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Theoretical Principles of Slub Yarn Profile, Count and Twist Distribution

دراسة نظرية لاسس تركيب خيط السلب ونمر وبرمات الخيط

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ملخص البحث :

يقدم هذا البحث دراسة حول اسس تركيب، و انتاج خيوط السلب ، تصنيف خيوط السلب ، العناصر الاساسية لتصميم خيط السلب ، نماذج رياضية لتقييم الخصائص والنمرة وتوزيع البرمات لخيط السلب.

Abstract

The present work proposes the analysis of the basic principles of producing slub effect yarn as well as presents the slub yarn classification, describes the basic terms of slub yarn profile, the theoretical model of numeric evaluation of slub parameters, yarn count and twist distribution.

1. Introduction

Slub yarns have penetrated into many domains of textile industry. the mechanical properties of slub yarns were analyzed based on mathematical statistics(11) .

Yuzheng(1) build a mathematical model to deduct the twist distribution in the slub yarn which considered a base for the analysis of the mechanical properties of slub yarns. Uster technologies has developed a sophisticated software for the uster tester 5 which permit measurement of slub yarns(2,3) .Also, uster uses certain terms to describe a slub yarn but the relationship between the basic terms of slub yarn parameters, count and twist was not mentioned. In this paper the numeric evaluation of slub yarns and its relationship with count and twist distribution is predicted in order to provide information for the spinner , to Egyptian textile industry, to create and develop slub yarn

2. Slub yarn classification

Slub yarn is one of the kinds of fancy yarns. The geometry of the effect could be very different , Up to now, through the available reference sources it is possible to suggest the criteria that are significant for the grouping of assortment of slub yarns (18) as shown in fig(1)

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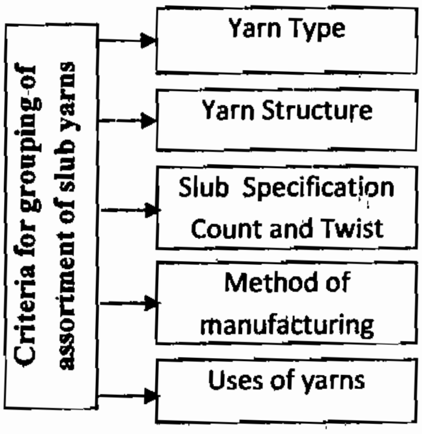


fig(1)

3- The Basic principle of producing effect types :

In addition of cheaper, oldest methods "fiber mixing" and the modification of the mechanical drive of the drafting system; The computer control of the drafting rollers using servo motors is another option which also has the added benefit of producing the slub effect types (4), see fig (2).

(i) Slub of same count and same length:

For the production of equal slub length and thickness, the duration of overfeed "the duration for the increase in speed of the back and middle roller " and also the amount of overfeed (%age increase in speed of back and middle roller" is kept constant for all slubs.

(ii) Slub of same count but Irregular length :

For the production of different slub length but same thickness the duration of overfeed is varied depending on length of slub required, but the amount of overfeed is kept constant for all the slubs.

(iii) Slub of Irregular Count and Irregular length:

For the production of different slub length and thickness, the duration of overfeed is varied depending on the length of slub required and the amount of overfeed is also varied depending on the thickness of slub.

(iv) Slub over slub with different length and thickness:

For the preparation of this type of yarn in the same duration of overfeed. The amount of overfeed is varied many times depending on the different thickness of slub required.

(v) Multi count yarn:

Each slub in a slub yarn can be extended to make a multicount yarn. i.e multicount yarn is a yarn in which the count of yarn changes at intervals along its length. The count of yarn changes within a pattern repeat, the yarn twist remains unchanged and the yarn twist multiplier changes due to the yarn sections with different count (5).

Multi effect is a special kind of effect produced by synchronized draft and twist variation with control devices. Multicounts are produced with a second servo motor connected to the front roller (6). Multi count yarn can also have short slubs in each count and this type of yarn known as Multicount - Multi slub yarn.

Multi Count yarn "are presently in great demand for denim yarn (7), pattern repeat consist of 2 to 5 yarn counts. The length of the yarn sections in the individual count is between 0.5 to 5 meters.

(vi) Multi twist yarn :

In Multi twist yarn, the yarn count remains unchanged, but the yarn twist changes and the yarn twist multiplier changes. These different twist levels create variations in the yarns dye intake, Thus creating a special fabric appearance. The twist difference causes a colour change in the fabric. Yarn sections with different twist absorb the colour particles differently which causes the colour effects.

vii) Combination of Multicount and Multitwist:

In some cases both methods are combined. The yarn count charges within a pattern repeat, the yarn twist changes and the yarn twist multiple also changes as showing in fig (2) b, c, d

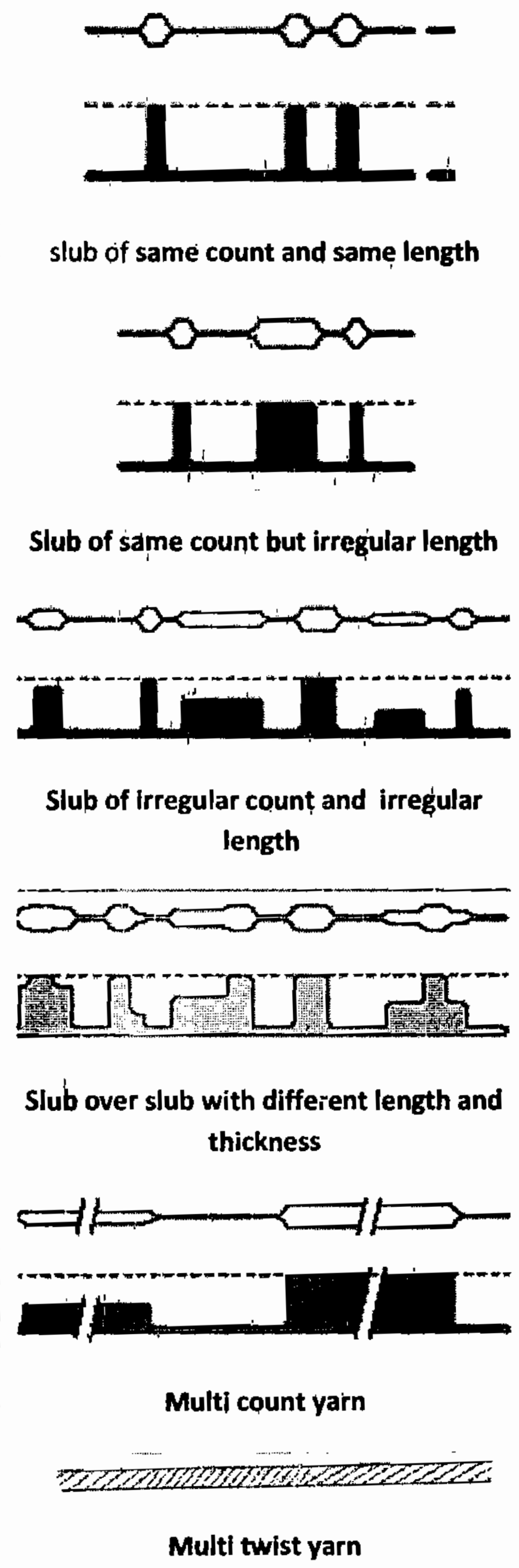
4-The Basic Terms of the slub yarn profile:

There are several terms used to describe a slub yarn. These terms are described (8) as following in order to give a clear picture of yarn construction and how to measure its parameters, see fig (3) and fig (4).

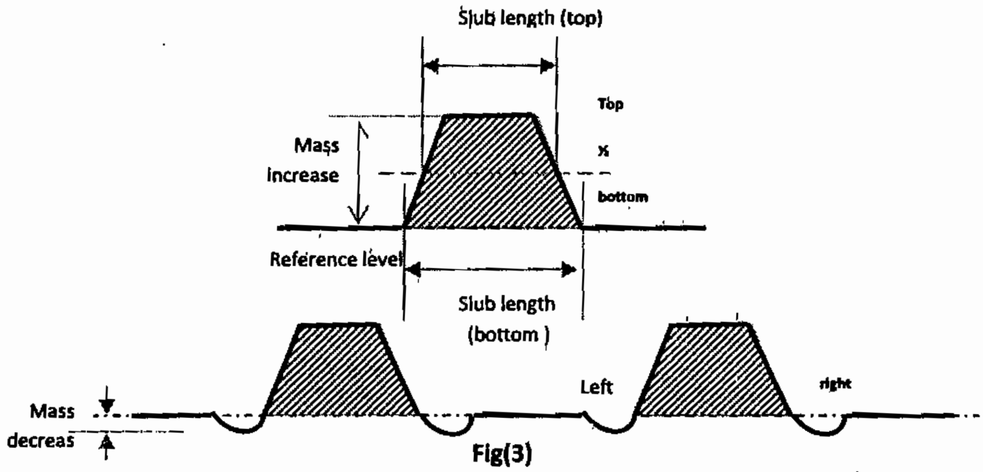
Ideal Slubs: For the slub making a trapezoidal shape was selected as it covers most of the slub shapes.

Reference Level: It is a line which is on the level of the base yarn. It's value defined as a percent (%) between the base and the top of the trapezoid and is set automatically by the software

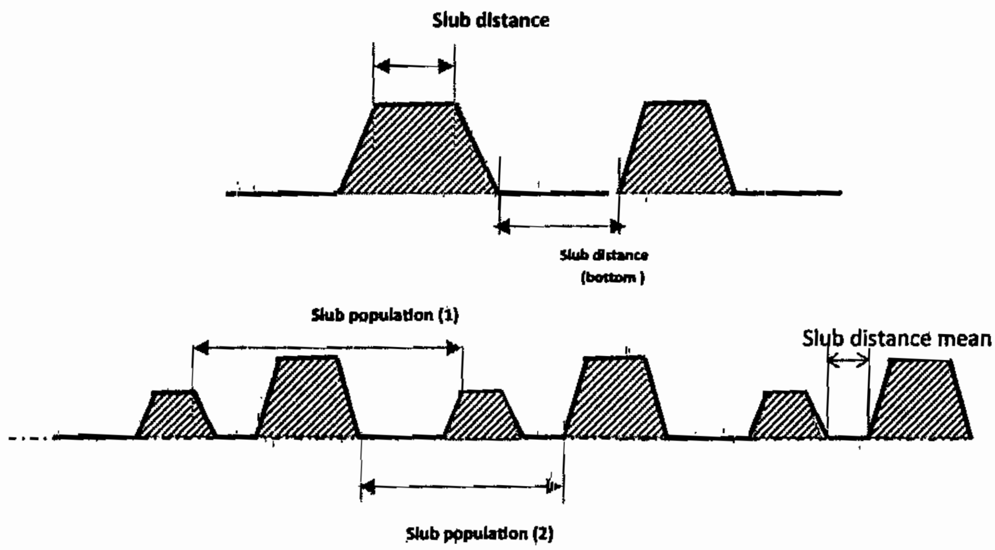
Mass Increase: is defined as the mass increase from the base to the top trapezoid. Percentage increase is equivalent to the mass increases of the slubs compared to the overall mass of the yarn.



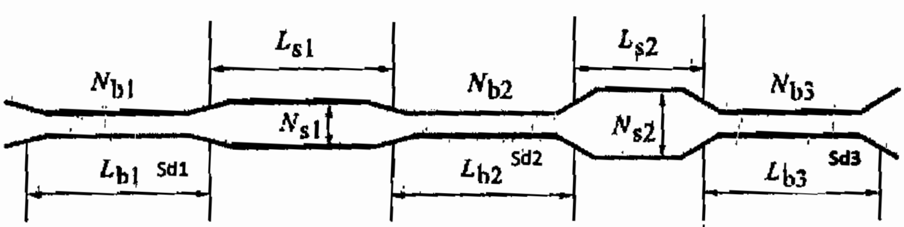
Fig(2) a- Slub effect types



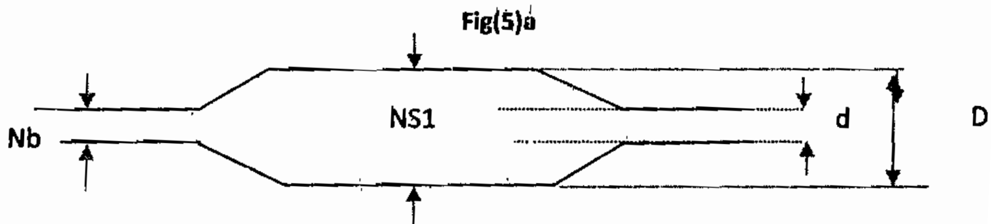
Fig(3)



Fig(4)



Fig(5)a



Fig(5)b

Fig(5) Geometrical parameters of slub yarn

The repetition pattern indicated by definition of the slub yarn mechanism of ZJ-V as follow:

i) Periodic slub yarn: has periodicity in its parameters setting, which means there are repetitions of slub length and slub distance based on ranking parameters.

ii) Random proportion slub: is to choose randomly the parameters in a particular series of data

Type	setting		Circle rule	periodicity
	Slub length	Slub distance		
*periodic slub	SL_1,SL_2,SL_3	Sd_1,Sd_2,Sd_3	$Sd_1\ SL_1,\ Sd_2\ SL_2,\ Sd_3\ SL_3$	Yes
* Random proportion slub	SL_1,SL_2,SL_3	Sd_1,Sd_2,Sd_3	Sd1 or Sd_2 or Sd_3 SL_1 or SL_2 or SL_3	No

6. Numeric Evaluation of slub yarns

6.1 Determination of basic parameters:

Possible numeric values of slub yarn are offered for the analysis of yarns. Referring to geometrical parameters of slub yarn, these are :

i. Number of slubs per unit length

Slub per meter =

$$\frac{\text{Absolute number of slubs}}{\text{overall total length}}$$

or

Ns/m= n/TL ---------(2)

Where : overall total length is the sum of total slub lengths and total slub distances i.e

$$TL = \sum_{i=1}^{n} SLi + \sum_{i=1}^{n} Sdi \quad \text{and}$$

$$\sum_{i=1}^{n} SLi = SL_1 + SL_2 + \ldots\ldots\ldots\ldots SLn$$

$$\sum_{i=1}^{n} Sdi = Sd_1 + Sd_2 + \ldots\ldots\ldots\ldots Sdn$$

ii. Average slub distance :

Average slub distance =

$$\frac{\textbf{Total slub distances}}{\textbf{Absolute number of slubs}}$$

or

$$Sdm = \sum_{i=1}^{n} sdi \Big/ n \qquad \text{----------------(3)}$$

iii. Percentage of slub distances (%)

It is equivalent to total slub distances comparing with the overall total length of program

% age of slub distances =

$$\frac{\sum_{i=1}^{n} Sdi}{\sum_{i=1}^{n} Sdi + \sum_{i=1}^{n} SLi} 100 \quad \text{------(4)}$$

where $sd_{min} \leq sd_m \leq sd_{max}$

sd_{min} : minimum slub distance [cm]

sd_{max} : maximum slub distance [cm]

iv. Average slub length

Average slub length =

$$\frac{\text{Total slub lengths}}{\text{Absolute number of slubs}}$$

or

$$Sl_m = \sum_{i=1}^{n} SLi \Big/ n \quad \text{-----------------(5)}$$

Percentage of slub length's :

It is equivalent to total slub lengths comparing with the the overall total length of program .

% age of slub length's =

$$\frac{\text{Total slub lengths}}{\text{overall total length}} . 100$$

or

$$\% SL_m = \frac{\sum_{i=1}^{n} SLi}{\sum_{i=1}^{n} SLi + \sum_{i=1}^{n} Sdi} * 100 \text{------(6)}$$

where $SL_{min} \leq SL_m \leq SL_{max}$

SL_{min} = mininum slub lengt(cm)

SL_{max} = maximum slub length (cm)

minimam slub length is about 20 mm and it depends on: fiber quality, while max. length depends on yarn choice .

The slub effect lengths are changed practicaly through a potentiometer and synchonized with ring spinning machine speed. Also, they are established by punching at your liking the film controlled by the electronic system. In general, it is possible to get every slub length but not shorter than the fiber length. On open – end spinning machines, the minimum slub length equal to the circumference of the rotor fitted on the machine .

vi. The slub effect size "or slub thickness"

The slub size is obtained by adjusting the charge acceleration through a pneumatic regulator, provided with graduated scale, placed on the actuator group. Slub thickness varies between 0.1 to 5 (steps = 0.01)

Slub thickness is the ratio of the maximum diameter (of slub) and the minimum diameter of base yarn, see fig (5)b

$$\textbf{Slub Thickness} = \frac{\textbf{Maxi Diameter}}{\textbf{Min Diameter}} \quad \text{or}$$

$$ST = D_s / d_b \quad \text{---------(7)}$$

Mean slub thickness =

$$\frac{\text{Total slub thickness}}{\text{Absolute number of slubs}} \quad \text{or}$$

$$ST_m = -\sum_{i=1}^{n} ST \Big/ n \quad \text{-----------(8)}$$

Where

ST_{min} : the minimum slub thickness (mm)

ST_{max} : the maximum slub thickness (mm)

and $ST_{min} \leq ST_m \leq ST_{max}$

vii. Slub per minute or "insertion per min" :

The optimal speeds are been determined by the yarn characteristics and the production of slubed yarn on the spinning machine is no more left to mechanical factor but depends only on the strength and quality of the processed fibers .

Insertion per min =

slub per meter * front roller speed

ns/min = ns/m * vd ---------------(9)

ns/min < 35 insertion / min for electromagnetic clutch, and ns = 200 insertion / min for electro-pneumatic clutch .

6.2 Count of base, slub and final yarn :

Slub yarn is produced from spinning machine with slub yarn attachment. As soon the device is put into action, the draft in the main drafting zone of the drafting arrangement in ring frame is cancelled by accelerating the back and middle and bottom roller of the drafting system so that the under drafted roving appears as slub in the spun yarn. The nominal yarn count (**N_o**) is determined by the roving count (**N_r**) and spinning draft (**V**) .

Several factors influencing the characteristics and appearance of slub yarns are: (**N_f**) metric count of finial yarn (m/g), The average number of slubs per meter (**ns/m**); The ratio of the maximum to the base diameter (**D/d**); The average distance between two consecutive slubs (**sdm**), and slub length (**SL**) .

Thus, from the slub yarn parameters: min and max sulb length, min and max slub distance, min and max slub thickness and absolute number of slub (**ns**), it can be calculated the different slub yarn parameters as given in section (6.1), such as :

Ns/m : number of slub per meter

SLm : average slub length

Sdm : average slub distance and

D/d or ST : slub thickness

These parameters are required to produce slub count, the base count and the final yarn count as following :

Total number of slub in 100 meter =

number of slub per meter * 100

TSL = 100 . ns/m ———(10)

Total slub lengths in 100 meter

= Total number of slub in 100 meter *

mean slub length

TSL = 100 ns/m . SLm ———(11)

Total slub distance in 100 meter

= 100 – Total slub lengths in 100 m

= 100 – Tns/m . SLm

= 100 – 100 ns/m . SLm

= 100 (1-ns/m . SLm) ———(12)

Thus, the metric count of the slub free yarn is Nf. It is possible to determined by the following relation :

Final yarn count (N_f)

$$= \text{Length (m) / weight (g)}$$

$$= 1/Q \text{ (gram)}$$

$$= 1/(Q_m + \Delta Q_m) \quad \text{---------(13)}$$

where : Q_m: mass of the base yarn

$$(\text{equal to } 1/Nb) \quad \text{------(14)}$$

ΔQ_m = the additional amount of roving required for slub formation .

In practice, to obtain ΔQ_m, a certain yarn length (L') not less than 100 meter is measured, and this known length is used the mass difference between the slub yarn and a yarn of equal count and length but without any thickening,

The value of ΔQ_m necessary to obtain the final count value can be determined :

Q_m = (mass with slub – mass without slub) / length considered

$$= \frac{\text{Total slub length/100m . slub thickness}}{\text{base count}}$$

or

$$= \frac{TSL/100m. * ST}{Nb} \quad \text{-------------(15)}$$

by substituting from Eq (14) and Eq (15) in Eq (13), we get final count (Nf)

$$Nf = \frac{100}{\frac{TSd/100m}{Nb} + \frac{TSL/100ST}{Nb}} \text{ or}$$

$$Nf = \frac{100Nb}{TSd/100m + TSL/100m.ST} \text{---(16)}$$

where Nb : metric count of the base yarn

from Eq. (16) we can determine the metric count of the slub free yarn (g/m)

$$Nb = \left(\frac{TSd + TSL.Slub\ ThicknesS}{100}\right).Nf$$

$$= (\%TSD + \%TSL.ST).Nf \text{----(17)}$$

by substituting from eq.(11) and (12) in Eq (17) we get

$$Nb = (I + ns/m. \frac{SLm}{100}(D/d - 1)) \text{--(18)}$$

Also slub count "Ns"

$$= \frac{\text{percent total slub lengths}}{\text{add.amount of roving}} = \frac{\%TSL}{\Delta Q_m} \quad (19)$$

By combining Eq (15)and (19)

$$Ns = \frac{ns/m.SL_m \quad Nb.Nf}{100\ (Nb - Nf)} \quad \text{-----(20)}$$

$$\text{or} \quad \frac{ns/m.SLm.CR \quad Nf}{100(CR - 1)}$$

where CR is base count / final count ratio .

6.3. Twist Distribution in the Slub Yarn :

From the geometry of yarn (9, 10) as shown in fig (6) and fig (7), the yarns are assumed to be circular in x-section, no fiber migration, center fiber will follow straight path. Density of backing fibers in the yarn is constant, yarn is made of a large of number of fibers .

h : length of yarn in one turn of twist .

ℓ, L : length of fiber in on turn of twist

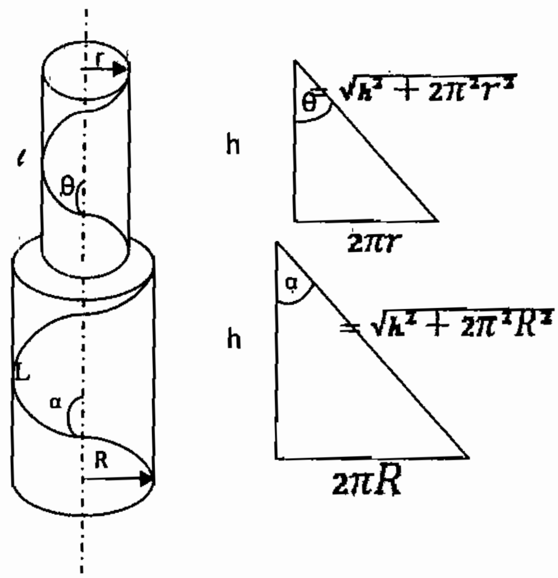
r, R : radius of cylinder containing the helical path of a particular fiber and yarn

T : yarn twist "|turns per unit length

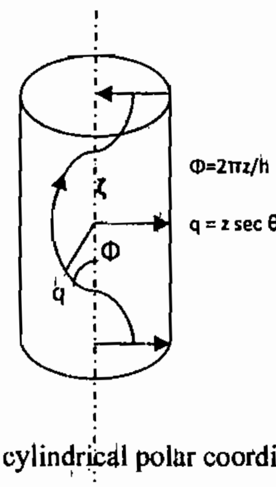
θ, α : helix angle at radius r and R

φ : angular rotation about yarn axis

q, z : length along a fiber and yarn



Fig(6) idealized helical geometry



fig(7) cylindrical polar coordinates

In any yarn has a cylindrical form in x-section, it can be drive yarn count, yarn diameter, twist factor, angle of twist and its relationship as follows:

i. **(Ntex) yarn count in tex =**

$$10^5 \frac{\Pi R^2}{\gamma y} = 10^5 (\Pi dy^2/4)\ \sigma y \quad \text{--------(21)}$$

Where

γy (cm^3/g) : is the specific volume of the yarn

σy is the yarn density

ii. Yarn diameter :

From Eq. (21)

$$dy = 3.569 * 10^{-3} (Nt. / \varphi.\ \sigma f)^{0.5} \text{---(22)}$$

Where φ is packing factor which is affected by twist

$$\varphi = \frac{\text{yarn density}}{\text{Fiber density}} = \frac{\sigma y}{\sigma f}$$

$$= \frac{\text{fiber specific volume}}{\text{yarn specific volume}} \quad \text{---------(23)}$$

iii- Twist factor and helix angle :

$$\tan \alpha = \Pi d/h = 2\Pi RT \quad \text{----------(24)}$$

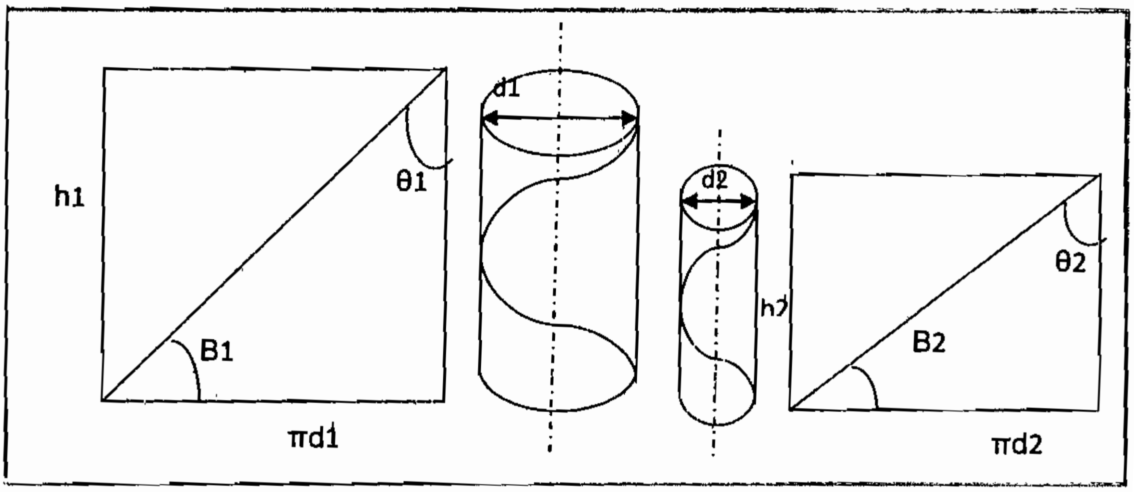
by combining Eq (24) with Eq (22) we get

$$\tan \alpha = 0.01121\ \gamma y^{0.5} Ntex^{0.5}.T \text{----(25)}$$

For two yarns having the same angle of twist, the same material, with different count or diameter and combining Eq.(25) with Eq.(24), as shown in fig(8),hence, T (turns/m) equal to:

$$\text{Twist} = \alpha_{tex} / \sqrt{tex}$$

$$\alpha_{tex} = T_1 (N_{tex1})^{0.5} = T_2 (N_{tex2})^{0.5}$$



Fig(8)

From this point of view, its clear that these are a relative between twist factor and twisting angle, the two quantities are directly related in yarns of the same specific volume so that yarns of different count but of the same twist factor will be geometry similar differing by a dimension less scale factor and thus .

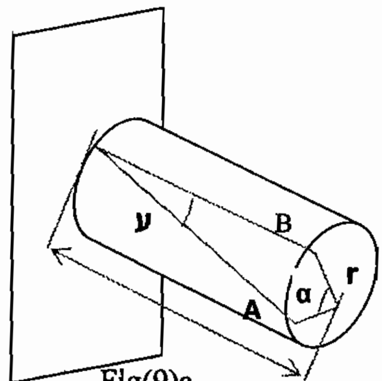
$$\alpha_{tex} = T\sqrt{N_{tex}} \quad \text{------------------(26)}$$

$$= T.\ Tex^{0.5}$$

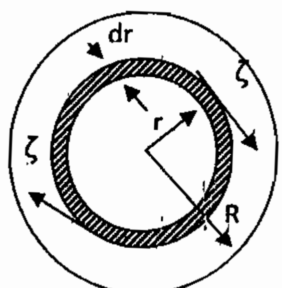
by combining Eq. (25), and Eq. (26) we get

$$\tan\alpha = 0.01121\ \gamma y^{0.5}\alpha^{tex} \quad \text{-------------(27)}$$

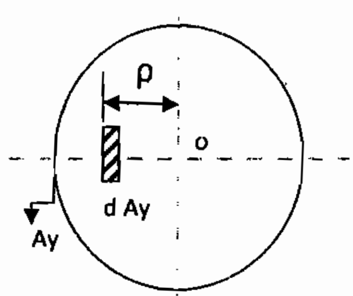
from the mathematical and mechanical relations of the stress, strain and torsion of a subject (11) as shown in fig (9) the torsion of a subject is consistent with the following equation .



Fig(9)a



Fig(9)b



Fig(9)c

length of arc (AB) = γ L = rα ---- (28)

where

γ : shear stress angle

L : length of the bar

r : radius of the bar

α: Is the torque angle

$$\text{Shearing modulus (G)} = \frac{\text{Stress}(\tau)}{\text{Strain}(\gamma)} \quad \text{— (29)}$$

Shear stress (τ) =

$$\frac{Shearing\ load(Q)}{Area\ of\ rod\ x-seetion(A)} \quad \text{—— (30)}$$

Shearing modulus (G) =

$$G = \frac{\tau}{\gamma} = \frac{Q}{A\gamma} \quad \text{----------(31)}$$

and combining Eq. (28) and (31) we get

$$\frac{G\alpha}{L} = \frac{\tau}{r} \quad \text{-------(32)}$$

Also, the relation between torque and shear stress as shown in fig (9) the torque applied to the circle at center M is equal to τ. 2πrdr,r while the cylinder.

$$M = \int_0^R \tau'.2\Pi r^2 dr \quad , \frac{\tau'}{\tau} = \frac{r}{R}$$

$$= \frac{2\Pi\tau}{R}.\frac{d^4}{64} = \frac{\tau}{R}\left(\frac{\Pi d^4}{32}\right) = \frac{\tau}{R}I \quad \text{---(33)}$$

where

I = polar moment of inertia=$\pi d^4/32$

by combining Eq. (32) with Eq. (33) we get

α= ML / GI

For a yarn it can be expressed as

$$\textbf{Twist (T)} = \alpha / L = M/GI \quad \text{----- (35)}$$

Also, it has been proven that the yarn density "σ_y" increases with the twist multiplier, Baralla (12), and σ_y affects the shearing modulus "G_y" and the polar moment of inertia "1_y" of the yarn .

Assuming the cross-section of the yarn with uniformity distributed fibers is circular, the yarn density on certain cross-section is "σ_y" and the fiber density "σ_f". The filling ratio of the yarn "ψ" is defined as follows :

$$\psi = \sigma_y / \sigma_f \quad \text{---------(36)}$$

Also, from eq (31), for yarn the shearing modulus will be

$$Gy = Q/A_y\gamma \quad \text{--------(37)}$$

Where Q is the shearing load on the yarn, and Ay area of yarn cross section and □ is the yarn strain

Assuming that both the fibers and pores will be deformed but actually all shearing is acted only on the fibers. If Q is relatively small the shape of the yarn would not change. Also, the volume ratio of the fibers would have the same strain thus the sum of shearing load acted on the fibers is equal to "Q" and all fibers have the same shearing modulus Gf

$$Gf = \frac{Q}{A_f.\gamma} = \frac{Q}{A_y.Q\gamma} \quad \text{-------------(38)}$$

from Eq (38) and Eq (37) we get

$$Gy = Q\ Gf \quad \text{-------------(39)}$$

From the relation represented the polar moment of inertia and considering the fibers are uniformly distributed in the yarn as shown in fig (9) c .

Iy =

$$\int_{Ay} \rho^2 dAy.Q = Q \int_{Ay} \rho^2 dAy = \frac{\Pi}{32} d^4 y.Q \quad \text{------(40)}$$

From Eq. (40) and Eq. (21) we get the relationship between σ_y and l_y

$$I_y = \frac{Nt^2}{2\times 10^{10}\Pi\ Q\sigma^2 f} \quad \text{------(41)}$$

From Eq. (41), Eq. (39) and Eq. (35) we can get the twist distribution in the yarn .

$$\mathbf{TNt^2 = 2.10^{10}\, \pi \left(\frac{M\sigma^2 f}{Gf}\right)} \quad \text{------ (42)}$$

For slub yarn, the torque "M" in any cross section along the yarn axis is equal and fiber density "σ_f" and shearing modulus "G_f" are constant so that

$$\mathbf{T.N_t^2 = Constant} \quad \text{------(43)}$$

That means, the twist in any cross section varies inversely as the square of linear density (yarn tex) of yarn .

To investigate the influence of some parameters of slub yarn on twist distribution. Testore et. al (13) and wang et. al (14) indicate that the yarn appearance is influenced by the length and linear density of two parts: base and slubs .

Also, Yuzheng et. al (1) prove that the twist is inversely proportional to the square of linear density, twists should be equal as long as having the same linear density, moreover, the increased linear density leads to the decreased twists .

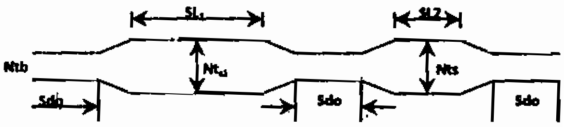


Fig (10) showed the appearance of a regular slub yarn in a cycle

On the assumption that, the slub yarn is periodic and acceding to conservation of twists, in a cycle, the twist number would determined by the spinning machine. For ring spun machine, the design twist is related to the configuration of the twist gear .

If we consider that :

$$\mathbf{Td = \alpha m\, .\, \sqrt{Nmf}} \quad \text{------(44)}$$

or

$$\mathbf{= ns_p / vd}$$

where :

nsp : spindle speed (r.p.m)

vd : delivery speed (m/min)

αm : metric twist multiplier and

$N_m f$: final yarn count metric system

Td : the design twist (t/m)

Tb : is the twist of the base yarn (turns / meter)

Sdo : is the sum of all base yarn length in a cycle or all the slub distances

Ntb : is the linear density of the base yarn

n : is the number of slubs with different linear density

Ntsi (i = 1 to n) : is the linear density of the slub

Tsi (i = 1 to n) : is the twist of the slub with linear density (Ntsi)

Sli (i = 1 to n) : is the sum of the length of slubs with linear density Ntsi in a cycle.

And suppose that the transition section is not present, the relationship mentioned above can be expressed as follows .

$$Tb.\ Sdo + Ts_1\ Sl_1 + Ts_2.\ Sl_2 + \dots\dots\dots + Ts_n.\ SL_n = \sum_{i=0}^{n} Tj.Lj$$

$$\sum_{j=0}^{n} Tj.Lj = Td\sum_{i=0}^{n} Lj \quad \text{----------(45)}$$

$$T_b.Nt^2b = Ts_1.Nt^2s_1 = Ts_2.Nt^2s_2 = \dots\dots\dots = Tsn.\ Nt^2sn = Tn\ Nt^2sn$$

$$Ti\ Nt^2s_i = Constant(C) \qquad i=0\ ,\ \dots.n$$

$$Tj = C/Nt^2i \quad \text{-----------(46)}$$

From Eq (45) and Eq (46)

$$\therefore Ti = \frac{Td\sum_{j=0}^{n} Lj}{N_t^2 si\sum_{j=0}^{n}\frac{Lj}{Nt^2 j}} \quad \text{-------(47)}$$

Because Ntb is the smallest in Nti (i = 0 to n), twist of base is always larger than design twist **(Tb > Td)** for the thickest slub in yarn with the largest linear density $\mathbf{Nt_{si}}$, $\mathbf{Ts_i}$ must be smaller than design twist (**Td**), i.e

$\mathbf{T_{si} < Td}$.

When the slub is not periodic, along section of the yarn can be chosen, turning the non periodic slub yarn into periodic one, and then relation given by Eq. (47) can be used to analyze the twist of the chosen section of the slub yarn .

In order to simplify the analysis, the regular slub yarn only with one slub in its cycle is supposed for analysis, then the equation (47) can be rewritten as following :

$$Tb = \frac{Td(Sdo + SL_1)}{Nt^2b(\frac{Sdo}{Ntb^2} + \frac{SL_1}{Nts_1^2})} \quad \text{-----(48)}$$

or

$$= \frac{Td\ (1 + \bar{R})}{1 + \bar{R}\ /X^2} \quad \text{------(49)}$$

and

$$Ts_1 = \frac{Td(Sdo + SL_1)}{Nts_1^2(\frac{Sdo}{Ntb^2} + \frac{SL_1}{Nts_1^2})} \quad \text{----(50)}$$

or

$$= \frac{Td\ (1 + \bar{R})}{X^2 + \bar{R}} \quad \text{-------(51)}$$

Where $\bar{R} = \frac{SL_1}{Sdo}$ ratio of slub length/slub distance

$\mathbf{X} = \left(\frac{Nts_1}{Ntb}\right) \succ 1$; **X** is the multiplier : or thick ratio between slub and yarn base

Equation (49) indicate that :

$\bar{R}$ is a key factor to **Tb** (base yarn twist),

X affects **Tb** slightly and Tb increases significantly with increase of $\bar{R}$ .Equation (51) reveals that x is a key factor to Ts, while $\bar{R}$ rarely has impact on $\mathbf{Ts_L}$ and the increased **X** leads to the significant decrease of $\mathbf{Ts_1}$. In practical production $\bar{R}$ reflect the length of the slub, thus the control of $\bar{R}$ can avoid **Tb** exceeding the critical twist while the control of **X** can adjust

Ts_1, in case that twists of the slub is too low to make the yarn failure .

To simplify the mathematical relations for determining the amount of twist for slub yarn taking into consideration the following :

Firstly we indicate that the slub yarn linear density is influenced by length, density of two parts of yarn "base and slubs" as well as slub thickness and number of slub per meter and defined as follow.

Nb = (% Tsd + % Tsl. SLm). Nf -(17)

and

$$Ns = \frac{ns/m.\ SLm.\ CR.\ Nf}{100\ (CR-1)} \quad \text{---(20)}$$

Where:

SLm; % TSL : mean slub length and % age total slub lengths.

Sd, % Tsd : slub distance and % age of total slub distances

STm, CR : average slub thickness and Base count to final Count ratio.

Nf : Required final yarn count

Ns: slub count

Secondly, The relation of yarn count and Twist factor represented by empirical formula as follow.

$$\alpha_{tex} = T\sqrt{N_{tex}}$$

$$= T\ C^{0.5}\ \text{turns tex}^{0.5} \quad \text{-------- (26)}$$

Thus, The Twist values for slub yarn can be determined as follow :

Design Twist (Td) = $\alpha_m\ (Nf)^{0.5}$ -(52)

For Base yarn : by combining equation (17) in equation (52) we get.

Base Twist "Tb" = $\alpha_m\ (Nb)^{0.5}$

$$= Td\left(\frac{Nb}{Nf}\right)^{0.5}$$

$$= Td\ (\%\ Tsd + \%\ Tsl\ STm)^{0.5} \text{ --- (53)}$$

For slubs : By combining equation (20) in Equation (52) we get:

Slub Twist Ts = $\alpha_s\ (Ns)^{0.5}$

$$= Td\left(\frac{Ns}{Nf}\right)^{0.5}$$

$$= Td\left[\frac{ns/m.SLm.CR}{100(CR-1)}\right]^{0.5} \text{ -----(54)}$$

7- Graphical evaluations of slub yarns:

Based on the numeric data of the slub yarn, a software has been developed in the present work to :

- Permits the accurate calculation of slub yarn parameters,
- Giving detailed analysis of the slub in order to provide information for the spinner to create and develop slub yarn effect, and
- Offers a wide range of graphical possibilities to evaluate the yarn like
  - (i) The pattern slub yarn parameters "size of slubs, their distance and the mass increase".
  - (ii) The frequency distribution analysis.
  - (iii) The sequence of the slubs diagram.
  - (iv) Original mass diagram "Original, with slub zoomed and without slub"
  - (v) Histogram for slub length, slub distance and for mass increase.
  - (vi) The spectrograms "for slub only, slubs removed and spectrogram mass".
  - (vii) Yarn appearance.

We have design the graphical user interface (GUI) to design a fancy yarn model depending on number of steps in each step we can control in three effected variables. These variables are yarn base (pausa), Slub Length (SL) and Slub Thickness (ST).

And we have opened up the possibility for the user to control three variables and determine whether these variables variable or fixed as shown in fig.(11)a:

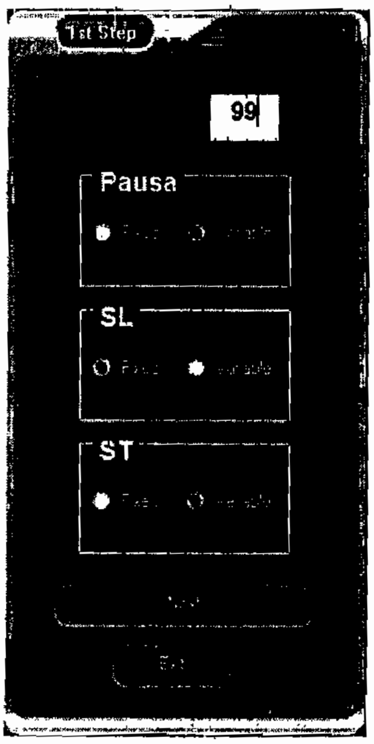
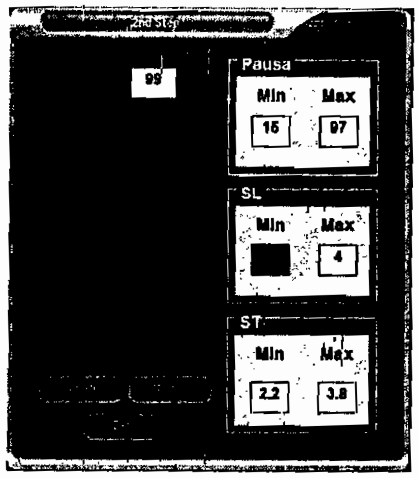


Fig.(11)a

In the following fig(11)b, a user can specify the minimum and maximum values for the variables and thus have defined the form of the model of fancy yarn.



Fig(11)b

According to the user's choice of the values of variables the program are determining the yarn forming and can imagine the final form of yarn and determine its own features and analysis.

Fig.(11)c illustrates the frequency distribution of Slub distance, Slub length and Thickness for designed fancy yarn model.

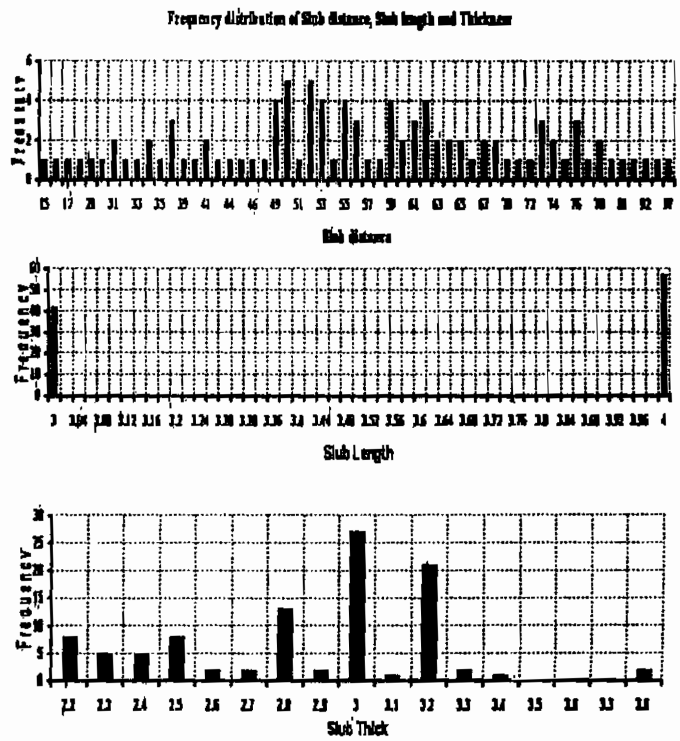


Fig.(11)c

Mass diagram:

As shown from the Fig.(11)d, the mass diagram is the basis for all calculations. In this diagram, the measurement of the yarn can be followed over the x-axis. The y-axis gives the mass increase of the yarn. The slubs can be analyzed in detail. When zooming in, the trapezoids of the ideal slubs get visible. In order to analyze the base yarn without the slubs, it is possible to remove the slubs from the diagram

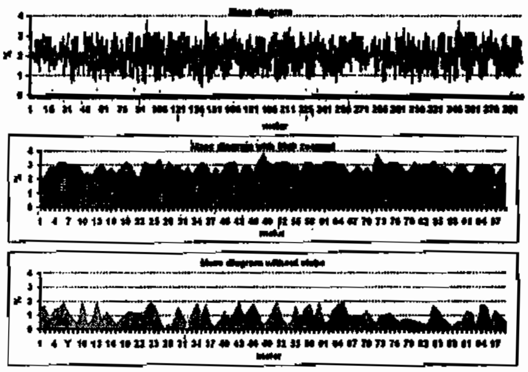


Fig.(11)d

Sequence diagram:

The purpose of the sequence diagram Fig.(11)e is to make patterns in the sequence of the slub easily visible. This diagram shows the exact sequence of the slubs separated in slub distance and slub length. The x-axis shows the number of the slubs, whereas the y axis shows the lengths of the slub (orange) and the distances (blue) between the slubs.

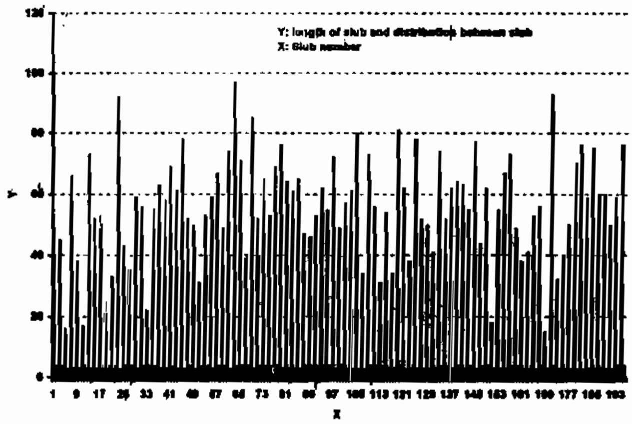


Fig.(11)e

Histogram:

The spectrogram Fig.(11)f is an ideal tool to check various aspects of a slub yarn. With the possibility to separate the base yarn from the slubs, the base yarn can be evaluated separately. Deliberate disturbances on the spinning machine or unexpected faults can be detected separately from the slubs.

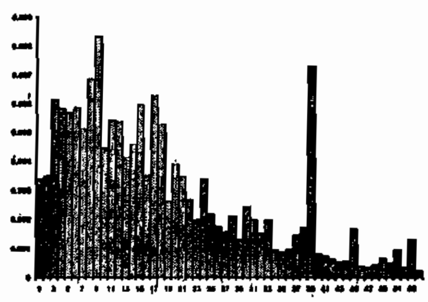


Fig.(11)f

8-Experimental work

To verify the theoretical assumption (sec.6), the experiment was constructed for production slub yarn Ne 20 at six levels of design effect and five levels of twist multiplier as shown in Table (1). In this concern the present work was planned according to the standard technique (1)

Table (1)

Program Code No.	Slub parameters: Slub distance "pause"(cm) min	max	Slub length (cm) min	max	Slub Thickness min	max	Twist Multiplier (α e) 3.4	3.6	3.8	4	4.2
I	25	269	3	5	2	5	×	×	×	×	×
II	46	104	4	6	2.5	5	×	×	×	×	×
III	11	133	3	7	2,1	3	×	×	×	×	×
IV	15	97	3	4	2,2	3.8	×	×	×	×	×
V	6	67	3	7	2	2.5	×	×	×	×	×
VI	10	30	8	12	2	2	×	×	×	×	×

Ne= 20, Roving count(Ne)=1

Table (1.1) Numeric Evalution of slub yarn

Program code No.	Program total length TL(m)	Percentage of Slub dist Sd%	Percentage of Slub length SL%	Number of slubs/meter us per meter	Slub Dist. (mean) cm	Slub length (mean) cm	Slub Thickness (mean) STm
I	168.2	97.66	2.34	0.589	165.92	3.969	3.84
II	79.9	93.72	6.28	1.240	75.68	5.0	3.76
III	73.4	93.51	6.49	1.348	69.4	4.76	2.57
IV	58.7	94.58	5.42	1.686	56.0	3.20	2.50
V	34.2	86.53	13.47	2.898	29.9	4.59	2.10
VI	29.4	67.28	32.71	3.367	20.1	9.62	2.0

Table (1.2) calculated " Twist and count" of " slub and yarn base" at different level of slub yarn parameters, (Ne 20)

Program code Number	Nominal count Ne	Input roving Ne	Actual draft	Calculated (Ne) base count (Nb)	slub count (Ns)	Calculated (T/m) base yarn twist 3.4	3.6	3.8	4	4.2	Slub twist 3.4	3.6	3.8	4	4.2
I			21.33	21.3	7.50	618.2	654.6	640.9	727.3	763.7	366.6	388.2	4097	431.3	452.8
II			23.47	22.47	8.40	648.4	686.6	724.7	762.9	801	387.9	410.8	433.6	426.4	479.2
III			22.04	22.04	13.86	628.4	665.4	702.4	739.32	77.3	498.3	527.7	556.9	586.3	615.6
IV	20	1	21.63	21.63	14.40	622.5	659.1	695.7	732.3	768.9	507.9	537.8	567.7	597.6	627.5
V			22.96	22.96	20.64	614.4	679.1	716.9	754.6	792.3	608.1	643.9	679.8	715.5	751.3
VI			26.54	22.54	26.28	689.6	730.2	770.8	811.3	851.9	686.2	726.6	766.9	807.3	847.9
			Nominal Twist			598.6	633.8	669.1	704.3	739.5					

9-Results and Discussion :

The theoretical analysis of slub yarns are based on the assumption given in section (6).

For slub yarn Ne 20, the selected programs shown in Table (1), used for determining numeric evaluation, table (1.1), calculation of count; twist of slub yarn is shown in table (1.2).

The obtained data plotted graphically in fig (12) to fig (16) and several relationship can be predicted as follow

9.1 Influence of overall length of effect program :

For any count of slub yarn" ex. Ne 20" produced on modified ring spinning machine with constant number of slubs through different programs, it can be concluded that :

The increase in the total length of program due to varying the basic terms of slubs "Length, distance and thickness" within the range between min. and max. value for each considering the technological limitations affect significantly on the effect types.

- Varying overall total length of the program "from 29.4 to 168.2m" resulted in an increase of slub distance and slub thickness while slub length decreases, as shown in fig (12.1), Fig (12.2) and fig (12.3).
- The same trend has been observed for mean slub distance, it varies from 20 to 165 m, and mean slub thickness varies between 2 to 3.84 while mean slub length varies from 9.62 to 3.469 cm, as shown in fig (13.1).
- Also, the total % age of slub lengths decreases from 32.7% to 2.34% see fig (13.2) and % age of total slub distances increases from 67% to 98% as shown in fig (13.2)

Finally, These changes causes a decreases in slub per meter from 3.37 to 0.589 as shown in fig (13.3).

9.2 Influence of slubs per meter

Theoretically, as shown in fig (14.1), Fig (14.2) and fig (14.3), slub per meter affect significantly on count of slub and based and consequently affect on amount of twist inserted through the two parts of yarn "slub an base".

(i) It is clear that, a lower rate of slubs per meter causes slubs more coarse than nominal yarn count up to 3 slub / meter, This slub become finer than nominal yarn count as slubs per meter exceed 3 slubs / meter. The general trends shows a reduction in slub size as slubs per meter increases. Also, The count of base yarn become finer than nominal count of final yarn.

Also, yarn width ratio influenced by slubs per meter. Width ratio of base/slub decreases from 2.84 to 1, and width ratio of base/ final yarn increases from 1 to 1.33 as slubs per meter increases from 0.58 to 3.37.

(ii) the amount of twist of slub yarn is affected by varying slubs per meter, This attributed to the variation in yarn size.

The base yarn twist is greater than the design twist thus ratio of base twist/design twist varies between 103% and 115% overall variations in slub per meter.

Also, slubs show less twist than nominal yarn. It is about 61% at low rate of slubs per meter, while at about 3 slubs per meter slub twist is equal to design twist. On the other hand, at high rate of slubs per meter > 3, slub twist/ design twist reaches about 115%.

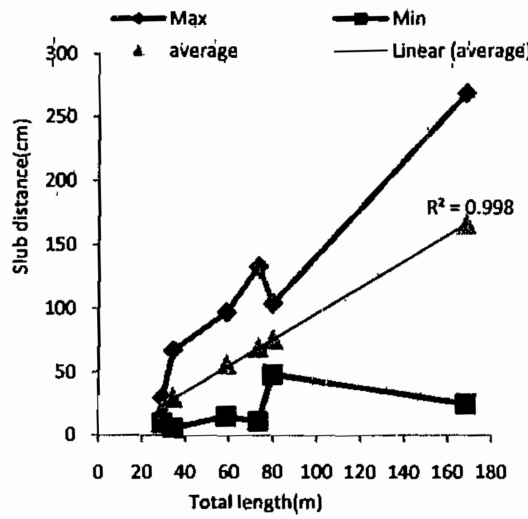
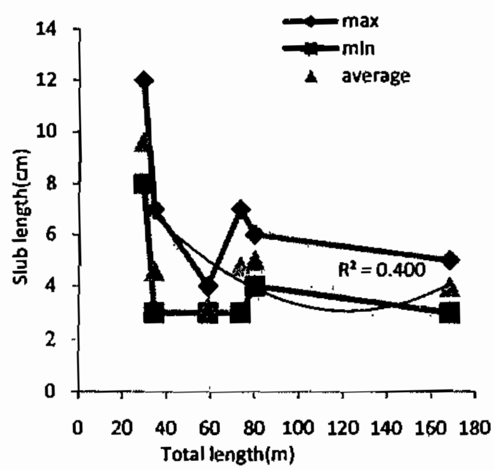
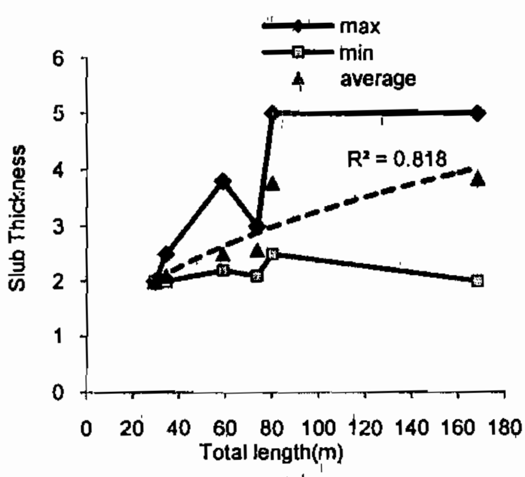


Fig (12.1)

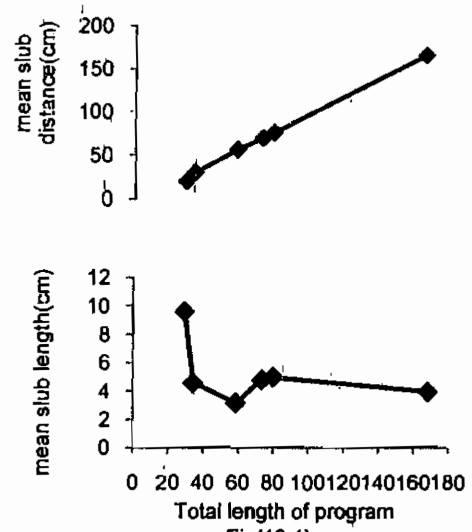


Fig(12.2)

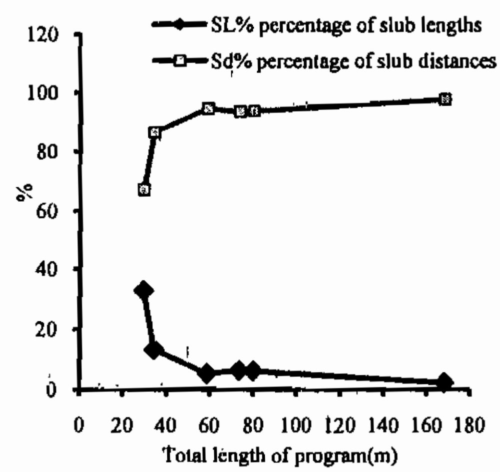


Fig(12.3)

Fig(12) Effect of varying overall total length of program on parameters of slub yarn "slub distance, slub length, slub thickness"



Fig(13.1)



Fig(13.2)

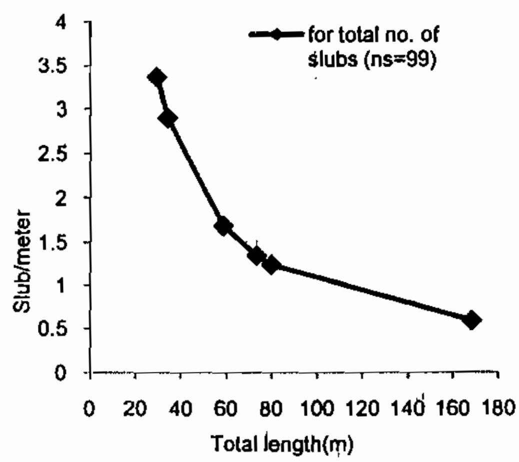
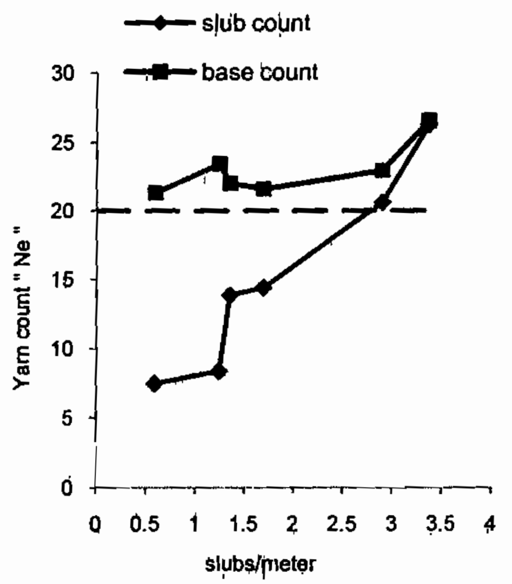
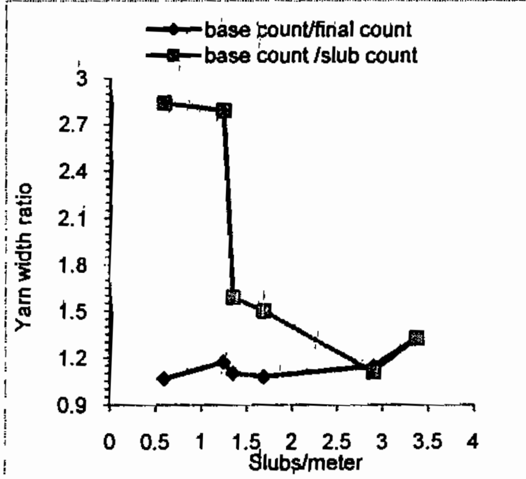


Fig (13.3)

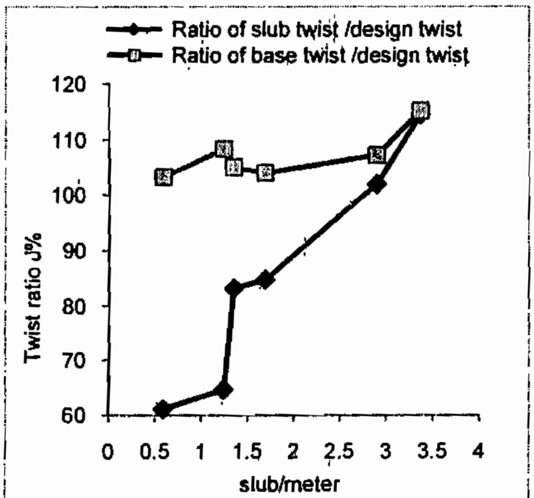
Fig(13) Effect of varying total length of program on mean and % of slub length, slub distance and slubs per meter



Fig(14.1)



Fig(14.2)

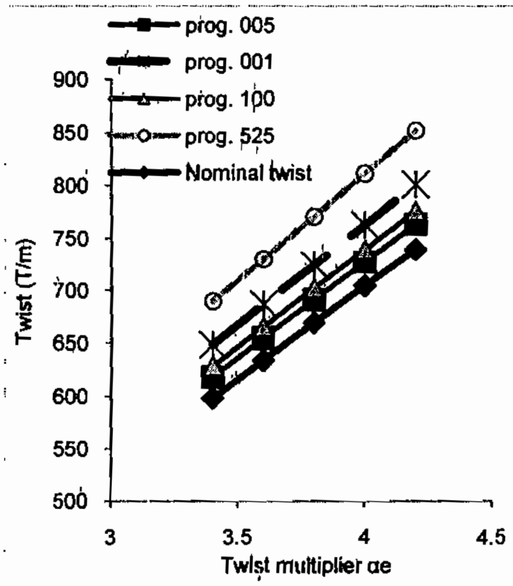


Fig(14.3)

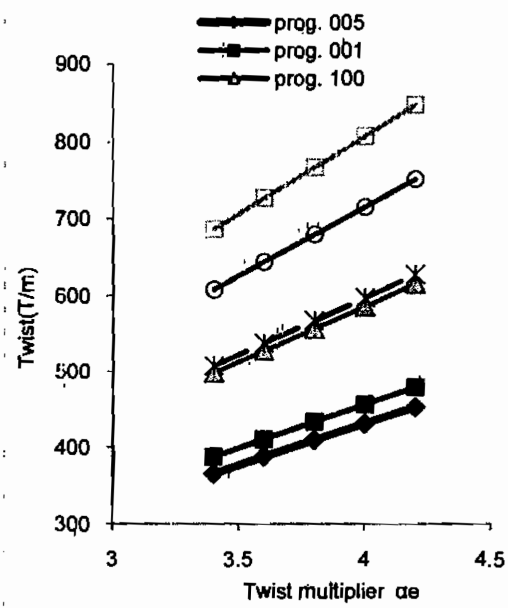
Fig(14) effect of slub per meter on slub count .base count ,yarn width ratio and twist ratio

9.3 Influence of average slub distance, slub length and slub thickness.

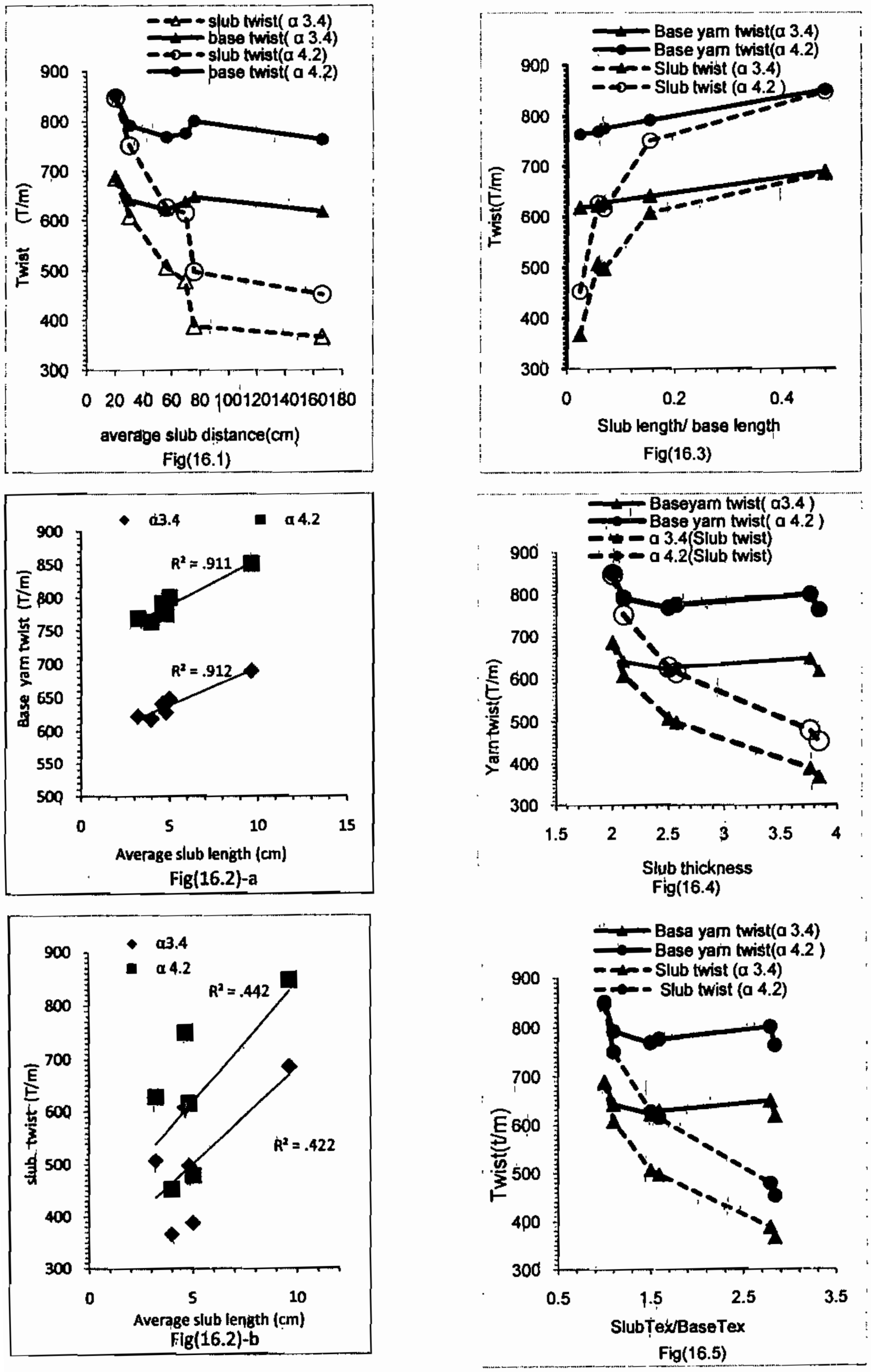
The slub parameters "Length, distance and thickness" affect significantly on twist (T/m) of slub, base and the final yarn at different twist multiplier. Figures (15.1) and (15.2), indicate the linear relationship between twist multiplier(αe) and the calculated twist per meter for base yarn and slub.



Fig(15.1) Theoretical base yarn twist at different twist multiplier (20Ne)



Fig(15.2)Theoretical slub twist at different twist multiplier (20Ne)



Fig(16): Relationship between average slub parameters and twist /m for slub, base yarn at different twist multiplier

Also, The base yarn twist is higher than design twist, while slub twist is lower than design twist.

i. As the average value of slub distance increases causes a reduction on the amount of twist for base and slub. At two level of twist, the same trend has been observed, while the reduction of slub twist is markedly than those for base twist, see fig (16.1), with the increase of slub distance.

ii. The average value of slub length affect on base twist and slub twist as shown in fig (16.2) and fig (16.2)b. The calculated twist increases as average slub length increases. High correlation R2 = 0.91 associated with base yarn, while lower correlation (0.44 = R2) obtained for slub twist.

iii. Also, slub length/ base length ratio affect on amount of twist for slub and base yarn, as shown in fig (16.3). At low ratio up to 0.2, the rate of changes in base twist is lower than those for slub twist and the differences is highly significant while slub/ base length ratio from 0.2 to 0.5, the differences is very small and the twist values for base and slub are close.

iv. Slub thickness, as shown in fig (16.4) affect significantly on slub twist. At low and high twist multiplier, twist per meter for slub decreases as slub thickness increases, while twists for base yarn slightly decreases and remain constant .

v. Ratio of slub/ base count on twist, is shown in fig (16.5). The base yarn twist is equal to slub twist at yarn width ratio equal one. In addition the base twist is higher than slub twist as width ratio increases. The difference is highly significant at high ratio of yarn width. Also the slub twist decreases gradually as width ratio increases, while the base twist decreases then remain constant .

10. Conclusions :

In the present work, the following conclusions may be drawn :

10.1 Design of mathematical model for slub yarn parameters:

Few literature's published about mathematical model to deduce the relations between slub parameters and slub yarn properties (1,17). In the present work we seek to design a models or rebuild or modified a mathematical expressions to describe :

- Relation between overall total length and slubs per meter.
- Relation between slubs per meter and count of slub, base and final yarn as well as twist distribution.
- Relation between slub length, base and slub thickness and count of slub, base and final yarn comparing with nominal yarn . Also, twist distribution in sections of slub yarn comparing with the design twist.

The formulae we built up, utilized to verify the results and give Information about slub pattern help the spinner for making a quality yarn and know principles of slub making device and its features.

10.2 Fundamental parameters that characterize slub yarn:

(i) For any count of slub yarn produced on modified ring spinning machine with constant number of slubs through different programs it can be concluded that :

- The increase in the total length of program due to varying the basic terms of slubs "length, inter slub distance, thickness" within the range of min. and max. value for each considering the technological limitations affect significantly on the effect types .

- Varying overall total length of program causes an increase of inter slub distance and slub thickness while slub length decreases. Also mean slub distance, mean slub thickness increases and mean slub lengths. In addition, percentage of total slub distance increases and percentage of slub lengths decreases. Finally, slubs per meter decreases as total length increase.

ii- Slubs per meter affect significantly on count of slub, base, final yarn and twist inserted through the two part "slub and base" as well as the final yarn .

- A higher rate of slubs per meter shows a reduction in slub size and the count of base yarn become finer than the count of final yarn.
- The base yarn twist/ the design twist > 100 overall rate of slubs per meter. While slubs show lower twist than design twist at lower slubs per meter and equal values at higher rate of slubs per meter.

(iii)Slub yarn parameters "slub length, inter slub distance and slub thickness" affect significantly on the calculated values of twist distribution of slub yarn .

- As mean slub length increases causes a reduction on the amount of twist for base and slub .
- The average slub length affect on base and slub twist high correlation is evident with base yarn, while low correlation is obtained with slub twist.
- Slub length/base length ratio affect on the amount of twist for base yarn and slub. At lower lengths ratio the rate of increase in base twist is lower than those for slub twist and the differences is highly significant. While at higher ratio of slub length/ base length the difference is very small and the twist values are close.
- Slub thickness affect significantly on slub twist, it decreases as slub thickness increases. While, the twist for base yarn slightly decreases and almost remain constant .

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