Mansoura Engineering Journal

Volume 35 | Issue 2 Article 12

11-21-2020

Comparative Study between Plied "Conventional and Compact" Spun Yarns Characteristics.

Moaz Mostafa
Textile Department, Faculty of Engineering, Mansoura University, Mansoura, Egypt

Ismail Rakha
Professor of Textile Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.

Fawkia Fahim
Professor of Textile Department., Faculty of Engineering., Mansoura University., Mansoura., Egypt.

Eman Elshahat
Assistant Professor., Textile Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.

Recommended Citation

Mostafa, Moaz; Rakha, Ismail; Fahim, Fawkia; and Elshahat, Eman (2020) "Comparative Study between Plied "Conventional and Compact" Spun Yarns Characteristics.," *Mansoura Engineering Journal*: Vol. 35 : Iss. 2 , Article 12.
Available at: https://doi.org/10.21608/bfemu.2020.124660

Mansoura Engineering Journal, (MEJ), Vol. 35, No. 2, June 2010.

Comparative Study between Plied "Conventional and Compact" Spun Yarns Characteristics

دراسة مقارنة بين خواص خيوط الغزل الحلقى التقليدية والمدمجة المزوية

Eng. Moaz Ahmed Samy Mostafa, Prof. Dr. Ismael Mosa Rakha, Prof. Dr. Fawkia Fahim, Dr. Eman Elshahat.

Textile Department, Faculty of Engineering, Mansoura University

ملخص البحث

نظام الغزل الحلقى المدمج هو نظام يعتمد على نظام الغزل الحلقى التقليدى ولكن بعد إضافة بعض التعديلات فى منطقة السحب مما يؤدى إلى تحسين خواص الخيوط المنتجة. تعتبر خصائص الخيط المدمج أفضل من خواص الخيط التقليدى. تقدم هذه الدراسة مقارنة بين الخيوط المنتجة على ماكينة الغزل الحلقى التقليدية Rieter G5/1 وماكينة الغزل الحلقى المدمج Rieter K44 تم إنتاج خيط 60 إنجليزى بكلا النظامين بأس برم مفرد عند 4 مستويات مختلفة ثم تم زوى كل خيط على 3 مع إستخدام 5 مستويات مختلفة من أس البرم المزوى. بزيادة أس البرم المزوى تتغير خواص الخيط بالزيادة أو النقصان بعد النسبة بين أس البرم المزوى والمفرد بمقدار 1.1. تتحقق أعلى متانة للخيط المزوى لكلا النظامين عند نسبة بين أس البرم المزوى والمفرد أعلى من 1.1. يمكن الإستفادة من خواص الخيط المدمج بإستخدام خيط مدمج بأس برم مفرد منخفض وأس برم مزوى متوسط بدلا من خيط تقليدى بأس برم مفرد متوسط وأس برم مزوى عالى وتكون خواصه أفضل وبإنتاجية أعلى.

Abstract

Compact spinning system is simply the modification of conventional ring-spinning system. Compact yarn compared with classical yarn was characterized by better properties. This paper presents an analysis and comparison of the parameters of compact yarn spun on Rieter K44 (com4 spin) compact spinning frame and on Rieter G51 conventional ring spinning frame. Combed yarn Ne 60 yarns were produced with different levels of single twist factor for each system. Also each single yarn was plied on 3 plys taking different levels of ply twist factor. By increasing ply twist factor, plied yarn properties changes by increase or decrease after a ratio between ply and single twist factor of 1.1. With a twist ratio of ply twist factor to single twist factor over 1.1, maximum strength was achieved. Compact yarn with a low single twist factor and medium ply twist factor can be used instead of conventional yarn with a medium single twist factor and high ply twist fac0tor and will be better in all characteristics and as well as higher spinning productivity.

1. Introduction

When rotor yarns made their debut in the 1970s, many people thought the days of ring spinning were numbered. Ring yarn was too expensive, too unproductive, more difficult to process, and its positive characteristics were hard to exploit. Other processes with high productivity – and lower yarn quality – were investigated and some of them were marketed. Then the unexpected happened: Ring yarn staged a comeback after the invention of compact yarns, not only as a result of automation and higher speeds, but also because of the better characteristics of the end product. The marginal fibers are no longer on the surface as in conventional ring yarn, but are

---

Accepted June 30, 2010.

completely integrated in the fiber bundle. As a result, the hairiness is reduced and the yarn strength is increased by up to 20%. The COM4 spin process uses a conventional drafting system, complementing it with an additional add-on unit whose effect is comparable with the process described above. This equipment is usually used for converting existing ring-spinning machines. At the latest since the ITMA 1999, this development Andreas Hellwig has even been taken a stage further, compact spinning has been introduced.

Compact spinning is simply the modification of conventional ring spinning, which achieves a remarkable improvement in yarn structure and quality.

The aim of applying the compact spinning systems is improving yarn quality by means of narrowing and decreasing the width of the band of fibers which come out from the drawing apparatus before twisting into yarn, and by the elimination of the spinning triangle..

At present, the Rieter, Suessen, Zinser and other companies have produced compact spinning systems. [7 and 10]

Research work into the structure of compact yarns and into spinning frame development had been carried out not only by the Suessen Company, but also by other machine makers such as Rieter and Zinser [1, 2, 3, 8, and 9].

Many researches [3, 4, 6, 9, 11, 12, and 13] have been carried out in the field of compact spinning technology and properties of compact yarns and it has been included that:

- Less yarn breakage (by about 30-60%) during the spinning process (as well as during further processing).
- The possibility of decreasing the twist is 20%.
- Higher efficiency connected with higher tensile strength, and with the possibility of spinning with decreased twists of fibers.
- Smaller amount of dust released, due to the more compact yarn structure.
- The possibility of increasing the winding and warping velocities.
- the possibility of decreasing the twist by 20% also during twisting yarn on a twisting frame (the yarn structure with lowered twist allows both better dye absorption and lower dye consumption to be obtained).
- Reduction of size consumption by 25-50%;
- Single and plied yarn does not require singeing.
- Lower hairiness and higher tensile strength decreases yarn breakage during warping by 30%.
- A decrease in the number of sized and wedged joints formed over shedding.
- Plied yarn can be replaced in the weaving process by the cheaper single yarn.
- warp yarn breakage during weaving decreases by 50%, and those of weft by 30%.
- The number of breakages which occur by weft picking on rapier looms decreases by 33%, whereas on pneumatic looms this figure reaches 45%.
- The picking velocity on pneumatic looms can be raised from 500-600 m/min to 700-800 m/min [5 and 8].

Yarn manufactured by means of the compact spinning system compared with classical yarn was characterized by:

- Better smoothness,
- Higher luster,
- Abrasion fastness better by 40-50%,
- Hairiness lower by 20-30%, as measured with the use of the Uster apparatus,
- Hairiness lower by 60%, as measured with the use of the Zweigle apparatus,
- Tenacity and elongation at break higher by 8-15%, and smaller mass irregularity.

2. Aim of work

The present work intended to compare the properties of yarns manufactured by means of compact and conventional spinning systems at different twist levels for both single and plied yarns.

3. Experimental work

3.1 Material used

Egyptian cotton G86 has a specifications listed in table (1).

Table (1): Fiber specifications

Property	Test name	Device	Result	Description
Length	Upper half mean length (mm)	Uster® HVI Spectrum	32.5	Long staple
	Uniformity index		86.6	Very high
Strength	Strength (gm/tex)		45	Very high
	Elongation (%)		6.4	Medium
Fineness	Micronaire (microgram/inch)		4.51	Medium
Color	Reflectance (Rd %)		75.6	
	Yellowness (+b)		8.6	
Trash	Trash area (%)		0.5	
	Trash count		27	
Maturity	Maturity (%)	Micr-omat	89	Mature
Count	Count (millitex)		169	

3.2 Method of yarn production

Cotton fibers were processed in blowroom, carding, combing, drawing and roving for producing combed roving Ne 1.0 at standard machine setting and processing variables. The roving was fed to Rieter K44 (COM4 spin) compact and Rieter G5/1 conventional ring spinning machine for producing Ne 60 combed compact and combed conventional ring yarn. Four different levels of twist factor of 3, 4, 4.5 and 5 were used for both compact and conventional ring yarns. Condensing zone of the Comforspin system as shown in fig. (1), consists of the rotating perforated suction drum (3), a suction unit (4) with a slot (S), which extends from nip (3-31) to nip (3-32) and the top rolls (31 - 32). When the machine starts, an air current is generated by a tube connecting the suction unit (4) through the slot (S). This generates negative pressure or a suction effect so as to condense and straighten the fibers as soon as they leave the nip (3-31) and until they reach nip (3-32). After leaving the condensing zone twist is instantly inserted into the yarn. Condensing fibers is supported by air guide element mounted on the perforated drum. It ensures that the suction effect occurs only along the slot(S) area, thus reinforcing the condensing process and guaranteeing uniformly low hairiness of yarn.

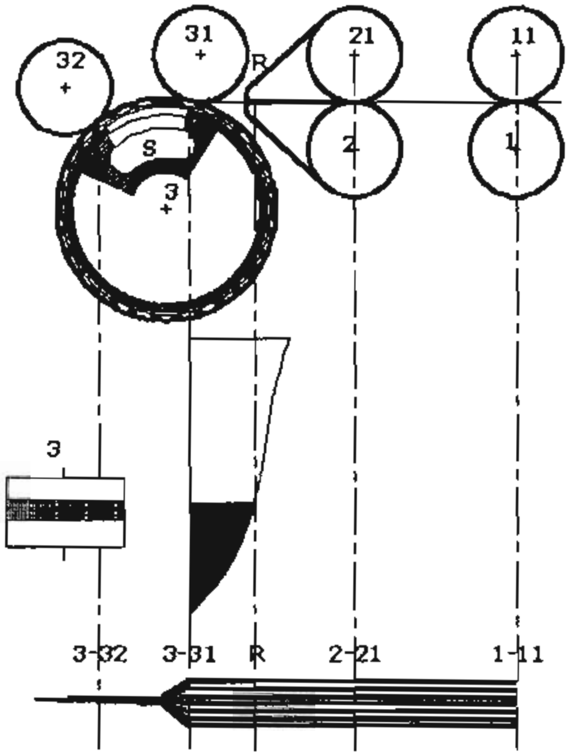

Fig. (1): Comforspin system

Each yarn of these 8 single yarn was winded on cone then plied / 3 in Z direction using 5 levels of ply twist factor producing 40 samples of compact and conventional plied yarns as shown in fig. (2). Twisting machine used was Volkmann-FT two for one twister with a speed up to 15000 rpm and twist range of 3-70 turns per inch.

3.3 Measurements

All single and plied yarns were tested for evenness (cv%), thin & thick places, neps and hairiness using Uster tester 4, where a total length of 1000 yd/cone was tested at a run speed of 400 yd/min and evaluation time was 2.5 min, 10 cone were tested for each yarn.

All the tensile properties of these yarns (strength, breaking elongation and work of rapture) were measured using Uster Tensojet where 1000 measurements were taken per cone and individuals as well as mean values are reported.

All curves were plotted using the measured actual single and ply twist factor.

3.4 Statistical analysis

Factorial analysis was used to investigate the effect of spinning system, Single and plied yarn twist factor on single and plied yarn properties.[18] A full factorial design has 3 factors A*B*C was used where:

A is spinning system (2 levels).

B is single yarn twist factor "α_{cs}" (4 levels).

C is plied yarn twist factor "α_{ep}" (3 levels).

Levels of different factors are shown in table (2).

Table (2): Statistical analysis

Factor / Level	Level 1	Level 2	Level 3	Level 4
Spinning system	Convent-ional ring	Com-pact	-	-
Single yarn twist factor "α_{cs}"	3	4	4.5	5
Plied yarn twist factor "α_{ep}"	3	4	5	-

Analysis of variance of yarn properties is summarized in table (5) and (6).

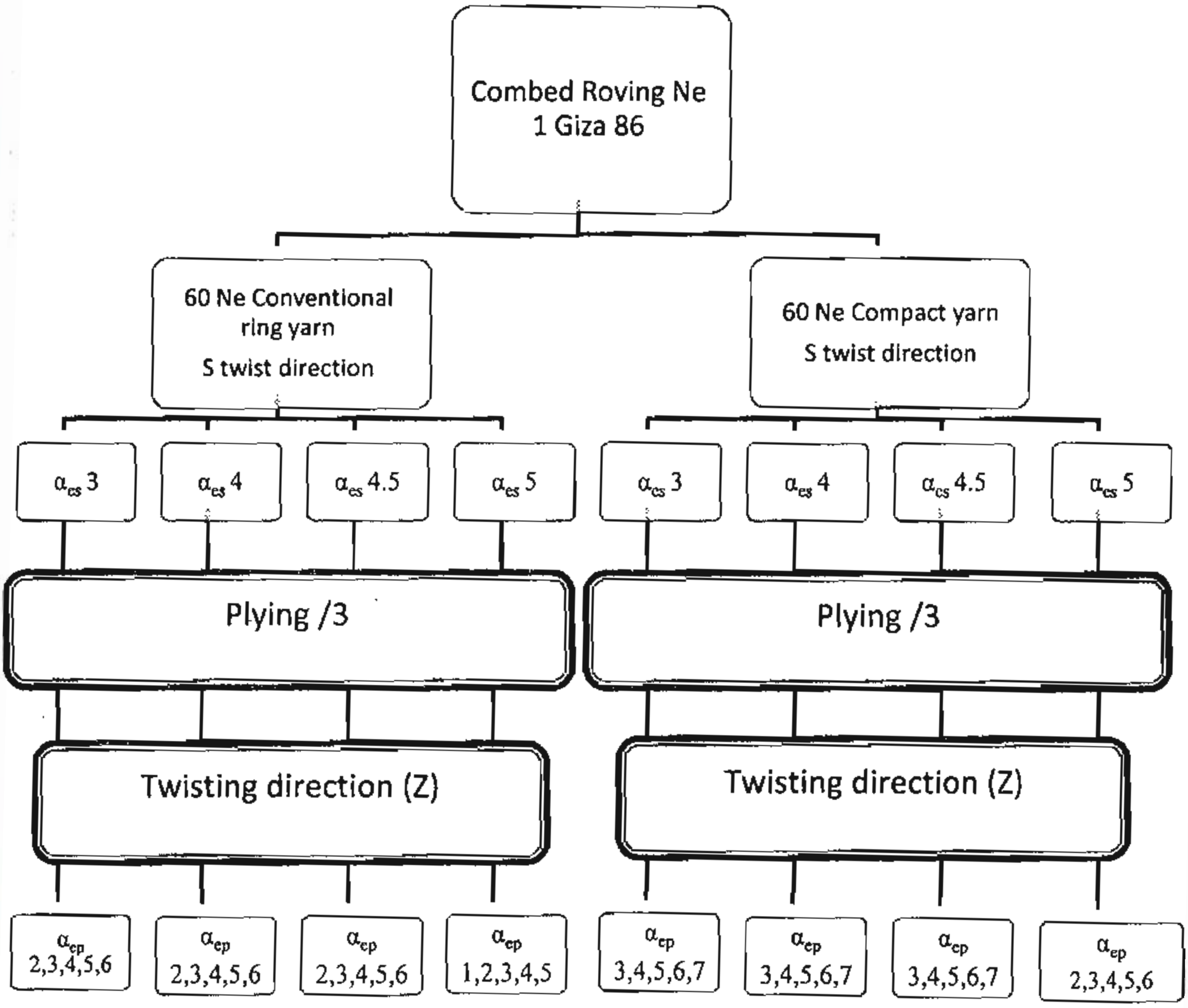

Fig. (2): Experimental plan carried out to produce the different yarns.

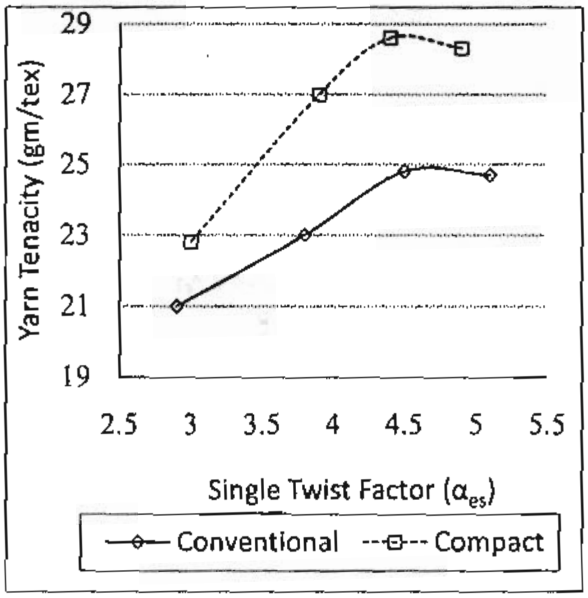

Fig. (3): Relationship between Single Twist Factor and Tenacity.

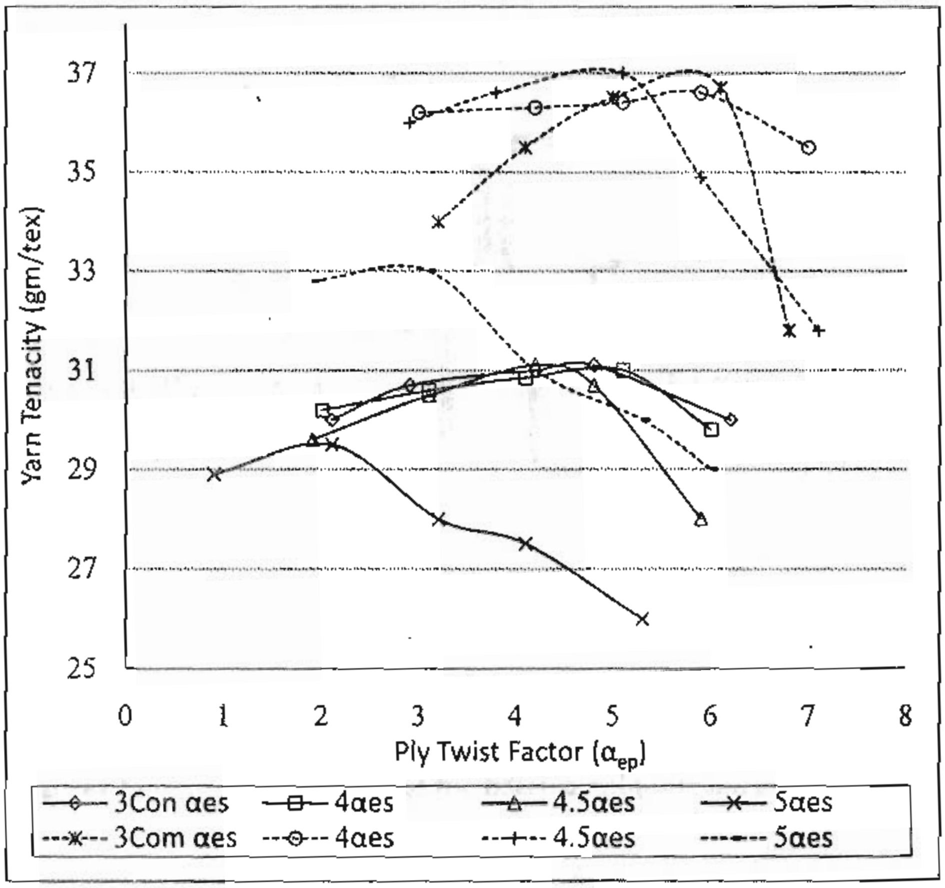

Fig. (4): Relationship between Ply Twist Factor and Tenacity.

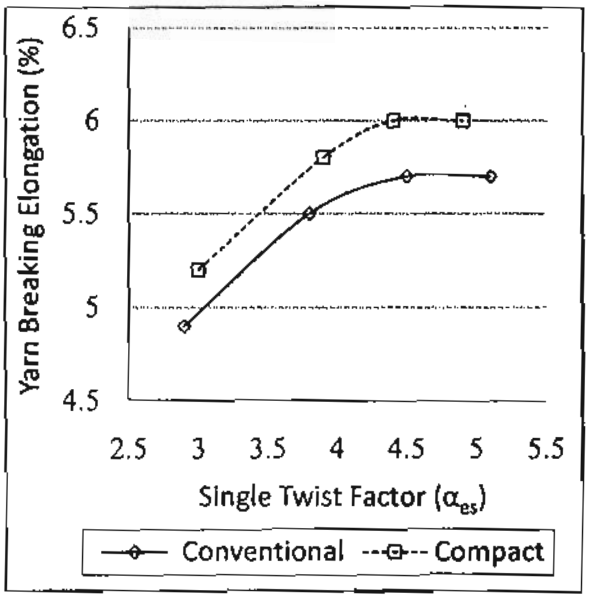

Fig. (5): Relationship between Single Twist Factor and Elongation.

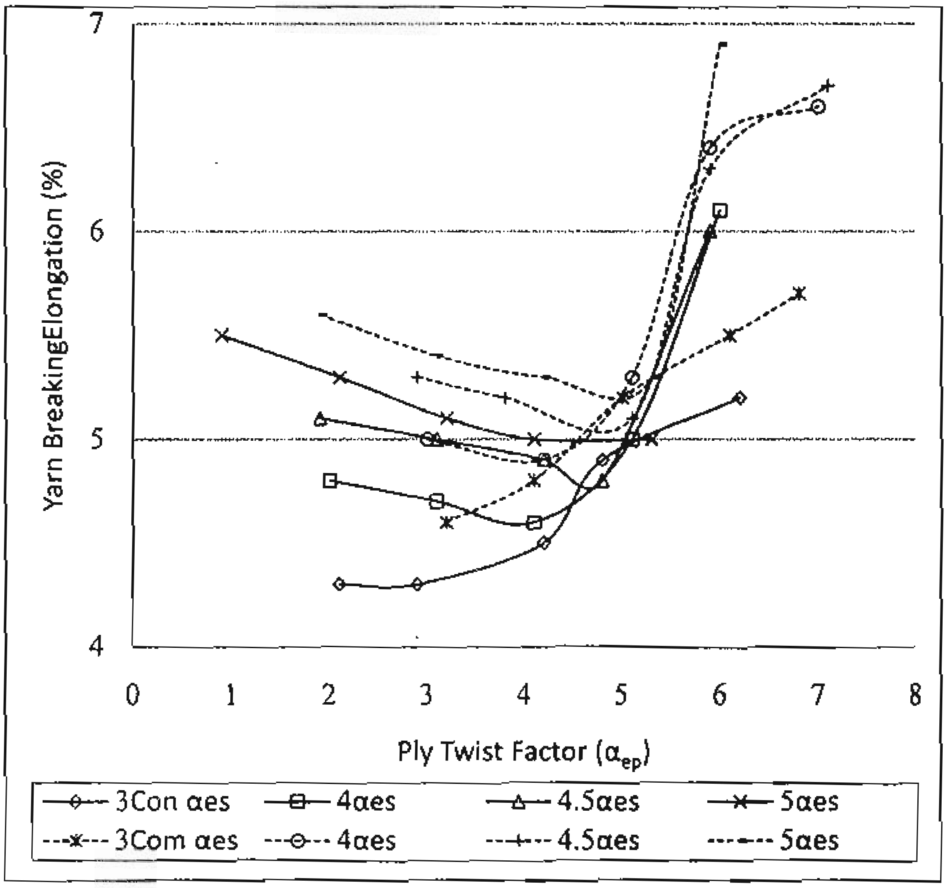

Fig. (6): Relationship between Ply Twist Factor and Elongation.

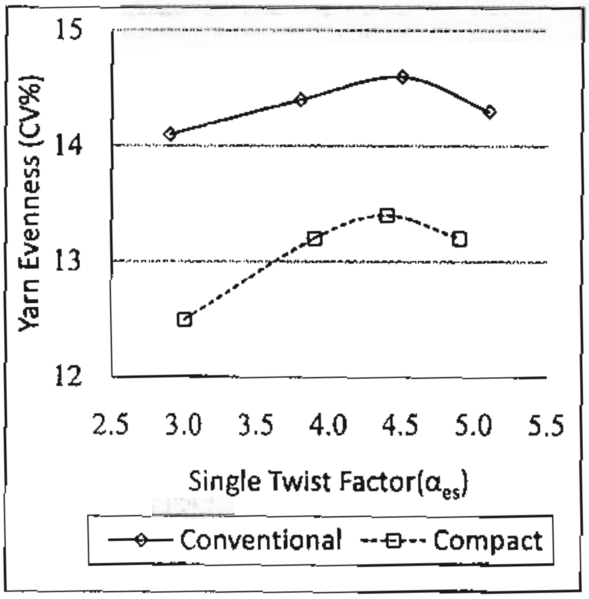

Fig. (7): Relationship between Single Twist Factor and Evenness.

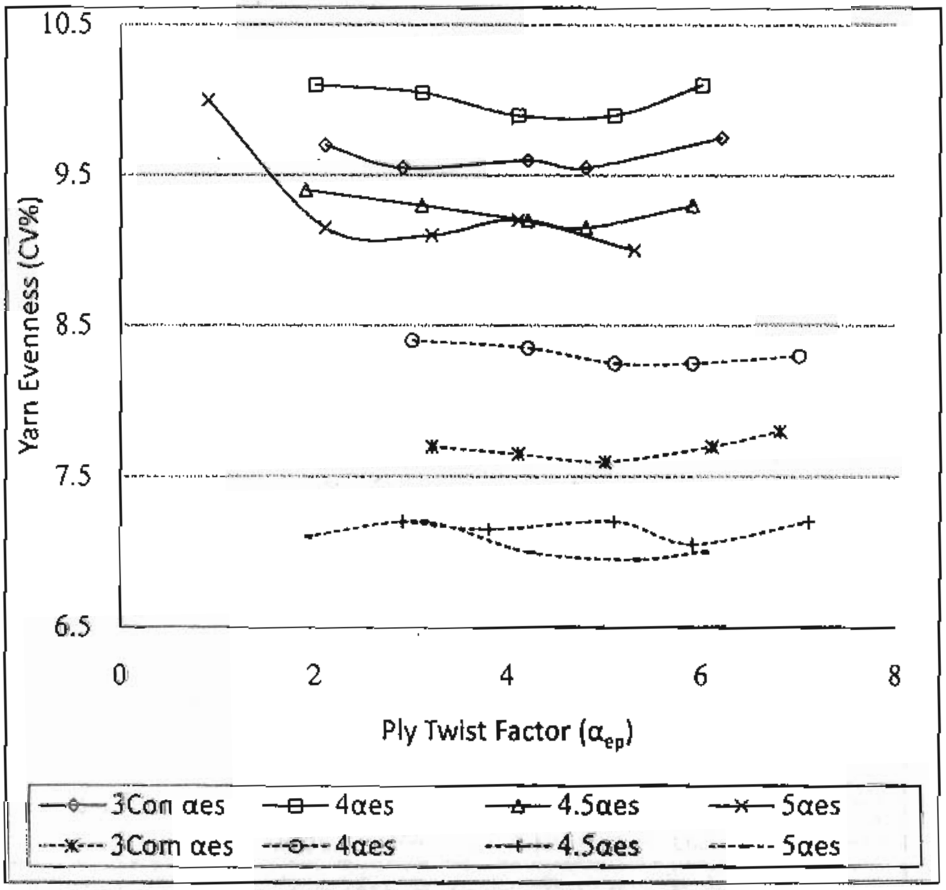

Fig. (8): Relationship between Ply Twist Factor and Evenness.

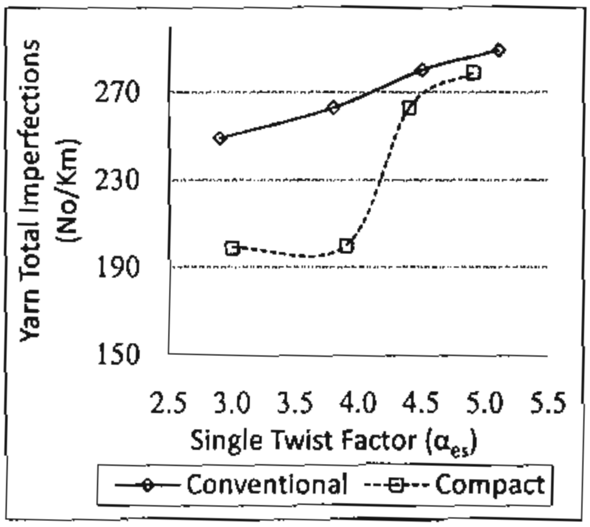

Fig. (9): Relationship between Single Twist Factor and Imperfections.

Table (3): Relationship between Ply Twist Factor and Imperfections for conventional yarns.

α_{es}	3					4					4.5					5				
α_{ep} "Z"	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6	1	2	3	4	5
α_{ep}/α_{es}	0.7	1.0	1.3	1.7	2.0	0.5	0.8	1.0	1.3	1.5	0.4	0.7	0.9	1.1	1.3	0.2	0.4	0.6	0.8	1.0
Neps "+200%/km"	4	3	2	2	3	2	1	1	0	1	4	1	1	0	0	1	1	1	1	3
Thin "-50%/km"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thick "+50%/km"	1	1	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0
Total imperfections "IPI/km"	5	4	2	2	3	3	2	1	0	1	4	1	2	0	0	1	1	2	1	3

Table (4): Relationship between Ply Twist Factor and Imperfections for compact yarns.

α_{es}	3					4					4.5					5				
α_{ep} "Z"	3	4	5	6	7	3	4	5	6	7	3	4	5	6	7	2	3	4	5	6
α_{ep}/α_{es}	1.0	1.3	1.7	2.0	2.3	0.8	1.0	1.3	1.5	1.8	0.7	0.9	1.1	1.3	1.5	0.4	0.6	0.8	1.0	1.2
Neps "+200%/km"	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1
Thin "-50%/km"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thick "+50%/km"	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
Total imperfections "IPI/km"	1	2	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1	1	1

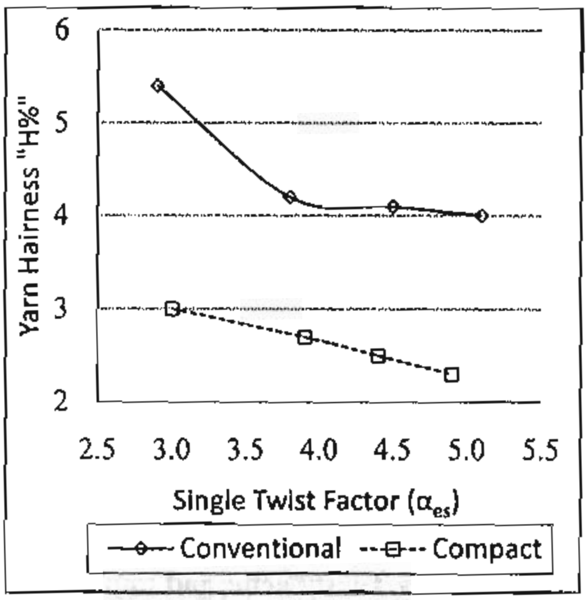

Fig. (10): Relationship between Single Twist Factor and Hairiness.

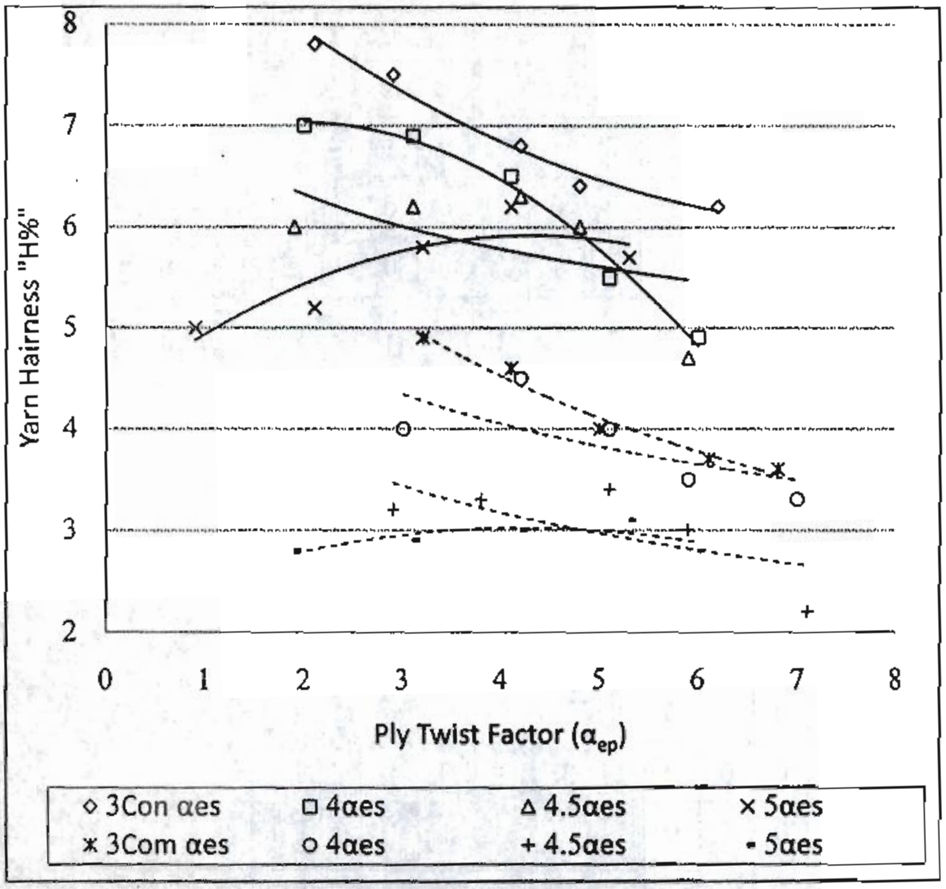

Fig. (11): Relationship between Ply Twist Factor and Hairiness (trend line).

Table (5): Summery of variance analysis of single yarn properties.

Mean square								
Property / Variable	Strength	Elongation	Evenness	Thin places	Thick places	neps	Total imperfections	Hairiness
A	217 •	2 •	33 •	300 •	960 •	420 •	2485 •	65 •
B	295 •	9 •	5 •	51 -	4 -	3 -	36.7 -	13 •
A*B	15 •	2 •	1 •	1023 •	123 •	1308 •	994 •	2 •
Error	13	14	8	48	41	31	120	10

A: Spinning system. **B**; α_{es} .
*: Statistically significant at 99% confidence limit.
-: Statistically non significant at 99% confidence limit.

Table (6): Summery of variance analysis of plied yarn properties.

Mean square							
Property / Variable	Strength	Elongation	Evenness	Thick places	neps	Total imperfections	Hairiness
A	1470 •	5 •	228 •	2 •	4 •	5 •	398 •
B	803 •	8 •	1 -	0.2 -	0.2 -	2 -	55 •
C	1 •	1 •	0.5 -	0.1 -	0.1 -	2 -	12 •
A*B	28 •	0.3 •	1 •	2 •	2 •	3 •	6 •
A*C	3 •	0.3 •	1 •	0.1 -	0.1 -	2 -	3 •
B*C	89 •	4.3 •	1 -	0.4 -	0.4 -	4 -	9 •
A*B*C	16 •	0.5 •	0.5 •	0.4 -	0.4 -	4 -	4 •
Error	16.6	7.6	21.6	7.2	41.7	69.4	8.3

A: Spinning system. **B**: α_{es} . **C**: α_{ep} .
*: Statistically significant at 99% confidence limit.
-: Statistically non significant at 99% confidence limit.

4. Results and Discussion:

Yarn tenacity:

The results indicate that spinning method and single twist factor are significantly affect yarn tenacity at 99% confidence levels. As shown in fig. (3), compact yarns have tenacity compared to conventional yarns with the same twist factor by a ratio between (9-17)%, or compact yarn have the same tenacity of conventional yarns with lower twist factor. Where compact yarn strength at twist factor α_{es} 3 is identical to conventional yarn strength of twist factor α_{es} 4. This means that up to 25% reduction in yarn twist can be obtained using compact spinning while maintaining yarn strength identical to conventional ring yarn. This reduction of twist factor can result in an increase in spinning productivity while maintaining yarn strength. This improvement in compact yarn strength is to the reduction of spinning triangle by air suction in compact zone leading to more fiber contribution in yarn structure. For both compact and conventional yarns as single end twist factor increase, maximum yarn tenacity was found at the average twist level α_{es} 4.5 as shown in fig. (3).

Table (7) shows the tenacity and elongation CV% values for the tested single yarns. Uster statistics curves shows that compact yarns lies at (5-50)% and ring-spun yarns lies at (25-50)%.[23]

Table (7): Tenacity and elongation CV% values for the tested single yarns.

Tenacity CV%				Elongation CV%			
Con.		Com.		Con.		Com.	
3	8.3	3	9	3	8.7	3	6.6
4	8.6	4	8.3	4	7.8	4	7.5
4.5	9.3	4	8.5	5	8.2	4	6.9
5	9	5	8.8	5	7.3	5	7.8

As shown in fig. (4), for both spinning

methods, as ply twist factor α_{ep} increases, plied yarn strength increases to a maximum and subsequently decreases. This trend agrees with previous researches [14,15,16]. The decrease was carried out at the following points:

α_{es}	3	4	4.5	5
α_{ep}/α_{es} Conventional	1.67	1.25	1.12	0.4
α_{ep}/α_{es} Compact	2	1.5	1.11	0.6

This means that compact yarns can afford ply twist factor before tenacity decreases higher than conventional yarns. The results indicate that spinning method and ply twist factor are significantly affect yarn tenacity at 99% confidence levels. For both compact and conventional yarn, plied yarn tenacity is higher than corresponding single yarn tenacity, this may be due to improving fiber extents due to plying. It can be noticed that increase in tenacity of plied conventional yarns is 33% and is 35% for plied compact yarns. For conventional yarn, maximum tenacity was obtained using α_{es} 3, α_{ep} 5 or α_{es} 4.5, α_{ep} 4.5. For compact yarn, maximum tenacity was obtained using α_{es} 3, α_{ep} 6 or α_{es} 4.5, α_{ep} 5.

Fig. (12) shows the tenacity CV% values for the tested plied yarns. Uster statistics curves shows that compact yarns lies at (5-50)% and ring-spun yarns lies at (25-50)%.[23]

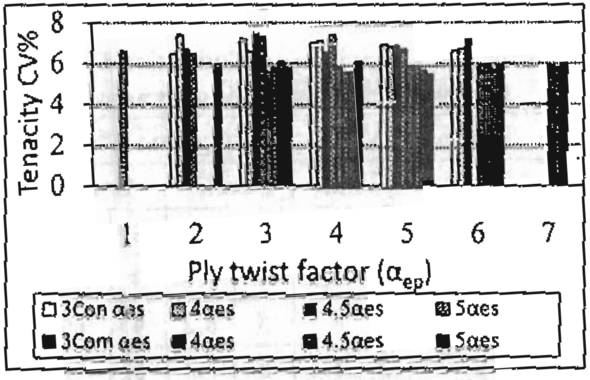

Fig. (12): Tenacity CV% values for the tested plied yarns.

Yarn breaking elongation:

It can be noticed that spinning method and single twist factor are significantly influence yarn breaking elongation at confidence level of 99% respectively. Fig. (5) shows breaking elongation of compact and conventional yarns. Compact spinning offers higher breaking elongation at the same twist level by a ratio between (5-6)%. For both yarns an increase of breaking elongation was observed for twist level higher than α_{es} 4.5.

As shown in fig. (6), for both spinning systems, yarn breaking elongation increases with the increase of ply twist factor, but compact plied yarns had higher breaking elongation than conventional yarns by about 12%. The results indicate that spinning method and ply twist factor are significantly affect yarn breaking elongation at 99% confidence levels. By increasing (α_{ep}), elongation decreases until a ratio between (α_{ep}/α_{es}) of approximately 1 to 1.3. After that, elongation increases. This is because when (α_{ep}) increases, untwisting happens to the plied yarns which are in S directions until yarn reaches the zero twist. Then twists added in Z direction, hence increasing tension under which they were plied and elongation increases. This trend agrees with previous researches [19,20,21,22].

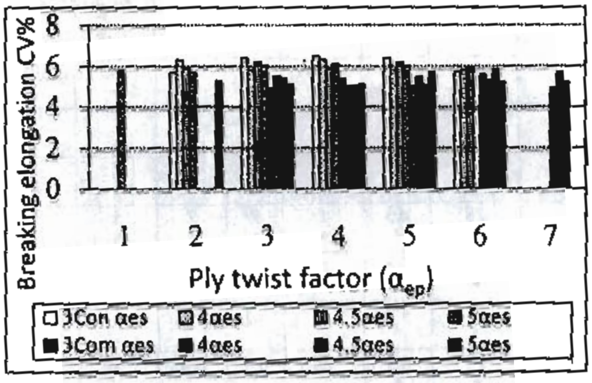

Fig. (13): Elongation CV% values for the tested plied yarns.

Fig. (13) shows the elongation CV%

values for the tested plied yarns. Uster statistics curves shows that compact yarns lies at (5-50)% and ring-spun yarns lies at (25-50)%.[23]

Yarn evenness:

As shown in fig. (7), it can be observed that evenness of compact yarns was better than the evenness of conventional yarns by a ratio between (7-11)%. For both spinning methods, by increasing single twist factor yarn mass variation increases then decreases again at single twist factor 5.

When twist is low, the thick places of the yarn after leaving the front roller nip may get themselves slightly extended because of spinning tension. When the twist is high, it flows to the nip of the front roller at a quicker rate and the tendency for the thick places to get extended will be less and as such, the %U will be slightly greater at higher twist multiplier.[17]

Spinning method significantly affects yarn evenness at 99% confidence levels. Ply twist factor affects yarn evenness non significantly.

As shown in fig. (8), plied yarn evenness is better than that of corresponding single yarn by about 33% and 27% for compact and conventional yarn respectively. This is due to doubling effect which reduces mass variation. Evenness of plied compact yarn is better than that of equivalent conventional plied yarn by about 20%.

Yarn imperfections:

As shown in fig. (9), compact yarns had lower total imperfections than conventional yarns by a ratio between (3-23)%, this difference may be due to the suction applied in the condensing zone that suctions dust, small trashes, short fibers and flys during machine running. Results shows that spinning method influences yarn thin, thick, neps and total imperfection.

As shown in table (10) and (11), for both spinning methods, with the increase of ply twist factor, total yarn imperfections decrease until a ratio between ply twist factor and single twist factor of approximately 1 to 1.3, after that total yarn imperfections were almost constant. Ply twist factor affects yarn total imperfections non significantly. Thin places was found zero. This is may be due to doubling effect. The overall decrease in yarn total imperfections from single to ply for compact was 99.1% and for conventional 98%.

Yarn hairiness:

The Uster hairiness of compact yarns is significantly lower when compared to the hairiness of conventional yarns as shown in fig. (9). The results displayed that compact yarns exhibit from (36-42)% less hairiness than conventional ring yarns. In ring spinning due to the presence of spinning triangle, there is a large difference in path flowed by the edge and center fibers. Due to this the edge fibers don't properly integrate into the yarn body. In addition minimizing spinning triangle in compact spinning leads to less hairiness of the yarn. Statistical analysis showed that single yarn twist factor has significant influence on yarn hairiness, the hairiness tends to decrease as single twist factor increases for yarns spun on the two spinning systems.

As shown in fig. (12), Spinning method and single and ply twist factor are significantly affect yarn hairiness at 99% confidence levels.

for both spinning methods, As a trend, When ply twist factor increases yarn hairiness decreases for yarns with α_{es} 3, 4 ,4.5. This trend agrees with previous research [22]. Plying results in higher hairiness in both compact and conventional yarns. In the plied conventional ring yarns, the increase in hairiness (about 18%) is higher than that of plied compact yarns (about 13%). Hairiness values remain lower for plied compact at different twist levels.

5. Conclusion:

- Single yarns manufactured by means of the com4 spin system compared with conventional ring spun were characterized by:
  - Higher strength by 14%.
  - Higher elongation by 5%.
  - Higher evenness by 10%.
  - Lower yarn total imperfections by 12%.
  - Lower hairiness by 40%.

- Plied yarns manufactured by means of com4 spin system compared with conventional ring spun were characterized by:
  - Higher strength by 17%.
  - Higher elongation by 12%.
  - Higher evenness by 20%.
  - Lower hairiness by 43%.

- After plying, compact yarns characteristics improves better than conventional yarns.

- At confidence limit of 99%, compact yarn with a low single twist factor and medium ply twist factor can be used instead of conventional yarn with a high single twist factor and high ply twist factor and will be better in all characteristics and as well as higher productivity.

- For conventional yarn, maximum tenacity was obtained using αes 3, αep 5 or αes 4.5, αep 4.5. For compact yarn, maximum tenacity was obtained using αes 3, αep 6 or αes 4.5, αep 5.

- Up to 25% reduction in yarn twist can be obtained using compact spinning while maintaining yarn strength identical to equivalent conventional ring yarn.

References:

1. Artzt P., 'Influence of Short Fiber Content on Yarn Properties in View of Launching compact Spinning in the Market', Bremen International Cotton Conference, 13-16, March 2002.
2. Brunk N., 'Three Years of Practical Experience with the EliTe Compact Set in Short-staple Spinning', Spinnovation No17, 3/2002.
3. Brunk N., 'EliTe CompactSet the Third Generation', Spinnovation No 19, 10/2003.
4. Cheng K.P.S., Ya C., 'A Study of compact spun Yarns', Textile Research Journal No 4, 2003.
5. Clapp D.M, 'Suessen EliTe Ring Spinning Evaluation', 14th EFS® System Conference North Carolina, March 2001.
6. Furter R., 'Experience with the quality management of compact yarns', Melliand International, No 1, 2003.
7. Prospects of the Suessen Company: 'Spinning machines Fiomax 1000 and Fiomax 1000 El'.
8. Rusch B.: 2nd generation of Comforspin compact yarns. Melliand International 2001, No 4, p. 28.
9. Stahlecker H.: Spinning System – 18 Months after ITMA in Paris, Spinnovation No 12/2000, p.6.
10. Stahlecker P., 'EliTe CompactSet. Recent Developments and Applications', 62nd Plenary Meeting of the International Cotton Advisory Committee, Gdańsk, Poland September 7-12, 2003.
11. Stalder H, Rusch A.: Successful compact spinning process. International Textile Bulletin, 2002, No 1, p. 42.
12. Suessen EliTe Spinning System website.
13. Rieter, Comfort through Com4, New potential in downstream processing.
14. Louis A. Fiori, J. Brown, and Jack E. Sands, Effect of single and ply twist on the properties of a 31/2 carded cotton yarn, Textile research journal, Mar 1954, vol. 24, p.267-272.
15. Louis A. Fiori, J. Brown, and Jack E. Sands, Effect of single and ply twist on the properties of a 15.5/2 carded cotton yarn, Textile research journal, May 1954, vol. 24, p.428-433.
16. C.B. Landstreet, P.R. Ewald, and J. Simpson, The relation of twist to the construction and strength of cotton roving and yarns, Textile research journal, Jun 1957, vol. 27, p.486-492.
17. J. Simpson and L. Fiori, How yarn twist affects yarn uniformity and imperfections?, Textile research journal, May 1975, vol. 45, p.136-137.
18. George E. P. Uox, Lewis. R. C, Wilfred R. C, Owen L. D, Francis R. H., and George P. S., "Design and analysis of industrial experiments" edited by Owen L. P, London, 1963.
19. G. Dakin, The effect of twist on some physical properties of an 80s/2/3 thread twisted z/z/s, Journal of textile institute, July 1957, vol. 48, p.321-332.
20. A. F. W. Coulson and G. Dakin, The influence of twist on the strength and certain other properties of two-fold yarns, Journal of textile institute, July 1957, vol. 48, p.207-231.
21. G. Dakin, The effect of twist and structure on the physical properties of some manifold yarns, Journal of textile institute, July 1957, vol. 48, p.293-319.
22. Hassan Husein, Study of some factors affecting physical and mechanical properties of ply compact yarns, Alexandria university, Egypt, 2008.
23. Uster® statistics 2001, 13.22 & 13.24 & 14.26 & 14.28.