



Influence of twist on tensile and abrasion properties of DREF-II friction spun plied yarns

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Abstract: As it is already known that the Dref II friction spun yarns without core yarns/filaments are weaker than ring and rotor spun yarn and these are not readily acceptable due to its poor tenacity and extension to withstand the rigorous tensile and abrasive action of weaving and knitting, So the present work is concerned to find the suitable plying technique to improve these properties. Four yarn samples of 118 tex (5.0s Ne) have been spun at different spinning drum speed in Z direction and then these single yarns are plied with 608 TPM (twist per meter) in S direction and 312 TPM in Z directions. The packing fraction, tenacity, breaking elongation, and yarn to emery abrasion were studied. The test report shows that Z plied yarns have higher packing coefficient and tenacity but lower breaking extension and abrasion resistance in comparison with S plied yarn. Then the single yarns having lower packing fractions were further plied to four plied twist levels in S direction and four plied twist levels in Z directions to study the ply assistance in both S and Z direction. It has been shown that the S ply assistance increases gradually with increase in ply twist but Z ply assistance increases to maximum and then decreases with increase in ply twist. The favorable ply assistance may be recommended at ply TM (twist multiplier) level of 10.1 in S direction and 4.2 in Z direction.

Keywords: DREF Spinning, Packing fraction, Ply Assistance, Twist Multiplier. Abrasion Resistance

I. Introduction

Several studies¹⁻⁵ have been carried out to find the correlation between single yarn and ply yarn properties and optimised the extent of twist imparted in the ply yarn. Ply yarns are more uniform in linear density, have higher strength and smoother surface than single yarns. Ply twisting of staple fibre yarn in opposite direction, in almost all cases, increases tenacity and extensibility¹. It has been reported² that packing coefficient increases by 18.14% for regular ring spun yarn and 11.72% for compact yarn after doubling. It has also been reported³ that the abrasion resistance of two plied cotton yarn increases tremendously with increase in both single yarn twist and ply twist. It also has been reported^{4,5} that the strongest ply yarn is obtained when low twisted singles are plied together. DREF II Friction spinning has established itself in coarse count sector as an alternative to conventional ring spinning system. However, the yarns spun in this system are not readily acceptable due to its poor tenacity and extension. It has been observed that friction spun yarns are generally about 15-40% weaker than equivalent ring spun yarn⁶ and 10-15% weaker than comparable rotor spun yarns^{7,8}. The lower strength is generally ascribed to the low fibre extent and poor packing, inferior fibre alignment and poor migration which are the structural weakness of the yarn. On the contrary, high productivity and the possibility to produce yarns directly from sliver to larger packages are inherent merits of this technology. Lord and Radhakrishna⁹ plied the friction spun yarn at twist levels from 0 to 5 TM (twist multiplier) and found that when the friction spun yarn was plied Z on Z, the tenacity was considerable higher than when it was plied S on Z and the best tenacity appeared to be obtained at 4.2 TM. He also noticed that the Z on Z yarns felt harder and smoother than S on Z. Chattopadhyay and Chakraborty¹⁰ also plied the friction spun yarns at five different ply twist levels and found that plying enhances tenacity and extension of friction spun yarns and Z on Z plied yarn becomes more extensible than S on Z plied yarn. Not much gain in tenacity was observed with increase in ply twist level irrespective of its direction. In the literature no one studied the behavior of variation of twist of friction spun yarn on the tensile property and abrasion resistance after plying. This study deals with the impact of packing of fibres on tensile and abrasion properties considering favourable twist directions at different twist level of DREF II friction spun yarns.

II. Materials and methods

II.1 Raw Material

Four cotton slivers each of 4.4 ktex have been used for this investigation.

II.2 Preparation of Yarn Samples

Four yarn samples of 118 tex (5.0s Ne) were spun on a laboratory model Dref II friction spinning machine at spinning drum speeds of 1900, 2200, 2500 & 2800 rpm with constant feeding speed of 1.0 meter per minute and delivery speed of 140 meter per minute. The machine parameter such as carding drum speed, spinning drum setting and suction pressure were maintained at 4200 rpm, 0.4 mm and 25 mbar respectively.

II.3 Ply- twisting

The single yarns were plied in a conventional ring twisting machine at 608 TPM (twist per meter) to produce four S on Z ply structure (S ply yarn) & at 312 TPM (twist per meter) to produce four Z on Z ply structure (Z ply yarn). The twist level of Z ply yarn was kept approximately 50% lower than S ply yarn due to the incidence of more snarling tendency in Z ply yarn in comparison to S ply yarn. Then the single yarn having lowest packing fraction (i.e. 1900 rpm spinning drum speed) were further plied at 4 different ply twist levels such as 724, 608, 492, 378 TPM in S direction and 312, 259, 186 and 126 TPM in Z direction.

II.4 Test Methods

II.4.1 Determination of Packing Fraction

The packing fraction is defined as the ratio of specific volume of fibre to specific volume of yarn. This was measured following the method suggested by Hearle¹¹. The yarn diameter was measured by Wild Leitz optical microscope. Forty readings were taken to determine the average yarn diameter. Assuming circular yarn cross section the specific volume of yarn was calculated by using the formula

$$\text{Specific volume of yarn } (V_y) = \frac{\pi d^2}{4} \times \frac{10^5}{\text{Tex}} \text{ cm}^3/\text{g}$$

$$\text{Specific volume of fibre } (V_f) = 1/\text{fibre density} \quad (\text{for cotton } V_f = 1/1.54 \text{ g/cm}^3 = 0.649 \text{ cm}^3/\text{g})$$

$$\text{Packing fraction} = V_f/V_y$$

II.4.2 Determination of Tensile Strength

The tensile test of the yarn was performed on ZWICK/ Roell Z010 tensile tester with 200mm gauge length and 300mm/min speed.

II.4.3 Determination of Abrasion Resistance

The yarn to emery abrasion test was performed on a MAG SITRA ABRA TEST tester having abrader paper size of LJ 220 (LION Brand). No of strokes required to break the yarn was determined. Fifteen such readings were taken for each sample and from it the RRI (Relative Resistance Index) of the yarn was calculated by using the formula suggested by SITRA yarn abrasion tester manual.

III. RESULTS AND DISCUSSIONS

Table I. Packing Fraction, Tensile and Abrasion Resistance Values of the Yarns

Yarn Properties	Type of Yarn	Spinning Drum Speed (R P M)			
		1900	2200	2500	2800
Packing Fraction of yarn	Single	0.22	0.27	0.32	0.38
	Ply S twisted	0.34	0.31	0.30	0.28
	Ply Z Twisted	0.37	0.36	0.43	0.47
Tenacity of Yarn (mN/Tex)	Single	19.0 (16.2)	22.5 (16.7)	24.6 (11.7)	26.0 (9.7)
	Ply S twisted	42.1 (5.7)	39.8 (4.4)	38.4 (6.7)	37.6 (4.4)
	Ply Z Twisted	55.0 (4.3)	55.9 (8.0)	55.7 (6.5)	53.8 (7.8)
Breaking Extension %	Single	6.4 (21.6)	7.2 (18.8)	7.3 (21.7)	6.9 (14.5)
	Ply S twisted	14.6 (9.1)	15.1 (8.6)	14.8 (10.2)	16.1 (10.4)
	Ply Z Twisted	12.3 (5.5)	11.7 (7.0)	13.7 (8.4)	12.5 (9.2)
Abrasion Resistance (Relative Resistance Index)	Single	32.6	34.1	102.9	101.5
	Ply S twisted	4990.2	7028.5	9042.0	9821.1
	Ply Z Twisted	988.5	1834.9	3734.9	1814.8

*The values in the parentheses indicate CV% RRI= No of strokes to break the yarn X Weight of load/ $\sqrt{\text{Tex}}$

III.1 Effect of spinning Drum Speed (Single Yarn Twist) on Packing Fraction

From the Table 1 and Fig 1, it is shown that the packing fraction of single yarn increases with increase in spinning drum speed which is due to increase in twist level. The plied yarns have more packing fraction than single yarns due to the additional plying twist. But when the yarns are plied together the packing fraction improves in Z direction and reduces in S direction. As it is known that the individual strands also receives twist depending on the direction of ply. A Z ply will insert Z directional twist in singles which have already Z twist from its origin so, the overall twists in singles as well as in plied yarns are increased. Hence Z-Ply structural consolidation may be expected. However, With S- ply, the structure of individual strand opens up due to removal of twist or loosening of wrapped sheath fibres because of opposite twist resulting in decrease in packing fraction.

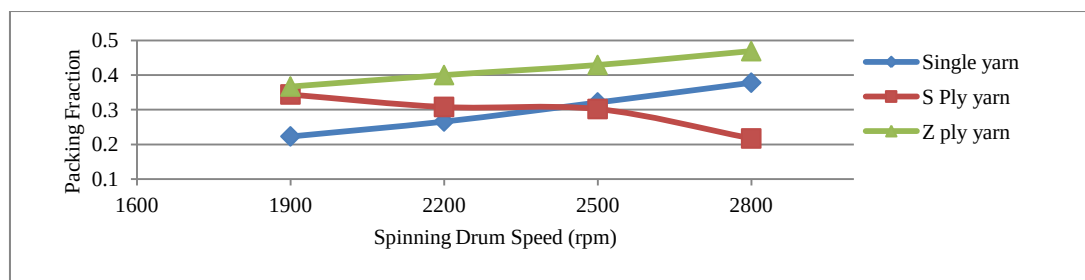


Fig 1: Spinning drum speed with Packing fraction

III.2 Effect of Spinning Drum Speed (Single Yarn Twist) on Tenacity

From Table 1 and Fig 2, it is clear that the tenacities of plied yarns are tremendously higher than single yarns which may be due to effect of doubling and the mutual support of individual strands towards the load bearing capacity. It is also observed that the tenacity of Z ply yarn is more than S ply yarn, which may be due to the increase in packing fraction of Z ply yarns than S ply yarns. But the tenacity of Z plied yarn gradually increases to maximum value with increase in twist and then decreases with further increase in twist which may be due to the obliquity effect of fibre and the gradual decrease in resistance to slippage of fibres after optimum twist, however in case of S ply yarn the tenacity decrease gradually with increasing single yarn twist which may be due to the gradual increase in opening or loosening of component yarns making them more prone to slippage.

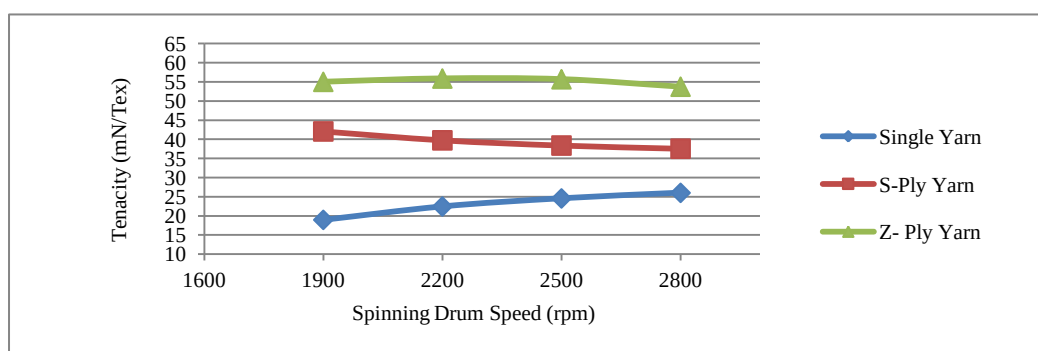


Fig 2: Spinning drum speed with Tenacity

III.3 Effect of Spinning Drum Speed (Single Yarn Twist) on Breaking Extension

Table 1 and Fig.3 show that the plied yarns have higher breaking extension than the single yarn which may be due to the improvement in uniformity, reduction in imperfection level and mutual support of individual strand towards the load bearing capacity. The S ply yarns have higher breaking extension which may be due to the surface protruding fibres of individuals are entrapped during plying and the core fibres of individuals are opened or loosened so the yarn becomes soft, voluminous and springiness. The yarn breakage takes place after breakage of the surface fibers which leads to higher extension. However, in case of Z ply yarns the surface fibres as well as the core fibres are over twisted which increase its strength and rigidity but reduces the breaking extension due to the fibre breakage of over twisted fibers.

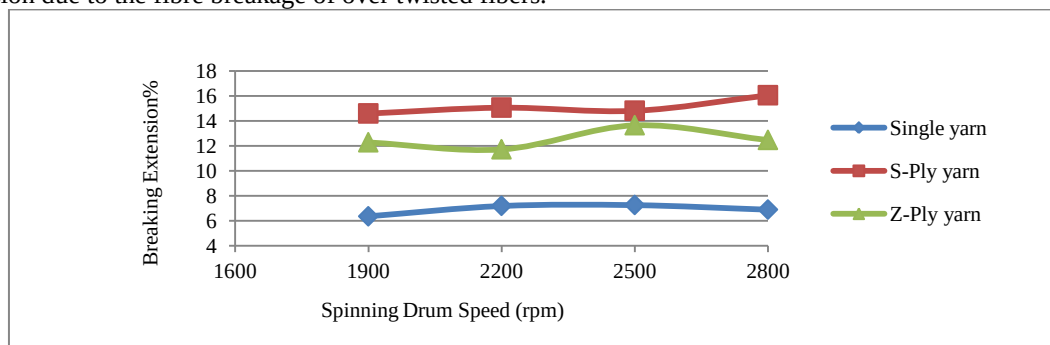


Fig 3: Spinning drum speed with extension%

III.4 Effect of Spinning Drums Speed (Single Yarn Twist) with Abrasion Resistance

Table 1 shows that there is not any substantial improvement in abrasion resistance with increase in single yarn twist but after plying there is substantial improvement in abrasion resistance. From fig 4 it has been found that the S-ply yarns have higher abrasion resistance than Z- ply yarns and it increases with increase in single yarn twist level. The reason may be due to the decrease in packing fraction and increase in voluminous and

springiness of yarn. On the other hand Z ply yarns have compact structure and less resistance to abrasive actions.

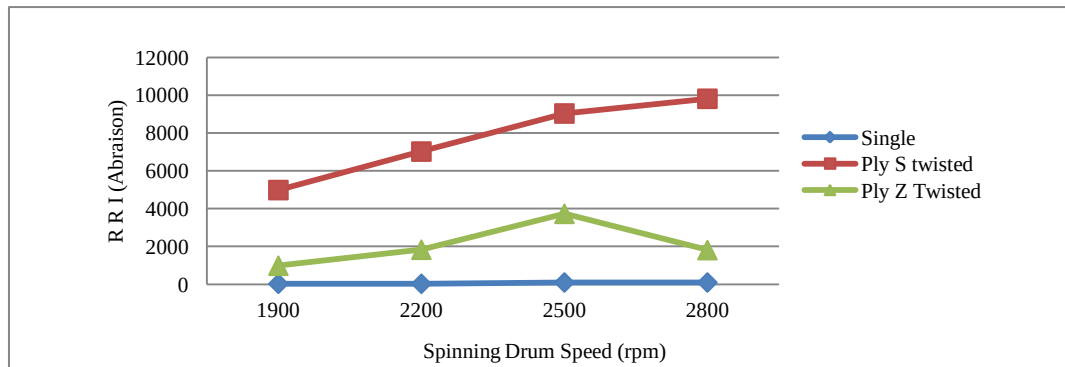


Fig 4: Spinning drum speed on abrasion resistance.

III.5 Ply Twist with Ply Assistance

From Table 2 and Fig 5, it is clear that the S Ply assistance increases linearly with increase in plied twist level and it is more than 1 when the TPM value reaches more or equal to 492 (TM 8.1). Spinning Drum speed of single yarn was kept to 1900 only.

Table 2 Ply Assistance Values at Different Ply Twist

Single yarn tenacity mN/tex		19.00			
Ply Assistance	S Ply TPM	724	608	492	378
	S Plied Yarn Tenacity mN/tex	48.70	42.10	38.40	34.40
	S Ply Assistance	2.56	2.22	2.02	1.81
	Z Ply TPM	312	259	186	126
	Z Plied Yarn Tenacity mN/tex	55.00	55.90	48.40	40.50
	Z Ply Assistance	2.90	2.94	2.55	2.13

During handling of yarns at Plied TPM level of 492, 608, and 724, it has been noticed that the yarn having TPM of 608 (TM =10.1) has reached the balanced twist level i.e. low snarling tendency. Hence this TM level may be recommended to get a balanced plied yarn in S direction. Ply Assistance is calculated as :

$$\text{Ply Assistance} = \text{Plied Yarn Tenacity} / \text{Single Yarn Tenacity}$$

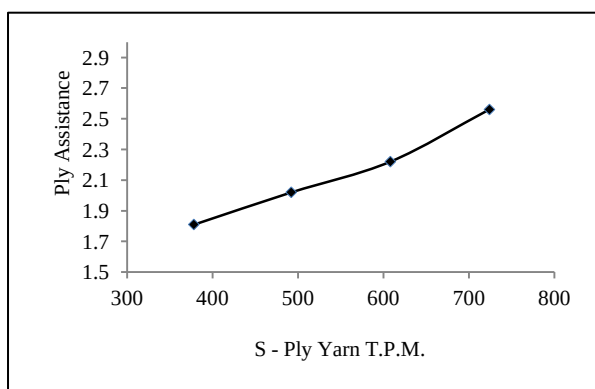


Fig 5: Ply Assistance at various TPM of S Plied Yarn

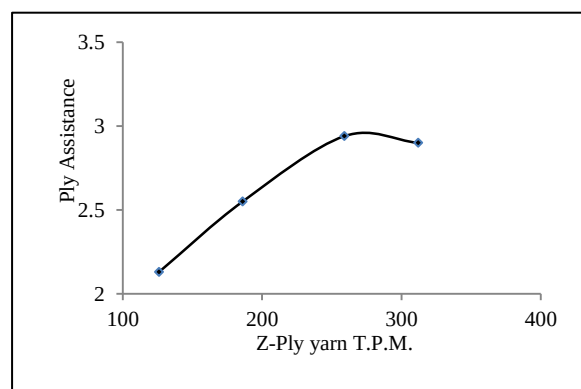


Fig 6: Ply Assistance at various TPM of Z Plied Yarn

From Fig. 5 and Fig. 6, it is clear that the Z ply assistance increases with increase in yarn TPM and reaches maximum at plied twist level of 259 TPM (TM 4.26) and then decreases. Hence this TM level may be recommended to get a balanced plied yarn in Z direction.

IV CONCLUSIONS:

1. Packing fraction of Z on Z plied yarn is higher than S on Z plied yarn of DREF 2 friction spun yarns even at the insertion of 50% less plied twist levels than S on Z plied yarn.

2. The tenacity of Z on Z plied yarn is higher than S on Z plied yarn. The tenacity of S on Z plied yarn decreases with increase in single yarn twist level but in case of Z on Z plied yarn it gradually increases to maximum level and then decreases with further increase in single yarn twist.
3. The breaking extension of S on Z plied yarn is higher than Z on Z plied yarn and there is no significant difference in breaking extension of plied yarns with increase in single yarn twist level.
4. S on Z Plied yarns have higher abrasion resistance than Z on Z plied yarns and it increases with increase in single yarn twist level but in case of Z plied yarn it increase to maximum value and then decreases with increase in single yarn twist level.
5. Ply assistance of S ply yarn increases with increase in ply twist level and in case of Z ply yarn the ply assistance increase to maximum vale and then falls. The better plied yarn may be found at TM level of 10.1 in S direction and 4.2 in Z direction.

From the above discussion it is inferred that friction spun single yarns without core or without plying can not be used in weaving or knitting due to lower strength and S on Z plied can be used to produce soft fabrics and Z on Z plied yarns can be used to produce stiff fabrics.

References

- [1] Hari P K, Balsubramanian P, Sengupta A K & Chavan R V, Effect of doubling on the tenacity of rotor spun yarns, J Text Inst, 76(5)(1985) 383-386
- [2] Isthiq S M, Subramanian P, Kumar A & B. R. Das structural and tensile properties of ring and compact plied yarns. Kolandaisamy, P and Mohamed, P Effect of the single yarn twist and ply to single twist ratio on the hairiness and abrasion resistance of cotton two ply yarns. AUTEX research journal, vol 6, No 2, June 2006.
- [3] Coulson A F W, & Dakin G, Doubled yarns, Part I to III, J Text Inst, 48, T207-T292, 1957
- [4] Dakin G, Doubled yarns, Part IV and V, J Text Inst, 48, T293-T332, 1957
- [5] Deussen H, Conventional and novel short staple spinning system, Melliand English, 11, E352-E354, 1989.
- [6] Lord P. R., Joo C. W. & Ashizaki T., The mechanics of friction spinning J Text Inst, 1987, 78, 234-254.
- [7] Neuhaus L, spinning process as competitors, Textile Asia, 1986, 17, No 10, 49-55.
- [8] Lord P R, Radhakrishna P, Tenacities of plied Friction spun, Rotor spun and Ring spun yarns. J Text Inst, 78, 140-142, 1987.
- [9] Chattopadhyaya R., Chakrabarti A.K., Influence of plying on tensile behavior of friction spun yarns Resume Papers 39th Technological Conference 21-22 March 1998, NITRA.
- [10] Hearle, J.W.S., Grosberg, P. and Backer. S., Structural mechanics of fibres, yarns and fabrics, vol I, Wiley-Interscience, 88-90, 1969.