THE PROPERTIES OF FABRICS PRODUCED FROM ROTOR AND RING SPUN YARNS

A Dissertation submitted in fulfilment of the requirements for the degree of Master of Science (M.Sc.) in Textile Science and Technology of Ahmadu Bello University, Zaria,

by

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Being an account of work carried out in the Department of Textile Industries, The University of Leeds, under the supervision of

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DEDICATION

In memory of my beloved father,

To my affectionate mother,

With gratitude to my family.

CERTIFICATION

This dissertation entitled "THE PROPERTIES OF FABRICS PRODUCED FROM ROTOR AND RING SPUN YARNS", by Hussaini Doko Ibrahim, meets the regulations governing the award of the degree of Master of Science in Textile Science and Technology of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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"May Allah Bless all" (Amen)

Ibrahim, H.D.

ABSTRACT

A comparative study is carried out into the properties of plain woven fabrics produced from a range of ring and rotor-spun yarns produced at different twist levels.

From the study of the fabric properties, it is apparent that yarns produced by both spinning techniques have different physical properties for the same fibre. This is reflected in the behaviour of the fabrics produced from these yarns. The nature and trend of these effects are discussed.

As a result of dyeing, the crimp, thickness, cover factor, fabric dimension and extension are altered, which consequently affects other fabric parameters such as air permeability, strength, bending and abrasion characteristics. The changes after dyeing and different yarn characteristics lead to a considerable difference in fabric properties.

Based on the laboratory evaluation of the fabric properties, an attempt was made to predict the end-use performance of the produced fabrics. It is shown that fabrics produced from rotor-spun yarn compare favourably with conventional ring-spun fabrics. If the comparison is made at commercially used twist factors, then it is shown that the unique properties of rotor-spun yarns may result in fabrics which offer advantages over conventional fabrics.

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CHAPTER 1

1. Introduction

The success of textile products such as garments, upholsteries, etc. depends on their physical and mechanical properties as well as their decorative or aesthetic properties. That is to say a fabric is valued for its attractiveness and performance during use. The growing competition in the commercial market is intense in today's world. This necessitates the fact that products with comparatively low cost and satisfactory quality are not only essential but also desirable by the producer and consumer.

A woven fabric is an assemblage of fibres which has passed through a number of processing stages in the course of being converted into a fabric.[1] The most important stage of this conversion is the assembly of fibres into what is called "yarn". A yarn has structural features such as linear density and twist, both of which govern the appearance and behaviour of the various yarns. It has been established that many of the performance parameters of woven fabrics are due precisely to those complicated interactions between the geometrical and physical properties of the yarns, which give added complexities in relation to fabric weaving.

Yarn is the constructive element in woven fabrics during preparation and weaving. It is subjected to structural changes depending on the fibre distribution in the yarn which is, in turn, influenced by the spinning technique employed. Hence from the technical point of view, good workability and good use value in the product are essential. All these demands entail a certain "quality of yarn"; therefore a spinner's main objective and ultimate goal is always to produce a yarn

of acceptable quality at an acceptable price, since the end-use applications of spun yarns depend directly on their properties and structure.

Ring spinning has continued to be the prevailing method of conventional yarn production. It practically covers the entire yarn sector, producing a wide range of quality yarns for weaving and knitting. It has continued to be improved, is versatile and is available at a low capital cost.[2]

However, the continual demand in the textile industry for higher productivity has led to the search for alternatives to the ring frame. This situation has been countered on the ring frame by the greater use of automation in order to achieve greater productivity and reduce labour costs. There are, however, still technological limitations to the production rate of the ring frame and these restrictions are almost exclusively related to the speed at which the system can insert twist into the yarn.

There has been considerable improvement in the rate at which yarns can be made from fibres. However, in spite of these new developments, and the shortcomings of the ring frame, there is still a considerable demand for ring-spun yarns in general and this could be attributed to the fact that it produces a yarn structure which is similar to hand-spun products, to which the weaver, knitter, and the final customer are accustomed.[3] Thus, any other yarn-making system is likely to result in a product which is more or less different in characteristics from those to which they have been hitherto accustomed.

It is obvious then that before any process becomes commercially attractive, it must have a well-defined operational, economic or aesthetic

advantage over the existing process.[2] Thus it will require considerable effort far beyond the spinning step. The process should also be flexible in that it can produce a range of products which have useful end-use requirements. It could be an enterprise containing many risks, since the chance for success cannot be judged on an economic basis alone.

The most successful alternative to ring spinning, which has to a certain extent fulfilled these conditions, is the break-spinning or open-end spinning (as typified by rotor spinning) which has not only reached operational success but also commercial acceptance with a very promising future. The yarn spun by the new process differs in structure and properties from the familiar ring-spun yarn. Hence subsequent developments necessitate close examination not only by the spinners, but also by weavers, knitters and finishers. As a consequence of these structural differences, one expects certain differences in the behaviour and properties of fabrics produced from both systems.

The difference in the yarn properties have been attributed to the method and mechanism of production which is quite different in both systems.[4,5]

It is a widely held view that rotor yarn should not be regarded as a substitute for ring spun, but rather as a new type of yarn that is suitable for certain types of fabric with a character of their own. However, until rotor spun yarn properties have been established, and properties of end-uses defined, the ring-spun yarn will continue to be the reference standard by which the quality of the yarn and fabric will be assessed.

The first part of this work reviews the major differences between

the yarns for better understanding of their probable influence on the fabric properties.

The study of mechanical properties of textiles normally refers to their behaviour to tensile stresses, stretching, bending, abrasion, etc. Unfortunately in use textiles are not subjected to each type of deformation in isolation, but usually to complex combinations of them. It is therefore necessary to understand the behaviour of fabrics in the several simple component deformations which contribute to the highly complex behaviour occurring in practice. It may be possible not only to use these simple properties to have a general idea and predict the more complex behaviour of textile products in use, but also to set up standards so that a fabric can be constructed in a manner that will give it the desired performance. Most of the earlier work carried out has been to investigate the properties of rotor yarn as compared to ring spun yarns. Little seems to have been done in the area of fabric properties as compared to ring spun fabrics. However, the majority of the textile end-products are in fabric form.

Therefore the main aim of this research is to investigate the influence of rotor and ring-spun yarn properties on the physical and mechanical properties of woven fabrics, and an attempt will also be made to predict their end-use performance.

An attempt will also be made to dye these fabrics from rotor and ring-spun yarns and to look critically on how these affect the fabric properties and, in turn, to compare them with grey fabrics.

It seems that little work of this nature, if any, has been done in this area in Nigeria. It is therefore hoped that this work will be able to shed light in some areas for future work. Finally it is

also hoped that this will serve as an original documentation and reference for those who would be interested, in future, to work in a similar area.

CHAPTER 2

2. Review of literature

Whilst there is a considerable amount of published information related to rotor spinning, it is intended only briefly to review basic concepts of rotor and conventional ring spinning systems, yarn structure and properties, which are considered to be of immediate relevance to the present work.

2.1 Principles of ring and rotor spinning

The normal process of yarn formation consists of the opening and cleaning of cotton in the blowroom, conversion into sliver form at cards and then doubling and drafting of such slivers in two passages of the draw-frame. For both the spinning techniques, this process is the same.

In the ring-spinning process, further attenuation of the sliver is required to form a roving on a speed frame by drafting and twisting. Further attenuation and twisting is carried out on the ring frame to produce the final yarn, employing the technique of a traveller, with the spindle revolving in the centre of an annular ring.

In rotor spinning the sliver is converted into individual fibres by means of an opening device, from where the fibres are carried by an airstream through a feed tube and are then guided to, and re-assembled on, the inner wall of a rotating element, i.e. the rotor. Once a "seed yarn" makes contact with the fibre ribbon deposited on the wall, it is withdrawn as a result of which fibres are mass-twisted by the rotor into a yarn in a continuous manner, and subsequently wound onto a package by a winding unit outside the twisting elements. Following

this sequence the "six phases of rotor spinning" are successfully carried out.[2]

The fundamental concept in rotor spinning is to introduce a "break" into the material between the supply package and the yarn being formed. The rotor performs the function of collecting the fibres and inserting twist, the subsequent winding being independent of the rotor. In this way the twist is inserted by rotating only the yarn-end instead of the whole yarn package, as in ring spinning. There is no need for a speed frame. These basic differences between the two systems have enabled rotor spinning to produce yarn at significantly higher speeds than the ring frame. The manner in which the yarns are formed are quite different in the two systems of spinning.

2.2 Yarn properties

2.2.1 Yarn structure

It is quite clear that the distinct differences in the mechanism of yarn formation of the two spinning systems has led to different yarn structure.[5] Kasparek[6] has suggested that ring spun yarns have an approximately circular cross-section, whilst the cross-section of a rotor spun yarn is roughly oval.

The ring spun yarn is evenly packed and quite dense. Over 90% of the fibres are "straight" and lie in helical form of varying radii, i.e their radial positions change along their length so that a fibre does not exist as a perfect helix at a constant radius from the yarn axis. This phenomenon of "fibre migration" is due to the differences in fibre tension during twist insertion. As the fibres emerge from the nip of the front rollers on a ring frame, they are twisted from

a more or less flat assembly into a roughly circular shape. The consequence of this results in a variety of fibre tensions; those fibres on the outer layer of the yarn have higher tensions and bigger components of forces acting towards the yarn core, whilst those fibres in the yarn core possess low tensions and they tend to be displaced towards the outer surface of the yarn, resulting in fibres being interlocked through various layers of the yarn and are thus firmly and coherently held together.

The rotor spun yarn is, however, considered to be of a two-part structure composed of concentric structures.[5,7,8] The inner core contains most of the fibres which are straight, compact and highly twisted, similar in structure to ring-spun yarn but with a lesser degree of fibre orientation, and this inner core contains 40 - 70% of the total fibres. The loose outer sheath contains fibres in a random disarray wrapped round the core with a variable twist level, and these are often referred to as "wrapper fibres". The formation of wrapper fibres lies in the basic method under which the yarns are being produced, and these fibres form an oblique angle with the yarn axis but are firmly held to the core and cannot be displaced. This arrangement is claimed to be important in relation to some specific properties of these yarns. It has been demonstrated[5,9,10] that the level of preferential migration in rotor spun yarn is generally very low. This has been attributed to the higher doubling effect on the collecting surface, the greater number of folded fibres and lower tension developed during rotor spinning. The fibres are held laterally against the collecting surface by the centrifugal force of the rotor. They are force restrained rather than position restrained, so that

fibres can move without causing a significant change in their tension. This has been said[9,10] to reduce the fibre migration since the fibre tension differences are small. Some migration, however, does take place and this is referred to as "local migration"[2] and is reported to be about one-sixth of the migration found in a ring-spun yarn.[9]

Analysis of the yarn cross-section has shown that rotor yarns generally have a lower fibre packing density and this tends to give the yarn a more bulky nature,[5,9] having a specific volume about 10 - 15% greater than ring-spun yarn.[2,8]

2.2.2 Yarn tensile strength and elongation

The factors influencing the strength of spun yarns can be summarised as follows:

(1) The degree of fibre orientation and parallelization
(2) Evenness in fibre distribution
(3) The amount of twist inserted, and
(4) The type of fibre.

In all the available literature, it has been generally accepted that rotor-spun yarns have lower tensile strength when compared to the equivalent ring-spun yarns and this difference in strength is of the order of 10 - 30%.[11,12] The major contributing factors have been related to the low degree of fibre orientation and the magnitude of wrapper fibres. This gave credence to the assumptions[13] that "the greater the extent of fibre utilization in the yarn, the greater the chance that the given fibre will contribute to yarn strength". Amongst other factors reported[9,13] to be responsible for the lower yarn strength is the poor participation of fibres and inferior fibre migration within the yarn body. Twist tends to increase yarn strength

by increasing cohesive lateral forces which impede or reduce inter-fibre slippage, but in the case of rotor-spinning this effect is largely offset by wrapper fibres. It has been reported[11,12,14] that as the amount of twist increases the number of wrapper fibres increases, and their effect on yarn strength becomes greater. Thus, a rapid increase in strength with increasing twist does not occur as in ring-spun. Lower strength variations have been reported for rotor yarn and they are characterised as having a higher elongation at break. This has been explained in terms of the folded and entangled nature of the fibres which act as an extensible component of the systems.[9,13,15] There is a better chance for fibre straightening and slippage to occur thus giving rise to the higher elongation than ring-spun yarn. The twist level of the yarn is also believed to have some effect on the extension of the yarns, as it increases their breaking extension first, rises and then falls. At higher twist levels, the rotor yarn is said to have lower extension than ring-spun yarn and this is probably due to the higher percentage of wrapper fibres at higher twist levels (and hence less core forming fibres). The reduced core component then suffers from fibre breakage when a load is exerted on the yarn.

2.2.3 Yarn abrasion resistance

The ability of a fibre to withstand abrasion or frictional wear has been said to depend on its inherent mechanical properties and the abrasion resistance of a yarn will depend on the structure of the yarn and how firmly the fibres are being held in the system. It is thus logical to assume that different abrasion characteristics would be expected for the conventional ring-spun and rotor-spun yarns. It is

widely claimed[16] that rotor-spun yarns are more resistant to abrasion forces than are ring-spun yarns. This is related to the unique nature of the structural differences in the yarn and its performance which is extremely different from the ring-spun yarn.[16,17] The outer-layer of the rotor-spun (wrapper fibres) is expected to be the decisive factor in the abrasion resistance of yarn. The influence of wrapper fibres on rotor-spun yarn properties seems to be highly effective. The existence of the outside sheath which coats the yarn core and contains different configurations and populations of wrapper fibres appears to contribute to the different yarn properties. Fibre migration is more local in rotor-spun yarns with one layer being interlocked with adjacent ones rather than being locked through the whole structure. The increased abrasion resistance of rotor yarn is also attributed to this effect, since fibre removed from the yarn surface would not affect the internal structure of the yarn to any great extent.[2]

From the available literature there appears to be no conclusive agreement as to the question of which yarn has a better resistance to abrasion forces. Indeed different authors have different opinions as to whether ring-spun or rotor-spun yarn is superior in respect of abrasion resistance.[18] It has been reported[14,18] that abrasion resistance is dependent on testing conditions and the technique employed, and other factors acting jointly with abrasive effect. Instruments using higher yarn tension have shown lower abrasion resistance for rotor-yarns. The work of Ibrahim[14] seems to support this view, and states that within the range of twist levels of rotor and ring-spun yarns used, it is unrealistic to draw any conclusions in favour of either conventional ring-spun or rotor-spun yarn abrasion resistance. He[14] showed the

results to be greatly influenced by processing and testing conditions and clearly demonstrated that, depending on the experimental conditions used, it could be shown that either ring or rotor was best. The only definite conclusion which he[14] claimed could be drawn from the large amount of data he had accumulated was that twist has a significant role on the abrasion characteristics of both ring-spun and rotor-spun yarns.

2.3 Fabric Properties

2.3.1 The tensile strength and extension of fabrics

The strength of a yarn spun from staple fibres is largely attributed to the pressures between individual fibres which prevent fibre slippage. These pressures are created by the twist inserted during spinning but an additional pressure comes into play when the yarns are interlaced in the fabric. This results in making the fabric strength usually exceed that of the combined strength of all the component yarns.

It has been shown[2,8] that the higher strength of ring-spun yarn, relative to its rotor equivalent, is reflected in the fabric state, and Lord[8] has shown that the work of rupture of rotor-spun fabric was less than that of equivalent ring-spun fabric. However, this is to a lesser degree, and strength difference between fabrics is much lower than that between yarns. The explanations advanced for this is that the wrapper fibres which are non-load-bearing fibres in the rotor-spun yarn get trapped at points of interlacing, i.e. cross-over points in the fabric and consequently contribute to fabric strength.

It has been established[16] that in addition to fabric structure,

the extensibility of fabrics is also affected by the yarn characteristics which, in turn, determine the properties and performance of the end-product. The relation between changes in fabric length, width and thickness[1] is believed to be very much influenced by the extensibility of the yarn used in the woven fabric. It has also been indicated that fabrics from ring yarns have higher extension at break than rotor fabrics at the same twist level. According to some workers[8] the sometimes better yarn elongation of rotor yarn is not reflected in the fabric characteristics. This behaviour has been attributed to some fibre elements of the yarn which tend to be locked in the fabric structure to give a higher effective yarn tensile strength and lower overall extension.

2.3.2 Fabric abrasion resistance

The abrasion resistance of fabric is mostly determined by complex interactions and combinations of several fibre and yarn properties, fabric construction and finish, as well as external environment. The mechanical destruction of textiles is generally referred to as "abrasion" and "wear". Wear is a broad term referring to the effects of all types of deteriorating action and abrasion could be said to be the most important part of wear. The resistance of fabrics to abrasion according to Backer[19] should be restricted to the "ability of a fabric to withstand direct rubbing under conditions of intended use". Another definition[20] of abrasion is that it is a type of destruction resulting from frictional forces on fabrics, and this was referred to as the "rubbing away of fabric by attrition", which may occur as a result of the friction of fabric on fabric, or fabric on an external object, as

well as the friction between fibres and dust within the fabrics.

A general fabric abrasion mechanism has been proposed[19] which consists of three elements, the relative magnitude of each element depending upon the nature of the abradant, the behaviour of the fibres in the fabric structure, and the general conditions of rubbing. These elements have been generally classified as:

(1) direct frictional wear
(2) surface cutting, and
(3) fibre plucking or slippage.

It is, therefore, clear from this that fibres not firmly held in the yarn are readily subjected to plucking action of the abradant, while those held firmly will suffer frictional wear. It has also been shown[24] that damage to cotton fibres and yarns results from direct displacement and removal of fibres from the yarn. The yarns and fibres which are firmly held in the fabric get the most serious abrasive damage.

The differences in the yarn structure of rotor and ring-spun yarns results in different abrasion properties. However, which yarn produces fabric with the better abrasion characteristics still remain an unanswered question. Some authors[8,13,22] have reported that rotor yarn fabric displayed poorer abrasion compared to the corresponding ring-spun fabrics, whereas others[14,18,23] hold the view that the claim of superiority of either of the fabrics in terms of abrasion resistance is far from being realistic when the same twist level is employed. They[14,18,23] concluded that rotor fabric abrasion resistance is due to several factors which include "wrapper fibres". The results generally depend on the testing atmosphere and conditions, including the yarn processing parameters. One thing that has been generally pointed out[8,14,24] is that abrasion resistance of fabrics generally

increases with increase in twist up to an optimum twist level, where further increase in twist shows a deteriorating effect. The dependence on twist reflects the changes in fibre cohesion exceeding the optimum, brings about no further improvement in the fibre cohesion, and additional twist therefore causes stresses on the fibres and reduces the capacity of the yarn to flatten or to rotate. An increase in twist in rotor yarn leads to an increase in the number of wrapper fibres formed on the outer layer. This, then, results in a more open structure to the outer layer as well as a lowered percentage of fibres forming the yarn core.

CHAPTER 3

3. Experimental Procedure

3.1 Spinning (production of yarns)

The raw material used for the production of the yarns used in this work was supplied in sliver form. This was a commercial blend consisting of a mixture of fibres from different sources (Cameroun, Australia and California) having a mean fibre length of about 30 mm. It was decided to use this blend because it was considered to be very similar in characteristics to Nigerian cotton. The rotor and ring-spun yarns were produced from this same fibre under "identical" conditions, for a more realistic comparison to be made. Although it is well known that the rotor-spun yarns require a higher twist factor than ring-spun, it was considered necessary, in order to carry out a scientific assessment, that the range of twist factors used for the two types of yarn should be as close as possible.

Ring-spun yarns of 36 tex count were produced on a ring frame, Platt type 800, Superspinner, and five twist factors (dtex = turns/cm x $\sqrt{\text{Tex}}$), 31.57, 34.44, 38.27, 41.14 and 45.92 were selected.

These yarns were spun by using corresponding twist change wheels which were calculated from the required values of twist per centimetre and twist constant of the spinning frame.

$$\left(\text{Twist change wheel} = \frac{\text{Twist constant}}{\text{Twist/cm}}\right)$$

Rotor-spun yarns of similar count, 36 tex, were processed on open-end frame: Platts Rotorspin Type 883 (side-feed) to the following twist factors - 32.53, 36.35, 39.22, 41.14, 45.92. The same procedure was adopted to find the required twist change wheel gear for these different twist levels. Unfortunately it was not possible to exactly match the

ring-spun and rotor-spun twist factors because of the availability of the necessary change wheel; however, it may be observed that the levels used are very similar.

Before spinning trials were commenced, a preliminary series of trials were carried out to verify the range of twist which could be spun in practice. Whilst it would have been useful to obtain lower twist factors, it was impossible to produce these on the rotor spinning machine and thus the range of twist factors used was restricted to the above.

3.2 Weaving (production of fabric samples)

The processed series of rotor and ring-spun yarns with a range of twist factors were woven as weft across a "common" warp (R 72/2 tex cotton yarn).

The yarns were re-wound onto pirns separately, under the same pre-set tension and at the same speed.

A plain fabric was woven from both rotor and ring yarns used as weft, starting with the lower twist factor and finishing with the higher twist levels. A black marker thread was inserted after each twist level was woven for identification purposes. Exactly the same processing condition was used for both the rotor and ring-spun yarns.

The weaving was carried out on No. 14 "Northrop" running at a weft insertion rate of 142 m/min with a reed width of 127 cm. After weaving the fabric was allowed to relax under standard atmospheric conditions before any testing took place.

3.3 Dyeing of the fabrics

The grey fabric was divided into two equal parts to enable a comparison to be made of dyed and grey (loom state) fabric. The fabric to be dyed was scoured after being marked properly with an indelible ink and then subsequently dyed.

Scouring. The fabric was processed on a "winch" machine in rope form. The bath contained:

10 gram/litre Caustic Soda
2 gram/litre Sandozin N1

Time of treatment: One hour
Temperature of scouring: 100°C

After scouring the fabric was given three hot water rinses and was finally cold water rinsed, then hydroextracted and dried.

Dyeing. The dyeing of the scoured material was carried out on a "winch machine". The bath contained the following:

2% Durazol Blue 4RS (a direct cotton dyestuff)
5 gram/litre Sodium Chloride.

The fabric was raised to the boil over 20 minutes and then dyed for a further 45 minutes at the boil. It was then given two hot water rinses and finally cold water rinsed, hydroextracted and then dried.

An area of 10 cm x 10 cm was marked on the grey fabric at three different places on each fabric sample. These were later re-measured after scouring and dyeing and the % area shrinkage was calculated.

$$S = \frac{A_o - A_1}{A_o}$$

where: S = per cent area shrinkage
A_o = area before treatment
A_1 = area after treatment

whereas L_o and L_1 replaces A_o and A_1 respectively for calculating the warp and weft shrinkages.

3.4 Testing

The grey (loom state) and dyed fabrics were evaluated for those properties which it was considered may be influenced by the yarn type. The various tests and techniques adopted are summarised below:

3.4.1 The width of the woven fabric

The woven fabric was measured for width immediately after removal from the loom and was then conditioned in accordance with British Standard (B.S.) 1930 Specifications in a standard atmosphere for at least 48 hours to allow for sufficient relaxation and accurate measurement. The fabric was placed on a table at full width, free from creases, and the over-all width re-measured again by carrying out three determinations at approximately equal distances for each twist level of both the rotor and ring-spun samples.

3.4.2 Crimp testing

The woven fabric was conditioned under standard atmosphere for at least 48 hours and laid free from tension and creases. A rectangular strip of about 50 cm x 2.5 cm was carefully marked along the warp and weft directions and yarn samples were carefully removed using a dissecting needle. The yarn samples were tensioned to the level recommended by B.S. 2863 for cotton yarns (0.2 tex + 4g). Thus 11.2 grams was used for all the weft yarns (36 tex) and 20 grams for the warp yarns (72/2). Twenty readings were taken for each case and the mean calculated. The same procedure was followed in the case of dyed fabrics. The crimp was evaluated using the "Shirley Crimp Tester". The crimp values were calculated from:

$$\text{Crimp (mean) per cent} = \frac{\text{Mean yarn length straightened} - \text{Flap length of fabric}}{\text{Flap length of fabric}} \times 100$$

3.4.3 Measurement of fabric thickness

The grey and dyed fabrics were conditioned under standard atmosphere for at least 48 hours. Each sample was placed between the anvil and the presser foot of the thickness tester. The latter was allowed to descend gently on the fabric. The tests were carried out initially under a pressure of 1lb/sq.in as recommended.[25] Ten readings were taken for each sample and the mean was calculated.

In order to determine the fabric compressibility, another set of readings were taken under a slightly higher pressure of 5lb/sq.in. The compressibility was calculated from the difference between the thickness at high and low pressures and divided by the thickness at low pressure and this was expressed as a percentage.

3.4.4 Air-permeability measurements

The "Shirley Air Permeability" tester was used to carry out the assessment of fabrics' permeability to air. The main principle of the instrument is to measure the rate of air flow drawn through a given area when subjected to a specific pressure difference across the fabric.

The woven fabrics (both grey and dyed) were conditioned in a standard atmosphere for more than 48 hours, the temperature being 20 ± 2°C and 65 ± 2% relative humidity. The cutting of the specimen and testing were carried out in accordance with B.S. Specifications (3717). Fig. 3.1 shows the instrument. The sample was held in position between the upper and lower parts of the specimen holder, with the valve (M) opened, (J) and (K) being closed. The switch was turned on to start the pump and then to bring rotameter No. 1 into the circuit. The flow

"SHIRLEY" Air Permeability Tester

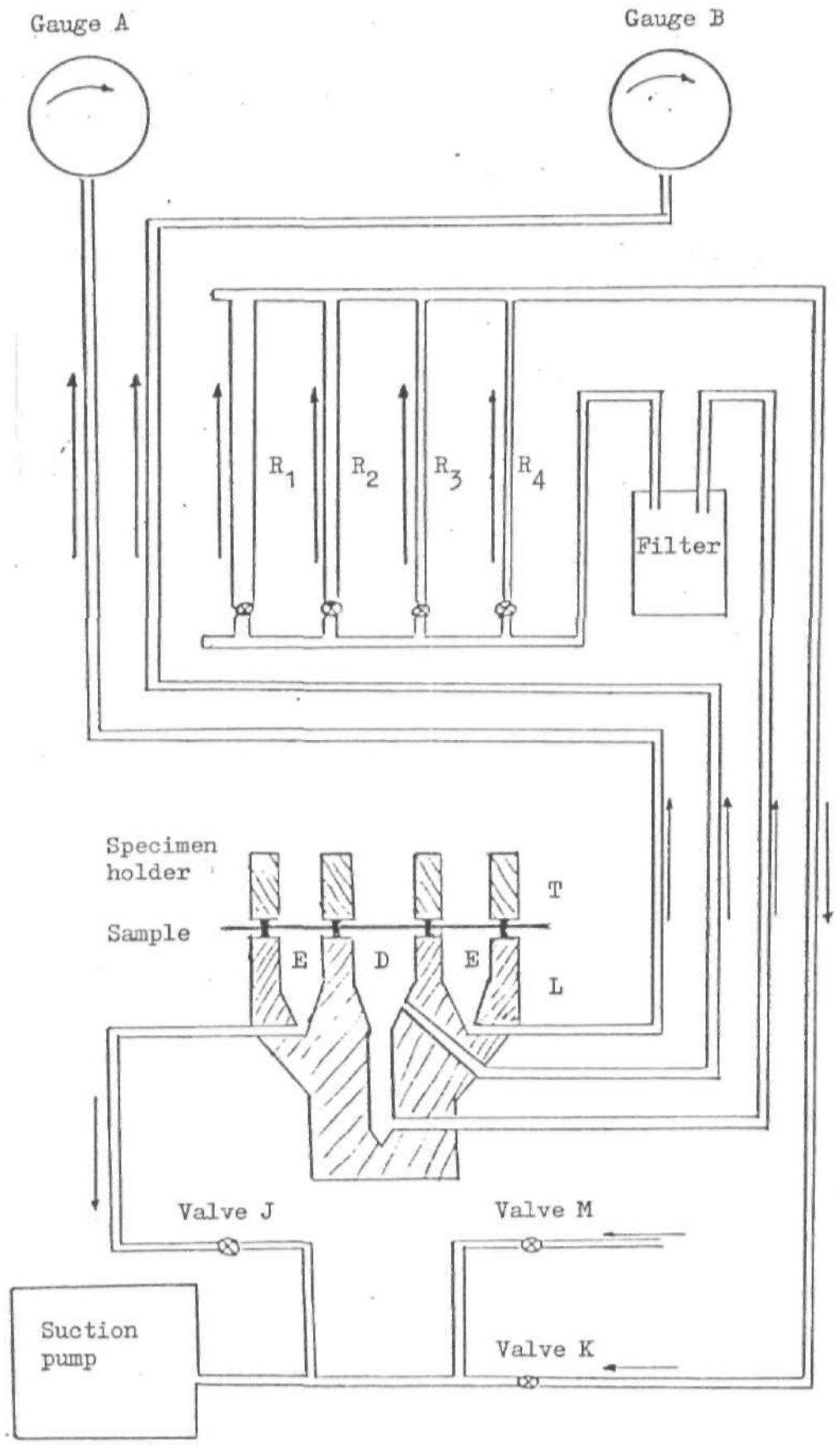


Fig. 3.1

of air through the tested area was adjusted by means of valves K and M until the required difference in pressure (10 mm of water) was achieved. Ten readings were taken from different parts of each fabric and the average was divided by 5.07 cm^2 to give the air permeability in cm^3/sec.

3.4.5 Thread counting

The number of threads per unit length of the woven fabric at each twist level were determined for rotor and ring fabrics, as specified by B.S. 2862. A standard one-inch counting glass was used. Both grey and dyed fabrics were conditioned in a standard atmosphere before the measurements were carried out. Ten readings were taken for warp and weft threads and the mean value was determined for each fabric sample.

3.4.6 Tensile strength testing

The loom state and dyed fabric samples were conditioned under a standard atmosphere (testing laboratory) and the tests were carried out under this condition. The specimen preparations and tests were carried out according to the procedure described by B.S. 2576. Five warp and weftwise samples were cut to a size of 5 cm x 30 cm for each twist level.

An Instron "Model 1026" with a 2512-110 load cell (full scale range 50 - 500 kg) was used for these tests, with a cross-head speed of 100 mm/min. Preliminary setting up of the Instron after switching on the machine was carried out as described in the instrument manual handbook and consisted of (a) Zeroing, (b) Balancing, and (3) Calibration. The distance between the two clamps was adjusted to 200 mm (the so-called "gauge length" for the tensile test). The limit stops were adjusted

and secured at the correct points. The fabric sample was then fixed on the clamps and the upward button was pressed until the sample broke. The rapid downward button was then pressed for a quick return. The tested sample was then removed and the same procedure was followed for other samples. Five readings were taken for each sample (warp and weft) for the strength and the extension at break.

The full-scale load dial setting for the tests was at 10. This gives a range of breaking load of up to 100 kg.

3.4.7 Double-Tongue tear test

An Instron "Model 1026" with load cell 2512-101 (0 - 50 kg) was used to investigate the tear strength of both rotor and ring-spun fabrics, using a cross-head speed of 100 mm/min. The fabrics were conditioned and tested under standard atmospheric conditions.

The test specimen was prepared as specified, samples being cut from different parts of the fabric so as to represent the material as fully as possible. The tests were carried out in the weftwise direction only (i.e. across the weft threads). Five specimens of 18 cm x 15 cm, with the width (15 cm) in the direction of the threads to be torn, were prepared. The cutting and line marking was carried out according to the specification by B.S. handbook (Shirley Institute Leaflet p. 253).

The Instron was set with the jaws 10 cm apart and the central strip was placed in the centre of the top jaw up to the line, and the other strips in the bottom jaw maintaining the spacing between them and equally spaced from the centre of the jaw.

The five highest and five (minimum) readings were taken from the jagged trace chart and the mean values were determined.

INSTRON MACHINE

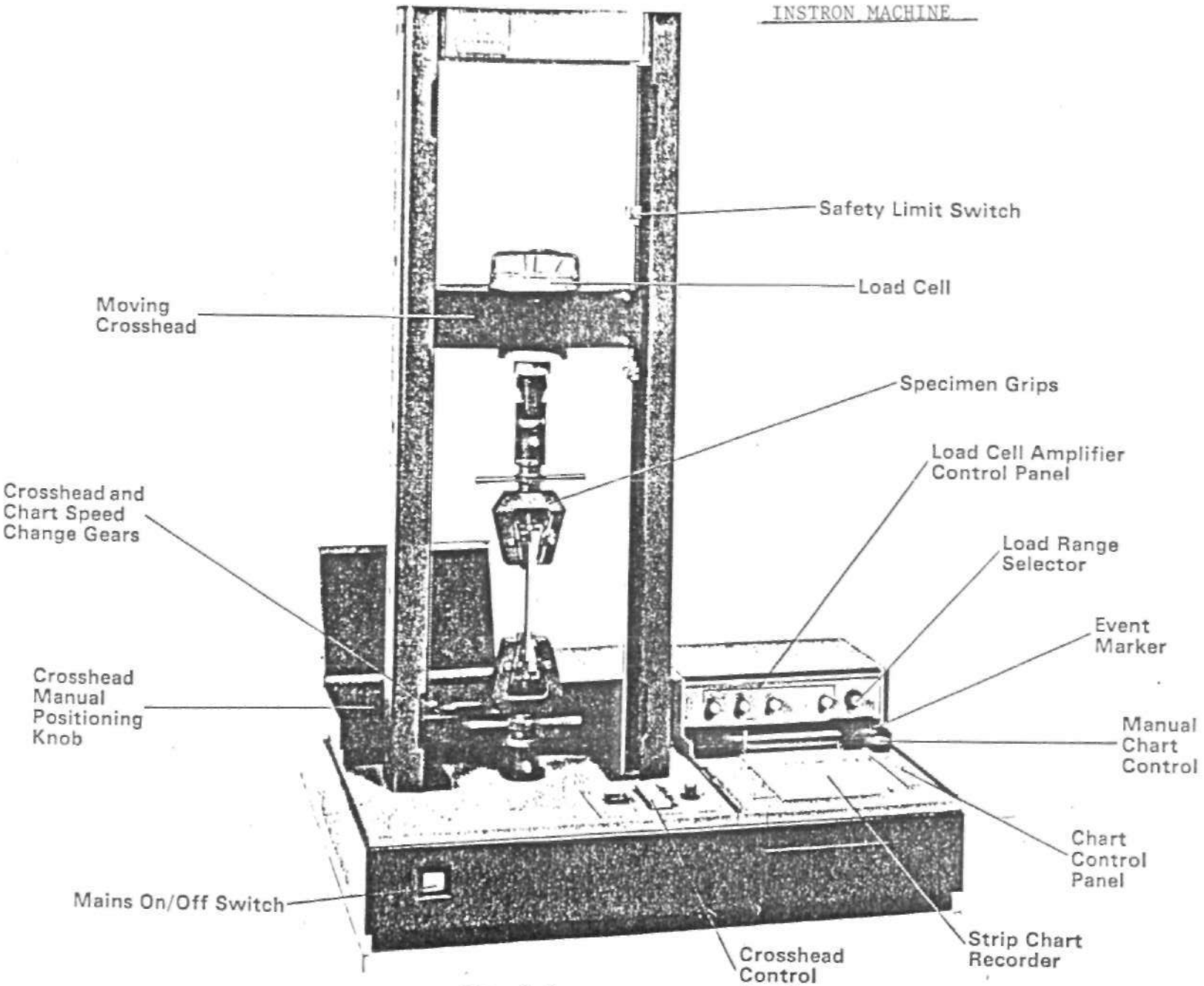


Fig. 3.2

3.4.8 Abrasion test

Method of assessment:

A Martindale Abrasion Tester was used to investigate the fabric abrasion resistance which was assessed in terms of number of abrasion cycles required to produce an end point, where at least two threads broke.

Both the abradant and the specimen preparation and mounting was carried out according to the procedure described by B.S. No. 11, 1974, and the abrasion of each specimen was performed under a load or pressure of 12 kpa.

Twenty test specimens of the same size were cut out randomly from each sample according to the test recommendation. Five abrasion tests were carried out on each sample; in each test four specimens of the fabric were mounted on the four heads of the tester. The same procedure was followed for grey and dyed fabric samples. Intermittent checkings were carried out to determine the end-point, especially on the first run. After each run the standard abradant fabric was replaced. All the tests were carried out under the same standard atmospheric conditions maintained in the testing laboratory.

3.4.9 Fabric bending length measurement

The bending stiffness of fabrics can be measured by many methods generally grouped into two classes:

(1) Those based on bending under the fabric's own weight, and

(2) Those involving forces and couples applied externally.

The simplest method in the first group is the cantilever test. This method has been modified and adopted as a standard method.[27]

The apparatus used is a Shirley Stiffness Tester (a fixed angle Flexometer, with the angle of drop constant at 41.5°). The method of operation is slightly different from that explained in B.S. 3356. The fabrics were conditioned under a standard atmosphere. Three samples both in warp and weft directions were cut to size, 2.5 cm x 20 cm, at different parts of the fabric randomly. A strip of fabric was clamped horizontally at one end in the flexometer, while the other end hung freely under its own weight. By moving the ruled slide horizontally until the angular deflection of the fabric touches the inclined plane, readings could then be taken. Four readings were taken for each sample by testing both ends of the strips and back and fronts of the fabric.

Unfortunately it was not possible to measure the grey fabric bending length. This was because of the curling that occurred, especially with the highly twisted ring-spun fabrics. A similar observation was made for rotor fabrics but to a lesser degree. An alternative approach in which the test samples were put under slight weight was tried; however this does not improve the situation to warrant any meaningful test, and was rejected since it was believed it might invalidate the results of the measurements. The tendency to curling might be due to twist levels and the nature of the component yarns, since the sized warp yarns were yet to be desized and were stronger. Despite this, efforts were made to calculate the grey and dyed fabric shear stiffness.

3.4.10 Colour Measurement

The strength of colour or depth of shade of dyed rotor and ring-spun fabric assessment was carried out using a Macbeth Colour Eye Spectrophotometer, which has an attached digital computer on which the readings are displayed and a pen recorder. The instrument was set and calibrated according to specifications.

The samples to be tested were folded and fixed onto the instrument as recommended. Ten readings were taken in each fabric direction (warp and weft). The average was also recorded for each sample.

Degree observer is 10°
Primary illuminant is D
Secondary illuminant is A
Colour difference formula - Lab.

CHAPTER 4

4. Results and Discussions

4.1 Properties of yarns used for weaving

The properties of the rotor and ring-spun yarns used in weaving the fabrics are summarised in Table 4.1 and further detail of these yarns are given elsewhere.[28]

TABLE 4.1

Conventional ring-spun yarn properties			
Twist factor dtex	Count (tex)	Tenacity (g/tex)	Extension
31.57	34.00	15.03	7.9
34.44	35.40	16.19	8.6
38.27	35.22	17.46	8.7
41.14	35.35	16.08	8.7
45.92	35.29	18.15	7.7
Rotor yarn properties			
Twist factor dtex	Count (tex)	Tenacity (g/tex)	Extension
32.53	34.69	6.31	5.10
36.35	35.36	10.69	7.80
39.22	35.01	11.80	7.90
41.14	35.12	11.76	7.90
45.92	34.64	13.03	8.50

4.2 Fabric specifications

4.2.1 Woven fabric width

During weaving, fabrics and their component yarns are subjected to applied tension under varying conditions, as a result of which there is an appreciable alteration in the fabric dimensions when it is removed from the loom. This is particularly noticeable in the weft direction. This is due to the gradual recovery from the imposed strains and stresses, including the effect of crimp interchange which is perhaps influenced by yarn character. In order to define other additional parameters that influence fabric performance, the fabric cover factors were also determined.

The results are presented in Table 4.2 from which it may be observed that the contraction of the relaxed fabric in the weft direction decreases with increase in twist factor for both ring and rotor-spun fabric. At lower twist levels rotor-spun yarn fabrics have higher width contraction than their ring equivalents; but at the highest twist level employed the rotor fabric shows slightly lower contraction. The possible reasons for the differences in contractions may be attributed to the structure of the yarns and the nature of the crimp interchange that occurs to bring the fabric to a more stable state. As may be seen in the next section, the lower twist levels have higher weft crimp, thus producing greater reductions in cloth width. Therefore the changes in cloth dimension off the machine may be related to the crimp. In addition, the applied tensions during weaving might also be a contributing factor since it is likely that the yarns have different responses to tensions due to their different extensibilities. It may then be assumed that the effect of tension applied is greater on rotor yarns, which is shown to be less extensible (Table 4.1).

TABLE 4.2

FABRIC WIDTH

(a) Ring-spun fabric

Twist factor dtex	(cm)	(cm)	(cm)	Average width (cm)
32.57	113.80	113.60	113.20	113.50
34.44	113.60	114.00	113.50	113.70
38.27	114.20	113.40	113.20	113.60
42.14	114.20	113.90	113.50	113.90
45.92	113.90	114.20	114.20	114.10

(b) Rotor-spun fabric

Twist factor dtex	(cm)	(cm)	(cm)	Average width (cm)
32.53	113.30	113.10	113.20	113.20
36.35	113.40	113.40	113.00	113.30
39.22	113.50	113.70	113.40	113.50
41.14	112.90	112.70	113.50	113.00
45.92	119.00	113.50	113.10	115.20

Comparing the fabric width to the original reed width, it is shown that about 9 - 11% contraction has taken place generally in both fabrics.

4.2.2 Cover factor

The cover factor of a woven fabric is defined as "the ratio of the area of fabric which is occupied by the yarn within a unit cell of fabric to the area of the unit cell".[25,26]

When considering the warp and weft covers (Figs. 4.1 and 4.2) it may be seen that in general the cover increases with increase in twist factor, this being true for both dyed and grey fabrics. The trend is more obvious with the ring spun grey fabric, while for rotor grey fabric the trend appears to vary as twist factor increases.

Table 4.4 and Figure 4.3 show that the cover factors (calculated as shown in Appendix 1) increases with increase in twist factor for both ring and rotor fabrics. In the grey state the rotor fabrics show better over-all fabric cover than the corresponding ring-spun fabric. This could be attributed to the higher specific volume of rotor-spun yarns which is claimed[2,8,29] to be about 10% greater than their ring equivalents. When considering grey fabric, it may be observed that at low twist factors the rotor yarn appears to give better cover than the ring, whilst at high twist factors the ring yarn is better. This, perhaps, shows that at a lower twist factors yarn bulkiness is a major contribution to the cover, but at higher twist levels the threads per centimetre are more critical (i.e. high twists giving more compact threads, thus permitting more threads per unit area). The effect of weft twist on the warp cover shows that the rotor fabric has better warp

cover in the grey state than the equivalent ring fabric.

The situation, however, is reversed in the dyed fabric. The dyed ring fabric has better fabric cover than the equivalent rotor fabric. For both fabrics the cover increases as the amount of twist increases. The reasons for the better ring cover in the dyed state could be attributed to the fact that rotor yarns are spun under lower tensions and there is a considerable degree of stress relief during spinning operations. During aqueous treatment the opening of the yarn is not to the same extent as the ring yarn because there is less strain to be released. Before the treatment the yarns are more bulky than equivalent ring yarns because of a fairly large percentage of hooked and folded fibres, but they are not much more bulkier after dyeing, hence the reduced cover factor when compared with equivalent ring fabrics.

The cover factor for both dyed fabrics is greater than the grey state, the increase being about 2.8% at higher twist factor and 4.5% at lower twist factors. It is interesting to note that for ring weft cover the increment follows a descending order, whereas the rotor weft cover initially follows an ascending order and then falls away. The rotor fabrics have better warp cover in the dyed state than their ring equivalents. In general the warp cover appears to pass through a maximum value as the twist factor is increased, and this is true for both types of yarn.

The twist factor 41.14 may be considered the optimum twist level for ring dyed fabric; it has the maximum cover at this point, further increase in twist decreasing the fabric cover. No optimum values seem to be established for the rotor fabric within the twist range used,

which perhaps indicates that a further increase will increase the fabric cover. It should be observed from Fig. 4.3 that the difference in the fabric cover for both rotor and ring fabrics is only slight. However, the rotor has better fabric cover in the grey state and lower in the dyed state when compared to its equivalent ring fabric, and the fabric cover is greater in the dyed state than in the grey state for both fabrics.

TABLE 4.3

THREAD COUNT

(a) Ring spun fabric

GREY FABRIC			DYED FABRIC	
Twist factor α_{tex}	Ends/cm	Picks/cm	Ends/cm	Picks/cm
31.57	15.98	19.96	16.97	21.26
34.44	16.14	20.08	17.24	21.26
38.27	15.91	20.35	17.24	21.26
42.14	15.98	20.47	17.13	21.54
45.92	15.98	21.10	17.13	21.46

(b) Rotor spun fabric

GREY FABRIC			DYED FABRIC	
Twist factor α_{tex}	Ends/cm	Picks/cm	Ends/cm	Picks/cm
32.53	16.14	20.55	17.05	20.94
36.35	26.14	20.55	17.24	20.94
39.22	15.98	20.43	17.44	21.18
41.14	16.06	20.12	17.20	21.34
45.92	16.38	21.06	17.24	21.50

TABLE 4.4

FABRIC COVER

(a) Ring-spun fabrics

Twist factor / tex	GREY FABRIC			DYED FABRIC		
	K_1	K_2	K_f	K_1	K_2	K_f
31.57	0.366	0.445	0.650	0.389	0.474	0.679
34.44	0.370	0.457	0.658	0.395	0.483	0.687
38.27	0.365	0.462	0.658	0.395	0.482	0.687
41.14	0.366	0.465	0.661	0.393	0.489	0.690
45.92	0.366	0.479	0.670	0.393	0.487	0.689

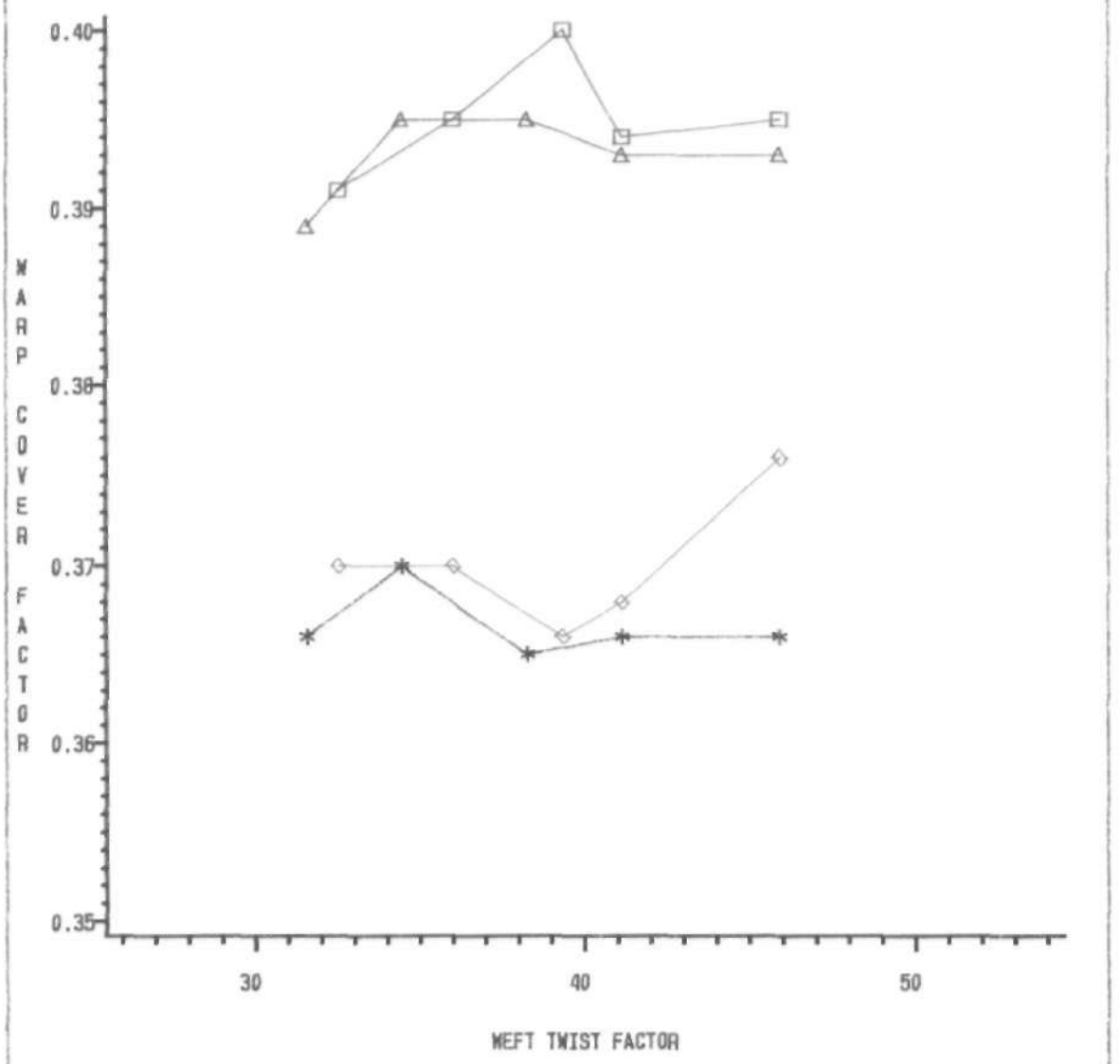
The cover factors are calculated as shown in Appendix II.

(b) Rotor-spun fabrics

Twist factor / tex	GREY FABRIC			DYED FABRIC		
	K_1	K_2	K_f	K_1	K_2	K_f
32.53	0.370	0.463	0.661	0.391	0.471	0.678
36.35	0.370	0.467	0.664	0.395	0.476	0.683
39.22	0.366	0.462	0.659	0.400	0.479	0.687
41.14	0.368	0.463	0.660	0.394	0.483	0.687
45.92	0.376	0.474	0.671	0.395	0.484	0.688

Fig 4.1

WARP COVER FACTOR VS TWIST FACTOR



RING GREY FABRIC

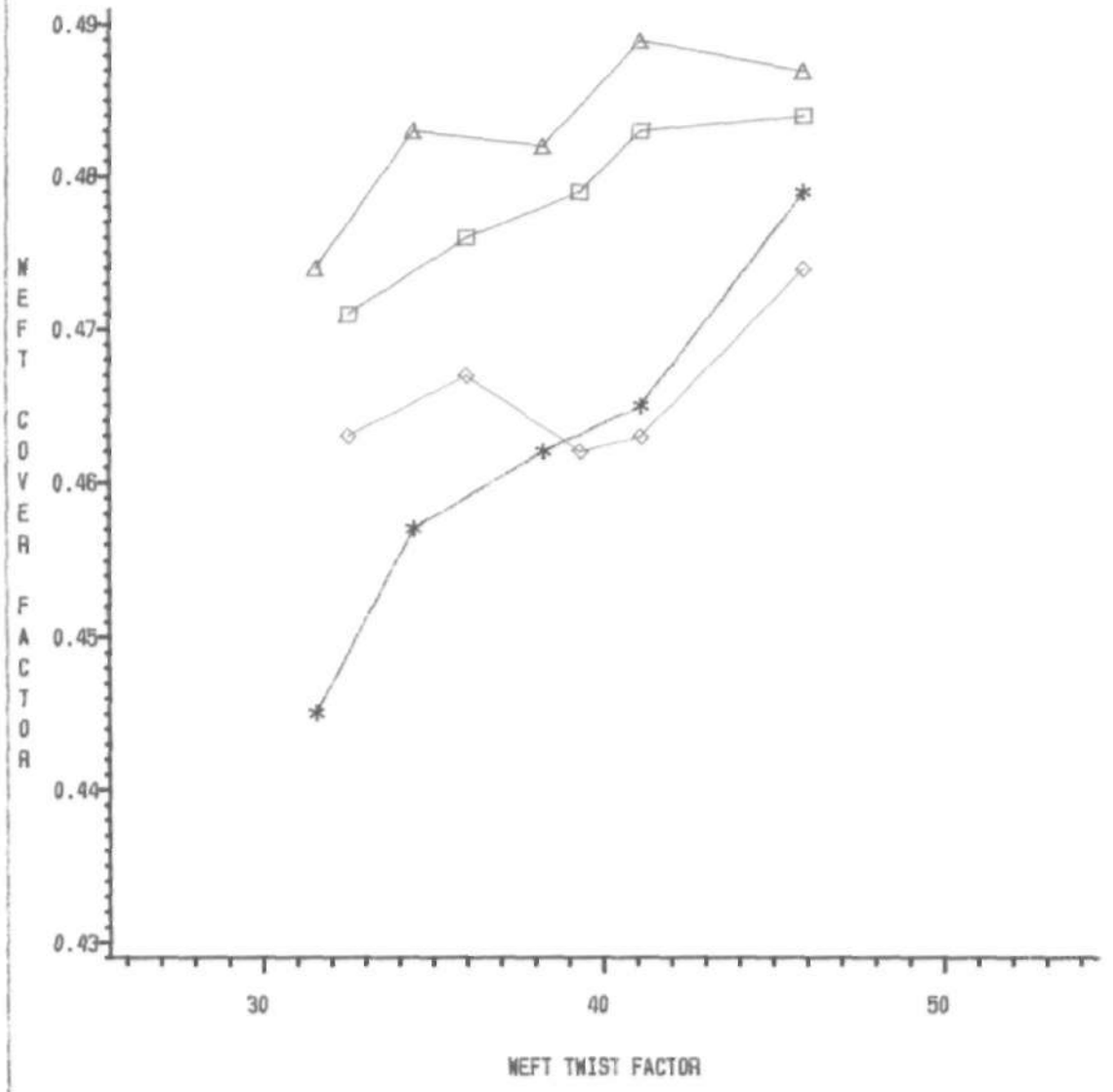
ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

Fig 4.2

WEFT COVER FACTOR VS TWIST FACTOR



RING GREY FABRIC

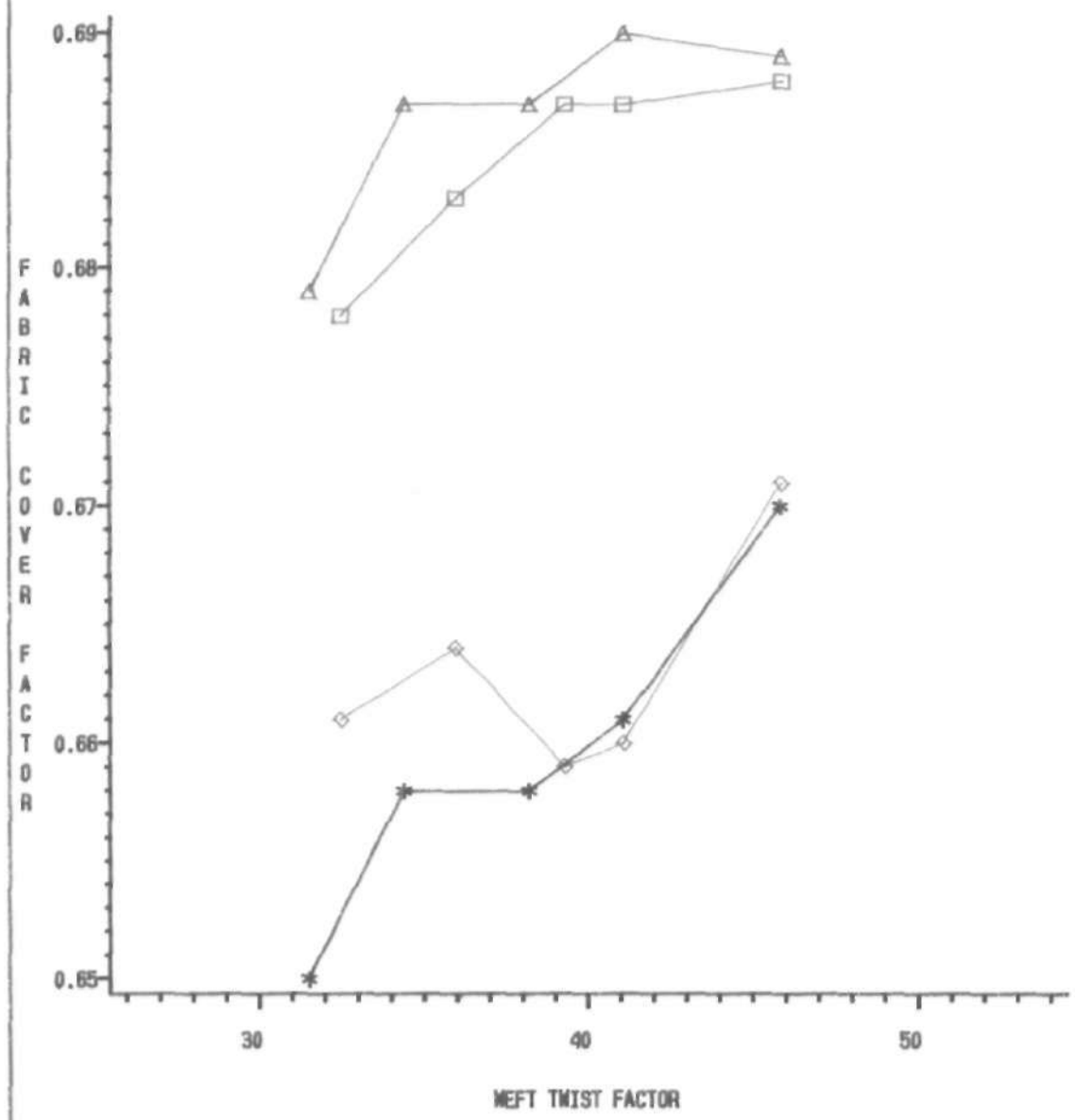
ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

Fig 4.3

FABRIC COVER FACTOR VS TWIST FACTOR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

4.2.3 Crimp

Yarn crimp in a woven fabric is an important parameter in the design of fabrics for particular end-uses, and is known to affect fabric characteristics and behaviour. Crimp results from the fact that the yarns are interlaced to form a fabric. This interlacing of warp and weft yarns imposes crimp on both yarns, resulting in an effective decrease in yarn length in the fabric.

It may be observed from the results in Table 4.5 and Figs. 4.4 and 4.5, that the weft crimp is generally higher than warp crimp for both fabrics. Crimp in either direction of a fabric is claimed[1,8] to be dependent on the fabric structure, but it is also largely affected by the yarn count and the thread density. The tensions to which the yarns are subjected during weaving and yarn swelling on dyeing are also believed to play a significant role in determining the amount of crimp in the yarn.

The warp yarns are generally under a higher tension and in the current experiment the warp yarns are thicker and perhaps also stiffer (due to applied size) than the weft yarns. This might give the weft yarn a greater amount of crimp since it has to bend round all warp yarns simultaneously, whilst each warp yarn is bending around only one weft yarn during any one beat-up.

It may be seen in Table 4.5 and Fig. 4.4 that the warp crimp generally increases with increase in weft twist factor for both fabrics. The loom state warp crimp is generally higher with the ring-spun weft than with the rotor spun weft, even though a "common warp" was employed. The reason may be that the rotor yarns, whilst being comparatively thicker, are also more compressible, thus yielding more under the warp

TABLE 4.5

CRIMP

(a) Ring fabric

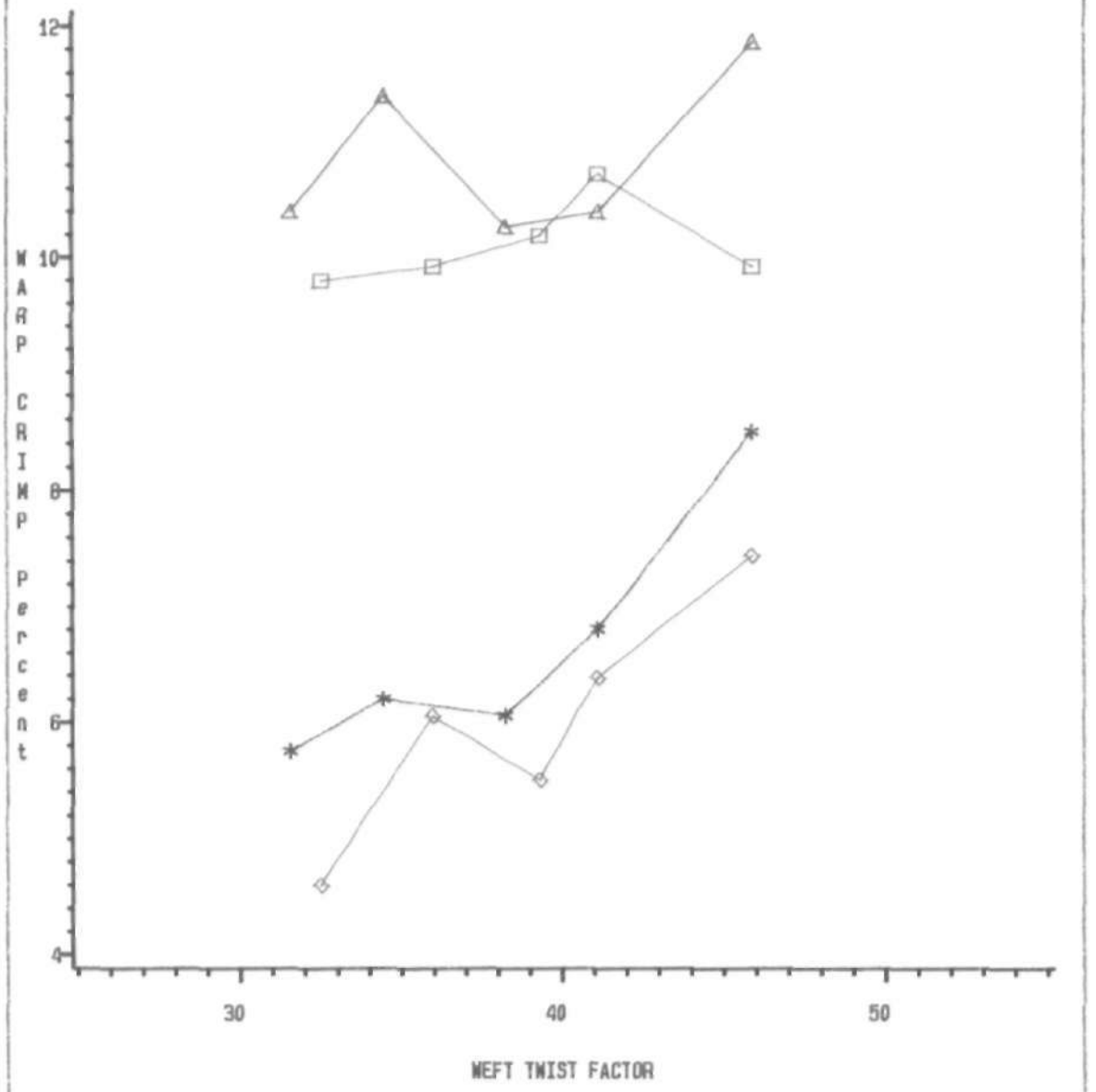
Twist factor dtex	GREY FABRIC		DYED FABRIC	
	Warp (%)	Weft (%)	Warp (%)	Weft (%)
31.57	5.75	13.03	10.40	22.13
34.44	6.20	12.17	11.40	21.27
38.27	6.05	12.27	10.27	19.47
41.14	6.80	11.33	10.40	18.47
45.92	8.50	10.67	11.87	20.93

(b) Rotor fabric

Twist factor dtex	GREY FABRIC		DYED FABRIC	
	Warp (%)	Weft (%)	Warp (%)	Weft (%)
32.53	4.60	10.73	9.80	20.00
36.35	6.05	11.90	9.93	22.20
39.22	5.50	11.53	10.20	21.67
41.14	6.38	11.60	10.73	20.07
45.92	7.45	10.80	9.93	18.07

Fig 4.4

WARP CRIMP VS TWIST FACTOR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

tension and hence giving a lower warp crimp. This explanation is further strengthened by the observed lower weft crimp at lower twist levels, and slightly higher crimp values at higher twist levels (i.e. as twist increases, weft yarn becomes less compressible).

It appears from Fig. 4.5 that for the grey fabric with the ring-spun weft, crimp generally decreases with an increase in the weft twist factor. Apart from an initial increase in weft crimp with twist, the rotor-spun weft gives a similar trend. The rotor weft tends to give lower crimp than the ring weft at a low twist factor, but the difference in weft crimp between the two fabrics becomes smaller as twist increases. The difference could be attributed to compressibility and extensibilities of the yarns (i.e. at low twists the rotor yarn is more extensible) which changes as twist increases. At higher twist factors both the yarns become harder but more extensible, thus giving lower crimp values.

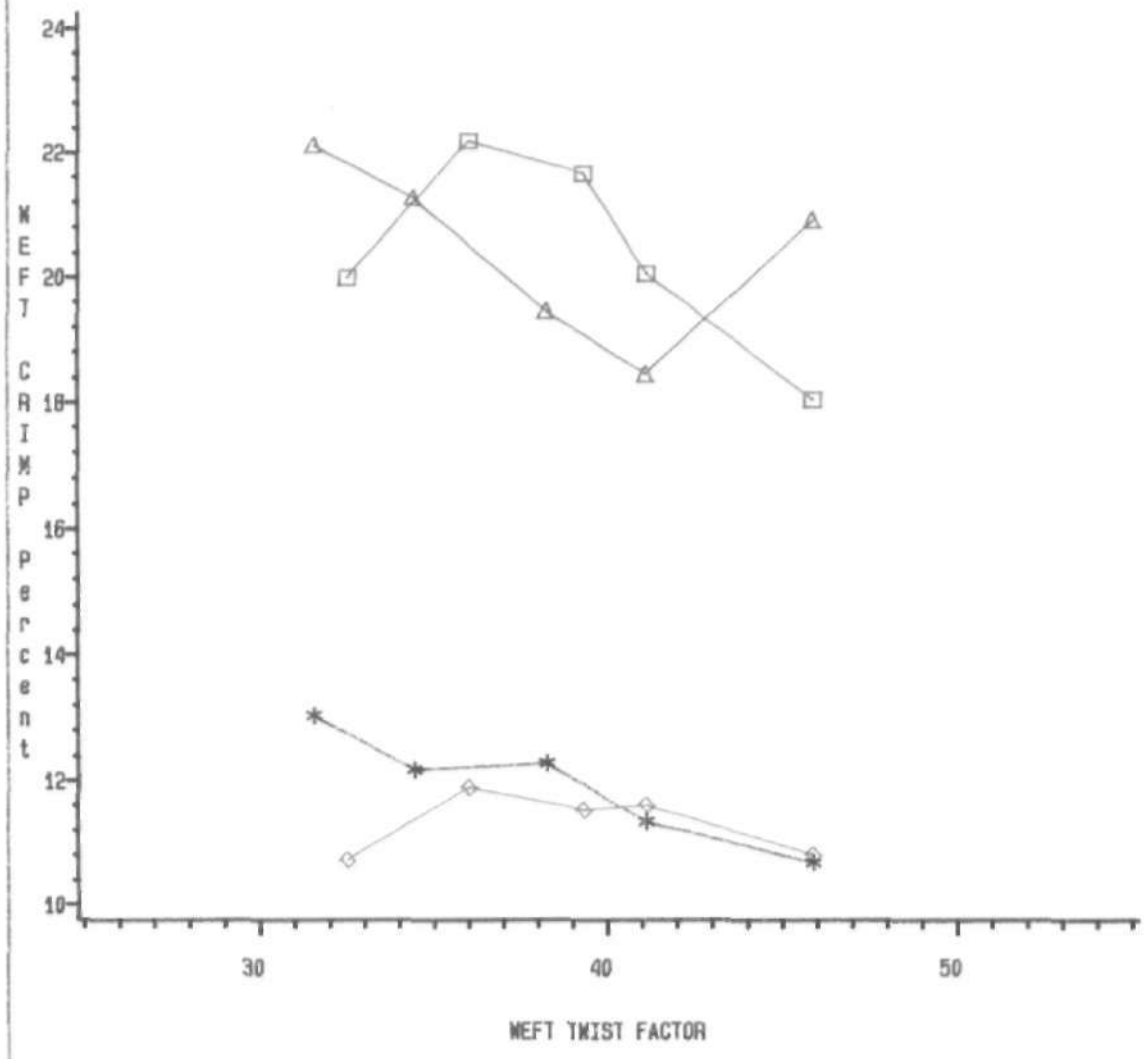
The dyed fabrics showed a general decrease in weft crimp as the weft twist factor increased, and had much higher weft crimp than the loom state fabrics.

The effect of tensions applied during weaving may also play a role in the general crimp behaviour. It has been shown elsewhere[1] that the distribution of crimp is largely affected by the tension applied during weaving, which is usually affected by the indeterminate geometrical shape of yarns and their elastic properties which do not strictly obey Hooke's Law. In addition, the behaviour of the yarns differs in the free state and when trapped in the fabric by pressures applied to the yarn by the rest of the fabric. These factors may account for the deviations observed in the results.

It may be important to note that the nature of crimp interchange

Fig 4.5

WEFT CRIMP VS TWIST FACTOR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

is also complex in that during relaxation of the fabrics they tend to return to their most stable state. Thus, as may be seen in Table 4.5, a lower crimp in one direction is balanced by a higher crimp in the other fabric direction. This may be seen in Fig. 4.4 and Fig. 4.5, that whilst the warp crimp is increasing the weft crimp is decreasing with increase in weft twist. With certain structures a complete interchange may not be possible and thus the maximum crimp achieved for a particular group of yarns may differ.

There is a considerable increase in the crimp values, in both warp and weft directions, of the two fabric samples after dyeing, this being 33 - 146% and 67 - 88% for rotor warp and weft crimp respectively, whilst the ring has an increase of about 39 - 83% and 59 - 97% for warp and weft respectively. The greater increase in rotor fabric weft crimp may substantiate the fact that rotor yarns are most sensitive to changes in the applied tensions during dyeing treatment, and may therefore require more precision in setting during weaving, and a slightly different finishing technique to the ring-spun fabric.

4.2.4 Fabric shrinkage

A textile fabric is required to satisfactorily maintain its dimensions throughout its useful life. The dimensional changes that usually occur are brought about by fabric shrinkage, especially when subjected to washing treatments. Therefore a fabric would have great technical merit if it could maintain its dimensions at a desired level.

The phenomenon of dimensional change after aqueous treatment of woven fabrics has been attributed[30] to the fibre swelling, which causes the interlocking yarns to become more curved and thus produces area

shrinkage. Therefore, the shrinkage of fabric is mainly due to yarn swelling and perhaps the resulting increase in crimp that simultaneously takes place. The shrinkage that usually takes place in cotton yarns on swelling has been attributed to arise from two sources:[13] the true swelling or extension into space of fibres; and secondly, the changes in length arising from the release of mechanical strains in the fibres. The latter is as a result of the inevitable extension suffered by the fibres during the spinning process.

It may be seen from Table 4.6 that the % warp, weft and area shrinkages varies with increase in weft twist for both fabrics. It is obvious from this table that the rotor and ring fabrics have slightly different shrinkage values in both fabric directions. It may be seen (Table 4.6 and Fig. 4.6) that the scoured fabrics seem to indicate generally that fabrics produced with the rotor-spun weft have higher % shrinkage in both fabric directions and in the over-all % area shrinkage than the equivalent ring fabrics (Fig. 4.6). When the fabric is dyed, however, the rotor fabrics showed slightly lower values for % weft and area shrinkage at low twist levels, but higher values at higher twist levels. Generally, the % weft shrinkage passes through a maximum (Figure 4.6 and Fig. 4.7) and then starts decreasing with increase in weft twist factor. This observed trend may be attributed to the penetration of the scouring and dyeing liquor which is likely to be insufficient at higher twist levels, since yarn compactness increases with increase in twist. This may offer resistance to fibre swelling of the core fibres in the yarn samples.

As for the other trends observed for both fabrics, the yarn structural differences may be responsible for this behaviour. The results

TABLE 4.6

SHRINKAGE MEASUREMENT

(a) Ring-spun fabrics

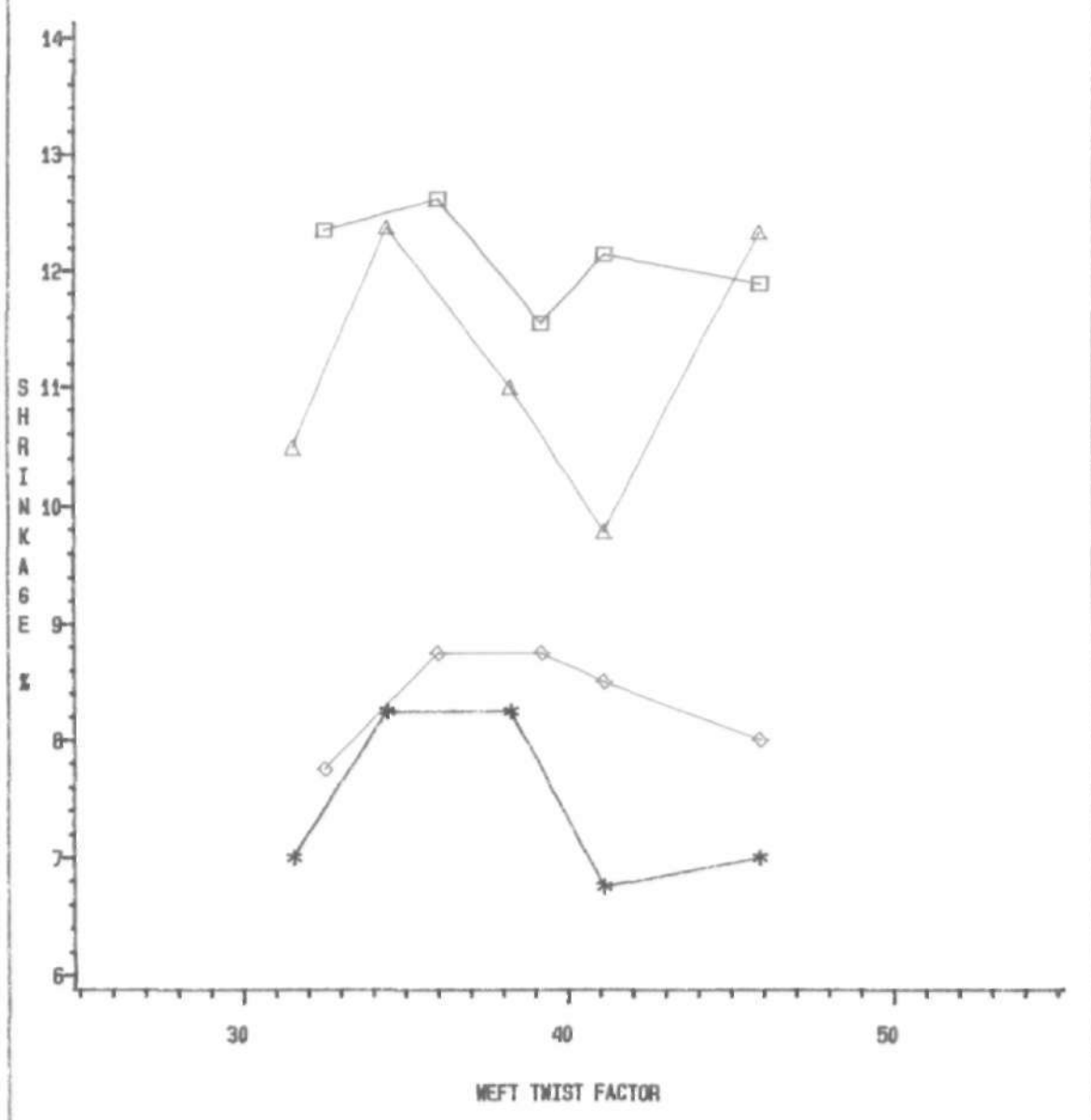
Twist factor α_{tex}	Grey Fabric			Dyed Fabric		
	Warp (%)	Weft (%)	Area (%)	Warp (%)	Weft (%)	Area (%)
31.57	3.75	7.00	10.49	5.20	8.20	12.98
34.44	4.50	8.25	12.38	6.50	9.00	14.91
38.27	3.00	8.25	11.00	4.20	8.50	12.34
41.34	3.25	6.75	9.78	4.00	6.00	9.76
45.92	5.75	7.00	12.35	5.70	7.50	12.77

(b) Rotor-spun fabrics

Twist factor α_{tex}	Grey Fabric			Dyed Fabric		
	Warp (%)	Weft (%)	Area (%)	Warp (%)	Weft (%)	Area (%)
32.53	5.00	7.75	12.36	4.50	7.70	11.85
36.35	4.25	8.75	12.63	5.00	9.00	13.55
39.22	2.75	8.75	11.56	3.50	9.50	12.67
41.14	4.00	8.50	12.16	4.50	8.50	12.62
45.92	4.25	8.00	11.91	4.70	8.80	13.09

Fig 4.6

FABRIC SHRINKAGE Vs TWIST FACTOR



RING WEFT SHRINKAGE

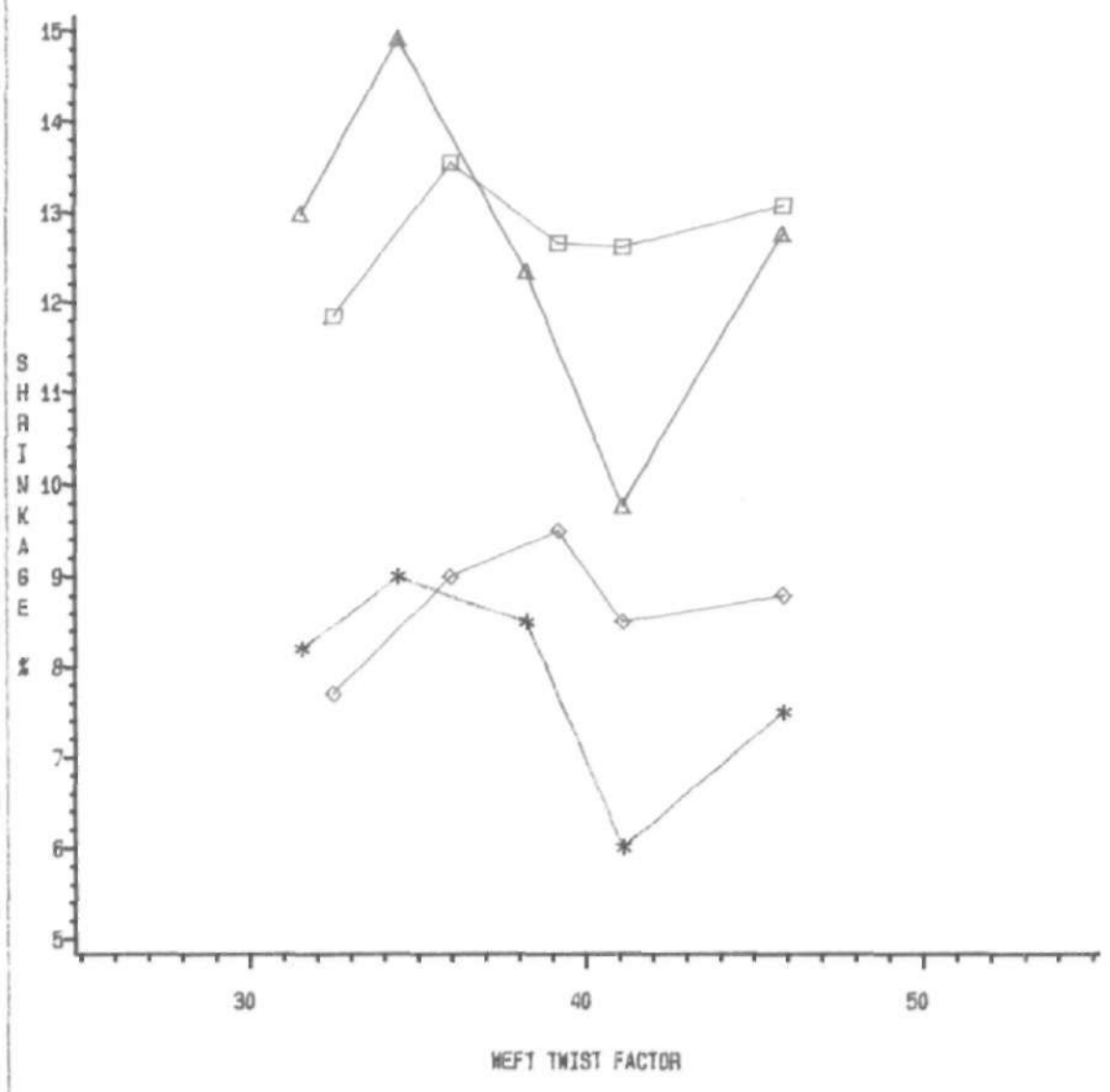
ROTOR WEFT SHRINKAGE

RING AREA SHRINKAGE OF SCOURED FABRIC

ROTOR AREA SHRINKAGE OF SCOURED FABRIC

Fig 4.7

FABRIC SHRINKAGE Vs TWIST FACTOR



RING WEFT SHRINKAGE

ROTOR WEFT SHRINKAGE

RING AREA SHRINKAGE OF DYED FABRIC

ROTOR AREA SHRINKAGE OF DYED FABRIC

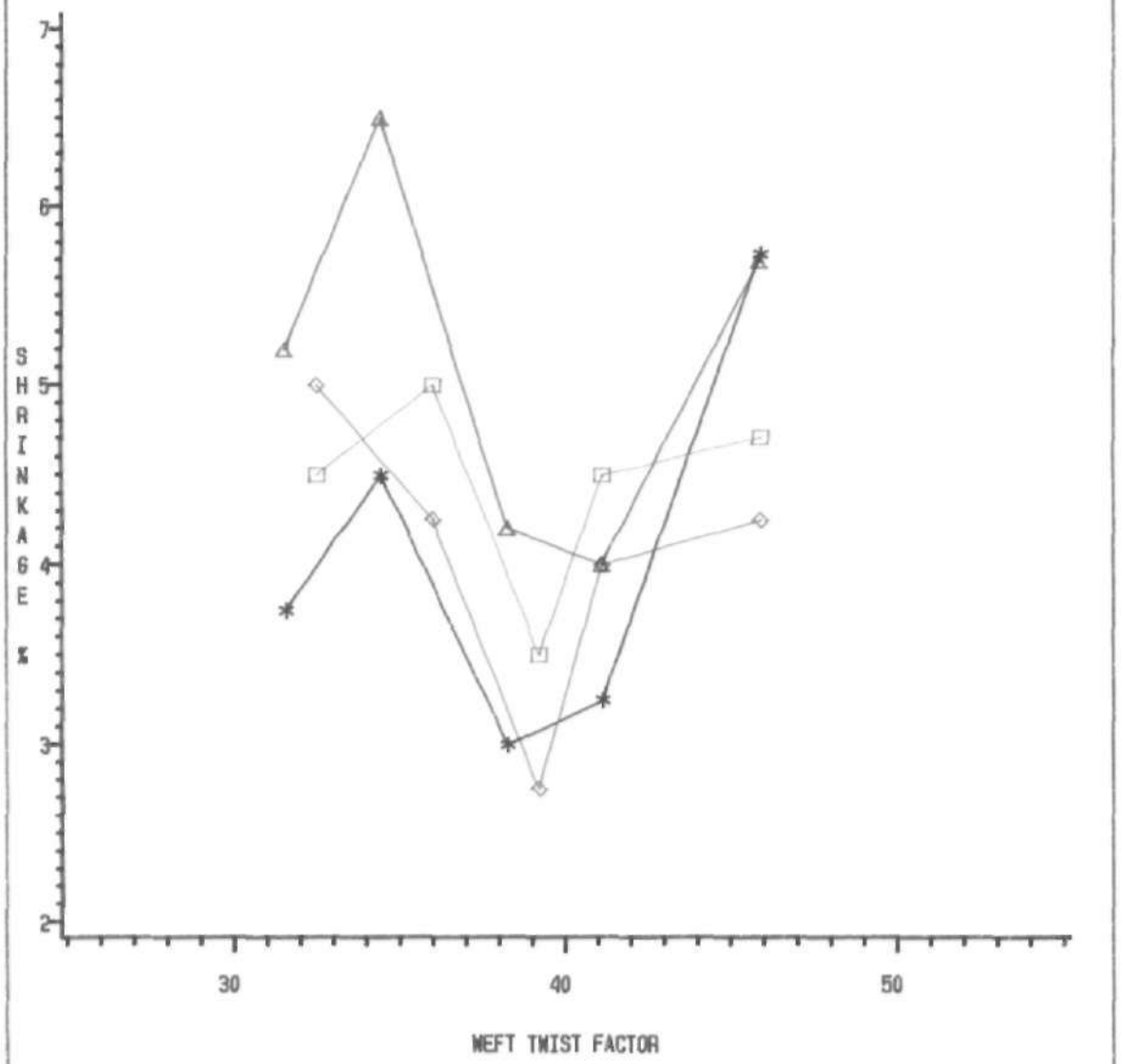
obtained for the % shrinkage after dyeing (Fig. 4.7) may be related to Fig. 4.5, where a similar trend is followed for the results in crimp testing. Fig. 4.9 seems to suggest that % crimp achieved in a fabric may be related to the % shrinkage obtained afterwards. Therefore the higher % shrinkage for rotor fabrics, especially at higher twist levels, may be as a result of higher crimp. It may thus be concluded that in addition to fibre swelling and mechanical strain releases, the yarn compressibility and extensibilities governing crimp may also be taken into account for the amount of shrinkage that may result.

The nature of crimp interchange is a general determining factor also, since it may be observed that % warp shrinkage is slightly higher for ring fabrics than rotor fabrics (Fig. 4.8), thus resulting in the lower % weft shrinkage for ring fabrics. Ring fabrics, having relatively higher crimp in the loom state, may be said to reach a "critical crimp balance" earlier than rotor fabrics - hence the lower values obtained.

The slight deviations in the results may also be attributed to the complicated nature of the interactions of the component warp and weft yarns. It is possible that the somewhat over-all higher % weft and area shrinkages for rotor fabrics may be associated with the presence of wrapper fibres on the yarn surface, which may result in a reduced amount of slippage in the fabrics, but it is obvious that further work in this area would be necessary before any definite conclusions could be reached.

Fig 4.8

FABRIC SHRINKAGE Vs TWIST FACTOR



RING WARP SHRINKAGE (SCOURED)

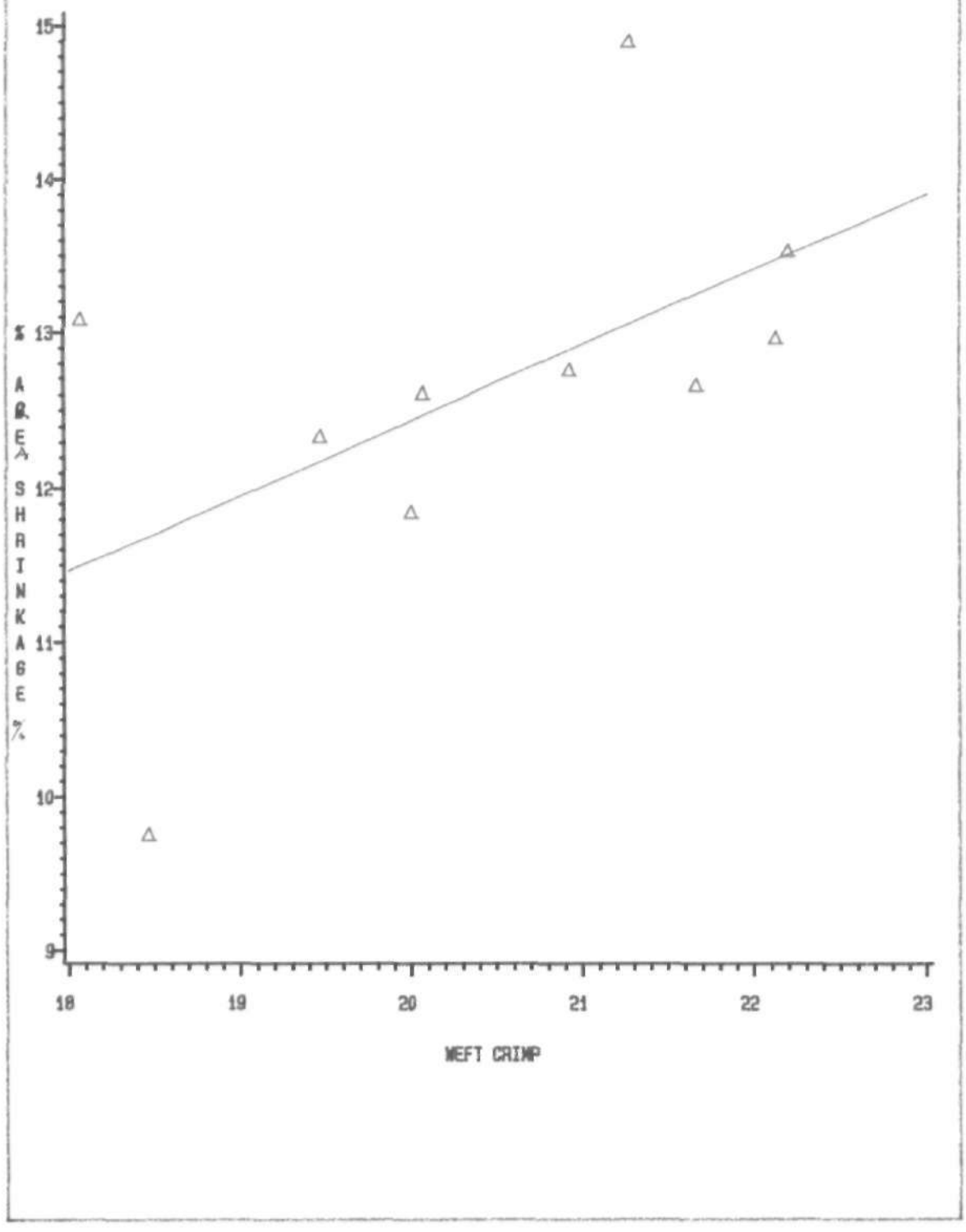
ROTOR WARP SHRINKAGE (SCOURED)

RING WARP SHRINKAGE (DYED)

ROTOR WARP SHRINKAGE (DYED)

Fig 4.9

INFLUENCE OF CRIMP ON FABRIC SHRINKAGE



4.2.5 Thickness of the woven fabric

Fabric thickness[1,25] is important in the study of other fabric characteristics such as thermal insulation, resilience, dimensional stability, fabric stiffness, abrasion, etc. The thickness of a woven fabric is usually regarded[1] as being independent of the number of threads per unit length, but dependent on the degree of crimp interchange between different groups of warp and weft threads, and the yarn diameter or bulk densities of the yarn. The fabric thickness is, however, at its minimum when the crimp is most evenly distributed between all yarns, and increases with increasing inequality of the crimp distribution.

The results in previous sections have shown that due to the difference in the structure of rotor and ring-spun yarns, they differ in yarn bulk and the manner in which the crimp interchange occurs in the woven fabric, and this is reflected in the differences in the fabric thickness, shown in Table 4.7. It may be seen that for the grey fabric the thickness measured under one pound per square inch, decreases with increasing twist, and then levels off, whereas the rotor fabric tends to increase in thickness with increasing twist and then levels off (Fig. 4.10). Both of the dyed fabrics exhibited the same sort of trend when fabric thickness was plotted against twist (i.e. fabric thickness passed through a maximum value at a twist factor of 39.35 and 38.27) (Fig. 4.10).

In order to evaluate the compressibility of the fabric, the thickness was also measured under a higher load of 5 lb/sq.in. It may be observed that, under this higher load, twist appears to have little effect on the thickness of grey fabrics, but the thickness of the dyed

TABLE 4.7

FABRIC THICKNESS

(a) Ring fabrics

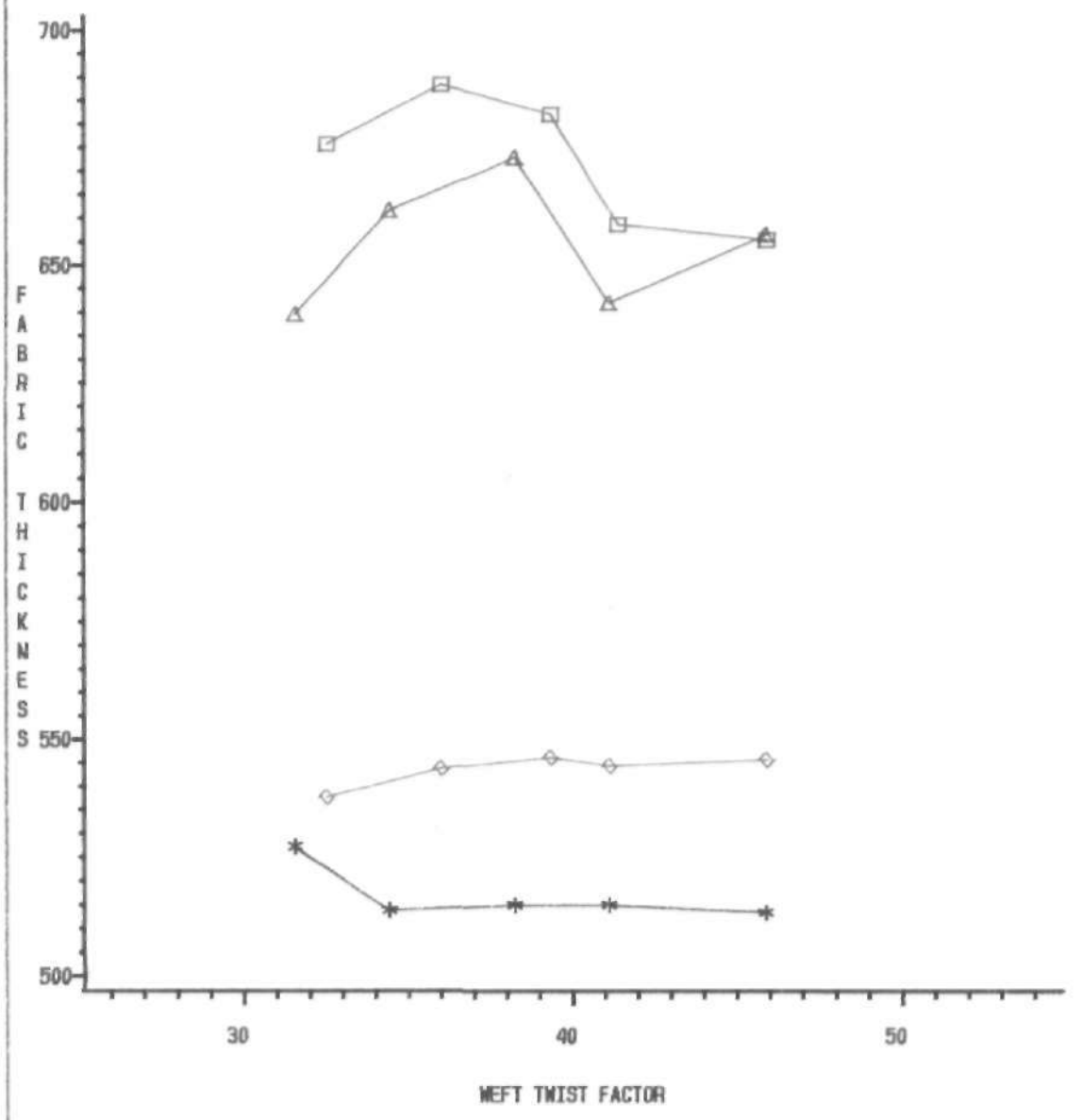
Twist factor α_{tex}	Grey fabric			Dyed fabric		
	Under 1lb pressure x 10^{-3} (mm)	5 lb pressure x 10^{-3} (mm)	Fabric compress-ibility (%)	1 lb pressure x 10^{-3} (mm)	5 lb pressure x 10^{-3} (mm)	Fabric compress-ibility (%)
31.57	527.05	455.93	13.50	639.57	572.77	10.44
34.44	513.59	462.79	9.90	661.67	574.04	13.24
38.27	514.86	456.44	11.30	673.10	579.12	13.96
41.14	514.86	455.93	11.40	642.11	562.02	12.47
45.92	513.08	455.42	11.20	656.59	568.96	13.35

(b) Rotor fabrics

Twist factor α_{tex}	Grey fabric			Dyed fabric		
	1 lb pressure x 10^{-3} (mm)	5 lb pressure x 10^{-3} (mm)	Fabric compress-ibility (%)	1 lb pressure x 10^{-3} (mm)	5 lb pressure x 10^{-3} (mm)	Fabric compress-ibility (%)
32.53	537.46	467.61	13.00	675.64	586.23	13.23
36.35	543.81	465.84	14.30	688.34	593.85	13.73
39.22	546.10	468.63	14.20	681.99	584.20	14.34
41.14	544.32	468.45	13.90	658.62	574.04	12.84
45.92	545.59	469.90	13.90	655.32	573.53	12.48

Fig 4.10

FABRIC THICKNESS VS TWIST FACTOR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

fabric still passes through a maximum as twist is increased. It is obvious from the results presented that, apart from the dyed fabric produced from the highest twist ring-spun weft, in all cases rotor-spun yarns give a thicker fabric. Similarly, in general it can be concluded that rotor-spun yarns produce a more compressible fabric than ring-spun yarns (Fig. 4.11).

It was difficult to find any satisfactory explanation for the differences in trends exhibited by the grey and dyed fabrics (both ring and rotor) since whilst the grey fabric thickness seems to be relatively unaffected by twist, the dyed fabric thickness is clearly influenced by twist.

The variations observed may not be surprising because the results obtained by workers on yarn thickness in their free state led to different views and opinions. However, it has generally been stated that the degree of twist has its effect on the yarn cross-section which could produce a tightly packed yarn or loosely packed one, the nature of packing having its effect on the yarn compression. One of the views[31] says that yarn diameter increases as twist increases, whilst the opposite view[32] shows that at a low pressure the situation is more complex and the yarn thickness can increase, decrease or remain unaltered as twist increases. Other workers[33] investigating the effect of twist on yarn cross-section have shown that the thickness of a continuous filament yarn decreases with increase in twist up to "critical twist", then starts to increase again. This behaviour was attributed to the fact that perhaps the filaments are loosely packed at low twist and as twist increases the air space between filaments decreases, resulting in the reduction of yarn diameter. The helix

path followed by each filament about the yarn axis is affected as more twist is inserted, thus giving an elliptical yarn cross-section. The extent of ellipticity increases from zero at the centre to maximum at the outside, leading to an increase in yarn diameter. This behaviour in the yarn state perhaps is a major contributing factor to the slight deviations or the general trend observed; the warp yarns might also influence the results.

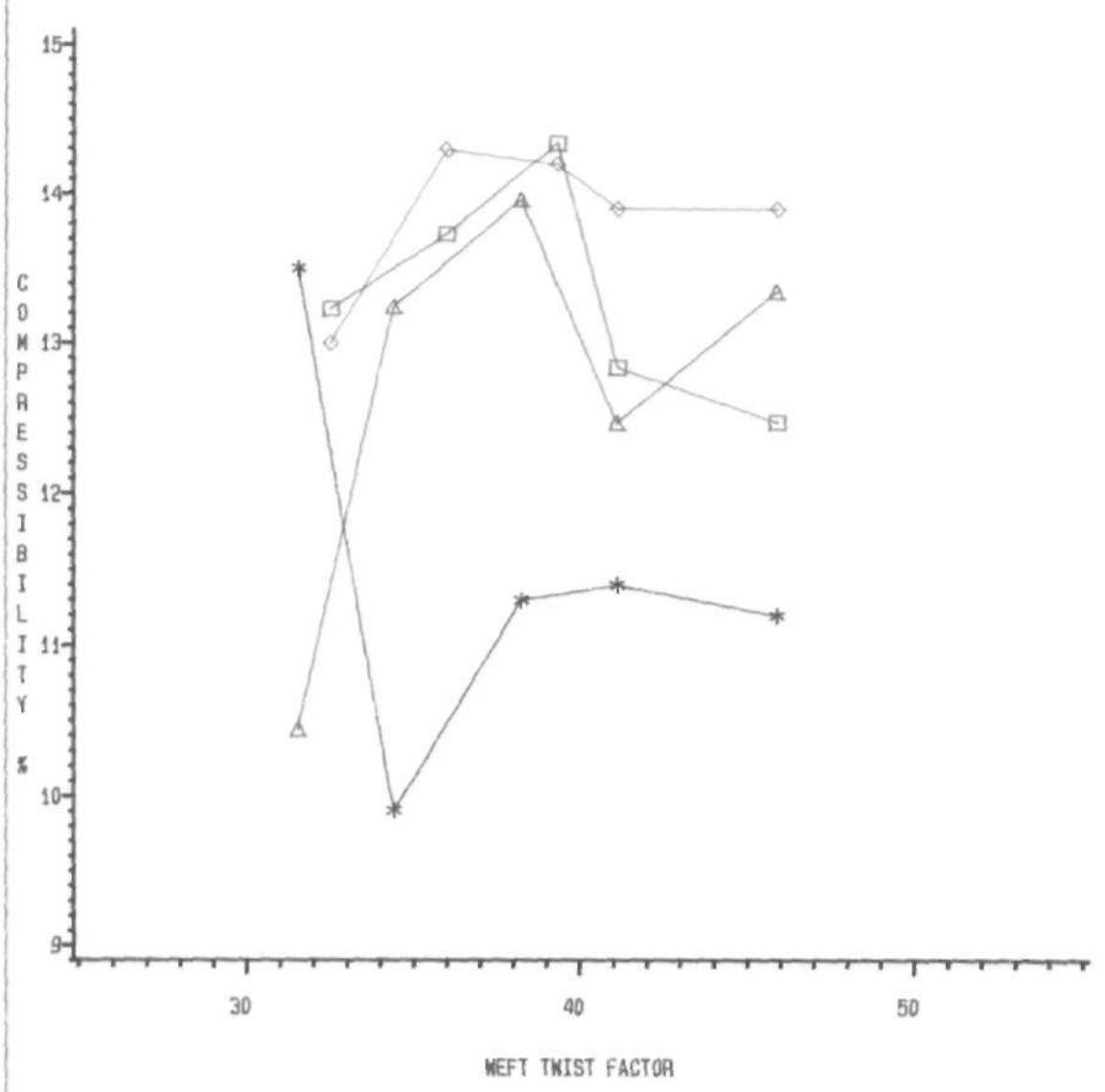
The main feature of the results obtained is that it has succeeded in showing that rotor fabrics have greater fabric thickness than their equivalent ring-spun fabrics. The structural differences in the yarn could be responsible for this; the rotor yarn is bulkier, it contains entangled and folded fibres and also low fibre tensions in spinning. The nature of crimp interchange and its distribution might also have some effect on the fabric thickness generally.

The thickness of both rotor and ring fabrics are generally increased after dyeing. This is as a consequence of shrinkage, increase in crimp and fibre swelling, which effectively alters the fabric dimensions.

It has been shown[32] as mentioned earlier, that twist is the most important factor influencing yarn thickness and compression, producing either loosely or tightly packed yarn. It may be seen in Table 4.6 that a thick fabric is easily compressible, implying that it has lower initial compression modulus.

Fig 4.11

FABRIC COMPRESSIBILITY VS TWIST FACTOR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

4.3 Air Permeability

Air permeability of textile fabrics is a means of assessing the serviceability of the fabrics for different end-uses. The manner in which yarns are interlaced in a woven fabric allows the presence of air space. The distribution of these air spaces influences many of the fabric properties, such as warmth, protection against wind and rain in clothing and some industrial uses. The air permeability has been defined[26] as "the volume of air, measured in cubic centimetres, passed per second through one square centimetre of fabric at a pressure of 10 mm of water". The permeability to air of fabrics is, however, a complex property that depends on many characteristics such as fibre properties, yarn structure and fabric structure. It has been shown that a number of factors play a very important role in determining the permeability of textile fabrics to air. The primary fabric parameter governing this behaviour has been shown[34] to be:

(a) the cross-section area of each opening between yarns,
(b) the depth of each opening (this is related to the fabric thickness),
(c) the number of openings per unit area of fabric.

It is therefore obvious that a bigger opening would mean higher flow rate of air through the fabric. In a similar manner, if all other parameters are equal, a fabric with a higher number of openings per unit area would be expected to permit a higher flow rate of air. The thicker the fabric the more difficult it would be for air to pass through.

As has been seen in earlier sections (Tables 4.2 and 4.3), because of the change in amount of twist inserted in the yarn, the diameter of the yarn changes and this consequently results in changes in the number of threads per unit length. These changes affect the fabric cover as

demonstrated in Figure 4.3, and it could be predicted from these results that the fabric permeability to air is affected by the spinning system and by yarn twist.

In fact, the thread densities and yarn diameters have been found[1] to influence the number and size of interspaces between threads in a woven fabric. The size of individual interspaces is, however, critically dependent on the uniformity of the thread densities and yarn diameters. The processing methods for producing rotor and ring-spun yarns differs, i.e. the nature of yarn formation leads to differences in their yarn diameter.

From the results obtained in the present investigation (Table 4.8 and Fig. 4.12), it is obvious that the air permeability of all fabrics (i.e. grey and dyed produced from both rotor-spun and ring-spun weft increases with increasing weft twist factor). This may be due to the easiness of low twist yarn to compress, due to the effect of warp tension and inter-yarn forces allowing the spread of yarn in the fabric direction, leading to decrease in the fabric interspaces, and thus lower permeability. On the other hand, another explanation offered by Robertson[35] is that an increase in twist results in increasing the inter-yarn openings produced by twist consolidation of the hairy yarn structure and reduced air space in the yarn - hence the air permeability increases with increase in the twist factor.

It is also obvious from Fig. 4.12 that the ring fabrics in the loom state and when dyed showed higher air permeability than equivalent rotor-spun fabrics. As earlier mentioned, this may be attributed to the structural differences in the yarn. Rotor yarn is known to be bulkier and thus may occupy more volume in the fabric than ring-spun

TABLE 4.8

AIR PERMEABILITY

(a) Ring-spun fabrics

Twist factor α_{tex}	Grey Fabric Air Permeability ($cm^3/sec/cm^2$)	Dyed Fabric Air Permeability ($cm^3/sec/cm^2$) at a pressure drop of 10 mm.
32.57	18.20	7.55
34.44	20.05	7.81
38.27	21.60	8.78
41.14	27.35	9.82
45.92	30.30	9.98

(b) Rotor-spun fabrics

Twist factor α_{tex}	Grey Fabric Air Permeability ($cm^3/sec/cm^2$)	Dyed Fabric Air Permeability ($cm^3/sec/cm^2$) at a pressure drop of 10 mm.
32.53	18.54	7.30
36.35	19.69	7.00
39.22	21.50	7.77
41.14	21.30	8.11
45.92	22.62	8.58

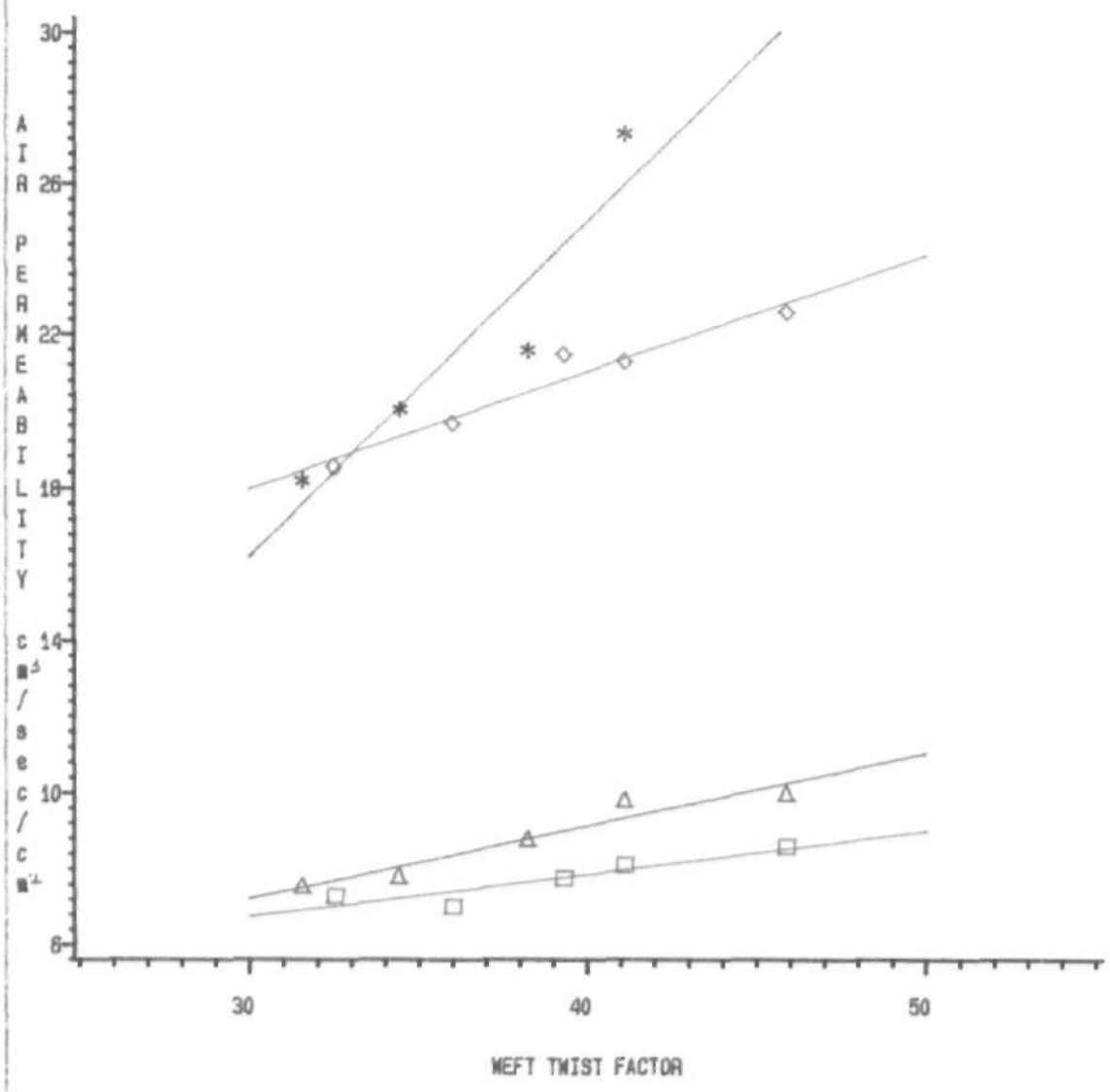
thereby reducing the inter-yarn pore sizes. This fact seems, however, to be substantiated by the higher fabric thickness for rotor fabrics, perhaps indicating the effect of yarn diameter. In addition, it has been said[34] that moisture pick (moisture content) of samples could alter air permeability of fabrics. The effect could be large, especially with closely woven fabrics composed of very hygroscopic fibres such as cotton; under the same atmosphere the rotor yarns excel the ring yarns in moisture content being 8.5% and 7.5% respectively.

The air permeability of both fabrics are reduced when dyed (60 ± 4%). This may be attributed to the effect of the scouring and dyeing on the flow of air through the fabrics. Fibre swelling, fabric shrinkage and crimp, effectively alter the fabric thickness, and flattening of yarn by pressure changes the fabric interstices. These may result in reducing the area of the inter-yarn openings or number of openings per unit area, and thus may result in a general decrease in the air permeability of both fabrics.

The physical characteristics desirable in active wear can be determined through the manner in which they affect the outer environment, which is known to vary. That is to say that what is suitable for one clothing system is more often than not completely unsuitable for another. From the results it may be concluded that rotor fabrics would provide better thermal comfort properties compared to their equivalent ring fabrics. However, this would very much depend on fabric structure and the intended end-use.

Fig 4.12

FABRIC AIR PERMEABILITY VS TWIST FACT OR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

4.4 Breaking load and extension

The breaking load is often defined[26] as the maximum load applied to a specimen in stretching it to rupture, and the extension at this breaking load is often referred to as the breaking extension. The load-extension characteristics of a fabric are important in indicating the changes that occur when a fabric is subjected to a certain load. The tensile strength measurements of the grey and dyed samples were carried out as earlier indicated, but unfortunately with fewer samples (four samples instead of five) for dyed fabric due to the amount of samples that would be available for other tests.

The breaking load of a fabric in either warp or weft direction is, in part, determined by the strength of the yarn and other additional effects due to fabric structure. It may be seen in Table 4.9 and Fig.4.13 that although a "common warp" was used for weaving the rotor and ring-spun fabrics, the warp strength differs slightly with respect to the increase in weft twist. The differences do not follow a particular trend, but vary with weft twist factor. The grey and dyed rotor fabrics show slightly higher warp strength than ring fabrics, and it may be observed that the variation in strength is lower for rotor fabrics with increasing weft twist (Tables 4.9 and 4.10). These observations may be related to the manner in which yarn interactions take place within the fabric, and more particularly the crimp interchange. The better warp strength for rotor fabrics may be attributed to the fact that it has a greater number of yarns per unit length in the warp direction (Table 4.3) than its ring equivalent. Thus more yarns are made available to take the load in this direction. Mashaly[36] from his work suggested that the strength per yarn in woven fabric is

TABLE 4.9

BREAKING LOAD OF GREY FABRIC

(a) Ring-fabric (warp breaking load) "grey"

Twist factor α_{tex}	(kg)	(kg)	(kg)	(kg)	(kg)	Mean kg/5cm	Mean kg/cm
31.57	70.0*	66.0	67.5	50.0**	72.0	68.50	13.70
34.44	61.0	59.0	59.0	70.5	73.0	64.50	12.90
38.27	70.0	72.0	65.0	69.5	69.0	69.10	13.82
41.14	68.0	71.0*	69.0	73.0	72.0	70.00	14.00
45.92	59.0	70.5	70.0	71.0	70.0	68.10	13.60

(b) Rotor-fabric (warp breaking load) "grey"

Twist factor α_{tex}	(kg)	(kg)	(kg)	(kg)	(kg)	Mean kg/5cm	Mean kg/cm
32.53	73.50	68.0	70.0	72.0	69.50	70.60	14.12
36.35	73.0	72.0	70.0	71.0	71.00	71.40	14.28
39.22	69.0**	67.0**	65.0	67.5	67.00	66.25	13.25
41.14	68.0	72.5	71.5	73.5	68.50	70.80	14.16
45.92	69.0**	74.0	70.0	73.5	70.00	71.88	14.38

* Top jaw break

** Bottom jaw break

TABLE 4.10

BREAKING LOAD - DYED FABRIC

(a) Ring fabric (warp)

Twist factor α_{tex}	(kg)	(kg)	(kg)	Mean kg/5cm	Mean kg/cm
31.57	65.0	66.0	66.5	66.50	13.10
34.44	67.0	65.0	70.0**	66.00	13.20
38.27	51.0	77.0**	60.0*	64.00	12.80
41.14	67.0	67.0	60.0*	67.00	13.40
45.92	83.0	72.0	70.0	75.00	15.00

(b) Rotor fabric (warp)

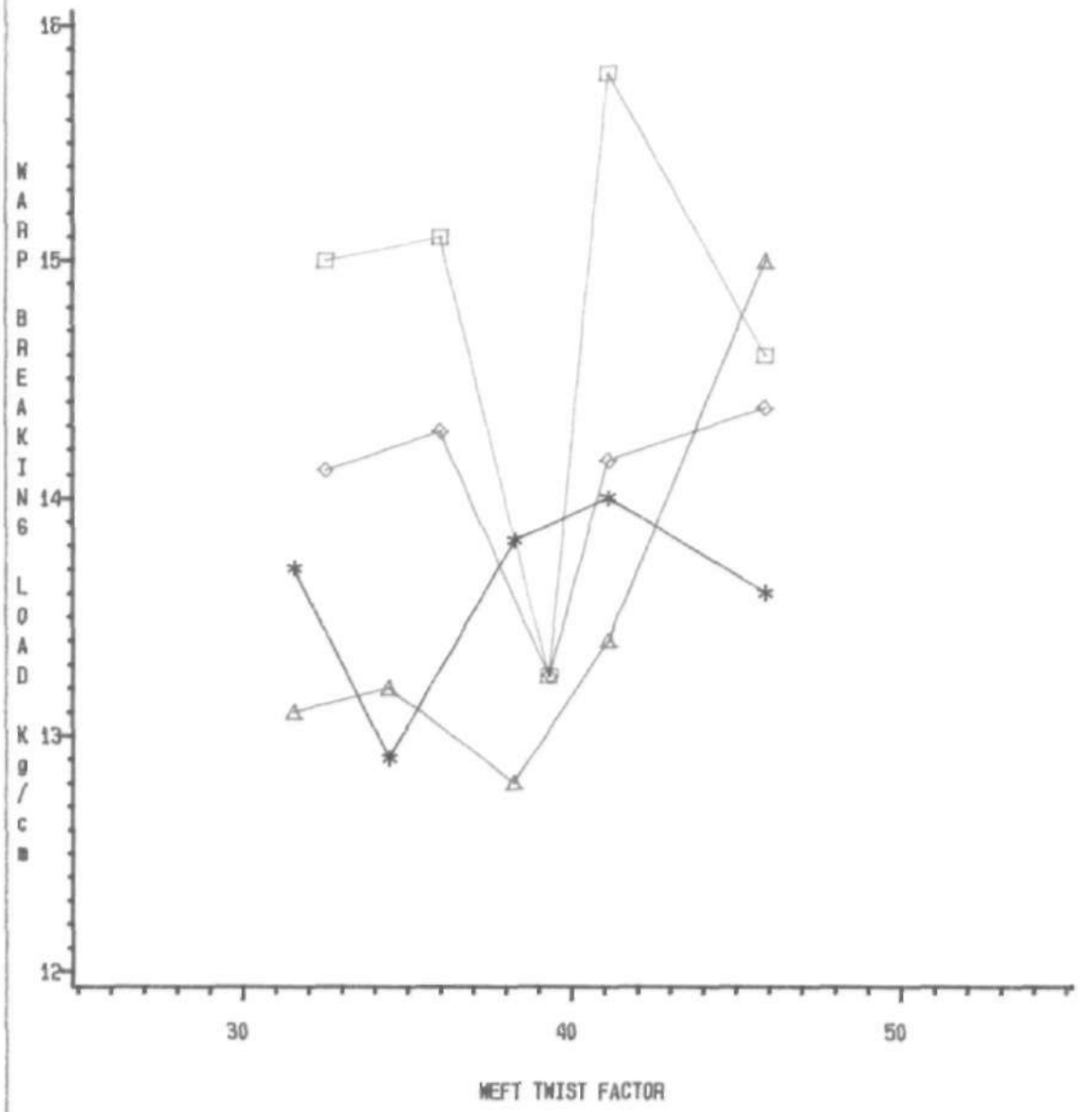
Twist factor α_{tex}	(kg)	(kg)	(kg)	Mean kg/5cm	Mean kg/cm
32.53	75.0	74.0	76.0	75.00	15.00
36.35	74.0	77.0	70.0*	75.50	15.10
39.22	65.0	67.5	66.5*	66.25	13.25
41.14	77.0	81.0	79.0	79.00	15.80
45.92	78.0	68.0	60.0**	73.00	14.60

* Top jaw break

** Bottom jaw break

Fig 4.13

WARP BREAKING LOAD VS TWIST FACTOR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

affected by spacing of the yarns which lie in the direction of the load - the smaller the thread spacing, the higher the strength. In addition, the slightly higher number of crossing threads might have also contributed to the better rotor warp strength, especially the grey fabric. This seems to suggest that rotor yarn has better strength utilization in the fabric form.

It has been known that rotor yarn has lower strength compared to its equivalent ring-spun. The reasons given have been reviewed in greater detail in Chapter 2. The lower strength of the rotor yarns is reflected in the woven fabrics. The fabric strength in the weft direction is generally lower for rotor fabrics (grey and dyed) than the ring equivalents. Comparing the differences in the yarn state (Table 4.1) it may be said that the differences in strength is greatly reduced. A possible explanation for this is that when the rotor yarns are assembled in fabric form, the interlacings tend to restrain slippage and make it possible for rotor fabric strength to be higher than yarn strength, i.e. the external pressure acting on the yarn at the cross-over points in the fabric causes more wrapper fibres to bear the load.

It may be interesting to note that in the loom state the ring weft strength passes through a maximum (twist level 41.14). Whilst no optimum seems to be observed for rotor fabrics, this may imply that increasing the amount of twist in the yarn will perhaps increase the fabric strength.

When both fabrics are dyed the weft strength passes through a maximum with increase in twist level (Fig. 4.14). The rotor fabrics, however, show an increase in weft strength, whilst the reverse was the case for ring-spun fabrics. It may be suggested that due to yarn

TABLE 4.11

BREAKING LOAD - GREY FABRIC

(a) Grey Ring Fabric (weft)

Twist factor α_{tex}	(kg)	(kg)	(kg)	(kg)	(kg)	Mean kg/5cm	Mean kg/cm
31.57	56.0**	52.5	53.5	54.0	58.0**	53.33	10.67
34.44	54.0	56.0**	58.0	52.0	41.5	54.67	10.93
38.27	60.0	62.5	58.5	59.0	61.0	60.20	12.04
41.14	55.0**	63.5**	62.0	64.5*	65.0	62.00	12.40
45.92	62.0	63.0	53.0	66.0**	52.5	59.33	11.87

(b) Grey Rotor Fabric (weft)

Twist factor α_{tex}	(kg)	(kg)	(kg)	(kg)	(kg)	Mean kg/5cm	Mean kg/cm
32.53	41.75	36.0*	33.5*	39.0	39.0	39.92	7.98
36.35	33.50	44.5**	41.0	42.0	36.0*	38.83	7.77
39.22	43.00*	32.0*	29.5	44.0	40.0	36.75	7.35
41.14	35.0	49.5	44.0	37.0	40.0*	41.38	8.28
45.92	47.5	47.0	45.5	46.0	47.5	46.70	9.34

TABLE 4.12

BREAKING LOAD - DYED FABRICS

(a) Ring fabrics (weft)

Twist factor dtex	(kg)	(kg)	(kg)	(kg)	Mean kg/5cm	Mean kg/cm
31.57	49.00	52.00	53.0	52.50*	51.33	10.27
34.44	45.00	58.00	48.0	50.50	50.33	10.07
38.27	51.00	55.50	64.0	55.50	56.50	11.30
41.14	48.00**	42.00**	52.0	52.00	52.00	10.40
45.92	52.00**	54.00	58.0**	54.00**	54.00	10.80

(b) Rotor fabrics (weft)

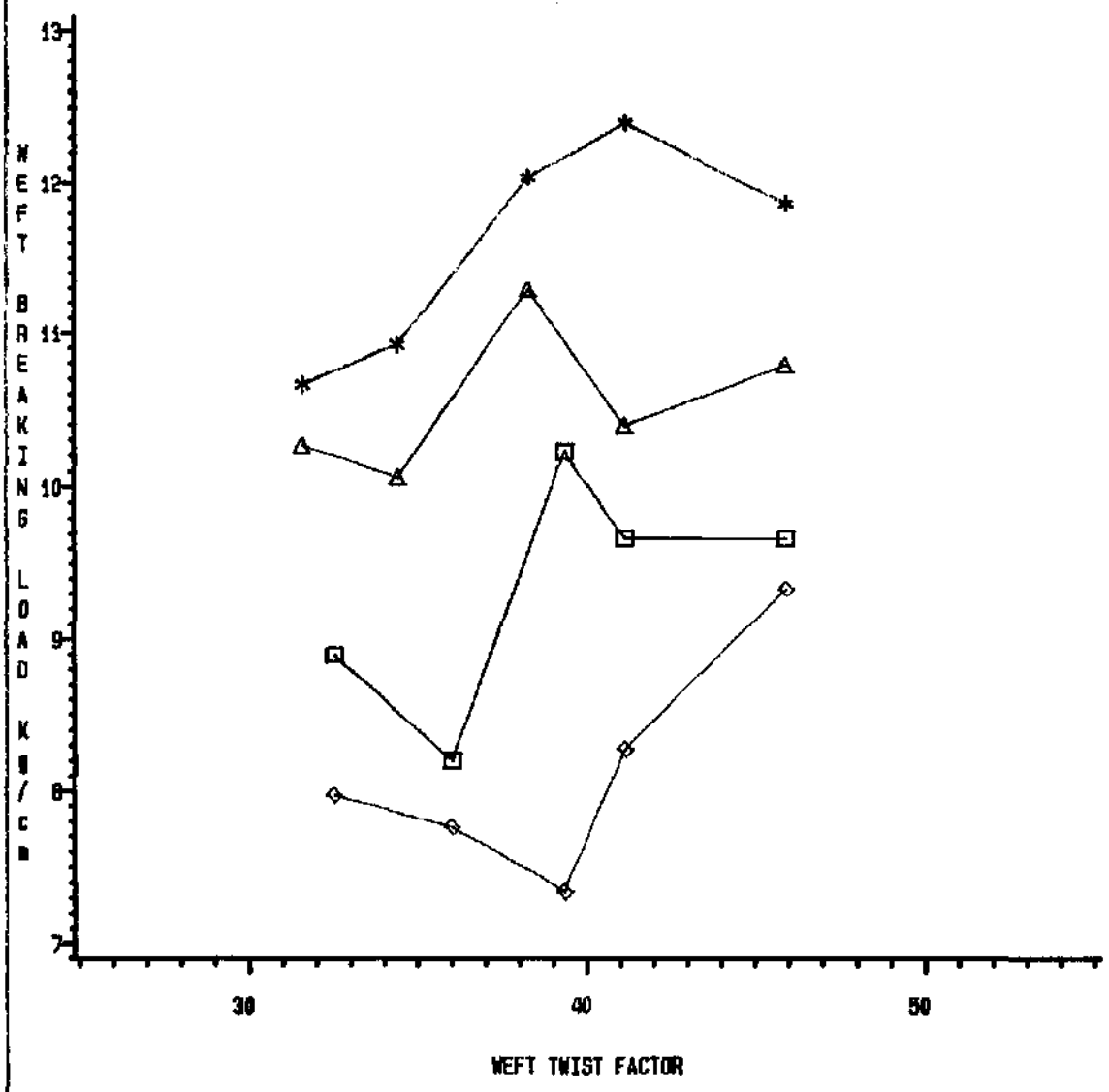
Twist factor dtex	(kg)	(kg)	(kg)	(kg)	Mean kg/5cm	Mean kg/cm
32.53	41.0	44.0**	48.0	33.0**	44.50	8.90
36.35	41.0	52.0**	46.50**	41.0	41.00	8.20
39.22	54.0	51.0	49.0	50.5	51.13	10.23
41.14	47.0	51.0	47.0	38.0**	48.33	9.67
45.92	51.0	51.0	43.0	48.5	48.38	9.67

* Top jaw break

** Bottom jaw break

Fig 4.14

WEFT BREAKING LOAD VS TWIST FACTOR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

swelling the contact between wrapper fibres (weft) and the warp yarn is increased; thus the lateral forces (pressure) between the yarns is increased, hence reducing slippage occurrence. The interlocking caused by the interlacing of yarns causes the fibres on the outer layer of the yarn to carry a higher share of load than in the free state. Taking into account that rotor yarns contain a larger per cent of hooks and wrapper fibres, as a result of fibre swelling and higher shrinkage for rotor fabrics, this probably reduces the slippage occurrence and may thus result in increasing the fabric strength in both directions. The loss of strength for ring weft may be attributed to the internal stress in the yarn. From the results obtained, it may thus be observed that rotor fabrics show an improvement in the fabric strength. The difference in strength is reduced to 10 - 15% as compared to loom state, which has a difference of about 30%.

Further work may be suggested to ascertain the factors responsible for increase in rotor fabric strength when dyed.

4.4.1 Extension at break

Extending the test strip fabric in one direction leads to removal of crimp and the yarns straighten out. This causes the yarns at right angles to the loading direction to be crimped further, which is referred to as crimp interchange. The breaking point is the sum of the extension due to crimp interchange and extension of the yarn itself. Thus the over-all breaking extension of the fabric may be dependent on crimp.[8]

It may be seen in Fig. 4.15 that warp extension varies with increase in weft twist factor for both fabrics, with rotor showing

TABLE 4.13

EXTENSION AT BREAK

(a) Ring fabrics

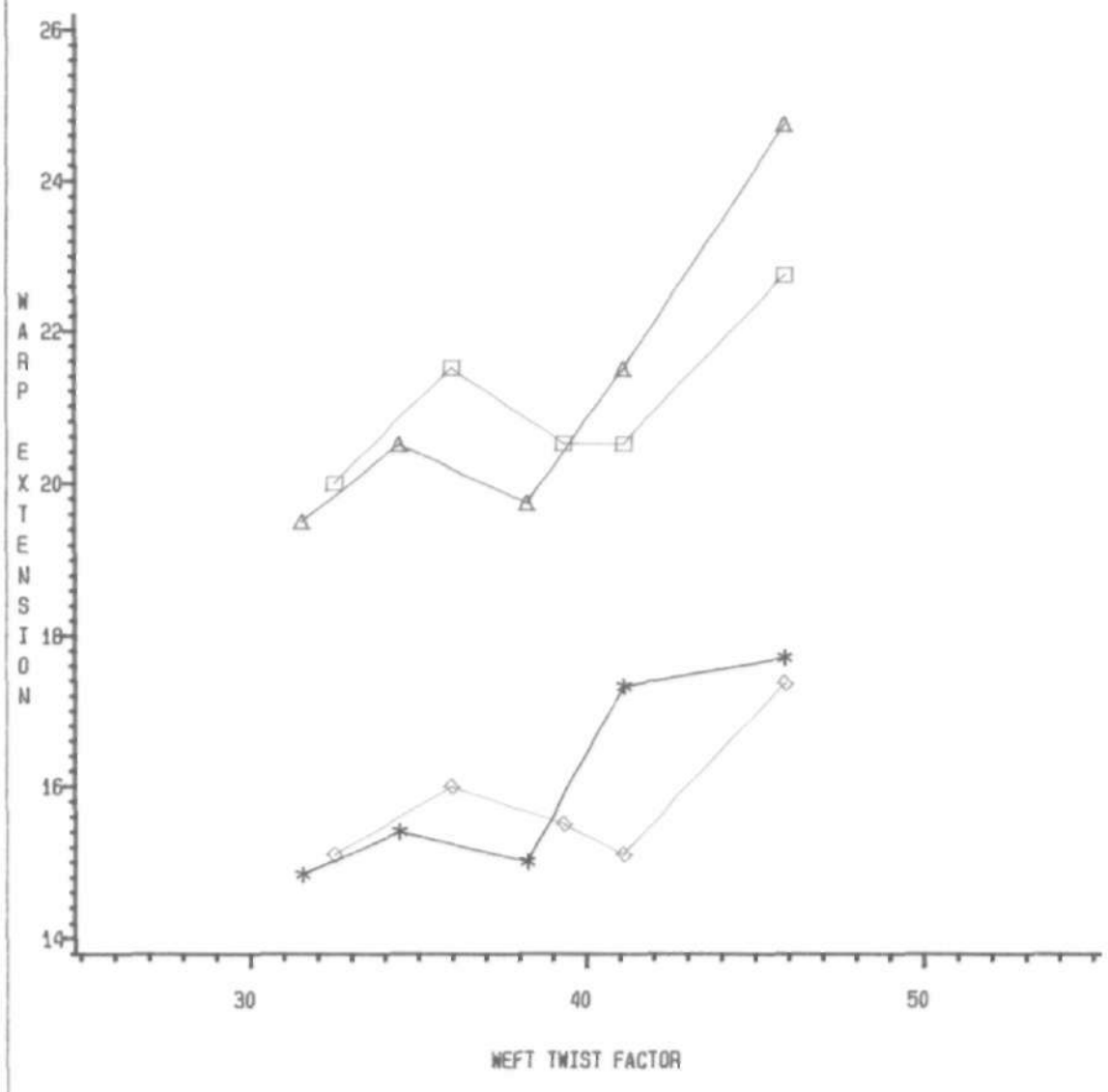
Twist factor dtex	GREY FABRIC		DYED FABRIC	
	Warp (%)	Weft (%)	Warp (%)	Weft (%)
31.57	14.83	19.33	19.50	28.17
34.44	15.40	19.33	20.50	28.33
38.27	15.00	20.50	19.75	28.17
41.14	17.33	21.00	21.50	27.00
45.92	17.70	19.00	24.75	28.25

(b) Rotor fabrics

Twist factor dtex	GREY FABRIC		DYED FABRIC	
	Warp (%)	Weft (%)	Warp (%)	Weft (%)
32.53	15.10	17.50	20.00	28.00
36.35	16.00	17.00	21.50	28.50
39.22	15.50	25.00	20.50	28.33
41.14	15.10	18.25	20.50	27.00
45.92	17.38	19.90	22.75	28.17

Fig 4.15

INFLUENCE OF TWIST ON WARP EXTENSION



RING WARP GREY FABRIC

ROTOR WARP GREY FABRIC

RING WARP DYED FABRIC

ROTOR WARP DYED FABRIC

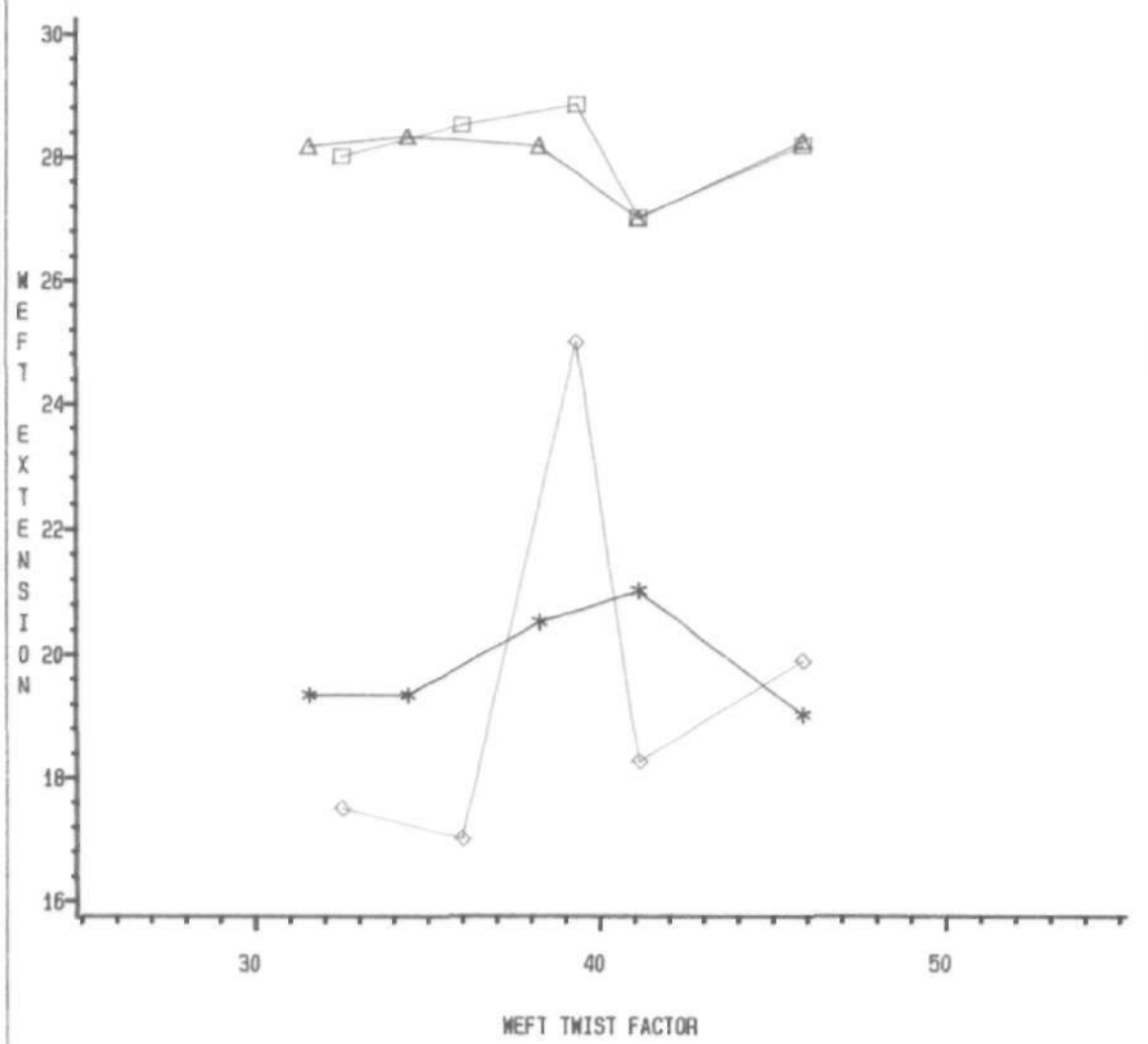
slightly higher values at lower twist levels, but lower extensions at higher twist levels. It appears that when the fabrics are dyed the warp extension generally increases with increasing weft twist (Fig. 4.15) and a similar trend is followed as observed for loom state fabric. It is therefore clear that change in weft twist affects the fabric extension in the warp direction. This may be attributed to the crimp interchange that takes place during testing and the extensions of the yarns themselves.

The weft extension passes through a maximum, and apart from twist levels 39.35 and 45.92 (Fig. 4.16), the rotor fabrics showed low weft extensions compared to their ring equivalents. This may be attributed to the yarn structural features; the rotor yarns have a higher percentage of wrapper fibres than the fibre forming core, so that breakage occurs when a load is exerted in the yarn, and rotor yarns show lower elongation (Table 4.1), in addition to other factors. When both fabrics are dyed the weft extensions follow a very similar trend, but there is no significant difference between the weft extension of both dyed fabrics. These thus reflect the higher crimp increase (Section 4.2.3) for rotor fabrics. The influence of crimp interchange cannot, therefore, be over-emphasised, but this somehow complicates any interpretation that may be given to the results obtained for weft-extension, especially when the fabrics are dyed. One thing that is clear, however, is that an increase in weft twist transfers its effect to the fabric warp extension.

There is a general increase in breaking extension after dyeing for both rotor and ring fabrics, and this may be as a result of increased crimp when both fabrics are dyed.

Fig 4.16

INFLUENCE OF TWIST ON WEFT EXTENSION



RING WEFT GREY FABRIC

ROTOR WEFT GREY FABRIC

RING WEFT DYED FABRIC

ROTOR WEFT DYED FABRIC

4.4.2 Tear strength

In tear strength, it is only a few yarns that share the load at any one time, unlike tensile testing, where all the yarns in the test direction share the load. This is why the response of woven fabrics to tear and tensile loading differs.

It is apparent from the results (Table 4.14) and Fig. 4.17 that the tearing strength across the weft yarns generally increases with increasing twist factor for both rotor and ring fabrics. In addition to the fact that twist generally increases the yarn strength until optimum is reached, the observation may also be related to changes in the lateral forces between the yarns. It has been pointed out[8] that crimp levels alter the extensibility of the yarns at the zone of interfacing, and thus the number of yarns taking the load. This fact may also account for the slight deviations observed.

The ring fabrics have higher tear strength than their rotor equivalents (grey and dyed). The difference between the tear strength of grey fabric is in the region of 30%, but reduced greatly to about 10 - 20% of its ring equivalent. This may be attributed to the lower rotor yarn strength (Table 4.1) and the improvement may be attributed to the surface character of the yarn.

The rotor and ring fabrics (Fig. 4.17) appear to indicate a general loss in tear strength when dyed. It is, however, greater for ring fabrics, 40 - 45%, whilst for rotor it is about 20 - 40%.

It is interesting to note that when rotor fabric was dyed it showed an improvement in the fabric strength (Section 4.4), but this was accompanied by a decrease in tearing strength. This appears to confirm the earlier statement of behaviour of fabrics being different

TABLE 4.14

FABRIC TEAR STRENGTH

(Weftwise)

(a) Ring fabrics

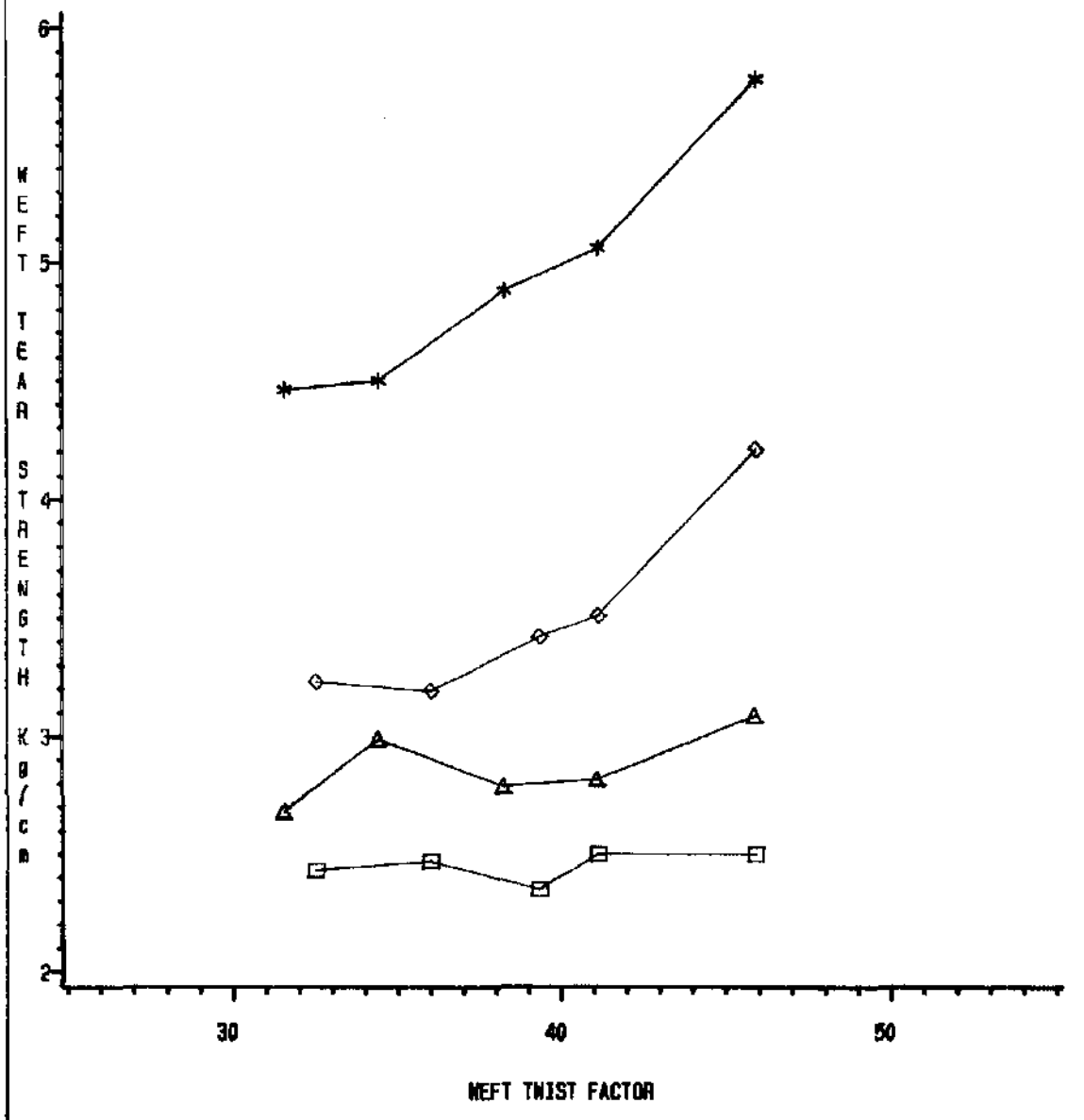
Twist factor α_{tex}	GREY FABRIC		DYED FABRIC	
	Max.(kg)	Min.(kg)	Max.(kg)	Min.(kg)
31.57	4.46	2.38	2.68	1.28
34.44	4.50	2.22	2.99	1.48
38.27	4.88	2.34	2.79	1.38
41.14	5.06	2.72	2.82	1.54
45.92	5.78	3.00	3.09	1.73

(b) Rotor fabrics

Twist factor α_{tex}	GREY FABRIC		DYED FABRIC	
	Max.(kg)	Min.(kg)	Max.(kg)	Min.(kg)
32.53	3.23	1.80	2.43	1.20
36.35	3.19	1.70	2.47	1.23
39.22	3.42	1.93	2.35	1.20
41.14	3.51	1.88	2.50	1.24
45.92	4.21	2.01	2.50	1.27

Fig 4.17

WEFT TEAR STRENGTH VS TWIST FACTOR



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

under tear and tensile loading. However, the important thing is that the yarn surface character must have played a significant role in this aspect since the results follow the same pattern for ring fabrics.

It is obvious from the above results that further work is necessary to investigate the behaviour of wrapper fibres in determining the fabric tear and tensile strength, especially after dyeing.

4.5 Abrasion resistance

Fabric abrasion resistance is an important property in terms of fabric performance. The assessment of abrasion resistance of textile fabrics usually provides the fabric with similar conditions to those to which they may be subjected in use. It has always been indicated[25,26] that it is often difficult to give any physical meaning to the results. However, they are comparative and therefore useful for merit rating of the tested samples.

The results obtained are presented in Table 4.15 from which it may be observed that the rotor loom state fabrics have shown considerable better abrasion resistance properties than their ring equivalents. This may be attributed to yarn structure and fibre distribution, both in the yarn core and outersheath (i.e. the two part structure). The wrapper fibres have been suggested[14,37] to be a decisive factor in influencing abrasion characteristics. The influence of wrapper fibres on rotor yarn properties seems to be highly effective, which thus influences the fabric abrasion properties. The wrapper fibres which are loosely wrapped round the yarn body (the outer layer) give it a considerable freedom of relative movement without disturbing the inner

layer. In other words, another explanation advanced[2] is that fibre migration is more local in the rotor yarns with one layer being locked through the whole structure. The abrasion property is increased because a fibre removed from the yarn surface would not affect the internal structure of yarn to any great extent.

According to Ibrahim[14] this can be explained in terms of the two-part structure of the rotor yarns too, in which the presence of the outer yarn sheath containing the wrapper fibres will isolate the yarn core from the early damage caused by abrasion forces. Increasing yarn twist will always be accompanied by an increase in both the wrapper fibres and the relative fibre friction inside the yarn core, which will, in turn, cause the yarn to be stronger and more isolated from the abradant by more wrapper fibres.

Further to the explanations offered for this, the fibres in rotor yarns do not form into a sufficiently interlocking structure, so the system will relieve traverse forces by relative motion, especially at the outer fibre layers where the amount of inward pressure is lower than that of the inner layers. Therefore, the relative motion of the fibres will reduce the abrasive damage which may result from rubbing with external objects. But this creates higher fibre-to-fibre friction causing greater abrasion within the fabric; however this is yet to be verified.

Dyeing has been shown to influence fabric parameters such as crimp in the yarn and thickness because of yarn swelling, which is, in turn, affected by the spinning tensions during yarn processing. As a result of these changes, the fabric resistance to abrasion for rotor and ring fabrics is also affected, but in a different manner.

TABLE 4.15

ABRASION RESISTANCE

(Number of abrasion cycles)

(a) Ring fabrics

Twist factor α_{tex}	Grey samples	Dyed samples
31.57	15,350	17,852
34.44	13,250	16,250
38.27	14,000	14,950
41.14	12,950	14,900
45.92	19,250	17,100

(b) Rotor fabrics

Twist factor α_{tex}	Grey samples	Dyed samples
32.53	16,750	14,185
36.35	16,050	15,650
39.22	13.750	16,750
41.14	19,250	15,500
45.92	18,400	16,300

The ring fabrics have shown a general decrease in resistance to abrasion as the twist factor increases, except at the highest twist level, whilst the rotor fabrics have shown the opposite with the abrasion resistance property increasing generally with increase in twist factor. The inconsistencies observed for the loom state fabrics have, however, disappeared and the fabrics, after dyeing, tend towards a kind of trend. It will also be interesting to note that with ring fabrics it seems that there is an increase of fabric resistance to abrasion when dyed, whilst the rotor fabrics appear to indicate the reverse (except the twist level 39.22), with a general decrease in the abrasion property as compared to the loom state.

The possible explanation for this may be attributed to the component yarn interactions in the fabric structure and the configurations of the wrapper fibres on the yarn surface. The swelling of the fibres in the yarn core and outer layer might have either stiffened due probably to more fibre orientation, thus making the fibres in the inner core come into closer contact with the wrapper fibres or loosen the yarn structure slightly as compared to loom state. If it is the first case that occurs, the relative movement of the yarn is inhibited, and if it is the second case, it results in slightly low fibre cohesion. Either of these changes which may stiffen, orient or loosen the yarn structure in the fabric may have an adverse effect on abrasion resistance.

Contrary to the commonly held view, apart from the highest twist factor, the ring fabrics have displayed a trend of decreasing abrasion resistance with increase in twist factor within the ranges of twist factors employed in this work. The rotor fabrics, however, followed the expected trend whereby an increase in twist increases the fabric's

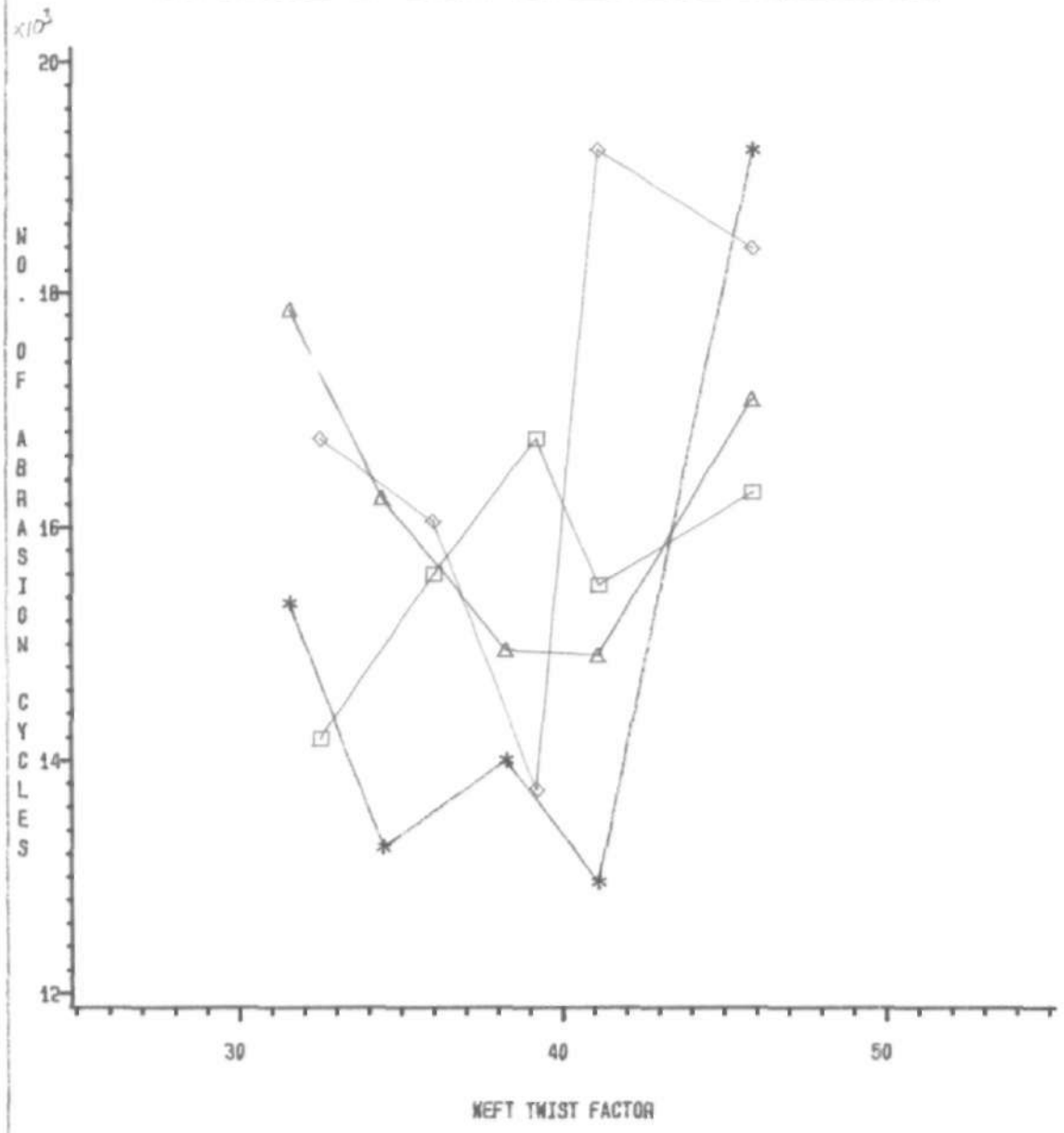
resistance to abrasion until optimum twist level is reached, 39.22, and then starts to decrease. The increase in twist may impose additional stresses on the fibre; thus the ability of the yarn to flatten or rotate is reduced such that the abrading force is concentrated on a few spots and breakdown occurs more easily. This is not surprising since it is well known that ring yarns are better spun at lower twist levels.

For the rotor fabrics, the dependence on twist reflects changes in fibre cohesion. As twist increases the number of wrapper fibres increases and the yarn core gets more twist to such an extent that the removal or displacement of fibres due to plucking is minimized when cohesion is high.

Comparing the two fabrics when dyed from the results presented in Table 4.15 and Fig. 4.18, the rotor fabrics have indicated lower abrasion resistance at low twist levels, but better resistance to abrasion at higher twist levels (from 39.22) than their ring equivalents. With rotor yarns, higher twist will increase the twist in both the inner core and the fibres surrounding the core, and this may enable the outer sheath of fibres to protect the core during abrasion. Ibrahim[14] has also suggested in his work that at low twist levels the lower abrasion properties of rotor fibres may be due to the sheath being abraded, whilst at higher twist levels, the situation changes. The change is possibly due to the fact that in the case of ring-spun yarns, increased migration leads to abrasion damage across the whole yarn structure, whereas with rotor yarns, the higher twist strengthens both the sheath and the core, thus improving the fabric abrasion resistance. In the loom state fabric, the higher values obtained

Fig 4.18

INFLUENCE OF TWIST ON ABRASION RESISTANCE



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

at the higher twist factors may be attributed to the fact that the abrasion forces are indeed acting on a more compact yarn body, in which the fibres are more tightly held together. In the ring yarn the increased fibre migration might give a greater consolidation to the yarn and hence improved abrasion characteristics.

It seems from Tables 4.5 and 4.15 that the yarn crimp level in the yarn may have some influence on the abrasion properties of both fabrics. It has been reported[38] that yarns with high crimp take the brunt of abrasive action. This is because crowns formed as the yarn bends round a traverse thread will protrude from the fabric surface and meet the destructive abrasive agent first, while those lying in the centre of the fabric will only play their part in resisting abrasion when the highly crimped yarns are nearly worn through. The relationship is more obvious with the ring-spun yarn in this work. However, no satisfactory explanation could be given for the trend observed.

It is difficult to say definitely which of the two fabrics has better abrasion resistance properties, because of the nature and trend of the results obtained. However, it may be stated that rotor fabric has displayed better abrasion resistance in the loom state and higher twist levels when dyed, but lower values at low twist levels compared to its ring equivalent. Taking into account the industrial yarn processing, rotor spun at twist level 43.0 and ring at its normal 36.00 it shows that rotor yarn has better abrasion resistance both in the loom state and when dyed.

In addition to other conditions earlier mentioned which may affect testing results, the state of the fabric, i.e. loom or dyed, is also a determining factor, and twist levels also play an important role.

The structure of the fabric also affects the values obtained for abrasion tests. It has been shown[8] that rotor yarn with its wrapper fibres when made into a fabric with floats, leads to an increase in the number of poorly secured fibres, and this shows up to the disadvantage of rotor yarns in relation to ring yarns in such fabrics.

4.6 Fabric bending behaviour

The bending of a fabric has a direct influence on the fabric stiffness and handle, and also determines its ability to buckle and recover from such deformations.[23] During the use of fabric, for instance in garments, the bending of a trouser leg and even the natural folding, often involves buckling.

Grosberg[39] has suggested that the resistance to bending is brought about by the interactions of warp and weft yarns, and this was assumed to be composed of three elements:

(1) the bending resistance of the yarn lying in the direction of bending,

(2) some unspecified interaction between the yarns,

(3) a frictional restraint.

A detailed analysis of the problem of bending has been given in a series of published papers.[40,42] Furthermore, studies of bending properties and problems of factors controlling stiffness with particular reference to handle, have been given considerable attention by many researchers.[42-47]

The bending parameters investigated in this section are:

(1) Bending length - which is described as a measure of stiffness determining the draping qualities of a fabric.[43] It is related to the quality of stiffness that is appreciated by visual examination of the draped material.[26]

(2) The Flexural Rigidity of a fabric, which is a measure of the stiffness as appreciated by the fingers, i.e. a measure of the resistance of the fabric to bending by external forces. When the fabric is bent in a direction perpendicular to either warp or weft, the quantity is known as weft or warp bending length and flexural rigidity respectively.

(3) Bending modulus which indicates the measure of the inherent rigidity of the material of unit thickness and used as a measure of the "paperiness" of the material.[26]

As mentioned in Section 3.4.9, it was impossible, because of curling, to assess the undyed fabrics and thus the experimental results present in Table 4.16 are for dyed fabrics only, and only the calculated shear stiffness is given for the grey and dyed fabrics. It may be seen from Table 4.16 that the theoretical calculations of the fabric shear stiffness gives similar over-all trends to the experimental data obtained for the bending length for both rotor and ring fabrics. The method of calculation is given in Appendix I. Fig. 4.19 shows that the shear stiffness of both grey fabrics generally increases with increase in twist factor. After dyeing, the ring fabric varies in shear stiffness with increase in weft twist, whereas, apart from twist level 32.53, the rotor fabrics show an apparent general increase as the twist levels increase. In addition there is a general decrease in the fabric shear stiffness after dyeing. The trend obtained may be a result of many changes in fabric parameters that occurred after dyeing of both fabrics, e.g. thickness, as a result of crimp, shrinkage, etc.

The main feature of the results is that, in both cases, the higher

TABLE 4.16

BENDING BEHAVIOUR OF ROTOR AND RING FABRICS

(a) Ring fabrics

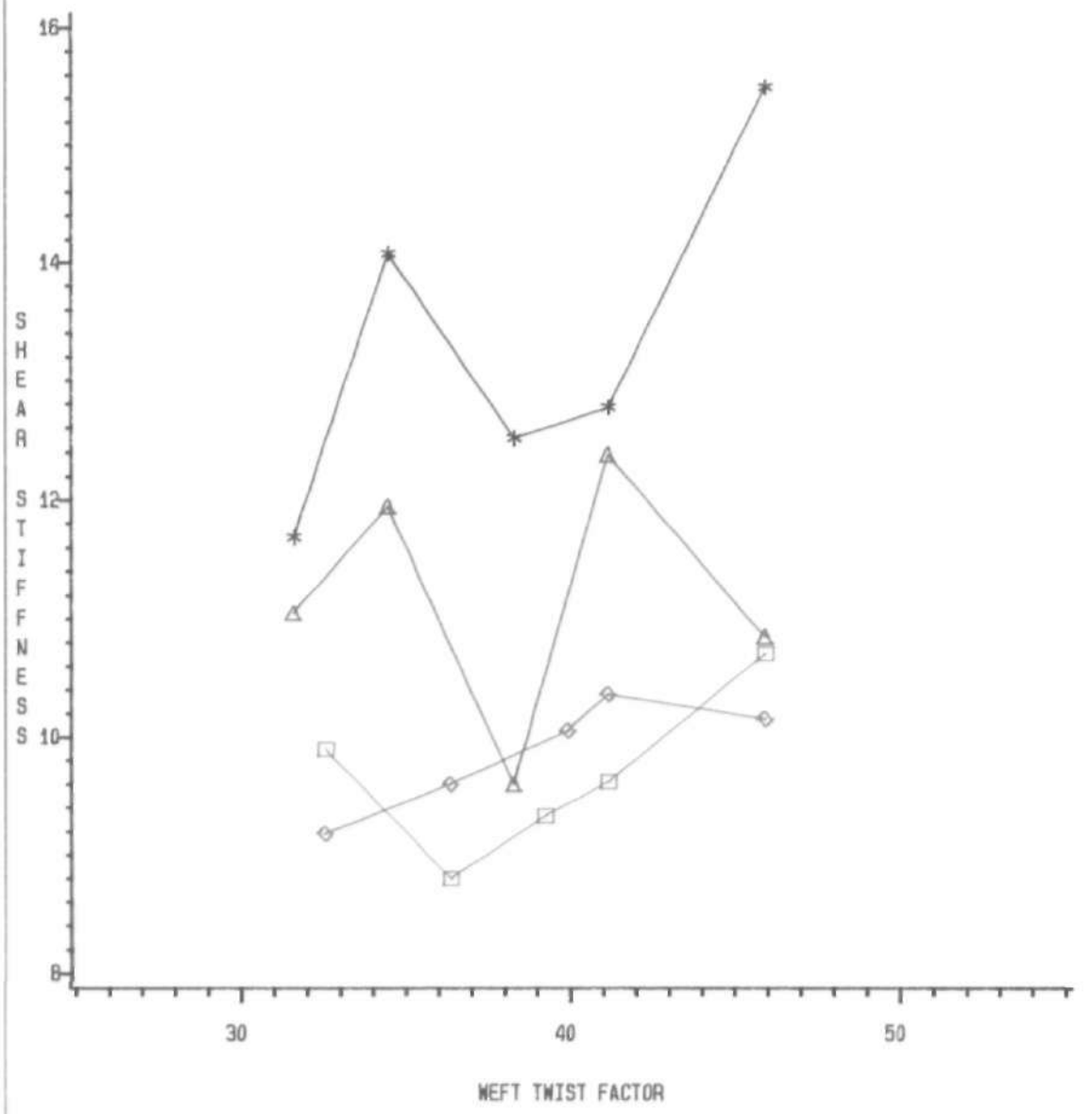
Twist factor dtex	Grey fabric S x 10^2	Dyed fabric S x 10^2	Warp B.L. (cm)	Weft B.L. (cm)	Gwp mg cm	Gwf mg cm	G_o mg cm	q_1 kg/cm^2	q_2 kg/cm^2
31.57	11.68	11.05	1.86	1.44	147.43	68.40	100.42	6.96	3.14
34.44	14.07	11.95	2.30	1.51	289.57	81.30	153.43	12.00	3.32
38.27	12.50	9.60	2.12	1.54	217.93	85.00	136.10	8.57	3.35
41.14	12.76	12.38	2.29	1.53	280.27	83.00	152.45	12.71	3.77
45.92	15.48	10.85	2.45	1.59	241.18	94.30	179.37	14.50	4.01

(b) Rotor fabrics

Twist factor dtex	Grey fabric S x 10^2	Dyed fabric S x 10^2	Warp B.L. (cm)	Weft B.L. (cm)	Gwp mg cm	Gwf mg cm	G_o mg cm	q_1 kg/cm^2	q_2 kg/cm^2
34.53	9.18	9.89	2.19	1.38	244.00	61.10	122.10	9.50	2.38
36.35	9.60	8.79	2.19	1.49	241.97	77.00	136.50	8.90	2.84
39.22	10.09	9.32	2.18	1.57	238.71	89.30	146.00	9.07	3.39
41.14	10.36	9.61	2.25	1.55	258.57	84.50	147.81	10.86	3.55
45.92	10.15	10.70	2.09	1.52	210.03	81.30	130.67	8.97	3.47

Fig 4.19

INFLUENCE OF TWIST ON SHEAR STIFFNESS



RING GREY FABRIC

ROTOR GREY FABRIC

RING DYED FABRIC

ROTOR DYED FABRIC

values for ring fabrics seem to suggest that rotor fabrics will have better draping and better handle qualities. The effect of twist on the shear stiffness is more pronounced in ring fabrics.

From Figs. 4.20 to 4.23, it is obvious that a similar kind of trend is generally followed. The ring warp bending length, modulus and flexural rigidity appear to increase generally with increase in weft twist factor, whilst the rotor warp appears to indicate an apparent general decrease with increase in weft twist. Ring fabrics have higher values than rotor fabrics, with significant variation with increase in weft twist.

The weft bending length, modulus and flexural rigidities (Figs. 4.20 - 4.23) appears to increase generally with increase in weft twist, but rotor yarn passes through a maximum. The ring fabric showed higher values than its rotor equivalent. These differences observed may be attributed to the differences in the yarn structural features in relation to the manner in which the fibres are assembled and arranged in the yarn.

Livesey and Owen[44] suggested that fabric flexural rigidity is affected by the flexural rigidity of the single fibres comprising the yarns from which the fabric is woven. One of the major factors affecting the fibre arrangement in a yarn is the nature and amount of twist inserted. This has been indicated[48,50] to affect fabric stiffness, with two contradictory factors playing different roles - limiting the freedom of fibre movement will increase the stiffness, while the helical configuration will reduce it. When these factors are considered, it may be suggested that wrapper fibres of the rotor-spun yarns may be the major contributing factor for its lower values.

Fig 4.20

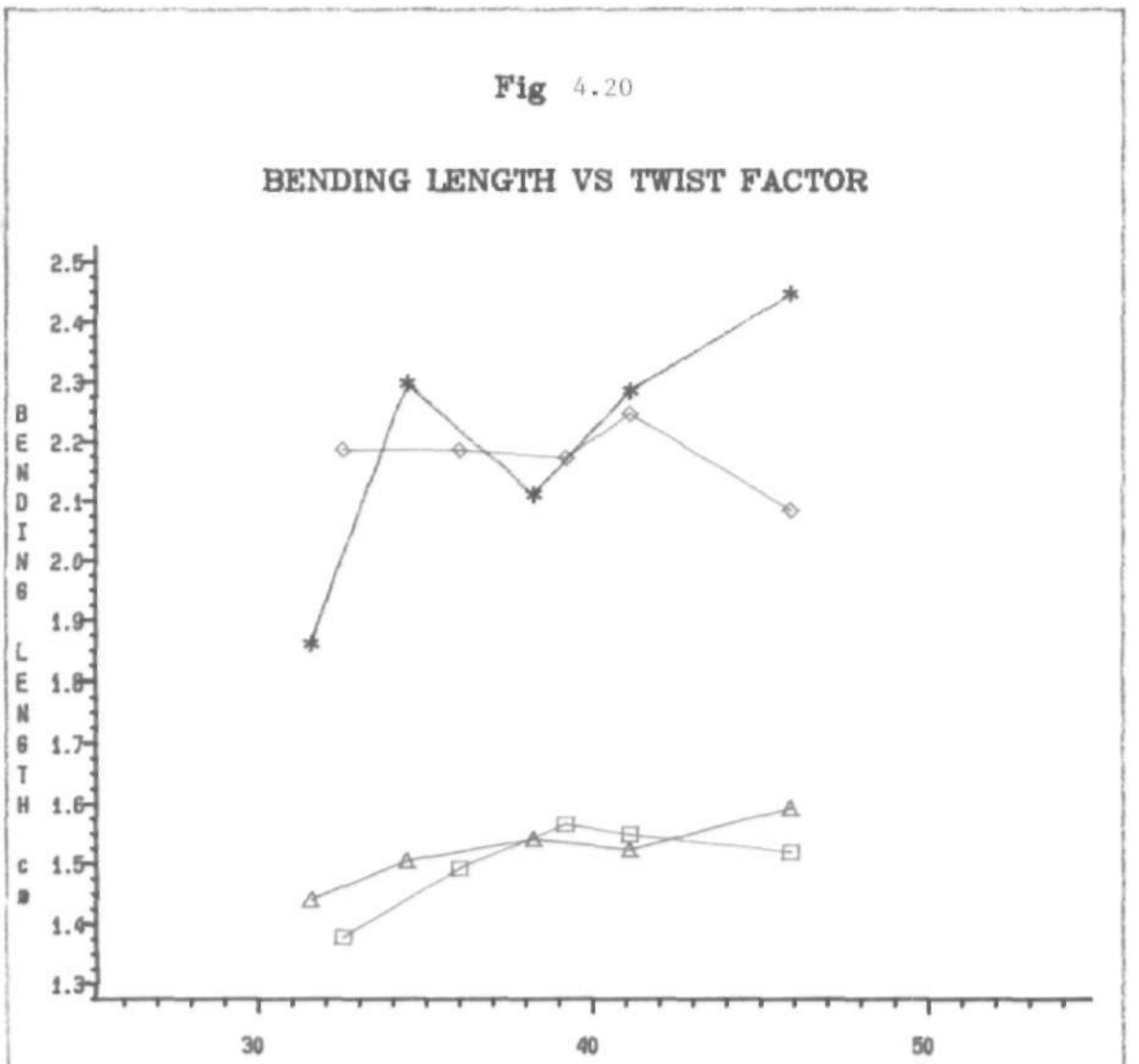
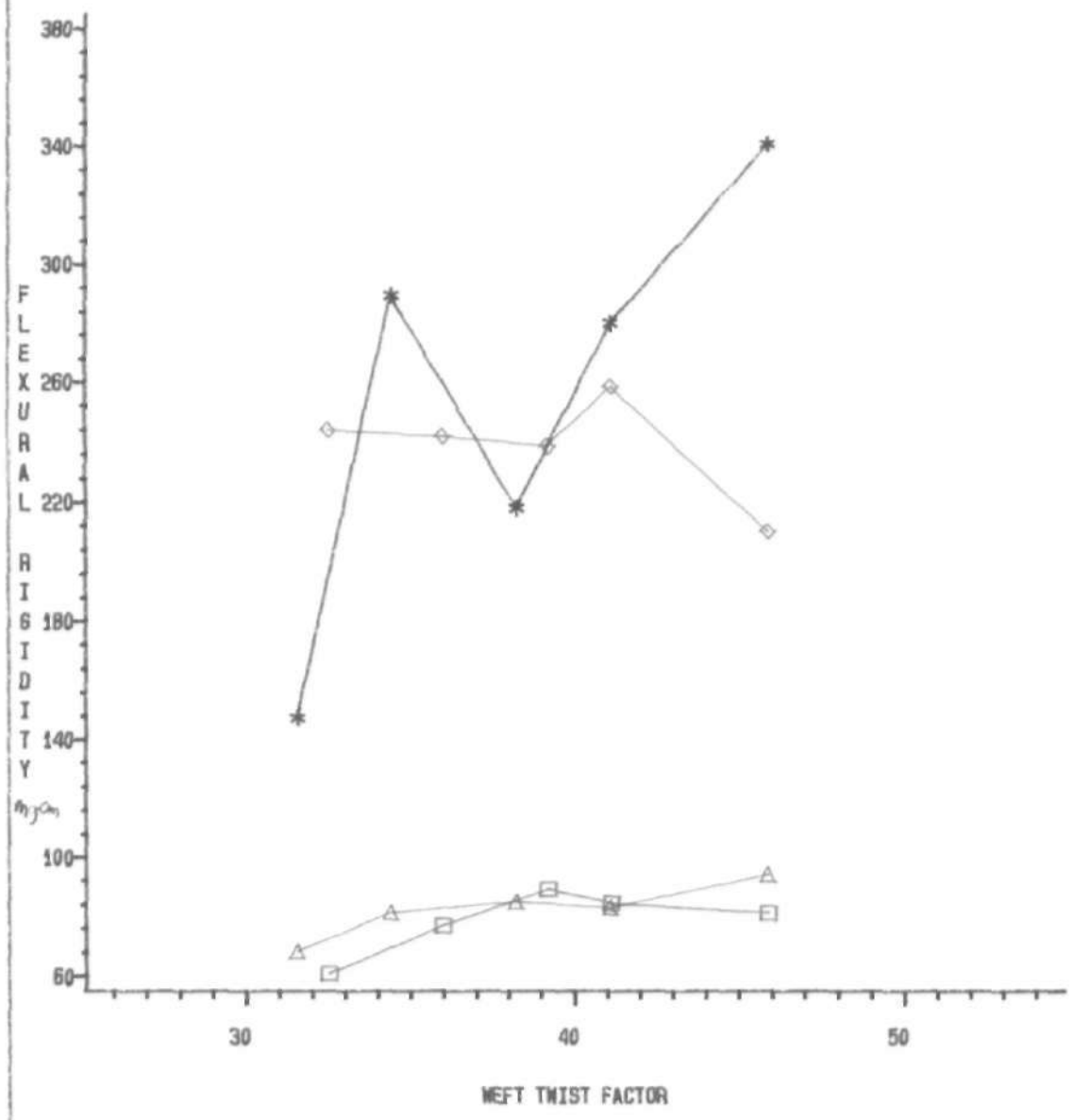

BENDING LENGTH VS TWIST FACTOR
BENDING LENGTH cm
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
30
40
50
WEFT TWIST FACTOR
RING GREY FABRIC
ROTOR GREY FABRIC
RING DYED FABRIC
ROTOR DYED FABRIC

Fig 4.21

FLEXURAL RIGIDITY VS TWIST FACTOR



RING WARP

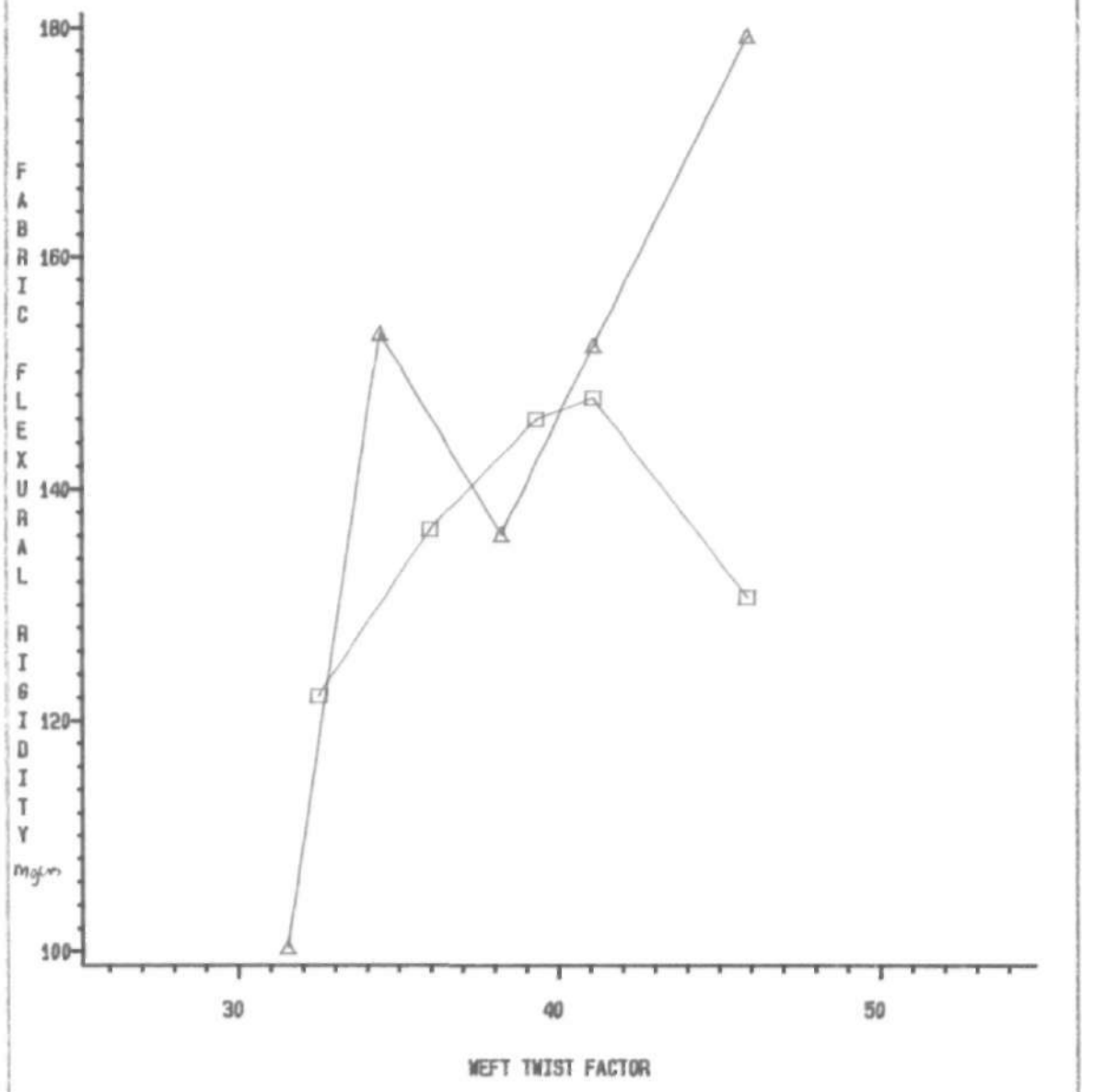
ROTOR WARP

RING WEFT

ROTOR WEFT

Fig 4.22

INFLUENCE OF TWIST ON FABRIC FLEXURAL RIGIDITY

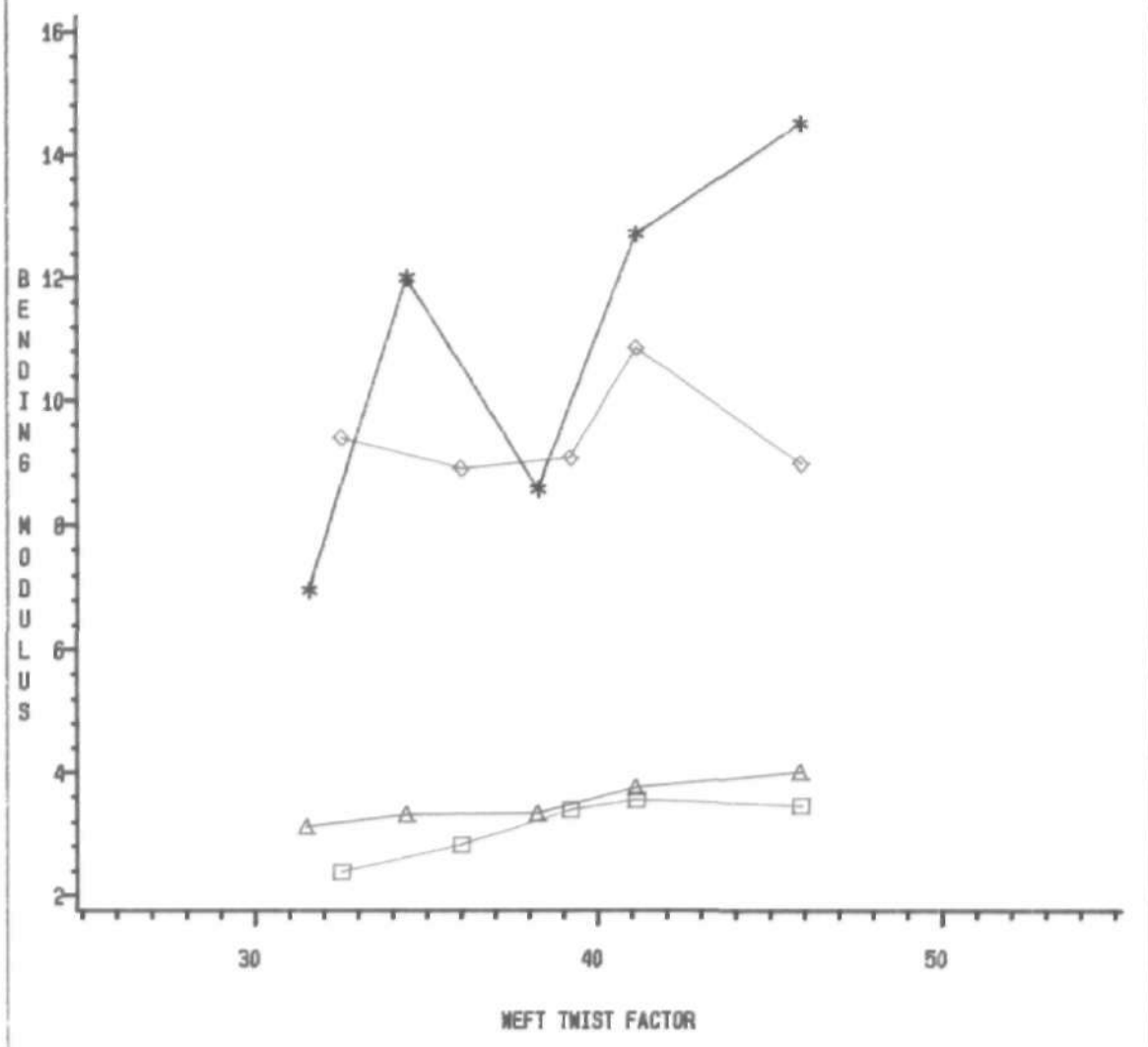


RING FABRIC

ROTOR FABRIC

Fig 4.23

INFLUENCE OF TWIST ON BENDING MODULUS



RING WARP

ROTOR WARP

RING WEFT

ROTOR WEFT

Since wrapper fibres are loosely wrapped around the body of the yarn, it may give the fibres composing the yarn a considerable relative freedom of movement than the ring-spun yarns, which are largely more oriented and parallel.

The results obtained also indicate that for both types of yarn the fabrics are generally stiffer in the warp direction than in the weft direction. The higher values for warp than weft may be attributed to the fact that the warp yarns are folded, of heavier count, and in addition the probable residual size in the warp yarns may also be a contributing factor. It may also be inferred from the results for weft bending length, modulus and flexural rigidities, that rotor fabrics are likely to have better draping qualities, and that ring-spun fabrics will be stiffer and more papery to hand feel than their rotor equivalents. Apart from twist levels 39.22 and 41.14, rotor yarns appear to have better handle.

Even though it has been reported[41,42] that the cantilever method may not be used for absolute determination of flexural rigidities and other frictional couples, because of the omission of the effect of frictional resistance to bending, the comparison, using the cantilever method, however, gives a good indication of subjective stiffness and is adequate in predicting bending behaviour of the fabrics, but no indication of liveliness. Improvements have, however, been carried out[42,50-53] on the methods of determining the bending and flexural rigidities of fabrics, e.g. Shirley cyclic bending, but this has the disadvantage of being time-consuming and a tedious method.

4.7 A review of the effect of dyeing on the properties of rotor and ring fabrics

Most fabrics are not used in the condition in which they are manufactured. They usually undergo some kind of chemical treatment such as scouring, bleaching, dyeing, stentering, calendering, etc. This is one of the most important processes from the point of view of fabric structure because it allows changes to be made in width and length and, of course, in other structural parameters. However, these changes that might take place are inter-related in such a way that no parameter can be changed in isolation.[1,54] This indicates that certain basic properties are built into the fabric during the weaving process which cannot be altered later; also these properties are not only dependent on the design of the fabric, but on weaving parameters such as warp and weft tensions, which are often difficult to control.

The yarn produced by both spinning techniques differs, but there is no difference in the principles of dyestuff application. Moreover, they are spun from the same type of fibre. The dyeing of the fabrics was carried out on a winch machine under the same conditions using Durazol Blue 4RS dye as earlier mentioned.

The assessment of the colour strength or depth of shade of the dyed fabrics was carried out based on two approaches:

(1) Colour measurement as earlier indicated
(2) Subjective tests by visual observation.

A spectrophotometer (Macbeth Colour Eye instrument) was used for colour measurements to obtain spectral reflectance values for the dyed samples within the range of wavelengths (λ), 400 - 700 nm. The reflectance is related in a general way to the lightness of the colour perceived. Thus, the higher the percentage reflectance of a

specimen, the lighter is the colour perceived for the sample. The results in Table 4.17 show the (%) reflectance at = 600 nm (being the point where the least values are obtained, and average of 10 readings).

In both cases, it may be seen from this table and Fig. 4.24 that the depth of shade appears to initially increase with increase in twist factor, but decreases as the yarn becomes more compacted (i.e. at higher twist levels). It may also be observed that apart from the highest twist levels the rotor fabrics showed lower reflectance (%) values than their ring equivalents. It may, therefore, be inferred that dye absorption by rotor fabrics is relatively higher, hence the least reflectance (%), and thus would be expected to have darker shades in appearance than their ring equivalents.

The subjective tests by visual assessment indicated that at low twist levels the rotor fabrics showed a slightly darker shade than their ring equivalents with the exception of the lowest twist level of 31.57; whilst at higher twist factors the rotor fabrics showed a relatively lower shade than their ring counterparts. However, overall it was indicated that judges found difficulty in discerning any significant difference in the depth of shade of dyed rotor and ring-spun fabrics.

The two results showed a reasonable agreement, the only apparent discrepancy being at the lowest twist level. The fabrics produced at the lowest twist levels were unusual in that a critical examination of the reflectance values through the range of the wavelength seemed to suggest that there would be points of intersection if the reflectance (%) is plotted against wavelength. Where this occurs[55] it may

TABLE 4.17

COLOUR MEASUREMENTS

(Spectrophotometer)

Ring fabrics

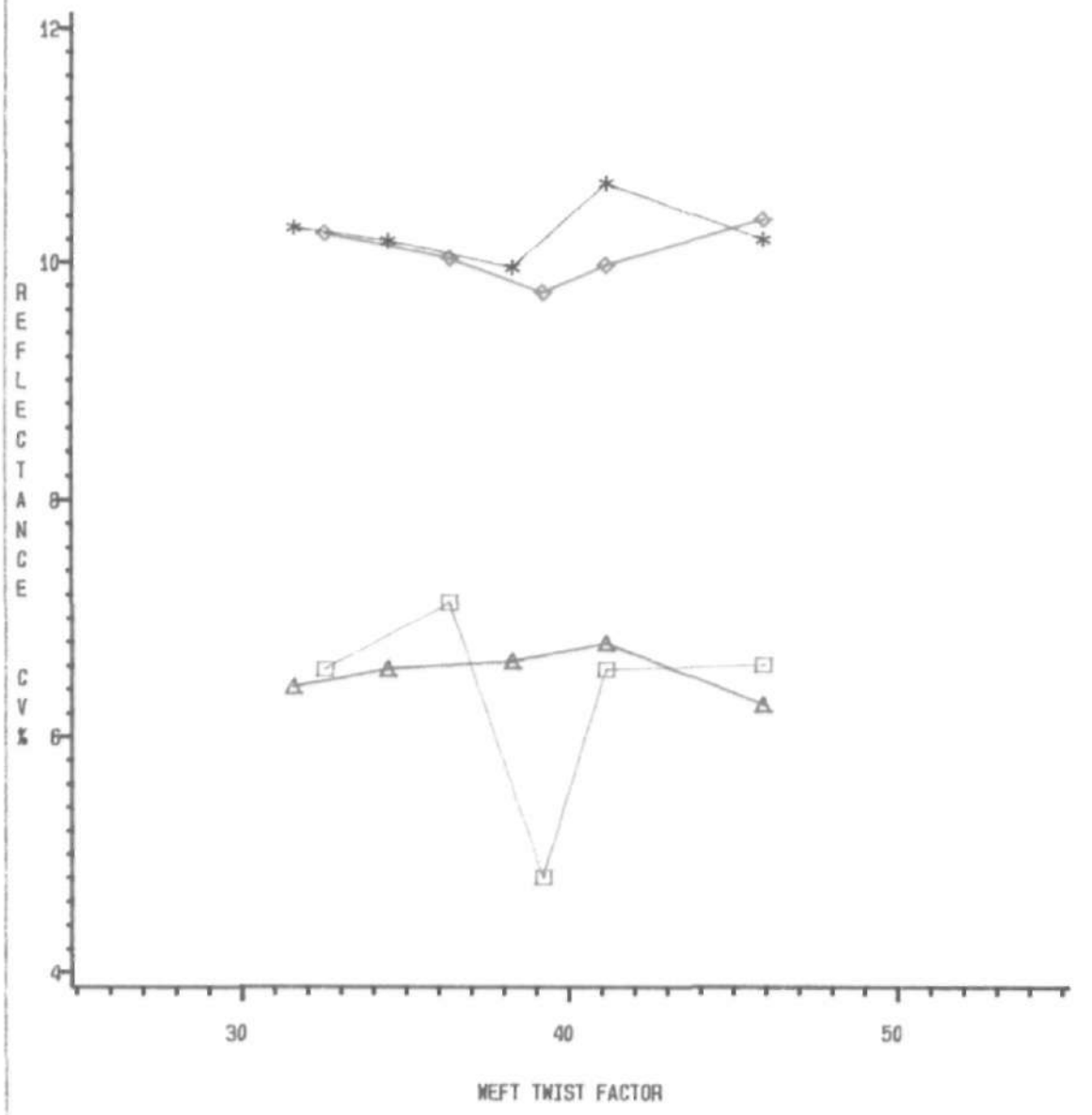
Twist factor α_{tex}	Reflectance at 600 nm	C.V.% at 600 nm
31.57	10.30	6.42
34.44	10.19	6.57
38.27	9.97	6.64
41.14	10.69	6.79
45.92	10.21	6.27

Rotor fabrics

Twist factor α_{tex}	Reflectance at 600 nm	C.V.% at 600 nm
32.53	10.25	6.57
36.35	10.04	7.14
39.22	9.75	4.80
41.14	9.99	6.57
45.92	10.38	6.61

Fig 4.24

INFLUENCE OF TWIST ON REFLECTANCE AND CV%



RING FABRIC(REFLECTANCE%)

ROTOR FABRIC(REFLECTANCE%)

RING FABRIC CV%

ROTOR FABRIC CV%

not be possible to tell by mere inspection in what way the colours of the specimen differ; a general colour difference will then be perceived depending on the light and observers giving rise to a phenomenon called metameric stimuli.[55,56,57] Secondly, the eye has no power to analyse the spectral distribution of the light producing this simple colour impression, and cannot distinguish by inspection, sources having different spectra which happen to produce the same integrated colour sensation.

The view[58] of some researchers questions whether there is any real colour differences at all between the yarns from the two spinning techniques. Nevertheless, some of the available literature indicates that rotor-spun yarn is dyed deeper[59,60] and some have also claimed that this may offer potential savings in dyeing.[61,62] The reasons advanced for the deeper shade of rotor-spun fabric is attributed to the nature of fibre geometry in terms of bulk contributing to the improved colour yield and its lack of fibre orientation, results in reduced colour reflection and this makes it look duller. The results obtained for colour measurement seem to confirm the fact that rotor yarns absorbed more dyes than their ring equivalents. It was, however, observed that ring yarns appear to be duller in appearance (less lustrous) than their rotor equivalents. This perhaps is the reason for its apparent deeper shade, especially at high twist levels, based on visual assessment, and in addition the rotor spun weft fabrics may be masked by the influence of the warp yarns.

It has also been reported[5] that rotor yarns have higher exhaustion rates, and rising of liquor through the rotor yarn is more regular, but it is also obvious that the optical characteristics due to physical

construction inherent in the yarn seem to affect the colour effects of fabrics produced from yarns of both systems. As earlier mentioned, it has been indicated[58] that under certain conditions of illumination and observation, one would appear brighter and the other would appear brighter under other conditions of illumination. This may imply that the appearance of the dyed material is dependent on the relationship of illuminant yarn and the observer.

Fig. 4.24 shows the influence of yarn twist on the coefficient of variation of the reflectance measurements. For the ring-spun fabrics, the coefficient of variation (C.V.%) passes through a maximum as the twist increases, whereas the rotor fabrics seem to be more greatly influenced by twist factor.

Aesthetic qualities of a fabric is most usually determined by taking into cognisance their visual appearance. The evaluation of fabric properties in this term seems to indicate that rotor fabrics are generally more level dyed with better uniformity and appearance. Perhaps this is due to their better fabric surface appearance associated with better yarn evenness,[63] fewer imperfections, fewer neps (these are embedded in the yarn[64-66]), and possessing fewer short protruding hairs[14] because the fibres are slightly wrapped and tend to be concealed by the belts.

From the analysis of the results in the earlier sections, it is shown that dyeing of both fabrics results in changes in the fabric dimensions. Fibre swelling results in increased crimp, number of threads per unit length and fabric cover, which also results in an effective increase in fabric thickness. These changes, in addition to flattening of the yarns, resulted in reducing the inter-yarn

openings or number of openings per unit area and the fabric air permeability is consequently decreased.

The strength of the fabric is affected in both directions after dyeing. The tear strength is also affected in a similar manner. The trends for both fabrics have been explained in detail in earlier sections. The extension at break of both fabrics appeared to show a general increase with increasing yarn twist level.

The abrasion characteristics of both fabrics are also affected by dyeing. The trend of twist influence on the abrasion resistance of both fabrics becomes more apparent after dyeing, with the fabrics showing a contrasting trend as earlier indicated.

It was not possible to measure the bending length of both fabrics in their grey state due to curling. Thus, there are no results to compare the dyed and grey fabrics. However, changes might take place due to removal of warp size, swelling of the fibres and alterations in other parameters such as thickness and weight per unit area as a result of scouring and dyeing. The theoretical calculations for shear stiffness in both fabric states seem to predict the likely trend. There was a decrease in the dyed fabric shear stiffness as compared to its shear stiffness in the grey state.

From the indicated trends of the general results, it may be concluded that both twist and dyeing have some influence on the fabric properties. The component yarn structure is altered, which consequently changes the fabric dimensions. In most cases of the assessed parameters, the trends observed before and after dyeing were the same for both fabrics, except in the case of the strength and abrasion characteristics which showed contrasting trends.

CHAPTER 5

5. Summary and Conclusion

5.1 In this chapter it is intended to briefly discuss the influence of twist, dyeing and yarn properties on the properties of rotor and ring spun fabrics which have been investigated in the present study.

5.1.1 The effect of twist

The yarns used in this work were all of the same count, but with varying twist levels, often referred to as "twist factor". The primary aim of inserting twist in staple yarn is to give it fibre cohesion and strength.[23,67] Twist in a yarn plays an important role in affecting the fibre arrangement in the yarn. Usually the fibres forming the yarn do not lie straight, but in a roughly helical configuration which is imposed by twist, and held into corrugated shapes in the weaving process.[68] Thus the yarn properties are influenced by the amount of twist imparted, which consequently influences the properties of the fabrics produced from these yarns.

Fabrics woven from both rotor and ring yarns showed better appearance and uniformity as the twist level was increased, this being in part due to the fact that at high twist levels the number of protruding hairs is reduced. Rotor fabrics, however, showed a better fabric appearance and uniformity than the equivalent ring fabrics.

The fabric contraction in the width during relaxation, shrinkage as a result of dyeing, and crimp in the yarn generally varies with changes in twist. The observed changes have been attributed to the yarn structural features, particularly the extensibility and compressibility of the yarns. These are, in turn, governed by the amount of

twist in the yarn (for example, the yarn extensibility increases with increase in twist until an optimum is reached, due to factors already explained).

As a result of twist change, the yarn diameter is changed and the number of threads per unit length in both fabric directions is increased, thus affecting the fabric cover, giving a general increase in cover factor with increase in twist. From the results it has also been shown that the effect of twist on the fabric thickness becomes more apparent when the fabric is dyed.

The fabric air permeability is affected by changes in twist in which it increases with increasing weft twist. It has been reported by Kaswell[25] that "for a given fabric no other construction variables were found to have nearly as great an effect on the fabric air permeability as twist".

The strength of a fabric, in part, depends on the strength of the yarn from which it is woven. From the results discussed so far, it is clear that twist does play a vital role in determining the strength of the yarn. Thus, there was an increase in strength with increasing yarn twist (the fabric strength in the weft direction). A similar trend was observed for tearing strength across the weft yarns. There is also an indication that the amount of twist in the weft yarn does have some effect on the warp yarns, but the nature in which this takes place is slightly more complicated.

The extension at break of both fabrics under test varies with increase in twist factor.

One of the most important factors that have often been considered to affect consumer appreciation of a textile fabric is subjective

assessment of handle. It has been shown[50] that the most important elements contributing to fabric handle are fabric stiffness, smoothness, thickness or weight. All the named parameters are influenced by twist as evidenced by the results of the bending tests. It is shown that the bending length, modulus and flexural rigidities vary with changes in amount of twist in the weft yarn. There was a general increase with increase in twist.

The abrasion characteristics of both fabrics is shown to be influenced by the amount of twist. There was no particular trend followed in the grey state, but the effect of twist in a defined trend is more apparent after dyeing of both fabrics.

It is obvious from the discussion so far that many of the fabric properties such as drape, tensile and tear strength, resistance to abrasion, air permeability, etc. are generally affected by the amount of twist in the yarn. Twist is indeed one of the variables that is known to influence other fabric properties such as visual appearance, handle and even reflection from the yarn surface. A variety of fabric effects may, therefore, be achieved by varying the amount and direction of twist in the yarn.

It may also be concluded that the manner in which twist is inserted affects the yarn structural features and properties, which in turn influences the physical and mechanical properties of fabrics produced from these yarns. The properties of the resultant fabrics are critical in determining their performance in use.

5.1.2 The effect of yarn properties

It is well known that fabric properties and behaviour are

generally influenced by the properties of fibres and yarns from which the fabric is woven. The relationship between fibre properties, yarn properties and fabric properties have, however, not been established. This is perhaps due to the complex nature of interactions of various parameters, and variables which influence the properties of the loom state and dyed fabrics.

The performance during the process of fabric manufacturing depends on uniformity of strength and linear density, and sometimes yarn hairiness. Both yarns from the two spinning techniques appeared to perform adequately well during weaving.

The yarn properties are generally influenced by twist and linear density as earlier mentioned. In this work, the former was varied but the latter was the same for all yarns. Thus, twist may be the major determining factor for the yarn properties in this case.

The appearance of fabrics seems to be influenced by the amount and nature of protruding hairs. Rotor yarn may, therefore, be suitable for production of fabrics requiring a pleasing appearance.

The spacing of the yarns and their width is determined by the yarn diameter in the free state and the extent to which it spreads in the fabric structure thus governs the cover factor, crimp, shrinkage and fabric thickness. In addition, the air permeability depends on the aforementioned fabric parameters which ultimately depend on the yarn properties. Thus the differences observed for rotor and ring-spun fabrics.

The relation between changes in the length, width and thickness of a fabric is known to be influenced by the extensibility of the yarn.[1] The fabric extensibility is also affected by the characteristics of

the yarns which alter and determine the properties of the end product.[16] From the results obtained, rotor yarns appear to be more sensitive to applied tensions than their ring equivalents.

As already mentioned, the strength of a fabric is determined, in part, by the strength of the yarn, but in addition on the behaviour of the fibres or yarns at the cross-over points which may be said to be governed by the yarn structural features or properties. Due to the unique method of fibre assembly and twist insertion method adopted in rotor spinning, its yarns seem to perform better in the fabric than in the yarn free state.

The bending behaviour of both fabrics appeared to be affected by the yarn properties. Ring yarns with more parallel fibres in the yarns, in contrast to random distribution in rotor yarns, determine the stiffness of the fabric.

The abrasion characteristics of fabrics seemed to be determined by how firmly the fibres are held. In the case of rotor yarns, the wrapper fibres played a significant role. As earlier indicated, increase in twist is believed to increase the amount of wrapper fibres which reduce the yarn strength. It, therefore, seems to indicate that appropriate specification according to the intended end-use of the yarns to obtain optimum fabric properties, are not only desired but necessary.

The dye penetration into a yarn is determined by the yarn properties; with highly twisted yarns, penetration may be more difficult. This also affects the light reflection from the fabric surface. The depth of shade is influenced by these factors also.

From the discussions made so far, including those of the earlier

sections, it is obvious that the rotor and ring-spun fabric properties are generally influenced by the yarn properties, which are governed by the twist in the yarn and the nature of the twist insertions. With this in mind, yarns may therefore be used to advantage by utilizing them in the cases where the desired fabric characteristics in the end product can be obtained. The study has also indicated that the performance of a yarn is better assessed when woven into a fabric.

CONCLUSION

Through the review of the rotor and ring yarn and fabric properties it has been shown that the manner in which both yarns are spun is different, and this results in yarns of different geometrical and mechanical properties. In this work the fabric properties which are considered to be influenced by the yarn properties are investigated in relation to the effect of varying the yarn twist level and dyeing of the fabrics. The grey and dyed fabrics of both rotor and ring spun yarns are, in turn, compared.

From discussion of the results it has been shown that yarn properties are greatly influenced by the amount of twist in the yarn. This became more apparent from the results of the assessed fabric properties in which it is shown that fabrics woven from these yarns are consequently affected by the yarn properties. In addition, within the twist levels used, the differences in the yarn structure and properties affects the fabric structure, and this is reflected in the behaviour of these fabrics. Consideration of the fabric properties of yarns produced at the same twist level has revealed that rotor fabrics have better cover and may be the same when the fabric is dyed. Rotor yarns also showed better fabric appearance and better bending properties, slightly lower air permeability and this, coupled with higher fabric thickness, may provide better thermal comfort. Rotor yarns also give fabrics which possess better abrasion resistance in the loom state, but when the fabrics are dyed their superiority is only apparent at the higher twist levels. However, it has also been shown that rotor fabrics possess lower tensile (weft) and tearing strengths than their corresponding ring fabrics, but slightly better warp strength. From the samples produced in the current investigation

there is not much colour differences in the dyed fabrics.

It may be appreciated that most of the textile products are in fabric form and mostly often dyed. From the analysis of the results obtained it may be suggested that the fabrics may be better assessed in the state of intended use and, in fact, the quality of a yarn would be better assessed when woven into fabric than in the free state (for example, the strength of rotor yarns is better in the fabric than in the free state). Considering the effect of twist and dyeing on the fabric properties, it may be inferred that the fabrics should be assessed after being given aqueous treatment such as washing, scouring and dyeing, since they can hardly be used in the loom state. It has to be subjected to some, if not all, of these treatments at one time or another.

In a real sense, comparison of fabrics from both rotor and ring yarns at the same twist level has indicated that rotor yarns compare favourably, but the assessment would be further improved if yarns of "commercial twist factors" were considered (i.e. rotor twist factor is greater than the ring twist factor). Thus, to optimize the properties of fabrics produced from these yarns, it is necessary to aim at finding optimal constructions and consideration must also be given to the excellent uniformity of rotor yarns, their higher volume and higher abrasive resistance. It is, however, of great importance also to consider the changes in fabric construction which occurs during dyeing and finishing.

The performance of textile fabrics is characterised by a number of parameters which cannot all be optimized in every case. It is, therefore, thought that in making realistic attempts to predict the

performance of the fabrics produced from rotor and ring-spun yarns, it may be necessary to take into account the twist levels commercially used in producing these yarns. This should give trends which are more closely related to those which would be obtained in "normal practice". It is well known that both yarns are often spun at different twist levels. As a rule, more twist is inserted into rotor yarn, this varying from 0 - 20% more than the ring spun equivalent according to their end-use. Except for special purposes, the twist factors often employed are α_{tex} 36 and α_{tex} 43 for ring and rotor yarns of 36 tex, respectively. The yarns are always spun at twist levels which give near maximum strength, and this is usually higher than minimum twist.

A fabric is valued for its attractiveness and performance during use. These criteria are influenced by a number of complex properties, such as handle, abrasion, permeability to air, strength and bending; all these are among the properties that determine the quality of a fabric.

The assessment of rotor fabric as compared to ring fabric properties has shown that rotor fabrics perform fairly well and may be better in some properties than ring fabrics. It may be seen from the summarised table in Appendix II that at commercial twist levels rotor fabrics have generally shown equal or better fabric properties than the ring spun fabrics. The rotor fabric possesses better appearance and uniformity; dyed more level but usually of a similar depth of shade; gave greater fabric thickness and better grey cover; had better air permeability both in the loom state and dyed states, which may give the fabric better thermal and hygienic properties.

The main disadvantage indicated in the test results for rotor fabrics is the lower weft and tearing strength which may raise the question of its durability, but the difference is much reduced when the fabric is dyed and may not be of any consequence. Moreover, it showed better strength in the warp direction. In some woven fabrics, strength may not be as important as appearance, and the lower strength may not affect consumer acceptance of fabrics produced from rotor yarns.

At the commercial twist levels (Appendix II), the weft bending length and modulus seem to suggest that the rotor fabrics may drape more stiffly and more papery to hand feel; the flexural rigidity, however, seems to indicate otherwise.

The rotor fabrics at these commercial twist levels displayed better resistance to abrasion forces in the loom and dyed state than their ring counterparts.

From the trend of results, it is obvious that the "common warp" used had some influence on the behaviour of both fabrics. However, it would be appreciated in objective terms that the results predict, to a reasonable extent, the influence of yarn properties on the assessed properties of fabrics produced from rotor and ring-spun yarns as weft, and consequently the performance of both fabrics in use.

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APPENDIX 1

A. Cover Factor

Formula used:

$$K_f = K_1 + K_2 - K_1K_2$$

where: K_f = cloth cover

K_1 and K_2 = the warp and weft covers

$K_1 = n_1 d_1$

$K_2 = n_2 d_2$

where: n_1 n_2 are the ends/cm and picks/cm

d_1 d_2 are the warp and weft yarn diameters

$$d = 4.44 \left[\left(\frac{Tex}{\rho}\right)^{\frac{1}{2}} \times 10^{-3} \right] \text{ cm}$$

ρ = 1.35 for cotton fibre density.

B. Shear Stiffness (S)

$$S = 0.3 \left(W^5/H^4\right) \times 10^{-15}$$

where: W = weight of fabric in g/m^2

H = fabric thickness (m).

C. Date for fabric weight

(a) Ring fabric

Twist factor: (α_{tex})	31.57	34.44	38.27	41.14	45.92
Weight (g/m^2), Grey:	1.975	2.008	1.965	1.973	2.045
Weight (g/m^2), Dyed:	2.280	2.380	2.310	2.340	2.320

(b) Rotor spun fabric

Twist factor: (α_{tex})	32.53	36.35	39.22	41.14	45.92
Weight (g/m^2), Grey:	1.909	1.947	1.973	1.978	1.974
Weight (g/m^2), Dyed:	2.330	2.310	2.320	2.270	2.310

D. Flexural Rigidity of the cloth (mg/cm) was calculated from the formula:

$$G = W_2 C^3 \times 10^3 \quad mg/cm$$

$$G_o = \sqrt{Gwf \times Gwp}$$

E. Bending Modulus:

$$q = \frac{12\ G}{g_2^3} \times 10^{-6}\ kg/cm^2$$

F. where:

B.L = C = Bending length

W_2 = Cloth weight in gm/sq.cm (dyed)

g_2 = is the cloth thickness in cm measured at a pressure of 1 lb/sq.in.

Gwf = Weft flexural rigidity

Gwp = Warp flexural rigidity

G_o = Fabric flexural rigidity (over-all)

q_1 = Warp bending modulus

q_2 = Weft bending modulus.

APPENDIX II

Comparison of Ring and Rotor Fabric Properties
(with reference to the commercial processing of the yarns)

Fabric parameters	Ring fabrics	Rotor fabrics	Rotor : Ring	
The width of the woven fabric (cm)	113.55	114.35	1.01	Rotor better
% Crimp:				
Grey: warp	6.13	6.92	1.13	Rotor higher
weft	12.22	11.20	0.92	Rotor lower
Dyed: warp	10.80	10.33	0.96	Rotor lower
weft	20.37	19.07	0.94	Rotor lower
Thickness (x 10^{-3}) (mm)				
Grey:	514.86	544.32	1.57	Rotor higher
Dyed:	667.00	657.00	0.99	Rotor lower
% Area Shrinkage:				
Scoured:	11.69	12.04	1.03	Rotor higher
Dyed:	13.63	12.86	0.94	Rotor lower
Air permeability ($m^3/sec/cm^2$):				
Grey:	20.85	21.96	1.05	Rotor better
Dyed:	8.30	8.35	1.01	Rotor better
Breaking load: (kg/cm)				
Grey: warp	13.36	14.27	1.07	Rotor higher
weft	11.49	3.81	0.77	Rotor lower
Dyed: warp	13.00	15.20	1.17	Rotor higher
weft	10.69	9.67	0.90	Rotor lower
% Extension:				
Grey: warp	15.20	16.24	1.07	Rotor higher
weft	19.95	19.08	0.96	Rotor lower
Dyed: warp	20.13	22.63	1.12	Rotor higher
weft	28.25	27.59	0.98	Rotor lower

Continued .....

APPENDI II (Continued) ...

Fabric parameters	Ring fabrics	Rotor fabrics	Rotor : Ring	
Weft tear strength (kg/cm):				
Grey:	4.70	3.86	0.81	Rotor lower
Dyed:	2.96	2.50	0.84	Rotor lower
Bending properties:				
Bending length:				
warp	2.207	2.169	0.98	Rotor better
weft	1.525	1.536	1.01	Rotor more stiff
Overall flexural rigidity:	144.77	139.24	0.96	Rotor better
Bending modulus:				
warp	10.28	9.92	0.96	Rotor better
weft	3.33	3.51	1.05	Rotor more papery
Shear stiffness:	13.29	10.25	0.77	Rotor better
Fabric cover:				
Grey	0.658	0.665	1.01	Rotor better
Dyed	0.687	0.687	1.00	The same
Abrasion resistance:				
Grey	13625	18825	1.38	Rotor better
Dyed	15600	15900	1.02	Rotor better