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HIGH-SPEED YARN TRANSPORT SYSTEMS SIMULATION

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Abstract: *Stability of the unwinding process has a direct influence on the efficency of the process and on the quality of the final product. An optimal shape of the package leads to an optimal shape of the balloon and to small and steady tension even at high unwinding velocity. Computer modelling is a valuable tool in search of the optimal package shape. We demonstrate a mathematical model for simulating the unwinding from cylindrical and conic packages. We show how the winding angle and the apex angle influence the angular velocity of the yarn during the unwinding. Since the centrifugal forces on the yarn in the balloon depend on the angular velocity, this velocity has a large influence on the tension that we wish to reduce.*

Key words: *mathematical model, winding angle, tension, simulations*

1. INTRODUCTION

Oscillations in the yarn tension 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. The theory of yarn dynamics during unwinding was developed as early as in 1950's (Padfield, 1958) and is still an active area of research (Praček, 2002). The theory was recently compared with experimental results with considerable success (Kong, 1997; Kong et al, 1999; Clark&Fraser&Stump, 2001).

Bulding on this fondation we have simplifield the problem even further. We will show how a simple model function that describes the package can be used to estimate the unwinding properties of packages of different geometries and different winding types.

2. THEORETICAL PART

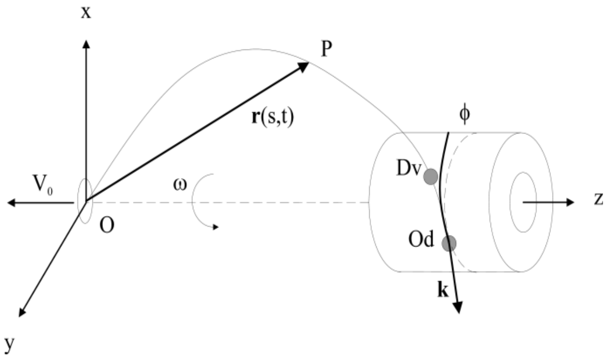

Fig. 1. Mechanical setup in overend yarn unvinding from cilimdrical package

The yarn is being withdrawn with velocity V through an eyelet, where we also fix the origin O of our coordinate system (Fig.1). The yarn is rotating aroun the z axis with an angular velocity ω. At the lift-off point Dv the yarn lifts from the package and forms a balloon. At the unwinding point Od the yarn starts to slide on the surface of the package. Angle ϕ is the winding angle of the yarn on the package.

On cylindrical packages the relation between the angular velocity of the yarn during unwinding ω, the unwinding speed V and the package radius c at the lift-off point, where the yarn lifts off from the package surface, is (Fraser &Ghosh&Batra,1992):

$$\omega = \frac{V}{c}\left(\frac{1}{\cos\phi} - \tan\phi\right)^{-1} = \frac{V}{c}\frac{\cos\phi}{1-\sin\phi} \quad (1)$$

In deriving this expression we neglected the variation of yarn length in the balloon during the time interval when two layers unwind.

The dimensionless angular velocity can obviously be expressed as:

$$\Omega = \frac{\cos\phi}{1-\sin\phi} \quad (2)$$

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 dependance od Ω on the winding angle is shown in Fig2.

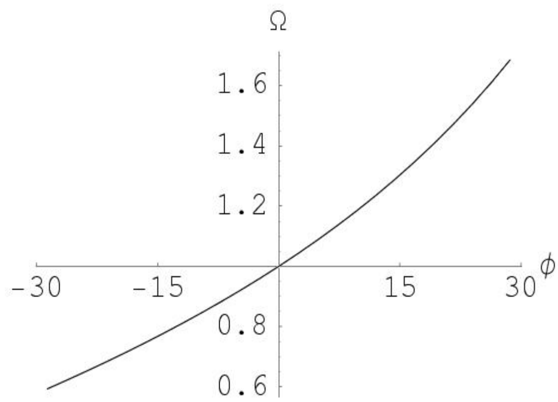

Fig. 2. Dependence of Ω on the winding angle (Kong, 1997)

In conical packages the relation is only slightly modified:

$$\omega = \frac{V}{c}\frac{\cos\phi}{1-\cos\alpha\sin\phi} \quad (3)$$

Here α is the apex angle of the conical package. For typical values of α there is little difference between cylindrical and conical packages.

3. MATHEMATICAL MODEL

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:

$$f(t) = \mathrm{sign}(\sin t)|\sin t|^{1/40} \tag{4}$$

The diagram of this function is shown in fig.3.

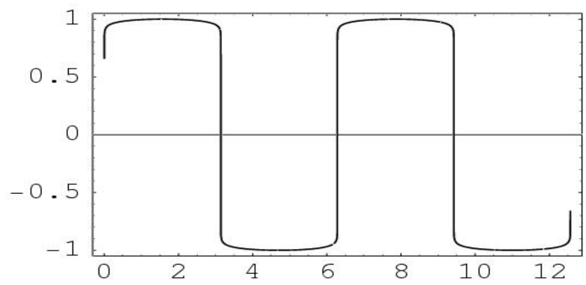

Fig. 3. Model function for winding angle

The physical reality is somewhat different, especially in cross-wound packages, made using circumferential driving of the tube. The diagram shown in Fig. 3 would apply to precision wound cross-wound packages, made using direct driving of the tube. The loops would then lie next to each other.

If we considered a few loops of the rear end of the tube, before the next layer starts to unwind in the direction of the front end, and a few loops from the front end of the tube, before the next layer begins to unwind in the direction of the rear end, then we would obtain the diagram in Fig. 3. In this case we would have to neglect all the loops in between.

Speaking of the unwinding process, we are mostly interested in the maximal tensions in the yarn and the oscillations of the tension as a function of the unwinding speed. We aim to achieve the highest possible speed, while keeping the tension in the yarn and oscillations as low as possible.

The variations of the dimensionless angular velocity (Fig. 4) are more pronounced in cross wound packages with a high winding angle. In cross-wound packages it is therefore inadmissible to consider the winding angle as a small quantity and to neglect it in the first approximation.

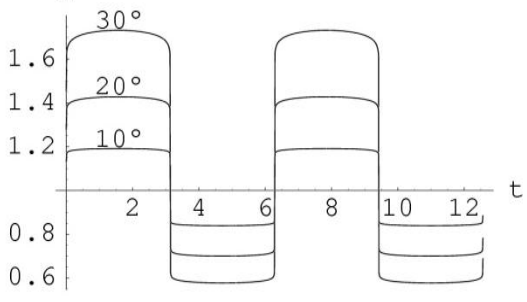

Fig. 4. Variations of the dimensionless angular velocity

The lower the winding angle is, the lower will the oscillations of the tension be. The maxima will then be lower and we'll be able to increase the unwinding speed. The problem is that most of the winding machines in use throughout the world use circumferential driving of the tube. This method of package winding makes it impossible to change the winding angle, while this is possible with winding machines using direct driving of the tube. In recent times the fraction of such winding machines is increasing.

4. CONCLUSION

Cross-wound packages made using circumferential driving of the tube do not permit to achieve the unwinding speeds necessary on fast weaving loom, where the cross-wound package is used as a wefting package. For this reason two wefting packages are necessary for every color of the weft, as well as two weft feeders of weft which is expensive and irrational.

In circumferential driving of the package the winding angle does not change. The direct consequence is the mirror winding – the winding of one layer on top of the other, which can be avoided by modulation The threads do not lie parallel to each other (the pitch of the helix is usually large and the points of contact of two consecutive layers are sparse). Because of the large contact area it occurs that entire layers slip or that the yarn breaks.

In modern winding machines with a direct driving of the tube, the winding angle can be changed. Each layer has a determined winding angle, so that there are more points of contact as in the packages made with circumferential driving of the tube. Of special importance is the fact, that loops on one layer aren't parallel to the loops in the next layer, which reduces the possibility of slips during unwinding. Furthermore there are no difficulties of mirror winding, so that there is no danger of yarn falling off the package.

The winding machines with a direct driving of the tube allow greater flexibility of winding of cross-wound packages compared to the winding machines with a circumferential driving. They allow construction of packages that can be unwound at higher unwinding speeds.

In no case can we avoid the oscillations of yarn tension near the edges of a package, when the direction of motion of unwinding and lift-off points changes. The winding of the packages has to be optimized so that the absolute value of the yarn oscillation is as low as possible. In the foture we will revie the results of our extensive simulations and show how unwinding properties of a package can be improved by using alternating layers of parallely wound and cross wound layers

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