Time for a new look at composite yarns?

Alan Parker compares the performance and production of composites with all-staple yarns

Continuous filament yarns even in textured form, although setting new standards for stretch, easy care properties, fabric fault levels and machine efficiency in beaming, weaving and knitting, do not offer the flexibility of fabric type, comfort, or aesthetic appeal of staple yarns particularly yarns containing natural fibres.

Extensive effort, over many years, by a diversity of organisations has gone into trying to combine in one yarn the advantages of continuous filament with those of staple.

In practice, no one yarn will ever be ideal for every end-use and today there is an increasing range of end-products placing different emphasis on the advantages of both filament and staple fibres.

For example it has become common place, only within the last few years, for essentially 100% staple products to be produced with stretch characteristics. This has been achieved by the use of a very small percentage of an elastomeric filament, combined with either short or long staple fibres. It has been nowhere more noticeable than in mens, womens and childrens trousers. Who would have thought even 20 years ago that there would ever be stretch denim mens jeans?

The unique properties of elastomerics and the very small percentage needed to influence significantly the stretch properties of fabrics containing it, demand that this should be examined as a subject in its own right.

In this article I will examine the features needed for composite yarns of continuous filament and staple to compete with medium to fine count 100% staple products and particularly how a composite yarn of cotton staple with polyester filament compares with an intimate blend of cotton and polyester staple.

Table 1: Filament yarn count for different yarns at different contents

	Composite yarn count		
	20s c.c. (29.5 TEX)	50 c.c. (14.8 TEX)	60 c.c. (9.8 TEX)
35% Filament Content	10.3 TEX (93 Dtex)	5.2 TEX (47 Denier)	3.4 TEX (31 Denier)
50% Filament Content	14. TEX (133 Denier	7.4 TEX (67 Denier)	4.9 TEX (44 Denier)
65% Filament Content	19.2 TEX (173 Denier)	9.6 TEX (87 Denier)	6.4 TEX (57 Denier)

When combining two dissimilar fibre types as an intimate blend the resultant strength is always lower than one would obtain by adding together the potential contribution of the constituent parts (e.g. a 50% polyester/50% cotton intimate blend is normally only marginally stronger than a 100% cotton yarn and significantly lower than a 100% polyester yarn of simiar resultant count).

A major problem of an intimate blend of cotton/polyester staple is that whilst one wishes frequently to use high tenacity polyester to maximise resultant yarn strength this increases pilling.

When wishing to combine filament with staple in one yarn, specially when the staple is a natural fibre, as for example wool or cotton, there are a number of special factors to take into consideration.

Objectives

A composite yarn should seek to give a better and/or less expensive product than that it is seeking to replace, or be able to be used for products which can not be serviced by existing yarns and at a price such a product could command.

It has already been demonstrated that composite yarns using glass fibre filament[1], nylon filament[2] and polyester filament[3], spun by the ring frame route, can show significant advantages over conventional 100% staple products.

In all these instances there was however a significant cost increase with the composite yarn.

If one wishes to produce a composite yarn of, say for example, a polyester filament and wool staple, this should not be compared either in price or properties with a 100% wool product. Instead it should be compared with what could be achieved with an intimate blend of wool and polyester when appropriate.

The labelling on the final garment must clearly indicate the composite yarn as a blend product. It will not be purchased by those customers wishing to purchase 100% natural fibres.

With composite yarns one should aim to produce a wide variety of end-products with properties adapted to suit different applications.

Therefore the use of a trademark would not convey to the public a marketable feature in the same way that Lycra conveys stretch.

The selection of which staple to apply is largely determined by the market sector at which the yarn is aimed.

A feature of all the composite yarns is that there should not be too great a filament content and so lose the aesthetic appeal of the staple component.

The selection of filament and the price to be paid for this filament in comparison with staple is almost certainly the key factor in determining whether a composite yarn will ever achieve commercial reality on a large scale.

Production

Any spinning system that can produce a 100% staple yarn can be adapted to produce a composite yarn.

There are also some spinning systems in which the filament is an essential requirement to produce a yarn at all.

I will examine several of these systems and indicate a personal opinion as to whether they provide a satisfactory vehicle for producing a commercial composite yarn.

The average number of fibres in a typical yarn cross section for the finer yarns with a high filament content has become very low. This will inevitably lead to a high irregularity in the staple component. This will not be easy to detect from the composite yarn irregularity and may not even show up in spinning performance due to the filament supporting the staple.

In many instances this staple irregularity may only show up as an irregularity dyed fabric and may restrict, for certain applications, high filament content yarns. It is more important, in my opinion, to minimise this potential problem by selecting fibre that gives a regular, rather than

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yarn when spun independently as a 100% staple yarn.

Polyester filament is available in regular tenacity with a tenacity of the order of 4–5 cN/tex (36–45 gm/tex) and an elongation of the order of 20–30%, for use as a feedstock for texturing, or for direct use.

It is also available in high tenacity form with a tenacity of the order of 8 CN/tex (72 gm/tex) and an elongation of the order of 10–12% for use in technical yarns.

The more a filament is drawn the greater the tenacity and the lower the extension. As a rule of thumb guideline tenacity √ elongation remains constant for any filament up to the level to which it can be drawn.

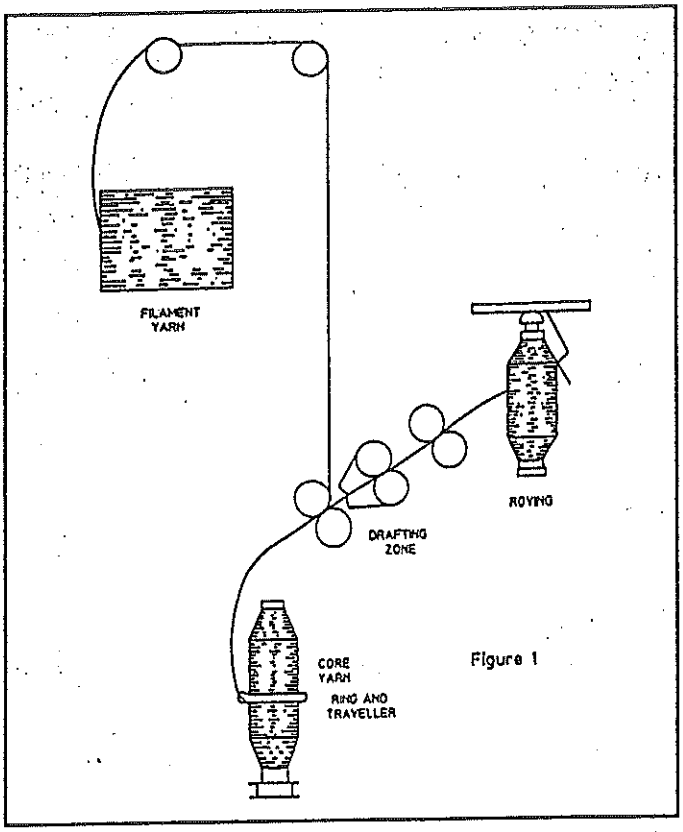
Currently available high tenacity filament yarns have been produced to meet very stringent standards demanded for technical yarns particularly in consistency of strength and regularity. These yarns are, in strength terms, ideally suited for use as the filament component of composite yarn.

However, there is a price differential of more than 2:1 between these filament yarns and staple which in my opinion would preclude composite yarns containing these filaments achieving any significant market penetration except for technical composite yarns such as sewing threads.

The feedstock for texturing is normally supplied as POY (partially oriented yarn) and the final drawing is carried out on the "draw texturing machine." Latest figures indicate that in Britain both POY and staple are available at a similar price of around 100–120 pence per kilo whereas fully drawn regular tenacity filament of similar deniers is around 140–160 pence per kilo.

The dramatic improvements that have been made in the spin – draw machinery for filament yarns with take-up speeds up to 8000 metres/minute, are such that it is predicted that very soon fully drawn yarn will be available at a similar price to POY.

There is therefore cause for optimism that an economically viable filament feedstock for composite yarns could be made available if there was sufficient demand to justify it.



Adaptation of ring frame for experimental purposes: A creel supports the filament yarn plus tensioning and guide arrangements to position the filament correctly.

In producing this feedstock the following guidelines would I believe be appropriate.

There is an area, somewhere between normal and high tenacity, for which a yarn suitable for use as a compostite yarn feedstock may be able to be produced at a price close to existing POY prices. This yarn must be suitable for use directly off the spin draw machine.

In recent years it has been demonstrated quite conclusively that rotor spun yarn performs better than ring spun yarn in many applications because, although the rotor yarn is weaker, its CV of strength is much better, giving rise to fewer weak spots.

Therefore I believe the primary target for a composite yarn is that it should be at least as strong as a ring spun yarn, with a CV of strength at least as good as a rotor yarn. To pay extra for a filament yarn to enable the composite yarn to exceed these standards may well exclude the yarn on cost.

Because the filament will form part of a composite yarn which contains a variable staple component, it will not need the same stringent controls on filament strength, regularity and dye uptake as those required for filament yarns used alone.

The spin-finish, both in specification and consistency of application, is crucial for satisfactory texturing. However for use in a composite yarn spin-finish is less critical, and the main purpose is to assist in preventing easy separation of filament and staple components.

Different composite yarn spinning systems may well require different finishes for optimum performance.

The selection of the denier of the individual filaments forming the filament yarn and the cross-sectional shape of the filaments will be affected by the staple fibre with which it is to be combined, the end-use and the composite yarn spinning system to be used.

Spinning system

Over the years there have been literally hundreds of patents claiming a new method of producing a yarn combining the advantages of staple and filament, but a very limited number have had even limited commercial success.

I will examine the features of a number of different methods to produce a yarn containing both a filament and staple component.

Ring spinning

There are over 150 M. ring spindles installed world wide and composite yarns for sewing threads are already extensively produced by this route.

To adapt an existing ring frame for experimental purposes merely requires a simple creel to support the filament yarn plus tensioning and guide arrangements to position the filament correctly. However, running a plant on a commercial scale requires careful consideration:

- There will need to be provision of a filament creel with ready access for bobbin changing. If this cannot be accommodated above the existing ring frame creel a floor-mounted creel, although ergonomically more attractive, will significantly increase floor space.
- If there is a filament, or more usually a staple, break, the system may continue to produce either a 100% staple, or 100% filament product. It is advisable to fit suitable stop-motions to prevent this happening, or alternatively significantly increase operative supervision.
- It will be necessary either to increase draft at the ring frame or use a lighter weight roving compared with a 100% staple product, or usually a combination of both.

A major problem of the ring spinning route, for composite yarns, is that, for the counts to being considered, delivery speed is only of the order of 12–24 metres/minute and the capital cost of applying a creel, associated filament guides and stop-motions at every position add significantly to the capital cost. Compare this with a modern texturing machine able to operate at speeds in excess of 1,000 metres/minute.

New ring spinning machine coming onto the market are claimed to be able to operate at almost double the speds indicated (i.e. from 20 to 40 metres/minute) which will significantly reduce

Table 2: Number of cotton fibres in a composite yarn cross section yarn

	Composite yarn count and cotton fibre type		
	20 c.c. 4.2 micronaire	40 c.c. 4.1 micronaire	60 c.c. 3.8 micronaire
35% Filament Content	155	79	57
50% Filament Content	119	61	44
65% Filament Content	83	43	30

Table 3: Average number of wool fibres in a composite yarn cross section

The method of classification of wool makes it more difficult to relate the number of fibres to a specific parameter. Therefore for convenience an approximation of an average of 3 denier fibres over the counts considered is used.

	30 wc (29.5 TEX)	48 wc (18.4 TEX)	72 wc (12.3 TEX)
35% Filament Content	58	36	24
50% Filament Content	45	28	19
65% Filament Content	31	20	13

additional cost per kilo of yarn produced in applying a creel etc. to accommodate a filament yarn.

In ring spun yarns, because the filament is twisted alongwith the staple, the possibility of separation of filament and staple is minimised. There is a natural tendency for the filament to migrate from the inside to outer surface of the yarn. Although suitable guides can reduce this, it remains difficult, because of the narrowness of the ribbon in counts within the range being considered, to prevent the filament occasionally appearing on the surface of the yarn.

Repco Selfil Spinner: A system for worsted yarns in which the self-twist principle of alternating zones of Z and S twist was applied to wrap two phased filaments around an untwisted strand of fibres.

This system while technologically very clever and having many original engineering features was quickly taken off the market.

Although the yarn was torque free and could be processed at up to 300 metres per minute the cost per position was very high, the use of two fine, very expensive filaments increased very significantly the raw materials and the yarns were prone to stripbacks (separation of fibre and filament) on fine count yarns.

Air Vortex: Varimex, of Poland introduced a spinning system for 100% staple yarns using an air vortex rather than a rotor. This allowed high production rates to be achieved, but produced an extremely weak, irregular yarn with a high percentage of fibre loss.

This machine, not unnaturally, was a commercial failure and subsequently a core yarn version of the machine was introduced which camouflaged, to a great extent, the inherent weakness and irregularity of the spinning process.

The problems inherent in this technology, in particular the fibre loss and irregularity of the staple component make this, in my opinion, an unsuitable vehicle for producing a commercial composite yarn.

Rockwell's Electrostatic Spinner: During the 1970s North American Rockwell, in collaboration with the Batelle Institute, developed a spinning system in which drafted fibres were combined with a core filament by a combination of electrostatic forces and false twist. Unfortunately the machine never reached the market and all development has probably now stopped.

There are indications that work is continuing on electrostatic spinning in the USSR.

I believe that if electrostatic forces could be safely harnessed in a controlled and economical manner on fibres and filaments at high speed, a composite yarn system could result. Whether this is five or 100 years away I would not hazard to guess.

Bobtex is by far and away the most complex of the composite yarn systems and it was claimed to operate at speeds up to 600 metres per minute.

Although this system was around for many years and described in detail in many publications, it never achieved any commercial success. Within the last few years a company was formed in Leicester to operate this process on a commercial scale but they failed.

To the best of my knowledge this process has now been abandoned and it was not proposed to operate in the count ranges with which this article is concerned.

Wrapped Yarn Systems: In this system a drafted strand of yarn is passed through a hollow rotating spindle on which a binder yarn normally filament or monofilament, is mounted. The binder is attached to the untwisted strand of fibres upstream of the hollow spindle and as the binder and strand pass through the hollow spindle the binder wraps around the untwisted strand.

This system has achieved some commercial success particularly as replacement for two-fold worsted-spun yarns and commercial machines are available from a number of reputable suppliers.

The primary objective of the binder is to lock in the untwisted staple to increase inter-fibre cohesion. To retain the aesthetic handle of the staple, a binder of very fine filament should be wrapped around the staple with as few turns as possible. An exception to this requirement is when cut pile fabrics, as for example velvet or Saxony carpets, are produced.

Such fine filaments supplied by the fibre producer are already expensive, but the cost is increased by the need to rewind this yarn onto spools suitable for wrap-spinning.

Coarser filaments are normally rewound onto larger spools with an inevitable reduction in hollow spindle rotational speed, as coarse filament on small spools requires an excessive frequency of spool changing.

I believe the aesthetic limitations and cost factors of this system will prevent it achieving major impact across a variety of end-uses in the area at present served by polyester/cotton or 100% cotton yarns. The Americans are said to have been using some such yarn in a short staple form for terry manufacture.

Frictions spinning lends itself quite naturally to having a filament core and wrapping this with staple to produce a composite yarn. DREF has already established a niche market in composite yarns in the coarse count area and has been described in numerous articles[5].

Friction-spinning, however, suffers from the problem of all core yarns in which the filament is neither wrapped around nor twisted together with the staple, namely the relatively easy separation of the core from sheath fibres when load is applied to the yarn.

This problem is magnified when there are relatively few fibres in the cross section. In my opinion, by selecting the filament finish and cross-section according to the particular needs of this process and refinements in friction spinning technology, this system eventually should be able to compete in this sector.

Rotor Spinning: There is already a composite rotor spinning machine producing a yarn with the trade name Rotona, from Strojimport, Czechoslovakia. This machine operates at a maximum rotor speed of 60,000 and a maximum delivery speed of 125 metres/minute. It is claimed to produce yarns as fine as 30s c.c. (20).

Rotor-spun yarn is normally assumed to require a minimum of 110 fibres in a cross-section and most of the yarns considered would fall outside this range. Even if the filament acts as a carrier to create yarns with few fibres, further development in rotor grooves would be required to handle the very fine staple component in many of such yarns.

As there is already a commercial machi

other manufacturers could undoubtedly produce similar machines, any composite yarn evaluation should include this system.

This evaluation would need to include both economic and technical considerations and these should be sufficiently exhaustive to indicate whether this yarn needs to be rewound to remove faults and/or piecings.

Jet Spinning: There are claims that the harshness of fabrics made from these yarns, which has been mainly responsible for this technology only gaining a small market penetration (mainly in the Far East and Southwest of the USA) can now be overcome.

If this proves to be so, without too great a loss in strength, not only should this technology increase its market share in 100% staple yarns, but may be a viable method to produce a composite yarn.

There is very little doubt that a composite yarn can be produced with good adhesion between the filament core and sheath at the conditions that prevail when producing a harsh but commercially undesirable fabric.

However it will be more difficult to achieve this good adhesion for a yarn while producing a softer fabric.

Selection

It is impossible to ignore price when talking about any volume product and until satisfactory filament yarn for composite yarn is available, at the right price, mass production of composite yarns will be a non starter.

There will need to be close co-operation between a yarn spinner and a fibre producer already operating in a developed country but still wishing to remain in the commodity, rather than just the high tech area, or one seeking to become established in a developing country. As discussed earlier I consider that the technical specification for a composite yarn filament to be less demanding than for other applications.

Although initially one should seek to target a limited number of products I believe it possible to be able to operate across a wide band of products.

This is not a new yarn in the strictest sense of the word, because of its use in sewing thread. However for the market sector being considered here, it needs to be treated as new, with all the exhaustive tests that involves.

Choosing the yarns

The following are the key parameters which the selection of a composite yarn should be made.

The individual fibre stress/strain curve is only one of many factors which affect the ultimate strength and elongation of a staple fibre yarn.

A composite yarn is a far more complex structure than a staple yarn. It is always weaker than the potential contribution of its individual parts and can even be weaker than the strength of the filament yarn alone!

I do not believe that using a filament with a similar initial modulus (stress divided by strain) as the staple component while optimising yarn strength is, however, a pre-requisite for a commercial yarn.

It would appear that in almost all instances the extensibility of a composite yarn lies somewhere between the staple and filament components.

In a staple yarn one of the parameters which determines cotton selection is the strength it imparts to the yarn. Its strength contribution to a composite yarn is less important and this allows other cotton parameters to figure more prominently in cotton selection.

I have already discussed the target minimum requirements of a composite yarn as being to match a ring-spun yarn strength with the co-efficient of variation as good as or better than, a rotor yarn.

There is a natural tendency to believe that a composite yarn, because of the regular filament component, will be more regular than an equivalent intimate blend yarn.

This is not necessarily so as the reduced number of fibres in a composite yarn cross-section increases the probability of irregular drafting. The ability to set the drafting system for the cotton (or wool) rather than for a blend, to some extent offsets this.

The increased potentiality of irregular drafting means that the incidence of thick places and neps will not automatically be lower. However the incidence of thin places should be extremely low, particularly on high filament content yarns.

As indicated, the reduced significance of fibre strength allows fibre to be selected to give priority to regularity.

The surface of a composite yarn of say a polyester filament core and cotton staple will closely resemble a 100% cotton yarn but will generally exhibit less hairiness, which are incorporated in the core of the yarn, can still have a leading or trailing end protruding from the yarn which clearly does not happen with a filament core.

There will be differences compared with an intimate blend of polyester/cotton, because of the effect of the polyester on the surface. One important difference is that the pilling, associated with polyester, does not occur with the composite yarn.

There will be a similar level of trash in both yarns, but more of it will be closer to the surface and therefore more visible in the composite yarn. Because the surface of the composite yarn is all-cotton, the advantages of combing will be more apparent.

A composite yarn exhibits a reduced air permeability and improved cover[4], compared withan equiivalent 100% cotton product, or intimate polyester/cotton blend.

The denier of the individual strands of the filament yarn can be selected either to maintain or even enhance this improved cover, or to bring it into line with 100% staple products.

Conclusions

Ring-spun composite yarns using expensive, high tenacity filament, are now increasingly used for technically demanding applications. A significant market penetration into conventional knitting and weaving will not be achieved in this way.

I have examined how composite yarns can be produced to exploit their other advantages, without the use of such expensive filament components. I have also indicated why this type of filament feedstock should be less technically demanding than that for other applications. It is ideally placed to take advantage of the progress made in spin-draw equipment and technology.

To this end, I am optimistic that the climate is right, either today or in the very near future, for the production of competitively priced ring-spun composite yarns for conventional weaving and knitting.

On the assumption that this is so, I have also examined and continue to research, other known methods of producing composite yarns, and indicate which methods are likely to achieve commercial success and what will be needed to achieve this success. ■

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