DEVELOPMENT OF THE INFRARED DRYING CHAMBER FOR LINES ON PRODUCTION OF FLOCKED YARN

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Abstract. *The Analysis of the obtained results allows to identify an interesting pattern, which is extremely important for deriving empirical formulas and for calculating the technological parameters of the process of applying a binder to threads accordingly.*

Keywords: *connecting threads, adhesive layer, core thread, shaft.*

INTRODUCTION

The need in creation of new materials and impart qualitatively new properties to materials, along with the problem of recycling polymer and other waste, as well as the rational use of raw materials, determine the prospects of alternative scientific and practical directions for processing fibrous raw materials [1,2].

The flocked yarns are used for the production of pile fabrics, non-woven and knitted fabrics for furniture, decorative and upholstery purposes (for covering the seats of vehicles - especially cars), carpets, drapes, clothing items and other products.

Materials and products made from such a thread combine high wear resistance with an attractive appearance and the volumetric structure (flocked thread) provides good water and air permeability, sound and thermal insulation, moisture absorption; combinations of these properties for a specific thread are achievable with the appropriate selection of components: core thread, flock, glue [3].

In technology of electroflocking, particularly for the production of flocked yarn, the method and design of the drying chamber has an extremely strong influence on the productivity and energy consumption of the line.

The most suitable method for curing the binder on flocked yarn is apparently the drying method using infrared radiation.

The use of infrared (IR) emitters makes it possible to carry out curing of the adhesive composition in a non-contact manner, provides a fairly intense flow of energy, practically without inertia and allows you to easily regulate the curing process.

In addition to the ideas mentioned above, it is necessary to add that the drying chamber, as was substantiated in detail there [4] must be built according to a modular principle, which gives the following advantages [5] in each module that can set ones own optimal heating mode; It is easy to change the length of the drying chamber at any case, for example, while increasing the flocking speed.

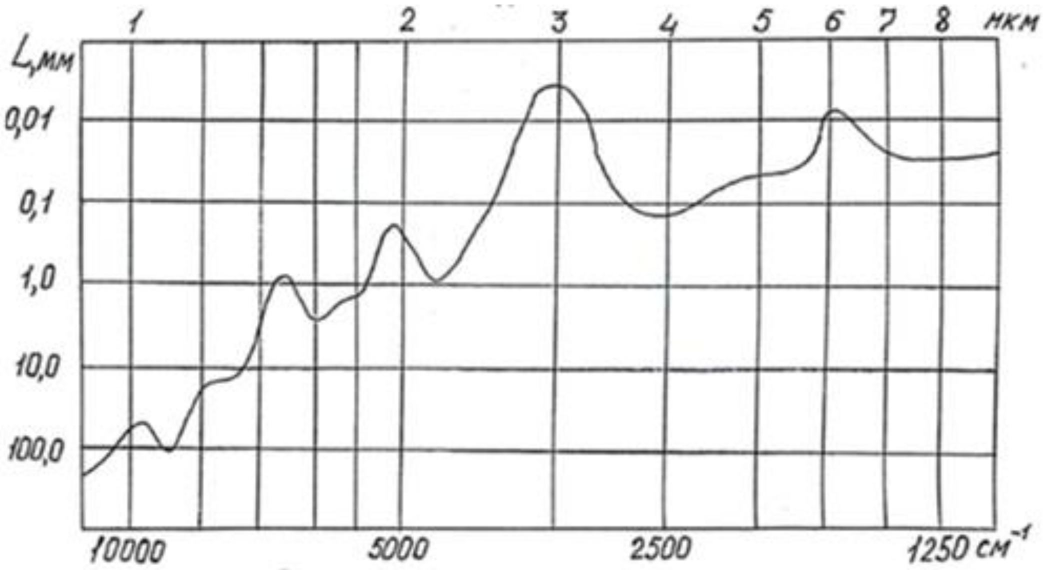
MATERIALS AND METHODS

In the given article, there should be considered a possible scheme for calculating the parameters and operating mode of emitters while curing an adhesive composition on flocked yarn using IR radiation.

In the production of flocked yarn, a binder based on aqueous dispersions is usually used and the proportion of solvent, i.e. water, is 50-60%.

Firstly, it is necessary to select the emitter and its temperature based on the absorption spectrum of the liquid binder. So, for example, if the transmission spectrum of water is taken into account (Fig. 1). which makes up the main share in acrylic binders, it is easy to notice a very strong absorption band in the region of λ 3 μm. This wavelength corresponds to the emitter surface temperature T = 9700 K [4,8].

Wavelength



Amount of wave

Ricture.2.1

L- layer thickness, which weakens the intensity

I,b E times, absorption coefficient at X=I/L

Further, knowing the surface temperature of the emitter, it is easy to obtain the value of the radiation density, which in this case will be equal to R = 5.046 W/cm2.

The emitter temperature approximately corresponds to the operating temperature range of nichrome wire [7]. Other maximum absorption, which is important to us correspond to wavelengths around 1.5 and 2.0 μm. These wavelengths correspond to higher emitter temperatures, and in this case, for example, emitters with a tungsten spiral can be used. As an example, in detail the calculation scheme for an emitter with a nichrome spiral is presented.

RESULTS

Based on the given data, it is easy to calculate what power or voltage should be supplied to the IR lamp so that the maximum radiation falls on the wavelength λ -3 μm. Let us calculate a slightly more complex case, namely, how long the nichrome wire should be so that at a voltage of 220 V, it had a maximum radiation at the required wavelength, which would allow the emitter to be used at maximum power. The position in the spectrum of the maximum spectral density of radiation is determined by Wien’s law [6].

$\lambda T = C0$ (1)

where: C0= 2.893 10-3 m K ~ 2900 μm K

according to the Stefan-Boltzmann law

$R = \sigma T4$ (2)

where: b = 5.67-10-8 W\(m2K4) = 5.67 10-12 W (cm2K4)

R=F/S, S - surface area of the emitter, F - radiation flux (W).

Thus,

$$F = \sigma \cdot S \qquad (3)$$

Further, considering that the main power is released in the form of radiation and, recording the power of the emitter through the voltage U applied to it, it can be obtained

$$\frac{U^2}{R'} = \sigma \pi d \ell(T) \qquad (4)$$

where R is the resistance of the nichrome wire,

d - wire diameter,

l (T) is the length of the wire at temperature TK.

Now, expressing the resistance R1 through the resistivity ρ (T), it can be determined the length of the wire that will most effectively radiate at the desired wavelength λm

$$\ell(T) = \frac{U}{2}\left(\frac{\lambda_M}{C_0}\right)^2 \sqrt{\frac{d}{\sigma \rho(T)}} \qquad (5)$$

The resistance of a radiating wire having this length is equal to

$$R(T) = \frac{2U}{\pi d}\left(\frac{\lambda_M}{C_a}\right)^2 \sqrt{\frac{\rho(T)}{\sigma d}} \qquad (6)$$

Based on this, there can be calculated the power released at the emitter

$$F = \frac{\pi d U}{2}\left(\frac{C_0}{\lambda_M}\right)^2 \sqrt{\frac{\sigma d}{\rho(T)}} \qquad (7)$$

Meanwhile it is necessary to calculate what energy is required to remove the solvent from the binder on the threads, after which there can be determined the amount of such emitters are required to remove the solvent in time t.

The amount of heat required to heat the mass dm by **∆**T0 is equal to

$$dQ_1 = C_1 \Delta T_1 dm$$

where C1 is the specific heat capacity of the binder.

The amount of heat required to evaporate the solvent, taking into account that the mass of the removed solvent is less than the mass of the binder

i.e. dm -ɳ dm (0 <1 ɳ<1), equals:

$$dQ = r \eta dm$$

where r is the specific heat of vaporization of the solvent.

Next, it is usually necessary to heat the binder by another **∆** T2 to carry out the polymerization process.

$$dQ = C_2 \Delta T_2 (1-r)\, dm$$

Then the total amount of heat required for heat fixation on the threads will be

$$dQ = \left[C_1 \Delta T_1 + r\eta + C_2 \Delta T_2 (1-\eta)\right] dm \tag{8}$$

Let us write it down for convenience, defining ϒ as the mass per unit length of the thread, i.e. as the linear density of flocked yarn, but with wet glue, then

$$dQ = \left[C_1 \Delta T_1 + r\eta + C_2 \Delta T_2 (1-\eta)\right] \gamma' dz \tag{9}$$

It can be assumed that while passing through the drying chamber, the yarn absorbs a fraction of the emitted energy equal to Xo. That is, a section of thread dz, passing through the drying chamber in time t, will receive part of the energy emitted by the IR emitter during this time. Further, we will assume that we have M emitters sufficient to impart the required amount of heat to the N threads. That is, the fraction of radiated energy received by a section of threads dz during the passage of a drying chamber of length L at a speed V will be equal to

$$\varkappa_0 \frac{MF}{L_0} dz \cdot \frac{L_0}{V} = \varkappa_0 \frac{MF}{V} dz \tag{10}$$

Equating this value to the amount of energy required for drying a section of thread dz, we obtain

$$\varkappa_0 \frac{MF}{V} = \left[C_1 \Delta T_1 + r\eta + C_2 \Delta T_2 (1-\eta)\right] N\beta \tag{11}$$

Based on the formula obtained, it is possible to determine, for example, the required number of emitters M with power F for drying N threads, provided that the wavelength range of IR radiation corresponds to the zone of greatest absorption

$$M = \left[C_1 \Delta T_1 + r\eta + C_2 \Delta T_2 (1-\eta)\right] \frac{N\beta V}{\varkappa_0 F} \tag{12}$$

DISCUSSION

It is important to suggest that in formula (12) the value of the emitter power p is used, so this formula can be used to determine the required number of standard infrared lamps produced by industry, if it is known at what power they emit in the required wavelength range.

In practice, however, things are much more complicated. The fact is that in formulas (12) it is possible to approximately estimate the value of all the parameters used, except for the parameter X. This parameter depends on such heterogeneous factors as the proportion of radiation power pertaining to the desired wavelength range; the share of power spent on heating the drying chamber body; the share of power spent on heating the air in the thermal chamber; absorption of IR radiation by water vapor formed in the heat chamber during drying of the binder.

The desire to achieve the maximum value of the coefficient requires significant research to create the most suitable heat chamber design for yarn.

Thus, it is clear that the value of the parameter can be quite reliably estimated experimentally only for this specific design of the drying chamber.

CONCLUSIONS

In conclusion, the results of specific calculations can be presented. So, for a nichrome wire with a diameter of 1 mm to have a maximum spectral radiation density $\lambda = 3$ μm at a voltage of U-220V, it must have a length (in the heated state) of -14.3 m. In this case, the total radiation power will be approximately equal to 2300 W and the required number of such emitters for drying 100 threads, without taking into account energy losses is equal to 6.

As a result of the research, a technology was developed (experimental setup and technological mode) that ensures the production of flocked thread with specified properties - pile density, linear density, torsional rigidity. In fact, the efficiency of using emitters for drying yarn in practice will apparently not exceed 20%, and the number of emitters will then be required at least 60, i.e., the power consumption will be at least 75 kW.

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