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Study on Splicing Performance of Different Types of Staple Yarns

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Abstract: The present paper reports the detailed study on the splicing behavior of viscose staple fiber yarns made from ring, rotor, friction and air-jet spinning technologies. The linear density of all the yearns was kept constant at 29.5 tex. The splicing parameters like splicing pressure and duration of the splicing were taken as variables. Three levels of splicing pressure at constant splicing duration and three levels of splicing durations at constant splicing pressure were considered. Splices were introduced at all these levels for the four different technologies. These splices were tested for their tensile properties and the properties of splices were evaluated in terms of retained splice strength (RSS) and splice break ratio (SBR). The splice photographs were taken and splices were analyzed for their structure and for diameter profile along the length of the splice.

Keywords: Air pressure, Duration of compressed air pressure, Retained splice strength, Splice break ratio

Introduction

End breakages are unavoidable in spinning and post spinning operations. If the breakage occurs during spinning process itself, a forming length of yarn breaks, then it is a simple matter for an experienced operator to join ("piece up") the broken ends, by twisting them into the oncoming fibers. This produces a hardly noticeable join that will be quite acceptable for subsequent processing and in the ultimate fabric. However, if breakage occurs in fully formed yarns after spinning, acceptable yarn joins may not always be so easy to achieve. There are several ways of joining the broken yarn ends. Knotting is the traditional practise of joining the yarn ends. But knotting in many occasions causing serious defect on the fabric appearance due to its width and length of tail ends. Frequent failures of the knots also affect the process efficiency. Several knot free yarn joining methods have been developed like adhesive bonding, wrapping, fusion bonding, electrostatic splicing, mechanical splicing and pneumatic splicing. All other methods, expect pneumatic splicing, are not well accepted because of their inherent limitations like suitability for specific applications, cost and etc. Pneumatic splicing has been accepted as a better means of yarn joining and now became indispensable in textile processing of knot free yarn joins. It has become prerequisite for the production of export quality yarns. In pneumatic splicing yarn ends are overlapped in a turbulent air blast adjustable in duration and consumption to meet the needs of the spliced yarn quality. Pneumatic splicing produces splices adequate to all processing requirements in terms of strength and appearance with only slight increase in the normal diameter of the yarn. Previous studies [1,2] revealed that splice comprises of three regions viz. wrapping, twisting and intermingling.

Bulk of the yarns spliced is from ring spinning. Because of the limited size of ring cop as well as the necessity of clearing faults from ring yarns, high-speed winding machines are normally equipped with splicers for making knot free joints. The structure of ring yarn (nearly helical) facilitates the easy removal of the twist and helps in good opening of the yarn. In case of other types of yarns like rotor, air-jet and friction spun yarns, we normally get bigger delivery packages at the spinning stage, which directly can be used in further processes. In these yarns, the splicing has got relatively less importance. But in some specific cases, we require rewinding of faulty wound packages or joining of leftover packages. For this, splicing has provided the ready solution. The main drawback for splicing these types of yarns is their structure. The multi layered twist structure and wrapper fibers resist the untwisting process during splicing.

A number of studies [3-7] were reported on how material and machine variables affect the spliced yarn quality parameters like splice strength, appearance, bending and other properties. Machine variable like compressed air pressure, its duration and splice length are considered to be significant. Very few studies [8] have reported on the splicing behavior of rotor and air jet yarns. This study was carried out to investigate the tensile behavior and structural properties of ring, rotor, friction-spun and air-jet yarns, respectively.

Materials and Methods

Viscose yarns of all the four commercially successful spinning technologies viz. ring, rotor, friction and air-jet were used for this study. The nominal count for all the yarns was 29.5 tex. Raw material details are given in Table 1. The yarns were subjected to splice trails on the pneumatic splicer of the Schlaforst Autoconer 338 winding machines. In this study splicing pressure and duration of the splicing air blast are considered as variables. Overlap setting was kept constant. A large number of splices for all the four types of yarns (i.e., ring, rotor, friction and air-jet) were introduced in two series. For both the series opening air pressure and duration of the opening air blast were kept at constant level. The other

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Table 1. Details of fibers and yarns

Yarn type	Fiber parameters			Yarn parameters		
	Length (mm)	Denier	Tenacity (gf/tex)	Twist (TM)	Breaking strength (gf)	Breaking elongation (%)
Ring yarn	44	1.5	24.0	3.5	508.01	14.16
Rotor yarn	44	1.5	24.0	3.7	238.75	9.63
Friction-spun yarn	44	1.5	24.0	-	193.59	10.75
Air-jet yarn	44	1.5	24.0	-	268.61	7.47

Table 2. Process parameters of splicing

Parameters	Values
Winding speed	1000 rpm
Yarn tension	20 cN
Opening air pressure	4 bar
Duration of opening air blast	5 (= 500 ms)

process parameters, which were kept constant, are given in Table 2.

Preparation of Splices

Series I

In the first series, splices were prepared for all the four technologies by varying the splicing air pressure. Three levels of air pressure were considered viz. 4 bar, 5 bar and 6 bar. In all the cases the duration of the splicing air blast was kept at constant level viz. 535 (time code).

Series II

In the second series, splices were produced for all the four yarn technologies by varying the duration of the splicing air blast keeping the splicing pressure at constant level 5 bar. The coded levels of the time considered were 333 (i.e., 180 ms), 535 (i.e., 260 ms) and 737 (i.e., 340 ms).

Test Conditions

Once the splice preparation was over, 50 splices for each level of each yarn technologies were tested for the tensile properties at a gauge length of 100 mm and at traverse speed of 50 mm/min. on Statimat ME tensile strength tester. The parent yarns were also tested for their tensile properties keeping the same test parameters. Using Leica microscope photographs of splices for all levels of the four different yarns were taken. These photographs of the splices were analyzed for longitudinal structure and for the diameter distribution of the splice from one end to other end. Figures 1(a), 2(a), 3(a) and 4(a) show the photographs and Figures 1(b), 2(b), 3(b) and 4(b) show the diameter profiles of typical spliced portion of ring, rotor, friction and air-jet spun yarns respectively.

Results and Discussions

Two splice performance indicating parameters were determined. The breaking strength of the spliced yarn is expressed as retained splice strength (RSS) rather than actual breaking strength. The RSS is defined as the ratio of the strength of the splice expressed as the percentage of the parent yarn in which the splices are inserted. Other parameter is splice break ratio (SBR), which is defined as the ratio of number of the times the breakage takes place, within the test zone, at the splice to the total number of breaking tests. Tables 3 and 4 show the tensile properties of splices of different types of yarns.

Spliced Ring-spun Yarns

The helical structure of the ring yarn facilitates the good

Table 3. Effect of splicing pressure on the properties of splices

Parameters	Ring yarn			Rotor yarn			Friction-spun yarn			Air-jet yarn		
	Splicing pressure (bar)			Splicing pressure (bar)			Splicing pressure (bar)			Splicing pressure (bar)		
	4	5	6	4	5	6	4	5	6	4	5	6
Splice breaking strength (gms)	364	387.8	405.2	236.1	296.3	289.3	173.3	180.8	196.0	116.7	96.4	120
Splice breaking elongation (%)	10.47	10.94	11.66	6.65	7.94	7.43	7.23	8.00	7.95	3.40	2.67	2.88
CV% of splice breaking strength	24.75	21.08	13.57	32.67	18.17	17.84	22.77	17.69	14.97	63.27	52.34	50.43
CV % of splice breaking elongation	25.99	23.85	15.06	41.85	27.63	14.66	36.95	27.60	19.23	70.48	56.46	49.12
Retained splice strength (RSS) %	71.6	76.1	79.2	69.8	87.3	85.5	89.5	92.9	100	43.4	35.8	44.6
Retained splice elongation (%)	73.9	77.3	82.3	69	82.4	77.1	67.2	74.4	74	45.5	35.7	38.5
Splice break ratio (SBR)	0.72	0.44	0.48	0.84	0.54	0.58	0.32	0.24	0.16	1	1	1

Table 4. Effect of duration of splicing on the properties of splices

Parameter	Ring yarn			Rotor yarn			Friction-spun yarn			Air jet yarn		
	Duration of splicing air blast (time code)			Duration of splicing air blast (time code)			Duration of splicing air blast (time code)			Duration of splicing air blast (time code)		
	333	535	737	333	535	737	333	535	737	333	535	737
Splice breaking strength (gms)	401	387.9	411.9	246	296.3	269.7	176.4	180.8	171	57.6	96.4	95.3
Splice breaking elongation (%)	10.96	10.94	11.54	6.19	7.94	7.54	8.47	8.00	7.22	1.47	2.67	2.33
CV% of splice breaking strength	19.53	21.08	16.61	30.44	18.17	20.21	17.73	17.69	20.19	55.33	52.34	51.13
CV % of splice breaking elongation	22.52	23.85	16.38	41.34	27.63	26.68	26.07	27.60	27.77	60.39	56.36	61.72
Retained splice strength (RSS) %	79.2	76.1	81	72.6	87.3	79.6	90	92.9	87.9	21.4	35.88	35.25
Retained splice elongation (%)	77.4	77.2	81.5	64.3	82.4	78.3	78.8	74.4	67.2	19.7	35.7	31.2
Splice break ratio (SBR)	0.4	0.44	0.34	0.74	0.54	0.58	0.23	0.24	0.27	1	1	1

opening of the structure during pneumatic untwisting process. This results in good intermingling of the fibers during twisting process. With the increase in the splicing pressure level, increase in the retained splice strength (Table 3) has been observed. At 4 bar the RSS was 71.6 % and increased to 79.2 % at 6 bar. Increase in the vortex intensity resulted in the improvement of entanglements in the splice region and it has been known that the contribution of the entanglements to the splice strength is more than 50 % of the overall splice strength. The increase in the splice breaking elongation percentage and decrease in the CV% of the both splice breaking strength and elongation with the increase in the pressure level clearly indicating the good fiber intermingling and gripping in the splice zone. Table 3 also shows that with the increase in the splicing pressure there is a reduction in the splice break ratio (SBR) for ring spun yarn. For a good splice it should be less. Higher splice retention strength in general corresponds to a lower SBR. A lower splice break ratio indicates that, the splice related end breakages in the down stream process would be less. A lower SBR at higher splicing pressure level also confirms the good fiber intermingling and gripping in the splice.

With the same splicing pressure (5 bar), increase in the duration of the splicing from time code 333 to 737 resulted in an marginal change in the tensile characteristics of splices in terms of the retained splice strength, CV% of splice breaking strength and elongation and SBR (Table 4). After initial drop in tensile properties they found to be improved at higher duration of splices, which indicates that entanglements are improved with the increased time availability of splicing. But the overall impact of duration of splices on the tensile characteristics is not very significant, indicating that the difference in the time levels might not enough to have an effect on the intermingling of the fibers.

The photograph and the diameter profile of the splices of ring-spun yarn, Figures 1(a) and 1(b) respectively, reveal that the diameter is less at the central portion of the splice and increase on either side. Because of proper intermingling, the diameter around the center of the splice seems to be less and

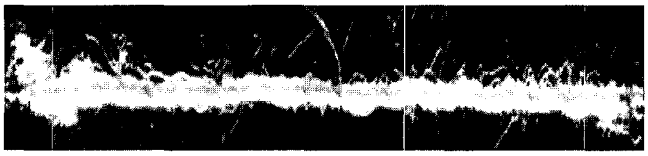

Figure 1(a). Photograph of typical spliced portion of ring-spun yarn.

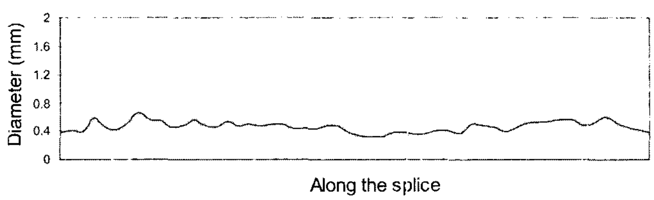

Figure 1(b). Diameter profile of typical spliced portion of ring-spun yarn.

increases on either side of central portion. The diameter in the wrapping regions at the each end of the splice zone is less because wrapping due to the tail ends having few number of fibers.

Spliced Rotor-spun Yarns

In case of ring spun yarn, its helical structure has facilitated the good opening of the yarn tail ends prior to the splicing. Rotor yarn structure is a layered structure consisting of core and wrapper fibers. During opening of the tail ends these wrapper fibers interfere in the satisfactory untwisting and so proper opening is prevented. Table 3 shows that with the increase in the splicing pressure from 4 bar to 5 bar, there is 25 % increase in the retained spliced strength (RSS). This can be attributed to the increase in the number of turns of yarn ends on each other, instead of intermingling of fibers as in case of ring spun yarn and to the good cohesion between the coils at the higher vortex intensity. With the increase in the air vortex intensity, the torque developed inside the chamber will be high causing more and compact coils. A further increase in the splicing pressure from 5 bar to 6 bar has not resulted in any increase in the RSS. This indicates that there was a threshold limit in the air vortex intensity, afterwards no increase is found in RSS with the increase in the pressure level. With the increase in the splicing pressure level from 4 bar to 5 bar the splice break ratio (SBR) showed an improvement from 0.84 to 0.54. But still the SBR is on the higher side due to poor intermingling.

Table 4 shows that the increase in the duration of splicing at constant splicing pressure resulted an initial increase in RSS and then drops. At higher time level, reduction in the RSS has been observed which is significant at 5 % level but not at 1 % level. This indicates that application of air for longer time has a negative effect for rotor spun yarns.

Analysis of the spliced ends of rotor-spun yarns revealed that opening of the tail ends during pneumatic air blowing prior to splicing is poor (Figure 2a). On either side of the center of the splice, the increase in the number of turns per unit length has been observed. This might be due to the increased air vortexing torque with the increase in the distance from the center of the splice. At higher-pressure levels 5 and 6 bar, a reduction in the diameter at the center of the splice has been observed. This is due to the intense action of air pressure perpendicular to the tail ends of the splice at the central portion and compactness caused by high torque air vortex around the middle portion of the splice. Figure 2(b) shows the typical diameter profile of splice portion of rotor-spun yarn.

Spliced Friction-spun Yarns

Table 3 shows that in case of friction-spun yarn the retained splice strength (RSS) is highest among all the yarn structures. In here, no intermingling of the fibers at the center of the splice was observed, as shown in Figure 3(a). The friction-spun yarn structure is unfavorable to the intermingling during splicing because of high helix angles of the surface fibers which are also widely distributed, of its high packing density at the yarn

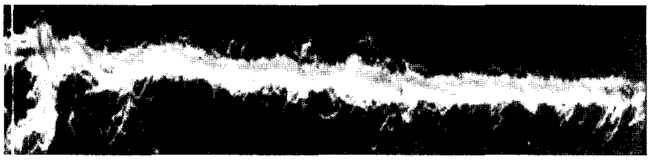

Figure 2(a). Photograph of typical spliced portion of rotor-spun yarn.

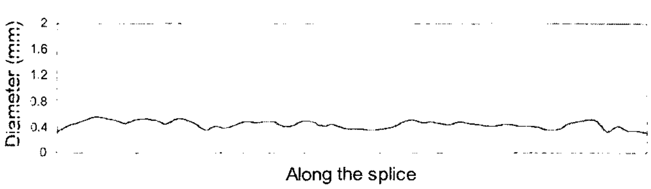

Figure 2(b). Diameter profile of typical spliced portion of rotor-spun yarn.

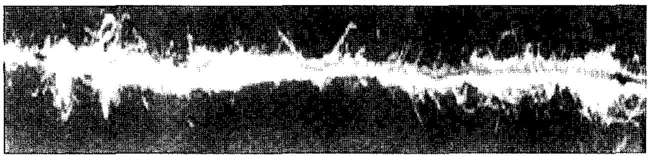

Figure 3(a). Photograph of typical spliced portion of friction-spun yarn.

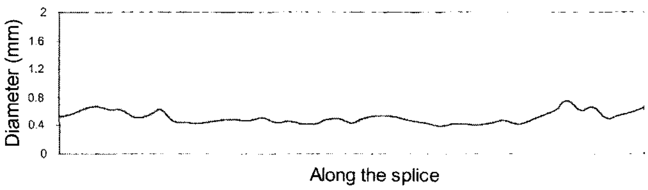

Figure 3(b). Diameter profile of typical spliced portion of friction-spun yarn.

surface and of its hairiness (which interfere in the untwisting). Because of these the opening restricted to the short length of the tail ends. So intermingling is very poor. The very high RSS can be attributed to the increase in the number of the coils, and to the wrapping of the surface fibers of the each strand in the splice zone. The increase in RSS with the increase in splicing pressure is due to the increase in coiling of the one yarn tail with the other. The CV% of splice breaking strength and elongation shows significant decreasing trend. This may be due to higher grip of one tail end with the other tail end during splicing at higher pressure. The friction-spun shows the lowest splice break ratio (SBR) among all the yarns. The increase in SBR with the increase in splicing pressure is due to the increase in coils at higher splice pressure.

It is evident from Table 4 that with the increase in the splicing duration at constant splicing pressure (5 bar), no significant change in the RSS initially, but at the higher duration the RSS values were increased significantly. There is no significant difference in the CV of splice breaking strength and elongation with the increase in splicing duration. This indicates that duration of splicing has no significant effect on the splice performance. Decrease in the splice diameter around the center of the splice was observed at the higher-pressure levels. In the remaining cases, this trend was not obvious. The typical diameter profile of splice portion of friction-spun yarn is shown in Figure 3(b). The twist at the center of the splice is less and increases on both sides. This can be attributed to the less twisting torque availability at the central potion.

Spliced Air-jet Yarns

It has been observed that the air-jet yarn was difficult to splice with the chosen parameters. The yarn structure consists of central core of fibers and the taut wrapper fibers, which wound helically on the core. The wrapper fibers offer great resistance

Figure 4(a). Photograph of typical spliced portion of air-jet spun yarn.

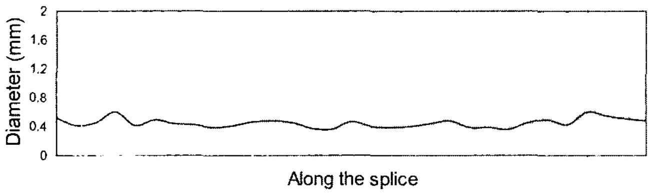

Figure 4(b). Diameter profile of typical spliced portion of air-jet spun yarn.

to opening resulting in negligible opening of the tail ends in the splicing process at the 4 bar opening pressure. So no intermingling was observed in the splicing region resulting very low retained splice strength (RSS). With the increase in the pressure level there was no particular trend in the RSS observed, as evident from Table 3. It has also been found that the CV% of splice breaking strength and elongation is very high for air-jet yarn (more than 50 %). This is mainly due to improper intermingling of fibers. Very low elongation at break indicates that resistance to slippage is very small. In all cases the slippage of the yarn ends in the spliced portion has occurred, so SBR is 1. Table 4 shows that the values of RSS with the different time levels at constant splicing pressure is also very less.

Looking at the splice one can clearly distinguish the two yarn tails (Figure 4a). In some cases, there was no twisting in the splicing region. Only wrapping of 2 or 3 coils at the each end were observed. In other cases few turns in the splice region were observed. The high torsional rigidity of the yarn offered more resistance to the twisting torque. The diameter profile (Figure 4b) shows no specific trend of diameter variation along the length of splice of air-jet spun yarns.

Conclusions

Ring yarns are most suitable for the splicing because of its helical structure that facilitating the good opening of edge fibers during pneumatic untwisting and thus proper intermingling during entwisting. The wrapping fibers in case of rotor yarn and air-jet yarns interfered in the opening process and resulted in inferior splice. It is very difficult to splice air jet yarn. The typical structure of friction-spun yarns has not facilitated proper opening, resulting in very poor intermingling. But it is showing good retained splice strength. The increase in the splicing pressure improved the strength of the splice portion of ring spun yarns, because of the improved intermingling. But for other yarns the increase in retained splice strength with the increase in splicing pressure is due to increase in the coiling frequency. In case of rotor yarn a threshold pressure level was observed. The duration of the splice seems to have a less significant effect on the splice strength in most of the cases. In case of rotor yarn higher time level has a negative effect on the splice strength. Decrease in the diameters has been observed around the central portion of the splice at higher splicing pressures. This is quite visible in case of ring yarns.

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