A Theoretical Study On The Effect Of A False Twister On The Spinning Triangle In Yarn Formation On A Ring Frame

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ABSTRACT

The spinning triangle is a critical aspect of the ring spinning process, where the formation of yarn occurs on the front rollers of the machine. The distribution of tension forces within the spinning triangle significantly influences the properties of the resulting spun yarn. Traditional theoretical models assume that fibre tension during yarn twisting is perpendicular to the line of intersection of the front rollers. However, this assumption may not hold when a modification device is introduced to create a false twist effect, ensuring constant fibre tension forces at the corners and sides of the spinning triangle. In this article, a novel theoretical study was conducted, considering a constant angle of fibre tension within the spinning triangle. This approach takes into account the impact of spinning parameters, the shape of the spinning triangle, and the specific angle of yarn breaking strength on the quantitative characterization of fibre tensile strength. The proposed theoretical studies aim to analyze the effects of various factors, such as different fiber masses, the number of twists, tension forces, and angles α and β within the spinning triangle. The study also introduces a modification device placed between the front rollers and the yarn guide during the ring spinning process. By incorporating the false twist effect and the constant angle of fiber tension, the theoretical framework presented in this work seeks to provide a more accurate understanding of the spinning triangle dynamics. This enhanced theoretical model enables a comprehensive analysis of how modifications to the spinning process, such as the introduction of a specific device, impact the overall tensile strength of the yarn. The findings from this study guide optimizations in ring spinning processes to achieve desired yarn properties and performance

Keywords: Ring spinning, spinning triangle, tensile force, fiber, yarn

Introduction

To bring the yarn quality to higher indicators, it can be achieved by introducing new modification devices to existing ring spinning machines, i.e. by changing the area of yarn formation. The scientific research conducted in recent years provides information about modified spinning systems [1]. Several areas of importance in yarn formation in these modified spinning systems have been studied [2-6]. One of these is the spinning triangle. The dimensions of the spinning triangle and the distribution of fibers in it have a decisive effect on the location of fibers both on the surface and inside the yarn [7-8]. The irregular arrangement of the fibers in the spinning triangle and the spinning tension cause the compressive force on the fibers to be uneven. The geometric dimensions of the spinning triangle affect the distribution of the spun yarn and fiber tension forces in the spinning triangle [9-10]. Radical structural change of the collecting fibers in the spinning triangle was studied by Pavlov [11-12]. Krause et al. made several theoretical studies to achieve the constancy of the spinning triangle for spun yarns taking into account the different distribution of fibers in the spinning triangle [13-15]. The processes in the spinning triangle became more complicated with the development of new technologies for the production of spun yarn. New models were developed by Wang and Chang to reduce hairiness of yarn obtained as a result of ring spinning machine for modifying devices [16-21]. However, the number of twists of the yarns spun for knitting products in ring spinning machines is high, and the devices that help to reduce it, improve the fiber migration in the yarn, and improve the balanced indicators of the yarn are almost not studied. For this purpose, it is necessary to install a false-twister between the front roller of the ring spinning machine and the yarn guide and to theoretically study its effect on the spinning triangle.

In the process of twisting the yarn being formed in the ring spinning machine, the change of the spinning triangle due to the tension of the yarn causes different tension forces in the fibers. Therefore, the constancy of the spinning triangle can be achieved by modifying devices, and the theoretical study of the spinning triangle is desirable.

In the traditional spinning process, the twist applied to the yarn using the bobbin affects the tension of the yarn, the twist does not always reach the spinning triangle in the same amount, which leads to different sizes of the spinning triangle and uneven load on the fibers. The proposed false-twister device is installed between the front roller the ring spinning machine and the yarn guide, and with the help of it, the forming yarn is falsely twisted to obtain the same number of twist in the spinning triangle, and as a result, the tension of the fibers in the spinning triangle is constant causes to be.

Theoretical Analysis

In the theoretical study of the spinning triangle, the model in Fig. 1 was adopted. In it, the speed of the fibers is constant during the yarn formation process. The compressive stress behavior of fibers follows Hooke's law for small compressions. Therefore, the law of conservation of mass was used to analyze the distribution of fiber tension in the spinning triangle under yarn tension.

The cross-section *AB (ds)* of the spinning triangle shown in Figure 1 is the cross-section of the front roller, its size is constant, the intersection of the two sides of the spinning triangle *AC* and *BC (dl)* is the approximate point *C* that affects it is taken without any forces and is the tip of the spinning triangle. In the initial state, all the fibers in the spinning triangle are assumed to have the same fiber length, so the fibers in the center of the spinning triangle are relaxed (unstretched) and the fibers next to the spinning triangle are straight and unstretched. Then the point of intersection of the two sides of the spinning triangle *C* is pulled by a constant load *P* with a certain angle relative to the vertical axis. Ideally, the direction of the load *P* should be taken at any angle to the vertical axis, regardless of the shape of the spinning triangle. However, this approach leads to mathematical difficulties in determining the relationship between fiber tensions. So, to simplify, *P* moves along a certain direction with *E* as the midpoint of the line of intersection of the output front roller and *C* as the twist arrival point to the spinning triangle. Based on this relationship, the direction of the load *P* is not arbitrary, but depends on the shape of the spinning triangle. Also, the spinning triangle changes its shape under the tension applied to the yarn, where one end of the fiber is held at the cross-section of the outgoing front roller and the other end is held by the twist reaching the spinning triangle. In addition, the cross-sectional surface of all fibers is assumed to have the same shape.

Based on the fact that the two sides of the spinning triangle AC and BC have two different lengths, the coefficient k of the spinning triangle is adopted in the following analysis to describe it. From Figure 1, k can be found using the following equation.

$$k = \frac{AC}{BC} \quad (1)$$

Where, AC is the length of the left side of the spinning triangle. BC is the length of the right side of the spinning triangle.

In general, the value of k is between 0 and 1. The higher the value of k, the more symmetrical the sides of the spinning triangle will be. When k = 0, the length of side AC of the spinning triangle is equal to 0. If k = 1, the two sides of the spinning triangle are equal to each other. When the angle g at point C of the spinning triangle is less than 90º and greater than 30º, respectively, to the two sides of the spinning triangle, the force P generated by the twist to the spinning triangle reaches optimal values. If the angle α exceeds 90º, the amount of load increases, and when it is less than 30º, the amount of load decreases, which leads to a lot of breakage of the yarn forming in the spinning triangle. Angles a and b are the angles attached to the side of the spinning triangle lying on the line of intersection of the front roller.

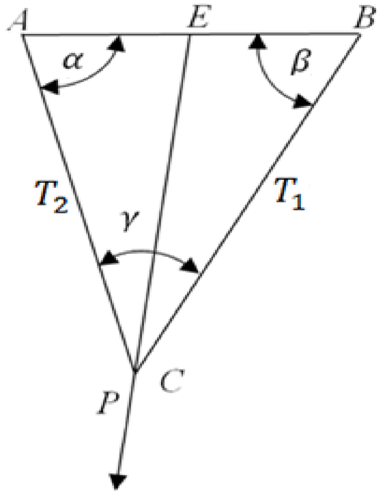

Figure 1. Spinning triangle

When the tension forces of the fibers in the spinning triangle shown in Figure 1 are in the state $T_1 = T_2$, that is, the ratio of AB side of the spinning triangle to BC is AB/BC=1, the twists reach the spinning triangle in one tex. Otherwise, it tends to AB/BC≈0 and the yarn forming in the spinning triangle is broken. Γ tends to AB/BC=1 when the angle is 30°< γ <90°. It is in the state $T_1 \approx T_2$. To achieve this goal, uniform transmission of fibers is described from the balance equations under the influence of external forces generated in the spinning triangle.

If a>b or b>a condition is observed, $T_1 > T_2$ or $T_2 > T_1$ condition is observed in the tension forces in the spinning triangle, which causes the yarn forming in the spinning triangle to break quickly.

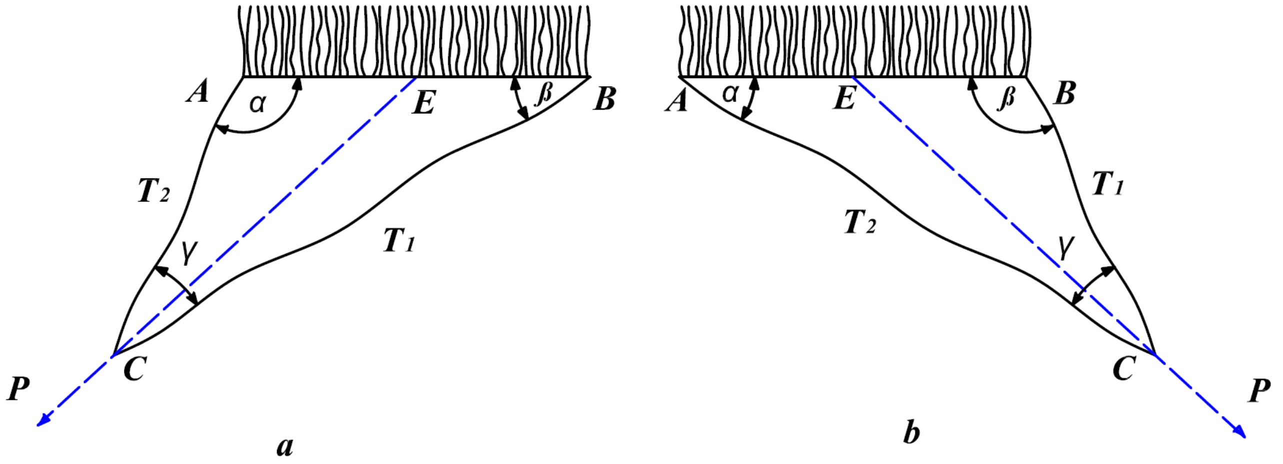

Figure 2. a – $T_1 > T_2$ case, b – $T_2 > T_1$ case.

The balance equation of the external forces acting on the spinning triangle during yarn formation using the drawing of the spinning triangle presented in Figure 2 was constructed as follows.

$$\begin{aligned} &\sum_{i=1}^{n} F_{ix} = 0; \quad T_1 \cdot \cos\alpha - T_2 \cdot \cos\beta - P \cdot \cos\phi = 0 \\ &\sum_{i=1}^{n} F_{iy} = 0; \quad T_1 \cdot \sin\alpha - T_2 \cdot \sin\beta - P \cdot \sin\phi - G_1 - G_2 = 0 \end{aligned} \quad (2)$$

From the balance equation (2), we derive the relationship between the tension forces in the spinning triangle. Will be equal to $G_1 = m_1 \cdot g = \frac{10^4 \cdot \alpha_t \cdot dl_1}{k^2} \cdot g$ and $G_2 = m_2 \cdot g = \frac{10^4 \cdot \alpha_t \cdot dl_2}{k^2} \cdot g$. In addition, determining the number of twists of the yarn depends on the ratio of the spindle speed of the machine (10000 min^{-1}) to the exit speed of the yarn. In conventional spinning, when we give 800 twists to the yarn, the number of twists in the yarn changes to 769, 800 and 833, and the output speed of this yarn is 12, respectively; 12.5 and 13 m/min lead to change.

Where, G_1 – *BC* side of spinning triangle is gravity, G_2 – *AC* side of spinning triangle is gravity, α_t - spinning coefficient, k – twist, dl_1 - length of *BC* side of spinning triangle, dl_2 - length of AC side of spinning triangle, g – free fall speed.

From the balance equation (2), the tension forces T_1, T_2 in the spinning triangle are determined as follows.

$$\begin{aligned} T_1 &= \frac{P \cdot \sin(\alpha - \beta) - (dl_1 + dl_2) \cdot \frac{10^4 \alpha_t}{k^2} \cdot g \cdot \cos\alpha}{\sin(\beta - \alpha)} \\ T_2 &= \frac{P \cdot \sin(\beta - \alpha) - (dl_1 + dl_2) \cdot \frac{10^4 \alpha_t}{k^2} \cdot g \cdot \cos\beta}{\sin(\beta - \alpha)} \end{aligned} \quad (3)$$

The graphs obtained using the Maple program, the graphs of the dependence of the number of twists of the yarn formed in the spinning triangle on the angles of the lengths of the sides of the spinning triangle using the equation (3) are shown in the Figure 3 and Figure 4.

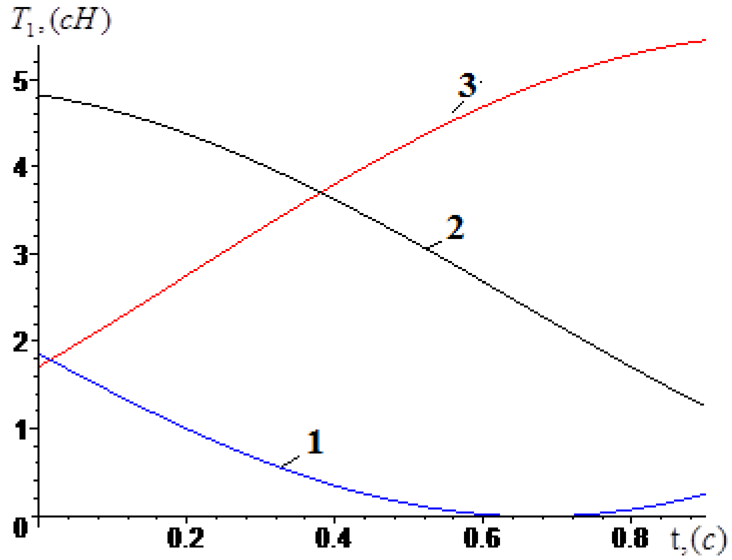

Figure 3. The graph of the tension force of the fibers on the BC side of the spinning triangle as a function of time at different $k_1 = 769$; $k_2 = 800$; $k_3 = 833$ values of the number of twists.

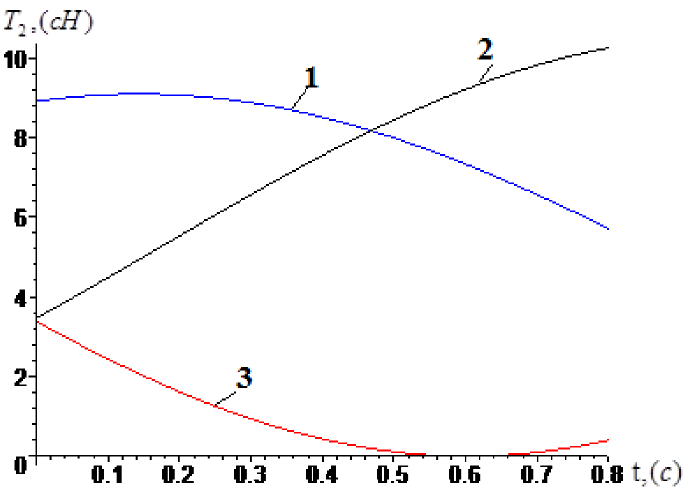

Figure 4. The graph of the tensile strength of the fibers on the AC side of the spinning triangle as a function of time at different $k_1 = 769$; $k_2 = 800$; $k_3 = 833$ values of the number of twists.

As can be seen from the graph, an increase in the number of twists reaching the spinning triangle leads to an increase in the fiber tension on the BC side of the spinning triangle and a decrease in the fiber tension on the AC side of the spinning triangle. The unevenness in this yarn leads to the breakage of the yarn forming in the spinning triangle due to the increase in hairiness. Therefore, it is necessary to ensure the same number of twists coming to the spinning triangle. To achieve this goal, it is necessary to install a false-twister device between the front rollers and the yarn guide. Using the device, the same twist is given to the spinning triangle.

As a result of giving the same twist to the spinning triangle of the device, the position of the angles α and β in the spinning triangle will be $\alpha \approx \beta$, then the tension forces will be $T_1 \approx T_2$.

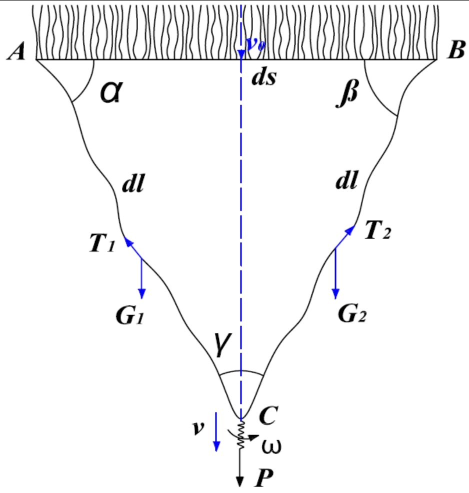

Figure 5. Scheme of action in forming a twist in yarn

Using the drawing of the spinning triangle in Figure 5, the welder formulates the balance equation of the external forces acting on the spinning triangle during yarn formation.

$$\sum_{i=1}^{n} F_{iy} = 0; \quad 2\cdot T\cdot \sin\alpha - P - 2G = 0 \tag{4}$$

From the equilibrium equation (4), the tension in the spinning triangle is generated. Will be equal to $G = m\cdot g = \frac{10^4\cdot \alpha_t \cdot dl}{k^2}\cdot g$. (4) to find the tension of the fiber in the spinning triangle. represents the tension force for the spinning triangle in position $\alpha = \beta$.

$$T = \frac{2\cdot 10^4 \cdot \alpha_t \cdot dl + P}{2\cdot \sin\alpha} \tag{5}$$

In the theoretical study aimed at increasing the quality of the yarn depending on the number of twists, the problem of the correct selection of the parameters affecting the yarn formed from the distribution of twists in the spinning triangle is posed. Using the equation (5) above, the dependence of the tension force of the yarn on the spinning triangle on the angle of distribution of the twists is analyzed graphically using the Maple program.

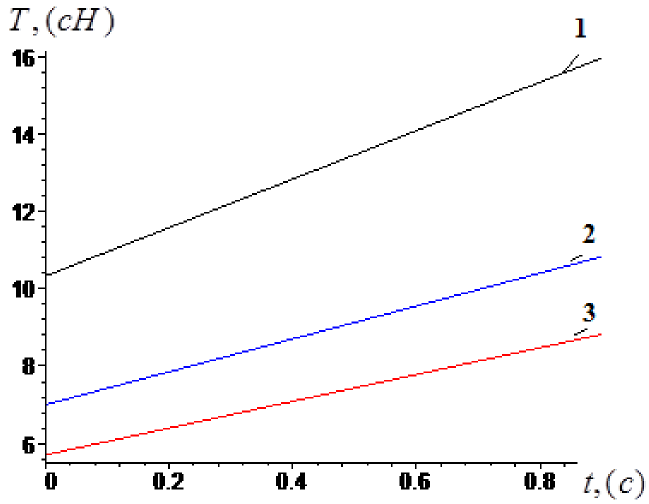

Figure 6. A graph of the tension force in the spinning triangle versus time at different $\alpha_1 = 30^0$ $\alpha_2 = 45^0$ $\alpha_3 = 60^0$ **values of the spinning angle.**

The propagation of twists is considered in the special case, where the angles of the twists are expressed as equal to each other.

$$\alpha = \beta \tag{6}$$

angles of a triangle when a yarn is formed.

$$\alpha = 90^0 - \frac{\gamma}{2} \tag{7}$$

$$\gamma = 90 - \frac{\gamma}{2}$$

$$\frac{dS}{\sin\gamma} = \frac{dl}{\sin\alpha} \Rightarrow \quad dS = \frac{\sin\gamma}{\sin\alpha} \cdot dl \tag{8}$$

Putting the equation (7) into the equation (8), the expression of the dependence of the length covered by the twists on the length of the twists was determined.

Expressions of the dependence of the twisting speed of the yarns formed in the spinning triangle in Fig. 5 on the number of twists, the tension force of the spinning yarn and the angles of coverage are determined. The speed of the twists formed by the propagation of twists in the AB zone is determined by taking the time derivative from equation (9).

$$\vartheta = \frac{dS}{dt} = 2 \cdot \sin\frac{\gamma}{2} \cdot \frac{dl}{dt} \tag{10}$$

From the equation (10), the expression of the dependence of the speeds of the twists on the angles of yarn formation and the initial speed is determined.

$$\vartheta = 2 \cdot \sqrt{\frac{1 - \cos\gamma}{2}} \cdot \vartheta_0 \tag{11}$$

Where; v_0 is the initial speed, γ - the angle of the twists during yarn formation.

$$\vartheta = \omega \cdot \mu \tag{12}$$

The mass dependence of the twists was determined as follows.

$$r \cdot d\varphi = dl \cdot \sin\beta \tag{13}$$

Substituting the expression (9) instead of dl, the expression of the dependence of twists in the formation of a yarn is derived.

$$r \cdot d\varphi = \frac{ds}{2 \cdot \sin\frac{\gamma}{2}} \cdot \sin\beta \quad \mathrm{r d\varphi} = \frac{\mathrm{ds}}{2\sin\frac{\gamma}{2}}\sin\beta \tag{14}$$

Reducing the number of twists in the production of yarn, by choosing the rational values of the parameters affecting the yarn, increasing the quality indicators of the yarn and determining the number of twists, we determine using the following equation.

$$K = \frac{100 \cdot \alpha_t}{\sqrt{T_i}} \quad \mathrm{K} = \frac{\alpha_t 100}{\sqrt{\mathrm{T}}}, \mathrm{buram/m} \tag{15}$$

Where, the number of K-twists, α_t-coefficient of twist, T_i - linear density of yarn. The linear density of the yarn is used to determine the equation of the dependence of the number of twists on the length and mass of the yarn.

$$T_i = \frac{m}{l} \tag{16}$$

Where, m - mass of yarn (g), *l* – length of yarn (km).

Putting equation (16) into equation (15), the equation of the dependence of the number of twists on its mass and length is created.

$$K = \frac{100 \cdot \alpha_t \cdot \sqrt{l}}{\sqrt{m}} \quad K = \frac{\alpha_t 100}{\sqrt{\frac{m}{l}}}, \text{buram/m} \tag{17}$$

The number of twists in the yarn can also be found by the ratio of the number of rotations of the spindle to the speed of front cylinder of the drawing tool.

$$K = \frac{n_v}{\vartheta_v} \quad K = \frac{n_v}{V_v}, \text{buram/m} \tag{18}$$

Where,n_v - the number of rotations of the spindle (min^{-1}), V_v - the speed of the front cylinder of the drawing tool.

Equations (17) and (18) are equated to each other.

$$\frac{n_v}{\vartheta_v} = \frac{100 \cdot \alpha_t \cdot \sqrt{l}}{\sqrt{m}} \quad \frac{n_v}{V_v} = \frac{\alpha_t 100}{\sqrt{\frac{m}{l}}} \tag{19}$$

From the equation (19), the exit speed of the yarn is determined.

$$V_v = \frac{n_v \sqrt{m}}{\alpha_t 100 \sqrt{l}} \tag{20}$$

By dividing both sides of the equation (14) by *dt*, the output speed of the yarn is obtained, and by putting the equation (20), the equation for determining the mass of the yarn is derived.

$$r \cdot \omega = \frac{\vartheta \cdot \sin\beta}{2 \cdot \sin\frac{\gamma}{2}} \quad r\omega = v\frac{\sin\beta}{2\sin\frac{\gamma}{2}} \tag{21}$$

Equation (20) is replaced by equation (21).

$$r \cdot \omega = \frac{\sqrt{m} \cdot n_v}{200 \cdot \alpha_t \cdot \sqrt{l}} \cdot \frac{\sin\beta}{\sin\frac{\gamma}{2}} \quad r\omega = \sqrt{\frac{m}{l}} \frac{n_v}{100\alpha_t} \frac{\sin\beta}{2\sin\frac{\gamma}{2}} \tag{22}$$

From the resulting equation (22), the mass through twists is found as follows.

$$m = \frac{4 \cdot 10^4 \cdot r^2 \cdot \omega^2 \cdot \alpha_t^2 \cdot \sin^2\frac{\gamma}{2}}{l \cdot n_v^2 \cdot \sin^2\beta} \quad m = \frac{r^2 \omega^2 4 \cdot 10^4 \alpha_t^2 \sin^2\frac{\gamma}{2}}{l n_v^2 \sin^2\beta} \tag{23}$$

Equation (23) determines the mass of twists in yarn formation. Based on the main essence of the matter, reducing the number of twists is aimed at providing high-quality twists and thereby increasing the breaking strength of the yarn, therefore, in reducing the number of twists, its mass is also important. Based on this, we determine the breaking strength of the yarn.

$$R_u = \frac{P_t}{T} \tag{24}$$

Putting the equation (23) into the equation (24), the equation of the dependence of the breaking force on the number of twists of the yarn, the mass and the speed of the yarn is determined.

$$R_u = \frac{P_t \cdot l}{m} = \frac{P_t \cdot l^2 \cdot n_v^2 \cdot \sin^2 \beta}{4 \cdot 10^4 \cdot r^2 \cdot \omega^2 \cdot \alpha_t^2 \cdot \sin^2 \frac{\gamma}{2}} \qquad (25)$$

Using equations (23) and (25), graphs were obtained and analyzed using the Maple program in order to determine the rational values of the parameters affecting the twists in improving the quality of the yarn.

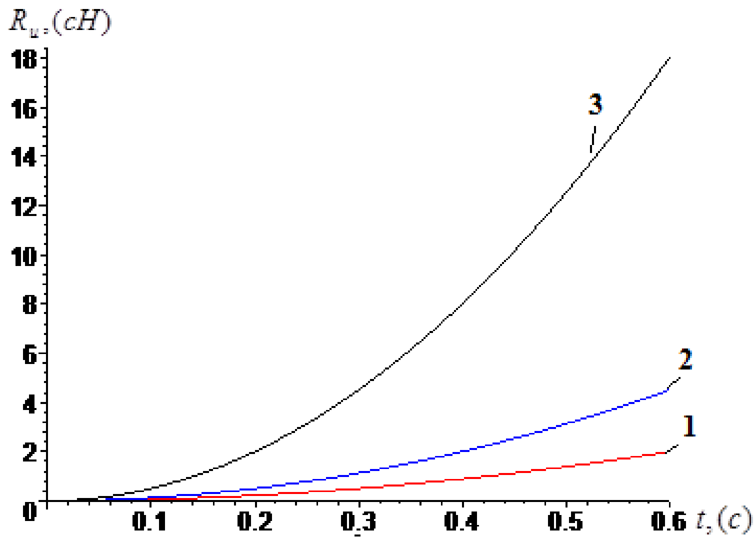

Figure 7. Plot of yarn breaking force versus time at different $\omega_1 = 6200\,\text{min}^{-1}$ $\omega_2 = 7200\,\text{min}^{-1}$ $\omega_1 = 8200\,\text{min}^{-1}$ **values of the twister's angular velocity.**

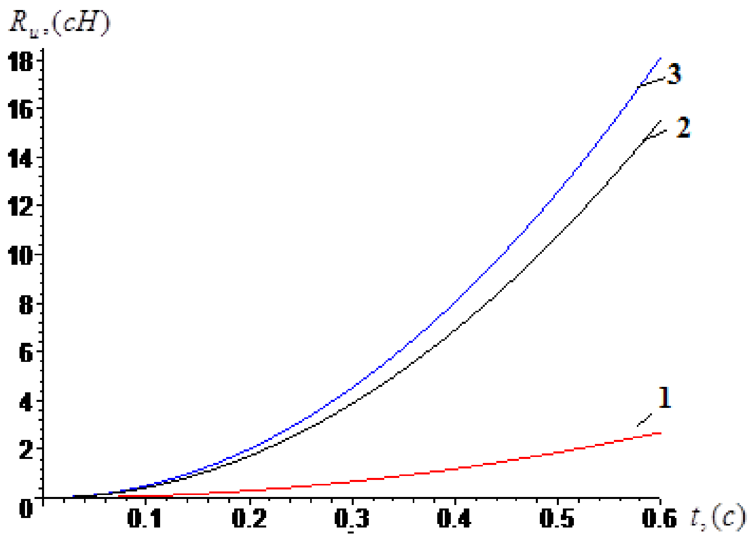

Figure 8. Plot of yarn breaking strength versus time at different $\alpha_1 = 30^0$ $\alpha_2 = 45^0$ $\alpha_3 = 60^0$ **values of spinning angle.**

Conclusion

The graphs of tension forces T_1 and T_2 depending on the number of twists during twisting at different corners of the spinning triangle are presented in Figures 3 and 4. If the number of twists increases, the tension force will increase, if the number of twists if decreases, tension forces decrease. Here, the variation of T_1 and T_2 tension forces according to the number of twists was studied when the angles of the spinning triangle are different.

The tensile strength was determined using the condition of the spinning triangle equilibrium equation, and the graphs of time versus time at different angles of the spinning triangle are given. From the graph in Figure 6, it was found $\alpha = \beta$ that the tension force increased to 9 cN, to 11 cN, and to 16 cN. It was found that an increase in the angle α in the spinning triangle causes an increase in the tensile forces. In particular, it was considered and given the same tension forces on the sides AC and BC in the case of $\alpha = \beta$ in the recommended cooking triangle, and the equations of the dependence of the yarn breaking strength and mass depend on the number of twists there and the same mass in this interval. They are presented in Figures 7 and 8, where it was found that the breaking strength of the yarn at different values of angular velocities of the false twisting device. It has been found that the peak breaking force of the false twisting device is when the angular velocity is high. Here, the highest tensile strength is achieved due to the homogeneity of fiber masses, number of twists, tension forces and angles α and β on the two sides of the spinning triangle.

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