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Study on the Properties of Cotton Yarn with Modified Yarn Path in Ring Spinning

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Abstract: Spinning triangle is a critical area that influences the physical and mechanical properties of yarn. Previous researchers have done several works related to spinning triangle by modifying yarn path primarily considering only one side diagonal yarn path meaning that either left or right diagonal yarn path. The others used single yarn count and twist level on different variety of raw materials. This research was produced cotton ring yarns by varying count (36 Ne, 40 Ne) and twist level (1014 TPM, 1080 TPM) using right and left diagonal paths in Z-twist direction. The yarns were tested and it was observed that 25%, 0.34%, 37% and 25% reduction in hairiness, CVm%, thin place and thick place respectively with slight decreasing of tenacity in left diagonal path yarn. In right diagonal path yarn there is 3%, 16%, 59% and 14% increasing of yarn hairiness, CVm%, thin place and thick place respectively with 10% reduction of tenacity. Therefore, the left diagonal path has a significant improvement of ring spun yarn quality in terms of physical properties. On the other hand, the right diagonal path yarn were deteriorated all the physical and tensile properties of ring spun yarn. This is occurring due to the mismatching of right diagonal path with Z-twist direction.

Keywords: Ring Spinning, Spinning Triangle, Left Diagonal Path, Right Diagonal Path

1. Introduction

Yarn production is an advanced technology that facilitates the manufacturing of different yarn structures with specific properties for particular applications. Ring-spinning technology is the most commonly accepted method for producing long and short-staple spun yarn due to its capability of spinning nearly all kinds of fibers types within a wide count range [1]. In the yarn manufacturing process, the strand of fiber coming from the draft zone is flat and almost all fibers are parallel oriented to the axis of the strand. As passing through the front roller nip line, the flat fiber strand gradually rotates around the axis of the strand under the force of twisting, which is produced by rotation of the traveler [2]. Although still now ring spinning system are needs many modifications to improve yarn quality and productivity.

The area of spinning triangle has the most important research topic and has concerned to increase attention recently [3-5]. The spinning triangle is a critical area that influences yarn properties [6] such as yarn hairiness, yarn unevenness, yarn elongation and yarn strength. The yarn mechanical state was influenced by the spinning triangle when fiber tension was transferred to the spun yarn [7, 8].

Several researchers were done research related to spinning triangle on conventional ring-spinning. The most common novelty's available commercially are siro-spinning [9], solo-spinning [10, 11] and compact spinning [12-18]. Siro-spinning and solo-spinning methods improve spun yarn properties by separating the conventional staple strand into alike and several ones, respectively [18].

Furthermore, the spinning triangle can be reduced by using a heavier traveler and then hairiness can be reduced [19, 20]. Modified ring-spinning system with the dynamic twist-resistant device were altered the distribution of twist in the spinning process and the geometry of the spinning triangle. It can also create the distribution of fiber tension in the spinning triangle more uniform. The purpose of this device is to produce resistant torque on the yarn so as to reduce the twisting torque at the twist point. Thus, the geometry of the spinning triangle will be changed correspondingly. The modified yarns have a better performance in terms of strength and hairiness compared to conventional yarns with no-significant effect on evenness.

Diagonal yarn path is one of the basic approaches to improve yarn properties. It produces the yarn by shifting delivered from a drafting unit is taken up by the adjacent bobbin to the left or right of the drafting unit, instead of the bobbin directly below it. In right diagonal yarn path, reduce yarn hairiness in S-twist can be due to the increased pre-twisting of fibers on the left-hand side, increased fiber tension on the left-hand side of the spinning triangle [21] and shortening the length of the spinning triangle on the right-hand side. In contrary to the yarn path diagonal to the left-hand side in Z-twist, yarn hairiness can be reduced due to the increased pre-twisting of fibers on the right-hand side, increased fiber tension on the right-hand side and shortening length of the spinning triangle on the left-hand side [22, 23].

Diagonal spinning is a simple geometric modification of the spinning triangle for producing yarns with reduced hairiness. Fibers from both edges of the spinning triangle undergo significant change in their wrapping behavior depending on the direction of the diagonal. The spinning triangle produced during ring spinning is asymmetric. If the yarn is twisted in the Z direction, then the fibers on the right-hand side of the spinning triangle often undergo a pre-twisting process. In contrast the fibers on the left-hand side of the triangle are under a lower level of control and more chances to hair formation [24].

However, some researchers considered only one side diagonal yarn path meaning that either left or right diagonal yarn path and the others used single yarn count and TPM on different variety of raw materials [25]. Therefore, this research work is aimed to fill the above research gaps by carrying out both right and left diagonal yarn paths. The yarn samples were made from the same cotton fibers by varying the yarn counts and TPM under the same other parameters and machine settings. Finally, it was applied experimental testing for all yarns and analyzed comparatively the effect of both left and right diagonals yarn paths with straight path on the yarn properties.

2. Materials and Methods

2.1. Materials

100% staple cotton fibers, 1.1 Ne roving, 36 Ne and 40 Ne yarns produced with 1014 TPM and 1080 TPM were used for this study. Table 1 shows that fiber parameters which are measured by Uster HVI 1000. Rieter G35 model ring frame machine was used to produce the yarn. Table 2 shows that the machine specifications during production of yarn.

Table 1. *Cotton fiber parameters.*

Fiber parameter	SCI	Mst (%)	Mic	Mat	UHML (mm)	UI (%)	SF (%)	Str (g/tex)	Elg (%)
Average	82	4.9	3.56	0.83	24.99	79.2	11.7	17.7	7.1

Table 2. *Ring spinning machine specifications.*

Parameters	Ring spinning specification for 36 and 40Ne
Spindle speed (rpm)	10800
Traveler number	7/0 - 4/0
Total draft	38.9
Ring type	T-flange ring
Spacer size	3.5
Delivery speed (m/min)	10
Twist direction	Z

2.2. Methods

The yarn was produced by using conventional ring frame machine with normal straight yarn path and modified diagonal path as shown in Figure 1. Both modified path yarns and straight path yarns was made from cotton fibers having same characteristics, roving count, machine settings and spinning parameters. However, the yarn path should be altered into straight, left and right diagonal yarn path. Hence, to carry out this, 100% cotton ring spun yarn having different counts (36Ne and 40Ne) and TPM (1014 and 1080) was conducted onto each diagonal paths.

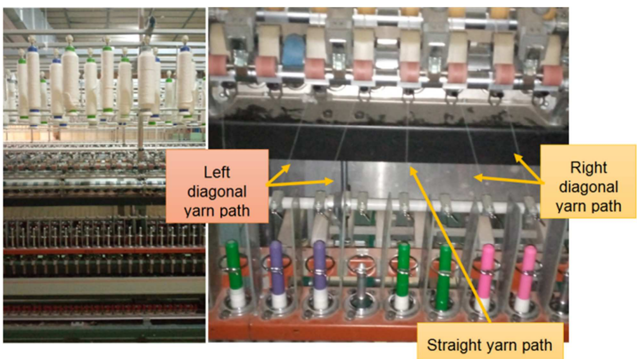

Figure 1. *Yarn producing by different yarn path in G35 ring frame machine.*

The test of the samples was carried out after conditioning atRH 65±2% and Temperature of 20±2°C. Yarn evenness and hairiness were tested using Uster tester 5 under ASTM D1425 standard. The tensile properties of the sample yarn were tested by universal strength tester using ISO 2062 standard. The test results were analysed using one-way ANOVA in SPSS and Microsoft excel software's.

3. Result and Discussion

Based on the data obtained from the test result in Table 3, it could be seen that the effect of each factor on the selected yarn properties related with the objectives of the research.

Table 3. *The average test results of yarn samples.*

Run	Factors			Responses				
	1	2	3	1	2	3	4	5
	Yarn path	Count (Ne)	TPM	Hairiness (H)	CVm (%)	Thin place (-50%/km)	Thick place (+50% /km)	Tenacity (cN/tex)
1	LDP	36	1014	5.73	20.68	128	1290	11.13
2	LDP	36	1080	5.02	21.80	104	1182	20.70
3	LDP	40	1014	5.92	20.01	145	1318	6.75
4	LDP	40	1080	5.13	20.49	133	1192	9.67
5	SP	36	1014	7.87	18.69	355	1527	11.00
6	SP	36	1080	6.65	22.28	248	1702	20.13
7	SP	40	1014	7.95	21.05	262	1665	8.11
8	SP	40	1080	6.55	21.24	232	1722	10.45
9	RDP	36	1014	8.05	24.18	481	2405	10.69
10	RDP	36	1080	6.67	22.59	582	2573	20.09
11	RDP	40	1014	8.83	24.40	768	2310	5.11
12	RDP	40	1080	6.20	25.43	915	2368	8.89

3.1. Effect of Diagonal Path on Selected Yarn Properties

The properties of diagonal path yarns were improved based on the correlation of path inclination with twist direction. The hairiness index of left diagonal path (LDP) yarn was reduced significantly compared to straight path (SP) yarn and right diagonal (RDP) yarn. as shown the result in Table 4. It is observed that the hairiness index of left diagonal path yarn was reduced by 25% and 27% compared with straight and right diagonal path yarn respectively. The improvement in yarn hairiness achieved by left diagonal path is attributed to longer path modification in spinning triangle and tension. Due to this the fibers which come through in right side of the spinning triangle gets more tension and controlled by pre-twisting. The yarn spun in Z-twist direction; the fibers present in the left side of the spinning triangle are more uncontrolled in nature than the fibers present in right side of the spinning triangle.

The coefficient of mass variation of left diagonal path (LDP) yarn was slight reduction than straight path (SP) yarn and a significant reduction than right diagonal (RDP) yarn as shown Table 4. The CVm% of LDP yarn is decreased by 0.34% and 14% compared with straight path and RDP yarns respectively. Most of the time CVm% of spun yarn was determined by the length of fiber rather than path modification.

Table 4. *Effect of diagonal path of selected yarn properties.*

		Sum of Squares	df	Mean Square	F	Sig.
Hairiness index (H)	Between Groups	9.655	2	4.828	6.441	.018
	Within Groups	6.746	9	.750		
	Total	16.401	11			
CVm%	Between Groups	30.295	2	15.147	10.688	.004
	Within Groups	12.756	9	1.417		
	Total	43.050	11			
Thin place (-50% /km)	Between Groups	108987.167	2	54493.583	24.835	.000
	Within Groups	19747.750	9	2194.194		
	Total	128734.917	11			
Thick place (+50% /km)	Between Groups	2686252.667	2	1343126.333	235.622	.000
	Within Groups	51303.000	9	5700.333		
	Total	2737555.667	11			
Tenacity (cN/tex)	Between Groups	3.166	2	1.583	.045	.956
	Within Groups	315.032	9	35.004		
	Total	318.198	11			

Effect of diagonal path on thin place (-50%/km) and thick place (+50% /km) were statistically significant in LDP yarn as shown in Table 4. The result shows, the thin place of LDP yarn was reduced by 37% and 60% compared to straight path and RDP yarn respectively. This is due to the higher trapping of the hair fibers in left side of spinning triangle, the yarn has less thin place in LDP Z-twisted yarn. In addition to this the left side of spinning triangle is very shorten and more fibers are twisted onto the yarn body rather than hairy on the surface. The thick place of LDP yarn was reduced by 25% and 48% compared to straight path and RDP yarn respectively. This is due to the fact that a greater number of fibers have to been trapped by the yarn body and the left diagonal path gives an opportunity of fibers arranged in uniformly in the right side of the spinning triangle in case of Z-twist direction. The tenacity of diagonal path yarn was slightly lower than that of the straight path yarn but not significant.

3.2. Effect of Yarn Count on Diagonal Path Yarn for Selected Yarn Properties

The hairiness of spun yarn made from short staple cotton fiber was reduced in finer count due to diagonal path spinning geometry. As the result shows that in Table 5, the hairiness of 40 Ne diagonal path yarn was slightly increased compared to 36 Ne yarn but not significant. The CVm%, thin place and thick place of finer count diagonal path yarns were increased 2%, 18% and 3.68% compared with coarser count yarns. This is due to the fact that as the yarn count is finer, the number of fibers per cross section should be reduced. Hence, during producing of finer yarn in diagonal path the fibers may not be arranged in uniformly throughout the yarn body. Thin place is increased in finer count due to produce the yarn in short staple cotton fibers and it has been less fiber to fiber cohesion during spinning in finer yarn count. Due to this the fibers were losing their proper arrangement by higher tension in diagonal path. All the above yarn properties were not statistically significant at 95% confidence level.

The tenacity of 40 Ne left diagonal path was decreased significantly compared with 36 Ne yarns. This is due to a greater number of fibers appear in the coarser count. Each fibers present in the yarn cross section were imparts some strength to the yarn by cohesion with twist. So, in left diagonal yarn path the fibers well binding on to the yarn body in Z-twist direction. Therefore, coarser count yarn has better strength in diagonal path yarn.

Table 5. *Effect of yarn count on diagonal path yarn for selected yarn properties.*

		Sum of Squares	df	Mean Square	F	Sig.
Hairiness index (H)	Between Groups	.029	1	.029	.018	.897
	Within Groups	16.372	10	1.637		
	Total	16.401	11			
CVm%	Between Groups	.480	1	.480	.113	.744
	Within Groups	42.570	10	4.257		
	Total	43.050	11			
Thin place (-50%/km)	Between Groups	5590.083	1	5590.083	.454	.516
	Within Groups	123144.833	10	12314.483		
	Total	128734.917	11			
Thick place (+50% /km)	Between Groups	13068.000	1	13068.000	.048	.831
	Within Groups	2724487.667	10	272448.767		
	Total	2737555.667	11			
Tenacity (cN/tex)	Between Groups	166.962	1	166.962	11.04	.008
	Within Groups	151.236	10	15.124		
	Total	318.198	11			

Table 6. *Effect of twist on the diagonal path yarn for selected yarn properties.*

		Sum of Squares	df	Mean Square	F	Sig.
Hairiness index (H)	Between Groups	5.508	1	5.508	5.057	.048
	Within Groups	10.893	10	1.089		
	Total	16.401	11			
CVm%	Between Groups	1.936	1	1.936	.471	.508
	Within Groups	41.114	10	4.111		
	Total	43.050	11			
Thin place (-50% /km)	Between Groups	6210.750	1	6210.750	.507	.493
	Within Groups	122524.167	10	12252.417		
	Total	128734.917	11			
Thick place (+50% /km)	Between Groups	19040.333	1	19040.333	.070	.797
	Within Groups	2718515.333	10	271851.533		
	Total	2737555.667	11			
Tenacity (cN/tex)	Between Groups	114.905	1	114.905	5.652	.039
	Within Groups	203.293	10	20.329		
	Total	318.198	11			

3.3. Effect of Twist (TPM) on the Diagonal Path Yarn for Selected Yarn Properties

The yarn twist has a significant influence on yarn hairiness. The results obtained in statistical test were shown in Table 6 as the yarn twist increases, the hairiness index decreases. The hairiness index of yarn spun in 1080 TPM was reduced significantly by 18% compared with yarns spun in 1014 TPM.

This is occurred due to the effect of left diagonal yarn path inclination, the high twist level yarns were the better binding of surface fibers on the yarn structure. The CVm% and thin place of yarn spun in 1080 TPM of the diagonal path yarn was increased by 4% and 19% compared with 1014 TPM yarn respectively. This is due to twist in a yarn is the resultant of the applied torque and its distribution along the length of the fiber assembly. The torque translation in the fiber mass takes place through the constitute fibers. So, any variation in the fiber mass distribution is likely to affect the twist and its distribution and retention in the fiber mass. The retention of twist in the fiber mass may be influenced by many factors; the number of fibers, flexibility of the fiber assembly, the fiber surface properties and tension behavior of the fiber assembly. The twist is expected to be more in a thin place than in a thick place due to difference in rotation. With increasing TPM yarn compactness and fiber inclination to the yarn axis increases and it creates mass variation along the yarn body.

The thick place of the yarn produced in 1080 TPM was reduced by 4% compared to yarns spun in 1014 TPM. This is due to the fact that twist is combine the fiber strands together after the nip point of the front drafting roller. When the twist level increases, the opportunity of creating thick place on the yarn body is reduced. Because of the fibers in the yarn cross section is more closely packed together irrespective of the other factors. The tenacity of yarn spun with 1080 TPM yarn was increased significantly by 70% as compared with yarn spun with 1014 TPM. It is evident that yarn strength increases with increase twist level because of increased fiber binding at higher twist level irrespective of the other factors. The yarns spun in short staple cotton fiber; twist has been a great impact on the strength of yarn.

3.4. Comparison of Modified Yarn with the Conventional Ring Yarn Properties

Hairiness comparison of diagonal path yarn with straight path yarn was described in Figure 2. The hairiness index of LDP yarn was lower than respective straight path yarn in all combination of count and TPM. Left diagonal path spinning geometry was combined the drafted strands properly in Z-twist direction. Due to this the yarn spun in LDP, the hairiness could be reduced due to the increased pre-twisting of fibers on the right-hand side, increased fiber tension on the right-hand side and shortening length of the spinning triangle on the left-hand side.

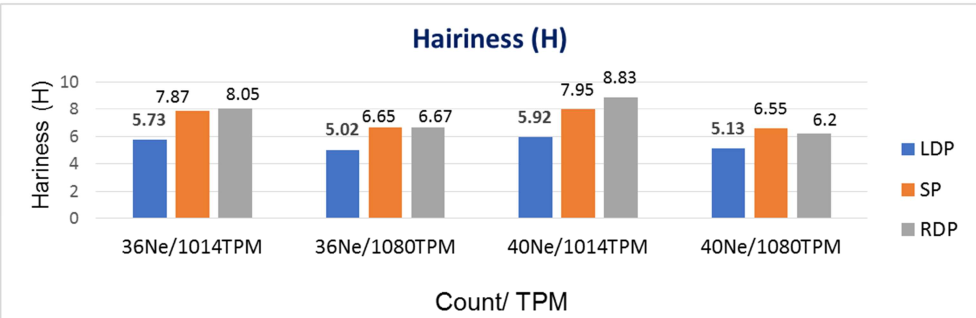

Figure 2. *Hairiness comparison of diagonal path yarn with straight path yarn.*

The coefficient of mass variation of LDP yarn were lower than the corresponding straight path and RDP yarns keeping under the same count and twist combination as shown in Figure 3. Because of all the yarns were spun by short staple fiber. The CVm% of left diagonal path yarn has slight reduction than straight path yarn. In 40 Ne /1080 TPM combination right diagonal path yarn CVm% was highly increased due to the increasing twist level with finer count.

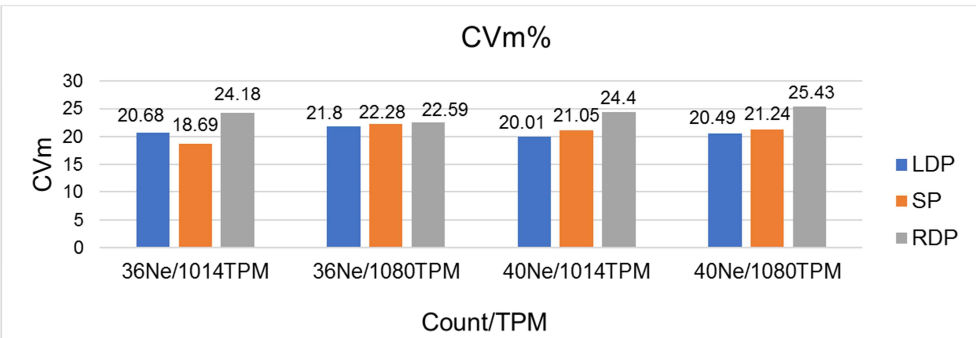

Figure 3. *CVm% comparison of diagonal path yarn with straight path yarn.*

Comparison of diagonal path yarn with straight path yarn in terms of thin place were shown in Figure 4. The number of thin places of left diagonal path yarn were lower than the corresponding straight path yarn in all combinations. This is due to the fact that the yarn spun in Z-twist direction, the better binding of hair fibers on the yarn and fill the thin part of yarns.

Whereas in right diagonal path yarn the number of thin places were higher than straight path yarn. Due to less fiber integration and alignment occurred in right diagonal path with Z-twist.

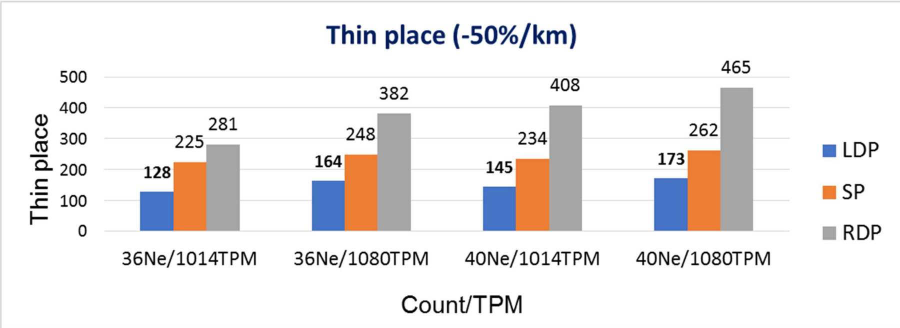

Figure 4. *Thin place comparison of diagonal path yarn with straight path yarn.*

Comparison of diagonal path yarn with straight path yarn in terms of thick place was shown in Figure 5. The number of thick places in left diagonal path yarn was lower than the corresponding straight path yarn. This is due to the better fiber alignment occurred in the longer right-hand side of spinning triangle in Z-twist direction. A longer spinning triangle presents a more uniform fiber distribution, which is beneficial for the yarn evenness. However, the yarns spun in right diagonal path has been highly increased as compared to straight path yarn. Because of in Z-twist direction, the right diagonal path yarn is always deteriorating its physical and tensile properties.

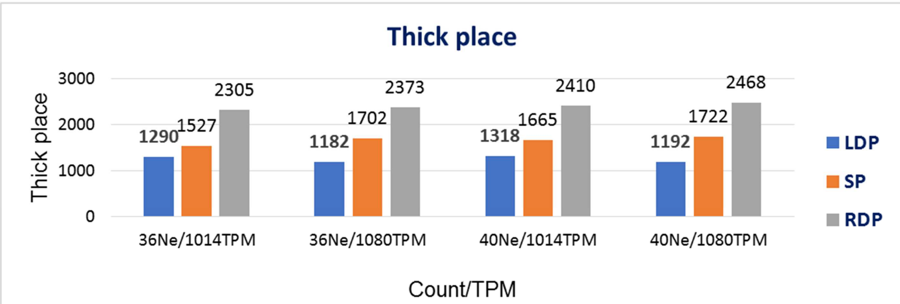

Figure 5. *Thick place comparison of diagonal path yarn with straight path yarn.*

Comparison of diagonal path yarn with straight path yarn in terms of tenacity was shown in Figure 6. The tenacity of left diagonal path yarn was slightly increased compared with the corresponding straight path 36 Ne yarn. However, there is some reduction of tenacity occurred in 40 Ne yarn. Due to this coarser yarn count are suitable for increase tenacity of left diagonal path. The tenacity of right diagonal path yarn is lower than the corresponding straight path yarn in all combination of count and twist. In this path the integration of fibers into the yarn body is less due to the effect of twist direction.

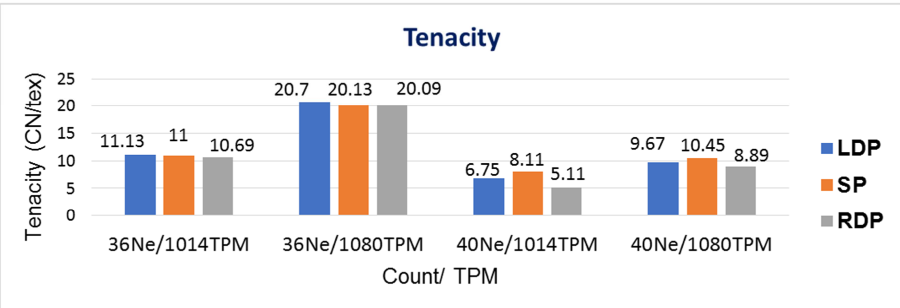

Figure 6. *Tenacity comparison of diagonal path yarn with straight path yarn.*

4. Conclusion

Yarn path modification in conventional ring spinning has an improvement of yarn quality by changing the shape of spinning triangle. The spinning triangle is a critical area that influences yarn physical and mechanical properties. Modification of yarn path into left and right diagonal path have an improvement of ring yarn properties. During modification, the spinning triangle changed into asymmetrical and unbalanced shape. The result shown that the hairiness, CVm%, thin place, thick place and tenacity of left diagonal path yarns were reduced by 25%, 0.34%, 37%, 25% and 3% compared to respective straight path yarn. But only hairiness, thin place and thick place were significantly reduced by changing the yarn path into left diagonal. On the other hand, the right diagonal path yarns were deteriorated the overall yarn properties due to mismatching of path diagonal with twist direction. Diagonal path yarns have more effectively improve the ring yarn properties in coarser yarn counts. Twist level has an effect on the physical and mechanical properties of diagonal path ring spun yarns. The hairiness and thick place of higher twist level diagonal path yarn was reduced by 18% and 4% compared to low twist level yarns respectively. This is occurred due to changing the shape of spinning triangle into asymmetrical shape, the higher twist level yarns have the better binding of hair fibers into the yarn bulk structure. Therefore, the yarn produced in coarser count with optimum high twist level has a better controlling of fibers in left diagonal path spinning system under Z-twist direction.

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