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DYNAMICS OF MOISTURE ABSORPTION IN MOVING THREADS

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Abstract
This article explores mathematical models developed to describe the moisture absorption process in moving threads. The models incorporate variables such as yarn density, structure, temperature, and ambient humidity. The study analyzes modern approaches and potential improvements in prediction accuracy. Special focus is given to the dynamic aspects of moisture absorption, which play a crucial role in producing fabrics with advanced technical properties.

KEYWORDS: Mathematical modeling, moisture absorption, moving yarns, textiles, thermal processes.

INTRODUCTION

The process of moisture absorption by moving yarns consists of complex mechanisms that are important for the production of high-quality fabrics. By understanding the mechanisms of moisture absorption and developing mathematical models that describe these processes, textile products can be optimized for different conditions of use. The purpose of this article is to analyze existing mathematical models describing the process of moisture absorption by moving yarns and to identify the main factors influencing these processes.

In the works reviewed, he presented two models describing the process of moisture transfer through the fiber. These models make it possible to predict how materials change under various conditions, taking into account heat and mass transfer [1]. Developed zero linear mathematical models describing the processes of isothermal moisture absorption. These models are used in the analysis of various textile materials [2]. Presented a mathematical model taking into account heat and mass transfer when changing the density and structure of the thread. The model is intended for the analysis of materials used in extreme conditions [3]. Studying the movement of moisture through fabrics, he showed the importance of the density and orientation of the threads. This model takes into account the structural properties of the material [4]. Studying leather fabrics, characterizing the physical and mechanical properties of the yarn, he developed a model analyzing the dynamic processes of moisture absorption [5]. Proposed a model illustrating the process of dynamic wet impregnation of two-layer knitted fabrics. This approach is successfully used to analyze sportswear [6]. Developed heat and mass transfer models for multi-level textile structures. The study showed that simplified models can be effective in predicting the behavior of fabrics [7]. Developed a model for predicting phase transitions between liquid and vapor in dynamic processes. This model is used in the analysis of textile materials under complex conditions [8]. He developed an empirical model describing the transfer of heat and moisture in multilayer textile structures [9]. Described a global mathematical model describing motion taking into account the effect of moisture on the physical properties of the thread. This model is used to predict the behavior of textiles under various conditions [10].

On the loom, the fabric is woven by adding warp yarn and feather tanda yarn. Before weaving, v1 is the yarn speed on the loom v1, the yarn speed on the loom v2. Before adding them, cold steam is supplied for the purpose of humidification. Given the steam speed, yarn speeds, air temperature and relative humidity, we need to build differential equations for the dependence of the moisture absorption rate of the yarn on time. Based on these models, the goal is to reduce the breakage of the floor and hairy tan yarn based on the optimal humidity values.

Main part

Hypotheses:

- Yarn speed: ground yarn speed v1, hairy yarn speed v2.
- Steam velocity: cold steam velocity V.
- Air temperature and relative humidity: air temperature T, relative air humidity ϕ.
- Moisture content: the amount of moisture at time t of the thread M(t), and the equilibrium moisture content ms under given conditions of temperature and humidity.

Additional Hypotheses:

- The rate of moisture absorption is proportional to the difference between the equilibrium moisture content and the current moisture content.
- The mass transfer coefficient depends on the relative velocity between the filament and the vapor.
- Equilibrium humidity is known as a function of temperature MS t and relative humidity.

Theoretical research

The change in yarn moisture content over time is expressed as follows:

$$\frac{dM}{dt} = k(M_s - M(t)) \quad (1)$$

Here:

- k is the mass transfer coefficient, which depends on the relative velocity.

The relative velocity Vratio is defined as follows:

$$v_{\text{отношение } v} = |v_{ip} - v_{\text{пар}}| \quad (2)$$

The mass transfer coefficient K is proportional to the relative velocity:

$$K = k_0 \leq v_v \quad (3)$$

Here:

- k0 is an experimentally determined proportionality coefficient.

we substitute K into the differential equation:

$$\frac{dM}{dt} = k_0 \leq v_v(\text{отношение } M_s - M\ (t)) \tag{4}$$

For floor thread (V1):

$$\frac{DM}{dt} = k_0 ℃\ |v_1 - v_{\text{пар}}|(M_S - M(T)) \tag{5}$$

For hairy warp yarn (V2):

$$\frac{DM}{dt} = k_0 ℃\ |v_2 - v_{\text{пар}}|(M_S - M(T)) \tag{6}$$

The equilibrium humidity function MS of air temperature T and relative humidity ϕ:

$$M_s = f\ (T, \phi) \tag{7}$$

This function is based on the sorption isotherms of the thread material.

Based on the above, we will compose general differential equations:

$$\begin{aligned} \frac{dM_1}{dt} &= k_0 \cdot |v_1 - v_{bug'}|(f(T,\phi) - M1(t)) \\ \frac{dM_2}{dt} &= k_0 \cdot |v_2 - v_{bug'}|(f(T,\phi) - M2(t)) \end{aligned} \tag{8}$$

These differential equations describe the change in yarn moisture content over time, taking into account yarn speed, steam speed, air temperature and relative humidity.

To solve these equations analytically, we rewrite the differential equations so that the variable is discrete, and find the general solution using the integral. This is a first-order linear differential equation involving the variable a and time t. We break this down into individual variables:$M1(t)$

$$\frac{DM_1}{f(t,\phi) - M_1(t)} = k_0 ℃\ |v_1 - v_{\text{пар}}|dt \tag{9}$$

This is a first order linear differential equation with time t. We break this down into individual variables:, связанное с переменной $M1(t)$

$$\int \frac{1}{f(T,\phi) - M_1(t)} dM_1 = \int k_0 \cdot |v_1 - v_{bug'}|dt \tag{10}$$

We solve the integral on the left:

$$-\ln|f(T,\phi) - M_1(t)| = k_0 \cdot \left|v_1 - v_{\text{этог}'}\right| \cdot t + C_1 \tag{11}$$

Where is the integral constant. Writing in exponential form, :c_1представим $M1(t)$

$$F(T,') - M_1(t) = c_1 E^{K_0'\left|v_1 - v_{\text{этог}'}\right|' T} \tag{12}$$

Now let's select M1 t separately:$M1(t)$

$$M_1(t) = f(T,\phi) - C_1 e^{k_0 \cdot \left|v_1 - v_{\text{этог}'}\right| \cdot t} \tag{13}$$

Using the initial conditions, . For example, at t=0 m1(0)=m1,0:мы находим c_1

$$M_{1,0} = f(T,\phi) - C_1 \tag{14}$$

$$C_1 = f(T,\phi) - M_{1,0} \tag{15}$$

Final decision:

$$M_1(t) = f(T,\phi) - \left(f(T,\phi) - M_{1,0}\right)e^{k_0 \cdot \left|v_1 - v_{\text{этог}'}\right| \cdot t} \tag{16}$$

Application for hairy yarn

$$\frac{dm_2}{f(t,\prime) - m_2(t)} = k_0 ℃ \,|v_2 - v_{\text{пар}}/\, dt \tag{17}$$

This is a first order linear differential equation with time t. We break this down into individual variables:, связанное с переменной $M1(t)$

$$\int \frac{1}{f(t,\phi) - m_2(t)} dm_2 = \int k_0 ℃ \,|v_2 - v_{\text{пар}}| dt \tag{18}$$

We solve the integral on the left:

$$-\ln|f(T,\phi) - M_2(t)| = k_0 \cdot \left|v_2 - v_{\text{этог}'}\right| \cdot t + C_2 \tag{19}$$

Where is the integral constant. Writing in exponential form, :c_1представим $M1(t)$

$$f(T,\phi) - M_2(t) = C_2 e^{k_0 \cdot \left|v_2 - v_{\text{этог}'}\right| \cdot t} \tag{20}$$

Now let's select M1 t separately:$M1(t)$

$$M_2(t) = f(T,\phi) - C_2 e^{k_0 \cdot \left|v_2 - v_{\text{этог}'}\right| \cdot t} \tag{21}$$

Using the initial conditions, . For example, at t=0 m1(0)=m1,0:мы находим c_1

$$M_{2,0} = f(T,\phi) - C_2 \tag{22}$$

$$C_2 = f(T,\phi) - M_{2,0} \tag{23}$$

Final decision:

$$M_2(t) = f(t,') - \left(f(t,') - m_{2,0}\right)E^{K_0 \prime |v_2 - v_{\text{этоG}'}|\prime\, T} \tag{24}$$

RESULTS

Based on these models, based on the change in the speed of cold steam, it becomes possible to see in graphic mode the degree of moisture absorption of strands on the floor and hairy tan. Figure 1.

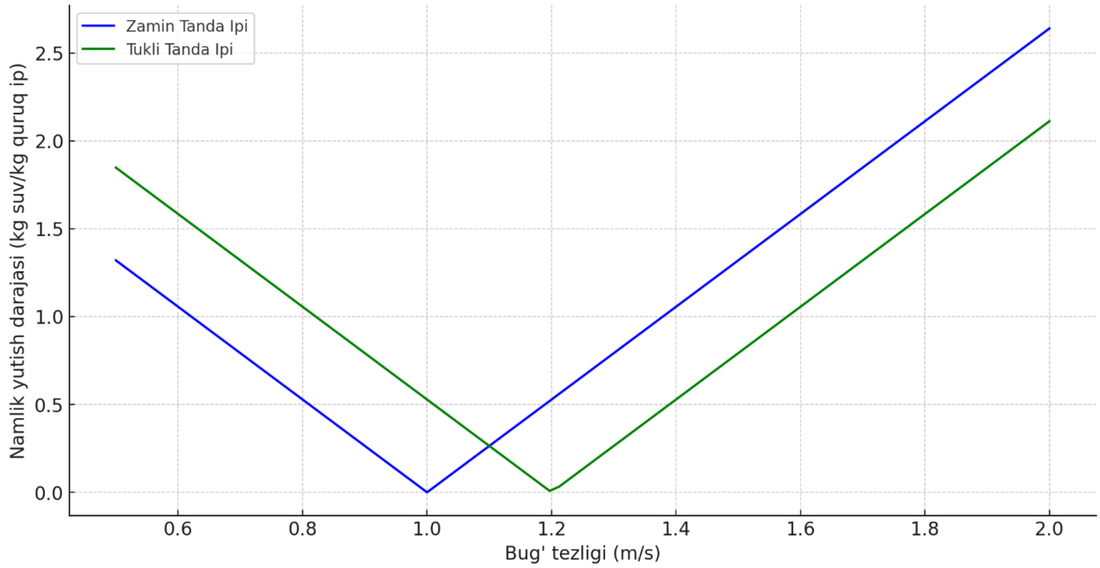

Figure 1.The degree of water absorption of a thread based on the change in steam velocity

B graph illustrating the moisture absorption rate for the Warp floor thread and the Warp hair thread based on the change in speedV (Fig. 1.). The graphs show the degree of moisture absorption by the threads within 1 second. You can see how the moisture content in the warp threads depends on the speed of the steam.

B graph illustrating the degree of moisture absorption for a threadBasicsand hairy threadBasicswith respect to time in relation to speed is shown in Fig. 2. In this graph you can see how the rate of moisture absorption by the threads changes over time for different steam speeds.

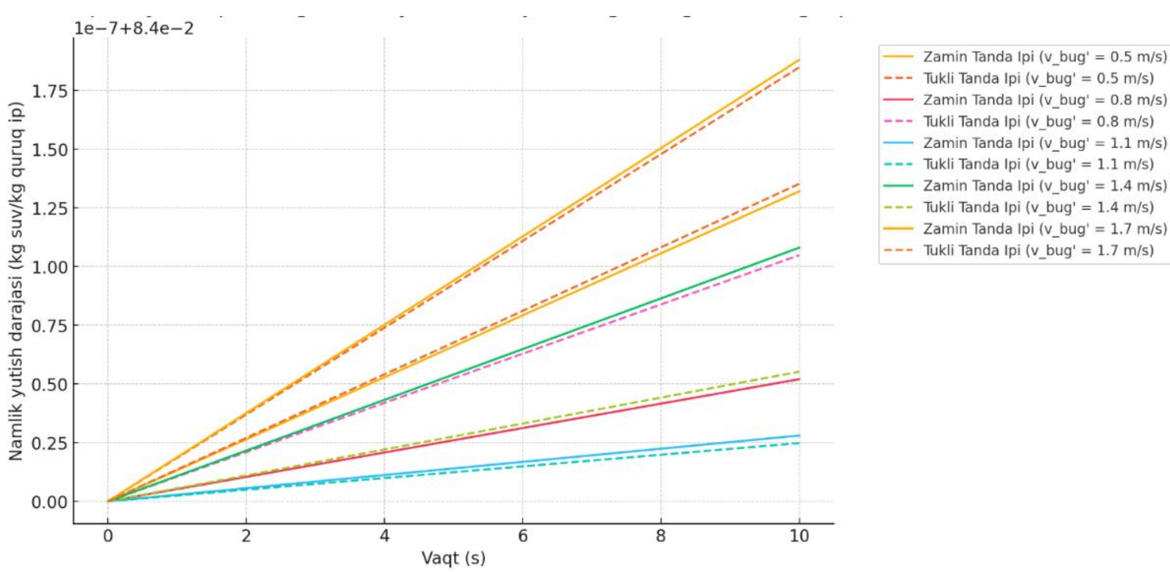

Figure 2.Change in moisture absorption level over time

To select the most optimal evaporation rate, we analyze the degree of moisture absorption and the time it takes to reach the state of moisture equilibrium. The optimal rate should be such that the strands absorb enough moisture to the target level, and this process should occur in the shortest possible time.

Analysis

To select the optimal speed, let's consider the following aspects:

1. Achieving target humidity levels: We must quickly and efficiently achieve the target moisture level of the yarn. The target moisture level Ms should be close to the equilibrium moisture Ms.

2. Stabilization of humidity levels: The change should slow down or stabilize after these strands reach some maximum moisture absorption. This is called a state of equilibrium and usually indicates that there is no excessive moisture absorption.

CONCLUSION

From the graphs above we can see the change in humidity over time for different steam speeds. For analysis, let's look at several key indicators:

- Delivery speed period: We must ensure that the yarn reaches the target moisture content as quickly as possible.

- Time to reach steady state: Once the humidity level reaches the target level, it should enter a stable state.

- Low steam speed (0.5 m/s): The process of moisture absorption is very slow and takes time. This means that at low steam speeds, the threads cannot absorb moisture sufficiently and this process takes too long.

- Average steam speed (1.0-1.5 m/s): At these speeds, the moisture absorption process is faster, the process of reaching the target humidity level is relatively fast, and the moisture absorption rate is stabilized.

- High steam speed (2.0 m/s): At this speed, moisture absorption is fast, but at very high speed, excessive moisture absorption or over-absorption may occur. In this case, the dryness of the threads decreases and excessive moisture is observed, which can cause problems in the weaving process.

Optimal Steam Speed:

The most optimal result is observed at medium steam speeds (1.0 - 1.5 m/s). At this speed:

- Fast and effective moisture absorption: the threads absorb moisture quickly and sufficiently.

- Achieving balance: The humidity level is reached faster, ensuring a stable moisture level in the strands.

Each strip represents the process of moisture absorption by the yarns at a certain steam velocity. It has been shown that the moisture absorption levels of the floor tanda yarn and the hairy tanda yarn differ and change over time.

The optimum steam speed should be around 1.0 - 1.5 m/s. At this speed, the yarn is effectively moistened, the moisture quickly reaches the equilibrium level and does not cause problems during the weaving process. At a very low speed, moisture absorption occurs slowly, and at a very high speed, the yarn may become wet, which will affect the quality.

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