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Short Communications

Determination of yarn position on cone surface of random cone winding system

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The parametrical differential equation of yarn curvature for suitable yarn random cone winding has been derived. Along with the determination of the yarn position on cone surface by numerical method, the suitable situation of random winding is also studied in various forms of yarn positions. The results show that the equation can determine the exact yarn position on surface of cone for optimum yarn winding conditions. Also, the wide start angle and tight cone angle cause tight yarn curvature and more yarn length on package, but these parameters are limited to winding and unwinding processes.

Keywords: Cone package, Random winding, Yarn, Yarn curvature

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The winding operation involves the rotation of the tube to draw the yarn, and traversing the yarn in the axial diversion of the tube so as to form the package. This action deposits the yarn in a helical path which is reversed in direction at each end of the package. These actions produce a stable package which has a cross-wound appearance. Figure 1 shows a conical package which can rotate with its drum.

When the package is subsequently used as raw material in a textile production process, it is important that the yarn unwinds with uniform ease. Hence, it is important to wind the conical package for some velocities of yarn unwinding.

Many authors have tried to solve this problem, mainly in connection with axial unwinding of yarn from package, as the winding process has not been studied enough to satisfy demand of modern machines for processing yarn, particularly on loom and knitting machine. Nobauer and Baumeler[1] studied unwinding resistance of yarn package using the package performance analyzer to determine suitable package conditions. Babaarsalan *et al.*[2] calculated winding of conical packages at a constant delivery rate. Their calculations were based on winding parameters of winding angle and its change during winding process.[3]

Winding onto a cone is done on cone winders; some two–for–one twisters and open-end spinners lead to a variation in yarn traverse speed along the cone. The cone is driven by a cylindrical grooved drum. The grooves in drum must be designed so as to keep the cone angle nearly constant from first diameter to final diameter of cone package. The slippage between package and grooved drum causes winding faults.[4] The slippage between package and drum depends on yarn properties, machine parameters and both package and grooves shapes.[5] Also, the variation in coil angle and traverse length in conical package can cause regularity of package while coil angle during traversing is calculated truly. Talukdar *et al.*[6], Zaitsev *et al.*[7] and Moiseev and gordeev[8] although offered this as very important parameter of package irregularity, they have not calculated suitable curvature of yarn position on package surface to determine optimum groove shape on winding drum.

In this study, the equation of yarn curvature has been solved in Cartesian coordination with the assumption that the yarn length on the cone package must be proportional to diameter of cone. By this

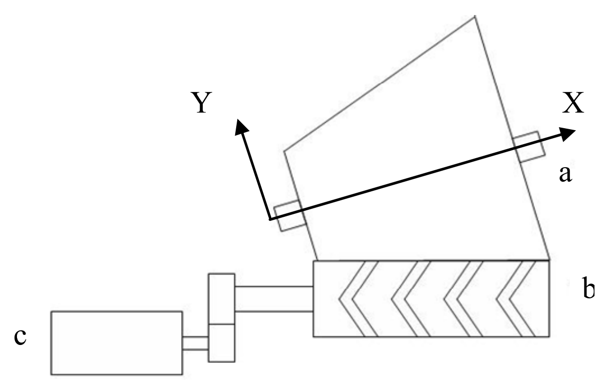

Fig. 1 — Random cone system [(a) conical package, (b) grooved drum and (c) motor]

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equation, it is possible to determine yarn position on the cone surface. The curvatures of yarn on cone surface have also been analyzed for various cones shape based on different heights of cone concentration point and start angles of winding.

Determination of Yarn Curvature

In the case of constant angle of cone in both situation of empty and wound package, the suitable winding process is followed By determination of yarn curvature in situation of constant angle of cone, it is possible to design the optimum grooves curvature of driving roller similar to the yarn curvature on cone surface.

The cone shape depends on its height and two different diameters. As shown in Fig. 2, the D_1, D_2 and h are the nose diameter, the base diameter and the height of cone respectively. Also D_x and x are the cone diameter and the yarn distance from cone nose in a sample position of yarn on cone surface, where A is the height of cone concentration point from its nose. The cone dimensions obey triangle rule, Therefore it is presented as:

$$\frac{D_1}{A}=\frac{D_x}{x+A} \quad \dots (1)$$

$$D_x=\frac{D_1(x+A)}{A} \quad \dots (2)$$

If the yarn curvature is extended in a two dimensional surface of Cartesian XY coordination (Fig. 3) (where X is traversing path of yarn and Y, the yarn rotation path on extended package surface in two dimensional form for successive rotations), it is claimed that for uniform winding where cone angle is constant for various layers, the portion of $\cos\theta / \cos\theta_1 = D_1 / D_x$ reminds cosine rule, where θ_1 and θ are the start point and a sample point of yarn winding on cone surface respectively. Therefore, winding angle of θ is related to cone diameter as shown below:

$$\theta = arc\cos\frac{D_1\cos\theta_1}{D_x} \quad \dots (3)$$

The yarn curvature can be assumed as a short line in each small element of curvature. Therefore, it is specified that $\tan\theta=\frac{dx}{dy}$ in each assumed element. Also, the yarn position in integration form is defined as $y=\int\tan\left(arc\cos\frac{D_1\cos\theta_1}{D_x}\right)dx$. This relationship is converted into following equation by replacement of D_x from Eq. (2):

$$y=\int\tan\left(arc\cos\frac{A\cos\theta_1}{x+A}\right)dx \quad \dots (4)$$

The yarn curvature was calculated from Eq. (4) by using algebraic solution.[9] For this purpose, parameters β and p were defined as

$$\beta = arc\cos\frac{A\cos\theta_1}{x+A}, \text{ and } p=\frac{A\cos\theta_1}{x+A}$$

By using these parameters, Eq. (4) can be presented as shown below:

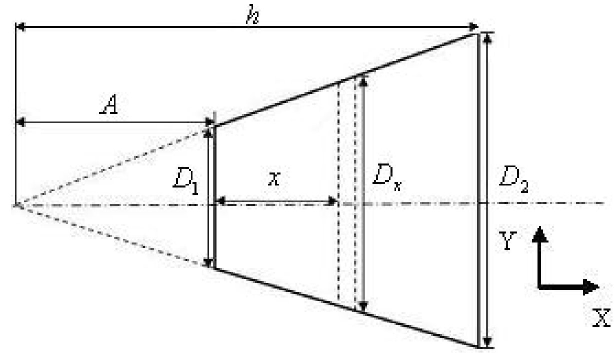

Fig. 2 — Cone dimensions [D_1— nose diameter, D_2— base diameter, D_x— diameter in x point, h— height of cone, and A— distance between concentration point and nose]

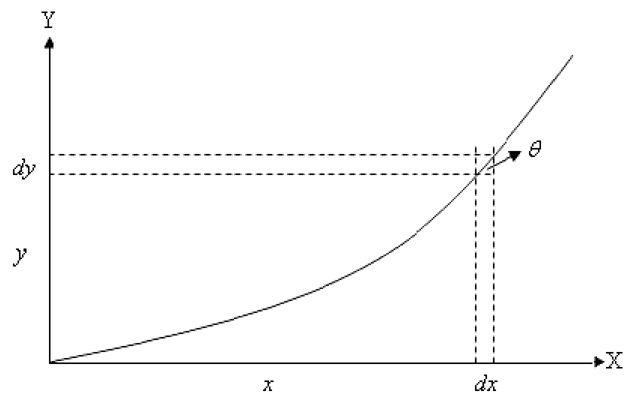

Fig. 3 — Schematic curvature of yarn in XY coordination

$$y = \int \sqrt{\frac{1}{p^2} - 1}\, dx \qquad \dots (5)$$

By replacement of p in Eq.(5), following relationship is obtained.

$$y = \frac{1}{A\cos\theta_1} \int \sqrt{(x+A)^2 - A^2\cos^2\theta_1}\, dx \qquad \dots (6)$$

The integrated part of Eq.(6) is defined as parameter φ, as shown below:

$$\varphi = \int \sqrt{(x+A)^2 - A^2\cos^2\theta_1}\, dx \qquad \dots (7)$$

By replacing the parameters $a = A\cos\theta_1$ and $\sec k = \frac{x+A}{a}$, Eq. (7) is converted into $\varphi = a^2 \int \tan^2 k \sec k\, dk$. Parameter φ is calculated by differential parametric method, as given below:

$$\varphi = \frac{a^2}{2}\left[\sec k \tan k - \ln\left|\sec k + \tan k\right| + c\right] \qquad \dots (8)$$

In Eq. (8), c is a constant value. By replacing the parameter k Eq. (8) is converted to the following relationship:

$$y = \frac{1}{2}.\frac{x+A}{A\cos\theta_1}\sqrt{(x+A)^2 - A^2\cos^2\theta_1} - A\cos\theta_1.\ln\left|(x+A) + \sqrt{(x+A)^2 - A^2\cos^2\theta_1}\right| + c' \qquad \dots (9)$$

where c' is a constant value and is calculated in point of (0, 0). By finding c', the yarn curvature equation on surface of cone in two dimensional status of XY coordination is determined, as shown below:

$$y = \frac{1}{2}.\frac{x+A}{A\cos\theta_1}\sqrt{(x+A)^2 - A^2\cos^2\theta_1} - A\cos\theta_1.\ln\left|(x+A) + \sqrt{(x+A)^2 - A^2\cos^2\theta_1}\right| + A\left(\cos\theta_1 \ln\left|A + A\sin\theta_1\right| - \frac{1}{2}\tan\theta_1\right) \qquad \dots (10)$$

Table 1 — Start angle of winding and height of concentration point for standard cones

Sample	Height of conc. point, cm	Cone angle deg	Start angle deg
Cone shape 1	31	5	60
			65
			70
			75
Cone shape 2	10	9	60
			65
			70
			75

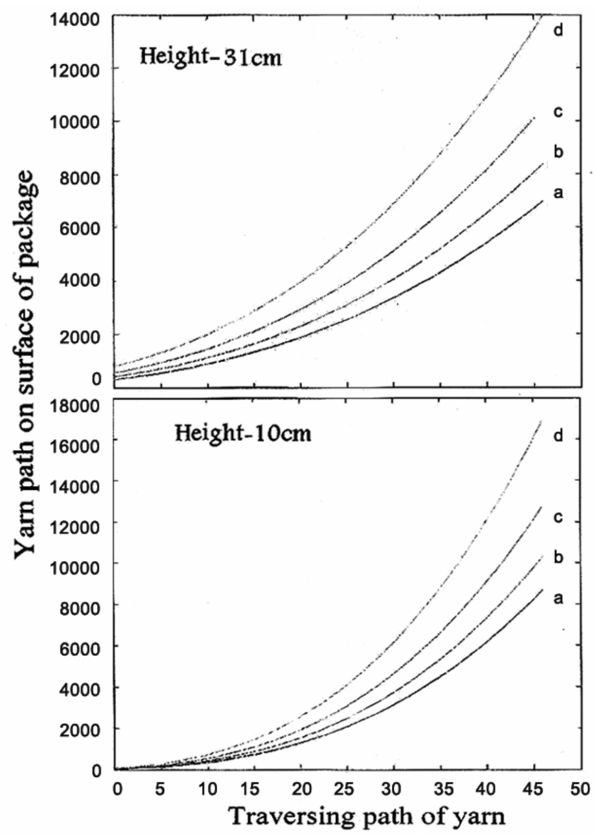

Fig. 4 — Yarn curvature for different heights of concentration point and various start angles of winding [(a) 60°, (b) 65°, (c) 70° and (d) 75°]

After determination of yarn curvature using Eq. (10), it is necessary to sketch the profile of yarn in two dimensional status of XY coordination. The cone shape is based on height of cone concentration point from its nose. Table 1 shows different start angles of winding and concentration point heights. The yarn curvature for various start angles of winding and cone shapes according to Table 1 were determined as shown in Fig. 4.

Figure 4 shows that the tighter profile of yarn curvature is occurred in tighter cone angle which is related to cone shape based on its height of concentration point from cone nose. Also, by increasing the start angle of winding, the profile of yarn curvature changes to tighter shape. Therefore, the yarn curvature depends on both the package shape and start angle parameters in constant profile of grooves curvature of driven drum.

Results show that the length of wound yarn increases while yarn curvature is tight during winding process. The yarn curvature is tight in small angle of package and wide start angle of winding. When the angle of package is small, the length of wound yarn increases but in this situation the unwinding process is difficult due to the increase in friction between yarn and package. Also, the start angle of winding is limited, because of increasing the winding angle during traversing process. The start angle of winding set as a big angle by increasing the winding angle limitation over 80° causes unstable edge situation of package.

For determination of grooved curvature in cylindrical from, it is necessary to find yarn curvature in X expressions. This calculation is very difficult in analytical method [Eq. (10)] and therefore, a simpler from of yarn curvature was determined from original one by best fitting numerical method. Grooved curvature is determined in extended from cylindrical coordination. Grooves curvature is rolled on drum surface. Grooves are beveled by CNC machine based on their pattern. Curvature fitting in connection joints of repeated curvatures is done by designer during beveling operation.

The yarn curvature is not exactly same as grooves curvature because of manufacturing limitation. Start and finish edges of curvature should be fit together in cylindrical order by manufacturer. Therefore, it is necessary to have curve fitting between two copies of curvature. Usually, curve fitting is done during manufacturing by designer. It is recommended to do this process by design software carefully.

In yarn winding onto conical package, the cone is driven by a cylindrical grooved driven roller. The curvature of grooves in drum determines yarn curvature on surface of cone package. To get uniform shape of package, the cone angle should be kept nearly constant from first diameter to final diameter of cone package. In this situation, length of yarn in each layer depends on package diameter.

In this study, the yarn curvature in Cartesian XY coordination was determined in assumption of constant angle of cone package from first to final layer of wound yarn. Then, the effect of start angle of winding and cone package shape was studied on the basis of calculated equation of yarn curvature.

The results show that the start angle of winding is effective on tightening of yarn curvature and the wider start angle causes tighter curvature and more length of yarn. The start angle is limited to increasing the winding angle during traversing process. Also, in small cone angle the yarn curvature is tight but unwinding process is difficult. The grooves of driven drum can be designed based on calculated yarn curvature. After that, it is possible to do some experimental industrial attempts for enhancement of grooved drum. In this study, only the theoretical aspect of yarn curvature is presented to guide industrial attempts for better designing of grooved drum based on desired yarn curvature as a mapping grooved shape in cylindrical form.

Industrial Importance: The reported method can be applied to estimate grooved drum curvature for every package with various cone angles. This design helps in getting constant cone angle during winding process, thereby providing more uniform and stable package during downstream process.

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