YARN UNWINDING FROM PACKAGES

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This Publication has to be referred as: Predovic, A[leksander] (2017). Yarn Unwinding from Packages, Proceedings of the 28th DAAAM International Symposium, pp.0698-0703, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-11-2, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/28th.daaam.proceedings.098

Abstract

The Yarn unwinding from a package is important in many textile processes. The stability of the unwinding process has a direct influence on the efficiency of the process and on the quality of the end product. During the unwinding, the tension is oscillating. This is especially noticeable in over-end unwinding from a static package, where the yarn is being withdrawn with a high velocity in the direction of the package axis.

The optimal form of the package allows an optimal shape of the yarn balloon and low and steady tension even at very high unwinding velocities. Using experimental data as an input, we will calculate oscillations of yarn tension for different package geometries and winding angles. These results will be used to suggest a design new packages.

Keywords: yarn unwinding; balloon theory; simulations; design new packages

1. Introduction

Oscillations in the yarn during the yarn unwinding from stationary packages have a direct influence on the quality of the fabric. The characteristics of the unwinding process are thus important for production of high quality garments and should therefore be optimized. All authors (since 1950 [1-4] to 2001 [4-12]) who developed theory of unwinding yarn from packages, used a few assumptions, which help them to set the winding angle of the packages on value 0° ($\Phi = 0^\circ$). In practical way, the winding angle in winding machines has values from 12° to 22° . For this reason, it is almost importance to determine the package geometry and the winding angle which allow to maximize the unwinding velocity given the allowed highest oscillations in the yarn.

2. Theoretical part

Angle ϕ is the winding angle of the yarn on the package. Its magnitude is the angle between the yarn at the unwinding point and the tangential direction at the package surface, while its signs determines whether the yarn is being withdrawn in the direction from the front end toward the rear end of the package ($\phi > 0$) or from the rear end toward the front end ($\phi < 0$) (Fig. 1).

Fig. 1. Winding angle during the yarn unwinding from package

The general equation of motion which govern the motion of the yarn are known [13-40]:

$$\rho \left(D^2 \mathbf{r} + 2\boldsymbol{\omega} \times D\mathbf{r} + \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r}) + \dot{\boldsymbol{\omega}} \times \mathbf{r} \right) = \frac{\partial}{\partial s} \left(T \frac{\partial \mathbf{r}}{\partial s} \right) + \mathbf{f}. \quad (1)$$

Here ρ is the mass per unit length of the yarn, $\mathbf{r}$ is the radius vector to a given point on the yarn, D is the co-moving time derivative operator, T is the yarn tension and $\mathbf{f}$ is the density of external forces acting on the yarn.

Equation of motion expressed in terms of the dimensionless quantities [7].

$$\begin{aligned} \bar{\mathbf{r}} &= \mathbf{r}/c, \bar{r} = r/c, \bar{z} = z/c, \bar{s} = s/c, \\ \bar{t} &= t/\tau = \omega t, \bar{\mathbf{v}} = \mathbf{v}/V, \bar{\mathbf{v}}_n = \mathbf{v}_n/V, \\ \bar{\mathbf{f}} &= \frac{\mathbf{f}c}{\rho V^2}, \bar{\mathbf{n}} = \frac{\mathbf{n}c}{\rho V^2}, \bar{T} = \frac{T}{\rho V^2}. \end{aligned} \quad (2)$$

When we rewrite the equation of motion with these dimensionless quantities we obtain

$$\bar{D}^2 \bar{\mathbf{r}} + 2\bar{\Omega} \times \bar{D}\bar{\mathbf{r}} + \bar{\Omega} \times (\bar{\Omega} \times \bar{\mathbf{r}}) + \bar{\Omega} \frac{\partial \bar{\Omega}}{\partial \bar{t}} \times \bar{\mathbf{r}} = \frac{\partial}{\partial \bar{s}} \left(\bar{T} \frac{\partial \bar{\mathbf{r}}}{\partial \bar{s}} \right) + \bar{\mathbf{f}} \quad (3)$$

Only one parameter remains in this equation it is the dimensionless angular velocity $\bar{\Omega}$.

On cylindrical packages the angular velocity depends on the winding angle Φ according to relation [5,6]:

$$\omega = \frac{2\pi}{t} = \frac{V \cos \Phi}{c (1 - \sin \Phi)} \quad (4)$$

The dimensionless angular velocity can obviously be expressed as:

$$\bar{\Omega} = \frac{\cos \Phi}{1 - \sin \Phi} \quad (5)$$

According to our simple model the dimensionless angular velocity thus only depends on the winding angle which will change with time because this angle is different for layers that are unwinding from front towards rear edge and those that are unwinding as the unwinding point moves from the rear towards front edge. The dependence $\bar{\Omega}$ on the winding angle is shown in Fig. 2.

Fig. 2. Dependence of Ω on the winding angle [27-31].

During unwinding the lift-off point moves up and down the package. We can presume that the winding angle is approximately constant in the middle of the package and it changes at the edges of the package where its sign is reversed. To describe the time dependence of the winding angle we must look for a periodic function, because motion of the point is periodic to a good approximation.

The most known periodic functions are trigonometric function, such as sine function. This function should be modified so that it will change only slightly when the point moves up or down the packages. We can achieve this by raising the sine to a low fractional power, say $1/40$ (we have to be careful about the signs, so we take absolute value of sine function and restore the sign using the signum function [26]):

$$f(t) = \text{sign}(\sin t) |\sin t|^{\frac{1}{40}} \quad (6)$$

3. Practical part

We measured how the tension at the eyelet depends on the angular velocity of unwinding. We measured the unwinding speed, package radius and tension of yarn as we unwound yarn from parallel cylindrical packages. We used a balloon limiter, that limits the balloon radius.

Fig. 3. Dependence of tension T on angular velocity ω of the yarn [37].

We must emphasize that this dependence was obtained by measurements on a simple, parallel wound package. In split of this we will use these data in our simulations of cross-wound packages. This approximation has little influence on the qualitative features of our results.

In our simulation, we calculate the winding angle using function (6), then we determine the corresponding angular velocity ω and finally we obtain an approximation for the tension using data from Fig. 3.

In our calculations, we considered unwinding for two consecutive layers of yarn, so that the package radius remains approximately constant during this time.

Figure 4 presents the changing tension in the yarn as we unwind yarn from a cylindrical package. The time is expressed in units of phase: 2π corresponds to one cycle of unwinding point up and down the package.

Fig. 4. Variation of the tension during unwinding, $V=1400$ m/min, $c=70$ mm. $\Phi \sim 0^\circ, 10^\circ, 20^\circ, 30^\circ$.

In a, cross-wound package with a very small $\Phi=0$ the tension is constant, since in such packages the angular velocity doesn't change with time. In packages with higher winding angle Φ , the tension does change with time. This happens because the angular velocity is higher when the unwinding point moves backwards as it is when the unwinding point moves forward. The tension is a function of angular velocity, so it is oscillating. When the direction of unwinding changes near the edges of the package, the yarn tension undergoes a rapid change. Such sudden jumps lead to strong strain in the yarn, the yarn can be damaged or even broken in two parts.

Figure 5 depicts how the amplitude of oscillations depends on the package radius and winding angle:

Fig. 5. Amplitude of the tension oscillation, $V=2000$ m/min.

3.1. New cross-wound packages

To reduce the tension oscillations, we devised new cross-wound packages. The package should be prepared so that the parallel wound layers are unwound when the lift-off point is moving backwards, and the interstitial cross wound layers are unwound when the lift-off point is moving forwards. This choice is motivated by the observation that cross wound packages lead to very high tensions when the yarn is unwound backwards. In addition, cross wound layers between two parallel wound layers are necessary to reduce the possibility of slips during unwinding.

In Fig. 6 we compare the amplitude of oscillations in regular and new packages. This amplitude is higher for old packages at all velocities and winding angles. The amplitude attains very high values in old packages while it is substantially lower in the new cross-wound packages.

Fig. 6. Comparison of tension oscillation in regular (blue) and new packages (red), $c=120$ mm.

4. Conclusion

We have derived the expressions for the time dependence of the angular velocity of the balloon rotation around the package axis, of the unwinding velocity and the winding angle during the yarn unwinding from cylindrical packages. The expressions allow to study the motion of the lift-off point on the package surface as we have shown. This method makes it possible to consider more general package designs where the package radius and winding angle are arbitrary functions which describe the package form and the type of winding of yarn in individual layers. This procedure allows to simulate yarn unwinding from general packages and to determine the package construction with the desired properties. We have thereby established that the parallel and the cross-wound packages differ by the absence or presence of the characteristic variations of the angular velocity and consequently the yarn tension during the unwinding. The problem of high yarn tension and its high oscillations can be avoided by constructing packages, where two types of layers are alternating, parallel layers and layer with higher winding angle. The alternating design helps to reduce sudden changes of tension, and it leads to higher stability of the unwinding process. In the near future, we would like and hopefully will implement our knowledge in the textile production and try to find out, how all research fields affect quality.

5. References

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