(REFEREED RESEARCH)

OPTIMIZING THE PRODUCTION PROCESS OF CONVENTIONAL RING SPUN AND COMPACT PLIED YARNS

KONVANSİYONEL RİNG VE KOMPAKT KATLI İPLİKLERİN ÜRETİM PROSESİNİN OPTİMİZASYONU

Moaaz ELDEEB[1], Ismael RAKHA [2], Fawkia FAHİM [2], Eman ELSHAHAT [2]

[1]Department of Textile Technology, Faculty of Textiles, Technical University of Liberec, Liberec, Czech Republic
[2] Department of Textile Engineering, Faculty of Engineering, Mansoura University, Mansoura, Egypt

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ABSTRACT

The present study deals with the optimization of spinning and plying process of raw and finished conventional ring spun and compact yarns. It was found that compact yarns have better properties before and after applying finishing process as compared to ring spun yarns. There was relative improvement in the properties of yarns after finishing process but this improvement was less in case of compact yarns. The hairiness of finished compact yarn (not singed) was better compared to the conventional singed ring spun yarn. A graphical method was utilized to find the range of alpha single and alpha plied twist factor to fulfill defined yarn parameters such as strength, elongation and hairiness (feasible region).

Keywords: Compact, plied yarn, finishing, twist factor, feasible region, singeing, mercerizing.

Corresponding Author: Moaz Ahmed e-mail: samy.moustafa.el.deeb@tul.cz

INTRODUCTION

It is known that plying process improves yarn properties. During this process, some single yarn twist are untwisted which improves end yarn appearance, stability, snarling and structure[1-4]. Several studies have investigated the influence of single and ply twist factor and their combined effect on yarn properties. Rakha et al studied the effect of plying parameters such as single yarn count and number of plies on yarn properties and presented a formula to calculate yarn twist multiplier[5]. It was noticed that with increase of ply twist factor, the yarn strength increases to a maximum level followed by subsequent decrease in strength. Barella studied the change of yarn structure after plying and explained how hairiness are affected[6]. Coulson and Dakin concluded that the strongest doubled yarn can be achieved by using a low single twist factor and high ply twist factor. It was also found that yarn irregularity is independent of ply twist factor however low single twisted yarns were more regular[7-8]. According to Palaniswamy, yarn with ply to single twist ratio 3/4 has low hairiness and high abrasion resistance[9]. As yarn quality is a combination of yarn properties, all yarn parameters should realize the predetermined levels of yarn quality. Customer will not pay more if some values of yarn parameters are better than the agreed level, but a penalty can be imposed or product can be rejected if some quality parameters did not meet the required quality level. This necessitates to set limits of chosen yarn properties and accordingly to find the range of independent factors to secure the needed quality. The above mentioned studies investigated the best combination between single and plied yarn twist factor but this combination might not be the best after yarn finishing process. Compact yarns have superior quality particularly in terms of strength and hairiness compared to conventional ring spun yarns and consequently there is improvement in post spinning performance[10-12]. Recently, there is an increase in trend to use plied compact yarns by making use of its better evenness, strength and hairiness properties. In this paper, a trial is carried out to optimize the quality of conventional ring spun and compact plied yarns in raw and finished condition using different levels of single and ply twist factor as an independent factors and finding the best combination between them.

EXPERMENTAL WORK

Material and Method

Egyptian cotton Giza 86 with upper half mean length of 32.5 mm, breaking tenacity of 45 cN/Tex, fineness of 4.5 microgram/inch and elongation of 7.8% was used to produce a combed yarn of 60 Ne. Rieter K44 machine (COM4 spin) was used for compact yarn production and Rieter G5/1 for the conventional ring spun yarns production. The running conditions and machine settings were kept constant during different levels of single twist factor (α_{es} 3, α_{es} 4 and α_{es} 5). Yarns were cross wound on Schlafhorst winding machine at 1000 m/min. The doubling machine was fed with yarn cones and plied on three ends at 700 m/min. Folded yarns were fed to “Volkman-FT” TFO twister to twist them at a spindle speed of 15000 rpm with different ply twist factor (α_{ep} 3, α_{ep} 4 and α_{ep} 5) for each level of single twist factor.

Finishing conditions were kept the same for the different plied compact and conventional ring spun yarns. Previous research results recommended that the singeing process should not be applied for compact yarn as it has less hairiness than conventional ring spun yarn[13]. Therefore, only the conventional ring spun yarns were singed using SSM GSX-2 singeing machine at a delivery speed of 500 m/min and 1.8/23 gas/air mixer. The singed conventional ring spun yarn, and the unsigned compact yarn samples were wound to hanks using ZERBO GX60 hank machine. The samples were mercerized using MM3-OH (Hydraulic hank yarn mercerizing machine). The treatment was carried out using 220 g/liter NaOH aqueous solutions at 25^{o}C for 150 seconds. Samples were then washed with distilled water (1% acetic acid) followed by rinsing with distilled water and dried at 43 ^{o}C. Samples were wound from hank to perforated cone using FADIS machine. Dyeing process was applied afterwards using reactive dyes followed by drying process and then winding from perforated cone to paper cone. Samples were conditioned under standard atmosphere for 24 hours at 20±2^{o}C and 65±2% relative humidity. Both raw and finished plied yarns were tested for tensile properties using Uster® Tensojet 3, while irregularity and hairiness were measured using Uster® Tester 4.

Method of Evaluation

The results were analyzed by applying the stepwise backward regression model. The coefficients were estimated and tested against F- value, either to keep the coefficient or to remove them in case of insignificance. The generalized regression equation is given as:

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_i^2 + \sum_{i<j}^{k} \beta_{ij} X_i X_j \qquad (1)$$

Where β_0 is the constant of regression equation and β_i is the coefficient for element X_i. The regression equations and squared multiple regression coefficient were estimated for raw and finished yarns and table (1) shows response surface equations for various finished yarn properties and afterwards contour lines with the response surface were plotted.

Feasible Region

Graphical method was done by overlaying of contour surfaces, applying the predetermined limits to find the feasible region. A simple program was written in Matlab code. The code was provided by the response surface equations of yarn tenacity, breaking elongation, irregularity and hairiness. Afterwards, the defined required limits for each property were applied to find the best combination of yarn parameters that leads to better yarn quality.

RESULT AND DISSCUSION

Yarn Tenacity

Figures (1) and (2) show yarn tenacity before and after the finishing process. It can be observed that, after yarn finishing process, tenacity trend of both compact and conventional ring spun yarns are the same at different levels of single and plied yarn twist.

For both compact and conventional ring spun yarns, as ply twist factor increases, yarn tenacity increases to maximum and consequently decreases and this agrees with the previous findings[6-8]. Values of yarn tenacity is found a bit high while elongation is a bit low and this might be due to very high strength of fibers. Also yarn tensile properties are measured on Tensojet instrument which generally gives higher tenacity and less elongation values[14].

It is evident that tenacity of both compact and conventional ring spun yarns are improved with respect to their corresponding plied yarns before finishing. This is because mercerizing process strengthens the weak links inside the fiber structure causing significant improvement in fibers' crystallinity and fibers' swelling converting their bean-like section to circular section which increases fibers' cohesion inside the yarn, resulting in higher yarn tenacity[15].

However, the improvement ratio in finished conventional ring spun yarns tenacity is higher than the finished compact yarns. This is ascribed to the greater compactness of compact yarn structure and fibers cohesion of compact yarn are already higher than conventional ring spun yarn. This makes the effect of mercerizing less pronounced for compact than conventional ring spun yarns. Results of yarn tenacity improvement percentage showed that differences in finished plied yarn tenacity are dependent on single yarn twist and spinning method. Results show that the lowest improvement (%) for compact and conventional ring spun yarns is found to be 1.9% and 4% respectively at (α_{ep}/α_{es})(5/3). For both yarns, improvement (%) in plied finished yarn tenacity (corresponding to their plied yarns before finishing) increases as ply to single yarn twist ratio (α_{ep}/α_{es}) decreases i.e. for the same single twist factor as ply twist factor decreases or for the same ply twist factor as single twist factor increases, improvement (%) in finished plied yarn tenacity corresponding to plied yarn before finishing gets higher.

Table 1. Response surface equations for various finished plied yarn properties.

Response		Response surface equation	Squared multiple regression coefficient (R^2)
Breaking tenacity (cN/tex)	Conventional	$5.33333 + 16.7027x - 0.184xy - 2.2x^2$	96.1
	Compact	$-27.0333 + 29.7x + 5.06667y - 1.35xy - 3.26667x^2$	99.4
Tenacity Improvement (%)	Conventional	$15.7333 - 3.004y + 0.376xy$	94.5
	Compact	$2.94 + 2.865x - 1.76833y + 0.25xy - 0.388333x^2$	99.3
Breaking Elongation (%)	Conventional	$0.136866 + 0.895545x - 0.165553xy + 0.162788y^2$	99.2
	Compact	$0.436866 + 0.895545x - 0.165553xy + 0.162788y^2$	99.2
Breaking Elongation Reduction (%)	Conventional	$81.8963 - 17.0729y + 1.38906xy - 0.860445x^2$	99.6
	Compact	$60.8333 - 10.3167y$	97.4
Irregularity (CV%)	Conventional	$8.97841 - 0.032038x^2$	67.5
	Compact	$7.22755 - 0.0298469xy$	71.3
Hairiness (H)	Conventional	$15.6333 - 5.25x - 0.516667y + 0.616667x^2$	90.9
	Compact	$7.11429 - 1.10714y + 0.189286xy - 0.159524x^2$	95.6
Hairiness Improvement (%)	Conventional	$-94.8333 + 71.408x + 1.448xy - 9.5x^2$	85.6
	Compact	$12.6823 + 1.7411xy - 1.17372x^2$	62.5

x: single twist factor, y: ply twist factor

Yarn Elongation

After finishing process of plied compact and conventional ring spun yarns, breaking elongation of all yarns decreases. This may be due to mercerizing process that increases the crystalline region in fibers and fibers become more oriented which results in higher yarn tenacity and lower breaking elongation. As shown in figure (3), with the increase of single and ply twist factor, yarn elongation increases. Also results shown in figure (4) reveal that breaking elongation decreased for both yarns after yarn finishing process and this reduction percent is lower for compact plied yarns than corresponding conventional plied ring yarns. After finishing, compact yarn has higher elongation compared to conventional ring spun yarn by a ratio between 6.3% to 9.7%.

For both compact and conventional ring spun yarns, at different single yarn twist levels, deterioration in plied yarn breaking elongation due to finishing gets lower as ply twist gets higher up to α_{ep} 5. It is also evident from the contour graphs shown in figures (3) and (4) that ply twist factor has maximum influence on the yarn breaking elongation and the yarn breaking elongation reduction (%) after finishing process.

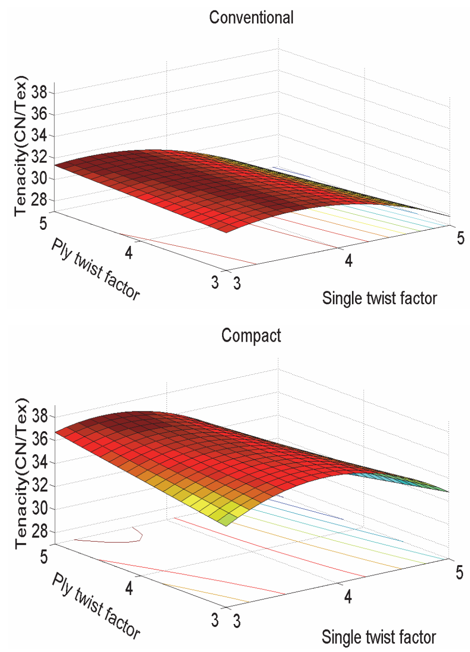

Figure 1. Tenacity of raw yarns at different single and ply twist factor.

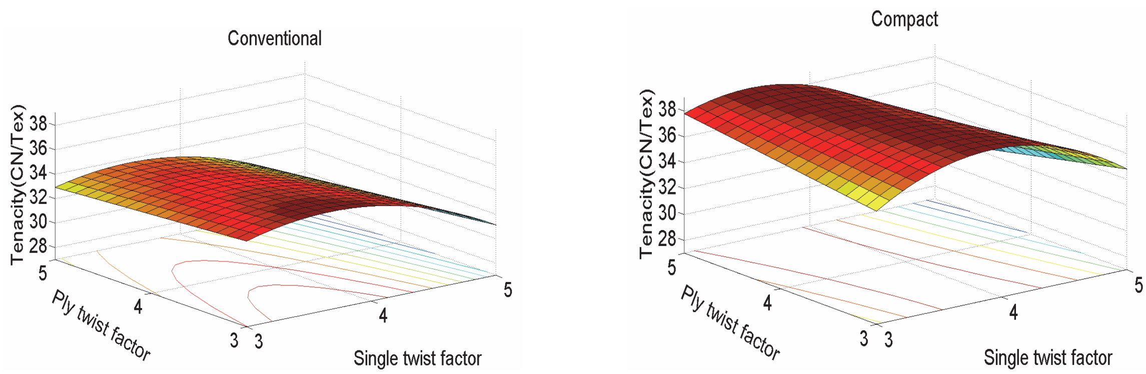

Figure 2. Tenacity of finished yarns at different single and ply twist factor.

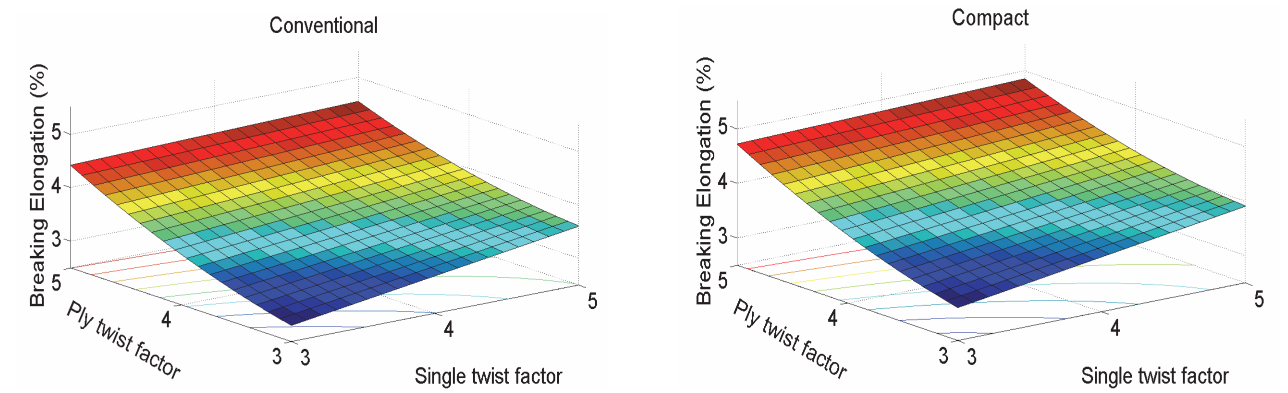

Figure 3. Breaking elongation of finished yarns at different single and ply twist factor.

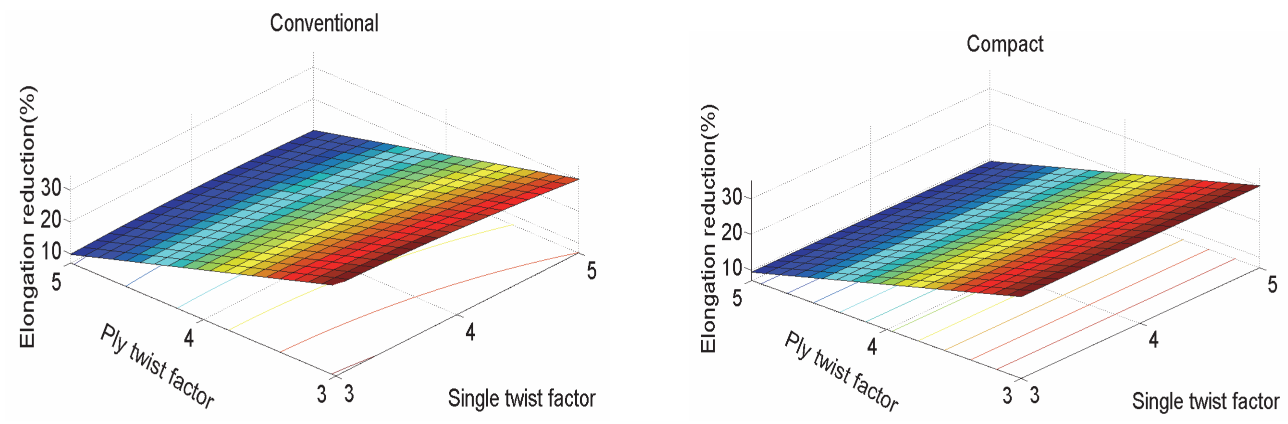

Figure 4. Breaking elongation Reduction (%) at different single and ply twist factor after finishing process.

Yarn Evenness

As shown in figure (5), after finishing process, yarn construction "compact or conventional ring spun" influences only plied yarn evenness while single and ply twist factor did not affect plied yarn evenness. Also results showed that compact finished yarn has lower mass variation compared to its corresponding conventional ring spun yarns by a ratio ranges from 18% to 23%.

Yarn hairiness

Figure. (6) and (7) show yarn hairiness with single and ply twist factor before and after finishing process. Finishing process reduced yarn hairiness significantly. Maximum reduction in hairiness is found at ply / single twist factor 5/4 and minimum reduction is found at (α_{ep}/α_{es}) of (3/4). After finishing process, hairiness (H) is reduced for conventional ring spun and compact yarns but this reduction is more observed for conventional ring spun yarns and this is because the high hairiness values of its raw yarns and the effect of singeing process. However, compact plied yarn hairiness is found less than corresponding conventional yarn. Results show that single and ply twist factor has influence on the yarn hairiness and the hairiness improvement (%) after finishing process.

Feasible region

Contour maps shown in figure (8) represents the hairiness of the finished conventional ring spun and compact yarns. These maps overlapped with another maps of different yarn properties and drawn at the same plot to conclude the feasible region as shown in figures (9) and (10) respectively.

Table (2) shows the limits of the chosen yarn quality parameters and their corresponding ranges of single and ply twist factor. These results also approved by the mathematical results using the Matlab code.

Comparison of compact and conventional ring spun yarns' feasible regions showed that compact yarn has different zone than conventional ring spun yarn to produce the same yarn quality. Both figures (9) and (10) showed that, feasible region is altered by finishing process. Also, it is clear from both figures that compact yarn feasible region is wider for raw and finished yarns and this enables the production of higher yarn quality with wider range of single and ply twist factor.

It should be noted that high levels of single and/or ply twist factor leads to yarn liveness can be mentioned and may be tested. According to Palaniswamy (2006), two-ply yarn with 3/4 the single-yarn twist has low hairiness and high abrasion resistance. (http://www.autexrj.com/cms/zalaczone_pliki/1-06-2.pdf)

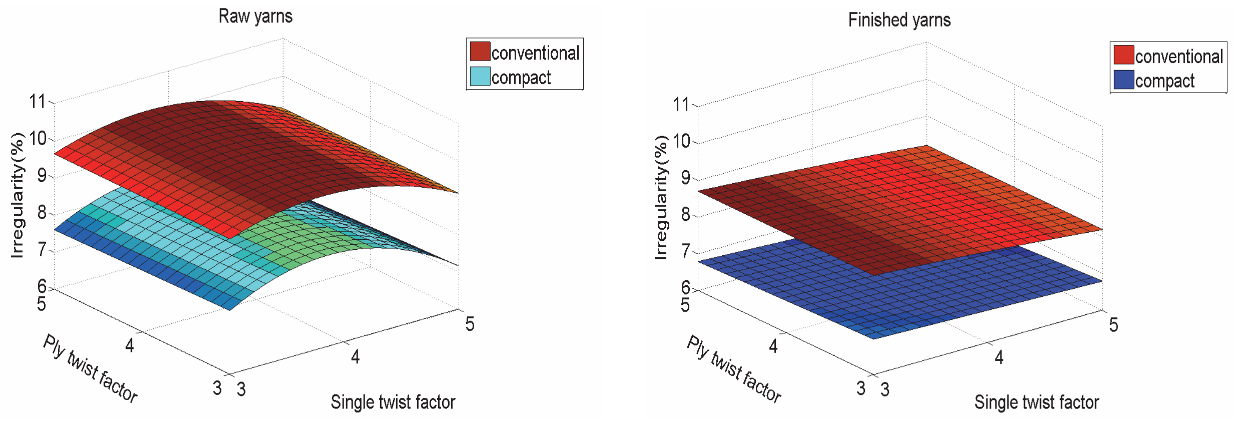

Figure 5. Yarns irregularity before and after finishing process.

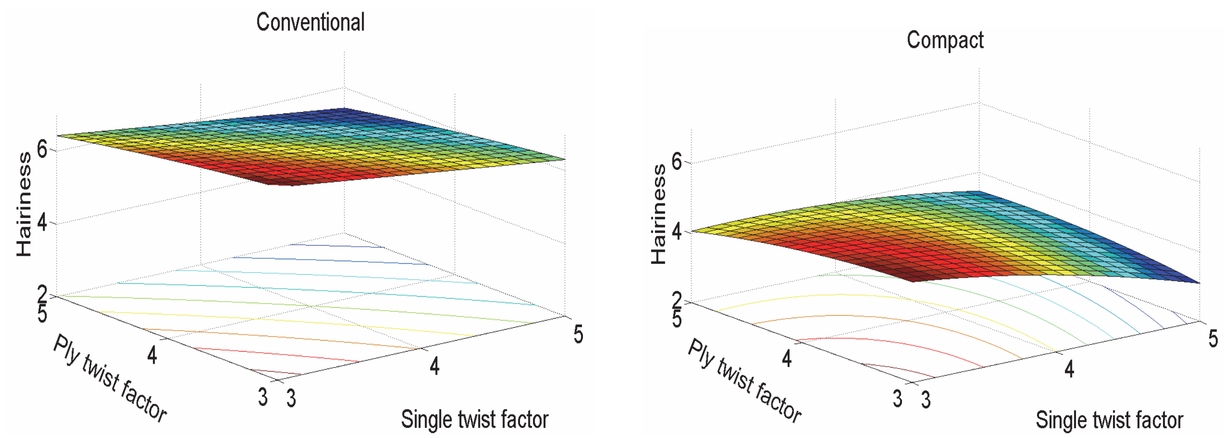

Figure 6. Raw conventional ring spun and compact yarns' hairiness values.

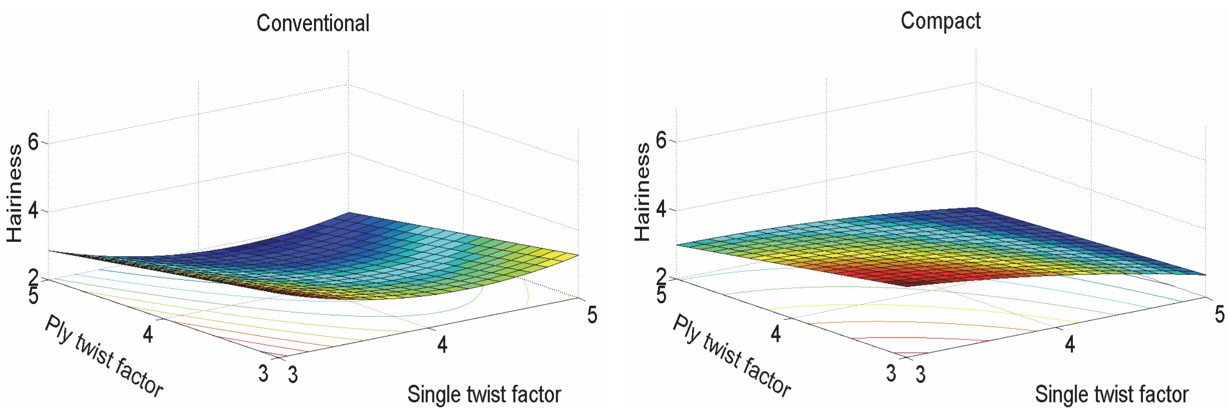

Figure 7. Finished conventional ring spun and compact yarns' hairiness values.

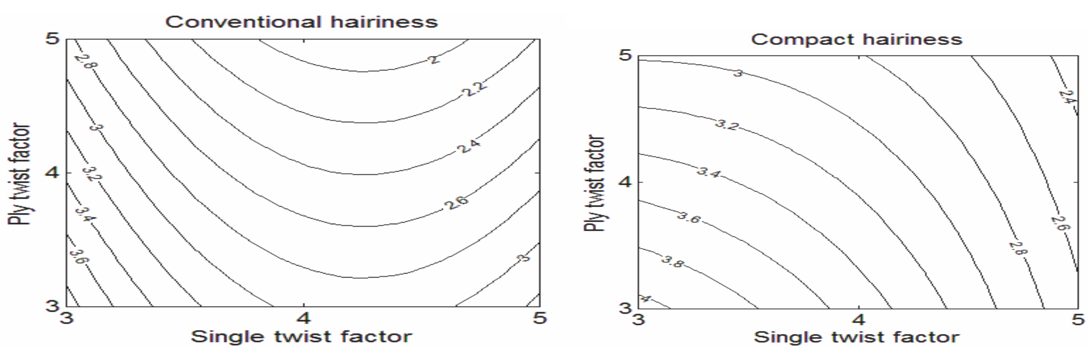

Figure 8. Contour representation of finished conventional ring spun and compact yarns hairiness.

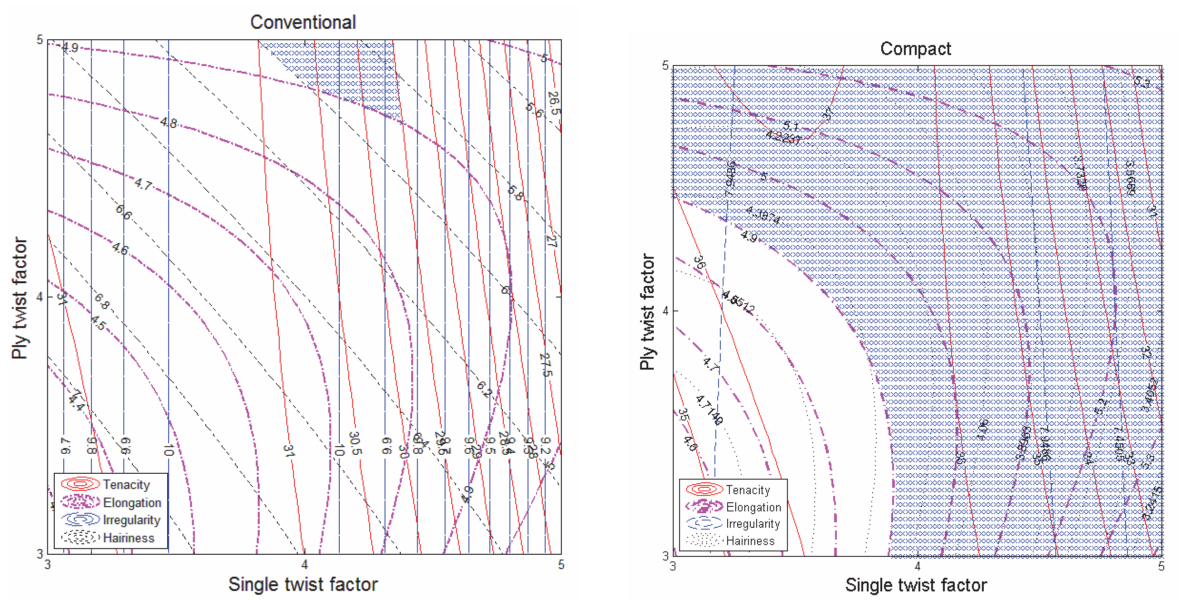

Figure 9. Contour maps used for raw yarn quality investigation.

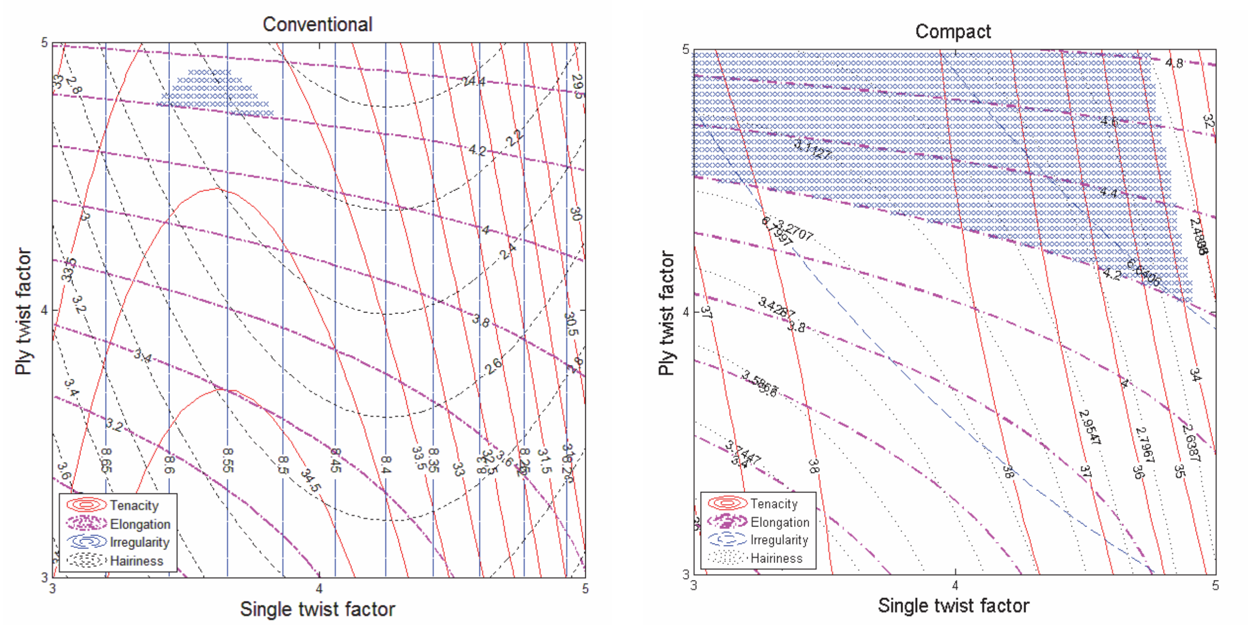

Figure 10. Contour maps used for finished yarn quality investigation.

Table 2. Yarn quality parameters and corresponding yarn twist factors.

Quality parameters	Raw yarns		Finished yarn	
Tenacity (cN/tex)	>29.5		> 33.7	
Elongation (%)	> 4.9		> 4.2	
Irregularity (%)	< 11		< 10	
Hairiness (H)	< 6		< 5	
Corresponding yarn twist factor	Conventional ring spun	Compact	Conventional ring spun	Compact
Single twist factor	3.8 to 4.3	3.9 to 5	3.3 to 3.7	3 to 4.9
Ply twist factor	4.7 to 5	4.3 to 5	4.8 to 4.9	4 to 5

CONCLUSION

In this study, conventional ring spun and compact yarns with different single and ply twist factor are manufactured and effect of finishing process is investigated. It is evident that tensile strength of both plied compact and conventional ring yarns is significantly improved by finishing process and the relative improvement is higher for conventional ring spun yarns. After finishing process, compact plied yarn hairiness is found to be less than corresponding conventional ring spun yarn even the later are exposed to singeing process. Response analysis determined the feasible region for optimized yarn properties and this region displaced after finishing process. 3D response curves showed that finished plied yarn properties are affected mainly by spinning method in addition to single twist factor and/or ply twist factor.

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