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IMPROVEMENT OF THE WORKING ELEMENT OF A DEVICE FOR STABILIZING THREAD TENSION IN THREAD REWINDING TWISTING MACHINES

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ABSTRACT

Across all sectors of global industry, including the textile sector, the development of modern weaving machines, their continuous improvement, and the enhancement of equipment efficiency are among the key priorities. In the process of thread rewinding, controlling thread tension is of critical importance. The quality and properties of the thread, particularly during the weaving process, require constant monitoring of its tension and the maintenance of uniform winding conditions. The improvement of devices that regulate thread tension contributes to increased operational efficiency, enhanced product quality, and the reduction of unnecessary waste. This article presents both theoretical and practical aspects of improving productivity through the enhancement of the working element of a device designed to stabilize thread tension.

Keywords: thread tension, tension stabilization, rewinding process, twisting machines, yarn winding, textile machinery, tension control device, mechanical stability, spring stiffness, metal rod substitution, yarn quality, bobbin uniformity, dynamic tension, textile engineering, TW2-D machine

INTRODUCTION

At present, the production of pile fabrics, which are considered export-oriented products, remains one of the strategic directions of the global textile industry. Pile fabrics are distinguished by their high moisture absorption capacity, low thermal conductivity, and hygienic properties. The primary factor determining the quality of these products is the properties of the threads that constitute them. It is well known that 80–85% of the structure of pile fabrics consists of twisted threads, which provides sufficient grounds for conducting scientific research on thread twisting technology and its preparatory processes [1].

The theoretical foundations of thread rewinding and twisting processes have been studied extensively by many scholars worldwide. In particular, researchers such as Vieira C., Chen J., and Kawabata S. have analyzed thread deformations in fabrics and their micro-mechanical structures. Furthermore, the works of scholars who made significant contributions to the development of classical textile mechanics—such as G.I. Efremov, V.A. Minakov, and A.P. Minakov—provide a fundamental explanation of the interaction between thread and winding mechanisms, as well as the laws governing variations in thread tension [2]. In addition, Uzbek scholars including A.D. G‘aniyeva, H.A. Alimova, H.H. Ibragimov, Q. Jumaniyazov, E.Sh. Alimbayev, S.S. Raximxodjayev, and others have developed theoretical and practical foundations for ensuring the quality of woven products [3]. However, the technological integration of modern high-speed machines—particularly the Swiss SSM TW2-D doubling (rewinding) machine and the German Saurer VTS-09 twisting machine—has not been sufficiently studied, especially with regard to the dynamic stabilization of thread tension at high operating speeds [2]. As a result of practical studies conducted at the “Artsoft Holding” enterprise—one of the major industrial entities in the Namangan region—an imbalance in the technological process was identified. It was observed that the mass of bobbins formed on the TW2-D machine varies from 700 grams to 1050 grams, representing a difference of up to 33.3%. This non-uniformity leads, at the subsequent stage—namely, the twisting process—to threads finishing at different times, which in turn causes dozens of working elements to rotate idly.

From a mathematical perspective, this phenomenon results from a disruption in the dynamic relationship between the thread winding speed and the tension force. The instability of tension during the winding process is typically caused by irregularities in the linear density of the thread, fluctuations in winding speed, and dynamic stresses in mechanical transmissions. If the tension is excessive, the thread becomes overstretched, loses its elastic properties, and the bobbin is wound too tightly. Conversely, when the tension is insufficient, the bobbin is wound loosely, resulting in a mass below the specified standard. This, in turn, leads to various specific problems in the weaving process.

The proposed thread tensioning device is designed to systematically address these issues, as it is capable of automatically compensating for fluctuations at the thread entry point [4].

METHODS

Based on the above considerations, this study involves analyzing the design parameters of thread tension regulating devices used in the TW2-D doubling (rewinding) machine and developing their mathematical model. The objective is to formulate scientific and technical solutions that ensure the uniformity of bobbin mass and thread length.

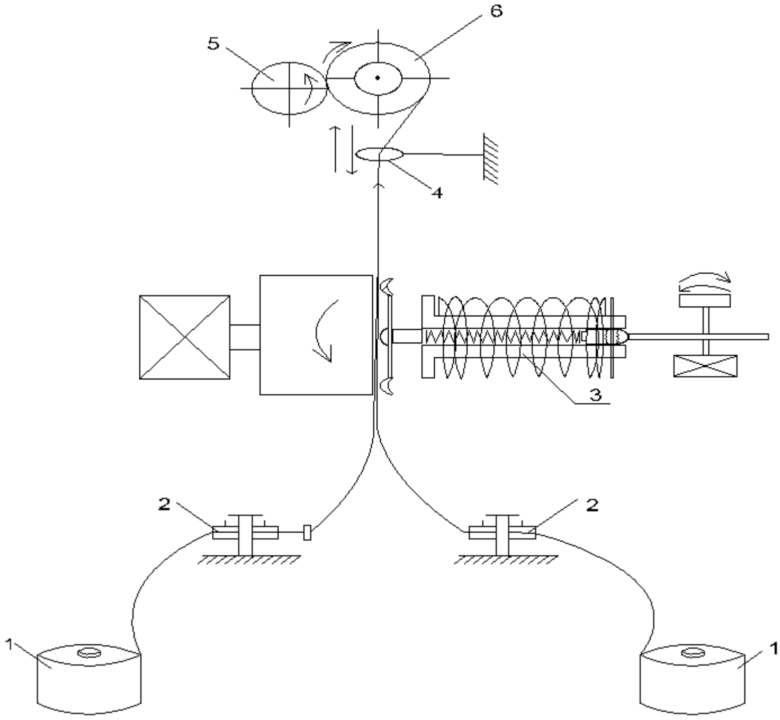

Figure 1. Technological scheme of the TW2-D machine for doubling (rewinding) two single threads, manufactured by the Swiss company "SSM."

In this scheme:

1. Bobbins wound with single threads.
2. Device for ensuring a uniform direction of the single threads.
3. Device for regulating the tension of the combined threads.
4. Guiding device for the combined threads before winding.
5. Drum for winding the thread onto the bobbin.
6. Bobbin wound with the combined thread.

The research was conducted at the facilities of "Artsoft Holding" on a TW2-D doubling (rewinding) machine manufactured by the Swiss company *Schärer Schweiter Mettler AG*. Within the technological scheme of the machine, the working element responsible for regulating thread tension was considered the principal component.

After two single threads are combined, they pass between a cylindrical disc and a plate-shaped disc. Between these discs, the threads move as a single unit under a certain level of tension and are subsequently wound onto the bobbin. The stable operation of the tension-stabilizing device is a key factor in ensuring the formation of bobbins with uniform weight and consistent winding density [5].

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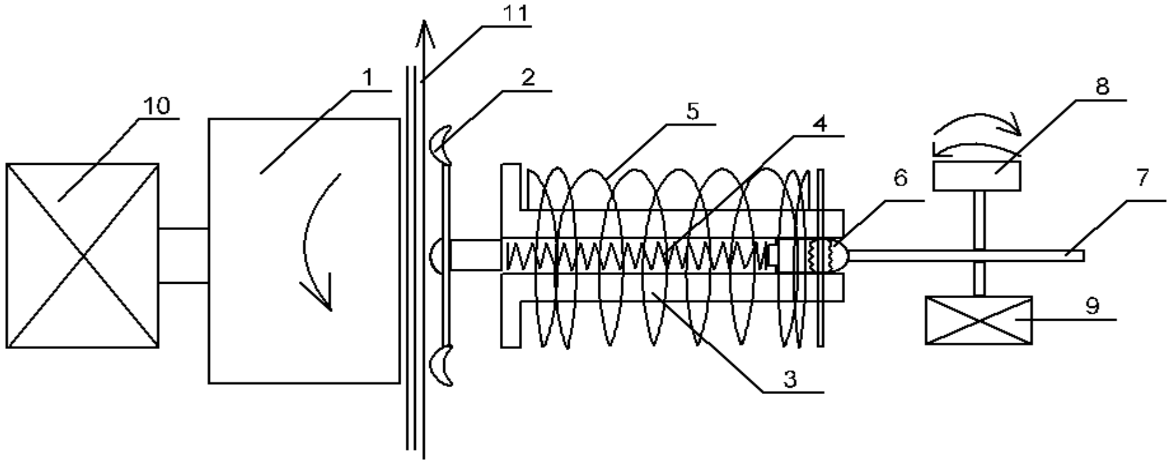

Figure 2. Tension regulating device for combined threads with a compression spring mechanism.

In this scheme:

1. Cylindrical disc.
2. Convex-shaped disc.
3. Cylindrical housing with two transmissions for the eccentric mechanism.
4. Helical spring for generating thread tension.
5. Helical spring for creating high-density tension.
6. Pusher (driver).
7. Eccentric.
8. Disc for manual rotation of the eccentric.
9. Electric motor for the eccentric mechanism.
10. Electric motor of the cylindrical disc.
11. Weaving thread.

The main normal pressure force acting on the yarn is generated by the plate-shaped disc. This pressure is provided by a special spring (Figure 2, element 4). The compressive force created by the spring determines the required level of tension during the winding of the yarn onto the bobbin.

The studies conducted show that the variation in yarn tension during the winding process is directly dependent on the stiffness and mechanical properties of the spring. If tension is not maintained at a stable level during winding, differences in density arise between the layers of the bobbin, which in turn leads to a reduction in productivity in subsequent technological stages, particularly in the twisting process.

Experimental results have confirmed that the stiffness of the spring has the primary influence on yarn tension. In order to analyze the mechanical properties of the springs used in the TW2-D machine and to evaluate their effect on tension levels, a special laboratory experimental setup was developed. Using this setup, the deformation of the springs under different loads, their compression characteristics under force, and their dynamic behavior in ensuring yarn stability were investigated.

The obtained results served as a basis for developing mathematical models aimed at reducing tension irregularities during the winding process. The compressive force of the tension-stabilizing device is determined by formula (1) [6].

$$T = T_0 e^{f\alpha} + \mu N \quad (1)$$

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As can be seen from formula (1), for the yarn tension force to remain uniform, the reaction force must also be constant. However, theoretical analysis shows that over time the force of the spring changes and becomes variable.

Therefore, we consider stiffness as a function of time in the form k=k(t). Since stiffness decreases over time, the first-order derivative of the function k(t) is negative (2).

$$\frac{dk}{dt} < 0 \qquad (2)$$

Empirically, in many metallic materials, the modulus of elasticity or spring stiffness decreases exponentially over time (3).

$$\frac{dk}{dt} = -\lambda k \qquad (3)$$

We reduce the differential equation (3) to a first-order ordinary differential equation (4).

$$\frac{dk}{k} = -\lambda dt \qquad (4)$$

By integrating equation (4), we obtain its solution:

$$\int \frac{dk}{k} = -\lambda \int dt \;\; \Rightarrow \ln k = -\lambda t + C \qquad (5)$$

Using the initial condition (6), we determine the value of the constant CCC (7).

$$t = 0, \;\; k = k_0 \qquad (6)$$

$$\ln k_0 = C \qquad (7)$$

Thus, we obtain:

$$\ln k = -\lambda t + \ln k_0 \;\Rightarrow\; k = k_0 e^{-\lambda t} \qquad (8)$$

$$N_0 = k_0 x \qquad (9)$$

From Hooke's law and relation (9), the following formula is derived (10).

$$N(t) = k(t) \cdot x = k_0 e^{-\lambda t} x = N_0 e^{-\lambda t} \qquad (10)$$

Using equations (1) and (10), we obtain relation (11).

$$T(t) = T_0 e^{f\alpha} + \mu N_0 e^{-\lambda t} \qquad (11)$$

Where:

T_0 — initial tension of the yarn before entering the tensioning device, N;

μ — coefficient of friction between the yarn and the tensioning device;

α — yarn wrap angle, rad;

N— reaction force generated by the spring, N;

N_0 — initial reaction force generated by the spring, N;

$e \approx 2,71$— base of the natural logarithm;

$\lambda>0$ — relaxation coefficient (rate of decrease with time), 1/s;

C — integration constant (constant value).

As can be seen from equation (11), over time the effective force of the device regulating yarn tension decreases due to spring fatigue. To solve this problem, the spring (element 4 in Figure 2) was

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replaced, in the experimental setup, with a metal rod as a test sample. The reliability and high resistance of metal rods to mechanical stress are closely related to their composition [7].

Metal rods are manufactured from iron-based alloys, into which alloying elements such as carbon, manganese, silicon, chromium, and nickel are introduced. Carbon provides hardness and strength to the rod, while manganese and silicon improve the internal structure, increasing elasticity and resistance to deformation. The metal rod maintains its shape under external forces, thereby ensuring stable structural behavior. As a result, a uniform level of tension can be maintained [8].

Based on the proposed device, 10 experimental samples were prepared and installed on the existing machines at the enterprise. During the experiments, the masses of bobbins produced using this device were measured, and the results were found to be uniform [9].

It was also established that even in cases where yarns of different linear densities are used, it is possible to adjust the tension during the winding process. This is achieved by changing the position of the eccentric element used in the tensioning mechanism, allowing the yarn tension to be regulated to the required level. This method enables the winding of yarns with different linear densities at consistent quality and increases the flexibility of the technological process [10].

CONCLUSION

The doubling process of cotton yarn with a linear density of 29.4 tex was carried out on the TW2-D machine. During the study, a comparative analysis was performed between the main performance indicators obtained when a spring was used in the tension regulating device and the case when the spring was replaced with a metal rod.

When the tension regulating device operated with a spring, the mass of the wound bobbins varied between 700–1050 g, and the yarn length ranged from 13605.4422 to 17857.14 meters. This variation is explained by the instability of yarn tension caused by the elastic properties of the spring.

However, when the spring was replaced with a metal rod in the tension regulating device, both the mass of the bobbins and the yarn length became constant values. In particular, the bobbin mass reached 1050 g, and the yarn length was 17857.14 meters. This demonstrates that the use of a metal rod ensures stable yarn tension and allows the doubling process to proceed uniformly.

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