SAWTRI SPECIAL PUBLICATION

A REVIEW OF THE PROCESSING OF WOOL AND WOOL BLENDS ON THE SHORT STAPLE (COTTON) SYSTEM

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INTRODUCTION

The past decade witnessed a growing interest in the processing of wool on the short staple (cotton) system and a great deal of research effort has been directed worldwide towards the solution of the various problems which present themselves when attempting to process wool in this manner. The intention of this publication is to provide a summary of published work on the processing of wool on the short staple processing machinery which, it is hoped, will be useful for the textile industry and for research workers in this field.

Many research institutes, including SAWTRI, have been concentrating considerable efforts towards determining the conditions under which wool and wool blends can be processed on short staple machinery and whether this is technically and economically feasible and if aesthetically desirable and commercially attractive products can be manufactured. If wool could be successfully processed along this route, it is anticipated that it would increase the demand for wool, helping it to maintain and even strengthen its position in the market place. One way this could be achieved is by expanding the product range for wool. The other way in which this could be achieved is related to the fact that textile production is rapidly moving towards low labour cost countries where short staple machinery predominate. Therefore a viable method of processing wool on the short staple system could encourage the wool processing and promote the use and demand for wool. Furthermore, since the textile processing equipment designed for the short staple industry dominates the market and as wool's share becomes a relatively smaller part of world textile fibre consumption, machine builders could re-direct research and development effort away from long staple wool processing equipment, hence necessitating a method of processing wool through a more universal system if it is to maintain a healthy position in the market place.

Short wools are generally required for processing on the short staple system and suitable wools are available in fair quantities, and in addition machines which can reduce longer wools to the required length are nowadays available which increases the range of suitable raw materials.

GENERAL TRENDS IN THE TEXTILE INDUSTRY

There has been a growth in the world consumption of textile fibres over the period 1930 to 1975[1]. However, the main growth has been in the man-made fibre field, followed by cotton with an annual growth rate of 3%, while wool showed only a marginal increase. In terms of the relative share of the textile fibre market, man-made fibres has increased their share dramatically over the past 25 years, their production today representing almost 50% of world fibre production. The market share of wool for the same period showed a decline from about 12% to 5%.

Cotton still accounts for the largest single share of the world textile fibre market. In IFCATI countries[2] (W. Europe, USA, Japan, Korea, Egypt and India), which represent about 75% of world total textile production, cotton's share amounted to about 71% of the total fibre consumption in 1977 and now has a share of approximately 55% of world total fibre consumption. This, coupled with the increasing production of man-made fibres, which can virtually be processed on any system, provides the one reason for the predominance of short staple processing equipment. In fact, it has been indicated[3] that within the developed (OECD) countries, the number of cotton spindles installed and running in 1975 amounted to approximately 82% of the total number of spindles while worsted spindles accounted for 13% and woollen for 5% of the total. It has also been stated[4] that the explosive growth of textile production in Asian (and African) countries favours short staple type machinery and that the American[4a] trend towards new spinning plants has become predominantly for cotton-type (short staple) fibres, while that used for wool being progressively outmoded.

Even though the exact number of wool spindles in the world are not available, it is believed that the percentages given above are not very different from that which applies worldwide. However, the total number[2] of short staple system spindles in the world increased from 123,4 million in 1950 to 148,5 million spindles in 1975. While the developed countries had 70,3% of the total number of short system spindles in 1950, this dropped to 33,6% in 1975, whereas that for the developing countries increased from 14,7% to 37,4% of the total number of short staple spindles in the world and that for the socialist countries from 15% to 29% over the same period. The implication of these figures is that the developing countries not only have a higher proportion of the short staple system spindles in the world but are steadily increasing their capacity and it is forecasted that the future will witness a similar trend in the installation of this type of machinery.

A similar pattern[2] to the above is also apparent in the fabric manufacturing sector of the industry. In 1975 the number of looms that were installed for the cotton textile industry in OECD countries was more than 8 times that for the wool textile industry. For the period between 1950 and 1975, there apparently[1] has been a significant reduction in cotton system weaving and spinning capacity in the developed countries (a decrease by approx. 50%) and a corresponding increase in the capacity of socialist and, more especially, developing countries. Although in 1950 the developing countries were importers of textiles to the extent of 0,36 million tonnes, by the year 1974 the situation changed such as to make them exporters of 0,52 million tonnes textiles valued at 3,4 billion US dollars.

As can be seen from the above facts, the demand for short staple processing equipment, mainly created by developing countries surpasses that for long staple processing; consequently the attention of the machine producers are increasingly directed towards this market, ensuring a steady development of suitable machinery. One very good example would be the successful penetration of open-end system spinning into the market which is developed mainly for short staple spinning.

Another important trend[5] for the wool textile industry, is the wool fibre's continual loss of its proportional share of the input fibres due to synthetic fibres increasingly being used in blends. This trend is more evident in cases of the carding section and worsted yarn production and also to a lesser extend in woollen spinning industry.

In the light of the above facts, many consider that the profitability of the wool textile industry can only be achieved by the short staple processing equipment and by taking advantage of its economics. This, of course in return will significantly increase the volume of machinery available (effectively tenfold[6]) for the processing of wool through the expected demand from the developing countries which are, otherwise, restricted to the short staple fibres.

PRESENT COMMERCIAL APPLICATION OF WOOL PROCESSING ON THE SHORT STAPLE SYSTEM

The spinning of wool on the short staple system is nothing new, cotton spinners having made serious efforts in this respect, mainly for commercial reasons hoping to enter markets in which the profit on yarns was higher. Another consideration is the inefficiency of the worsted system in producing blends involving wool and short staple fibres, most man-made fibres being produced for short staple system processing. On the other hand, the technologists' interest was purely professional due to the challenges it represented to their expertise.

The processing of wool on the cotton system was practised on a very significant scale many years ago. Somewhat different methods were used due to the traditional and labour intensive machineries available then; their design often being modified to handle blends of wool and cotton in the 1920's and 1930's. Fabrics[7] produced from these yarns were raised after printing to make popular "Union Flannelet" for shirting and children's nightwear.

India[6] is known to have produced blends of wool and cotton for many years on the short staple system and also in the recent years blends of wool and polyester for suitings. Germany[6] is said to have diverted a significant proportion of its top production to processing on the short staple system for wool and polyester blends. Several Japanese[8,9,10] firms offer wool-cotton blended fabrics produced from short staple system yarns. Besides these, there are also firms[4,6,11,12,13] in Italy, USA, France, Spain, Indonesia and Taiwan producing similar blends of wool on the short staple system. However, Viyella of UK is still regarded[6] as the market leaders in this field. In fact, for many years they have been producing 55% wool/45% cotton yarn and 80% cotton/20% wool yarn on a modified short staple system and their shirts are world famous.

Many research organisations and machine manufacturers have directed effort towards the successful processing of wool on the short staple system[6-65]. Research organisations working in this field include the IWS, CSIRO of Geelong (Australia), SAWTRI (South Africa), Texas Technical University Textile Research Centre and USDA in the USA and CRITR of France. Various developments are claimed to overcome the problem of long fibres on the short staple system and it is also being modified to deal efficiently with these fibres.

RAW MATERIAL REQUIREMENTS AND METHODS OF BLENDING

Considerations regarding fibre length

Problems will arise with use of the short staple system at the drawframe and afterwards, if wool with a mean fibre length exceeding about 40 mm is used. However, a small proportion of fibres longer than 65 mm may be permissable in the raw material since some breakages occur during processing. In theory, there is no restriction on fibre fineness, but the relatively small packages, commonly used on the short staple ring frames, necessitates the spinning of relatively fine yarns for economic reasons thereby limiting the fineness of wools to 23 μm and finer.

The short staple system generally requires wool which is reasonably open and free of burrs[6]. Some short wools, finer than 58's ($\approx$ 24 μm) with little burr, are available from Australia, South Africa and South America and according to an IWS[6] estimate such wools constitute about 3% of the world wool clip. These are suitable for the short staple system without any modification of the fibres. Although short scoured wools are potentially the cheapest raw material, relatively high waste losses during their opening and carding could off-set initial advantages in cost[6].

It has also been indicated[6] that suitable short staple wool tops are offered by top makers of various countries. Besides these, coarser wools of suitable lengths for short staple processing are also available on the market.

It is expected that as the research proves its success, and the necessary technical know-how becomes more freely available, the quantity of wool processed on the short staple system will gradually expand; hence resulting in shortages of suitable wools. It is generally believed that cutting or breaking normal length wool prior to drawing could meet this problem since there are various machines[6,7,14,15,46,49,50] available for this purpose.

Machinery[6,14] for cutting slivers, are used primarily for reducing synthetic tow to sliver, making use of helical knives. The appliction of this technique to a wool sliver, however, has the disadvantage that, in addition to the long fibres, *short fibres are also cut making them even shorter which results in an* unsatisfactory fibre distribution due to the excessive proportion of short fibres. Another disadvantage is that the out-put is only in open form and hence it can only enter the short staple system via the blowroom.

In contrast to the cutting process, discussed above, the stretch-breaking process could be expected to reduce the length of the longer fibres without causing[6,7,14,15,46,50] an excessive reduction in the lentgh of the shorter fibres, thereby producing a more satisfactory top than the cutting process (see Fig. 1). The breaking machine is fed with fibres in the form of top or sliver, and the staple is broken into a suitable length by employing successive pairs of nip rollers with different surface speeds hence the long fibres are simultaneously held by the nip of both pairs of rollers, which are spaced according to the fibre length requirements, resulting in the reduction of fibre length to a predetermined length. These converters apparently produce a controlled staple length diagram with very similar characteristics to that of the material fed into it, though the fibre distribution shows a tendency to be relatively square[15]. These stretch-breaking machines are offered by a number of manufacturers[6,15,16,17,46,50] such as Castella, Duranitre, Heltra, Schlumberger, Seydel and Tematex.

Another approach to the problem of increasing the quantity of short wool suitable for processing on the short staple system entails more frequent shearing but there are various biological and economic objections to this and it is considered to be economically viable only in those countries with relatively cheap labour. In the past few years the viability of shearing wool of suitable staple lengths for short staple processing has been investigated[13,18,19] in the USA. Lupton[13] stated that, although the processing of such short shorn wool may appear economically attractive because of the low price of raw material, the greater waste losses suffered during processing may offset the initial price advantage.

Louis and Pardo[20] found that the shortening of wool either by cutting or stretch-breaking method did not have an effect on the yarn and fabric properties produced from wool/cotton blends. Ellis and Robinson[21] also concluded that the choice of selected short wools or longer wools is influenced purely by economics and the availability of supply and not by processibility and product quality since they found that the processing and the quality of fabrics woven from wool fibres of various lengths were generally similar and good.

------ FIBRE DIAGRAM
—— HISTOGRAM

COMPARATIVE ALMETER CHARTS (14)

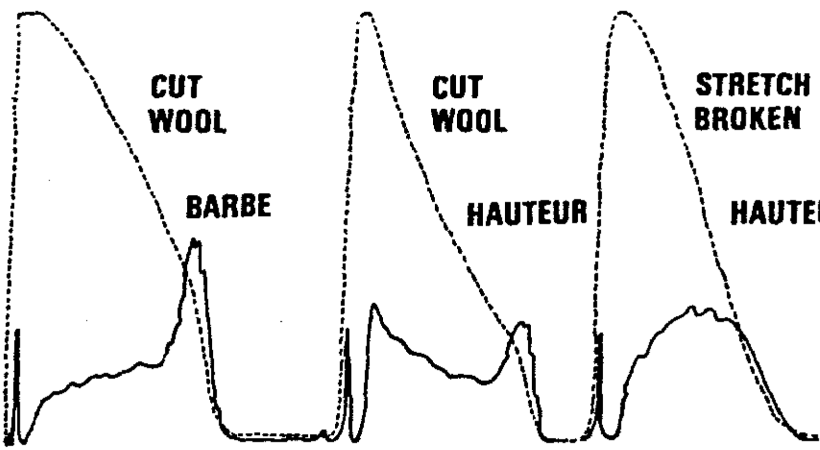

FIGURE 1

As far as the choice of other fibres to be blended with wool is concerned, it appears that polyester with a staple length around 38 mm and a linear density of between about 1,6-3,5 dtex would be suitable depending on the fineness of the yarn to be spun. A suitable cotton would probably have a staple length (2,5% span length) of about 30 mm .

Types of Wool Feedstock and Methods of Blending

As mentioned earlier, the material destined for short staple system should be reasonably open and free from burr. Hence the choice of wool may be confined to combed material although some trials on the processing of selected scoured (loose) wool have also been carried out.

At SAWTRI, a number of investigations were carried out using blends of short scoured wool and cotton and carbonised wools and cotton. It was noted[22] that the clean wools (free from vegetable matter) which had not been felted during scouring produced less waste both in the blowroom and at the card, with the waste also containing more wool when faulty and felted wools were used in the blend. Aldrich[23] also noted that the blend containing scoured wool produced more waste during carding than the blends containing the same wool but in the form of open top or top where the latter was blended with cotton at the card and the other two lots at the blowroom.

At the CSIRO[17,21,24,25,26,27], four types of wool supply were evaluated viz:

(a) dry and oil combed noils[27]

(b) carbonised lambs wool[27]

(c) dry-combed 40 mm wool in open "loose stock" and in bumped top form[24]

(d) dry-combed stretch-broken tops covering a range of fibre lengths[21].

It was concluded that all these wools could be processed successfully either alone or in blends with cotton, although noils and carbonised lambswool had a number of disadvantages. Suitable noils were limited to dry-combed Noble noils and it was difficult to produce laps and to handle the slivers when 100% noil was used and hence there was a need for blending early in the process. Furthermore, cotton combing, with its associated high processing losses, was necessary. On the other hand, carbonised lambswool also produced high processing losses due to the need for pre-carding (woollen) and subsequent cotton-combing and it also entailed loose stock blending.

The USDA[20] has investigated the performance of cut and stretch broken combed tops on the short staple system while CRITR[15] of France also conducted trials on stretch-broken tops. In the main, their findings tended to agree with the conclusions of others and that is that conventional short staple machinery can be used successfully with these feed stocks.

Lupton[13,28] compared the performance of combed cut-top with that of scoured short (shorn) wool. The results indicated that during processing the scoured (shorn) wool, produced more waste because of its entangled state and the presence of vegetable matter.

In general, it appears[6] that the processing of loose scoured wool in blends may not be commercially feasible because of the high fibre waste even though acceptable yarns can be produced.

Although trials in Japan[29], Australia[21,24,27], USA[28] and France[15] have indicated that all-wool yarns can be spun successfully, blends of wool with cotton or synthetic fibres may provide a greater potential for product development in knitting and weaving. It also appears that blends are more easy to process through the blowroom than 100% wool[30-32], although it is possible to process 100%[28] wool provided certain precautions are taken. Polyester offers certain technical advantages above cotton for use in blends with wool[6], with low-pilling polyester being preferable.

The form of the input material in most cases determine the blending point and preparatory sequences. In commercial production, however, the cost of the material and the processing sequences will require a certain form of input material while the end-product will determine the blend composition.

Wool in various forms such as scoured and carbonised stocks, tops, cut-and stretch-broken tops has been blended with other fibres at four different points in the short-staple processing line:

(a) By mixing the raw materials in the blowroom[13,22,23,27,28,30-34]

(b) Blending at the card using wool in the form of sliver and cotton in the form of lap[22].

(c) Blending slivers composed of different fibres at the drawframe using both conventional and slip drafting[6,20,21,22,23,24,29].

(d) Lupton[28] also referred to a trial which involved the blending of wool with cotton in the cotton spinning frame by utilising a double creeling technique, with wool on one roving bobbin and cotton on the other.

PROCESSING

General

Most of the trials, involving the spinning of wool-rich blends on the short-staple system, have been conducted on the same sequence of machinery used for cotton and cotton/synthetic blends. During the trials at CSIRO[24,27] the humidity and temperature conditions were maintained at 60-65% RH and 21°C, respectively, these being considered best although 55-60% RH was also reported to be satisfactory. Lupton[13], on the other hand, maintained the relative humidity and temperature at 55-58% and 26°C, respectively, for opening, cleaning, picking, roving and spinning but increased the relative humidity to 70% for carding and drawing so as to obtain reasonable production speeds. In another trial, Lupton[28] reported that the card room temperature was 25°C and the relative humidity 50%. For wool processing, an RH of 60% has been recommended[15] for drawing and 65% (and 20°C) for the roving operation.

Blowroom

King *et al*[32], Veldsman and Taylor[31] and Spencer and Taylor[30] all stated that it was not commercially feasible to produce an all wool lap in the blowroom. Various trials[27,30] indicated that a minimum of 20 to 25% of cotton or polyester was necessary to ensure the production of satisfactory laps by increasing interfibre cohesion. At SAWTRI layer blending followed by hand feeding to the blowroom was resorted to. The main advantage of blowroom blending is that a more intimate blend is obtained than when blending at the card or at the drawframe.

Most researchers accept[23,24,27,28,30,32,34] that, in light of earlier findings[32], the wool component should be treated with an antistatic lubricant prior to it entering the blowroom to enable it to perform satisfactory during processing, particularly during carding and spinning. It has also been reported[30] that the addition of a suitable antistatic was successful in eliminating the "roller licking" problem often experienced in the blowroom.

Because of wool having a higher bulk and a lower cohesion than cotton, the CSIRO preferred to use settings similar to those used for synthetics, especially acrylics during their trials and they found them suitable. On the other hand, Lupton[13,28] and SAWTRI[22,23] generally did not alter the settings from that used for processing cotton. It was reported[13,22,23,28] that as the percentage wool in the blend increased, it became more difficult to remove the lap-pin manually at the scutcher. The problem can be overcome by producing half laps (Lupton[28] reported an average mass of 11,3 kg). The production of full laps was further inhibited by the relatively high bulk and sponginess of the wool and its blends. Nevertheless, the restriction of the mass of the laps invariably eliminated lap splitting.

As mentioned earlier, it was noted[22,23] that, provided the wool component was not felted and was relatively free from vegetable matter, the blowroom waste produced when processing a wool/cotton blend was less than that produced when processing the cotton component on its own, suggesting that the wool acted as a "carrier" for the cotton. However, the position was reversed when the wool component was either felted or had a relatively high vegetable content (see Fig. 2).

It has been reported[27] that cotton machinery does not open matted wool fibres well enough for satisfactory processing, and consequently carbonised wool, which is usually matted, needs to be half-carded on the woollen card before it is introduced to the blowroom.

Carding

Wool can be fed to a cotton card in the following forms:

1. Scoured wool converted into laps via the blowroom;
2. worsted carded slivers, mounted on a suitable creel;
3. worsted carded and gilled slivers, creel mounted;
4. open or broken top prepared into laps via the blowroom.

A number of publications[13,22,23,24,27,28] reported that the carding performance of wool blends is satisfactory on cotton cards fitted with metallic clothing and employing the same settings as for cotton. CSIRO[24,27] reportedly used a cotton-type licker-in wire in their trials although they advocated the use of a synthetic type of licker-in wire for production runs. They also stated that reducing the tension draft between doffer and coiler by 5-6% provided a satisfactory web tension.

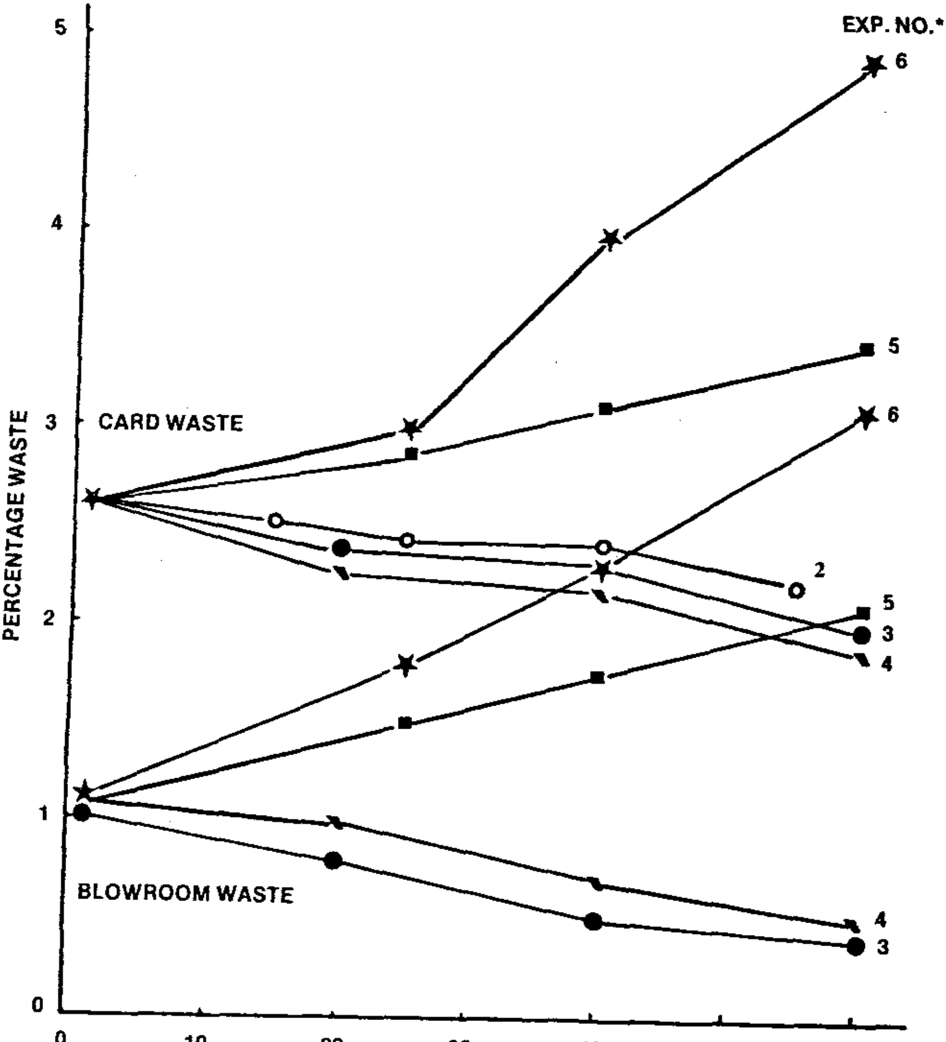

FIGURE 2

Percentage waste versus blend ratio[22]

*Exp. No.

2 — Wool top blended with cotton at the card.

3 — Broken top (the same wool used in Exp. 2) blended with cotton at the blowroom.

4 — 6 Months merino fleece practically free of vegetable matter blended with cotton at the blowroom.

5 — Transkei wool with 2% vegetable fault blended with cotton at the blowroom.

6 — Carbonised lambs wool (heavily felted) blended with cotton at the blowroom

According to the CSIRO[24] better card performance of wool in terms of reduced fibre breakage can be achieved by increasing the flats-to-cylinder setting by over 80% and reducing the licker-in speed and doffer speed by approximately 28% and 22%, respectively. Louis and Pardo[20] also processed a 100% wool stock on a cotton card but web sagging occurred and the web broke before it reached the trumpet located immediately before the calender rolls thus preventing a sliver from being formed. To overcome the problem of sagging a trapezoidal-shaped, stainless steel pan was fabricated to support the wool web.

Trials[34] were carried out at SAWTRI to determine the efficiency of single and tandem card in removing the vegetable matter, this being an extremely important consideration particularly with respect to the dyeing of fabrics made from wool/cotton blend yarns. The conclusion was that the tandem card was effective for the removal of vegetable matter and that it eliminated the need for either combing or carbonising when relatively coarse yarns are being spun. It appears that the cotton card is capable of performing an excellent cleaning action particularly if a double passage or a tandem card is used.

In the only reported trial[22] on blending at the card, the cotton component was processed through the blowroom and formed into a lap and then three or more wool tops (depending on the blend ratio) were fed together with the cotton lap to the card. The slivers were spread evenly across the width of the card. Some accumulation of wool fibres between the teeth of the licker-in was observed, although this did not affect carding efficiency since the accumulation was limited by the stripping action of the swift.

The amount of card waste (licker-in waste plus flat waste) has been reported[23] to decrease as the percentage wool in the blend increased when processing wools free of vegetable matter. On the other hand, the presence of vegetable matter in the wool component, caused more licker-in and flat waste to be extracted as the percentage of wool in the blend increased. It has also been reported[22] that the wool content of the waste increased as the wool content of the blend increased, the rate of increase depending on the type of wool used in the blend. CSIRO[27] studies showed that carding losses of wool/polyester blends could be as high as 8-15%, depending upon the blend ratio.

It has been suggested[23] that decreases in the 2,5 per cent Span Length which occur during the carding of wool/cotton blends were mainly due to the wool component suffering fibre breakage, a reduction of up to 30% in the length of the wool component having been observed[6] at the card it being lower when broken tops are blended in the blowroom. The fibre breakage of the wool component also resulted in a tendency for the uniformity ratios of the blends to decrease.

Aldrich[22] reported that, when relatively clean wools were used, the nep content of wool/cotton slivers decreased with increasing wool content. However, when heavily felted wools or wools with high vegetable content were processed, the nep content of the card slivers were either independent of the blend ratio or else increased slightly with an increase in wool.

Recently, there has been a new carding development[35,36] from Leeds University which is aimed at processing long-staple fibres on a modified Lancashire-type cotton card. The concept is based on using a pinned roller-feed system on the card. Basically the new feed consist of a stationary feed plate and a revolving feed roller with a pinned taker-in which transfers the fibres from the feed roller onto the carding cylinder. It is reported to be very gentle on fibres, producing practically no fibre breakage and yet providing an intense opening and cleaning of the fibres. It is apparently particularly suited to worsted type of fibre lengths and suitable for almost any such fibres. However, the new system will not handle wools with a high residual grease level and cannot provide an intimate blend of the fibres.

Drawing

Carding is generally followed by two passages of drawing or three passages for blends to ensure homogeneous blending. Probably the simplest method of introducing wool into the short-staple system is at the drawframe, in the form of pre-drawn tops[6] of low linear density.

Breaker and finisher drawing performances were found to be satisfactory during various trials[13,15,20,22,23,28,33,34] involving a number of different short-staple drawing frames. The drafting arrangements were generally adjusted to accommodate the longer wool fibres. Various workers[13,23,28,34] found that in most cases, a back zone roller setting about 6 to 6,5 mm greater than the mean fibre length and a front zone roller setting about 3 to 4 mm greater than the mean fibre length provided the best control over the shorter fibres in the blend, although this resulted in some breakage of the longer wool fibres in the blend. Spencer and Taylor[34] did not, however, consider the latter entirely undesirable since they were of the opinion that it would tend to bring the lengths of the blend components closer together, thereby possibly even improving yarn irregularity.

Workers at the CSIRO[21,24,37,38] revived the double-apron slip draft system used in the worsted industry thereby enabling fibres up to 65 mm long to be processed on the conventional short staple system, normally restricted to the processing of staple lengths no greater than 40-45 mm . The processing system was modified by employing slip drafting at all drafting stages from the drawframe to the ringframe. This is claimed to have various advantages, an important one being that it provides satisfactory drafting of the longer fibres while still controlling the shorter ones. Slip drafting enabled materials of very diverse length distributions to be blended successfully, and processed into acceptable end products which would not be possible with solid nips. In fact, even when materials of similar fibre lengths were blended, the regularity of the products was much better with slip drafting than with solid nip roller systems. After investigations[24] on pure wool, wool/cotton and wool/polyester blends, it was concluded that a recess of about 0,3 mm is optimum and that the roller settings were critical, various recommendations[21,24] being made in this respect.

Although certain workers[13,22,23] did not find it necessary to change the bore of the output trumpet of the coiler tube to accommodate the increased bulk of the sliver, the CSIRO[24] recommended that the core of the coiler be increased slightly should choking occur.

Many reports[6,20,21,22,23,24,29] have dealt with the blending of wool with other fibres at the drawframe. Apart from producing less intimate blending than either the blowroom or the card, drawframe blending can introduce a problem because of the large difference in linear density between cotton slivers (about 4 ktex) and wool tops (about 20 ktex). To ensure a uniform distribution of the material across the drafting zone, the linear density of the wool top has to be reduced by pre-drawing to match that of the cotton slivers. This obviously means an extra process and additional capital expenditure. One advantage of drawframe blending, however, is the very low fibre loss compared to that of blowroom- and card-blending.

It is generally agreed[28] that, at both the breaker and finisher drawing stages, cotton slivers are more regular than wool slivers and that the slivers become more irregular as the percentage of wool in the blend increases. This is probably mainly due to the fact that two materials differing in both fibre length and diameter are being blended, together with the fact that the number of fibres in the sliver cross-section will decrease as the percentage of wool increases since wool fibres are generally coarser than cotton fibres.

Combing

In trials conducted at the CSIRO[27], on carbonised lambs wool and noils, the blends were combed following a traditional combed-cotton route with the intention of reducing the short fibre content since it was intended to produce fine yarns. No specific problems were reported although the bi-modal distribution of the blends made the comb settings critical. Minimum noil removal was about 14-16%, with wool and wool-type wastes constituting at least 95% of the noil.

Trials were carried out at SAWTRI[34] on the combing of wool/cotton blends using the closest settings possible so as to reduce the vegetable matter content. The difference in residual vegetable matter in the combed sliver and the uncombed second drawframe sliver was found to be minimal, suggesting that the combing operation was unwarranted from this point of view. The combing noil amounted to 21% and consisted of 53% cotton and 47% wool. It was concluded that the capability of the combed sliver to be spun to finer linear densities was most probably due to the removal of short fibres and better parallelisation of the fibres.

Roving

It has been shown[13,20,22,23,28] that satisfactory wool and wool blend rovings can be processed on a short-staple speed-frame without any modifications other than those required to accommodate the slightly longer fibres and to reduce the twist. The need[28] to reduce the twist arises from the higher cohesion of wool in the roving as compared to that of cotton.

One important point is that the linear density of the feed sliver should be restricted since, because of the natural bulk of the wool fibres, the pressure of the upper rollers may cause the material to spread beyond the drafting rolls. On the other hand, a suitable roving can not be obtained from a very fine feed sliver. Morones[15] tackled this limitation by employing condensers (up to a width of 20 mm) immediately before the feed rollers, thereby also improving control over the fibres in the drafting zone.

The CSIRO[24], apart from using a slip drafting system with a recess depth of 1 mm, modified the machine to use a wider apron setting and due adjustments were also made to the lay and winding gears to accommodate the different physical nature of the wool. Lower twist levels were used to compensate for the higher cohesion of wool. It was also indicated that, although not essential, the use of longer drafting elements than normally employed for cotton can improve quality. Some information regarding processing conditions was also given.

Ring Spinning

It appears that, in general, wool blends can be successfully spun[22,23,27,33] on conventional short staple spinning frames without any modifications. However, Louis and Pardo[20] had to make slight adjustments to back drafts and roll settings to produce even yarns from some of their broken wool/cotton blends. Reporting on trials involving the production of all-wool from stretch-broken wool yarns, Morones[15] also pointed out the need to use a spinning frame with a drafting set capable of being adjusted to the required distances. He presented a graph for the spinning limits of short-staple wool on the ring-frame. (Fig. 3)

At CSIRO[24], satisfactory wool and wool blend yarns were produced on a spinning frame incorporating a slip drafting arrangement having a roller recess depth of 1,0 mm (2 mm in diam.). The 3 mm apron spacer used for cotton was also changed to 5 mm .

Since short staple spinning frames use smaller rings than worsted spinning frames, the yarn packages are smaller and consequently the system is economically more suited to the spinning of fine yarns. Therefore, when producing coarser yarns for commercial applications[28], the use of larger rings would be more economical.

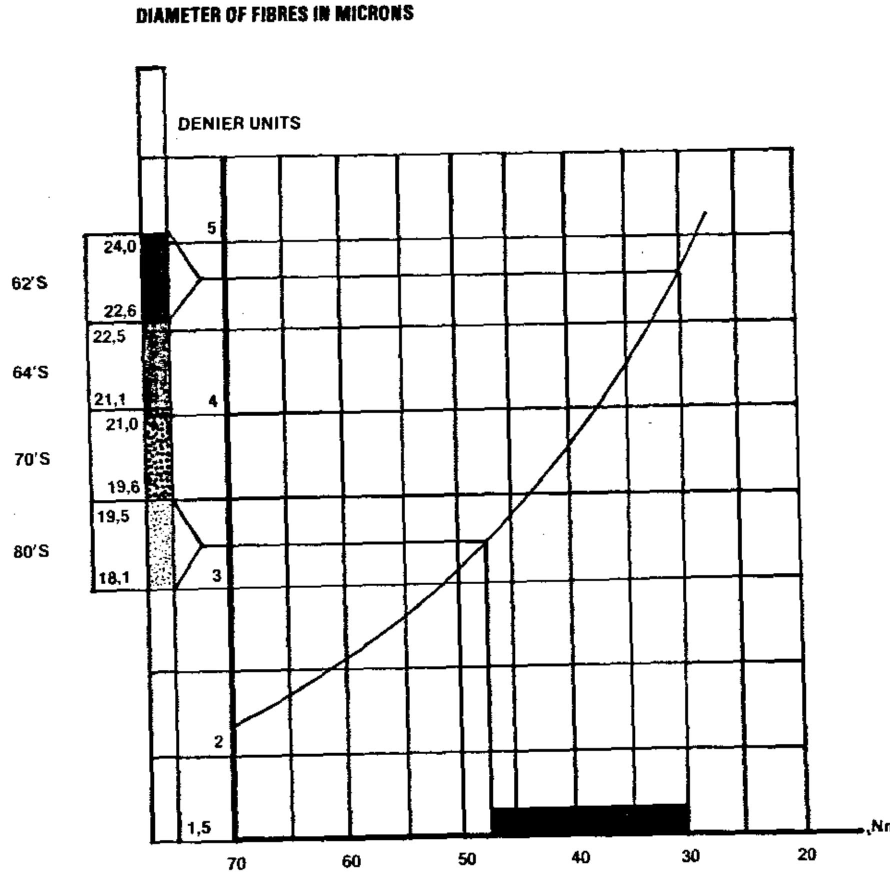

FIGURE 3
Ring Spinning Limits for Short-staple Wool[15]

Generally, the yarn twist levels are similar to those used for cotton yarns (i.e. a twist factor* of about 38) but higher than those generally employed for worsted yarns. The optimum twist level increases as the staple length decreases and as the yarn becomes finer. When selecting the twist factor[28], a compromise must be reached between optimum yarn strength and yarn liveliness thus depending upon subsequent end-use and processing efficiency.

Even though the short staple industry normally employs lower twist factors for weft yarns, most of the trials on wool and wool blends used the same yarn for both weft and warp because of the favourable economics associated with bulk production.

It has been noted[28], however, that polyester/wool blend yarns generally required lower twist factors than their cotton/wool counterparts to attain the optimum strength.

Rotor (Open-end) Spinning

Since its introduction in the late 1960's, the application of the rotor-spinning process has been extended by intensive research and a number of papers[30,31,34,48,52-63] have also been published on the rotor-spinning of wool. Adaptation of rotor-spinning systems to produce wool and wool blends on an industrial scale has potential economic advantages but necessitates careful choice of raw material, and the optimisation of the spinning elements and their settings. It is particularly important that the wool sliver is free of vegetable matter and dust[55] and that the total extracted matter does not exceed 1%[59].

Wool destined for rotor-spinning must not have too many long fibres, and the distance between the feed roller and the opening rollers is also critical. If the latter is too short then there will be a tendency for fibres to break. Another, and more serious, consequence of improperly set opening elements is the possibility of the wool scales being removed and then deposited in the rotor groove thereby disturbing the spinning process. It is also generally agreed[63] that fine slivers (3,5 to 4 ktex) with higher feeding speeds are opened more gently than heavy slivers with lower feeding speeds.

There has been a great deal of research[55,57,58] into the problems arising from the sensitivity of various fibres, e.g. wool, to the mechanical actions of the opening roller (the beater). One machine manufacturer[58] developed what has been called a "Selector" to replace the opening roller. It consists of a wheel comprising a number of non-circular plates which select individual fibres as they come within reach and accelerate them into the air stream. It is claimed to eliminate plucking, thereby reducing the number of fibre hooks and increasing the yarn strength.

Another open-end spinning machine manufacturer[57] increased the distance between the feed roller and the opening rollers and the diameter and width of the opening roller have also been increased to accommodate longer fibres and bulky slivers.

*Twist Factor = Turns/cm x $\sqrt{\text{tex}}$

It has been reported[57] *that, in commercial runs, both pinned and wired* opening rollers have performed satisfactorily. However, work at SAWTRI[31] indicated that, if anything, pinned opening rollers with speeds less than 7000 rev/min produced slightly superior yarns. It was also claimed[31] that, for all-wool yarns, smooth doffing tubes produced somewhat better yarns than grooved (4-grooves) doffing tubes. Optimum spinning conditions[57] can be achieved by using rotor diameters between 40 and 65 mm for short fibres and up to 90 or 100 mm for longer fibres, the rotor speeds being lower for larger rotors. Generally, most modern open-end spinning machines provide a high degree of flexibility due to the easy exchange of rotors and other components. Rotors[53] with V-grooves are preferred for the spinning of wool particularly from *the point of view of minimising rotor deposits*[56,59,60]. Weathering of the wool also appears to be reflected in the rotor deposits[54,59]. Spinning limits are generally considered to be of the order of 100 fibres in the yarn cross-section (See Figs 4 and 5).

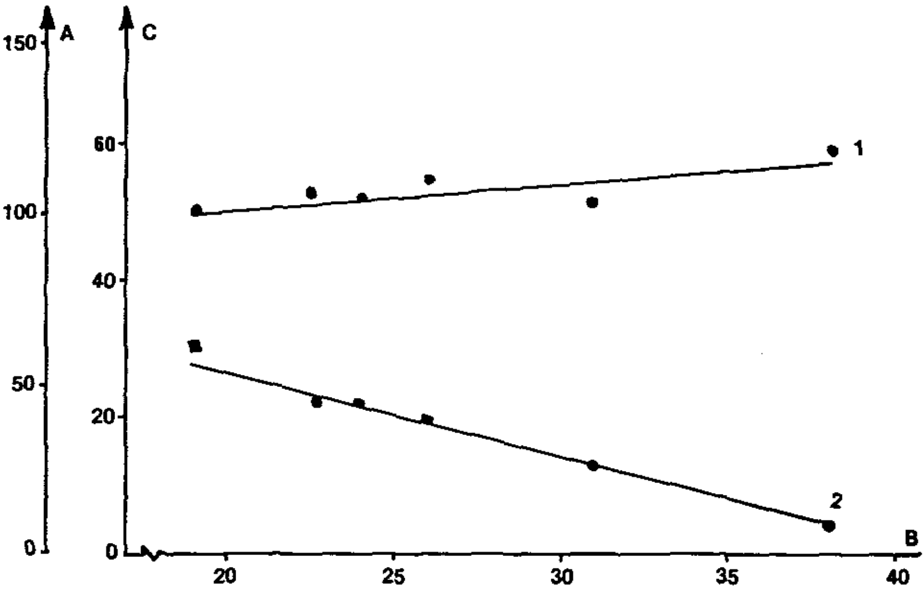

FIGURE 4

Spinning Range of Wool on the Rotor Machine as Function of the Mean Wool Fineness[59]

A Twist coefficient (∝m)
B Wool fineness (μm)
C Yarn fineness (Nm)
1 ∝m value
2 Spinning limit

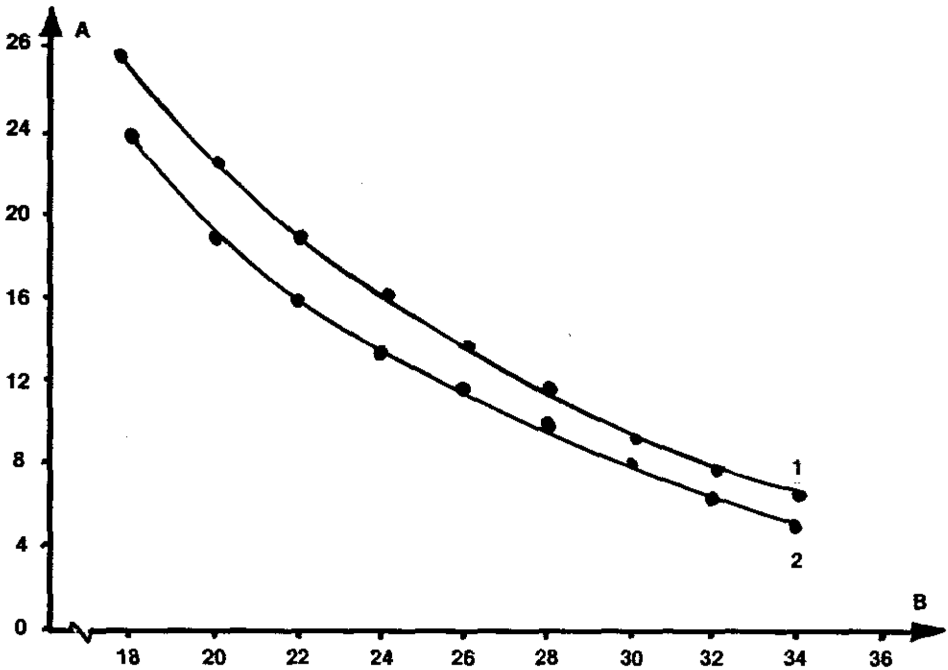

FIGURE 5
Spinnable Yarn Counts[59]

A Yarn fineness (Nm)
B Wool fibre fineness (μm)
1 Spinning limits with 120 fibres in yarn cross-section
2 Spinning limits with 140 fibres in yarn cross-section

Because the natural crimp[63] of the wool fibre produces a high fibre friction in the sliver, good fibre parallelisation in the sliver is necessary for easy and smooth opening. In fact, trials carried out at SAWTRI with merino wool[62] indicated that backwashing and then drying under tension, thereby reducing the fibre crimp, improved yarn spinnability and yarn strength.

Although the natural wool grease has the positive effect of reducing the friction between fibres and the surfaces of spinning elements, excessive grease may contaminate the opening roller and rotors.

Therefore, when using additives, the total extractable matter content should be below 1%. As a matter of fact, in many cases it is sufficient to add 10-20% water onto the wool fibres to attain the desired degree of moisture and softness. Trials conducted at SAWTRI[31] confirm these.

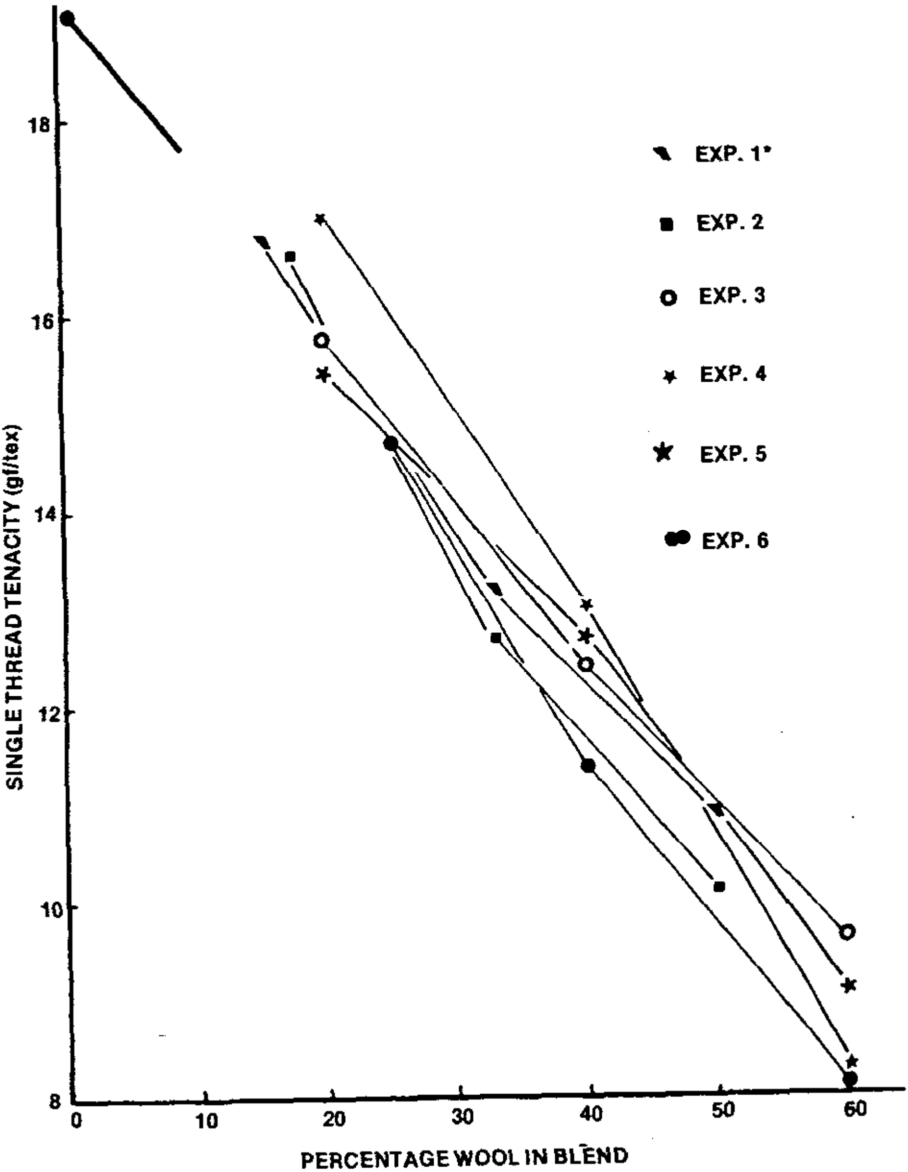

FIGURE 6
Yarn Tenacity versus Blend Ratio[22]

* See explanation in Fig. 2.

Properties of Wool and Wool Blend Yarns

From the results of various trials[22,28] it appears that the single thread tenacity of ring-spun yarns generally decrease linearly with an increase in the wool content of the blends. In fact, it is widely accepted that such losses in yarn strength are a characteristic feature for blends involving fibres differing widely in elongation, the elongation of wool being 30 to 40% compared to about 7% for cotton. SAWTRI workers[23] concluded that this rate of decrease in tenacity of ring-spun yarns was independent of the type of wool used or the method of blending (see Fig. 6).

In a paper presented at the sixth International Wool Textile Research Conference held in Pretoria in 1980 Lupton[28] claimed that the optimum strengths of ring-spun yarns containing fine wool fibres were marginally higher than similar yarns containing relatively coarse wools. Furthermore, his results showed that the optimum strengths of wool/polyester yarns were higher than those of similar wool/cotton yarns. With an increase in the proportion of cotton or polyester in the blend, yarn strength was found to increase although the yarn strength variation tended to decrease.

Lupton[28] found wool/polyester ring-spun yarns to be as even if not more even than typical cotton carded yarns (Uster classifications) and generally more even than the wool/cotton yarns. According to trials at SAWTRI[23], however, ring-spun yarns produced from drawframe-blends of wool tops and combed cotton material compared very well with typical 100% combed cotton yarns (Uster values). Lupton[28] concluded that the most apparent difference between wool/polyester and wool/cotton yarns was the superior appearance of the former.

It has been found that wool/polyester ring-spun yarns[27] have much higher elongations at break than wool/cotton ring-spun yarns[22] and in both cases the elongation values decreased with increasing wool content (see Fig. 7).

Louis et al[20] found that the rotor (OE) yarns spun from wool/cotton blends were less effective in utilising the constituent fibre strength than the corresponding ring-spun yarns (see Fig. 8). This also applied to other rotor yarns. In fact, rotor-spun yarns were found to have skein strengths which were about 20% lower than their ring-spun counterparts although worsted yarn strengths were very similar to those of OE yarns of similar blend levels. The yarn elongation at break values for all three systems of spinning (viz. rotor, short-staple and worsted) increased with increasing percentage of cotton in the blend and the short-staple ring yarns had higher elongation values than either rotor or worsted yarns, with worsted yarns similar or slightly inferior to the corresponding OE yarns.

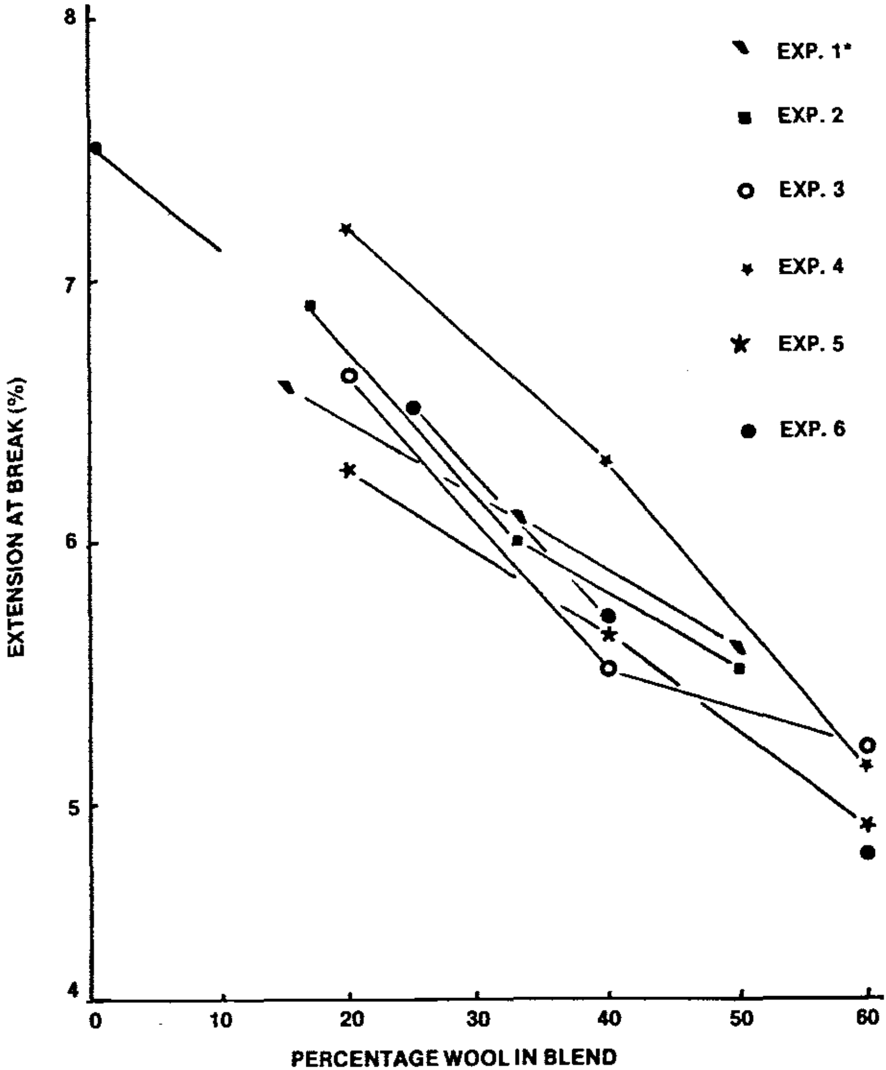

FIGURE 7
Yarn extension at break versus blend ratio[22]
*See explanation below Fig 2

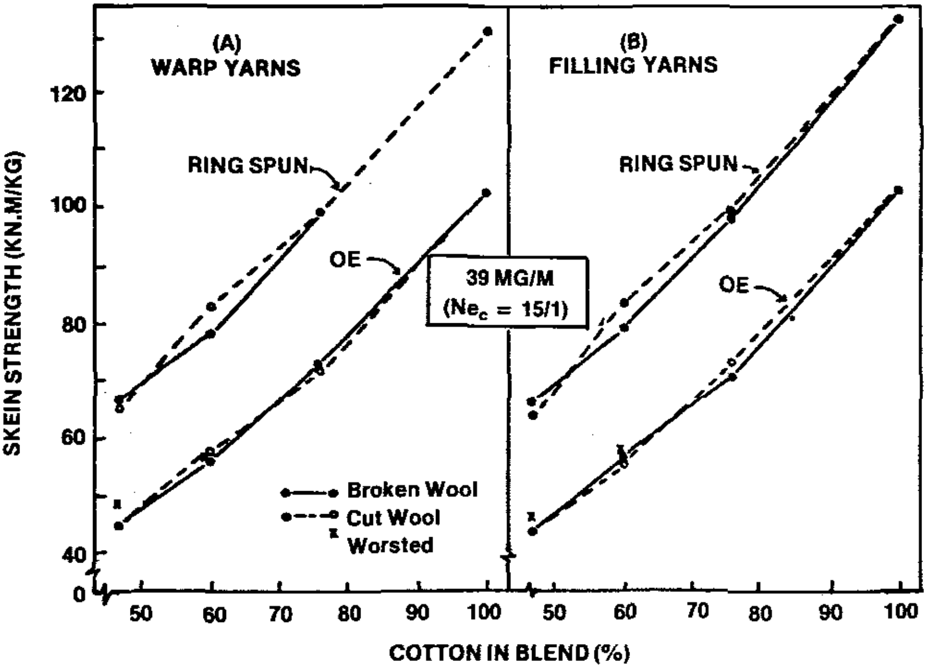

FIGURE 8
Strength Comparison on Ring, OE, and Worsted yarns[20]

According to the results of Louis et al[20] the various OE yarns were more irregular than their ring-spun counterparts which contrasts with the general trends for 100% carded cotton yarns. Futhermore, increasing the cotton component of the blends improved the evenness of both the rotor- and ring yarns. Even though blending the wool with combed cotton rather than carded cotton dramatically improved the ring-yarn evenness, it had very little effect on the evenness of the rotor yarns which is in agreement with results obtained at SWATRI[34].

Research reports[6,15,22,24,29,30] indicate that the spinning limits for wool and wool blend yarns on both short-staple ring-frames and rotor machines lie between about 20 and 30 tex although the corresponding end breakage rates suggest that only coarser yarns would be of any commercial interest. It has also been noted[24,30] that, for both ring- and rotor-spun yarns, increasing the wool component in blends with either cotton or polyester caused a deterioration in spinning limits, with finer yarns being possible on ring-frames than on rotor machines.

FABRIC MANUFACTURE

Wool and wool blend yarns produced on the short staple system need to be cleared and wound onto packages prior to weaving or knitting, with those destined for knitting having to be waxed as well.

It has been reported[15,24,27,64] that various single-jersey and double-jersey structures were knitted successfully using waxed yarns and that jacquard fabrics were produced from package-dyed yarns. The knitting performance of both dyed and undyed wool and wool blend yarns were found to be satisfactory although, as expected, the dyed yarns were generally weaker.

Most workers reported that, although warps from two-ply yarns were woven without size, singles yarns, especially the finer yarns, had to be sized prior to weaving, the short staple industry being more familiar with the process of sizing than the worsted industry.

Application of sizes to the yarns offsets any deterioration in yarn properties as a result of warp preparation, i.e. winding, clearing and warping, by increasing the breaking strength and reducing yarn hairiness. Polyvinyl alcohol type sizes are preferred for wool yarns as they are relatively easy to remove. Although starch sizes are not suitable for use with polyester due to the difficulty of removing them after heat setting, they can be applied to wool/polyester and wool/cotton blend yarns. A report[33] from SAWTRI indicated that sizes consisting of a mixture of polyvinyl alcohol and modified starch can also be used satisfactorily on wool blend yarns.

Research findings indicate[6,13,20,24,27,33,65] that, provided the yarn preparation was carried out properly, the weaving performance of wool and wool blend yarns processed on the short staple system was satisfactory. It has been suggested[6], however, that the use of narrow width looms common in certain sectors of the cotton industry may present problems since the narrow width fabrics they produce may not be acceptable to certain makers-up.

A large number of papers have been published in the field of fabric preparation, dyeing and finishing of wool and wool blends, many of which are not specific to the short staple system. Studies specific to the short staple system have covered desizing[6,66,67], bleaching[66], mercerising[66], dyeing[6,66,68] and printing[6,69,70] processes.

Ellis et al[68] investigated the finishing of wool blend fabrics according to routines likely to be encountered in non-wool mills. No difficulties were reported at any stage of the finishing sequence and the fabrics finished on the non-wool routine were considerably fuller and softer, presumably due to the consolidation of the fabric in overflow dyeing and to the absence of a high-temperature steam-setting operation in the routine. The authors also noted the considerable scope available for the finisher to vary the handle characteristics of the fabric. However, the greatest concern was the pilling of the short-staple blend fabrics and it was suggested that the polyester content should be limited to below 50% with the maximum twist which is practically possible being inserted in the singles yarn.

A number of chemical finishes have been specially developed for wool blend fabrics and these include stabilisation, easy-care finishes[71-76] and flame-retardant finishes[77,78].

PROPERTIES OF WOOL AND WOOL BLEND FABRICS

The use of wool blend yarns spun on the short staple system generally result in fabrics[6] with different properties to those obtained with worsted yarns of the same linear density. The use of shorter fibres usually results in softer and more lofty fabrics which are warm to wear yet still sufficiently air permeable to be comfortable. The fabric pilling propensity was generally found[65] to be lower, and the fabrics have good drape qualities. Machine washability also presents no problems to the makers-up. Ellis and Robinson[21] reported that the Martindale abrasion resistance of wool fabric deteriorated with a decrease in mean fibre length although this was not evident during wear tests.

When comparing off-the-loom greige fabrics made from ring, OE and worsted yarns of wool/cotton blends, Louis and Pardo[20] reported that fabric strengths of the short staple ring-spun lots were equal to or even up to 20% higher than those of the worsted ring-spun fabrics, while the fabrics from the rotor-spun yarns had strengths up to 19% below those of the worsted yarn fabrics. Fabric elongation was similar to that of fabrics produced from worsted yarn. The fabrics containing the short staple system ring yarn had tear strengths equal to or higher than that of the worsted fabrics, the tear strength decreasing with increasing wool content. The fabrics containing the rotor-spun yarns had much lower tear strength than the fabrics containing the worsted yarns. The greige fabric abrasion resistance exhibited similar trends as fabric tear strength. It was concluded that the quality of greige fabrics made from ring-spun yarns was comparable to that of worsted yarn fabrics while the fabrics containing the rotor-spun yarns did not perform as well as these fabrics in the various tests.

THE FUTURE OF WOOL AND WOOL BLENDS ON THE SHORT STAPLE SYSTEM

From the published literature it appears that, although certain precautions and expertise are necessary, wool blends can be processed successfully on the short staple system equipment. Most of the problems initially encountered during processing have been tackled and overcome and new developments are continuously emerging. For example, the main restriction which had been considered to be the availability of wools of the required fibre length has been solved by employing methods of fibre shortening viz: cutting or stretch-breaking processes. Problems of lap formation due to the bulk and sponginess of wool have been overcome by proper lubricants, production of half laps etc. The technology has also progressed in the field of dyeing and finishing.

As a result of all the above developments, the processing of wool blend products on the short staple system is accepted to be commercially feasible capable of producing fabrics acceptable both in aesthetics and quality.

The success of extending the short staple system to include the processing of wool and wool blends is generally agreed to depend upon the selection of suitable products and their successful marketing. The short staple industry is mainly orientated to the spinning of medium and fine yarns, which could be used to produce lightweight dress fabrics, shirts, blouses and childrenswear. Fabrics suitable for coatings, jacketings, menswear and medium weight dress fabrics can be produced from two-ply yarns. In view of the fact that certain of these are manufacturing areas into which the existing worsted industry is either unable or unwilling to enter, any adverse effect of production on the short staple system on the worsted industry would be minimised and the scope of the wool product range could be increased.

Another important point made by the IWS is the suitability of the products for mass production since the short staple industry favours long production runs, generally about ten times longer than that which is common in the worsted industry. For the fabrics to be suitable for mass production, the demand should be stimutaled by moderate price, application of proper design and colour and good washability properties.

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Fig. 3 on p. 15 L'Industrie Textile, June, 1973

Fig. 4 on p. 17 International Textile Bulletin/Spinning, January, 1977, pp 97-113

Fig. 5 on p. 18 International Textile Bulletin/Spinning, January, 1977, pp 97-113

Fig. 8 on p. 22 Textile Research Journal, Vol. 50, February, 1980, pp 130-136

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