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SPUN YARNS: NEW DESIGN POSSIBILITIES

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Abstract: *Spun yarns possess unique properties and surface texture which make them suitable for most of the apparel products. The technologies used for the production of spun yarn differ from each other in the way the fibres are attenuated and consolidated together into a yarn. Because of these differences, the surface texture and properties of the yarns are also different from each other. The technologies are capable to process different types of fibres of varying length, fineness and cross-sectional shapes. The technologies are also capable to process blended fibres. Such blending or mixing of fibres results in yarn with improved appeal and properties. With the advent of new fibres process able on such technologies, more and more opportunities are arising to produce yarns with unique features and properties. This is resulting in products with improved performance.*

Key words: *Spun Yarn, Fibre attenuation, Blending*

1. Introduction

Spun yarns possess unique properties and surface texture which make them suitable for most of the apparel products. The technologies used for the production of spun yarns differs from each other in the way the fibres are attenuated and consolidated together into a yarn. Because of this differences, the surface texture and properties of the yarns are also different from each other. The technologies are capable to process different types of fibres of varying length, fineness and cross-sectional shapes. The technologies are also capable to process blended fibres. Such blending or mixing of fibres results in yarn with improved appeal and properties. With the advent of new fibres process able on such technologies, more and more opportunities are arising to produce yarns with unique features and properties. This is resulting in products with improved performance.

2. Spinning technologies

Beside ring spinning the technologies which have established themselves as commercially viable process to produce yarns suitable for apparel sector are rotor, compact, siro and vortex spinning technologies (Fig 1). Each technology has its own strength and weakness in regard to productivity, processes ability, count range, yarn quality and energy consumption. Hence, for a specific need, one has to consider all pros and cons before selecting one. However, when yarns made from one specific technology do not enhance, the performance, quality or cost of a product, yarns from different technologies are to be used for exploitation the best of both.

The count range for the different spinning system are:

Ring spinning:	0.5 - 120 Ne,	Compact spinning:	20 - 60Ne
Rotor spinning:	6 - 40 Ne	Vortex spinning :	20 - 60 Ne

Some spinning systems are derivative or extensions of the existing ones. Compact spinning is essentially a ring spinning machine with an additional feature of compaction of drafted roving. Siro spinning is also ring spinning with provision to feed two rovings and draft them independently in the drafting zone. Similarly core spinning is also an extension of ring spinning with provision to feed a filament yarn at the centre under controlled condition. It is also possible to produce core spun yarn on rotor spinning machine. The technologies and their derivatives or extension are stated below:

Ring spinning
- Compact spinning
- Siro spinning
- Eli twist spinning
- Core spinning

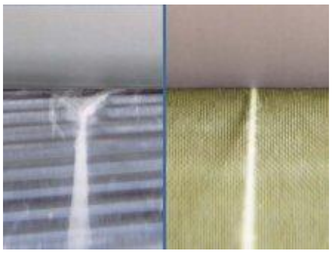
Open end spinning
- Rotor spinning
- Core spinning

Jet spinning
- Airjet spinning
- Vortex spinning

Using these technologies many new yarn structures can be developed by manipulating

Twist
Draft
Mixing water soluble fibre, conductive fibres , and
Blending newly developed fibres

a.



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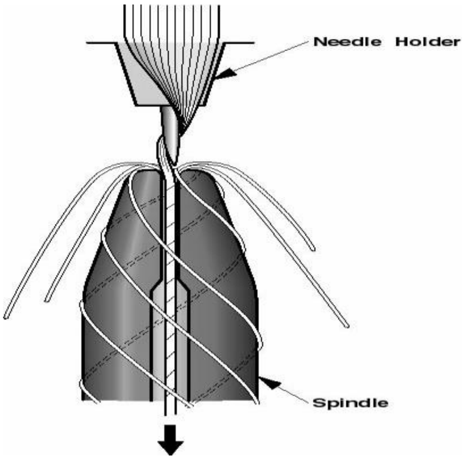

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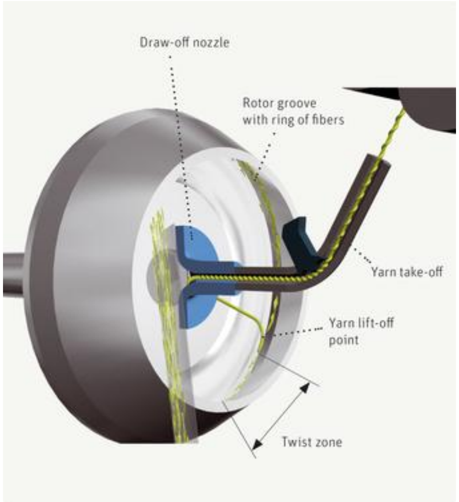


d.

Figure1: Different spinning systems: a. Ring spinning, b. Compact, c. Vortex spinning and d. Rotor spinning

3. Yarn structure

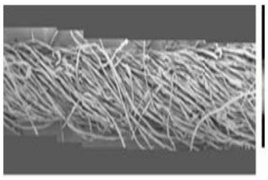
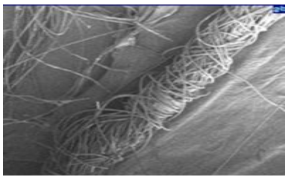
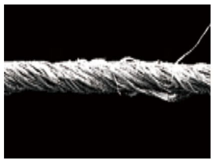
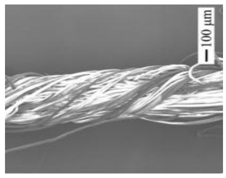
A brief discussion on structure produced by different spinning technologies will be relevant here as yarn properties are highly influenced by its structure . Many a times surface structural features of yarns becomes key to decide it's suitability for a specific end use. Table 1 list structural features of few yarns ring , rotor, compact and vortex yarns.

Ring and compact yarns show regular helical pattern of surface fibres. Vortex yarns also show similar helical arrangement of surface fibres. In rotor yarns many surface fibres are wrapped almost perpendicularly to the yarn axis. The surface of ring, compact and vortex spun yarns are much smoother than rotor yarns which have a rough surface. The free flight of fibres from opening roller to yarn formation zone causes many fibres to land on the yarn arm within the rotor leading to being wrapped perpendicular to the yarn axis. Compact spun yarns show minimum hairiness as protruding hairs get suppressed by the compaction process during drafting. Vortex spun yarns loose lot of short fibres during spinning as they are blown away by the centrifugal force while rolling around the spindle top and therefore they are less hairy. Compact spun yarns are leaner where as rotor yarns are little bulkier due to presence of hooked and loped fibres.

A comparison of property of all the yarns are stated in Table 2. The surface of rotor yarns being rough gives a dull fabric appearance and harsh feel or handle. The rotor spun yarns are relatively stiffer, weaker and rougher than ring yarns. It is suitable for producing coarse counts as property deterioration increases with fineness of yarn. Attempts are however being made to produce fine count rotor yarns using fine fibres. Medium length fine fibres will be suitable for this.

Due to regular helical pattern of surface fibres, ring give a neat look to the fabric and result in good handle. The compact yarn fabrics may not give a clean look. Being lesser in diameter and devoid of hairiness any fault in the yarn becomes too prominent in the fabric. Vortex yarns having a wrapped structure resembles ring yarn in appearance . It also shows less hairiness and therefore can be used wherever ring yarns are used. Compact yarns are stronger than ring yarns as more fibres in the cross-section participate in load sharing . and compact yarns.

Table 1: Structural characteristics of different yarn

	Ring	Rotor	Compact	Vortex
Characteristic				
Structure	Fibres are parallel w.r.t. each other and follow a uniform helical path. Lot of ends project out. No wrapper fibre	Fibres are less parallel, hooked and looped Distinct core – sheath type structure Many wrappers being loose can easily slide on yarn core forming slubs / neps	Fibres are parallel w.r.t. each other and follow helical path. Few ends project out in the form of hairs No wrapper fibre	Core made of parallel fibres with almost no twist & surrounded by 15-30% wrapper fibres.
Twist	Twist uniform across the cross section	Differential twist structure i.e. core to surface twist gradually reduces	Twist uniform across the cross section	Core parallel fibres surrounded by 15-30% wrapper fibres. Look very much like a fully twisted ring.
Bulk / volume		Voluminous than ring yarn due to low packing of fibres	Very compact	Bulkiest

4. Yarns with special attributes

4.1 Soft yarn

Soft yarns are desirable for many applications. Soft yarns are those which offers minimum resistance to bending and compression. Hence, bending rigidity of constituent fibres, frictional hindrance to shear deformation during bending and force with which fibres are compressed against each other are all important. There are many ways to produce soft & bulky spun yarns such as :

- Use of fine fibres,
- Spinning under lesser tension
- Spinning with low twist
- Plying
- Selection of right spinning technology (ring , rotor, air jet etc).
- Twist untwist principle

Use of long and fine fibres will obviously make the yarns very flexible and soft. Reduction possibility of twist due to increased cohesion , in case of finer and long fibres make the yarn soft and flexible. Amongst the various technologies available, ring spinning produces softest yarns. Rotor and vortex yarns are hard due to wrapped structure.

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Table 2: Properties of different yarns

Property	**Property w.r.t . equivalent ring yarn**		
	Rotor	**Compact**	**Vortex**
Count range	**10- 20s Ne**	**20-60s Ne**	**20- 40 s Ne**
Breaking strength	Lower, CV% of strength lower	better strength & elongation	tenacity is usually greater than air jet yarn but less than ring yarn
Hairiness	better	less hairiness (especially > 3 mm hairs)	hairiness is less than ring yarn
Breaking elongation	generally higher but may be less for long fibres and may even decrease with storage.	Better	though elongation % is less than airjet yarn
Mass irregularity	better	Better	better
Imperfections	lower, number of neps sometimes may be higher due to wrapper fibres getting counted as neps	less imperfection, the improvement in properties is more the shorter the fibres	lower
Stiffness	higher	More	more
Aesthetic appearance	rougher	Poor	
Lustre	dull	poor	Good
Handle	harder	Harder	harder
Wicking	lower	lower	wicking slower
Lint shedding	lesser	lesser	lesser than ring & rotor

Table 3: Properties of fibres

	Cotton	**Linen**	**Viscose**	**Polynosic**	**Lyocell**	**Wool**	**Polypropylene**	**Acrylic**	**Polyester**
Moisture regain (%)	6-8	8-10	11-14	-	11- 12	14 - 15	0	1-2	0.4
Tenacity (cN/d tex)	2-2.4	6-7	2.2-2.6	4.2	4.0-4.2				5.0-5.5
Elongation (%)	7-9	1.5-3.5	18-22	-	14-16				25-30
Wet tenacity (cN/dtex)	2.6-3.0	7-9	1.0-1.5	3.33	3.4-3.8				5.0-5.5
Wet elongation (%)	12-14	-	20-25	-	16-18				25-30
Modulus (cN /tex)	100	-	50		270	150-300	250	300-500	210
Water retention (%)	50	50--55	90-100	55-70	65	40-45	-	5-12	2-5
Thermal conductivity (J/m.s.K)	0.3-0.5	0.3	0.29			0.193	0.117	0.2	0.2-0.3
Creasing	High	High	High	High		Low	Average	Average	Low
Pilling	Low	Low	Low		High	Low	-		High

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Fibre cross-section and its density play an important role in deciding packing of fibres within yarn. Cotton being kidney bean in shape does not render high packing of fibres . As a result lot of pores exists within the yarn. Polyester fibres with trilobal, triangular, flat, dog bone and hollow cross-section can also result in larger diameter. Circular fibres lead to close packing and makes the yarn little stiffer.

Blending micro denier fibre with normal fibres can make yarn flexible and soft.

Spinning under low spindle speed (12- 14000 rpm) can increase yarn diameter in comparison to the same yarn spun at very high speed (16-18000rpm) as spinning tension is low. At low speed, the spinning tension is low which causes fibre packing to be low.

Plying could be another way to making a yarn soft. Selection of appropriate ply twist and its direction in relation to single yarn twist can make the ply yarn larger in diameter than an equivalent single yarn. The yarn becomes soft and the structure becomes more stable.

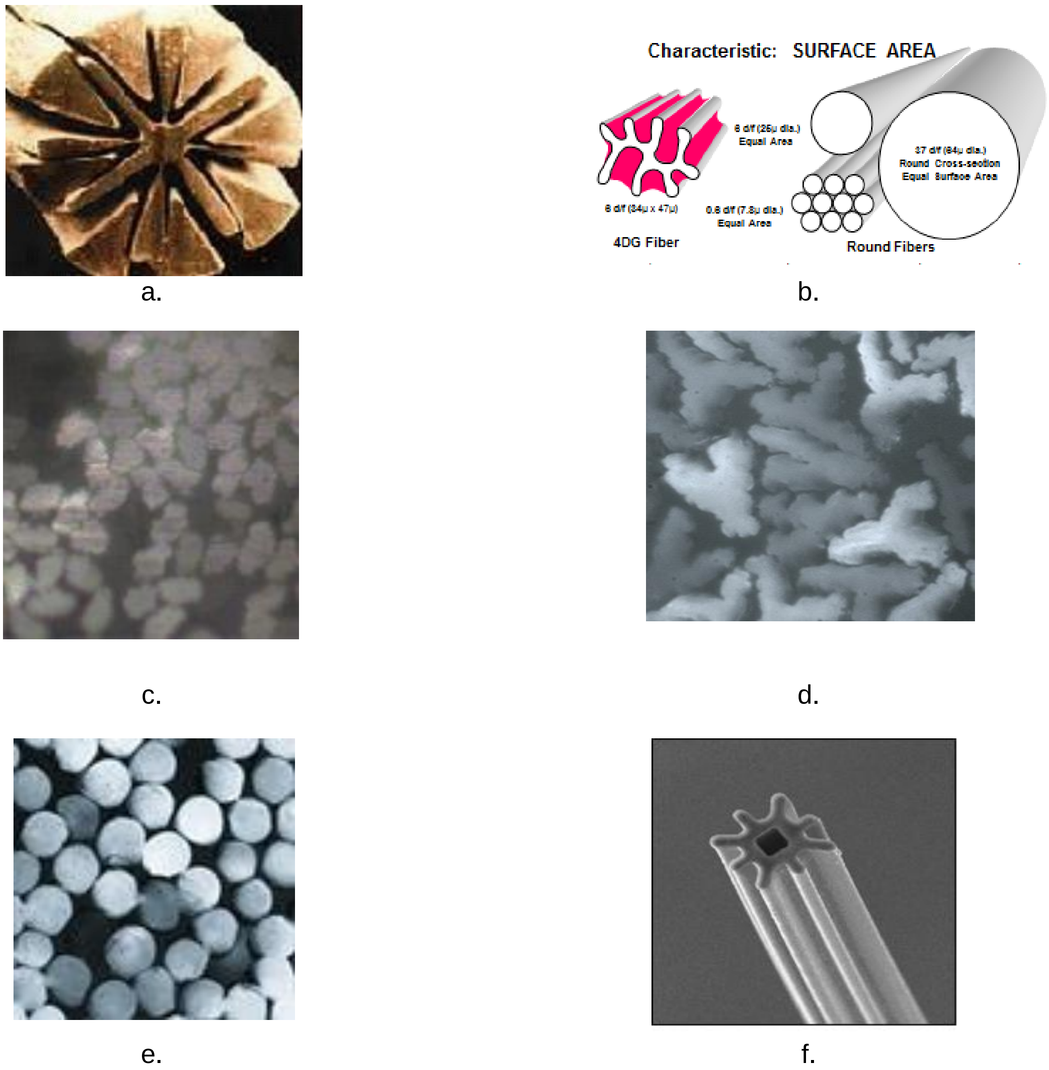

Figure 2: Cross-section of fibres; a. Micro fibre, b. 4 DG fibre, c. Bamboo fibre, d. Trilobal viscose (3.3 d tex) (Lenzing), e. Lyocell and f. Octa polyester fibre (Teijin)

The Twist – untwist principle can lead to little bulky yarn. A yarn is spun initially at higher twist level than normally used and subsequently ,part of the twist is removed to arrive at the desired twist level. The process of twisting and untwisting makes the yarn bulky and soft as shown by diameter increase in Table4.

Yarns produced from same fibres using different technologies show different level of softness. This is due to structural differences in the yarn produced on different technologies. It is well known that rotor and air jet spun yarns are stiffer than ring yarns of equivalent count spun from same fibres though diameter of rotor yarn is more than ring yarn.

By mixing shrinkable acrylic or polyester fibres (at least 20%) with cotton and following standard procedure blended yarns are produced . The yarn in hank form is then exposed to heat which causes the shrinkable component to shrink , forcing the non-shrinkable component to become crimpy generating bulk.

Table 4 : Influence of yarn modification on yarn diameter

Yarn count (Ne)	Initial TM	Residual TM	Average yarn diameter (mm)		Difference in yarn diameter (mm)	Percentage Change in yarn diameter (%)	Significance of difference t-test at 1% level
			Normal yarn	Modified yarn			
10	3.20	3.2	0.404 (0.056)	0.404 (0.056)	0	0	-
	4.30	3.2	0.404 (0.056)	0.443 (0.055)	0.039	9.6%	Significant
	4.55	3.3	0.404 (0.056)	0.473 (0.059)	0.069	17.1%	Significant
	4.81	3.4	0.404 (0.056)	0.48 (0.074)	0.079	19.6%	Significant
	5.15	3.4	0.404 (0.056)	0.500 (0.081)	0.096	23.8%	Significant
30	2.80	2.8	0.237 (0.047)	0.237 (0.047)	0	0%	-
	3.62	2.8	0.237 (0.047)	0.256 (0.047)	0.019	8.0%	Not
	3.90	2.9	0.237 (0.047)	0.300 (0.039)	0.063	26.6%	Significant
	4.16	2.8	0.237 (0.047)	0.313 (0.057)	0.076	32.1%	Significant
	4.44	2.8	0.237 (0.047)	0.345 (0.059)	0.108	45.6%	significant

(Figures within parenthesis indicate standard deviations)

4.2 Moisture absorbent and quick wicking yarns

4.2.1 Moisture absorption

The source of moisture absorption is the constituent fibre and in this regard cellulosic fibres, be it natural or regenerated outweigh others. Regenerated fibres absorb more moisture than their natural counterparts.

The water absorbency of a yarn is governed by absorbing capacity of constituent fibres and pores within yarn. Fibre plays a dominant role. It is the total pore volume that decides water holding capacity and hence an open yarn structure is always beneficial.

The size of pores within yarn is governed by fibre packing within yarn which in turn depends upon

- fineness, cross-sectional shape, specific bending rigidity of fibres and
- twist,

The numbers of pores depends upon yarn count and fibre fineness. The structure is technology dependent. The mass of water absorbing fibres is another important factor. In case of blending possibility, increasing the proportion of fibres whose moisture regain is higher than the other total water absorbency can be increased. Hence addition of viscose/ modal to cotton will help, as both have moisture content under standard atmospheric condition more than cotton.

4.2.2 Wicking

In wicking the water is transported within the yarn capillaries by capillary pressure. It depends upon surface properties of fibre, the geometry, size and number of capillaries. The capillary geometry in turn depends upon yarn structure.

Finer fibres produce finer capillaries, which would make the wicking faster due to higher capillary pressure. However too fine fibres (micro fibres) would make the capillaries so fine that wicking may be slower due to higher resistance to the flow of liquid through the capillaries.

Hence highly twisted yarn leads to low wicking due to reduced pore size and tortuous capillaries within yarn. Cotton yarns can be made to wick faster by ensuring that there is no trace of wax, oil in the hydrophobic fibre. Adding fibres that wick faster to the non wicking component or by mixing fibres with cross section specially developed to wick faster can also enhance wicking rate. 4 DG polyester fibre having special grooves improves wicking phenomenally . All synthetic fibres (hydrophobic) shows higher wickablity than natural hydrophilic fibres. Hence these fibres can be mixed with normal cotton or linen in low percentage to improve wicking rate.

4.2.3 Hollow & porous yarns

Hollow yarns can be produced by having water soluble PVA filament in the yarn core. PVA filament can be incorporated in the centre of the yarn following core spinning principle and subsequently dissolved in fabric form resulting possibly a hollow yarn. The yarns becomes bulky and soft. It is important to ensure that the PVA filament remains . There is every possibility of hollow core to collapse in actual use under pressure.
PVA staple fibres can be mixed with cotton at the during drawing stage to produce yarns which subsequently can be washed to remove PVA staple fibres. It generates micro pores within the yarn which can help in wicking water and hold them too.

PVA filament can also be twisted together with a single cotton yarn and washed out subsequently after fabric production.

4.3 Water repellent yarn

In humid climate water repellant fabric are desired so that the wearer gets a dry touch sensation. The yarn can play its role besides appropriate finishing treatment. Pore size is most important in water repellency. A tight structure leading to small pores will not allow water to penetrate easily. High twisted yarns (7 TM) being very compact will lead to slow absorption of water. Yarns made of micro or very fine fibres can also make the yarn resistant to water absorption. Fibres with round cross-section will be beneficial as it gets packed well within yarns.

4.4 Electrically Conducting yarn

There could be two methods

- mixing metallic fibre with cotton / polyester in a certain proportion (fine gauge copper, silver or nickel wire)
- core spinning using conductive material in the core covered by non conducting sheath fibres (polyester, cotton, viscose, etc.)

Using conductive material (e.g. Stain less steel fibre (8μm and 50mm length) or wire (50 μm /140 den) in the core and polyester, FR viscose or cotton in the sheath, a core-sheath type conducting yarn can be produced. Various yarn construction is possible with core having conducting material in filament form and sheath consisting a mixture of conducting and non – conducting fibres in different sheath layers. In such construction the outermost sheath layer is made of non conducting fibres. The core sheath ratio could be in the order of 30 :70. Out of 70% sheath, 10- 30 % could be made of conducting staple fibres. The placement of conducting sheath fibres can be manipulated by adjusting the location of the slivers in the drafting unit. Carbon particles are embedded in the polyester fibre. This fibre is blended with normal polyester fibre by (1%)to prevent discomfort from static in every day clothing and carpets. A mixture of 2-5% is required for safety work wear and for industrial filters.

- Resistivity could be to the order of 1-100MQ/m2.
- Application: carpets, in air craft blanket, dry filtration, safety work wear, upholstery.

4.5 Anti-microbial yarn

The silver fiber, having 99.9% pure silver permanently bonded to the surface of a fiber can be blended with other staple fibers which are both natural and manmade such as cotton, wool, polyester, acrylic etc . and spun into a yarn. The advantages of antimicrobial yarn are: (i) elimination of odor-causing bacteria (ii) *c*ooler in the summer, warmer in the winter (iii) a*nti-static*

4.6 Thermal insulation /conductive yarns

While thermal insulation is primarily due to presence of trapped air within yarn, thermal conduction is due to absence of it. Hence the two -properties are opposite to each other. A bulky yarn made of rough surface and crimpy fibres will result in more thermal insulation due to trapping of air and low contact with skin when touch. The opposite structural feature will be true for heat conductive yarns. Hence, hollow yarn or yarns having wool / acrylic fibre will be insulative in nature.

Addition of conductive metallic fibre can make the yarn conductive. Other than fibre, the surface smoothness of yarns and its compressibility can also affect heat transmission especially from human body. Heat transmission from human body can be made faster by increasing surface area of contact with yarns. Low twist yarn being soft will lead to large surface area of contact. Yarns with low hairiness or made from smooth fibres will also make large area of contact. And hence, can transmit heat faster from human body.

4.7 Coated yarn

Incorporating metals in the yarns makes the yarn heavy. And hence to overcome this problem metallic coating has been introduced. A yarn is coated by a conducting metallic powder such as silver, copper and nickel. The substrate could be filament, cotton & wool yarn. These coated yarns have low conductivity. As an example a thin layer of copper sulphide is grafted on the surface of the fibre making it a conductive fibre as well as imparting antibacterial properties.

5. Conclusion

The staple spun yarn technologies offer many opportunities to produce yarns with special properties and features. The advent of new fibres, unique cross -sectional shapes, improved functional features widens the scope further. One has to intelligently exploit the strength of the technologies to develop new product.

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