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Balance of Thread on the Surface of Fabric

Khamraeva Sanovar, Xaytmetova Raximaxon, Shaxobiddinova Mushtaribonu

Tashkent Textile and Light Industry Institute

Muminov Kodir

Bukhara Engineering-Technological Institute

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Annotation: In the article, on the basis of the formula of resistance of materials and mechanics of continuous media, assessments are given for the strength of the fabric and their optimal parameters are determined, which are substantiated theoretically. The static equilibrium of tissues at different internal pressure values is considered and the main theoretical formulas that allow evaluating tissues are indicated.

Here we offer to find the optimal structure of the fabric, calculation of selection of geodesic lines. Now we'll determine exertion of threads at inner pressure. For this the main laws of mechanics of deformed hard body and equations of mathematic physics are used.

Keywords: evaluation of fabric strength, optimal parameters, static balance of fabric, basic theoretical formulas, evaluation, fabric structure, load on threads at internal pressure, laws of mechanics, equations of mathematical physics.

Let's consider the thread put on the surface of rotation (fig. 1). The trajectory of the thread presents the curve the direction of the main normal of which does not coincide with the normal of the surface *n* in common case. As it is known, crookedness of the line may be characterized as the crookedness of its projection to the normal flatness passing through the tangent to the line and normal to the surface *n*.

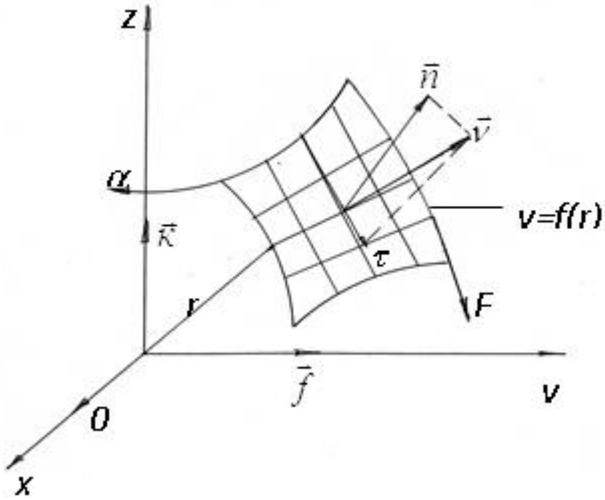

Fig. 1. Position of the thread lying on the surface of the fabric.

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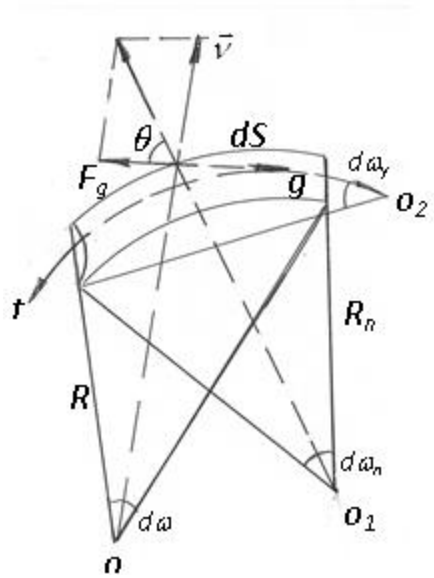

Fig. 2. Balance of the thread lying on the surface.

At this vector of crookedness of the line directed to the main normal of the curve v is projected on the normal of the surface n and the notion of normal crookedness is introduced (3)

$$\frac{1}{R_n} = \frac{1}{R}\cos\Theta \qquad (1)$$

where: R – radius of crookedness of the line.

Crookedness of line projection to the tangent flatness of the surface may be introduced as well. At this the vector of crookedness directed along the main normal is projected some straight lying in tangent flatness. From picture 2 we'll have [1]

$$\frac{1}{R_T} = \frac{1}{R}\sin\Theta \qquad (2)$$

The quantity $\frac{1}{R_T}$ is called a geodesic crookedness of the line.

Let's consider the balance of the element of the thread lying on the surface (fig.2). In the picture point O symbolizes the centre of crookedness of the line, point O_1 symbolizes the centre of normal crookedness and point O_2 symbolizes the centre of geodesic crookedness [2, 3].

Let the thread extend by force τ, which we'll call the tension of the thread. From the side of the surface the thread is under the influence of normal reaction Fn and force of friction F_T, which prevents slipping of the thread and is determined by Kulon's law

$$F_T = F_n \cdot \beta \qquad (3)$$

where: β – coefficient of friction.

Let's point out that the shown (Fig.3) force of friction corresponds to the maximum balance position of the thread. In common case the angle between F_T and tangent to the curve may differ from the straight angle. Projecting the forces influencing on the element of the thread on the tangent to trajectory we'll get

$dt/ds=0$, that is $t=const$

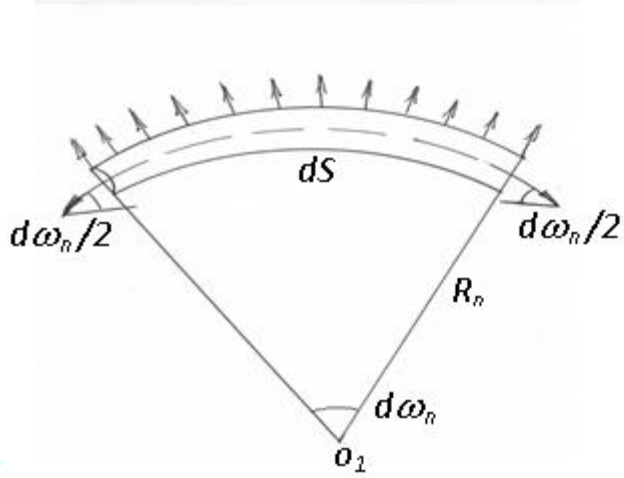

Fig. 3. Calculation scheme.

Let's project influencing forces on the normal of the surface n. On the base of picture 3 we'll get $2\tau\sin(d\omega_n)/2 = F_n ds$. From here, as $\sin(d\omega_n)/2 \approx d\omega_n/2$; $ds=R_n d\omega_n$, we'll find

$$\tau / R_n = F_n \qquad (4)$$

or with an account of equality (1)

$$\frac{\tau}{R}\cos\Theta = F_n \qquad (5)$$

In the same way projecting influencing forces on direction g we'll get (fig.4)

$2\tau \sin(d\omega_T)/2 = F_T ds$, as $\sin(d\omega_T)/2 \approx d\omega_T/2$; $ds=R_T d\omega_T$, we have

$$t/R_T = F_T \qquad (6)$$

From here on the base of equality (2) and (3)

$$\frac{\tau}{R}\sin\Theta = \beta F_n \qquad (7)$$

Correlation of (3) and (7) presents the equation of balance of the thread on the surface.

Condition of balance of the thread on the surface may be obtained from equations (6) and (7)

$$\mathrm{tg}\,\Theta = \beta \qquad (8)$$

If the cone of friction is introduced with the ax coinciding with the normal of the surface and with the angle of admixture *n=arctgb*, the condition may be interpreted geometrically. It is obvious that the main normal of the curve must be generatrix of the cone of friction [4, 5].

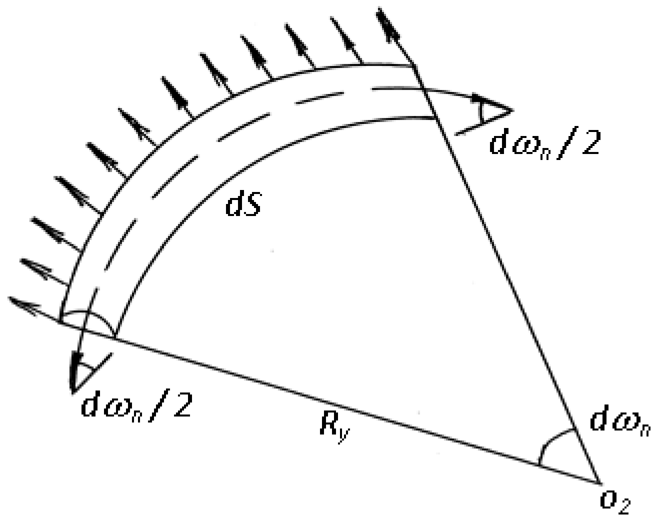

Fig. 4. Calculation scheme.

Equality (8) is a maximum condition of balance. Naturally, the thread is in balance if at all points of trajectory the main normal does not go out of the limit of the cone of friction, that is, the conditions providing the balance of the thread on the surface of the fabric laid with tension on the surface of the mandrel are determined by the following inequality [6, 7].

$$max\ |tg\Theta| \le \beta \quad (9)$$

At absence of friction between the thread and mandrel (β=0) the condition of balance takes the form

$$\Theta = 0,$$

that is, the main normal of the curve coincides with the normal of the surface at all points. The lines possessing this property are called geodesic.

Thus, in the process of weaving geodesic lines are wittingly provided by the stable position of the thread on the surface of the fabric and wide usage of geodesic schemes in practice is also explained by this.

One more circumstance essentially simplifying the technological process on geodesic lines connected with that the flexible thread laid with tension on the absolutely smooth surface takes the form of geodesic line. The condition of balance of the thread must be beforehand provided with the suitable value of friction coefficient β and parameters of trajectory and surface determining the angle Θ of geodesic declination [8].

We'll obtain the expression for $tg\Theta$. From the equality (1) and (2)

$$tg\Theta = R_n / R_T \quad (10)$$

Normal and geodesic crookedness of the line on the surface is determined by suitable correlations of differential geometry (2) and for the surface of rotation with generatrix *y (r)*

$$\left(\frac{1}{R_1}-\frac{1}{R_2}\right)\cos^2\varphi+\frac{1}{R_2}=\frac{1}{R_n} \qquad (11)$$

$$\frac{d\varphi}{dS}+\sin\left(\frac{\varphi}{r}\right)\sqrt{1+(y')^2}=\frac{1}{R_T} \qquad (12)$$

where R_1, R_2 – main radiuses of crookedness of the surface of the fabric determined by equalities

φ – angle between the curve and meridian [9, 10].

Substituting crookedness (11) and (12) to formula (10) and taking into account the fact that the radiuses of crookedness of the surface *a* of the element of the line arch making the angle φ with meridian

$$\sqrt{1+(y')^2 ds}=dr/\cos\varphi$$

finally we'll obtain

$$tg\Theta=-\frac{(r\cos\varphi d\varphi+\sin\varphi)dr\left(1+(y')^2\right)}{\left(ry''\cos^2\varphi+y'\sin^2\varphi\left(1+(y')^2\right)\right)} \qquad (13)$$

Thus, condition of thread balance ((9) on the surface of the fabric takes the form of

$$R_1=\left(-\frac{1}{y''}\right)\left[1+(y')^2\right]^{3/2};$$

$$R_2=\left(-\frac{r}{y'}\right)\left[1+(y')^2\right]^{1/2};$$

$$\sin\alpha=-\frac{y'}{\left[1+(y')^2\right]};$$

y = y(r) – which determines position of the thread on the surface of the fabric.

$$y'=\frac{dy}{dr}; \qquad y''=\frac{d^2y}{dr^2}$$

As it has already been stressed, for geodesic lines Θ=0. Equating the numerator of the right part of the equality to zero we'll obtain

$$1/r/d\varphi/dr+tg\varphi=0$$

Solution of this equation

$$r\sin\varphi=\cos t$$

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determines geodesic lines on the surface of the fabric and have been used many times before at analyzing optimal forms of fabric structure. Obtained formulas allow determining optimal forms of fabric structure with the means of direction accepted at the process of weaving on geodesic lines.

Here we offer to find the optimal structure of the fabric, calculation of selection of geodesic lines. Now we'll determine exertion of threads at inner pressure. For this the main laws of mechanics of deformed hard body and equations of mathematic physics are used.

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