European Science Methodical Journal
ISSN (E): 2938-3641
Volume 2, Issue 12, December- 2024

THE EFFECT OF FRICTION FORCE IN ELIMINATING NON-UNIFORMITY OF THREADS IN THE THREAD FORMATION ZONE

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Abstract:

The friction force in the thread formation zone has been studied in relation to the rigidity of the cylinder and threads, as well as their deformation equations and graphs. The dependence of the thread's stretching deformation on the wrap angle, the radii of the second cylinder, the density, and the thickness of the thread in the compression zone has also been analyzed, ensuring uniform elongation as a result of stretching.

Keywords: Friction force, Thread formation, stretching deformation, Cylinder radius, Uniform stretching, Wrap angle.

Introduction

The friction force largely depends on the rigidity of the cylinder and threads in the thread formation zone, as well as the deformation value, i.e., the density. The relationship between the friction force in the thread formation zone and the rigidity coefficients has been determined. The analysis of the constructed graphs indicates that when the overall rigidity coefficient of the twists in the thread formation zone ranges from 2.8 sN/mm to 8.0 sN/mm and the cylinder radius is $r = 17.5\ mm$, the friction force increases linearly from 0.19·10sN to 0.52·10sN. The friction force between the twists in the thread formation zone increases linearly from 0.45·10sN to 1.12·10sN.

Therefore, in order to increase the friction force between twists in the thread formation zone, it is advisable to reduce the number of twists and select rigidity coefficients in the range of (7.0÷9.0) sN/mm. In this case, a cylinder radius of $r = 17.5\ mm$ is recommended. The speed of the cylinder, i.e., the work productivity, primarily depends on the angular velocity.

In Figure 1, the graphs showing the dependence of the friction force between the cylinder and twists on the cylinder's angular velocity are provided. It can be observed that when the cylinder's angular velocity increases from $1.5 \cdot s^{-1}$ to $4.0 \cdot s^{-1}$, and the penetration angle is $1 - \varphi_2 = 15^0$, the F_{work} values increase linearly from $0.08 \cdot 10$sN to $0.36 \cdot 10$sN as a function of the twists.

However, if the differential cylinder penetration angle increases to $5 - \varphi_2 = 75^0$, the friction force increases non-linearly from $0.28 \cdot 10$ sN to $1.09 \cdot 10$ sN. It can also be noted that the increase in friction force leads to improved leveling of thread ends and ensures uniform stretching, which can be observed in Figure 1.

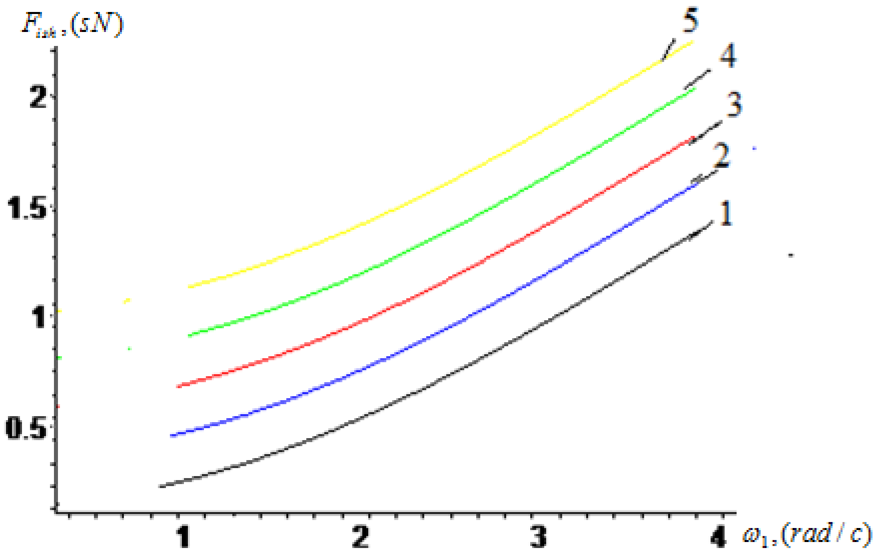

Figure 1. In the thread formation zone, the dependency graphs of the wrap angle during thread formation on the second cylinder at various angles $1-\varphi_2=15^0$, $2-\varphi_2=30^0$, $3-\varphi_2=45^0$, $4-\varphi_2=60^0$ $5-\varphi_2=75^0$with respect to angular velocity are provided.

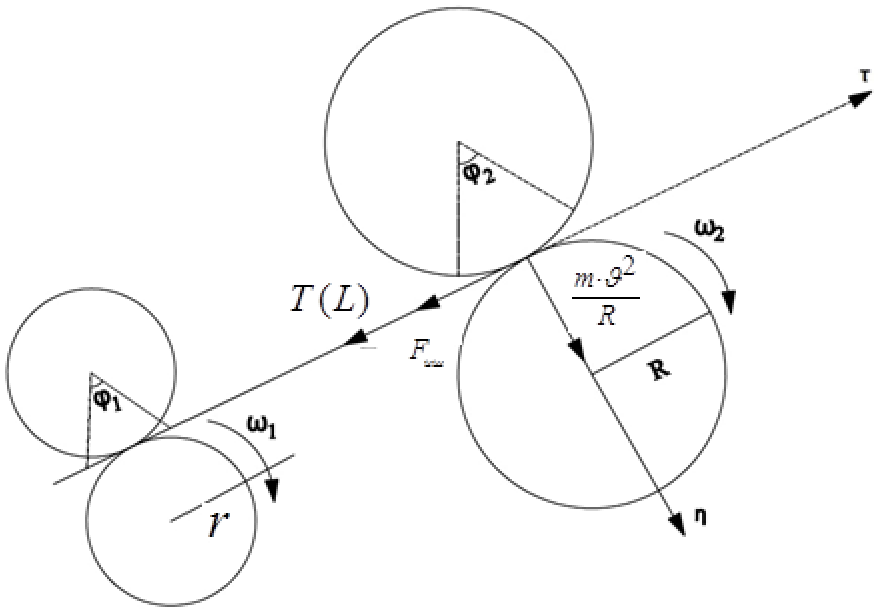

Figure 2: Drafting mechanism of the spinning machine

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The issue of correctly selecting the inclination angle of the rifled cylinder and the distances between the cylinders to determine the tension force of the thread between the first and second cylinders has been considered, using the condition $\omega_1 < \omega_2$ to ensure uniform stretching and thinning of the thread when passing from the rifled cylinder to the second cylinder. During the thread stretching process, the tension force $T(L)$ is defined as a function of L, the arc length during thread transmission. From the movement of the sliver on the gripping surface of the second cylinder and between the twists, the following expressions are derived.

$$L(T) \cdot \frac{dT}{dS} - \tau = 0$$
$$L(T) \cdot \frac{T}{R} - q = \frac{m \cdot \vartheta^2}{R} \qquad (1)$$

here $L(T) = 1 + \varepsilon$, $\varepsilon = \frac{T}{E \cdot S}$, $L(T) -$ the dependence of thread length on the tension force, ε - the relative elongation of the thread, m -the mass of the sliver in the gripping interval of the second cylinder, $\vartheta = \omega_2 \cdot R$ - the linear velocity of the second cylinder, $\omega_2 -$ the angular velocity of the second cylinder, $S -$the gripping surface area between the thread and the second cylinder, $\tau, q -$the normal and tangential forces acting on the thread, $E -$Young's modulus. The friction force generated on the surface as a result of the tensile force acting along the length of the thread is determined as follows.

$$\mu = \frac{\tau}{q} \qquad (2)$$

Here $\mu -$ is the coefficient of friction, and the wrap angle of the thread passing through the second cylinder is determined as $\varphi_2 = \frac{L}{R}$ Using equations (1) and (2), the tension force required for uniform stretching of the thread can be expressed as follows, i.e., the stationary state during the thread thinning process is determined by the following condition.

$$m_0 \cdot \vartheta_0 = m \cdot \vartheta \qquad (3)$$

Where m_0 and ϑ_0 - are the linear mass and velocity of the thread, respectively.

$$L(T) \cdot T - q \cdot R = m \cdot \vartheta^2 \qquad (4)$$

Substituting $Q_0 = m \cdot \vartheta$ into equation (4), we derive the following expression:

$$L(T) \cdot T - q \cdot R = Q_0 \cdot m \cdot R \qquad (5)$$

Using equations (5) and (1), we derive an expression for the tension force during the stretching process as a function of the angular velocity of the second cylinder, the deformation caused by the stretching, and the diameter of the second cylinder.

$$(1 + \varepsilon) \cdot \frac{dT}{R \cdot d\varphi_2} - f \cdot q = 0$$
$$(1 + \varepsilon) \cdot T - q \cdot R = Q_0 \cdot m \cdot R \qquad (6)$$

From the equations above:

$$(1 + \varepsilon) \cdot \left(\frac{dT}{d\varphi_2} - T \cdot f\right) = -Q_0 \cdot f \cdot \omega \cdot R \qquad (7)$$

During the stretching of the thread, its mass remains constant, while only the linear velocities of the cylinders change. Therefore, the following relationship holds:

$$\vartheta = \frac{\vartheta_0 \cdot m_0}{m} = \frac{\rho_0 \cdot S_0 \cdot \vartheta_0}{\rho \cdot S} \tag{8}$$

Where S_0-is the gripping surface of the thread on the first cylinder, S -is the gripping surface of the thread on the second cylinder, ρ_0-is the initial density of the thread on the first cylinder, ρ -is the density of the thread after stretching on the second cylinder. To determine the relationship between the linear velocity of the second cylinder and the deformation during stretching, we use:

$$\vartheta = R \cdot \omega_2 = (\varepsilon + 1) \cdot \frac{\vartheta_0 \cdot S_0}{S} \tag{9}$$

Substituting $S_0 = L \cdot h_0, S = L \cdot h$ where L −is the thread wrap length on the second cylinder, h_0 − is the initial thickness of the thread, and h − is the thread thickness after stretching), we get:

$$R \cdot \omega_2 = (\varepsilon + 1) \cdot \vartheta_0 \cdot \frac{h_0}{h}$$

From this:

$$h = (\varepsilon + 1) \cdot \vartheta_0 \cdot \frac{h_0}{R \cdot \omega_2} \tag{10}$$

Considering these expressions, the tension force is defined as:

$$T = E \cdot S_0 \cdot \varepsilon \cdot \frac{\vartheta_0}{R \cdot \omega_2} \tag{11}$$

Substituting equation (11) into equation (12), we can determine the expression for thread thinning and uniform transmission as a result of stretching.

$$(1 + \varepsilon) \cdot \left(\frac{d\varepsilon}{d\varphi_2} - \varepsilon \cdot f\right) = -\frac{Q_0 \cdot f \cdot \omega_2 \cdot R}{E \cdot S_0 \cdot \vartheta_0} \tag{12}$$

To simplify equation (4.66) for differentiation, we rewrite it in the following form:

$$(1 + \varepsilon)(\frac{d\varepsilon}{d\varphi_2} - f\varepsilon) = -f\frac{Q_0 R^2 {\omega_2}^2}{E S_0 v_0} = -f\frac{\rho_0 v_0 S_0 R^2 {\omega_2}^2}{\rho_0 a^2 S_0 v_0} = -f \cdot k^2$$

where $k = R \cdot \omega_2 / a, \; a = \sqrt{E/\rho_0}$ with these substitutions, the final equation takes the following form:

$$\frac{d\varepsilon}{d\varphi_2} - f(1 + k^2)\varepsilon = -f \cdot k^2 \tag{13}$$

Integrating equation (13), we obtain the expression describing the effect of stretching deformation on thread tension within the stretching zone:

$$\varepsilon = (\varepsilon_1 - \lambda^2) e^{f\left(\frac{k^2 \varphi_2}{\lambda^2}\right) + \lambda^2} \tag{14}$$

where $\lambda^2 = k^2/(k^2 + 1)$

From equation (14), it is evident that for $\varepsilon_1 > \lambda^2$, the deformation in the stretching zone increases as the wrap angle φ-increases, which leads to an increase in tension force and results in thread thinning. This in turn causes the strands to separate. Later, we consider the case where deformation decreases with decreasing $\varepsilon_1 < \lambda^2$ ensuring that thread tension decreases, preventing strand accumulation. For this, the thread deformation must remain uniform as $\varphi = \varphi_2$.

Substituting equation (14) into equation (10), the thickness of the thread during the stretching process is expressed as:

$$h = \frac{h_0 \cdot v_0}{R \cdot \omega_2}\{\lambda^2[1 - e^{(-f \cdot k^2 \phi_2 \lambda^2)]+1}\} \quad (15)$$

Equation (15) defines the thread's thickness based on the given linear velocity of the second cylinder, as well as angular velocity, geometric parameters, and the distances between cylinders. To ensure uniform thread thinning, appropriate parameters must be selected to maintain controlled movement along the compression flow zone. Figure 2 shows the relationship between the friction coefficient - f, the angle $\varphi = \varphi_2$, and the ratio $k = R \cdot \omega_2 / a$ for various values of k. Given parameters: $h_0 = 2$mm, $R = 10$mm, $L = 21$mm, $\omega = 0.9s^{-1}$ $E = 5$Pa, $\rho_0 = 8{,}5kg/m^3$, $v_0 = 0{,}006$m/c, $\varphi_2 = 40^0$, $f = 0.3$

$f = 0.3$ $\qquad\qquad$ $f = 0.5$

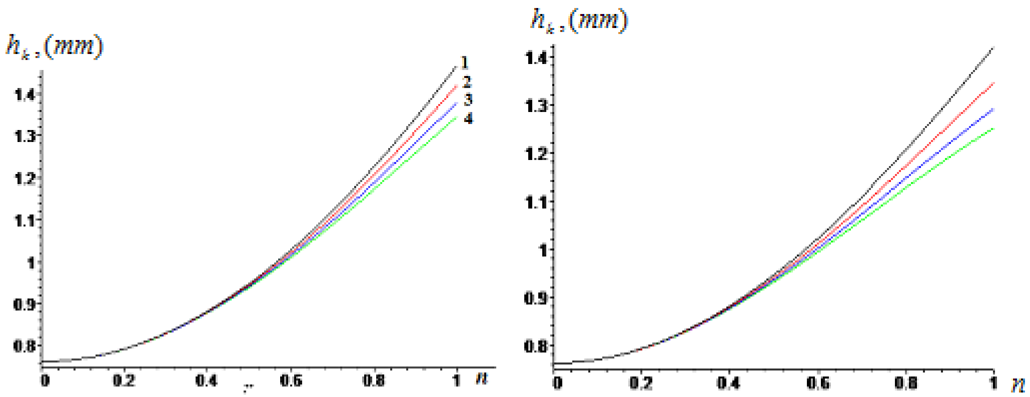
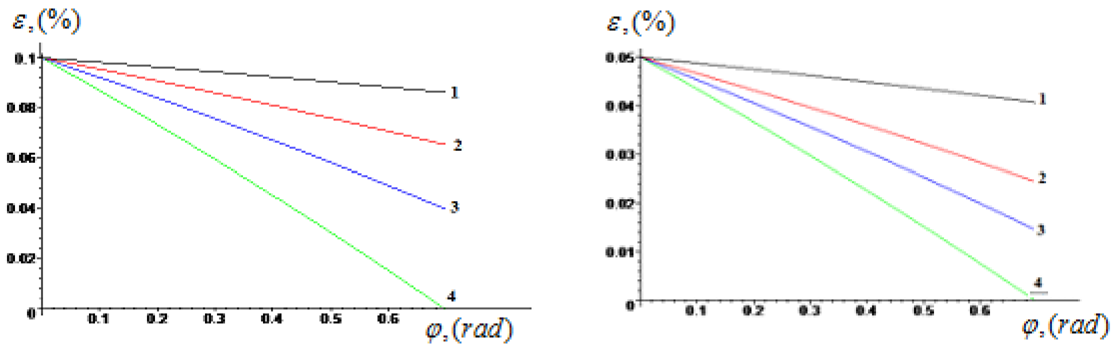


Figure 3. The graph of thread thickness h_k as a function of the friction coefficient f and the wrap angle ϕ_2 (degrees): $1 - \varphi_2 = 15^0$, $2 - \varphi_2 = 30^0$, $3 - \varphi_2 = 45^0$, $4 - \varphi_2 = 60^0$.

$\boldsymbol{\varepsilon_1 = 0.1}$ $\qquad\qquad$ $\boldsymbol{\varepsilon_1 = 0.05}$



a) $\qquad\qquad$ **b)**

Figure 4. (a) The initial stretching deformation of the thread $\varepsilon_1 = 0.1$;
(b) The subsequent stretching deformation $\varepsilon_1 = 0.05$ and the graphs of dependency on the wrap angle for different diameters of the second cylinder: $1 - R = 15mm$, $2 - R = 20mm$, $3 - R = 25mm$, $4 - R = 30mm$.

Conclusion

The graphs illustrate the dependency of the thread's stretching deformation on the wrap angle and the radii of the second cylinder. It can be observed that as stretching progresses, the density and the thickness of the thread in the compression zone demonstrate uniform elongation as a result of thinning.

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