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Studies on air-jet textured sewing threads

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Air-jet textured, textured-twisted and textured-plied yarns have been made from apparel-grade polyester flat yarns and compared with commercial cotton and spun polyester sewing threads for properties and seam efficiency. The uniformity characteristics of air-jet textured sewing threads are far superior to those of cotton and spun polyester threads. The tenacity, loop strength and knot strength of textured sewing threads are lower than those of spun polyester threads but slightly better than those of cotton threads. Textured threads have high friction values than commercial threads. The seam efficiency of fabrics stitched with textured threads is higher compared to that of fabrics stitched with cotton threads and close to that of fabrics stitched with spun polyester threads. Minimum knot strength has a good correlation with seam efficiency.

Keywords: Air-jet textured yarn, Coefficient of friction, Knot strength, Loop strength, Seam efficiency

1 Introduction

A sewing thread should meet the requirements of good sewability and serviceability at an affordable price[1]. High strength for the sewing thread is a basic requirement for good sewability as there is a minimum strength needed for the thread below which the thread would be too weak for the stitches to be pulled tight. In a typical high speed sewing machine, the sewing speed often reaches to 6000 rpm. The needle is accelerated in forward direction to a speed of 45 m/s, brought to rest, and again accelerated in backward direction before returning to rest in 0.01s. Sewing thread passes through needle eye 38 times (for 4 stitches/cm) before being set in the seam and requires a high abrasion resistance[2] and good sliding characteristics.

For the smooth running of sewing thread and to avoid thread breaks during sewing, the thread-to-metal friction should be low. The friction should be uniform along the thread for better stitch formation and appearance of the seam.

Thread must be capable of resisting the high temperature generated by the friction between needle and fabric being sewn at high sewing speeds. It has been reported that the needle temperature is in the range of 310-365°C at a sewing speed of 4200 rpm without a sewing thread. The presence of thread over needle brings down the temperature by 70°C which however is not sufficient[3]. Further, the cooling effect of thread is less at high sewing speeds. At high sewing speeds with synthetic threads especially the filament threads, the parts of surface filaments melt and this causes thread break and poor stitch appearance. Sometimes, the melting of thread also leads to blockage of needle eye.

At high sewing speeds, the needle cooling by convection would have to be attempted by forced external air cooling or by throwing the air pockets entrapped in the thread over the needle; the later being a better option. In this respect, the threads with sufficient bulk, viz. spun and air-jet textured threads, are the ideal choice. Cotton and core-spun polyester (covered with cotton) threads are excellent in cooling the needle. However, the cotton threads have less strength and abrasion resistance than synthetic threads[4].

Sewing threads should have good loop forming characteristics, i.e. the ability to form a sizable loop, during insertion of thread into fabrics to avoid stitch slippage. This indicates that the bending rigidity of threads should be sufficiently high. Cotton and core-spun threads have excellent loop forming characteristics.

The tenacity of air-jet textured yarns is around 40-80% of the feeder yarns, depending on the raw material and processing parameters. Despite this, the air-jet textured yarns offer few advantages. The production rate for air-jet texturing is 300-600 m/min which is much higher than the production rate of spun

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Table 1—Properties of polyester flat yarns

Yarn code	Yarn fineness, tex	No. of filaments	Tenacity cN/tex	Extension at maximum load, %	Elastic modulus cN/tex	Boiling water shrinkage, %
F1	7.7 (2.14)[a]	36	29.8	17.1	970	4.9
F2	7.7 (1.07)[a]	72	34.3	17.9	901	5.0

[a] Fineness of filament in dtex

yarns. In addition, the air-jet textured threads have high uniformity and freedom from imperfections[5]. Selecting a raw material with higher strength (high tenacity filament yarns) for air-jet texturing can compensate the reduction in tenacity of the yarns. By suitably adjusting the process parameters in air-jet texturing, there is a further scope to control the reduction in yarn tenacity.

Air-jet textured sewing threads have multi-directional sewing performance. The thread can be pulled off the cones in either direction as there is no twist to be affected[6]. This is useful in sewing with automated stitching jigs, where sewing can be in any direction. A twisted thread would vary in appearance or performance[5].

Majority of the sewing threads has twisted structures. In twin-needle chain-stitch sewing machines, the hooks rotate in the same direction and the threads are pulled in opposite direction. This results in one untwisted thread, which leads to frequent sewing thread breakage and thus gives different appearance of the stitch lines[5]. As a consequence, either the productivity of sewing machine goes down or it results in poor appearance of seam. For value added garments, seam appearance is highly critical. Air-jet textured threads are ideal choice for these kinds of applications as they are made mostly without twist.

From the serviceability point of view, the seam strength, seam security and shrinkage of sewing threads are important. To avoid seam puckering or severity of pucker after repeated wash of the sewn fabric, the sewing thread should have low boiling water shrinkage. Higher seam efficiency is possible only with a strong thread. Seam security refers to 'less easy undoing of the stitches'. In the case of a single-thread chain-stitch (class-100), if the last stitch is not properly locked or the thread is broken or a stitch slips, the stitch can be easily removed[5].

In this work, different types of air-jet textured sewing threads are compared with commercial cotton and polyester spun threads for tensile, evenness and frictional characteristics and for seam efficiency of sewn fabrics.

Table 2—Details of air-jet textured yarns

Parent yarn code	Number of ends	Yarn tex	Textured yarn code
F1	1	9.50	1A1
	2	19.5	2A1
	3	29.0	3A1
F2	3	29.0	3A2

2 Materials and Methods

Two polyester flat yarns, having the properties as shown in Table 1, were selected for the study.

2.1 Texturing

The texturing of polyester flat yarns was carried out on Eltex AT/HS air-jet texturing machine. Texturing was done with single, double and triple ends using the following processing parameters: air pressure, 9kgf/cm^2; overfeed, 30%; mechanical stretch, 4.7%; winding stretch, 0.7%; water pressure, 2kgf/cm^2; water consumption, 0.5 litre/jet/h; air nozzle, HemaJet core T-100; overfeed to heater, 0%; and heater temperature, 220°C.

The details of the textured yarn samples are given in Table 2. To reduce the shrinkage of textured yarns, the yarns were once again passed through the heater of the air-jet texturing machine (secondary heat setting). During secondary heat setting, the heater temperature was kept at 220°C. The textured yarns were fed to the heater with 3% overfeed.

2.2 Application of Spin Finish on Textured Yarns

During wet texturing, most of the finish present on yarn is dissolved and blown out in the secondary flow. The resultant textured yarn shows very high friction values. To compensate for this, a commercial spin finish of paraffin base (Sapco 1225 K) was applied on the textured yarns with 10% concentration using lick roller on the air-jet texturing machine. Lick roller speeds of 1, 2, 3 and 4 rpm and a yarn speed of 300 m/min were kept during the application of spin finish on a textured yarn. The lick roller speed corresponding to minimum friction was selected to apply spin finish for other textured yarns.

2.3 Twisting of Textured Yarns

To study the effect of twisting of textured yarn on yarn properties, two derivatives of textured yarns were produced. In one case, the yarn textured with three ends (coded as 3A1) was twisted on ring twister at 8 twists/inch, and in the other case three ends of textured yarn (1A1) were ply twisted on a ring twister at 8 twists/inch.

2.4 Testing of Yarn Properties

Tensile properties, knot strength and loop strength were tested using an Instron tensile tester. For the knot strength test, a knot was tied in the portion of specimen between the clamps and then it was subjected to break. In a loop strength test, two pieces of yarn were taken from the package. Both the ends of first piece were secured in one clamp of the testing machine so that the length of the loop is about one half of the gauge length. One end of the second loop was passed through the loop formed by the first piece of the sewing thread and both ends of the second piece were fixed in the other clamp of testing machine.

Frictional properties (yarn-to-metal and yarn-to-yarn) were tested on Lawson-Hemphill CTT yarn friction tester. The yarn-to-metal friction was tested using a wrap angle of 180°, input tension of 1 cN/tex, and rubbing speed of 100 m/min. For the measurement of yarn-to-yarn friction, the yarn was twisted with three turns of twist and the testing was done at a rubbing speed of 20 m/min with an input tension of 1 cN/tex.

Yarn irregularity characteristics were tested on Uster evenness tester-III. The testing speed was kept at 400 m/min. The sensitivity levels were: thick places +50%, thin places -50% and neps +200%. Yarn optical diameter and its variation were also obtained using Laser spot tester.

The bending rigidity of threads was measured on Shirley weighted ring yarn stiffness tester. For boiling water shrinkage of yarn, one meter length of the specimen was tested under 0.45 cN/tex tension. This yarn was loosely wound on a glass rod and dipped into boiling water for 30 min. After drying, the yarn was unwound and its length was again measured under a load of 0.45 cN/tex. For testing instability of textured yarns, DuPont method was used with minimum and maximum yarn tensions of 0.09 cN/tex and 4.5 cN/tex respectively. The permanent elongation percentage in the length of specimen was measured 30 s after the higher load has been removed. The permanent elongation percentage was taken as the direct measure of the instability.

2.5 Preparation of Sewn Fabric

To study the seam strength of sewn fabrics, a cotton fabric [weight-154g/m^2; and linear density-29.5 tex (warp) and 37.0 tex (weft)] was stitched. The thread density was 23.6 and 22 cm^{-1} for warp and weft respectively. The fabric strength was 470 and 510 N for both warp and weft directions respectively. Stitching was done in an industrial lock stitch machine with super-imposed seam at 2500 stitches/min. For general purpose sewing using lock-stitch machine, the denier range of sewing thread was 225-378 (25-42 tex). Textured, textured-twisted and textured-plied yarns in the same denier range were used for stitching along with the commercial sewing threads of similar size as shown in Table 3. A number 12 needle (70 Nm) was used for making the samples with a stitch density of 4 cm^{-1}. Samples were stitched along the weft direction at low and high tension levels (arbitrary) and for each tension level, five samples were made.

2.6 Testing of Fabric Properties

Unstitched and stitched fabric samples were tested for their breaking loads on Instron tensile tester using Grab test method as per the ASTM standard (D1683-90a), keeping the 5 cm jaw width. Equal amount of fabric was left on either side of the jaw and the seam was kept in the middle. The gauge length was kept at 7.5 cm. From the average breaking load, seam efficiency was calculated using the following relationship:

Table 3—Textured yarns and commercial sewing threads used for stitching

Yarn code	Yarn tex	Yarn or thread details
3 A1	29.0	Triple ends of F1 textured
3 A2	29.0	Triple ends of F2 textured
3 A1-T	29.4	Triple ends of F1 textured and twisted
1A1-3P	29.1.	Single end of F1 textured and 3-ply
C1	26.6	Cotton thread
C2	29.4	Cotton thread
SP	29.7	Spun polyester thread

$$\text{Seam efficiency (\%)} = \frac{\text{Breaking load of sewn fabrics across the seam}}{\text{Breaking load of unstitched fabric}} \times 100$$

3 Results and Discussion

3.1 Tensile Properties of Textured Yarns

It is found that after texturing, there is a considerable decrease in yarn tenacity and elastic modulus, and a slight increase in elongation at maximum load. The changes in tensile properties of textured yarn from that of parent yarn are shown in Table 4. Disorientation of the filaments during texturing and formation of loops result in poor load sharing among the filaments and this causes reduction in tenacity and modulus of yarns after air-jet texturing. The increase in elongation is due to the larger and less anchored loops which are pulled out from yarn surface. Earlier research works[7, 8] have shown that the reduction in tenacity of air-jet textured yarns ranges from 20 % to 60%, depending on the overfeed to the jet, type of texturing (dry or wet) and air pressure used.

3.2 Effect of Lick roller Speed on Frictional Characteristics of Air-jet Textured Yarns

The effect of lick roller speed on the frictional characteristics of textured yarns is studied for 3A1 yarn and the results are given in Table 5. It is observed that as the spin finish add on percentage increases, the coefficients of friction decrease up to 0.7% add-on and then stabilize. The lick roller speed corresponding to minimum friction is found to be 3 rpm. Therefore, for applying spin finish on other yarns, the lick roller speed of 3 rpm was selected. The yarn-to-yarn and yarn-to-metal frictional values of textured yarns for a lick roller speed of 3 rpm are shown in Table 6.

3.3 Effect of Heat Setting on Shrinkage of Air-jet Textured Yarns

Boiling water shrinkage values of air-jet textured yarns which are heat set once and twice are shown in the Table 7. It is found that there is a considerable reduction in boiling water shrinkage after second heat setting due to the better relaxation of yarn. The heater in the air-jet texturing machine is of non-contact type with a length of 1 m, giving a yarn residence time of 0.2 s in the heater. Referring to the boiling water shrinkage percentage of parent yarns (F1 and F2), the reduction in shrinkage of the textured yarns after first heat setting is around 40-50%. A heater length of one meter is not very effective in modifying the yarn shrinkage by any significant amount, only the loops are shrunk and not the core of the yarn. Since the air-jet textured yarns are covered with loops around the core, the heat transfer to portions of filaments in the core is not effective. For heat setting in a single stage, it is preferable to go for non-contact type heater of longer length.

3.4 Effect of Twisting and Plying on Textured Yarn Properties

The tenacity and frictional properties of textured, textured-twisted and textured-plied yarns are shown

Table 4—Percentage reduction in tensile properties of yarns after texturing

Yarn code	Reduction in tenacity, %	Increase in elongation at maximum load, %
1A1	32	3
2A1	34	2
3A1	32	15
2A2	37	9
3A2	36	12

Table 5—Effect of lick roller speed on coefficient of friction

Lick roller speed rpm	Spin finish %	Coefficient of friction	
		Yarn-to-metal	Yarn-to-yarn
0	0	0.29	0.18
1	0.3	0.28	0.17
2	0.5	0.27	0.16
3	0.7	0.25	0.16
4	1.1	0.25	0.16

Table 6—Frictional properties of textured yarn

Yarn code	Coefficient of friction	
	Yarn-to-metal	Yarn-to-yarn
2A1	0.28	0.18
3A1	0.25	0.16
2A2	0.28	0.20
3A2	0.28	0.19

Table 7—Effect of heat setting on yarn boiling water shrinkage

Yarn code	Shrinkage, %	
	After 1st heat setting	After 2nd heat setting
2A1	2.6	1.2
2A2	3.1	1.4
3A2	3.0	1.4

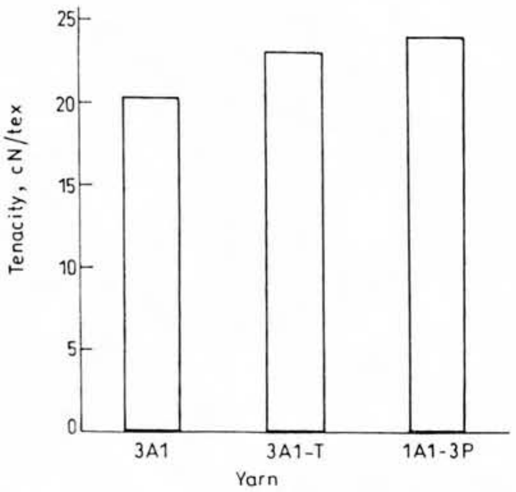

Fig. 1—Effect of twisting and plying of air-jet textured yarns on tenacity

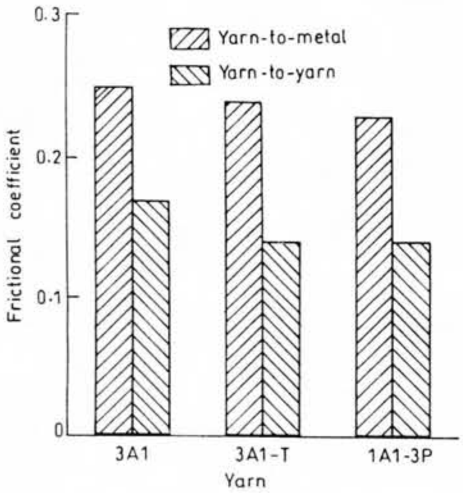

Fig. 2—Effect of twisting and plying of air-jet textured yarns on friction values

in Figs 1 and 2. It is found that after twisting, there is an improvement in yarn tenacity and reduction in coefficients of friction. The improvement in tenacity after twisting or plying is due to the folding of few loops on to the yarn core and partial alignment of the filaments towards the yarn axis by twisting tension. Yarn compactness improves after twisting/plying. The area of contact between rubbing surfaces would be less for compacted yarns which brings down the friction values of twisted and plied yarns compared to textured yarns.

3.5 Frictional Properties of Air-jet Textured and Commercial Sewing Threads

Table 8 shows the various properties of air-jet textured and commercial sewing threads. The coefficients of friction of air-jet textured yarns are higher than that of the commercial sewing threads. This is mainly due to the structural properties of air-jet textured yarns. As these air-jet textured yarns have more loops and larger diameters, they are easily compressed during rubbing, developing more area of contact and hence the high friction values. It has been reported that the packing density of air-jet textured yarns is lower than that of combed cotton yarns[9].

3.6 Evenness Characteristics of Air-jet Textured and Commercial Sewing Threads

Uniformity characteristics of air-jet textured yarns and their derivatives are far superior to those of commercial sewing threads. There are no imperfections in air-jet textured yarns. Air-jet textured yarn made from finer filaments (3A2) has less CV% than those made from coarser filaments (3A1). The presence of more number of filaments in the 3A2 yarn compared to that in 3A1 yarn may be the reason for it.

Table 8 – Comparison of properties of air-jet textured and commercial sewing threads

Yarn code	Coefficient of friction		Yarn diam. mm	Um%	Imperfections/km			BWS %	Flexural rigidity $\times 10^{-4}$, cN/tex
	Y/M	Y/Y			Thin place (-50%)	Thick place (+50%)	Neps (+200%)		
3A1	0.25	0.17	0.60	4.75	0	0	0	1.3	94
3A2	0.28	0.19	0.63	4.13	0	0	0	1.4	76
3A1-T	0.24	0.14	0.50	3.81	0	0	0	1.3	88
1A1-3P	0.23	0.14	0.51	3.73	0	0	0	1.3	72
C1	0.14	0.10	0.37	9.41	0	8	12	1.0	82
C2	0.18	0.14	0.46	9.21	0	40	40	1.3	49
SP	0.18	0.11	0.40	8.45	0	12	32	0.6	60

Y/M—Yarn-to-metal, Y/Y—Yarn-to-Yarn, BWS – Boiling water shrinkage.

Table 9—Tensile properties of air-jet textured and commercial sewing threads

Yarn code	Tenacity cN/tex	Loop strength cN/tex	Knot strength cN/tex (minimum)	Extension at max. load, %	Elastic modulus, cN/tex
2A1	19.7	17.6	19.4 (16.3)	17.3	274
3A1	20.3	19.2	20.0 (17.3)	19.7	233
2A2	21.6	20.1	20.8 (18.7)	19.5	311
3A2	22.0	22.0	21.0 (18.4)	20.1	278
3A1-T	23.1	22.3	22.8 (21.3)	19.9	251
1A1-3P	24.0	23.3	23.3 (20.1)	19.8	282
C1	21.8	20.7	17.8 (15.9)	4.7	450
C2	19.0	16.2	18.2 (15.2)	5.2	366
SP	31.6	28.8	25.1 (19.6)	13.9	549

3.7 Shrinkage of Air-jet Textured and Commercial Sewing Threads

Commercial spun polyester thread has a shrinkage value of 0.6%, while for others it is in the range of 1-1.4%. With a high residence time of yarn inside the heater, the shrinkage of air-jet textured yarns can be brought down further to meet the requirements of sewing threads.

3.8 Flexural Rigidity of Air-jet Textured and Commercial Sewing Threads

Flexural rigidity of air-jet textured yarn is comparable or higher than that of commercial sewing threads. In an air-jet textured yarn, the filaments are entangled while forming loops. The freedom of movement of filaments is restricted during bending due to the locked-in structure of the filaments. While twisting or plying the textured yarns, there is a loss in flexural rigidity. The reduction in yarn diameter on twisting decreases area moment of inertia and hence a lower flexural rigidity for twisted textured yarns.

3.9 Tensile Properties of Air-jet Textured and Commercial Sewing Threads

Tensile properties of different yarns are shown in Table 9. From the table it can be seen that the tenacity of textured yarns and their derivatives is equivalent to the tenacity of commercial cotton sewing threads while it is less than that of spun polyester sewing thread. Tenacity of textured yarns depends on the level of overfeed during texturing and tenacity of feeder yarns. It is to be noted that the tenacity values of textured yarns made from stronger filaments (2A2 and 3A2) are higher than that of yarns made from weaker filaments (2A1 and 3A1). The effective overfeed in this study is 27%. A lesser overfeed would have enhanced the tenacity of the textured yarns. In addition, the tenacity of parent yarns is more or less similar to the tenacity of spun polyester thread. Since the reduction in tenacity after texturing is around 35%, the air-jet textured yarns show less tenacity than the spun polyester thread. For air-jet textured sewing threads, the use of high tenacity polyester filaments either alone or blended with regular polyester filaments with lower overfeeds (10-20%) would have to be considered.

Table 10—Comparison of seam efficiency of different sewn fabrics

Yarn code	Yarn tension	Seam efficiency, %
3A1	Low	60
	High	58
3A2	Low	63
	High	59
3A1-T	Low	61
	High	59
1A1-3P	Low	63
	High	59
C1	Low	53
	High	50
C2	Low	48
	High	43
SP	Low	68
	High	63

Majority of thread breaks in a seam occurs at a looped part of a stitch and the loop strength of a thread is more closely related to seam strength than the yarn tenacity[5]. Correlation coefficient between tenacity and loop strength is 0.96 and that between tenacity and knot strength is 0.83. An earlier study[10] has indicated lower correlation coefficients. It has been demonstrated that the seam strength due to thread breakage can be calculated from the stitch density and minimum knot strength[5]. Spun polyester yarn has higher tenacity than air-jet textured yarns but the ratio of minimum knot strength to tenacity is lower than that of textured threads. This may be due to the higher irregularity of spun polyester thread compared to that of textured thread.

3.10 Seam Efficiency of Sewn Fabrics

The seam efficiency values of the fabric sewn with various threads are shown in Table 10. In all the cases, the seam efficiency of samples sewn at higher sewing thread tension is low compared to that of the samples sewn at lower sewing tension due to the high thread strain during the sewing. It is found that the seam efficiency of fabrics stitched with air-jet textured yarn and its derivatives is higher than that of fabrics stitched with cotton sewing threads but lower than that of fabrics stitched with spun polyester sewing threads. The correlation coefficient between minimum knot strength of the sewing threads and seam efficiency of the stitched fabrics is 0.85. The high strength of spun polyester thread does not necessarily give high seam efficiency. This is due to the lower minimum knot strength of the spun threads compared to its tenacity. As the commercial sewing threads are more irregular than the textured threads, the minimum knot strength and the seam efficiency are not in commensurate with their tenacity values. The uniformity characteristics of the threads have played a vital role in influencing the seam strength, through minimum knot strength.

4 Conclusions

Uniformity characteristics of air-jet textured sewing threads are far superior to those of spun cotton and polyester threads. Loop forming characteristics of air-jet textured yarns are similar to or better than those of commercial threads as indicated by the equal or higher yarn flexural rigidity values. Boiling water shrinkage of textured threads is similar to that of cotton threads but higher than that of spun polyester threads. Due to the reduction in strength of yarns after texturing at high overfeed, the mean tenacity, loop strength and knot strength of textured sewing threads are lower than those of spun polyester threads but slightly higher compared to those of cotton threads. Textured threads have high friction values than commercial threads. The seam efficiency of sewn fabrics stitched with textured threads lies in between those of the fabrics stitched with cotton and spun polyester threads, but is closer to that of the fabrics stitched with spun polyester thread. For spun threads, their poor evenness characteristics seem to have influenced their minimum knot strength, thereby the seam efficiency. Higher mean single thread strength for spun polyester thread has not translated itself in realizing higher seam efficiency due to the poor thread uniformity. Similar is the trend for the cotton threads.

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References

1 Wagner C D, *Melliand Textilber*, 60 (1979) 793.
2 Crook A, *Textiles*, (2) (1991) 14.
3 Howard G M, Virgilio D R & Mack E R, *Text Res J*, 43 (1973) 651.
4 Behera B K, *Text Trends*, March (1997) 33.
5 Carr H & Latham B, *The Technology of Clothing Manufacture* (BSP Professional Books, Oxford), 1992.
6 Glock R E & Kunz G I, *Apparel Manufacturing: Sewn Product Analysis* (Prentice Hall, New Jersey), 1995.
7 Rengasamy R S, *Studies on the influence of some raw material and other parameters on the structure and properties of air-jet textured yarns*, Doctoral thesis, IIT, Delhi, 1991.
8 Demir A, Acar M & Wray G R, *Text Res J*, 58 (1988) 318.
9 Pillar B & Lesykova E, *Melliand Textilber*, 63 (1982) 487.
10 Panigrahi R, *Evaluation of conventional sewing threads*, M. Tech thesis, IIT, Delhi, 2000.