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How a Balanced Ply Structure Can Be Achieved

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Abstract: Yarn plying effects various properties of yarn. Particularly the amount and direction of twist in plied yarn exerts critical effects upon mechanical properties of yarn. The balanced ply structure is that structure when maximum fibres are parallel to the yarn axis and at this stage the plied yarn has the maximum strength. This structure can be achieved when the direction of spinning and the folding twist is opposite and the twist multiplier is 4.

Key Words: Yarn, Yarn Doubling, Twist Multiplier, Twist Direction, Balanced Ply Structure, Plied Yarn Strength

Introduction

The plied yarn strength is usually more than double of the component yarn strength. The effects of folding twist on yarn strength follows almost the same pattern to the effect of twist on single yarn strength. The increase of strength depends on the details of yarn contraction and tension applied during folding.

Majority of the folded yarns has the folded twist in the opposite direction to the spinning twist. This situation is subsequently referred to as 'S' folding twist on 'Z' twisted component yarns or simply 'S' on 'Z' yarns and vice versa. Besides the S on Z twist yarns, there are folded yarns with folding twist in the same direction as the spinning twist. Such yarns are referred to as 'Z' folding twist on 'Z' component yarns or simply 'Z' on 'Z' yarns. Also the same applied to S on S twisted yarns. A third kind of folded yarn is also manufactured, in which the direction of twist of one component yarn is same as the direction of folding twist but opposite to the twist direction of second component yarn, which may be referred as S on SZ yarns or Z on SZ yarns.

Saeed (1971) found that the relation between the twist factor and lea strength. He found that with the increase in the twist factor upto a certain point the lea strength improved. Hall (1975) described that effect of twist on the yarn strength was considerable. The greater the amount of twist the more closely the fibres are interlocked, and more tightly did they cling to each other. He concluded that upto a reasonable degree of twist the yarn strength could be increased. Bennett and Postle (1979) found that for plied yarns, a ratio of ply twist to single yarn twist exists, for which the structure is torsionally insensitive to the changes in applied tension. Oxtoby (1987) stated that the plying increases the mean yarn strength. The effect of folding twist on yarn follows the same pattern to the effect of twist on the single yarn strength. Lord and Radhakrishnaiah (1987) found that when yarns are plied S on Z, the best tenacity appeared to be obtained at 4.2 T.M. they also found that when ring spun yarn is plied Z on Z, the outer fibres have a steeper helix angle, which reduces the tenacity of the plied yarns. Carnaby *et al* (1994) remarked that the reverse direction folding twist reduce the internal strain energy in the yarn that arise in spinning. There is a unique twist level at which the twist is " balanced". At balanced twist the yarn will be straight and without torque. Chattopadhyay (1997) reported that in plied yarn the cohesion and strength depends no longer on the fibre migration but merely on the wrapping of a strand, consisting of the parallel arrangement of fibres around each other, facilitating better utilization of the fibre properties. Fraser and Stump (1998) narrated that if the twisted strands are carefully folded length wise into a plied structure, of opposite to the initial twist inserted in the strands, a stable piece of two-ply yarn is produced. They also concluded that a balanced ply structure is one that will maintain its configuration without the application of external tension or torque.Lin *et al* (1998) found that the physical properties of plied yarns will be determined by difference in the twist direction of the plied yarns.

Materials and Methods

The present research work was initiated in the Department of Fibre Technology, University of Agriculture, Faisalabad and was conducted in Koh-i-Noor Industries Faisalabad.

Samples of polyester-cotton blend (52:48) were spun in both S and Z twist directions at 24s count. Their quality parameters were measured and evaluated then yarn samples were doubled under following process and programme.

Doubling Process: Doubling was done on Two-for-One unit, by combining the singles yarns in three combinations of twist directions viz. TDzz, TDsz and TDss in both the doubling directions i.e. S and Z. Five different twist levels i.e. TM=3, TM=4, TM=5, TM=6 and TM=7 were employed for each yarn sample.

Yarn Strength Testing: Single and double yarn strength was measured in terms of lea-strength with the help of pendulum type tester by "skein method" as suggested in ASTM standards (1997 b).

Statistical Analysis: Three factors factorial completely Randomized Design was applied in the analysis of variance for testing differences among the various quality characteristics studied in these investigations. Its significance is checked at 1 and 5 percent confidence levels. New Duncan's Multiple Range Test was also applied for individual comparison of means among the various quality characters. M-Stat Computer package devised by Freed (1992) was employed for statistical manipulation of the results.

Table 1a: Analysis of Variance Table For Lea-strength

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F.ratio	Prob	Standard Error
D	1	30.000	30.000	5.9276**	0.0169	0.2904
TD	2	128476.017	64238.008	12692.471**	0.0000	0.3557
TM	4	70403.700	17600.925	3477.68**	0.0000	0.503
TD X D	2	51257.150	25628.575	5063.823**	0.0000	0.4592
D X TM	4	564.667	141.167	27.8924**	0.0000	0.6494
TD X TM	8	19784.650	2473.081	488.6439**	0.0000	0.7954
TD X D X TM	8	42890.183	5361.273	1059.3075**	0.0000	1.1248
ERROR	90	455.500	5.061			
Total	119	313861.867				

Coefficient of Variation = 0.78 %

Table 1b: Average Lea Strength as Effected by Various Doubling, Twist Directions and Twist Multipliers

	DS			DZ		
	TDzz	Tdsz	TDss	Tdzz	TDsz	TDss
TM-- 3	302J	307 I	329F	335 E	293 L	295 KL
TM--4	374A	249 O	309I	312 H	274 M	370 B
TM-- 5	351C	235 Q	295KL	298 K	239 P	342 D
TM-- 6	341D	214 T	263 N	272 M	215 T	333 E
TM-- 7	333E	192 V	220 S	227 R	201 U	323 G
Average	340A	239 F	283 D	289 C	244 E	333 B

** Highly singificant * Significant NS Non Significant

Individual Comparision of Treatments Means at P = 0.05

Table 1c:

	TM3	TM4	TM3	TM6	TM7	Mean
Ds	312 B	310.0 C	294.0E	273 F	248 G	287.96 B
Dz	308 D	319.0 A	293.0E	273 F	250 G	288.97 A
MEAN	310	314.5	293.5	273	249	

Table 1d:

	TM3	TM4	TM5	TM6	TM7	Mean
TDzz	318 D	343 A	324 C	307 F	280 H	314.4 A
TDsz	300 G	261 J	237 K	215 L	197 M	242.0 C
TDss	312 E	339 B	318 D	298 G	272 I	307.8 B
Mean	310	314	293	273	250	

Any two means not sharing a letter in common differ significantly at 0.05 % level of probability

Note. a,b,c, and d are used separately for each column.

Results and Discussion

Yarn Lea Strength: The data of lea-strength as observed under two types of doublings, three types of twist directions and five twist multipliers with quadruplicate observations was subjected to analysis of variance which reveals a very highly statistically significant differences of all the mean values for main effects, second order interactions as well as third order interactions. The results are presented in the Table-1(a). The overall co-efficient of variation of experimental data on lea strength was as low as 0.78, which means that the quality of the experiment was highly satisfactory. The performance of mechanical operations seems to be almost in perfect control.

The average values along with the letters showing the differences among values is of main interest because of the highly significant interactions of TDxDxTM i.e. the three factor interaction. The Table depicts the variation in responses due to one-factor levels in the presence of other factors. For this reason it is not possible to explain explicitly the overall comparison of different levels of the same factor. As an example the average for Dz is statistically significant than the average values of Ds. The comparison under different levels of TM it does not hold good. The lea-strength for Ds is greater than Dz under TM3, it is lower under TM4 but statistically at par under TM5, TM6 and TM7.

In view of above facts the specific results for lea-strength are discussed for data given in Table 1(b). The Table reveals a comparison among means for all the thirty treatments, i.e. the variables design for investigation by using two doublings, three twist directions and five twist multiplier levels.

The best lea strength is observed under TM4, TDzz and Ds combination with a value of 374 pounds, followed by the same TM, i.e. TM4, TDss and Dz with respective values as 370 pounds. The Table also reveals consistently more lea-strength for the twist multipliers under TDzz x Ds as compared to TDss x Dz. The best strength at TM4 is because of the fact that at this level the ply yarn structure is balanced. As Fraser and Stump (1998) described that balanced ply structure will maintain its configuration without the application of external tension or torque and at this stage the yarn has highest strength. Also Lord and Radhakrishnaiah (1987) who found that when yarns are plied S on Z the best tenacity appeared to be obtained at 4.2 TM confirms present result.

The lea-strength under TDss xDs and TDzz x Dz is higher under TM3 where as it decreases when twist multipliers increases. It ranges from 329 to 220 and 335 to 227 pounds respectively. Lord and Radhakrishnaiah (1987) explained that when ring spun yarns are plied Z on Z the outer fibres have a steeper helix angle, which reduces the tenacity of the plied yarns.

The lea-strength values were lower for all the sets of twist multipliers under combination TDsz xDs as well as TDsz x Dz, which ranges from 307 to 192 and 293 to 201 pounds respectively. The inferior values for lea-strength were observed under the higher TM at TDsz for both doublings, which are 192 and 203 pounds. This happens because of untwisting of one component yarn i.e. the yarn with opposite direction of spinning and folding twist, and the over twisting of the other one i.e. yarn with same spinning and folding twist. This hypothesis is confirmed by Chattopadhyay (1997) who reported that surface fibres contribute mainly toward tenacity. When the ply twist of opposite direction is inserted the individual strand rotates on its own axis cause the wrapped fibres to become loose. Hence the strength is low because loose fibres do not contribute towards the structure reinforcing. Similarly when ply twist of same direction is inserted the wrapped surface fibres become twisted in the same directions which reinforce the structure in the beginning but gradually the strength decreases because of over-twisting which cause the fibres to break and causes weakening the structure. This quotation also explains the trends of S on S twisted yarns and S on Z twisted yarns.

Conclusion

The yarn strength increase with doubling and it touches an optimum value when the ply twist is balance. This balanced ply twist level seems to be at TM4 for the yarns of opposite spinning and folding twist.

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