INTERACTION BETWEEN FIBER MATERIAL AND CONTINUOUS ENVIRONMENT IN DRYING AND RINSE PROCESSES

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In the article, based on the materials of the authors` monograph, the mechanism of interaction of fibrous textile material with continuous media – gaseous or liquid in the processes of drying and washing is considered. The processes of drying and washing (extraction of process contaminants) of fibrous materials in the chemical technology of their finishing are the most energy- and resource-intensive ones. The influence of textile material properties as an object of technological processing on the processes of heat and mass transfer, on the diffusion rate of moisture and technological contaminants is considered. The analysis of the types of connection of the distributed component and the mechanism of their removal during the drying and washing process is carried out. A comparative analysis of methods for increasing the driving force in the drying and washing processes of fibrous materials is realized.

Keywords: fibrous material, technological contamination, washing, drying, processing facility

The drying and washing processes of textile materials are heterogeneous physicochemical processes that have much in common [1]. Indeed, if the drying process is a process of removing moisture from a textile material by evaporating it into a gaseous carrier stream due to a supply, the washing process is a process for removing contaminants from a textile material (dye, alkali, printing ink, textile auxiliaries, etc.) into the medium of a liquid carrier (washing water). Common to both processes is the transfer of the removed substance (moisture, colorant) from one phase (textile material) to another (gaseous or liquid). Therefore, such processes have received the name of mass-exchange processes in chemical technology. The transition of the removed component (from the terminology accepted in chemical technology – the distributed component) from one phase to the other occurs as a result of diffusion under the action of a concentration gradient in the volume of each phase and at the interface between phases, therefore such processes are also called diffusion [1].

Fibrous materials of both natural and artificial origin are high-molecular compounds – polymers. The properties of textile material as an object of technological processing (drying and washing) are of great importance for processes of heat and mass transfer, for example: material thickness; structure; the relationship between the distributed component and material; thermophysical characteristics. Obviously, the greater material thickness, the greater the inertia, and therefore the slower the drying or washing process, as the thickness of the material increases, the path length of the diffusion of the distributed component increases. For fiber-forming polymers, the porosity of the material layer, characterizing the distance between the particles of dispersed polymeric material in a suspended state, is of great importance. With increasing distance, all other conditions being equal, more favorable conditions are ensured for diverting the distributed component from the interface of dispersed particles to the volume of the continuous phase. As a result, the concentration gradient of the component in the polymer particles increases, which leads to an increase in the speed of the corresponding technological process.

The diffusion rate depends essentially on the pore size: in larger pores it is higher, and in smaller pores it is lower (large pores are considered to be pores whose diameter substantially exceeds the mean free path of the molecules of the diffusing substance). This is due to the different frequency of collisions of the molecules of the distributed component with the molecules of the continuous medium that fills the pores (molecular diffusion), and with the walls of the pores (Knudsen diffusion) [1]. The distributed component may be in the textile material in a loose or bound state. In the first case, in order to remove it from the material, it is sufficient to create a concentration gradient in the volume of the particle and on its surface (for dispersed material) or in the volume of the layer and on the surface of the layer of textile material (for a material consisting of mechanically interconnected fibers, material, filter layer of fibrous material, etc.). In the second case, in order to remove the distributing component from the textile material, in addition to creating a concentration gradient to the material, it is necessary to supply a certain amount of energy to break the connection between the component being distributed and the textile material. When carrying out the processes of drying and washing textile materials, it is necessary to remove both the free and bound distributive component, so the energy supply in both cases is necessary. When the loose component is removed from the textile material, the input energy is used to intensify the corresponding technological process, and when removing the bound component, both for the intensification of the process and for breaking the component's bonds with the material, i.e. to ensure the principle possibility of the process [1]. The supply of energy to the textile material can be carried out by various methods. The most commonly used convective and conductive methods of supplying heat with a gaseous or liquid coolant, or from the heating surface. Radiation power supply, heating by high or ultrahigh frequency currents, energy supply in the form of acoustic or ultrasonic oscillations, oscillations of a continuous medium, or by means of jets of continuous medium directed to the textile material through slotted nozzles (nozzle blowing) are also used. The effectiveness of the perception of the supplied energy by the textile material is determined by its thermophysical and (or) electrophysical properties (thermal conductivity, heat capacity, permittivity, etc.) [1].

In the drying and washing processes, it is not possible to ensure the complete removal of the distributed component from the textile material to the continuous phase, since the process of mass transfer between the textile material and the continuous phase can continue only until the (as with the direct contact of hot and cold bodies, heat exchange continues only until the temperatures of both bodies become the same) [monograph].

To calculate the parameters of the drying and washing facilities, it is necessary to be able to determine the rate of heat and mass transfer taking into account the specific conditions of the process and the connection of the component being distributed with the textile material. So, it is on the basis of the speed of the drying process that the basic dimensions of the drying equipment are determined or the necessary duration of the drying process at its given dimensions [1]. The speed of the drying process depends, with all other conditions being equal, on the driving force of the process, determined by the temperature difference between the coolant and the material, and also by the deviation of the current moisture of the material from its equilibrium moisture content. It should be noted that the increase in the coolant temperature is subject to limitations due to the thermal stability (thermal lability) of the material, and to reduce the equilibrium moisture content of the material, either an increase in the flow rate of the coolant or its temperature at the outlet from the device is required [1]. The driving force of the washing process is the deviation of the current contamination concentration in the material from its equilibrium concentration. The latter, all other things being equal, depends on the washing bath module: the higher the modulus, the lower the equilibrium concentration and the higher the driving force. In addition, the equilibrium concentration of contamination decreases with an increase in the temperature of the wash water and the material. The way to increase the driving force of the washing process by increasing the wash bath module is unacceptable, since it leads to an increase in the flow rate of water, and hence the volume of the waste water [1]. Like the speed of the drying and washing processes, the driving force does not remain constant in the course of movement of the textile material in the drying or washing machine in continuous processes or in time in batch drying and washing plants.

References

1. Sazhin B.S., Kosheleva M.K., Sazhina M.B. The processes of drying and washing of textile materials / Ed. By prof. B.S. Sazhin – M.: FGBOU VPO "MGUDT", 2013. p. 301.