INVESTIGATION OF THE TENSION RELATIONS IN RING SPINNING BETWEEN TRAVELLER AND YARN PACKAGE

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To know the tensile force arising in ring spinning in the yarn section between traveller and yarn, package is of vital importance. That section is the final spinning phase of the yarn to be produced. In order to determine the tensile force arising in this yarn section, and the winding tension, let us define the equilibrium condition of forces acting on the traveller (by "tension" force is understood throughout in this paper.)

According to *D'Alambert* the following forces act on the traveller during its movement:

1. the yarn tension directed towards the yarn guide,
2. the winding tension directed towards the yarn package,
3. the centrifugal force acting on the traveller,
4. the weight of the traveller,
5. the reaction force substituting the constraint produced by the ring.

Plotting the axes x and z of the co-ordinate system in the plane of the ring, the axis y will lie in the rotation axis of the spindle. Be the traveller in its momentary position in the point of intersection A $(x, 0, 0)$ of the ring circumference, and the axis x. Furthermore, be

S — the tension on the traveller directed towards the balloon,

S_{cs} — the winding tension,

$C = mr\,\omega^2$ — the centrifugal force acting on the traveller — where m is the mass of the traveller —,

r — the radius of the ring,

mg — the weight of the traveller, and

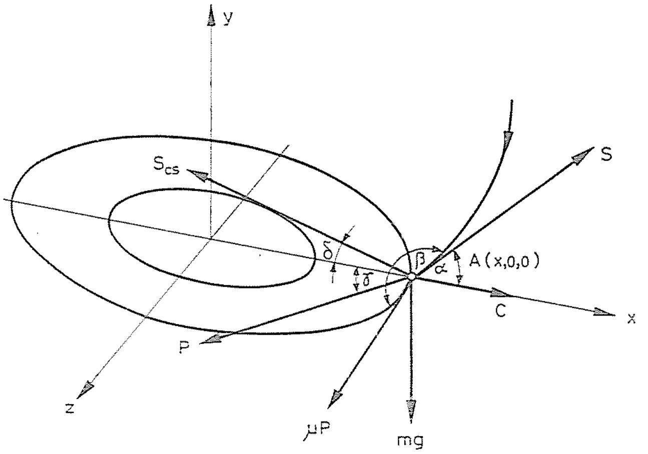
R — the reaction force produced by the ring.

The reaction force R is composed of two forces:

a) the friction force μP of a sense contrary to the movement of the traveller and falling in the direction of the tangent of the ring (here μ is the coefficient of the friction between the ring and the traveller),

b) the force P falling in the plane (xy) substituting the support of the traveller, and directed to below the base plate (xz).

The dynamic equilibrium condition of the traveller is that the sum of the projection of all the forces is zero in the direction of all the three co-ordinate axes.



On the basis of Fig. 1, the equations of the traveller are of the following form:

$$\Sigma X = C + S \cdot \cos\alpha - S_{cs} \cdot \cos\delta \quad - P \cdot \cos\gamma = 0$$
$$\Sigma Y = -mg + S \cdot \cos\alpha' \quad - P \cdot \sin\gamma = 0$$
$$\Sigma Z = \mu P + S \cdot \cos\beta - S_{cs} \cdot \sin\delta = 0$$

where α' is the angle between the force S and the co-ordinate axis y.

$$S = k \cdot S_{cs},$$

where

$$0 < k < 1,$$

consequently the equilibrium equation takes the following form:

$$C + k \cdot S_{cs} \cdot \cos\alpha - S_{cs} \cdot \cos\delta - P \cdot \cos\gamma = 0$$
$$-mg + k \cdot S_{cs} \cdot \cos\alpha' \quad - P \cdot \sin\gamma = 0$$
$$\mu P + k \cdot S_{cs} \cdot \cos\beta - S_{cs} \cdot \sin\delta = 0.$$

Multiplying the first equation by $\sin\gamma$, the second one by $\cos\gamma$ and adding the same we have:

$$C \cdot \sin\gamma + k \cdot S_{cs} \cdot \cos\alpha \cdot \sin\gamma - S_{cs} \cdot \cos\delta \cdot \sin\gamma +$$
$$+ mg \cdot \cos\gamma - k \cdot S_{cs} \cdot \cos\alpha' \cos\gamma = 0.$$

Now, multiplying the first equation by μ, the third one by $\cos\gamma$ and summing up we get:

$$\mu C + \mu k \cdot S_{cs} \cdot \cos\alpha - \mu \cdot S_{cs} \cdot \cos\delta + k \cdot S_{cs} \cdot \cos\beta \cdot \cos\gamma - \\ - S_{cs} \cdot \sin\delta \cdot \cos\gamma = 0.$$

Finally, multiplying the second equation by $-\mu$, the third one by $-\sin\gamma$ and summing up we can write:

$$\mu mg - \mu k \cdot S_{cs} \cdot \cos\alpha' - k \cdot S_{cs} \cdot \cos\beta \cdot \sin\gamma + S_{cs} \cdot \sin\delta \cdot \sin\gamma = 0.$$

From this the winding tension, and the winding angle are:

$$S_{cs} = \frac{\mu\, mg}{k(\mu\cos\alpha' + \cos\beta\sin\gamma) - \sin\delta \cdot \sin\gamma} = \\ = \frac{\mu\, C}{\cos\gamma(\sin\delta - k \cdot \cos\beta) + \mu(\cos\delta - k\cos\alpha)}$$

and

$$\sin\delta = \frac{\mu(k \cdot S_{cs}\cos\alpha' - mg) + k \cdot S_{cs}\cos\beta \cdot \sin\gamma}{S_{cs} \cdot \sin\gamma}$$

resp.

For the approximate determination of the winding tension it has to be considered, however, that $\cos\alpha' \approx \sin\alpha$ and $\alpha \approx \beta \approx 90°$, consequently, the approximate value of the winding tension will be

$$S_{cs} = \frac{\mu\, mg}{k\mu - \sin\delta \cdot \sin\gamma}$$

while the winding angle is

$$\delta = \text{arc}\sin\frac{\mu(k \cdot S_{cs} - mg)}{S_{cs} \cdot \sin\gamma}.$$

In principle, with a traveller of negligible weight we have:

$$\delta = \frac{\mu k}{\sin\gamma}.$$

This means that with decreasing winding angle the angle between the reaction force substituting the constraint P and the spindle axis will be smaller, thus the winding tension increases. As a consequence of the reduced effect of the centrifugal force the traveller is being pressed against the top edge of the ring, in contrast to the former case, where it is lying on the inner side of the ring. With increasing winding angle, however, the direction angle of the reaction force P decreases, thus the force P plays a more important part in balancing the centrifugal force, and consequently the winding tension decreases.

Since $\sin \delta \leq 1$, it follows from the latter equation that $\sin \gamma \geq \mu k$. However, if $\mu k > \sin \gamma$, then δ is not real, thus the traveller cannot move on the ring and consequently spinning becomes impossible.

The equation also shows the known experimental fact that the tension and the frictional force are proportional to the centrifugal force on the traveller. The coefficient of friction affects considerably both the tension arising in the balloon and the winding tension.

Thus from the equation it follows that

a) winding tension changes with the sine of the guiding and is indirectly proportional to it. When winding on small diameter, winding tension increases and vice versa,

b) changes depend somewhat on the coefficient of friction,

c) omitting air resistance, balloon form influences but slightly the winding tension.

Summary

On the basis of the forces acting on the traveller the equilibrium equations and hence the winding tension and the winding angle have been determined. In view of the complicated equations, neglecting the weight of the traveller (amounting to 0.03—0.07 g under processing conditions), with the component of balloon tension along the spindle axis (about 3.10^2 times higher) simple equations both for winding tension and winding angle have been derived.

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