A STUDY OF THE PLIED YARN TWIST FACTOR

دراسة معامل إس البرم للخيوط المزوية

by

Assoc. Prof. I. Rakha , Prof. R. El-Bealy and Prof. M.El_Messiry

الخلاصة: يقدم هذا البحث معادلة جديدة لحساب معامل البرم للخيوط المزوية. حيث تم دراسة تأثير العوامل المختلفة مثل خواص الشعيرات واس البرم المفرد ونمر الخيوط وعدد مرات الزوى على معامل البرم للخيوط المزوية. مع إجراء تجارب لتوضيح تأثير العوامل السابقة لخيوط الغزل الحلقى المزوية. وتم تحليل النتائج نظريا بناء على التركيب المثالى للخيوط. وقد أوضحت التجارب وجود اس برم حرج ثابت لجميع الخيوط المزوية من أقطان مختلفة وبنمر مختلفة وبأس برم مفرد مختلف وكذلك بعدد مرات زوى تتراوح بين ٢-٦.

Abstract:- This paper presents a new formula of twist multiplier for plied yarns. The study concerned the influance of several parameters such as: Fiber parameters, the bottom twist, single yarn liear density of plies. The experiments carried-out on Ring-Spun plied cotton yarns and theoretical analysis based on the idealized yarn structure. the results obtained with predicted formula show a constant twist multiplier for all plied yarns.

1. Twist structure of yarns

1.1. Infuence of fiber parameters on Single yarn twists

Much work has been done on predicating the most favorable structure for cotton in terms of its fiber parameters(1). Also, yarn Strength is generally the most important property required for cotton yarns.

Several research group have published formula's and tables for prediction the optimum twist to obtain maximum yarn Stength as follows:

(i) A table based upon the work of campbell (2) is used by mills for quick approximations. The equation giving the twist multiplier for maximum strength as an inverse function of the square of fiber length.

$$\alpha_s = 2.72 + \frac{1.55}{l_f^{1.85}} \qquad (1.1)$$

where α_s **is the yarn twist multiplier for maximum Strength t.p.i/count**$^{1/2}$

l_f **is the fiber length (inch)**

(ii) A formula developed by landstreet et.al (3) gives the twist multiplier as an exponentially decreasing function of the mean length times the square root of the surface fineness.

$$\frac{1}{\alpha} = \frac{-2.08}{l_f\sqrt{M_f}} + 0.38 \qquad (1.2)$$

Where :-

α_s = is the yarn twist multiplier for maximum strength t.p.i./count$^{1/2}$

l_r is the mean fiber length obtained from the fibrograph inch.

M_r is the fiber fineness by arealometer measurements (μg/inch).

(iii) Louis et. al (4) developed a linear regression equation for maximum fineness and tenacity along budle length of 43 cottons.

$$\alpha_s = C_1 - C_2 U - C_3 L_r + C_4 F \qquad (1.3)$$

Where :

α_s = is the yarn twist multiplier for maximum strength .

U is the tenacity length uniformity

l_r is the upper quartier fiber length by the sutter webb array.

C_i where i=1, 2, 3, 4 are constants depending on the yarn size.

F is the weight fineness from the array.

(iv) Louis and Fiori (5) developed a new twist formula for maximum Skein Strength within the fiber property ranges of the cotton used in this investigation.

$\alpha_s = 5.899 + 0.248$ (micronaire reading) - 4.236(50 % span length)
- 0.016 (Tenacity at 1/8 " guage)
- 0.039 (Bundle elongation). (1.4)

Also, a nomograph is provided to faciliate quick computation of twist multiplier from a given set cotton properties based on the above formula.

1.2 Relation between single and ply twist:

Because single yarn is an unbalanced Structure, it is not in equilbrium in the presence of a tensile stress only, but requires in addition the application of a couple about the yarn axis. Thus, a construction of involving serveral separate plies or single yarns together is to be prefered to a single yarns (6).

The plied yarns which are specially produced for technical objects, must had high breaking Strength and regular twist. Several Research workers (7,8) showed that the critical twist factor of plied yarns to obtain maximum strength was affected by: Single twist factor, the number of plies, fiber properties, tension during twisting (which depends traveller weight, spindle speed and ring diameter) and twisting technique.

Karetsky (9) studied the relation between plied yarn stength and twist multiplier when $\alpha_p = 0.85\,\alpha_{cr}$, which take the foem parabola and developed several formula's as follows:

(i) in terms of single twist, number of plies and yarn retraction.

$$\alpha_{Pcr} = \alpha_{Scr} \sqrt{\frac{m R_v}{\sqrt{m} - 1}} \qquad (1.5)$$

(ii) in terms of resultant linear density of plied yarn number of plies

$$\alpha_{pcr} = \frac{48 \sqrt[6]{T_p}}{\sqrt{m}} \qquad (1.6)$$

(iii) In terms of yarn linear density, number of plies and single twist

$$\alpha_{pcr} = \frac{C\sqrt[6]{T_p}}{\sqrt{m}} * \alpha_{cr} = \frac{C\sqrt[6]{T_S}}{\sqrt[3]{m}} * \alpha_{Scr} \quad (1.7)$$

where :

α_{Pcr} : Critical twist factor of plied yarn.

α_{Scr} : Critical twist multiplier of single yarn

m : number of plies

R_Y : Retraction of plied yarn.

T_P, T_S : Linear density (tex) of plied and single yarns

C : is proportional coefficient, its value depends on the condition of plied yarn production and its structure.

Sakalov (10) suggested the following formula for determing the critical twist angle of plied yarns:

$$\cos(\beta_{cr}) = \sqrt{1 + \frac{0.7d}{L_F\mu\sqrt{2(1+\varepsilon)m}} - \sqrt{\frac{0.49d^2}{2L_F\mu^2(1+\varepsilon)m} + \frac{1.4d}{L_F\mu\sqrt{(1+\varepsilon)m}}}} \quad (1.8)$$

where

β_{Cr} : Critical twist angle of plied yarn

d : plied yarn diameter in mm

L_F : Staple fiber length in mm

μ : coefficient of friction between fibers

ε : Breaking extenstion of plied yarn (%)

m : number of plies

2. Ply Twist formula for maximum Strength:

2.1. Object:

Several articles dealt with many formulas have been proposed for predicting the ply twist to obtain maximum strength. Most of investigations declard that the prddicted values obtained from the publised formulas were not accurate enough. As consequence, The present study has shown a new formula from which ply twist multiplier for maximum yran strength can be predicted.

2.2. Procedure :

For this purpose, ring spun yarns were produced from three types of cotton fibers. The construction details of experimentss are shown in tables (1 to 6) and indicate linear density of single yarns's, the bottom twist , number of plies, the ply twist and strength (g/tex) of single and plied yarns.

2.3 Formula Developments:

Several yarns are twisted together the resultant size of the ply yarn is expressed in the mathematical form as follows:

$$T_p = T_1 + T_2 + \ldots\ldots + T_i + \ldots + T_m \qquad \text{where } i = 1,2,\ldots\ldots,m$$

$$T_p = m\,T_s$$

where

T_p The resultant count of ply yarn.

T_s indicate count of each single yarn

m number of plies

Also, from the theoritical assumptions of idealized yarn Structure, the relationship between turns per meter and yarn linear density is given by:

$$\tau = \frac{\alpha_{tex}}{\sqrt{T_{tex}}} \text{ for single yarn} \qquad \tau_s = \frac{\alpha_s}{\sqrt{T_s}}$$

$$\text{for ply yarn } \tau_p = \frac{\alpha_p}{\sqrt{T_p}} \qquad (2.2)$$

By combining equations (1) and (2) we get

$$\alpha_p = m^{0.5}\left(\frac{\alpha_s}{\tau_s}\right)\tau_p \quad \text{or}$$

$$= m^{0.5} T_s^{0.5}\left(\frac{\alpha_s}{\tau_s}\right)\tau_p \qquad (2.3)$$

But the values of single twist multiplier for maximum strength according to (11):

$$\alpha_s = \tau_s \beta^{0.21} T_s^{0.55} (t.p\,mt\,tex^{0.55} (m^2/g))$$

β: a coefficient = $L_F \cdot \mu_F \cdot N_{mf} \cdot 10^{-2}$

L_F : is baised mean fiber length and equal to $L_{st} + \frac{\sigma^2}{L_{st}}$

L_{st} : Staple length in mm

σ : The Standard of fiber length

μ_F : The fiber coefficient of friction

N_{mf} : Fiber fineness in meteric count

for determination the critical ply twist " α_{pcr} " The experiments were constructed and lie in the two groups as follows:

(i) ply yarns 10 x3 and 15 x 2 tex produced from single yarns with diffrent bottom twist multiplier " α_s " and the number of plies (m) is kept constsnt. The experimental results are shown in tables (1,2,and 3) and plotted graphically as shown in fig. (3-a to 5-a). The Figure (1) shows the relstion between critical ply twist which coressponds to maximum strength and single twist " α_s" and expressed by following formula:

$$\alpha_{pcr} = \frac{3400}{(\alpha_s \cdot 10^{-4})^{0.74}} T_p^{0.1} \qquad (2.5)$$

and by combing eq.(2.5) and (2.3)

$$\tau_{pcr} = \frac{const}{(\alpha_s \cdot 10^{-4})^{0.74}} T_p^{0.6} \qquad (2.6)$$

to get constant ply twist multiplier

$$\alpha_{pcr} = \tau_{pcr} (\alpha_s \cdot 10^{-4})^{0.74} T_p^{0.6} \qquad (2.7)$$

(ii) ply yarns produced from diffrent single constants T_s : 15 , 12 and 10 tex with constsnt single twist multiplier " α_s ". While through twisting operation, the number of plies (m) varies 2,3,4,5 and 6 ply producing diffrent resultant count of ply yarns as well as final twist " α_p " selected at five levels. The experimental results shown in tables (4,5 and 6) are plotted graphically as shown in figs. (6-a to 8-a)

The Figure (2) shows the relation ship critical twist α_{pcr} determined according to eq. (2.7) and number of plies for different linear density of ply yarn and represented by the formula

$$\alpha_{Pcr} = 3360 \, (0.8)^{m/10} \qquad (2.8)$$

when the above formula is substitued in equation (2.7), The ply critical twist in term of single twist, number of plies and yarn linear density can be expressed as follows:

$$\alpha_{Pcr} = \tau_{pcr} (\alpha_s \cdot 10^{-4})^{0.74} T_p^{0.6} / 0.8^{m/10} \qquad (2.9)$$

3) Results and Discussion

The strength of plied yarn vary complicatedly according to its single twist and ply twist. Experimental studies into the subject has been made by several research workers (12, 8, 13), but not enough analyticaly research. On the other hand, Kyuma et.al (14) explained the mechanics of the strength of ply yarn compared with single yarns .

In present study, the experimental work carried out for predicting the ply twist to obtain maximum strength. The experimental results are shown in Figs (3-10). Figures 3-a, 4-a, 5-a, and 9-a shows the ply yarn strength against the ply twist factor for threads prepared with different twist nultiplier. Also, the effect of varying the ply twist and number of plies on the strength is shown in figs 6-a, 7-a, 8-a, 10-a. All the curves show the usual strenth. Twist charactersitics for ply yarns for any set of curves it can be noticed that: yarn strength increasing to maximum and subsequently decreasing as the ply yarn twist incresed.

- The maximum values increases as the single twist decreases, but at successively higher ply yarn twist. Maximum values also increases as the number of plies increases up to 5, then if it equal to 6 its maximum value lies under the maximum values for 3 and above that of two plies.
- Changes in ply twist result in more rapid change in strength up to maximum for the low twist than for the twist single yarns. beyond maximum strength, rate irrespective of single yarn twist.
- Generally, the ply twist strength curves for the 10 x 3, 12 x 3, 15 x 3 tex are similar and three is deferences in the twist level required for maximum strength.

The ply critical twist in terms of single twist, number of plies and yarn linear density, and the strength of single - plied yarns expresswd by equation (2.9). The results obtained by use of equation are presented in fig. (3-b to 8-b). Further investigation carried out on a selected sample of Egyptian cotton yarn, Ne 50 from Gize 77 combed 20% varying the bottom twist and number of plies. The predicted formula given by equation (2.9) used for determination the ply twist shown in tales (7 and 8) and figures 9 and 10 . The curves indicate the relation between the values of ply yarn are in almost in the same and equal to 3660 α_T for all yarns obtained in the presented investigation.

Conclusion:

The study of ply twist in terms of bottom twist considering the effect of fiber parameters, yarn linear density and number of plies permits the following conclusion:

(i) The present investigation affords a theoretical - emperical formula for ply twist multiplier.

$$\alpha_p = \tau_p(\alpha_s \cdot 10^{-4})^{0.74} T_p^{0.6} / (0.8)^{m/10} (((t.p\,mt)^{1.74} tex^{1.01} (mt^2/g)^{0.74}))$$

Where:

α_s : single twist multiplier (((t. p mt. $tex^{0.55}$(mt^2/g)))

T_p : Plied yarn linear density (tex).

m : the number of plies

(ii) The predicted value of ply twist is clearly dependet on the chosen variables and constant values of ply twist multiplier has been chosen for all tested yarn ranged from 10 to 25 tex.

Refrences:

1. Braschler E. , Die Festiggkiet Von Baum Wollgespin Sten, Zurich, Leemann 1935.
2. Cumpbell M.E., Private communication, see also textile world 109, no, 7M, 35, 213,1959.

3. Land Street C.B., Ewald, P.R., Hertel, K. Land Graven C.J.; Textile World 104, No. 10, 106-107, 213-1954.
4. Louis G.L. et. al., Textile Res. J., July 1964, P 605.
5. Louis G.L and Fiori L.A, Textile Bulletin, April 1967, P.49.
6. L.R.G. Treloar, Journal of Text. Inst. Sept 1964, P. 13.
7. Karetssky K.E. Engineerny praikteravania Textelnekh Matrialav. Moscow, 19971.
8. A. F. W. coulson and G.Dakin, Journal of the Text. Inst. No 7/8, 1957, p 203.
9. Karetaskey K.E Asnovy Praikteravania Svoistv Priagy. Moscow, 1962.
10. Sakalov G.V., Teoria Krotshenia Valaknestekh Materialav, Moscow, 1977.
11. Rakha I.M. Definition of Ring-Spum yarn Torsion coefficient Accounting the characteristics of cotton fibre, Tekhnalogia Textelnoy promushlenosty, No 5, 1993.
12. S. Kershaw, J. Text. Inst., 27, p263 (1936).
13. L.A. Fiori, J. J. Brown, J.E Sand, Text. Res. J., 24, 267, 248, 1954.
14. H. Kyuma, M. Kazama; J. Text. Mach. Soc. Japan, Vol. 16, No. 5 (1970).

Table (1)

Yarn Count	$\alpha_s = t T_s^{0.55} \cdot \beta^{0.21}$	Doubling T.P.M	$\alpha_{T_p} = t\sqrt{T_p}$	$\alpha_T = t\,T^{\frac{(\alpha_s 10^{-4})^{.74}}{(\beta)^{\alpha/10}}}$	Yarn Tenacity g/tex
14 82"3	3123	486	3234	2136	19.5
		589	3927	2594	21.8
		678	4521	2968	22.5
		764	5094	3366	22.7
		865	5768	3809	23.0
		978	6521	4307	21 6
14 93"3	3462	485	3246	2311	20.3
		589	3942	2806	21.5
		658	4404	3135	21 8
		763	5106	3636	22.5
		853	5742	4087	22 2
		943	6311	4492	21 0
15 05"3	3916	482	3239	2533	20.6
		573	3850	3011	21 0
		654	4395	3437	21.6
		765	5140	4020	21 6
		886	5963	4656	20 [illegible]
		970	6518	5097	19.2
15.12"3	4233	493	3253	2696	21 0
		592	3987	3305	21 3
		655	4411	3656	21 5
		768	5173	4278	21 1
		869	5785	4795	19.5
		976	6567	5443	18 7

Table (2)

Yarn Count	$\alpha_s = t T_s^{0.55} \cdot \beta^{0.21}$	Doubling T.P.M	$\alpha_{T_p} = t\sqrt{T_p}$	$\alpha_T = t\,T^{\frac{(\alpha_s 10^{-4})^{.74}}{(\beta)^{\alpha/10}}}$	Yarn Tenacity g/tex
25 7"2	2715	478	3427	2025	11.3
		639	4581	2707	13.5
		739	5298	3130	14.7
		837	6001	3546	15.2
		966	6919	4088	13.2
26.05"2	3354	468	3378	2337	12.0
		659	4757	3291	14.3
		720	5197	3596	14 6
		837	6042	4180	13 5
		958	6915	4784	12.6
26 38"2	3791	473	3436	2605	12.8
		639	4642	3519	14 3
		768	5578	4230	14.0
		837	6080	4610	13 1
		955	6937	5260	12.3
26.6"2	4362	467	3406	2863	13.4
		585	4267	3587	14.2
		720	5252	4416	13.1
		858	6244	5249	11.7
		975	7112	5978	11 1

Table (3)

Yarn Count	$\alpha_s = t T_s^{0.55} \cdot \beta^{0.21}$	Doubling T.P.M	$\alpha_{T_p} = t\sqrt{T_p}$	$\alpha_T = t\,T^{\frac{(\alpha_s 10^{-4})^{.74}}{(\beta)^{\alpha/10}}}$	Yarn Tenacity g/tex
9 8"3	2767	723	3920	2272	16 3
		867	4701	2724	18.0
		958	5194	3010	20.5
		1186	6431	3726	20.7
		1253	6794	3937	20.3
		1336	7244	4197	19 6
9 9"3	3101	759	4136	2610	17.3
		850	4632	2923	18.1
		962	5243	3308	19.7
		1182	6442	4064	19 8
		1248	6801	4291	19 0
		1350	7357	4642	18.1
10"3	3469	777	4256	2910	18 2
		898	4919	3364	19.3
		1005	5505	3764	19.5
		1164	6277	4360	18.8
		1255	6874	4701	18.0
		1355	7422	5076	17 3
10 2"3	4287	769	4254	3422	18 6
		846	4680	3764	19.0
		1012	5598	4503	18.3
		1182	6539	5259	18.0
		1247	6898	5548	17 7
		1346	7446	5989	16 7

Table (4)

Yarn Count	$\alpha_s = t T_s^{0.55} \cdot \beta^{0.21}$	Doubling T.P.M	$\alpha_{T_p} = t\sqrt{T_p}$	$\alpha_T = t\,T^{\frac{(\alpha_s 10^{-4})^{.74}}{(\beta)^{\alpha/10}}}$	Yarn Tenacity g/tex
14.93"2	3462	636	3476	2323	18.6
		775	4235	2831	20.3
		978	5251	3572	20.7
		1036	5661	3784	19 8
		1260	6885	4602	19.0
14 93"3	3462	485	3246	2311	20.3
		589	3942	2806	21.5
		658	4404	3135	21.8
		763	5106	3636	22.5
		943	6311	4492	21.0
14 93"4	3462	457	3532	2646	21 2
		542	4188	3138	22.4
		635	4907	3676	22.9
		793	6128	4591	22.5
		894	6909	5175	21 8
14.93"5	3462	409	3534	2768	22.4
		488	4216	3303	23 4
		572	4942	3871	23.5
		667	5763	4514	22.3
		812	7016	5495	21 6
14 93"6	3462	371	3511	2664	20.5
		430	4070	3320	20 8
		513	4855	3961	20.4
		326	5925	4833	18 9
		748	7080	5775	17.6

Table (5)

Yarn Count	$\alpha_s = cT_s^{0.66} \cdot \beta^{0.21}$	Doubling T.P.M	$\alpha T_p = c\sqrt{T_p}$	$\alpha_T = cT^{c}\frac{(\alpha_s 10^{-4})^{.74}}{(\beta)^{n/10}}$	Yarn Tenacity g/tex
12.43"3	3779	571	3487	2606	19.7
		527	4439	3318	21.5
		877	6367	4002	21.6
		989	8041	4613	21.0
		1131	6909	5161	20.5
12.43"4	3779	495	3487	2746	19.8
		630	4439	3493	22.6
		704	4965	3904	22.7
		768	5418	4259	22.0
		1040	7077	5568	20.6
12.43"5	3779	393	3100	2648	20.0
		490	3863	3177	22.4
		559	4407	3624	23.1
		668	5187	4266	22.6
		818	6409	5271	21.5
2.43"6	3779	390	3368	2884	20.0
		443	3828	3276	20.3
		560	4836	4142	20.1
		651	5622	4816	19.5
		838	7237	6937	18.8

Table (6)

Yarn Count	$\alpha_s = cT_s^{0.66} \cdot \beta^{0.21}$	Doubling T.P.M	$\alpha T_p = c\sqrt{T_p}$	$\alpha_T = cT^{c}\frac{(\alpha_s 10^{-4})^{.74}}{(\beta)^{n/10}}$	Yarn Tenacity g/tex
9.9"2	3101	736	3275	1940	16.0
		869	3876	2291	17.3
		1139	5008	3003	18.9
		1360	6207	3569	19.6
		1480	6686	3902	19.0
9.9"3	3101	769	4138	2610	17.3
		860	4632	2923	18.1
		982	5243	3308	19.7
		1182	6441	4064	19.8
		1350	7357	4642	18.1
9.9"4	3101	591	3719	2469	20.0
		636	4000	2663	21.6
		749	4713	3130	21.7
		880	5538	3677	21.9
		1018	6406	4253	20.9
9.9"5	3101	549	3863	2682	22.5
		642	4552	3160	22.9
		763	5298	3678	23.1
		866	6022	4181	21.5
		962	6698	4650	20.0
9.9"6	3101	482	3715	2686	20.4
		547	4216	3048	20.6
		638	4917	3555	20.9
		749	5718	4135	20.0
		825	6358	4697	19.4

Table (7)

Yarn Count	$\alpha_s = cT_s^{0.66} \cdot \beta^{0.21}$	Doubling T.P.M	$\alpha T_p = c\sqrt{T_p}$	$\alpha_T = cT^{c}\frac{(\alpha_s 10^{-4})^{.74}}{(\beta)^{n/10}}$	Yarn Tenacity g/tex
11.45"3	2593	590	3458	1940	21.1
		752	4407	2472	23.7
		1083	6347	3560	27.7
		1253	7344	4119	26.1
11.65"3	2980	551	3245	2029	24.4
		756	4452	2784	26.9
		1090	6419	4013	27.2
		1263	7438	4650	26.0
11.75"3	3462	504	2992	2084	24.0
		760	4612	3143	27.9
		937	5563	3876	28.6
		1087	6464	4495	25.3
		1265	7461	5189	25.0
11.98"3	3946	502	3010	2314	25.7
		748	4484	3447	27.4
		993	5354	4116	26.0
		1252	7506	5770	22.8
12.2"3	4432	504	3049	2569	24.8
		748	4525	3798	26.4
		926	5602	4702	25.7
		1260	7582	6347	25.7

Table (8)

Yarn Count	$\alpha_s = cT_s^{0.66} \cdot \beta^{0.21}$	Doubling T.P.M	$\alpha T_p = c\sqrt{T_p}$	$\alpha_T = cT^{c}\frac{(\alpha_s 10^{-4})^{.74}}{(\beta)^{n/10}}$	Yarn Tenacity g/tex
11.65"2	2980	717	3461	2024	20.3
		939	4533	2651	20.5
		1126	5435	3179	24.1
		1348	6507	3805	23.4
11.65"3	2980	551	3245	2029	24.4
		756	4452	2784	26.9
		1090	6419	4013	27.2
		1263	7438	4650	26.0
11.66"4	2980	511	3488	2286	24.3
		681	4612	2967	25.5
		1102	7523	4930	27.2
11.65"5	2980	465	3549	2432	26.9
		587	4480	3070	26.4
		864	6618	4467	27.9
		1102	8411	5764	25.4
11.65"6	2980	423	3637	2524	24.7
		534	4465	3186	26.3
		777	6496	4636	24.9
		945	7901	5639	23.5

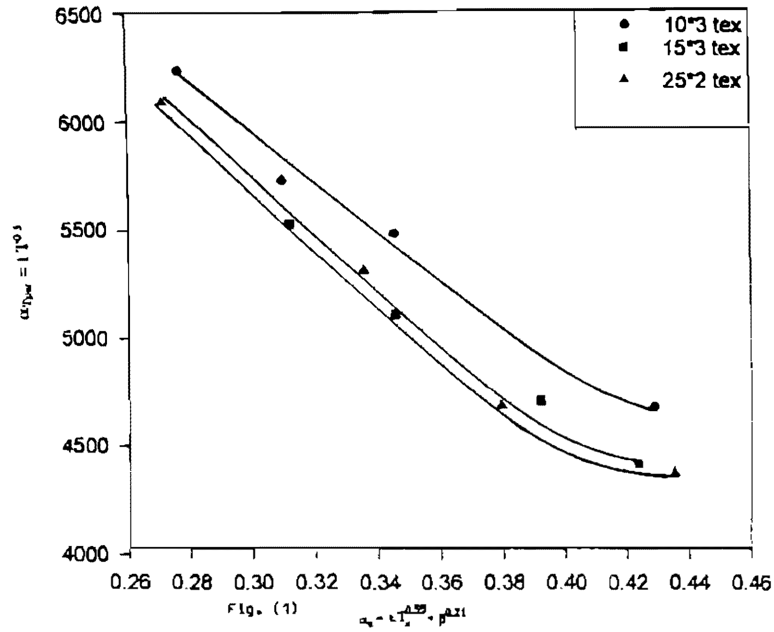


Fig. (1)

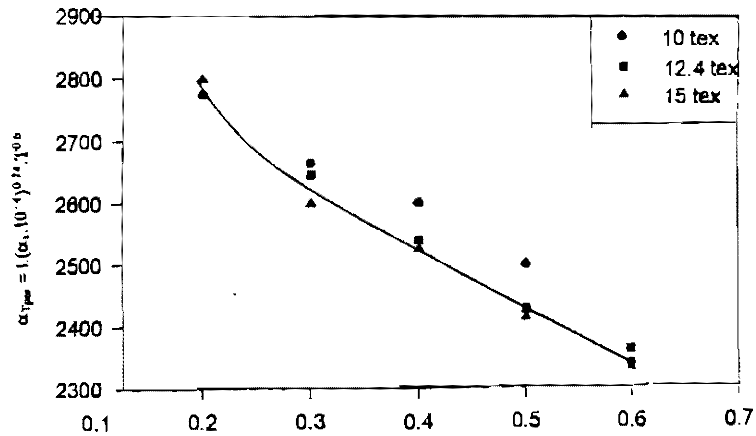


Fig. (2) No. of Plies (m/10)

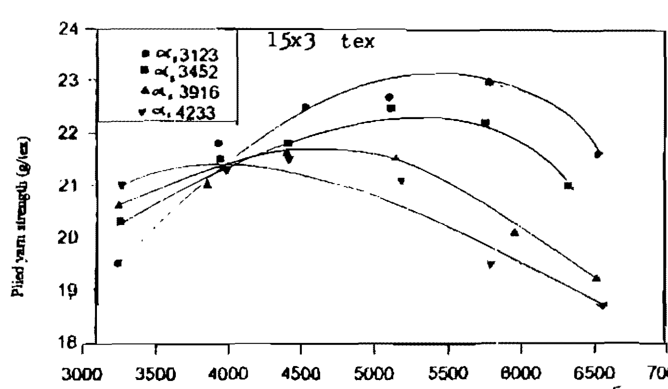


Fig.(3-a)

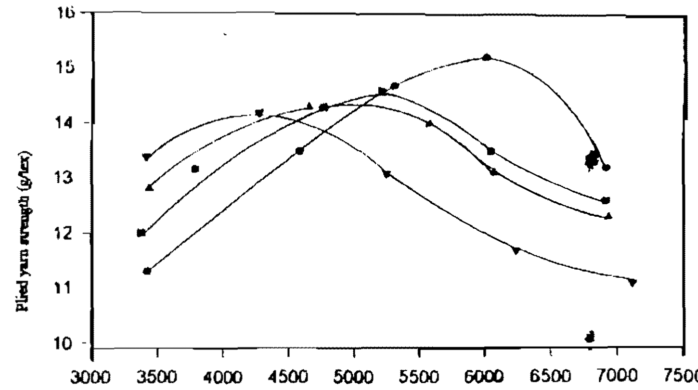


Fig.(4-a)

($\alpha_r = C.T_p^{.5}$ Ply Twist Multiplier)

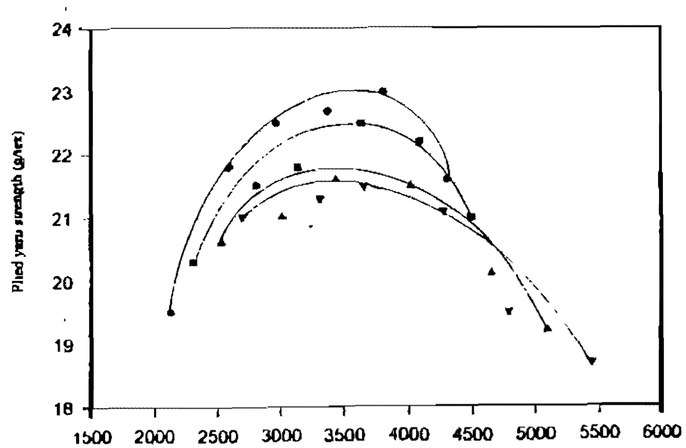


Fig.(3-b)

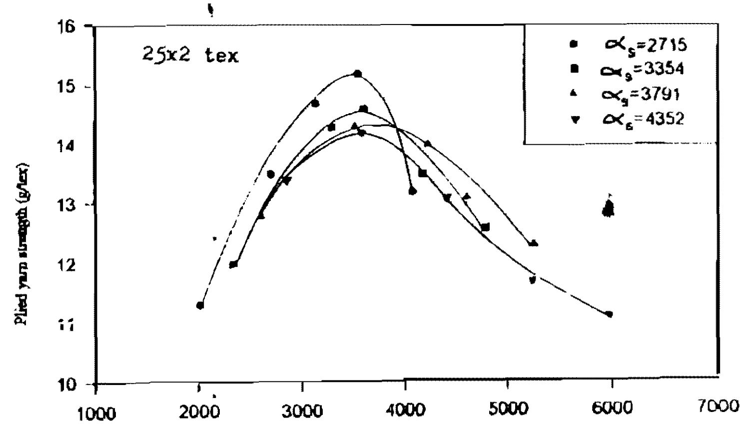


Fig.(4-b)

($\alpha_r = C.T_p^{.6}(\alpha_s 10^{-4})^{.74}/0.8^{m/10}$ Ply Twist Multiplier)

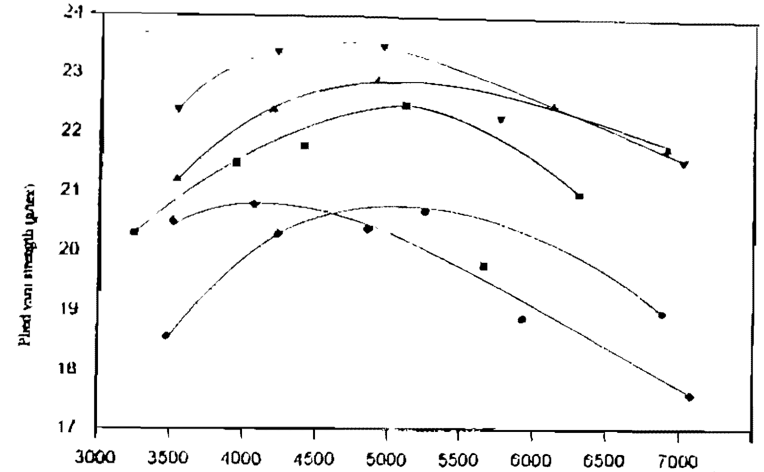
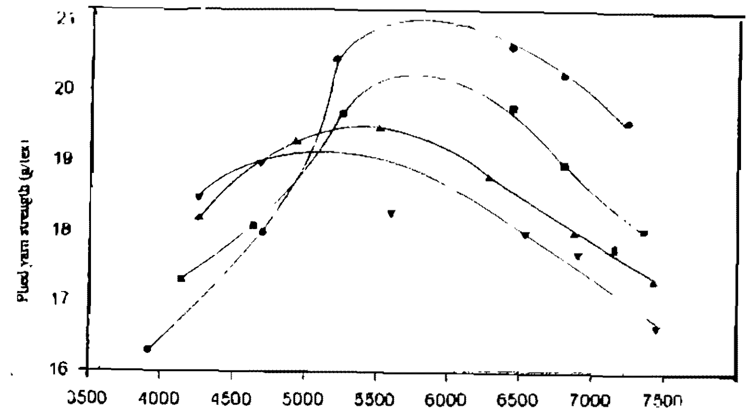


Fig.(6-a)



($\alpha_r = \tau . T_p^{.5}$ Ply Twist Multiplier)

Fig.(5-a)

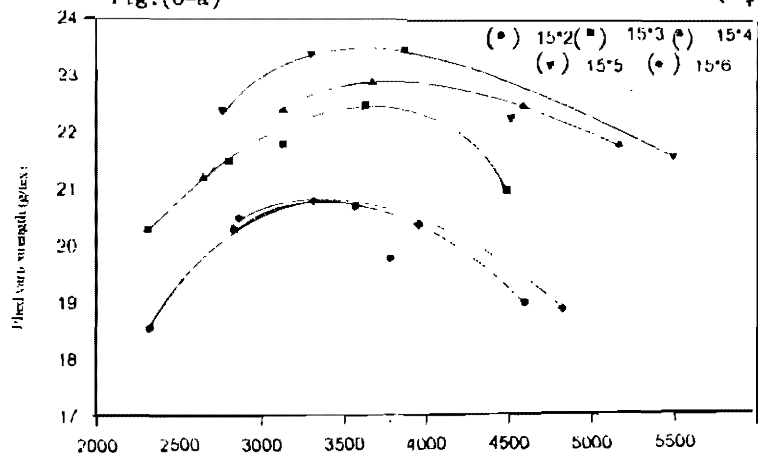
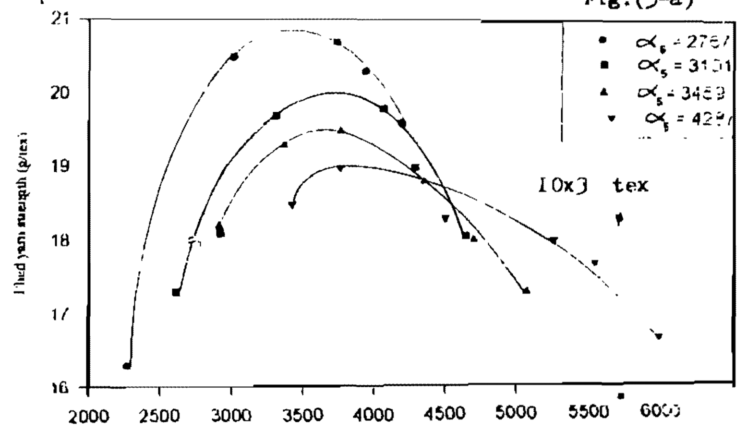


Fig.(6-b)

$(\alpha_r = \tau . T_p^{.6} (\alpha_s . 10^{-4})^{.74} / (0.8)^{m/10}$



Ply Twist Multiplier)

Fig.(5-b)

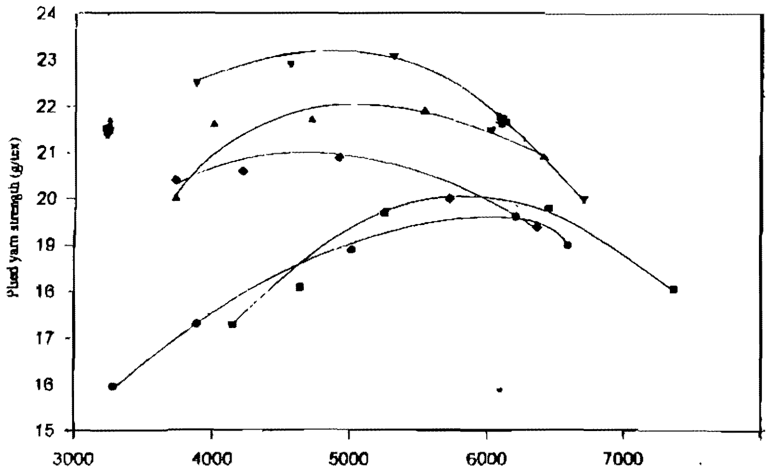


Fig.(8-a)

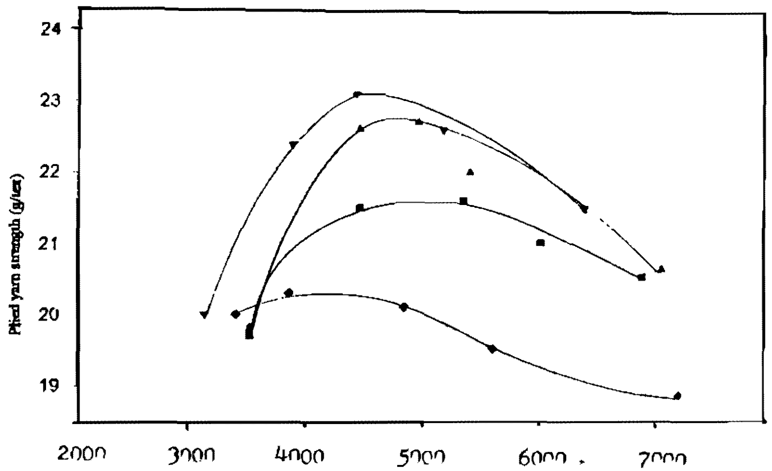


Fig.(7-a)

($\alpha_r = \tau . T_p^{.5}$ Ply Twist Multiplier)

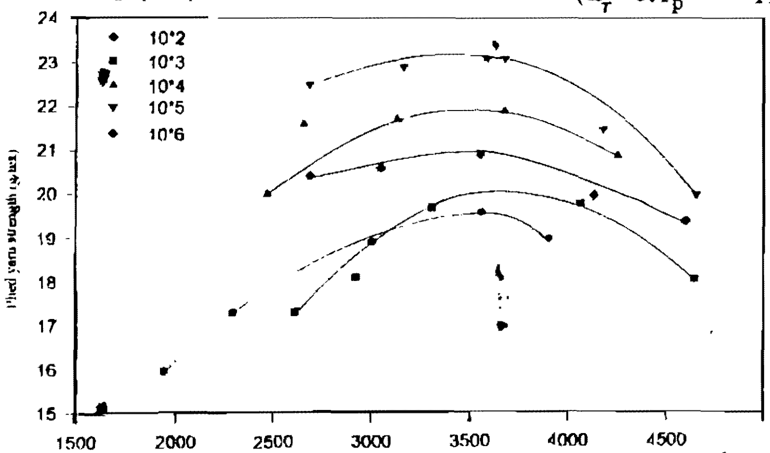


Fig.(8-b)

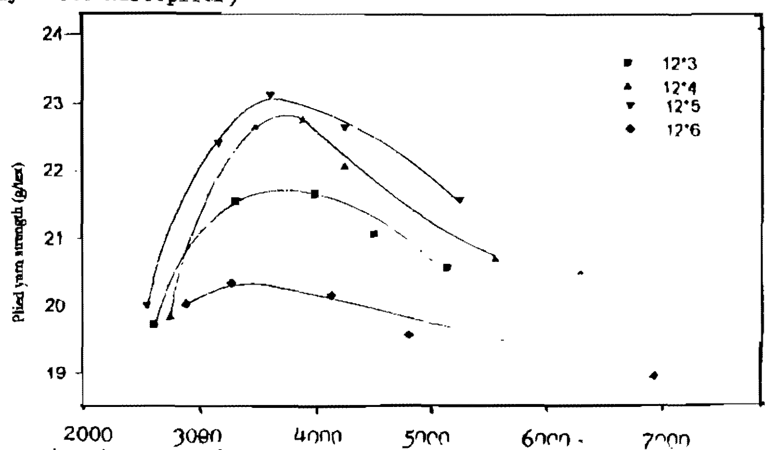
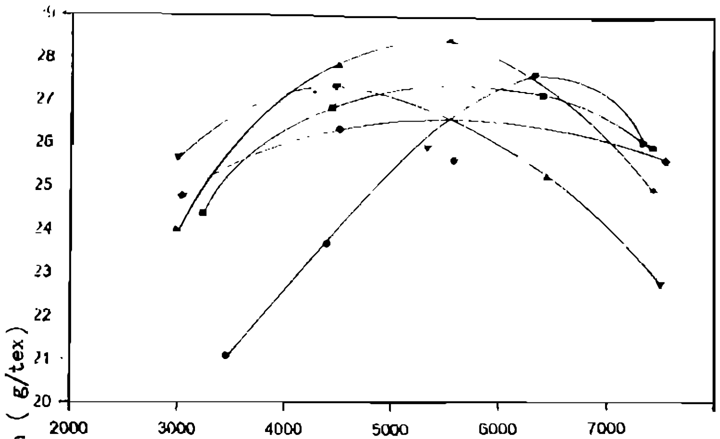


Fig.(7-b)

($\alpha_r = \tau . T_p^{0.6} (\alpha_s . 10^{-4})^{.74} / (0.8)^{m/10}$ Ply Twist Multiplier)



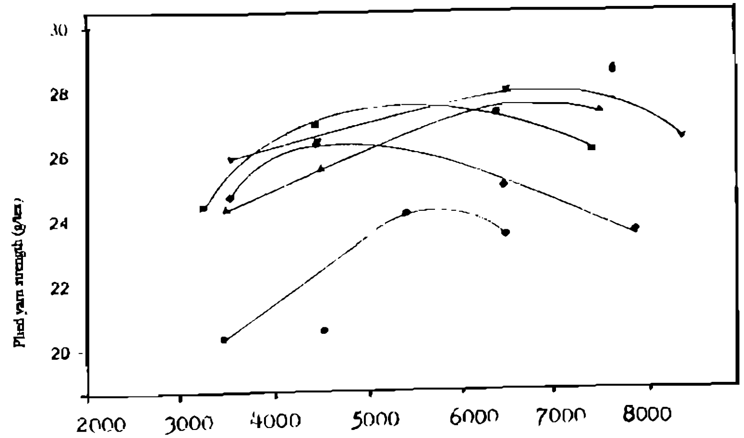
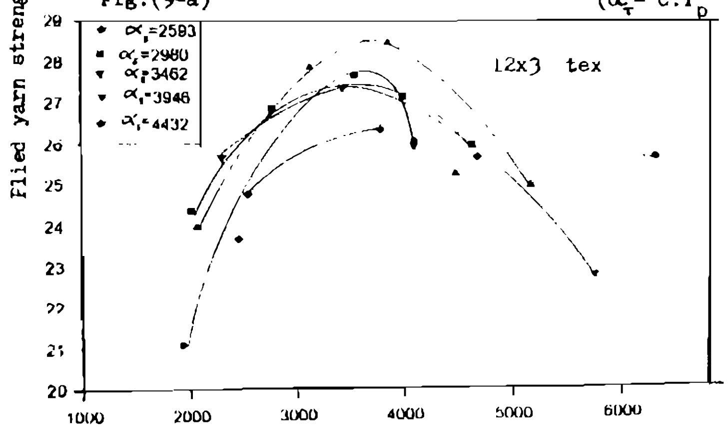


Fig.(9-a) ($\alpha_T = \tau . T_p^{0.5}$ Ply Twist Multiplier) Fig.(10-a)



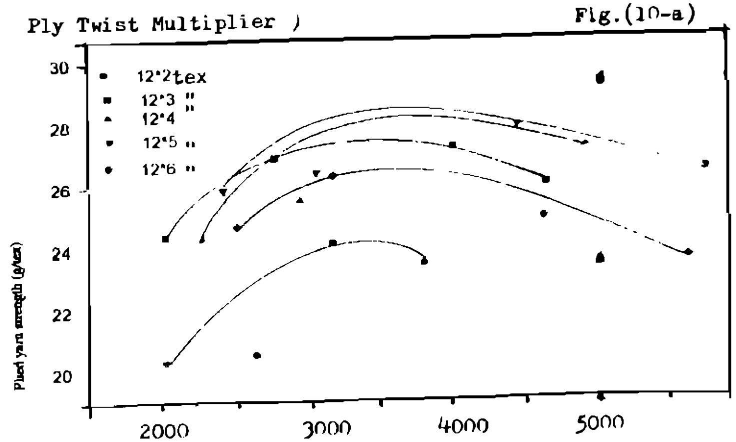


Fig.(9-b) ($\alpha_T = \tau . T_p^{.6} (\alpha_s . 10^{-4})^{0.74} / (0.8)^{m/10}$ Ply Twist Multiplier) Fig.(10-b