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Compact Spinning System for Fine Count Egyptian Cotton Yarns

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Abstract

This study evaluates the compact yarn characteristics spun from Egyptian cotton long and extra-long staple on three commercial compact spinning system as well as ring spinning. The analyses of the correlation between the properties of fibers and the main physical and mechanical properties of the compact yarn were given. The investigation indicates that the pneumatic compacting systems give the significant improvement of yarn properties than other systems. From the analysis of the results, it is clear that the fine long staple cotton with a low value of short fiber content interacts better with the principles of the pneumatic compacting system. The main properties of the yarn, tenacity, elongation, hairiness, evenness, and imperfection were measured in the case of improving the cotton quality through increasing the percentage of noil extracted at the combing processes. The percentage of noil should be connected with the quality of the yarn processed. A modification of the compacting system was tested to improve yarn quality and it gave better results.

Keywords: Compact yarn; Compact systems; Egyptian cotton; Ring spinning; Aerodynamic condenser

Introduction

In compact spinning, the spinning triangle associated with conventional ring spinning is eliminated by pneumatic compaction, which happens by suction and compaction on a perforated revolving drum/ apron in the front zone of the drafting system [1-10]. The process is characterized by the introduction of a fourth nip point downstream of the exit from the drafting system, which acts as an aerodynamic condenser. Such in the case of COM4, where the air current created by the vacuum generated in the perforated drum, condenses the fibers after the main draft. The fibers are fully controlled all the way to form the nipping line after the drafting zone to the spinning triangle. An additional nip roller prevents the twist from being propagated into the condensing zone. The compacting efficiency in the condensing zone is enhanced by a specially designed and patented air guide element. Optimal interactions of the compacting elements ensure complete condensation of fibers, ELiTe Compact system. After the fibers leave the drafting system, they are condensed by air permeable lactic apron. This slides over an inclined suction slot. The fibers follow this suction slot and at the same time they perform a lateral rolling motion. When the fibers leave the drafting zone they are compacted by the condense apron, whereas $RoCo_S$ Compact yarn is produced by compacting the strained fibers in a condensing zone, arranged after the drafting system, as not to allow the formation of spinning triangle while twisting the strained fibers into yarn [11,12]. In this system, there is no air suction, no air pipes, no perforated drum or aprons. No extra power is required and any ring spinning machine can be modified to this system. Several research works [6-7,13-20] have been done on the properties of compact spun yarns as systems modifications in comparison to ring spinning. They indicated that all compact yarns, whether produced of short-staple fibers (cotton, cotton-type chemical fibers, and their mixtures) or long-staple fibers (wool, wool-type chemical fibers, and their mixtures) when compared with conventional ring-spun yarns, have a significantly higher tenacity and elongation, work to break, and abrasion resistance. In addition, their surface smoothness, elasticity, and softness are much better thanks to the almost ideal structure of compact yarns. The objective of this work is to study which type of the compact spinning systems is most proper to be used for spinning fine yarns from long staple Egyptian cotton.

Material and Methods

Material

Four cotton varieties were selected, G.86, G.70, G.88, G.87. Table 1 summarized results of fiber properties analysis.

Fiber testing

The fiber properties were measured by means of an AFIS and HVI for the determination of the following properties: L(w)[mm], L(n)[mm],UQL(w) mm, Short Fiber Content by weight SFC(w)%, Short Fiber Content by number SFC(n) %, Fineness *mtex*, IFC %, bundle strength (cN/tex), Elongation E (%).

Yarn testing

After proper preconditioning for at least 24 hours under conditions (65% relative humidity, 20ºC),each sample was measured 10 times to obtain yarn evenness, strength, and hairiness. Results of yarn qualities are the average of 10 samples. Uster Tester 3 (UT4) for evenness and hairiness and Uster Tensorapid for single-end tensile properties were used.

Yarn spinning

All types of cotton were spun from the same combed roving on different compact spinning machines. The selected cotton were

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Table 1: Fiber properties.

Cotton / Type Fiber properties	G.86			G.70			G.88			G.87		
	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
L(w)[mm]	28	30	29	29	31	30	30	32	31	31	34	32.3
L(n)[mm]	25	26	26	25	28	26	26	28	28	26	28	27
Short fiber content By weight SFC(w)	1.6	3	2	1.5	2	2	1.2	1.7	1.5	2	2.3	1.9
Short fiber content By number SFC(n)	5.4	8	6	5.2	6.3	6	4.9	5.7	5.3	6	7.8	5
UQL(w)	31	33	32	33	35	34	36	38	37	36	38	37.2
Fineness. (*mtex*)	171	179	175	162	171	172	161	166	163	137	145	141
Nep count (Cnt/g)	2	6	4	2	8	6	2	4	3	0	12	5
Immature fiber percentage IFC %	3.3	4	4	4.2	4.9	5	4.1	4.8	4.3	4	5.5	4.9
Strength (cN/*tex*)	43	47	45	29	35	35	43	45	45	46	47	46.9
Elongation E (%)	4.9	6	5	4.5	6	5	4.6	5	5.6	6	6.4	6.25

Table 2: Properties of different yarns.

Spinning System	Ring Spinning RSD	Compact system CSC	Compact system CSB	Compact system CSA	Ring Spinning RSD	Compact system CSC	Compact system CSB	Compact system CSA
Cotton Type	G. 86	G. 86	G.86	G.86	G.88	G.88	G. 88	G. 88
Yarn Property								
Tenacity (cN/ tex)	21.3	20.89	23.42	25.91	22.24	22.84	22.21	27.11
Elongation %	4.96	4.78 S	5.45 S	5.85	4.55	4.32	4.43	4.97
CV_m %	11.94	12.22 S	11.7	11.16	15.25	16.67	15.55	14.39
Thin Places/ km	1	2.8	0	0	28.4	174.1	45	27
Thick Places/ km	6.5	11.6	7	5	77.8	160 S	113	45
Neps/ Km	6.3	10.9	7.8	5	110.9	130.3	147	64
Hairiness S3	4.86	4.39	3.56	3.41	3.44	2.41	2.64	2.26
Yarn Count *tex*	14.5 *tex*	14.5 *tex*	14.5 *tex*	14.5 *tex*	5.81 *tex*	5.81 *tex*	5.81*tex*	5.81 *tex*

processed on both conventional ring spinning, K44, and three types of compact spinning machines, K44-COM4, Suessen ELiTe, K44 Ring spinning machine attached with $RoCo_s$ device. Several combed yarns of counts in range 14.8 to 5.91 *tex* and twist factor 3800 (tpm/ $tex^{-1/2}$), with a combing noil percentage 18% were produced. Different compact spinning systems used were denoted by (CSA) for pneumatic cylinder compact, (CSB) for pneumatic belt compact, (CSC) for trumpet compactor, (RSD) for Ring Spinning System.

Results and Discussions

Comparison between the properties of yarns produced on different compact spinning systems

The set of the experiment was designed to investigate the different compact systems in comparison to the ring spinning while using Egyptian cotton. Table 2 gives the properties of the yarns of counts14.5 and 5.81 *texs* pun from cotton on different compact systems and conventional ring spun. The results of the different yarns properties are given in Figure 1a, Figure 1b for Egyptian cotton G.86 and G.88. Generally, in the case of both varies or cotton, the compact yarns spun on the different compact systems give a significant difference compared with ring spun yarns.

As it is expected, the yarn tensile properties and hairiness showed a highly substantial effect by the spinning process, conventional versus different compact systems. No significant effects were observed on yarn non-uniformity (mass CV %) or imperfections for system CSA or CSB. These results are in agreement with the previous research [15-17], although slight improvements of yarn mass variation (CV_m %) were reported in some cases [13,14]. It can be concluded from the Figure 1a, Figure 1b and the statistical analysis that the yarn produced by perforated drum (CSA) has the best properties followed by the yarn produced by perforated apron (CSB), then the yarn produced by compactor system (CSC). The tenacity of the processed compact yarn is higher for the most systems than the ring spun (RSD). However, the ratio of strength increased and reached up to 1.1 for G.85 and up to1.22 for G.88. This may indicate that in the case of the extra-long staple the compact spinning is more effective in compacting the fibers as well as reducing the hairiness. The compact spinning system CSA has the higher tenacity yarns than all the other system. The above results may be due to the difference in the mechanism of compacting in each case.

Several investigators [15-24] try to make a theoretical approach to explain the compact yarn formation in the various systems. Figure 2a, 2b,2c gives a sketch of the principles of the three systems under the investigation.

When fiber left the front nipping point of the drafting system, its tip portion is on the lattice apron or perforated drum and moving

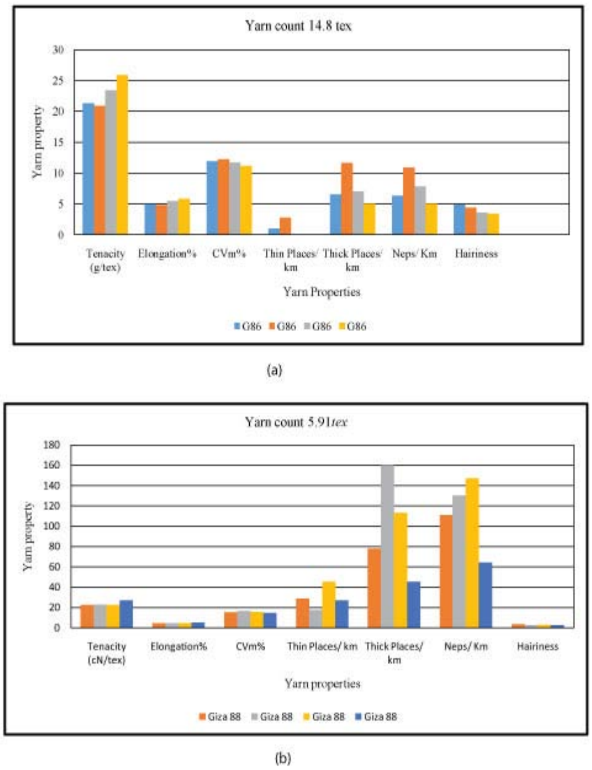

Figure 1 (a, b): Comparison between different properties of yarn counts14.8 and 5.91 *tex*.

with their peripheral speeds. As its tip crosses the upstream edge of the slot, there will be the increase in speed of the portion of fiber moving along the downstream edge. This causes the fibers to be gently stretched. Fiber away from the suction slot will be dragged by the effect of the air suction and will align itself closely to edge fibers, as they move to the end of the slot. Thus, a fiber bundle having a certain width upon leaving the front nipping point, and with the individual fibers neither parallel nor stretched, is transformed into a bundle where the fibers are perfectly parallel and highly compacted. That gives the compact yarn after twisting its final structure. The analysis of the forces acting on the fibers during their movement in the condensing zone shows a tendency of rotating the fibers on each other and the increase the likelihood of compacted fiber bundle during its entrance the pneumatic zone since part of the fiber length is gripped by the nip of darting system front roller while its end moving in the suction field.

In the pneumatic compactness system it's very important to control the air flow in the zone of compactness, either perforated drum or lattice apron-type compact spinning. Currently, there are numerous researchers studying pneumatic compacting spinning [7-13]. Research on the flow field in the condensing zone is always the emphasis and difficulty for pneumatic compact spinning. The problems which can't be easily taken into consideration are the influence of processing parameters on the quality of fiber compact in the condensing zone of compact spinning, the variability of the dimensions and shape, and coefficient of air drag of the cotton tuft, besides the non-homogeneity of fiber mechanical properties.

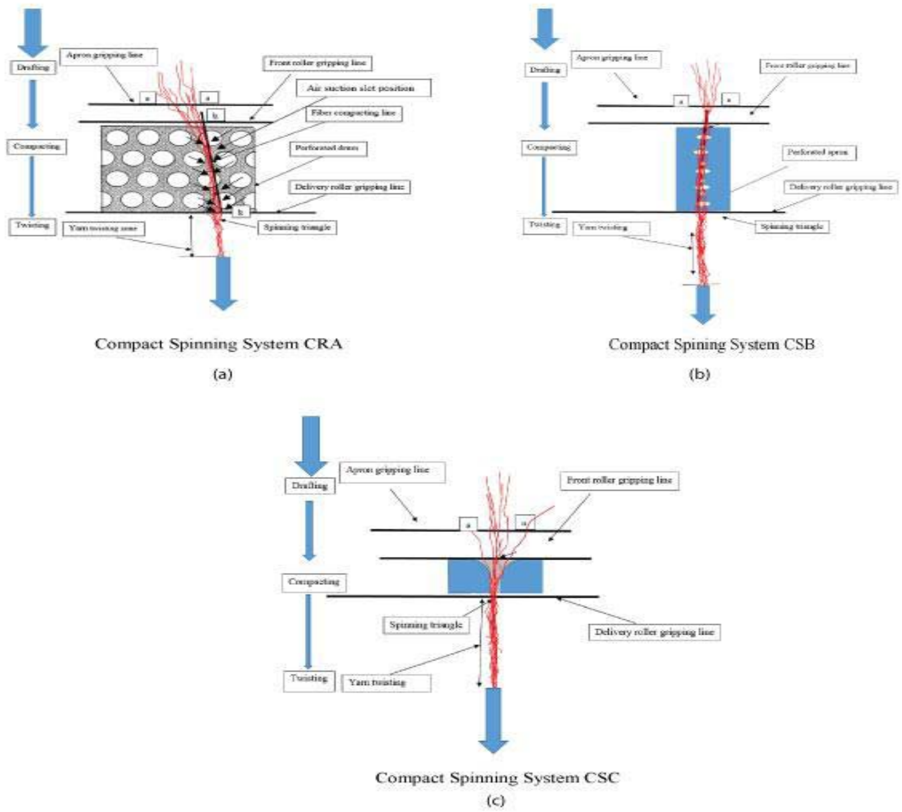

Figure 2 (a, b, c): Principles of Compact Spinning Systems.

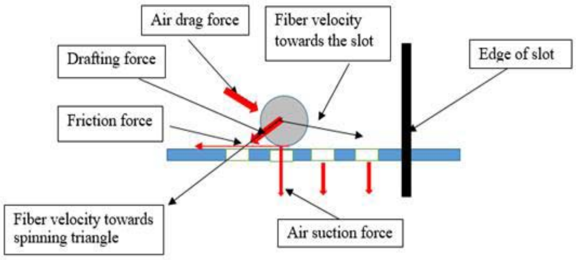

Figure 3: Forces acting on the fiber during compacting.

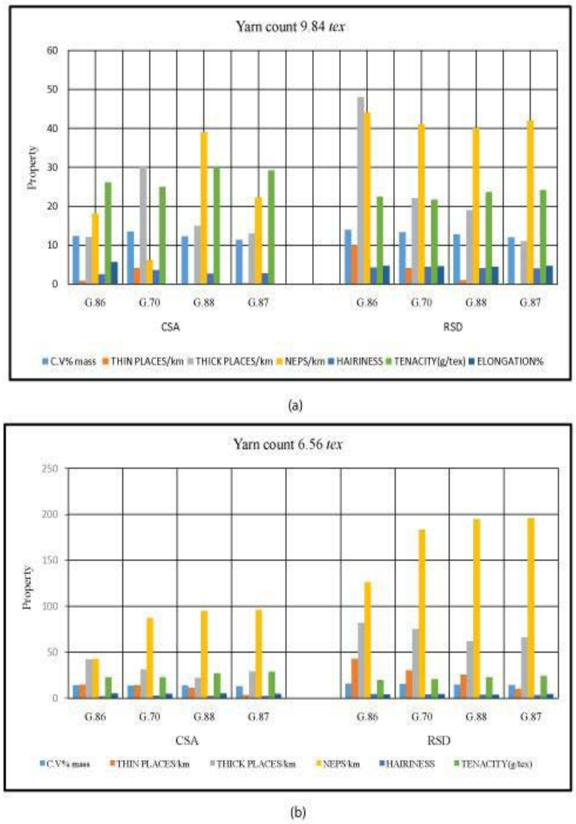

Figure 4 (a, b): Effect of cotton type on the yarn properties of Ring and Compact (CRA) systems.

Moreover, the designs of guiding device and its setting to the perforated drum flow field, that control the fiber movement, need precise attention to optimizing the fiber movement and improvement of yarn properties [25].

Figure 3 shows how the fibers in the condensing zone seem to be moved under the different forces acting on, forming compact structure instead of loss tuft. The long fibers will be gripped during their existing in the condensed zone more than the short fibers, resulting in more compact tuft and therefore better compact yarn. In two systems CRA and CRB, which are using air suction unit for the condensation of the fiber bundle, degree of fiber compactness depends on the inclination of the slot and the air flux [15-25]. The effectiveness of the fiber compactness depends on the fiber length, stiffness, fiber coefficient of friction, percent of short fiber, and coefficient of fiber

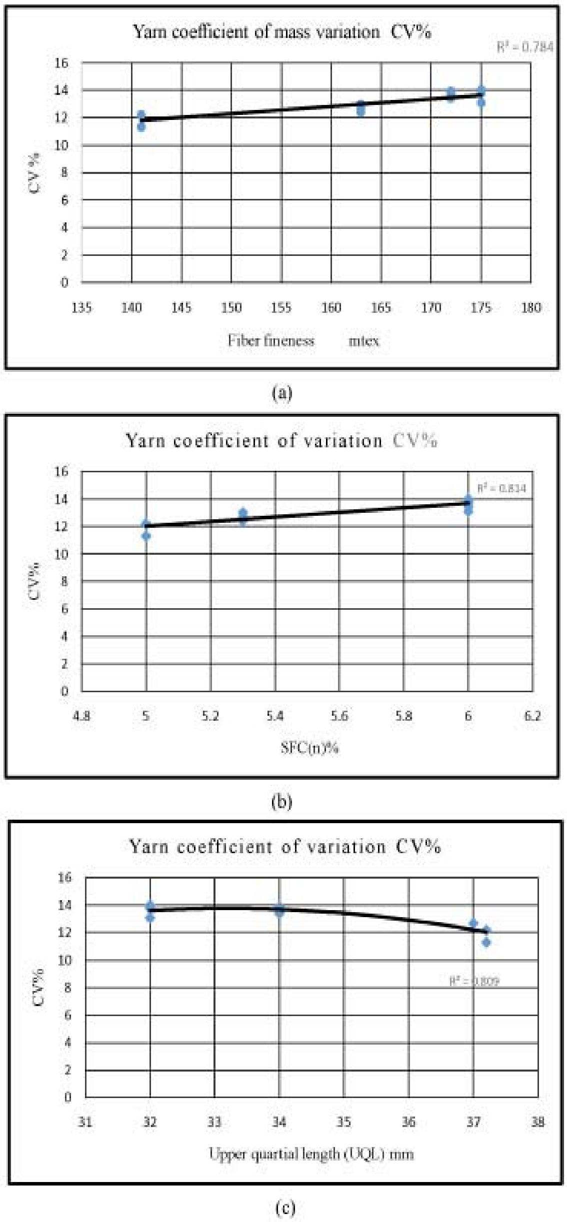

Figure 5 (a, b, c): Yarn coefficient of variation % versus fiber fineness, SFC(n)% and UQL mm.

air drag. The variability of the air suction forces will lead to variability of compacting forces. The success of the fibers compacting on such systems will be governed by creating enough forces to compact the fibers properly before they exist outside the drafting system.

In the method of compacting (CSC), the bundle of the fibers coming out from front roller is directly passing through a narrow trumpet in order to eliminate the spinning triangle: This will apply to the fibers transverse forces leading to the friction force that may disturb the moving of the fibers and, at the same time, may lead to its straightening. The outcomes will depend on the fiber friction coefficient with the trumpet as well as gripping of the top delivery roller. On the compactor exit, the compressed fiber bundle tends to increase its size due to fiber resilience, increasing the size of spinning

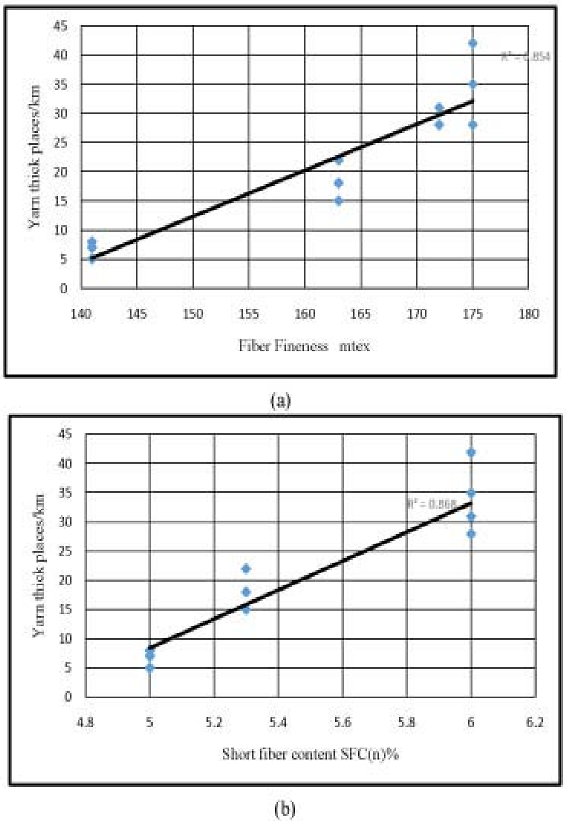

Figure 6 (a, b): Yarn number of thick places/km versus fiber fineness, SFC(n)%

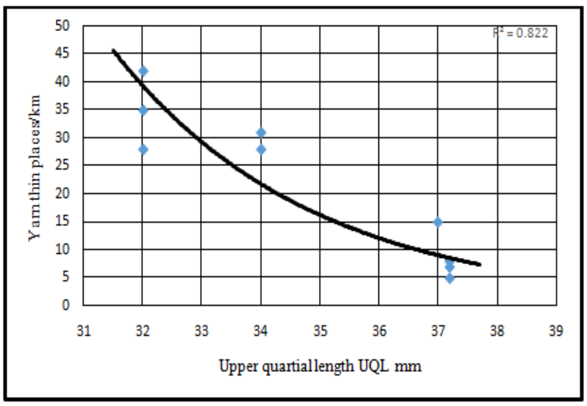

Figure 7: Number of yarn thin places/km versus UQL mm.

triangle. The above analysis designates that yarns spun on the CSA system are characterized by higher tenacity, higher elongation at break, smaller mass irregularity, a significantly smaller number of faults - like thin and thick places, neps, and considerably lower hairiness in comparison with the yarns from the other systems of spinning. As the yarn count becomes finer the difference between the systems becomes wider.

Effect of fiber properties on the compact yarn properties

In order to investigate the interaction between the principle of yarn formation and fiber properties, four types of Egyptian cotton

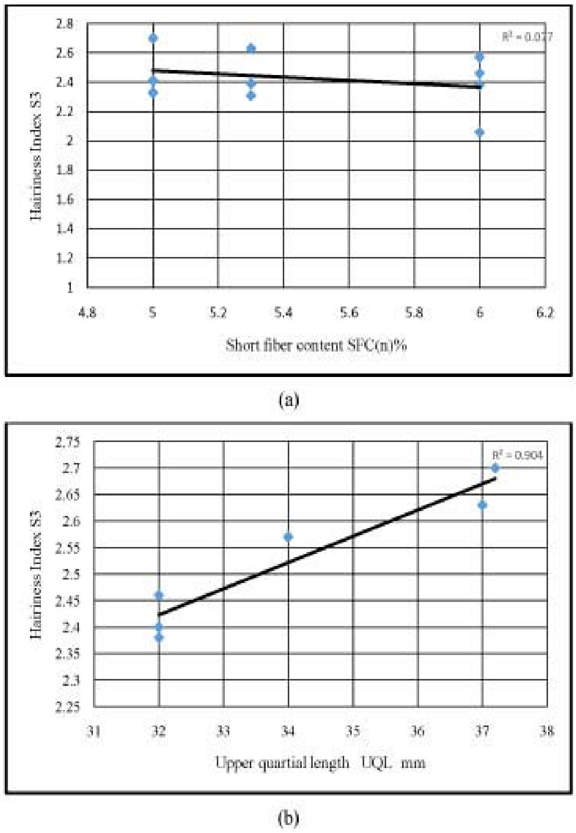

Figure 8 (a, b): Yarn hairiness versus SFC(n)% and UQL mm.

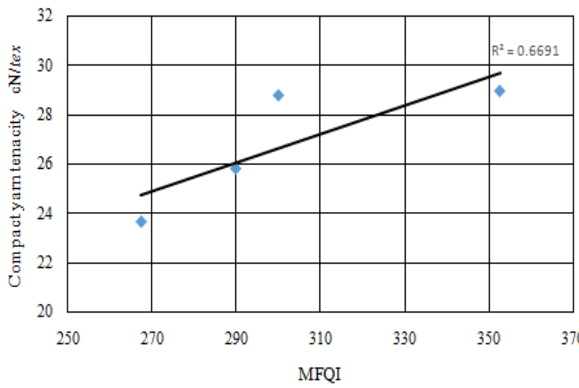

Figure 9: Compact yarn strength versus MFQI.

G.86, G.88, G.70and G.87 were chosen. Combed compact yarns of count 9.84, 8.44, and 6.56 *tex* are spun on compact systems (CSA) and (RS) and tested.

The results are illustrated in Figure 4a, 4b, which indicates that the fiber length has a significant effect on the yarn tenacity; hence the longer the fiber the more strong compact yarn produced due to the mechanism of compacting in the case of using the pneumatic systems. Another factor that contributes to the increase in the yarn tenacity may be the improved fiber migration along yarn axis [8,13,26]. The compact spinning system produces a yarn with higher migration intensity values, which means that the fiber migration in

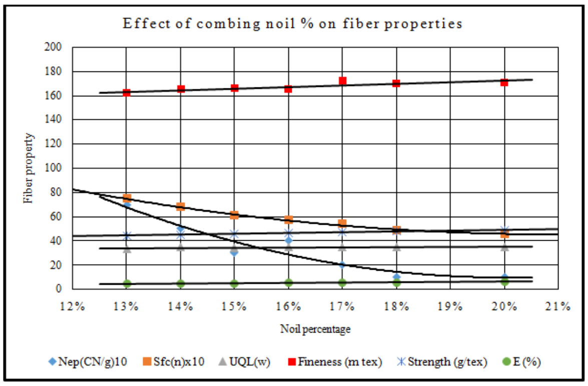

Figure 10: Fiber properties versus the noil percentage.

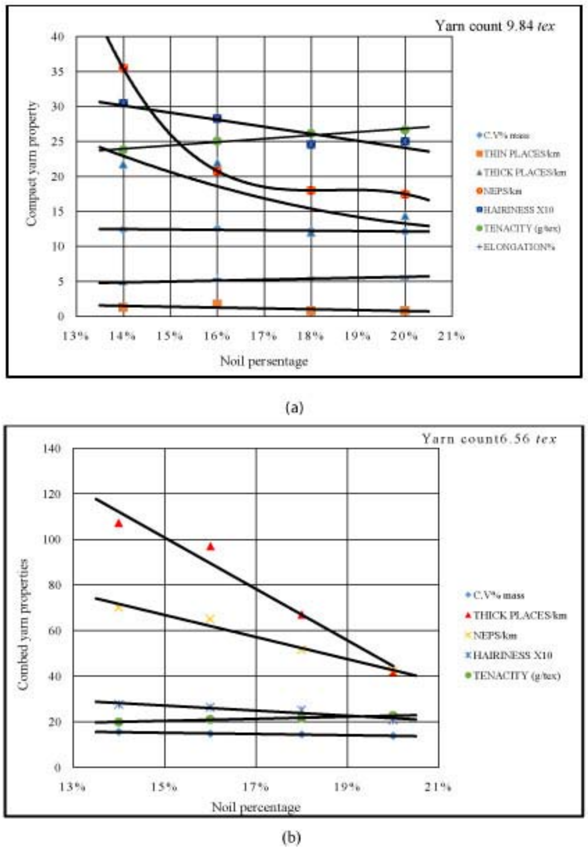

Figure 11 (a, b): Compact yarns properties versus the noil percentage for count 9.84 and 6.56 *tex.*

the compact yarn is deeper across yarn cross section. Thus, the longer fiber will assist the increase of yarn packing density according to the mechanism of compacting.

The analysis of the correlation between the most influential fiber properties and the different compact yarn properties are given in Figure 5a, 5b, 5c, Figure 6a,6b, Figure 7, and Figure 8a,8b [27].

The compact yarn and the ring spun yarn's strength are a function of the most properties of the used cotton fibers [28]. The Modified Fiber Quality Index (MFQI) [29] is given by Equation (1), which characterizes the quality of different cotton fiber varieties [30].

$$MFQI = UHL \times UI \times STRb \times (1 + EL) \times (1 - SFC(n))/MIC \quad (1)$$

Where, the fiber length is expressed by the upper length UHL in mm, UI in % stands for the fiber length uniformity index, STRb in cN/tex the bundle tenacity, EL in % the fiber elongation at break, (MIC) the micronaire value representing the fiber fineness and maturity, and SFC (n) in % for the short fiber content. The index MFQI is used for the prediction of yarn tenacity, which is a function of not only the fiber tenacity but also its length, its short fiber content, its fineness and its elongation at break. These properties should be taken into consideration while predicting the tenacity of yarns. Figure 9 illustrates the average of the compact yarn strength and the value of MFQI of the fibers used.

The quality of the cotton fiber can be improved through the combing process which changes the values of UQL, SFC (n), Neps and also the average fineness besides its effect of removing impurities. Figure 10 shows the results of the increasing the percentage of noil on the fiber properties of cotton G.86. This brings a direct reflection on the compact yarn quality. The most significant effect of the noil percentage increase is found in the reduction of thin places, thick places, and the neps. The strength of the yarn improved, too. However, the consequence of the extracted noil increase depends on the yarn count, as illustrated in Figure 11a, 11b. Moreover, each count has its optimum percentage of noil extraction [31].

Modification of comparator system (CSC)

The above results indicate that the compacting system CSC needs a modification to improve the yarn quality. We suggested some

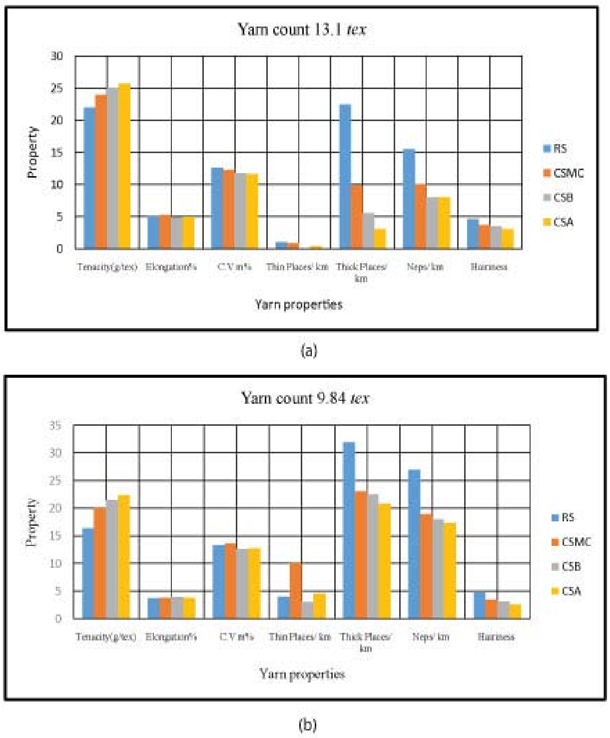

Figure 12 (a, b): Yarn properties of different systems - RS, CSA, CSB, and CSMC.

modifications:

1- Top delivery roller cot diameter 29mm.

2- The slots of the compactor are made from a new ceramic material which has a smoother internal surface with narrow inner dimension.

The increase of the diameter of the top delivery roller leads to increase in the area of contact between the top and bottom delivery rollers that may prevent the fiber bundle to retain some size after coming out of the comparator. The modifications aim at more fibers condensation before they come out to the twisting zone. The results of these modifications are given in Figure 12a,12b for two yarn counts 13.1 and 9.84 *tex*.

Modifying of the compacting system (CSMC) demonstrate a comparison with the other compact and ring spinning systems. The statistical analysis indicates that this modification makes the properties of the yarns spun on the compacting system "CSMS" better, however, not as yarns produced on system "CSA". When the spun yarn was finer, the quality difference between compact yarns produced on the different systems and CSMS narrows.

Conclusion

As in pneumatic compact spinning systems, the mechanical compact spinning system also gives significantly lower hairiness values than conventional ring spinning system. The pneumatic condensation is proved to be the most effective way of compactness. Yarn tensile properties, yarn imperfections and hairiness appear to be directly affected by fiber and compacting system interactions. The noil percentage can be a tool to modify the fiber properties, especially UCL, SFC and Neps. However, for each yarn count, an optimum percentage of noil should be chosen to reach the required yarn quality. The modification of mechanical compacting system improves the quality of compact fine yarn.

The analysis of the results indicates that for fine compact yarns long and extra-long Egyptian cotton is preferable to be used on any system of the compacting, however, compact pneumatic systems type CSA and CSB are recommended for the production of high quality fine compact yarn.

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