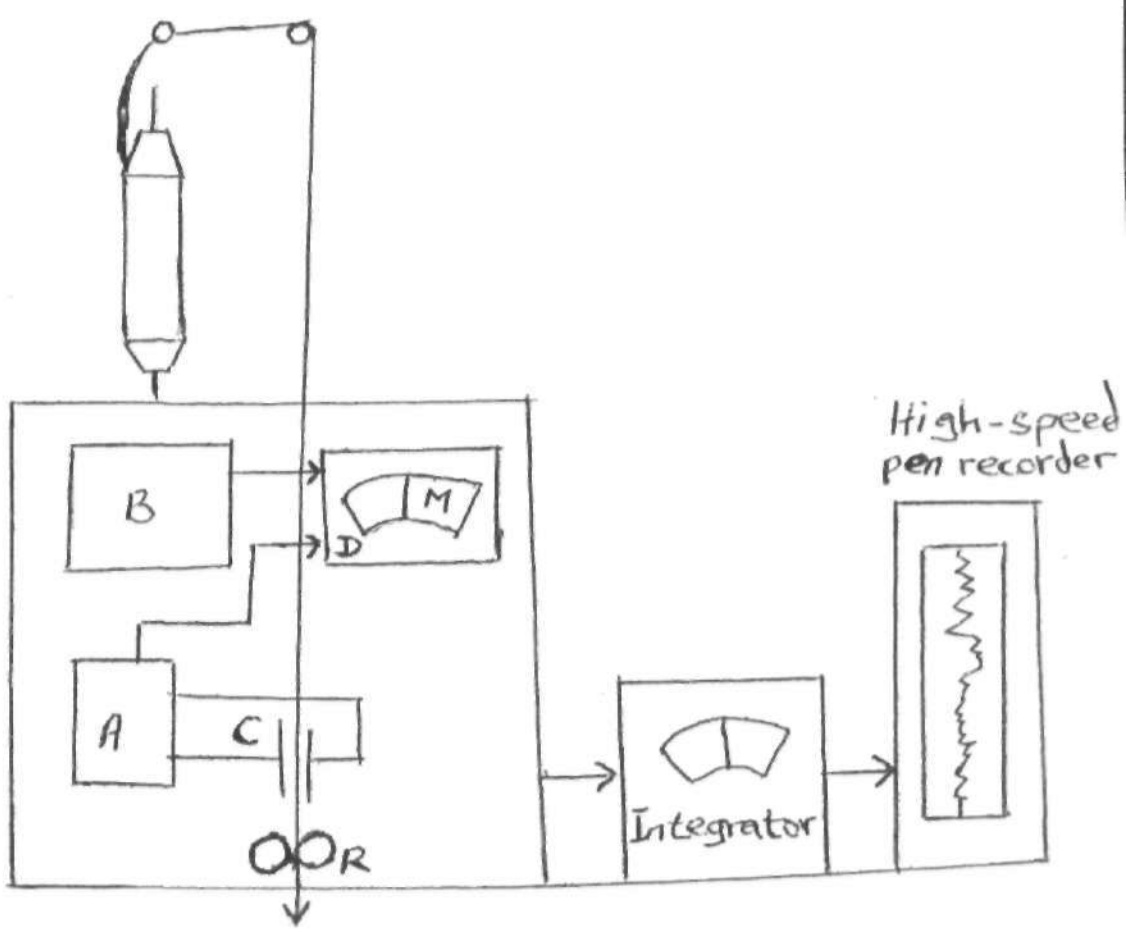
APPENDIX IV

Schematic Diagram of Shirley Yarn Hairiness Tester



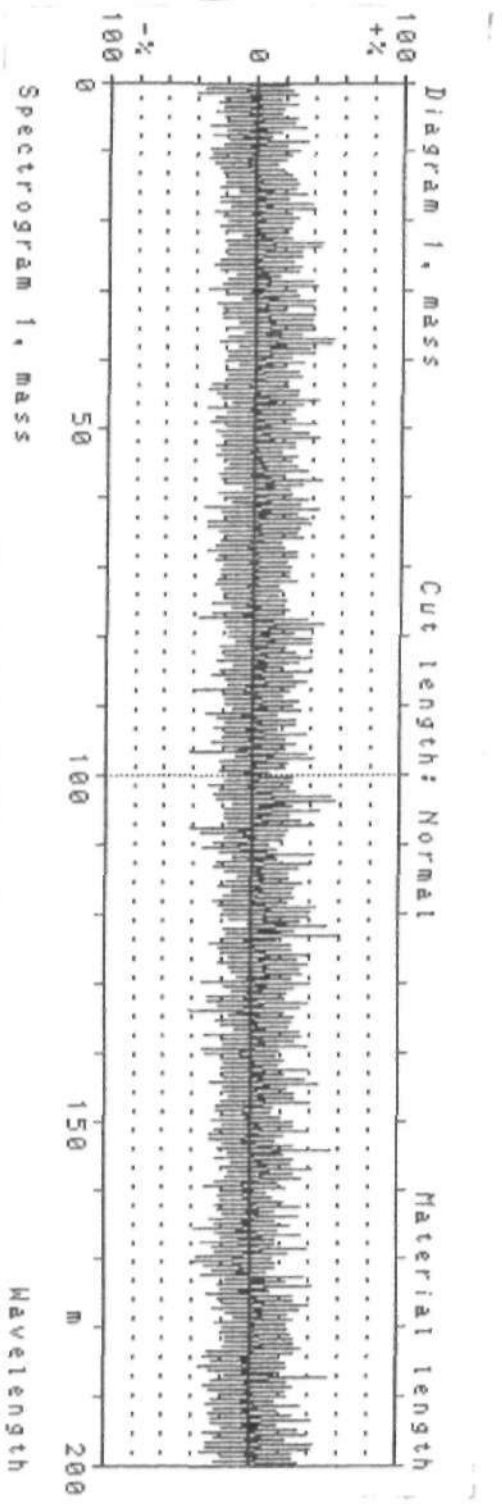
APPENDIX V

Schematic Diagram of Uster Tester 3

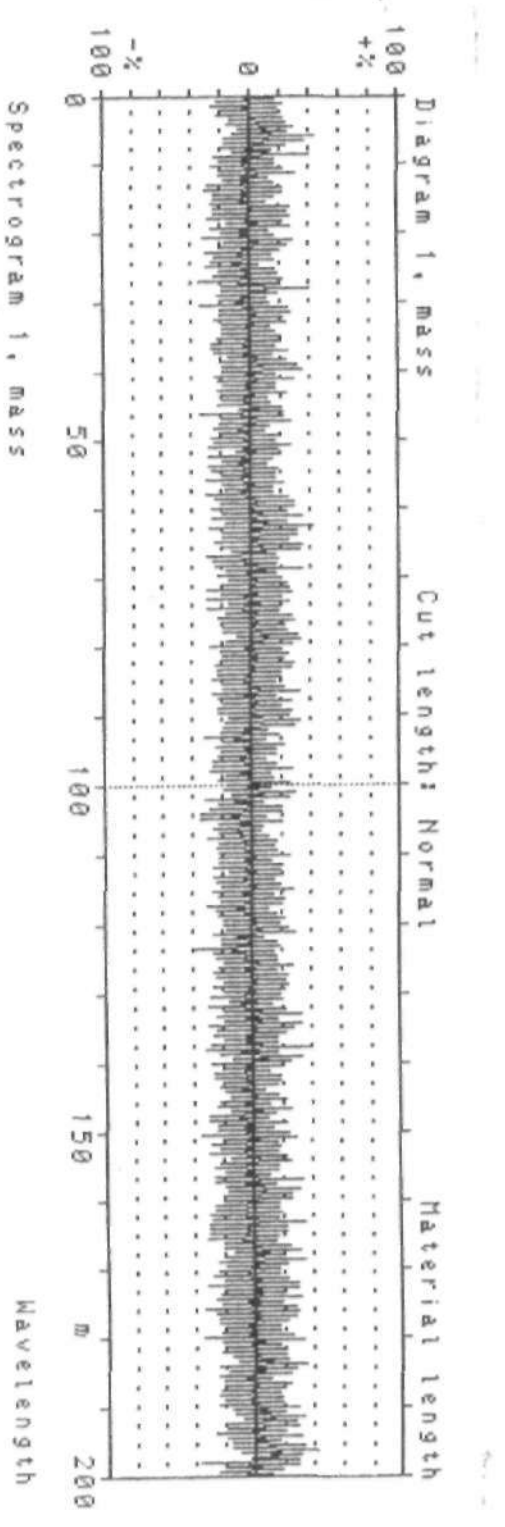


APPENDIX VI

Package 17/11 (polyester)
Irregularity Spectrum

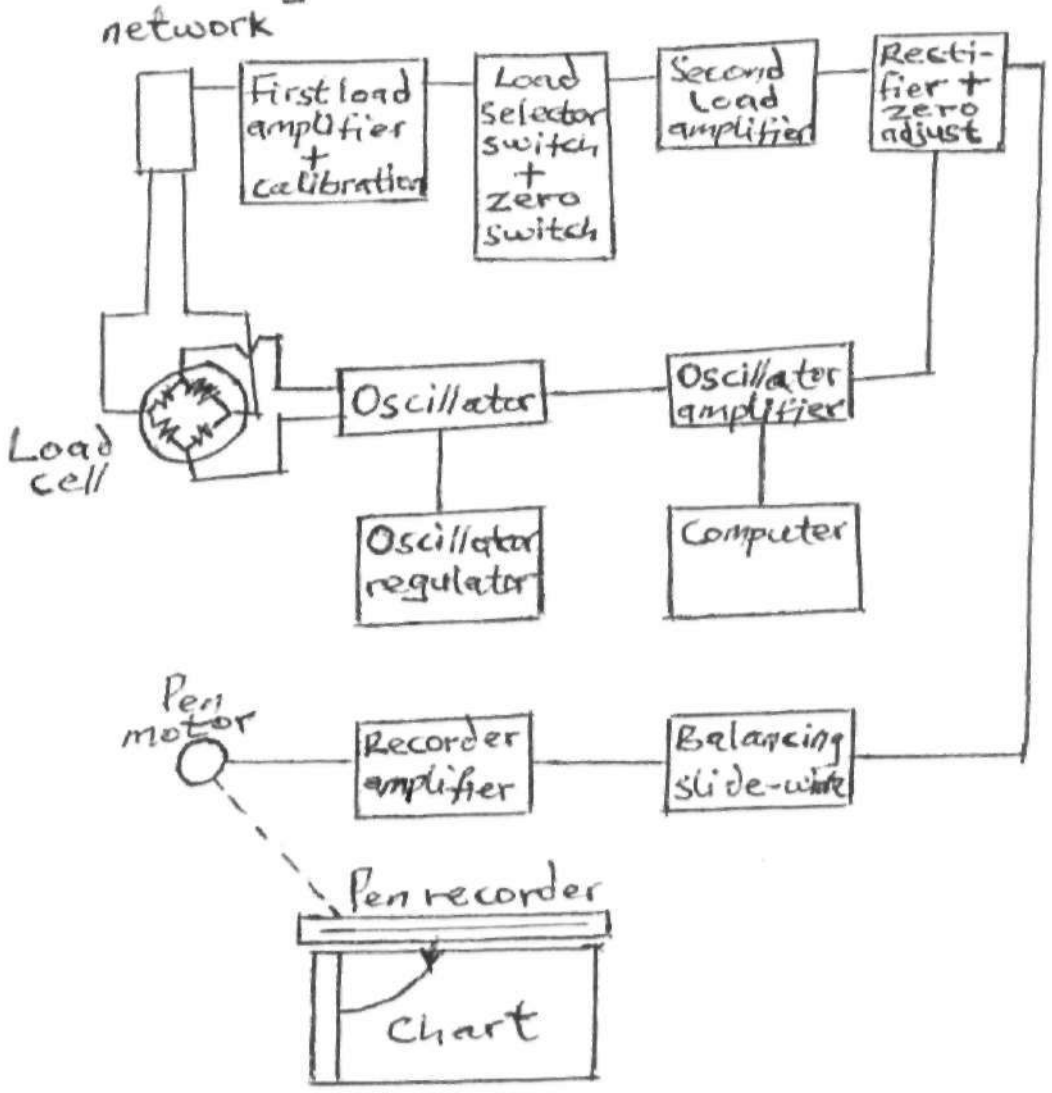


Package 17/1 (cotton)
Irregularity Spectrum

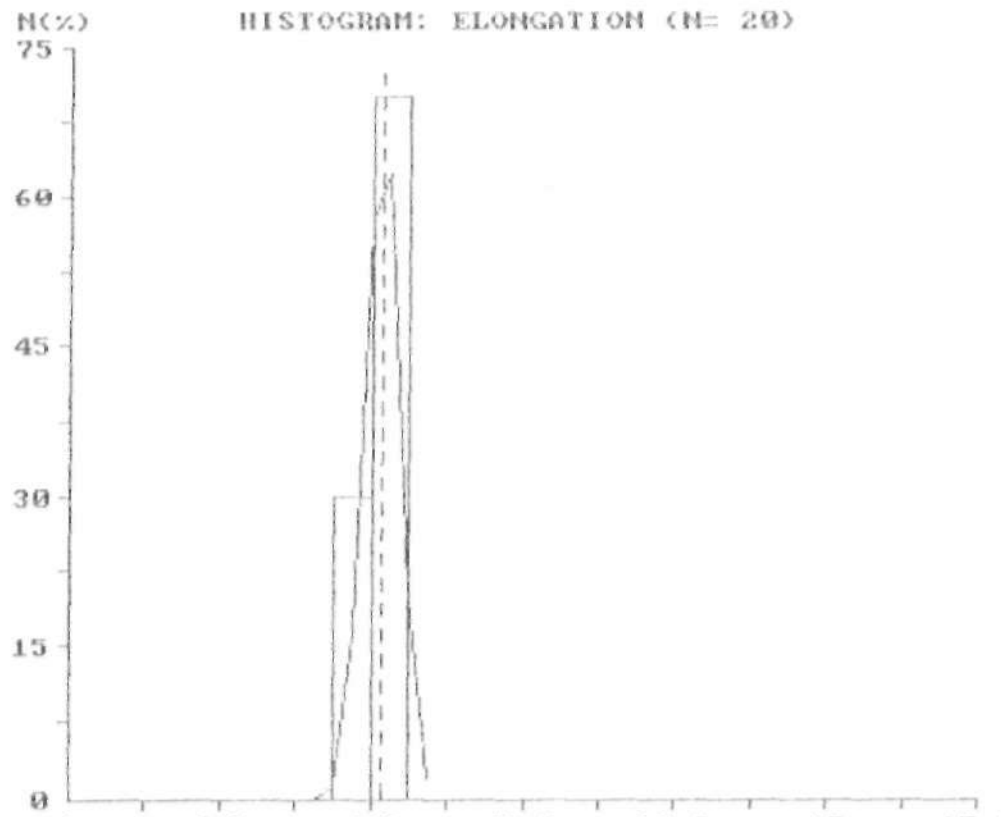


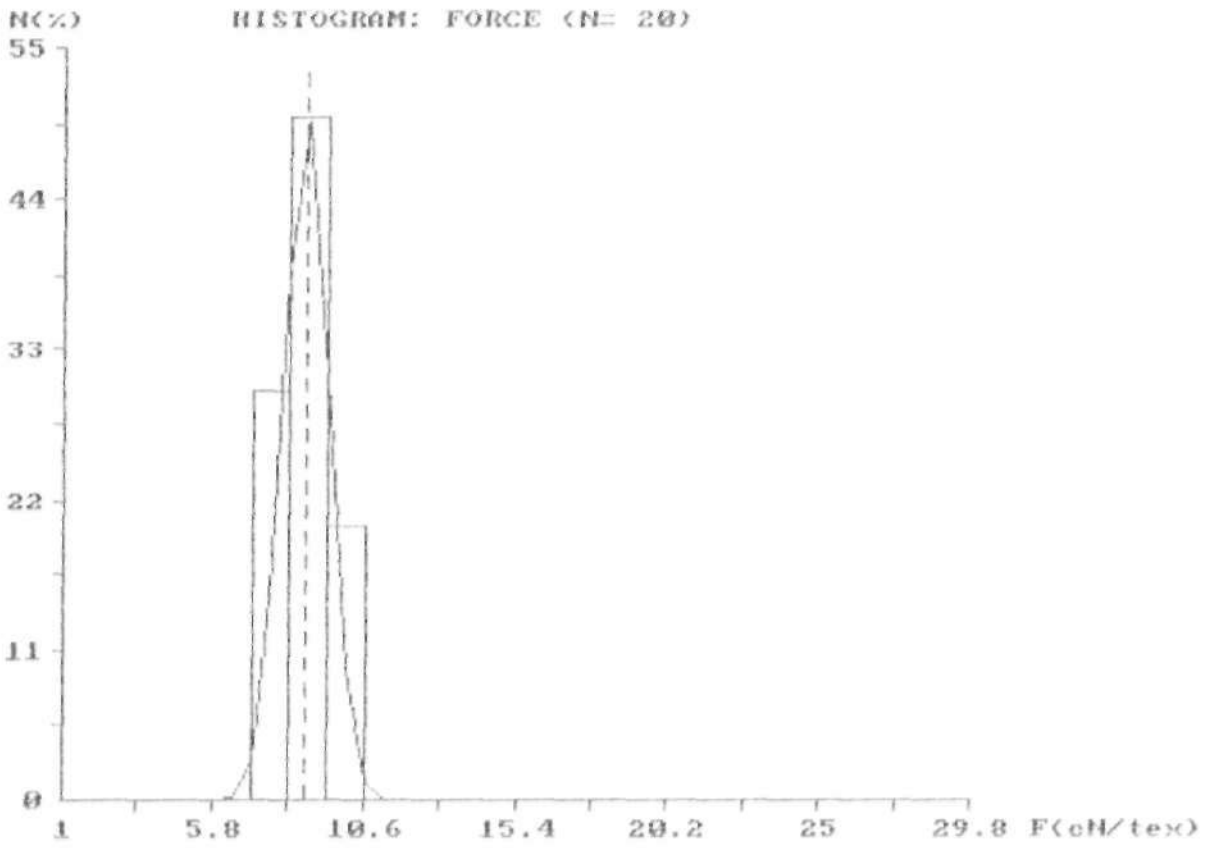
APPENDIX VII

Schematic diagram of Textechno Statimat M Test Machine



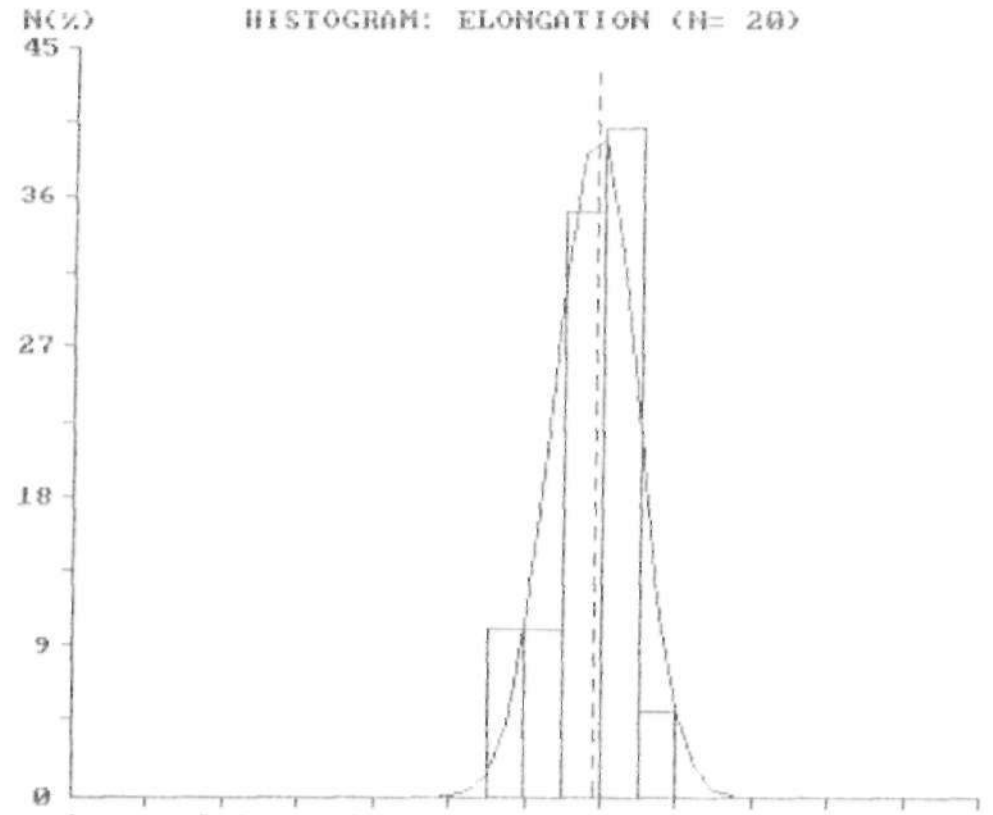
APPENDIX VIII

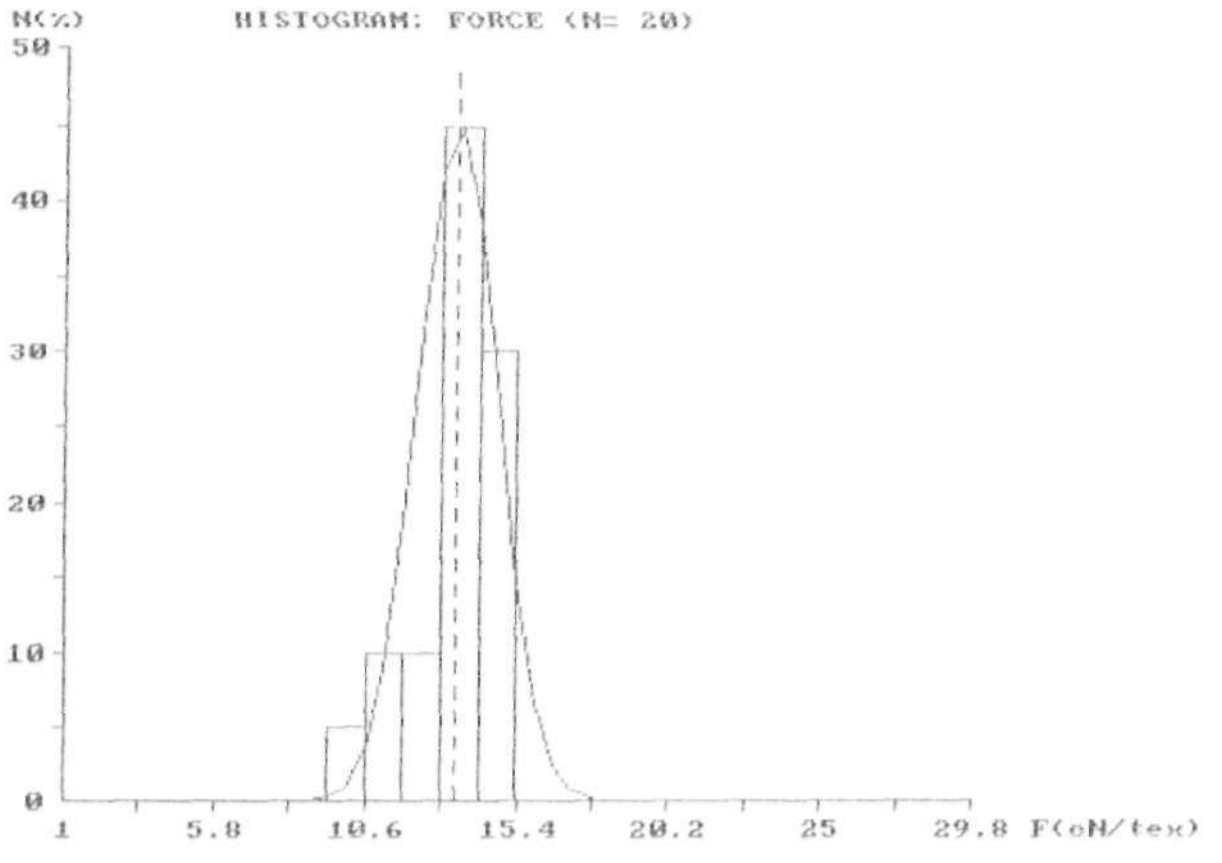




Package 17/1, cotton.

APPENDIX IX





Package 17/11, polyester.

APPENDIX X

OE ROTOR (BD200) MACHINE

