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Theoretical Density Study of Winding Yarns on Spool

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***Abstract*—**The aim of work is to define the distribution density of winding yarn on cylindrical and conical bobbins. It is known that parallel winding gives greater density and more regular distribution, but the unwinding of yarn is much more difficult for following process.

The conical spool has an enormous advantage during unwinding and may contain a large amount of yarns, but the density distribution is not regular because of difference in diameters. The variation of specific density over the reel height is explained generally by the sudden change of winding speed due to direction movement variation of yarn. We determined the conditions of uniform winding and developed a calculate model to the change of the specific density of winding wire over entire spool height.

***Keywords*—**Textile, cylindrical bobbins, conical bobbins, parallel winding, cross winding.

I. Introduction

THIS cylindrical or conical winding yarn on spool, takes the spirals layers form during rotation and distribution of the yarn along spool height. The winding period is the time during which the yarn makes a cycle distribution over the entire spool height. Most such spools are produced on winding machines by winding many thousand meters of single yarn on cylindrical or conical tubes. Textile yarns are usually wound into suitable spool form, used in processes variety such weaving and knitting [1].

When spool is used as raw material to textile production process, it is important that yarn unwinds with uniform ease [2].

In order to achieve this, the winding operation should maintain constant tension level in the yarn wound, as well as achieve a uniform spacing between successive yarn turns. The problem of unwinding from end regions of the spool is more complex. It requires specification of appropriate boundary conditions [3].

Tension is applied to yarn during winding for removing weak places on the yarn and building a stable spool of required density. The Yarn tension is introduced by means of tensioner disc or tensioner gate. As rule of thumb the winding tension should be about a mean 10 - 15 % of breaking load [4]. With natural fibers this means that weak zones will be removed during winding [5].

To make a bobbin, two movements are necessary: one progressive movement and another reciprocating.

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The type of winding depends to provision made in the bobbin, pitch, and a spires inclination angle. Winding with small inclination angle is called parallel turns, with large winding angle of turns is called crossover. In practice, There currently, three fundamentally different types of spool:

- The parallel spool winding: It comprises many yarns laid parallel to one another, as in warp. It is necessary to have a flanged package or beam to prevent collapse and instability of spool.
- The near parallel winding spool: It comprises one or more threads which are laid very nearly parallel to the layers already existing on the spool.
- The cross-wound spool: It is a type usually consisting of single yarn which is laid on the spool at appreciable inclination angle so that layers cross one another to give stability.

To obtain a correct spool, the second and third types of spools require a traversing mechanism on the winding machine. The to-and-fro movement of yarn on spool is controlled by a movable yarn guide. When winding the spool second type, the pitch between successive coils must be small and the minimum distance traversed to each revolution of spool is determined by yarn diameter.

The yarn approaches the laying point almost perpendicularly. When winding on conical bobbins of third type without flanges, the pitch between successive coils must be relatively large to obtain a stable spool. When the successive coils of yarn are laid closely on a spool and parallel, it is possible to produce a very dense package in which maximum amount of yarn is stored in given volume. With cross-wound spool, the pitch between successive coils is large, a considerable number of voids are created by multiple cross-overs and consequently spool is much less dense.

As spool diameter grows during winding, the yarn helix angle and distance between adjacent coils change. The investigation of the spool density distribution is one of important aspects of the wound spool random study [6]. The density of cross-winding depends to yarn nature. The intersection angle of turns spool plays an important role between the pressure and the yarn tension during the process winding [7].

II. Crossing Angle of Turns

Cross winding of yarn packages can be considered as a set of crossed yarn. Consider an element composed of two crossed yarn of length (l), (Fig. 1).

The volume element has a parallelepiped form to following dimensions:

$$V = a \cdot b \cdot \delta$$

According to diagram from Fig. 1

$$a = l \sin \propto \text{ and } b = l \cos \propto$$

Therefore volume will be equal to:

$$V = \delta \cdot l \cdot \sin \propto \cdot \cos \propto = \frac{\delta . l^2}{2} \sin 2 \propto$$

where 2α- crossing angle of the turns

Weight of the two wire considered is:

$$T = \frac{1000}{N} = \frac{1000\, g}{l}$$

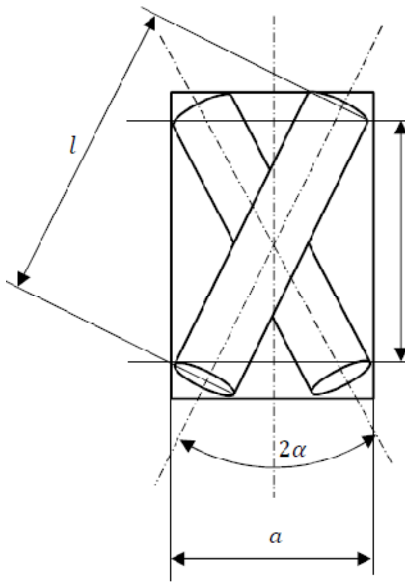

Fig. 1 Representation of volume element composed by two yarns (top view: height is equal to δ). a: width; δ: height; b: length

The weight of wire element is equal to:

$$\mathbf{g}_1 = \frac{l . T}{1000}$$

The weight of two wire members is determined by:

$$\mathbf{g}_2 = \frac{l . T}{500}$$

The winding density is calculated from volume occupied by two wire elements

$$\gamma = \frac{g}{V} = \frac{2. l. T}{500\, \delta . l^2 . \sin 2 \propto} = \frac{T}{250\, \delta . l . \sin 2 \propto}$$

Considering values (δ) and (l) constants for this wire element, we can write:

$$K = \frac{T}{250 \,. \delta . l}$$

So

$$\gamma = \frac{K}{\sin 2 \propto}$$

It follows that the winding density is inversely proportional to intersection angle of turns.

More angles is greater, smaller is the winding density.

The specific density of winding yarn on bobbin is not uniform along length; this reflects an unequal length of winding yarn into layer along spool axis.

Considering two cases:

A. Cylindrical Winding

Let us choose spool member of a height (h) bounded by two planes (P_1) and (P_2), as shown in Fig. 2.

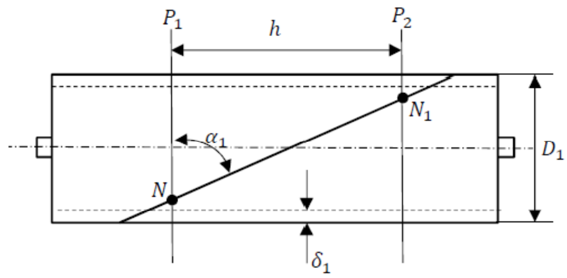

Fig. 2 Schema of volume element of cylindrical spool

The two planes are disposed perpendicular to the bobbin axis, limited by two planes in form of a cylinder volume. On the cylinder obtained is disposed a small portion of turns with length equal to l_1 = NN1.

$$l_1 = \frac{h}{\sin \alpha_1} \,(m) \tag{1}$$

Weight of wire element wound on the cylinder

$$\Delta m_1 = \frac{l_1}{N} = \frac{l_1 T}{1000} \,(gr) \tag{2}$$

where: T - Yarn thickness

Taking account of (1), we have:

$$\Delta m_1 = \frac{hT}{1000 \, \sin \alpha_1} \,(gr) \tag{3}$$

The winding of the turn gives some increase volume of basic cylinder which can be determined as the ring volume.

$$\Delta V_1 = \pi h \frac{(D_1+\delta)^2}{4} \,(cm^3) \tag{4}$$

The volume density of considered element is equal to

$$\gamma_1 = \frac{\Delta m_1}{\Delta V_1} = \frac{T}{250\pi\,(D_1+\delta)^2 \sin \alpha_1} \tag{5}$$

By analogy, volume density of winding, with another wire element, from another spool section is:

$$\gamma_2 = \frac{T}{250\pi\,(D_2+\delta)^2 \sin \alpha_2} \tag{6}$$

The densities ratio of winding (γ_1) and (γ_2):

$$\frac{\gamma_1}{\gamma_2} = \frac{D_2 \sin\propto_2}{D_1 \sin\propto_1} \quad (7)$$

From (7) deduced following relationship:

$$\gamma_1 D_1 \sin\alpha_1 = \gamma_2 D_2 \sin\alpha_2 = \cdots \gamma \text{n}\, Dn \sin \propto \text{n} = Cte \quad (8)$$

For cylindrical spool:

$$\gamma_1 = \gamma_2 = \cdots = \gamma\text{n} = Cte \quad (9)$$

Refer to (9) represents condition of winding uniform of yarn on cylindrical spool. It means for the cylindrical spool:

$$\text{D}_1 = \text{D}_2 = \cdots = \text{Dn and } \propto_1 = \propto_2 = \cdots = \propto \text{n}$$

B. Conical Winding

When winding the yarn on conical spool from its base to its top, the deposited layers during the winding of yarn are not identical. To study this phenomenon, we consider two elementary portions conical spool of same height (h) and different diameter (D_1) and (D_2). On the first cylinder surface is found a part of the spiral. Fig. 3 represents the respective intersection angles are ($\propto_1$) and ($\propto_2$). .

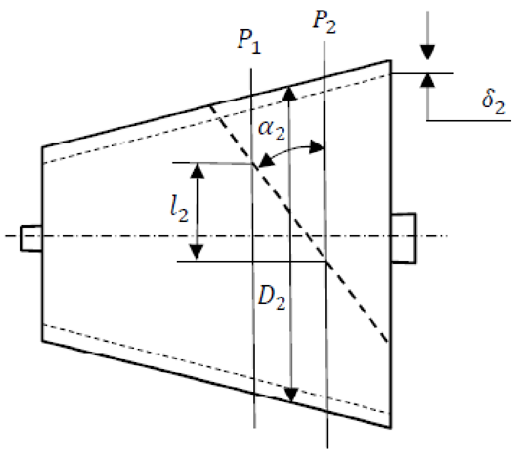

Fig. 3 Representation of thread element to conical bobbin

The spiral length on first cylinder is:

$$\text{l}_1 = \frac{h}{\sin\alpha_1}\,(m) \quad (10)$$

After thread winding on conical spool, the radius (ρ) increases by (X_1) and considering the ratio of the radius initial and final, we obtain:

$$\frac{\delta_1}{\delta} = \frac{\rho + X_1}{\rho} \quad (11)$$

The volume increase of first elementary cylinder will equal to:

$$\Delta\text{V}_1 = \pi \text{D}_1 \text{h}\left(\frac{\rho + X_1}{\rho}\right)(cm^3) \quad (12)$$

The mass increase of same volume considered is:

$$\Delta\text{m}_1 = \frac{hT}{1000 \sin\alpha_1}\,(gr) \quad (13)$$

The winding specific density of the first elementary cylinder is:

$$\gamma_1 = \frac{\Delta\text{m}_1}{\Delta\text{V}_1} = \frac{T\rho}{1000\pi D_1 \delta(\rho + X_1)\sin\propto_1} \quad (14)$$

By analogy, the specific density of yarn winding on the second spool part:

$$\gamma_2 = \frac{\Delta\text{m}_2}{\Delta\text{V}_2} = \frac{T\rho}{1000\pi D_2 \delta(\rho + X_2)\sin\propto_2} \quad (15)$$

The winding density ratio:

$$\frac{\gamma_1}{\gamma_2} = \frac{D_2(\rho + X_2)\sin\propto_2}{D_1(\rho + X_1)\sin\propto_1} \quad (16)$$

Considering the expression:

$$\frac{D}{2} = (\rho + X_2)\tan\beta$$

Diameters of two elementary cylinders are equal to:

$$D_1 = 2(\rho + X_1)\tan\beta \ (cm) \quad (17)$$

$$D_2 = 2(\rho + X_2)\tan\beta \ (cm) \quad (18)$$

$$\frac{\gamma_1}{\gamma_2} = \frac{(\rho + X_2)^2 \sin\propto_2}{(\rho + X_1)^2 \sin\propto_1} \quad (19)$$

Based upon (19) we conclude that:

$$\gamma_1 (\rho + X_1)^2 \sin\propto_1 = \gamma_2 (\rho + X_2)^2 \sin\propto_2 = \cdots = \gamma\text{n}(\rho + X\text{n})\sin\propto \text{n} = Cte \quad (20)$$

III. Conclusion

The formulas (19) and (20) gives the possibility to calculate the change of the specific density of the winding yarn over the entire height of the spool having spherical ends, to a concave basic shape and a convex shape at the top.

The change in the specific density over the height of the bobbin is explained in general by the sudden change of the winding speed due to change in the direction of movement of the wire, the maximum to (0) and (0) to the maximum. Therefore in the ends of the spool is wound amount from yarn of 1.5 to 2 times the average amount which is in the middle of the spool.

Based upon some of the experimental results, it can be said that:

– When winding the yarn on a cylindrical bobbin with a constant pitch, the winding density is evaluated in the ends by the following relationship:

$$\gamma e = \frac{\gamma m}{0.87}$$

– During the winding of the yarn on the cylindrical surface of the spool with a variable pitch, the winding density is evaluated in the ends by the following relationship:

$$\gamma e = \frac{\gamma m}{0.7}$$

– During the winding of the yarn on the surface of the conical bobbin with a variable pitch, the winding density is evaluated in the ends by the following relationship:

$$\gamma e = \frac{\gamma m}{0.9}$$

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