A STUDY OF THE DIAMETER AND CONTRACTION OF RING SPUN-YARNS

دراسه القطر والانكماش لخيوط الغـزل الحلقـــى

By

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الخلاصة :

يقدم هذا البحث بعض المعادلات التى يمكن استخدامها فى حساب قطر الخيوط ومعامل إنكماشها أثناء الغزل . وتشمل الدراسة تأثير اس البرم ونمرة الخيط وكثافة الحجم .

وقد أجريت تجاريت عملية على الخيوط القطنية المتخدمة فى هذه الدراسة بنمر مختلفة للتأكد من مدى صحة هذه المعادلات النظرية وتشير نتائج البحث النهائية إلى أن النتائج التى تم الحصول عليها باستخدام هذه المعادلات تتوافق إلى حد كبير مع النتائج الفعلية .

1. Abstract :

This paper presents some predicting formulas of yarn diameter and contraction of ring spun yarns. The study concerned the influence of twist multiplier, yarn count and bulk density. Experiments carried out on different cotton yarns to justify the results of the theoretical analysis. The results obtained with these empirical formulas agree satisfactorily with the actual data.

1. *Yarn Diameter :*

Several expressions for the calculation of yarn diameter have been put forward. The practical formulas suggested to express the yarn diameter can be devided into three groups :

i) The first group indicate that the variation of the yarn diameter with yarn count only[1,2,3]. Also, Pierce[4] and Onion et al.[5] made their measurements under com- pression arising from the fabric. Pierce[4] has stated that for cotton yarn, d (yarn diameter) = $36 / \sqrt{Ne}$

The constant represents an assumed specific volume of 1.1 c.c/g for all cotton yarns and the effect of tension and twist are ignord. Ashenhurst[6] used the equation

$$d = K \sqrt{\text{yards per Ib} * 840}$$

where K : is a constant which takes into account bulk density and compression of the yarn during weaving (K = 0.95 for cotton yarn). Law[7] proposed a similar relationship namely

$$d = \sqrt{800 * \text{counts for cotton yarns}}$$

where d : is the diameter of reciporcal (i.e. the number of threads that can laid side by side in unit distance "Inch" without over lapping).

ii) In the second of these account is taken of the yarn twist[8,15,16]. Van Issum et al.[8] pointed out that tension and twist affect yarn diameter. They suggested the form which can be translated to :

$$d = K' / \sqrt{Ne} + (\tau) \quad \text{or}$$

$$= K' / \sqrt{Ne} + (\phi - mT) \quad \text{(mills)}$$

Where K' : is a constant = 46.38

Ne : is the yarn count

ϕ : intercept of the regression line on the axis of ordinates.

m : slope of the regression line.

τ : is twist per inch.

Also, the effect of twist on yarn diameter statisti- cally determined and the regression equation take the form[9] :

$$d = 0.1765 + 0.004058\ T - 0.00114\ \alpha_{2/3} \text{ (mm)}$$

Where α : is the twist factor and T: is the yarn linear density (tex). Another form[10] for yarn count ranged between 17 tex and 50 tex with different twist multi- plier indicate the yarn diameter .

$$d = 4.496 / (\alpha_{2/3})^{0.2117} . Nm^{0.59115}$$

iii) The equations of the third group were set up with account taken of the density of the yarn[11,12]

$$d = 1.13 \sqrt{Nm. \ \gamma}$$

Where Nm : is meteric yarn count and γ : is the bulk density of the yarn viz 0.8 - 0.9 kg/m^3.

Barella[13] discuss the influence and application of the diameter factors and explore the effect of twist upon yarn density and postulated the law of critical diameter.

$$d = 2 \sqrt{\frac{Mm}{10^3 \, \pi \, \gamma}} \qquad \text{or}$$

$$= do - K'' \sqrt{F}$$

Where Nm : is meteric yarn count (m/g) or (Km/kg),

γ : is the yarn density.

do : Expermental yarn diameter in mm and

K" : is the coeffiecient equal to

$$\frac{2\left(\sqrt{\frac{1}{\pi\gamma}} - \sqrt{\frac{1}{\pi\,\gamma^1}}\right)}{\sqrt{10^3\ BL}}$$

Where γ^1 the fiber density, F_R : tenacity (g/den) and BL : Breaking length in Km and equal to $F_R . Nm/10^3$

Menshikova [14] suggested that the relation between the yarn diameter and its count is hyperbolic and described by the following equations :

$$d = \frac{a_o}{N_m} + bo \qquad \text{or}$$

$$= AT + bo$$

Also, the bulk density and count of yarn are linked by hyperbolic relation $= \frac{N_m}{C + F\,N_m}$ or $\frac{10^3}{CT + F}$

When Nm is the meteric yarn count; T is the tex of the yarn and γ is the density of yarn. It was found to vary between 0.53 and 0.78 for Nm 12 to Nm 85 while the literature gives a constant density of 0.8-0.9 Kg/m^3 for cotton yarn. ao, bo, c, F, A and F are

constant coefficients were calculated by the method of least squares Barella[13] has suggested the following formula for determining the yarn density as a function of twist multiplier

$$\gamma = a_1 + b_1\, \alpha_T^2 \quad 10^{-4}$$

where α_T is the twist multiple in tex system,
a and b_1 are coefficients that vary according to the type of fiber. Also, Karetsky[18] has found the type of fiber. Also, Karetsky[18] has found the relation between turns/m and yarn density as follows

$$\gamma = K_o \quad (\tau)^{0.5} \quad \text{where } K_o = 0.0285$$

In the present work, the first consideration is the prediction of a formula for the calculation of yarn diameter. In these calculations the yarn is usually assumed to have a cylinderical shape with small circular cross-section[21].

The mass in gram of a length of yarn "L meter"

$$M = V.\frac{1}{Y_y} = SL\ \gamma = \frac{\pi\ d^2}{4} L\ \gamma \quad (1.1)$$

$$= \frac{T}{1000}$$

Where S : area of yarn cross-section; V : the volume of lengh "L" of idealised yarn, Y_y : is the specific volume of the yarn expressed in $Cm^3/g.$, γ is the bulk density of yarn and T is the yarn linear density "tex" by equalizing Equations (1.1) and (1.2) and solving

for diamter $$d = 0.0357 \quad (T/\gamma)^{0.5} \quad (1.3)$$

The formula can be considered as original form for determination yarn diameter but the quantity of bulk density varies as obtained from the earlier ilterature[13,14].

From the expeimental results shown in table (1), the relationship between $Y_y = \frac{1}{\gamma}$ and γ is plotted graphically as shown in Fig.(1) and represented by the formula

$$\gamma = 0.0294 \quad \tau^{0.4887} \quad (1.4)$$

$$\text{where } \tau = \alpha_T / \sqrt{T} \quad (1.5)$$

By combining equations (1.4), (1.5) and (1.3) we get yarn diameter

$$d = 0.2082 \quad T^{0.622} / \alpha_T^{0.244} \quad (1.6)$$

Gregory[18] found that the twist multiplier for maximum strength could be represented as a function of "β" which equal to "$L_f\ \mu\ S$" where L_f : is baised mean fiber length, μ is the fiber friction coefficient and S : is mean.

Tab .1

Linear density tex	β $(m^2/g) \cdot 10^{-2}$	Actual twist T.P.m	$\alpha_T = \tau \beta^{0.21} T^{0.55}$	actual diameter mm	γ, cal. from eq. (1.3) gm/cm^3	diam. cal. from eq. (1.10)
25.7	0.38	571	2715	0.226	0.65	0.228
26.05		692	3354	0.218	0.69	0.217
26.30		768	3791	0.208	0.77	0.211
26.60		874	4358	0.200	0.84	0.204
27.05		987	5045	0.199	0.87	0.198
14.75	0.65	739	2885	0.160	0.73	0.161
14.82		792	3123	0.155	0.78	0.158
14.93		863	3452	0.151	0.83	0.155
15.05		965	3916	0.149	0.86	0.151
15.12		1038	4223	0.147	0.89	0.148
15.28		1143	4722	0.143	0.95	0.144
12.25	0.65	792	2792	0.146	0.73	0.146
12.33		887	3161	0.142	0.78	0.142
12.43		1045	3779	0.134	0.88	0.135
12.58		1216	4514	0.129	0.96	0.130
12.77		1393	5261	0.128	0.98	0.126
12.89		1487	5645	0.128	0.99	0.125

Specific surface of fibers (as a measure of fineness) and this coefficient "β" is drived by sullivan's theory[19].
Thus, the twist multiplier "α_T" calculated from the following formula[31] taken into account the coefficient "β"

$$\alpha_T = \tau \cdot \beta^{0.21} \cdot T^{0.55} \qquad (1.7)$$

$$\text{where } \beta = L_f \cdot \mu_f \cdot Nm_f \cdot 10^{-2} \qquad (1.8)$$

The values of twist multiplier applied for determining the bulk density "γ" and the following formula obtained and represented graphicaly in Fig. (2).

$$\gamma = 0.19 \ (\alpha_T^{0.54} \cdot 10^{-2}) / T^{0.18} \qquad (1.9)$$

By substituting from equation (1.9) in equation (1.3), the yarn diameter can be expressed as follows :

$$d = 0.0819 \left[T^{1.18} / (\alpha_T^{0.54} \cdot 10^{-2}) \right]^{0.5} \qquad (1.10)$$

In Fig. (3), the equation (1.10) has been represented. In such a graph the values of yarn diameter deduced from equation (1.10) are closely corresponding to those obtained experimentally.

2. Yarn Contraction :

The theoretical calculation of contraction has been dealt with Several Research Workers[20,21,22]. The treat- ment is based on the consideration of an idealized twist geometry and the occurance of fiber migration in the yarn.

Yarn contraction can be defined in terms of the length of zero twist yarn and the length of twisted yarn in two ways:

i) Contraction Factor "Cy" = $\dfrac{\text{Lengh of zero twist yarn}}{\text{Length of twist yarn}}$

Contraction factor is commonly used with staple yarn and $1 \le Cy < \infty$, and

ii) Retraction Factor "Ry" :

$$= \frac{\text{Length of zero twist yarn-length of twisted yarn}}{\text{Length of zero twist yarn}}$$

where $0 \le Ry < 1$ and the retraction is very useful when dealing with continuous filament yarn.

Among the theoretical relationship suggested to express yarn contraction factor in terms of twist multiplier we shall retain here one of the best knwon as following :

$$Cy = \frac{100}{\sqrt{1 \div E \quad \alpha_T^2}}$$

where :

E : is a constant takes several values as shwon in Table (2).

Table 2

Besset-Barella[23]	$E = 5.7 \times 10^{-5}$
Obukh[24]	$= 4.9 \times 10^{-5}$
Budnekov[25]	$= 5.97 \times 10^{-5}$

Another form suggested by Braschler[25] to express yarn contraction as follow :

$$Cy = \frac{2}{1 + \sqrt{1 + \frac{125.7}{10^3 \gamma} \left(\frac{\alpha_T}{100}\right)^2}} \cdot 100$$

Generally, from the idealized yarn geometry developed by Hearl[26], the relationship between the twist angle "α", turns per unit length (τ) and diameter of average spiral (ds) is :

$$\tan \alpha = 2 \pi R / h = \Pi \, ds \, \tau \qquad (2.1)$$

Schwarz[27] has reported that $ds = \delta \cdot d$ (2.2)

where δ is known as schwarz's constant and approaches unity for large numbers of fibers. Also, he has pointed out its usefulness in twist analysis. On the other hand, several research workers has reported the value of δ as show in the following Table (3)

Table (3)

Barella[13]	$\delta = 0.5$
Sakalov[28]	$= 0.71$
Karetsky[17]	$= 0.67$
Calculated value*	$= 0.80$

(*) From the present investigation

In Besset's report[23] the influence of twist on the length of cotton yarn is discussed and by analytical means arrives at the equation for yarn contraction

$$Cy = \left(1 - \frac{1}{\sqrt{1 + \tan \alpha^2}} \right) 100 \qquad (2.3)$$

From the theories that explain the phenomenon of yarn contraction, it would be possible in the present investigation to represent the relationship between contraction of ring spun yarns and twist multiplier, bulk density and yarn count.

If the values of yarn diameters Eq. (1.6) and (2.2) sub- stituted in Equation (2.1) we get

$$\text{Tan } \alpha = 0.523 \quad \alpha_T^{0.75} \quad T^{0.122} \qquad (2.4)$$

by combining this with the formula (2.3), a simplified expression is found for the contraction factor.

$$Cy = (1 - \frac{1}{\sqrt{1 + 0.2735\ T^{0.244}\ \alpha_T^{1.51}}} \quad 100 \qquad (2.5)$$

When the values of α_T and T are substituted in equation (2.5), the calculated contraction are not closer to the experimental values. Thus, we consider the formula of yarn diameter shown by equation (1.10).

$$d = 0.0819 \quad (T^{1.18} / \alpha_T^{0.54})^{0.5} \qquad (1.10)$$

and combining this with equation (2.2) in equation (2.1) we get

$$\tan \alpha = 0.2057 \quad \alpha_T^{0.73} \,.\, T^{0.09} \qquad (2.6)$$

When the above formula is substituted in equation (2.3) the contractions caused by twist refered to twist coeffiecient and yarn linear density can be expressed as follows :

$$Cy = (1 - \frac{1}{\sqrt{1 + 0.0423\ \alpha_T^{1.46} .\ T^{0.18}}} \quad 100 \qquad (2.7)$$

Also, a modified form of equation (2.7) in terms of twist multiplier "α " and bulk density "γ" can obtained as follows

$$Cy = (1 - \frac{1}{\sqrt{1 + 8.05 \quad (\alpha_T^2 / \gamma) .\ 10^{-5}}} \quad 100 \qquad (2.8)$$

The results obtained by use of this equation are presented in Fig. (4). The curves in Fig. (4) indicate the relation between the values of twist multiplier and the percent contraction. The calculated contractions are in almost exact agreement with the experimental results carried-out in the present study and the results obtained according to carminata's tables[29] and those of the Shirley Institute[32] and reproduced here in Fig. (4). On the same figure, it can be seen Braschler's, Besset-Barella, and Obukh-formulas gives the lowest values.

3. Conclusions :

The study of yarn diameter and contraction of ring spun yarns permits establishing the following conclusions :

i) Starting from the established theories for calculating yarn diameter and contraction, the study affords a empirical formula's to predict the probable.

Yarn diameter by means :

$$d = 0.0819 \ (T^{1.18} \ / \ \alpha_T^{0.54})^{0.5} \quad \text{and}$$

Yarn contraction by means :

$$Cy = (1 - \frac{1}{\sqrt{1 + 8.05 \ (\alpha_T^2/\gamma) \ 10^{-5}}} \ 100 \qquad (2.7)$$

Where α is the twist multiple, γ is the yarn density and yarn count in tex.

ii) The predicted values of yarn diameter and contraction is clearly dependent on twist multiplier, bulk density and fiber parameters.

iii) The calculated results deduced from the suggested practical formulas agree satisfactorily with the experimental data.

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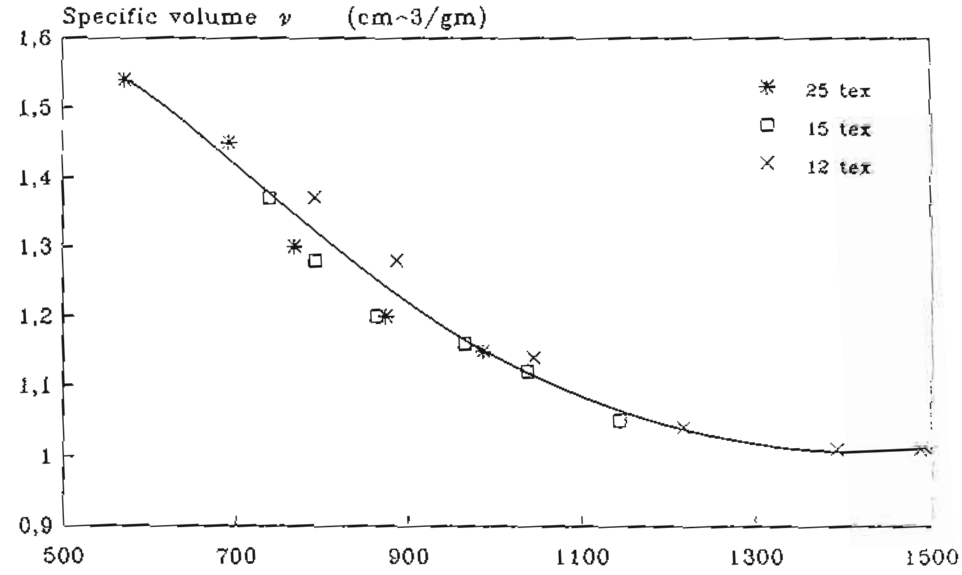
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1,5
1,4
1,3
1,2
1,1
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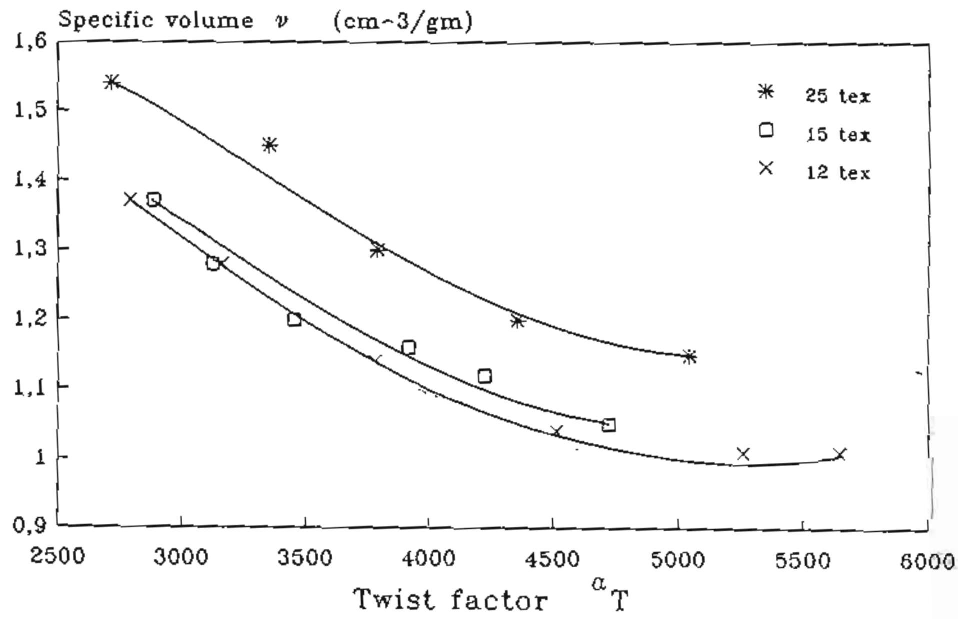
12 tex
500
700
900
1100
1300
1500
Twist τ (T.P.M)

Fig.(1)


Specific volume ν (cm-3/gm)
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1,1
1
0,9
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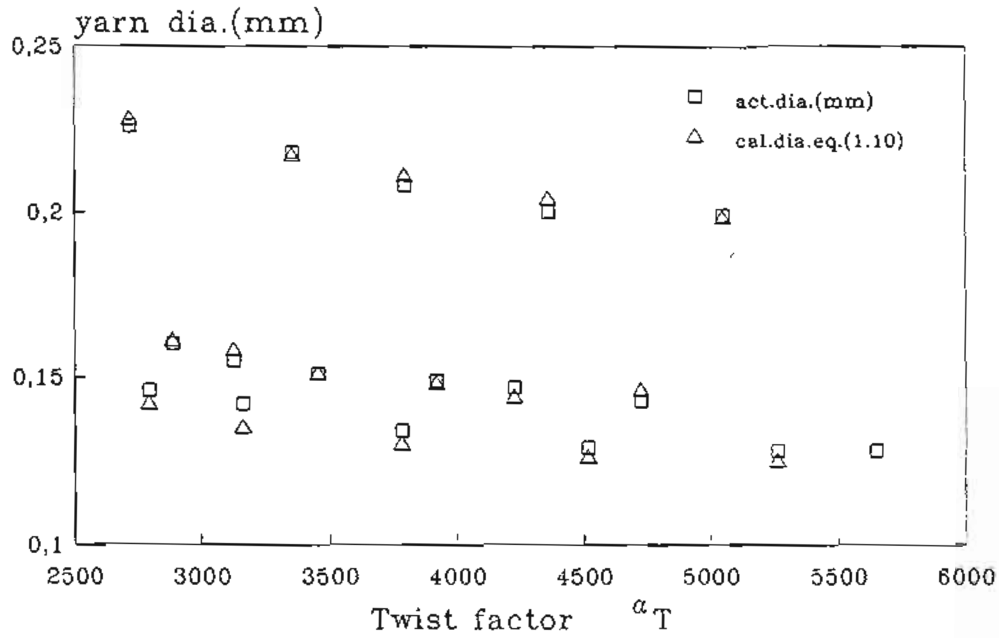
3000
3500
4000
4500
5000
5500
6000
Twist factor αT

Fig.(2)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0,2
0,15
0,1
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3000
3500
4000
4500
5000
5500
6000
Twist factor α_T

Fig.(3)

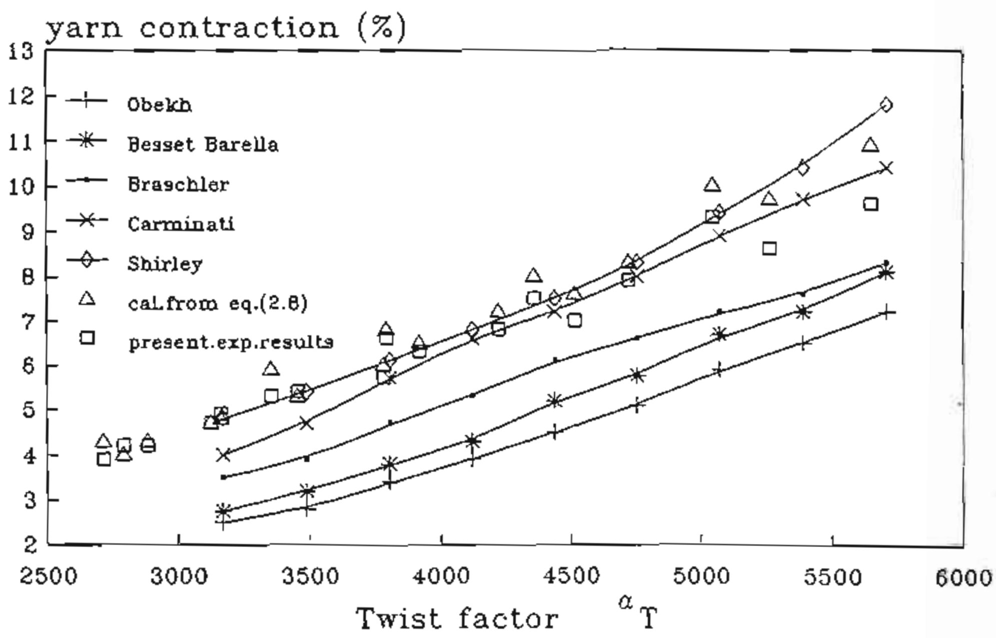
yarn contraction (%)
13
12
11
10
9
8
7
6
5
4
3
2
Obekh
Besset Barella
Braschler
Carminati
Shirley
cal.from eq.(2.8)
present.exp.results
2500
3000
3500
4000
4500
5000
5500
6000
Twist factor α_T

Fig.(4)