BASIC PRINCIPLES OF DIMENSIONING A RING SPINDLE SYSTEM

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Under ring spindle system we understand the mechanical system of spindle, spinning ring, traveller, lappet, front rollers, separator, and balloon ring connected with and operating in conjunction with each other. Into this system the yarn section between front rollers and winding-on point is also included.

The dimensions of the ring spindle system as well as those of yarn guiding are being developed on practical experiences, thus theoretical treatment of the problems arising which concern yarn length, balloon height, lift, ring diameter, etc. cannot meet the requirements of providing the best results in ring spinning.

In our paper, discussing some basic problems of the ring spindle system, we want to draw attention to the complexity and effect of the numerous interacting factors of modern ring frames with the purpose of creating a more exact basis for machine dimensioning.

1. Dimension of the spindle

The basic measurement of ring frame dimensioning is the height of the spindle. This value cannot be found by calculation. For yarns of particular quality, twist and count ranges the best spindle height, *i.e.* the height of the yarn-body on the bobbin: the *lift*, is developed on practical experiences.

The modern spindles in the cotton spinning industry are operated with lifts of 180—300 mm according to the yarn count to be spun. In Table 1, for the yarn count range $N_m = 27 - N_m = 130$ a lift length of 230 mm is given, according to the ring diameter. (The method can be reversed: *i.e.* lift length may be chosen on the basis of yarn count and ring diameter, though from the point of view of both the admissible maximum traveller speed and the gauge, taking spindle height as a basis, appears to be more correct.)

For choosing spindles, in addition to spindle height, the average diameter of the spindle resp. that of the tube are also to be considered.

Views differ concerning the length of lift to be applied. In case of excessive lift length (280—300 mm) the constructional height of the machine must be so high that its service becomes extremely difficult. When spinning yarns of finer counts, package building lasts so long that the yarn may get dirty. According to opposite views, however, increased lift length leads to improved machine efficiency, reduced costs in doubling and cross-winding, especially when taking into consideration the yarn speeds of 600—800 m/min and of 1200—1500 m/min on the modern machines for yarn preparation.

Owing to the prevailing contradictory views, lift lengths to be applied, used to be chosen according to the requirements of the industry.

When choosing spinning tubes, one must not fail to take into account, that though small tube diameter allows increased package weight, at the same time yarn tension will be higher, too. While on tubes of larger diameter less yarn can be wound on, employing them, results in reduced winding-on tension. (See Par. 9)

2. Spinning ring diameter

The cross section of the path of the spinning ring on modern ring frames has an "antiwedge" design. The second important step, when designing ring frames is to determine the inner diameter of the spinning ring corresponding to the chosen lift. The guiding principels to be considered here, are the following:

a) Yarn count.

b) Spindle speed, admissible from the point of view of the traveller burning.

c) Ratio of package dimensions.

a) *Yarn count*

According to GRISHIN, while ring spinning of yarn of different counts at a constant balloon height and spindle speed, yarn tension varies with yarn count

$$T_x = 0{,}112 \frac{n^2}{c^2 \cdot N_m}, \tag{1}$$

where T_x — the vertical component of the yarn tension (g),

n — traveller (spindle) speed (10^{-3} min^{-1}),

c — coefficient of the centrifugal force (cm^{-1}), interpreted in equation (8), and

N_m — metric count of the yarn.

From equation (1) it is to be seen, that f. i. with increased yarn counts, yarn tension decreases.

Changes in yarn counts are influenced however, by ring diameter too, according to the following relationship (1), valid for the yarn tension:

$$T_x = \frac{5.6 \cdot G \cdot D \cdot n^2}{\Phi + \phi}, \quad (2)$$

where

G — weight of teh traveller, (g)
D — diameter of the spinning ring, (cm)
Φ — an expression, dependent on the ratio d/D and on the coefficients of friction,
ϕ — a correction factor, and
d — diameter of the bobbin (cm).

Assuming that the admissible value of T_x is known, the relationship d/D taken up, and the spindle speed constant, so, for obtaining a constant yarn tension either the traveller weight or the spinning ring diameter has to be changed.

In case yarn tension is compensated by decreasing the traveller weight, and simultaneously an excessively light traveller is employed, thus traveller burning or balloon collapsing may occur, besides the package produced becomes too loose.

Conversely, compensating yarn tension by diminishing only the ring diameter may result in packages of disproportionally small diameter, and reaching the value taken for the ration d/D becomes impossible under mill condition.

In view of the above, in practice both traveller weight and ring diameter are to be reduced. Within the ranges of particular yarn counts however — as changing the ring are to be avoided — yarn tension, *i.e.* package density is controlled by changing the traveller weight only.

Table 1 gives the upper limits of yarn count ranges corresponding to the lifts and ring diameters employed in the cotton spinning industry (Platts).

Table 1

Yarn count ranges (N_m)

Ring diameter mm	180	200	230	260	280	300	Lift mm
38	200	200	—	—	—	—	
42	170	170	—	—	—	—	
44	150	150	—	—	—	—	
48	130	130	130	—	—	—	
51	100	100	100	68	—	—	
57	—	50	50	50	50	—	
64	—	27	27	27	27	—	

b) *Spindle speed*

According to equations (1) and (2) there is a quadratic relationship between traveller-, *i.e.* spindle speed and yarn tension. The admissible yarn tension may be considerably higher for yarns of greater breaking strength, thus, such yarns may be spun at greater speeds. If yarn tension is reduced by the use of balloon control ring, spindle speed may be still further increased.

Owing to the heating and burning of travellers, no use can be made of the maximum spindle speed admitted by the laws of kinetics, in spite of the fact that no excessive yarn breakages occur at that speed.

Ring diameters chosen, must therefore be controlled from this point of view, too.

In literature [2] there is a relationship to be found for "antiwedge" ring and elliptic traveller:

$$n \leq \frac{34.8}{\sqrt[3]{D^2}}, \tag{3}$$

where n — the traveller (spindle) speed (10^{-3} min^{-1}) and

D — the ring diameter (cm).

Thus, the maximum admissible spindle speed with a ring of $D = 4.8$ cm is $n = 12{,}200$ min^{-1}, while for a ring of $D = 5.1$ cm, $n = 11{,}700$ min^{-1}.

According to another relationship, originating from Grishin, in which the heating of the traveller has been taken into consideration:

$$C = n \cdot D^{0.55}, \tag{4}$$

where C = constant. The equality expresses the conditions of constant traveller temperature, varying ring diameter and variyng speed. The constant C is determined by the admissible number of traveller burnings.

c) *Ratio of package dimensions*

A further condition which must be considered when choosing ring diameter is to prevent the production of packages having disproportionate dimensions. Let us examine two extreme cases.

If ring diameter compared to the lift is too large, so both yarn tension and spindle speed will unnecessarily increase. Increased yarn tension is also to be found in balloons excessively distorted, due to the use of separators.

If the ring diameter compared to the lift is too small, so balloon collapses may occur in winding and spinning, which may prevent further technological operations (see Par. 5).

3. Spindle gauge

Under spindle gauge we understand the distance between the axes of two neighbouring spindles. The trend is for the possible number of spindles to be fitted into an unit length of the ring frame without causing a detrimental effect on spinning tension.

Let $\delta_{\max}$ — the possible maximum diameter of a free balloon (cm),
D — the ring diameter (cm), and
N_m — the metric yarn count,

so the following relationships are obtained:

$$\delta_{\max} = (1 + 1.75 \cdot K^2) \frac{D}{K \cdot \pi}, \tag{5}$$

where

$$K = 0.0022 \cdot D \cdot \sqrt{N_m} \cdot \tag{6}$$

As practical numerical values, taking $D = 4.8$ cm and $N_m = 40$, we shall get $k = 0.066$ and $\delta_{\max} = 23.2$ cm, *i.e.* the possible maximum balloon diameter is almost fives times as large as the diameter of the ring.

In order to prevent contacts between the balloons, a distance of at least 24 cm is to be provided for between the spindles, under the above conditions.

For obtaining winding of suitable density, practical spinning must occur at such a high yarn tension at which the possibility of developing an extreme balloon diameter is excluded. The ratio of ring diameter to actual balloon diameter (δ_m) for a single balloon of real amplitude is given by the following equation[1]

$$cH = \pi - \arcsin\left(\frac{D}{\delta_m}\right), \tag{7}$$

where

$$c = 0.335 \frac{n}{\sqrt{N_m \cdot T_x}} \, . \tag{8}$$

As a numerical example let us take $Nm = 40$, $n = 10$, $T_x = 17.5$ g. Then $c = 0.126$ and substituting $H = 28.0$ cm from equation (7):

$$\frac{\delta_m}{D} = 2.5$$

[1] (H — the height of the balloon examined.)

i.e. the maximum balloon diameter is 2.5 times larger than the ring diameter. Accordingly, for a ring diameter of 4.8 cm, in case there is no contact between the balloons, a spindle gauge of 12 cm is to be applied. From the point of view of exploiting spindel capacity, this value still appears to be too high. A further decrease in spindle gauge may be obtained on the basis of the following considerations:

a) Maximum balloon diameter develops at the beginning of the spinning procedure, when maximum package diameter had already been reached.

b) When using separators, balloon diameter can be reduced without considerably increasing yarn tension.

According to our practical example, with the use of separators, maximum balloon diameter can be reduced, on one side, by 2.25 cm, *i.e.* on both sides by 4.5 cm. For a ring diameter of $D = 4.8$ cm and for a balloon height of $H = 28.0$ cm the spindle gauge to be applied is:

$$t = D + 2.7 \text{ cm} = 7.5 \text{ cm}.$$

In Table 2 spindle gauge values suggested for cotton ring frames are given according to the above considerations and corresponding to the point of views of standardization, for different balloon heights (or lifts) and ring diameters (Platts).

Table 2

Ring diameter cm	Spindle gauge (mm)						Lift mm
	180	200	230	260	280	300	
3.8	6.4	6.4	—	—	—	—	
4.2	6.4	6.4	—	—	—	—	
4.4	6.4	7.0	7.0	—	—	—	
4.8	7.0	7.0	7.0	—	—	—	
5.1	7.0	7.6	7.6	8.3	—	—	
5.4	—	7.6	7.6	8.3	—	—	
5.7	—	8.3	8.3	8.9	8.9	—	
6.0	—	8.3	8.9	9.5	9.5	—	
6.4	—	8.9	8.9	9.5	9.5	9.5	
7.0	—	—	10.2	10.2	10.2	10.2	

In giving the values of Table 2 use has been made of the principles, according to which spindle gauge depends on ring diameter, balloon height and balloon diameter, respectively.

4. Initial distance between lappet and spindletip

The bottom position of the lappet, *i. e.* the initial distance between the lappet and the spindle tip is given by the condition, that at the smallest maximum balloon height, when winding on the smallest diameter, there should be no contact between the balloon and the upper flange of the tube.

As the above distance (x) influences both the yarn tension and the constructional height of the ring frame, it must be chosen to be as small as possible (see Fig. 1*a*—*b*).

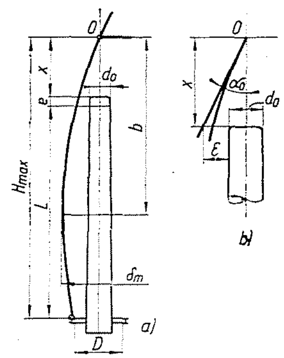

Fig. 1. a—b. Position of the lappet above the spindle tip

The danger of contacts between balloons and the upper flange of the tubes, when using lappets of long lifts, is especially great during the initial stage of spinning. Taking a minimum balloon height (H_{max}) for the chosen lift, the obtained value x has to be checked in respect to a contact between balloon and tube flange.

Let us represent the procedure for a practical example, where $L = 23$ cm, $H_{max} = 28$ cm, $D = 4.8$ cm, $d_0 = 2.0$ cm and $e = 1.0$ cm.

The yarn, after the lappet, passes inside the tangent of the balloon, thus for preventing contacts, the distance ε must be adequately chosen:

$$\operatorname{tg} \alpha_0 = \frac{\varepsilon + \frac{d_0}{2}}{x}; \quad x = \frac{2\,\varepsilon + d_0}{2 \cdot \operatorname{tg} \alpha_0}. \tag{9}$$

For the angle α_0, between the tangent, drawn at the balloon apex and the spindle shaft we may write:

$$\operatorname{tg} \alpha_0 = \frac{D \cdot \pi}{4 \cdot b \cdot \sin \frac{\pi \cdot H_{max}}{2b}}. \tag{10}$$

where b is the distance between the balloon amplitude and the balloon apex. The simplest way of finding this value is to photograph the balloon, because its calculation is rather cumbersome. As an approximation we may write $b = 2/3\ H_{max}$, and consequently

$$\mathrm{tg}\, a_0 = \frac{D \cdot \pi}{\frac{8}{3} H_{max} \cdot \sin \frac{3\pi}{4}} = 0.286\,,$$

For safety sake taking $\varepsilon = 0.3$, and carrying out the substitutions in equation (9), we have $x = 4.35$ cm. According to our initial condition, the distance will be:

$$x = H_{max} - (L + e) = 4.0 \text{ cm.}$$

Owing to the higher value, obtained by the checking procedure, it is advisable to increase the distacne x taken up by 1.0 cm, hence $x = 5.0$ cm. (It would be practical to repeat the calculations using the newly obtained value H_{max}.)

5. Relation between lift and ring diameter

The most advantageous ratio between lift length and ring diameter often seems to be problematic in ring spinning.

If we denote the lift of the ring frame by L and the ring diameter by D, thus the above ratio will be L/D. Examination of the ratio H_{max}/D seems to be, however, a more appropriate method, since $L = H_{max} - (x + e)$ and $(x + e)$ are in practice almost proportional to H_{max}.

Let us start out from the equation valid for the vertical component of the yarn tension:

$$T_x = 0.112\, \frac{n^2 \cdot H^2_{max}}{(cH_{max})^2 \cdot N_m}\,; \qquad H_{max} = \frac{(cH_{max}) \sqrt{N_m \cdot T_x}}{\sqrt{0.112} \cdot n}\,. \tag{11}$$

For expressing D we use the equality (2):

$$T_x = \frac{5.6 \cdot G \cdot D \cdot n^2}{\Phi + \phi}\,; \qquad D = \frac{T_x (\Phi + \phi)}{5.6 \cdot G \cdot n^2}\,. \tag{11a}$$

Dividing the two equations with each other, carrying out the simplifications and the reduction of the constants, the following equality will be obtained:

$$\frac{H_{max}}{D} = \frac{16.7 (cH_{max}) \sqrt{N_m} \cdot G \cdot n}{\sqrt{T_x} \cdot (\Phi + \phi)} \tag{12}$$

Thus, taking the maximum balloon diameter for constant, the relationship H_{max}/D varies with yarn count, traveller speed and yarn tension. If traveller speed and yarn count are considered as constants, so H_{max}/D depends on T_x only.

According to the above interpretation, the most advantageous ratio H_{max}/D is that at which with a given yarn count, traveller speed and balloon diameter, the value of the yarn tension still remains within practical admissable limits.

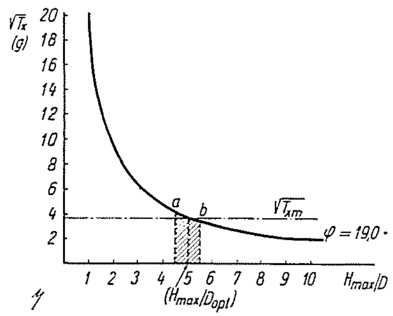

Fig. 2. Variation of the ratio H_{max}/D according to yarn tension

Taking the values of δ_m, N_m, n, G, d/D for constants, so equation (12) takes the form of the following function:

$$\frac{H_{max}}{D} = \left[\frac{16.7\,(cH_{max})\sqrt{N_m}\cdot G\cdot n}{\Phi + \phi}\right]\frac{1}{\sqrt{T_x}}\,. \tag{13}$$

Denoting the expression in brackets by

$$\frac{16.7\,(cH_{max})\sqrt{N_m}\cdot G\cdot n}{\Phi + \phi} = \varphi$$

we have

$$\frac{H_{max}}{D} = \frac{\varphi}{\sqrt{T_x}}\,. \tag{14}$$

For the different values of φ a set of curves may be drawn up representing the relationship between T_x and H_{max}/D. (In Fig. 2. the curve given for $\varphi = 19.0$ is shown.)

Having plotted the curves corresponding to the count of yarn, traveller weight, balloon resp. ring diameter, the value of the practically admissible yarn tension T_{xm} can be agreed on, while that of $(H_{max}/D)_{opt}$ belonging to point $\sqrt{T_{xm}}$ may be found on the curve.

Let us determine the most advantageous relationship L/D for a particular case taking the following values:
$N_m = 50$, $n = 10$, $G = 0.05$ g, $D/\delta_m = 0.75$, $d/D = 0.5$, $\Phi = 8.752$, $cH_{max} = 2.26$, $\phi = -1.75$, $D = 4.8$ cm. (Φ and ϕ may be taken from Table 1)

With the above numerical values $\varphi = 19.0$. Substituting it in to equation (14):

$$\frac{H_{max}}{D} = \frac{19.0}{\sqrt{T_x}}$$

with a yarn tension of $T_{xm} = 14.0$ g:

$$\left(\frac{H_{max}}{D}\right)_{opt.} = \frac{19.0}{\sqrt{14.0}} = 5.06\,.$$

(We choose the arithmetic mean of the limit values *a)* and *b)* obtained from the spinning conditions for the relationship $(H_{max}/D)_{opt}$.

In correspondance with our example, if $(H_{max}/D)_{opt.} = 5.06$, the following values are obtained for the maximum balloon height when using different rings:

D (cm)	H_{max} (cm)
4.8	24.3
5.1	25.8
5.7	29.0

Taking the values of $(x + e)$ into consideration, belonging to the different values of H_{max}: *i.e.* 4.5, 5.0 and 5.5 cm, on the basis of equation $L = H_{max} - (x + e)$, the suitable lifts will be:

D (cm)	L (cm)
4.8	19.8
5.1	20.8
5.7	23.5

The ratio $(L/D)_{opt.}$ gives almost identical values:

D (cm)	$(L/D)_{opt.}$
4.8	4.13
5.1	4.10
5.7	4.13

It is evident, that with a particular ring diameter — under otherwise fixed conditions of ring spinning — the value of the permissible yarn tension will be higher for reduced, and smaller for increased ratio L/D. Differences in yarn tension may be compensated, *i.e.* use can be made of them by changing the speed or the traveller weight, respectively. If yarn tension be too low or there is any danger of balloon collapse, so the employment of balloon control rings is recommended.

Investigation on the most advantageous ratio L/D proved to be suitable for controlling the values of lift length taken up as basic data.

6. Lappet movement

Under lappet movement we understand the distance between the bottom and top positions of the lappet during the spinning performance.

Theoretically, with decreasing balloon height yarn tension must also decrease according to the following relationship:[1]

$$T_x = 0.112 \frac{n^2 \cdot H^2}{(cH)^2 \cdot N_m}, \tag{15}$$

where T_x — the vertical component of the yarn tension (g),

n — the traveller speed (10^{-3} min^{-1})

H — the balloon height (cm), and

N_m — the metric yarn count.

Are short balloons developing at the end of the spinning procedure, so the expected drop in yarn tension does not take place, on the contrary, an excessively increased yarn tension can be observed. The explanation for this apparent contradiction lies in the variation of the cH. There are, namely, considerable differences in the magnitude of the yarn tension depending on the condition, if the spinning ring is situated *below* or *above* the maximum balloon diameter. In the former case the maximum diameter of the balloon can actually develop, while in the latter case it falls in the imaginary continuation of the balloon (see Fig. 3).

If the spinning ring is moving above the maximum balloon diameter, so

$$(cH)_1 = \arcsin\left(\frac{D}{\delta_m}\right)$$

if it moves below the maximum diameter, so

$$(cH)_2 = \pi - \arcsin\left(\frac{D}{\delta_m}\right).$$

In the equations

D — the diameter of the spinning ring (cm),

δ_m — the maximum balloon diameter (cm).

Inserting the above values of cH into equation (15):

$$T_{x1} = 0.112 \frac{n^2 \cdot H_1^2}{\left[\arcsin\left(\frac{D}{\delta_m}\right)\right]^2 \cdot N_m}$$

and

$$T_{x2} = 0.112 \frac{n^2 \cdot H_2^2}{\left[\pi - \arcsin\left(\frac{D}{\delta_m}\right)\right]^2 \cdot N_m}.$$

assuming: $D = 4.8$ cm, $\delta_m = 8.0$ cm, $D/\delta_m = 0.6$, $n = 10$, $N_m = 40$, the

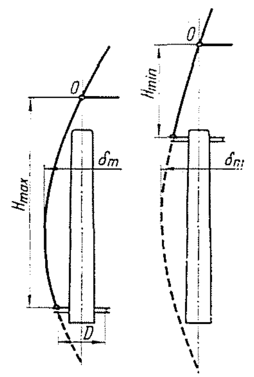

Fig. 3. Shape of the balloon in the bottom and top positions of the spinning ring

balloon heights in one of the top, respectively, in one of the bottom positions of the spinning ring $H_1 = 10$ cm, and $H_2 = 20$ cm.
With these numerical values:

$$T_{x1} = 66.3 \text{ g},$$
$$T_{x2} = 17.7 \text{ g}.$$

Thus, reducing the balloon height from 20 cm to 10 cm it increases the vertical component of the yarn tension to three and half times its value.

According to the above, for improving yarn tension conditions and to avoid excessive end breakage rates at the end of the spinning procedure, balloon height must reach a value at which balloons have an actual amplitude. The right principles of ring spinning are accordingly as follows: yarn tension should decrease gradually from the very beginning of the spinning procedure and its value must not increase even at the end stage of spinning.

The minimum balloon height at which an actual amplitude can still be formed is given by the limit condition $D = \delta_m$. Then

$$cH = \pi - \arcsin 1 = \frac{\pi}{2}.$$

Taking for example $T_{xm} = 17$ g, $n = 10$, $N_m = 40$, the permissible minimum balloon height will be according to equation (15):

$$H = H_{\min} = 12.1 \text{ cm}$$

while the same for a yarn of $N_m = 60$, $H_{\min} = 15.0$ cm.

The full movement of the lappet is determined by the maximum balloon heights. Since the maximum balloon height depends on the lift length and on

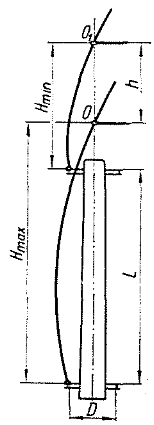

Fig. 4. Extreme values of lappet movement and balloon height

the initial position of the lappet, according to the notation in Fig. 4 and 1*a*, the lappet movement is

$$h = H_{\min} - (x + e).$$

With the data of our example, if the initial position of the lappet above the spindle tip is $x = 4.0$ cm, and the upper plane of the spinning ring lies at a distance of $e = 1.0$ cm below the spindle tip, so the lappet movement will be:

$$h = 15.0 - (4.0 + 1.0) = 10.0 \text{ cm}.$$

7. Angle of obliquity of the yarn

The yarn section between drafting — rollers and lappet form an angle with the horizontal, changing with the position of the lappet. Variation in the angle of obliquity is given by the difference $\beta_{\max} - \beta_{\min}$ according to Fig. 5.

The twist imparted by the spinning ring is to run up to the nip of the drafting rollers. The free run up of the twist is, however, hindered by the lappet. As can be seen from Fig. 6, owing to the inclination of the yarn, and in consequence of tensions T_0 and T, the normal force N is developed. As a result of the inclination of the yarn, the spinning tension T_0 increases according to relationship $T_0 = T \cdot e^{\mu\alpha}$, while the moment of friction produced by the normal force restricts the free run up of the twist. The smaller the angle of obliquity of the yarn, the more does this effect prevail. Therefore, while endeavouring to ensure large angles of obliquity, the following consideration may be followed:

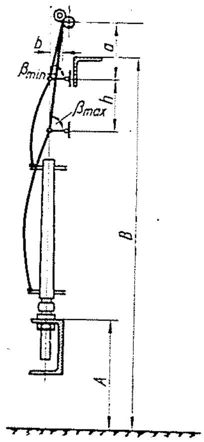

Fig. 5. Yarn guiding on the ring frame

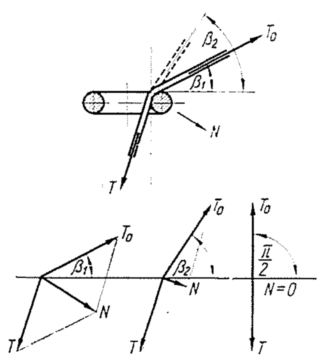

Fig. 6. Normal force, preventing running up of the twist

$$\beta_{\max} = \operatorname{arc\,tg} \frac{a + h}{b}$$

$$\beta_{\min} = \operatorname{arc\,tg} \frac{a}{b} .$$

The angle of obliquity is at minimum, if b *i.e.* the horizontal distance between the spindleshaft and the nip of the drafting rollers is the shortest, and a *i.e.* $(a + h)$ the vertical distance between the lappet and the drafting rollers is the longest.

The diminishing of dimension b is restricted by the position of the lappet, ring rail, separators and balloon control rings.

The constructional height of the ring frame determines the increasement of dimension a, first of all from the point of view of the easy operation of the frame.

The increasement of dimension h is also governed by the constructional height of the frame, *i.e.* by the particular value of $H_{\max}$.

Thus, taking into account the above aspects, the most advantageous (maximum) angle of obliquity for yarn guiding can be determinded.

8. Height of the ring rail and the draw-frame from the floor

The distances measured from the upper plane of the ring rail, and from that of the draw-frame to the floor (A and B) are dimensions which influence the total length of the yarn path on the ring frame (see Fig. 5). Both dimensions are governed by the conditions of the easy service of the machine. Dimension A depends both on the ease of accessibility of the spinning rings and on the length of the lift. Dimension B is governed by the easy service of the drawing frame and the roving.

For the purpose of comparison we are giving dimensions of A and B tabulated in dependence of lift length for a ring frame in the cotton industry (see Table 3).

Table 3

Lift mm	A mm	B mm
180	426	960
200	450	960
230	476	960
260	500	960
280	560	1050
300	590	1050

9. Ratio of tube diameter to spinning ring diameter

The problem is how to choose the ratio of tube diameter (d) in accordance with the spinning ring diameter (D), to be able to ensure the highest spindle speed at the lowest end breakage rate.

To clarify this problem we have to start out from the basic relationship of the balloon theory.

The equality valid for the vertical component of the yarn tension is

$$T_x = \frac{5.6 \cdot G \cdot D \cdot n^2}{\Phi + \phi}, \qquad (2)$$

where

$$\Phi = \mu \left(\cos \gamma + \frac{1}{f} \sin \gamma \right). \qquad (16)$$

In equation (16):

$$\mu = e^{\mu_0(\pi-\gamma)} \tag{17}$$

γ — the angle of winding on (see Fig. 7),
f — the coefficient of friction between the traveller and the spinning ring,
μ_0 — the coefficient of friction between the traveller and the yarn, for which the value 0.3 may be taken.

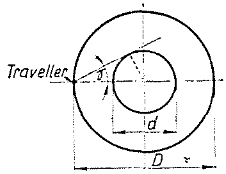

Fig. 7. Angle of winding-on

As

$$\sin\gamma = \frac{\mathrm{d}}{D}, \quad \text{and} \quad \cos\gamma = \sqrt{1-\left(\frac{d}{D}\right)^2}$$

furthermore,

$$\gamma = \arcsin\left(\frac{d}{D}\right)$$

substituting these values in to equations (16), (17), *i.e.* in (2), we have:

$$T_x = \frac{5.6\cdot G\cdot D\cdot n^2}{e^{0,3\left[\pi-\arcsin\left(\frac{d}{D}\right)\right]}\left[\sqrt{1-\left(\frac{d}{D}\right)^2}+\frac{1}{f}\,\frac{d}{D}\right]+\Phi}\,. \tag{18}$$

For that in relation to T_x transcendental equation, d/D cannot expressed. The value of d/D belonging to T_x is obtainable only by cumbersome calculations. In the equation the values of G, D, n, f are partly obtained, partly taken up. The determination of Φ appears to be more difficult. Though Φ may directly be taken from Table 1 in which it is given in dependence of cH, but in that case the value of cH must be known according to the relationship of

$$cH = \pi - \arcsin\left(\frac{D}{\delta_m}\right).$$

Here again the value of δ_m, *i.e.* the maximum balloon diameter is to be found, for which the simplest way is to photograph the balloon.

Substituting the values obtained by the above procedures, equation (18) may be considered as a function of both T_x and d/D. Taking for d/D different values from the range of 0 and 1.0, the values T_x belonging to them can be found by calculation, and the curve determined by the function

$$T_x = F\left(\frac{d}{D}\right)$$

can be plotted (see Fig. 8).

Indicating on the curve point T_x corresponding to the component of the admissible yarn tension, the value of $(d/D)_{opt}$, belonging to it, can be found.

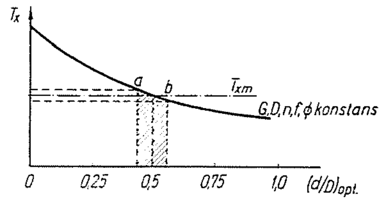

Fig. 8. Relationship between the ratio d/D and the yarn tension

According to the tolerance limits of T_{xm}, the value of $(d/D)_{opt}$ within the range of $a - b$ can be determined.

It is to be seen, that changing one of the variable factors in equation (18) results in a new relationship between T_x and d/D.

As an example, let us check the admissible ratio of $d/D = 0.45$ taken up for $T_{xm} = 17.0$ g, under the following conditions:
$n = 10$, $N_m = 40$, $G = 0.05$ g, $D = 4.8$ cm, $f = 0.12$ (antiwedge ring) $\phi =$
$= -1.75$.

In equation (18)

$$e^{0,3\left[\pi - \arcsin\left(\frac{d}{D}\right)\right]}\left[\sqrt{1 - \left(\frac{d}{D}\right)^2} + \frac{1}{f}\,\frac{d}{D}\right] = \Phi$$

the value of which may be found in Table 1 in dependence of d/D.

With the above values $\Phi = 10.339$. Substituting into equation (18)

$$T_x = 15.7\ \text{g}\,.$$

Since the permissible $T_{xm} = 17.0$ g is higher than 15.7 g, either the relationship $(d/D)_{opt}$ must be taken at less, or the spindle speed should be increased to $10.500\ \text{min}^{-1}$.

The determination of the ratio $(d/D)_{cpt}$ for more general spinning conditions requires further extensive research work and until no exact research data are available, practice must rely on empirical values.

By the calculation of the ratio $(d/D)_{opt}$ possibility may also be offered for checking the average diameter of the spinning rings, *i.e.* that of the tubes.

10. The admissible yarn tension

To carry out the calculations described in Par. 2, 5, 6, 9, the vertical component of the yarn tension T_{xm} must be known. This value can either be calculated directly, or measured. In ring spinning admissible maximum yarn tension is determined by the number of permissible maximum average end breakages, thus for finding T_{xm} the following method may be recommended:

a) The permissible specific average end breakage rate should be decided upon (number/10^3 spindle hours).

b) On a particular ring frame when spinning yarns of similar quality and uniformity, end breakage rate is influenced by the spindle speed, balloon diameter (traveller weight) and yarn twist.

Adjusting the ring frame to the particular operational speed and choosing the traveller at which the largest balloon diameter can develop, furthermore, taking the package density and the heating of the travellers into consideration, by varying the spindle speed, the traveller weight and the twist, the number of end breakages can be checked until the required admissible value is reached.

c) If the permissible average maximum end breakage rate is reached, thus the maximum balloon diameter has to be determined for the beginning and for the completion stage of the spinning procedure by photographing.

Accordingly we have all available data for the calculation of yarn tension on the basis of the following general equation:

$$T_x = \frac{0.112 \cdot n^2 \cdot H^2}{\left[\pi - \arcsin\left(\frac{D}{\delta_m}\right)\right]^2 \cdot N_m} . \tag{19}$$

d) The permissible end breakage rate under running conditions is, however, an average value related to the whole spinning cycle, therefore, T_x is to be determined both for the beginning (T_{x1}) and for the completion (T_{x2}) period of spinning. For the admissible yarn tension let us take the arithmetic mean of the above two values

$$T_{xm} = \frac{T_{x1} + T_{x2}}{2} . \tag{20}$$

e) Is T_{xm} for yarns of different count and quality to be determined, so the above procedure must again be repeated for every case. The value of δ_m can be controlled by varying the traveller weight.

11. Balloon control

Yarn tension can be decreased by the employment of balloon control rings. This effect can be made use of for increasing package dimension or for reducing end breakage rate.

The treatment of problems on balloon control will be the subject of a special paper.

Summary

The dimensions of a spindle system are investigated in relation to theory and practice on the basis of yarn tension values determined by admissible end breakage rate. Constructional dimensions of spindle, spinning ring, lappet and yarn guiding are evaluated and ratios of optimum lift length to ring diameter furthermore package diameter to ring diameter are dealt with. A practical method for calculating yarn tension is suggested.

Literature

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