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Study Of The Influence Of The Moisture Content Of Raw Cotton And Its Components On The Thermal Conductivity Coefficient

Alisher Usmankulovich,

Doctor of Technical Sciences, Associate professor,

Jizzakh Polytechnic Institute, Uzbekistan

Sadikov Farkhod Samandarovich,

Jizzak Polytechnic Institute,

Norboev Utkir Akbaraliyevich,

Master, Tashkent Institute of

Textile and Light Industry

Abstract: The article studies thermal conductivity of raw cotton and its components. Raw cotton consisting of seeds and surrounded by fibers has higher thermal conductivity than fiber and less than lowered and bare seeds. Lower seeds consisting of smaller number and length of fibers have lower thermal conductivity than bare seeds and greater than raw cotton and fibers. Naked seeds that do not have fibers on their surface have a higher thermal conductivity than lowered seeds, raw cotton and fibers. The dependence of thermal conductivity of raw cotton and its components on the temperature at different humidity is obtained, which allows to carry out calculations by the equation of heat and mass transfer during drying of raw cotton.

Key words: Raw cotton, heat insulator, temperature, size, heat, meter, thermocouples.

Rational choice of parameters of drying and storage of raw cotton and its components is first of all connected with its primary heat treatment - heating, heating, drying, humidification, etc. All these technological operations are inextricably connected with changes in thermal and humidity parameters. For correct choice of technological parameters of drying and processing of raw cotton such thermal characteristics as thermal conductivity of raw cotton, its fibers and seeds should be known [1].

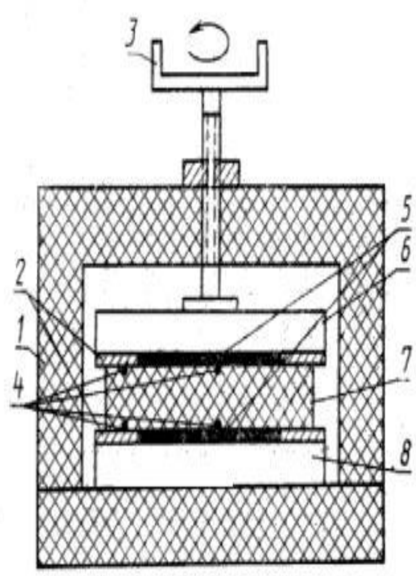
Cotton - raw material and its components (fiber and seeds) by their physical properties can be attributed to solid bodies such as insulators [2], when heated (dried), which undergo physical and chemical transformations, accompanied within certain temperatures by thermal effects of different forces. In this case, fiber and raw seeds partially change the structure, lose a significant part of their weight and acquire new, different from the original natural, physical and chemical properties.

In the given work thermal conductivity of raw cotton, fibers and seeds depending on temperature and humidity was investigated

Measurement of heat conductivity was made by well-known methods of stationary heat flow - the interstate standard [3].

The essence of the method is to create a stationary heat flux (Pic.1) passing through a flat sample and directed perpendicularly to the face edges (the largest faces of the sample, measuring the density of the heat flux, the temperature of the opposite face edges and the thickness of the sample). The sample under test is given a square shape of 250x250x5-10 mm. The sample is placed between the system of creating a stationary heat flow and the heat flow system. For a tight fit of the sample to these systems without air gaps a special clamping device is provided. The sample bulk material should be placed in a box, the bottom and cover of which are made of thin sheet material - annealed red copper. The length and width of the box shall be equal to the corresponding dimensions of the working surfaces of the device plates, the depth - to the thickness of the tested sample.

The relative hemispherical emissivity of the surfaces of the bottom and cover of the box shall be greater than 0.8 at the temperatures which these surfaces have during the test. The thermal resistance of the RL sheet material from which the bottom and lid of the box are made is known. For each test material, 8-10 samples of the same mass shall be produced. The bulk material sample shall be divided into four equal parts, which shall be poured into the box in turn, sealing each part so that it occupies a corresponding portion of the box's internal volume. The box is covered with the lid. The lid is attached to the side walls of the box.



Pic.1. Heat block diagram of the plant

1 - Thermal insulating cover; 2 - Security zone of the heat flow transducer; 3 - Clamping device; 4 - Temperature transducers; 5 - Heat flow transducers; 6, 8 - Heat exchangers; 7 - sample.

Weigh a box with a sample of bulk material. The density of the bulk material sample is calculated on the basis of a certain value of the weight of the sample box and pre-determined values of the internal volume and weight of the empty box.

The error in determining the mass and size of the samples should not exceed 0.5%. The system is then checked for leaks by placing the box under the vacuum hood and pumping it out. The weight loss should not exceed the accuracy of the analytical scales. The power supply systems of the unit and devices are switched on and heated up within 30 minutes. When working with temperatures above 150^0C it is necessary to switch on the system of water cooling of the enclosure. Shortening the input of the voltmeter B7-21 its readings are set to zero at a limit of 10 mV. This item should be performed periodically.

Determine the set temperatures of the refrigerator, the system of automatic regulation of the refrigerator temperature is activated, at temperatures below 1000C the system of water supply to the refrigerator is activated in order to ensure reliable operation of the heat flow. The main heater is supplied with power, and by its regulation the required temperature difference on the surface of heat exchangers is achieved. The systems of automatic regulation of temperature modes are switched on. After such heating, the sample to be tested is placed in the device. Location of the sample - horizontal, direction of heat flow from top to bottom.

During the test, the temperature difference between the face faces of the sample

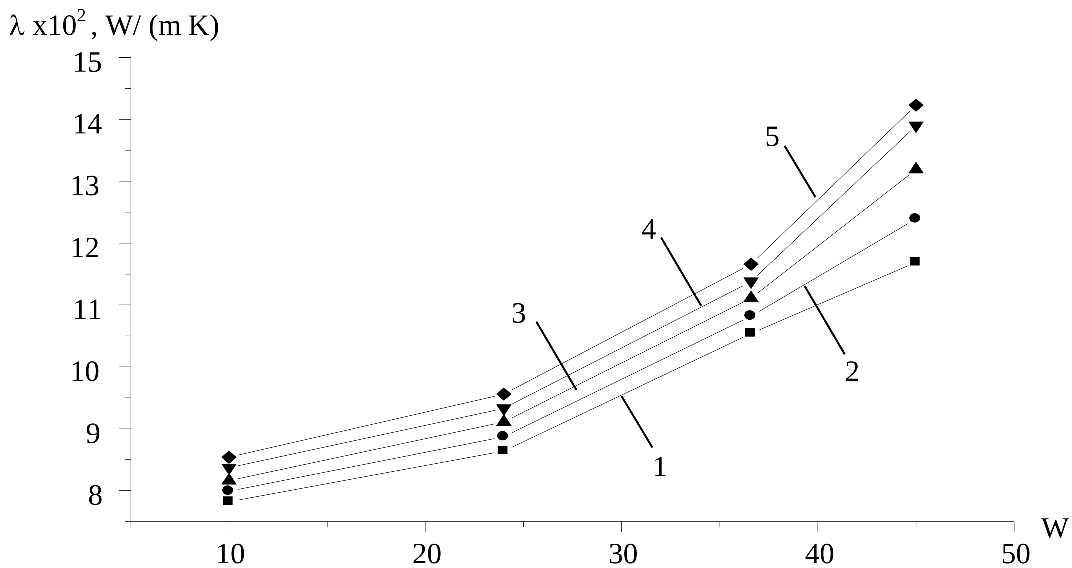
The ΔT_u must not be more than 3-4 K. Every 5-10 minutes, the signals from the e_u heat meter and the temperature sensors of the sample faceplates and the power supplied to the heater of the hot plate measuring zone of the device are sensed. The heat flux through the sample under test is considered to be steady (stationary) if the thermal resistance (thermal conductivity) of the sample, calculated on the basis of the results of five consecutive measurements of the temperature and power sensors' signals to the main heater, differs from each other by less than 0.5%, and these values do not increase or decrease monotonously. Additionally, the uniformity of the heat flow was controlled by means of a heat meter with 128 thermocouple contacts located on it and automatic measurement. After the end of the test, the mass of the M_3 sample is determined, if the change in mass does not exceed 0.5%, the test is considered a success. If not, the system is tested for leaks with a new fresh sample and the experiment is repeated.

Pic. 1 shows the results of experimental studies of the dependence of thermal conductivity on humidity, obtained at volumetric density $\rho = 111 \frac{\kappa\Gamma}{м^3}$. Curves 1 - 5 in Fig. 1 are obtained at temperature $T_1 = 40^\circ C$, $T_2 = 50^\circ C$, $T_3 = 60^\circ C$, $T_4 = 70^\circ C$ and $T_5 = 80^\circ C$, respectively.

It can be seen that with the growth of humidity and temperature the thermal conductivity of raw cotton increases. Inside the considered area of humidity curves 1 - 5 have two transition points.

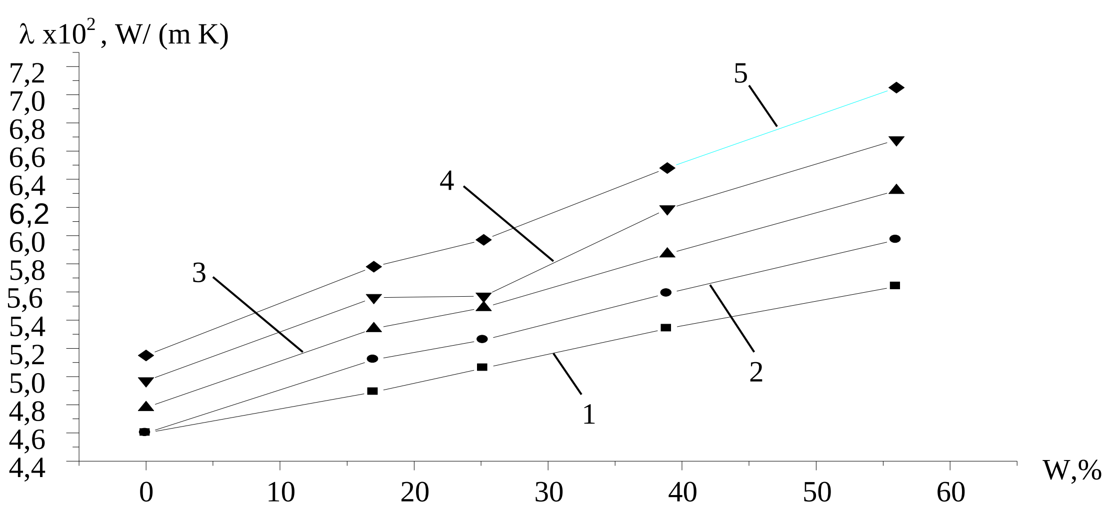
Pic. 2 shows the dependence of thermal conductivity on the moisture content of cotton fiber.

It can be seen that with the growth of humidity and drying temperature the thermal conductivity of cotton fiber increases. At drying temperature $T \cong 70^\circ C$, the heat conductivity curve has a drop zone. In the area of the heat conductivity $17\% < W < 25 \div 26\%$ curve with a horizontal axis forms a negative angle of inclination.



Picture 1: Dependence of raw cotton thermal conductivity on humidity at different temperatures. (Raw cotton temperature (^{0}C); 1-40, 2-50, 3-60, 4-70, 5-80, density 111 kg/m³).

Comparing the results of experimental studies presented in Pic. 1 and 2, which show the dependence of thermal conductivity of raw cotton and cotton fiber, respectively, we see that the humidity and drying temperature on the thermal conductivity of raw cotton affects more than the thermal conductivity of cotton fiber.



Picture 2: Dependence of thermal conductivity of cotton fiber on humidity at different temperatures. (temperatures (ºC): 1-40, 2-50, 3-60, 4-70, 5-80, density 76 kg/m³).

The value of thermal conductivity of raw cotton at a fixed humidity and drying temperature significantly exceeds the thermal conductivity of cotton fiber. With increasing humidity and drying temperature, the difference between the thermal conductivity of raw cotton and cotton fiber increases. The regularities revealed in this way indicate the difference in the character of heating and selection of moisture from raw cotton and its components.

Pic. 3 shows the dependence of the thermal conductivity of the lowered seeds on humidity and temperature. Curves 1 - 5 in Pic. 3 are obtained at drying temperature $T_1 = 40^\circ C$, $T_2 = 50^\circ C$, $T_3 = 60^\circ C$, $T_4 = 70^\circ C$ and $T_5 = 80^\circ C$, and accordingly. It can be seen that at low humidity the heat conductivity coefficient practically remains constant, and then with the growth of humidity it grows monotonically. This confirms the conclusion about the preservation of the property of homogeneity of the material of lowered seeds at low humidity.

It can be seen that in the area $0 < W < 7 \div 8\%$ the thermal conductivity decreases somewhat, in the area $W > 8\ \%$ it increases. The drying temperature does not significantly affect the character of the thermal conductivity change.

Picture 4 shows the dependence of the thermal conductivity of bare seeds on humidity and temperature.

The thermal conductivity of bare seeds in the area of humidity $0 < W < 10\%$ is almost independent of the drying temperature. The thermal conductivity of bare seeds with humidity $0 < W < 10\%$ at temperature $30^\circ C < T < 140^\circ C$ remains unchanged and takes on values within $\lambda = 0.12 \div 0.13$.

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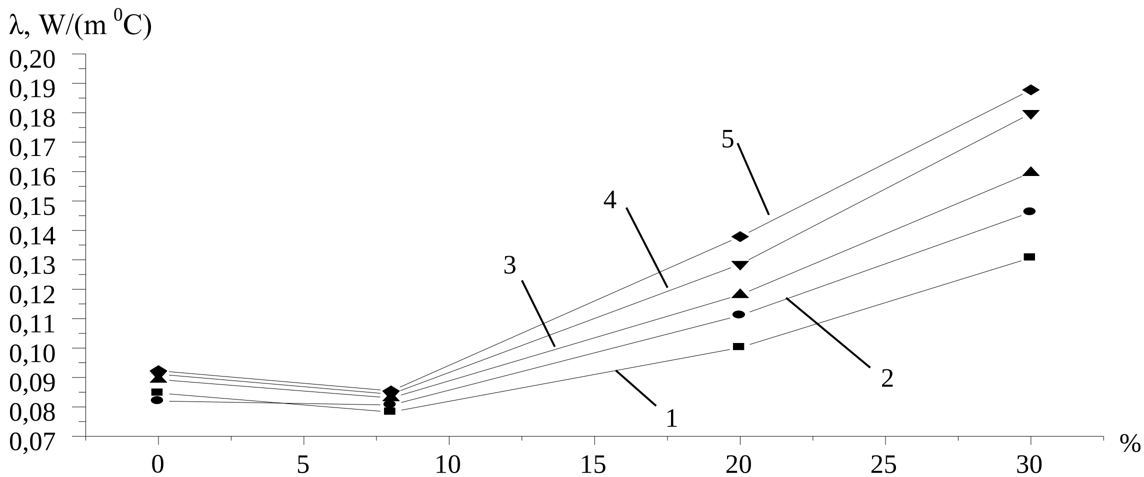
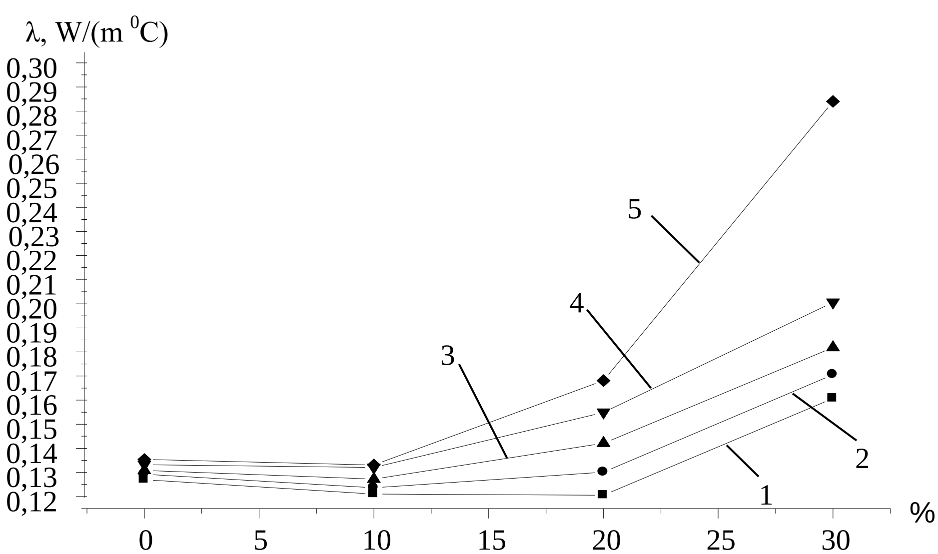
Within the drying area $30^\circ C < T < 60^\circ C$, the thermal conductivity of bare seeds with humidity $0 < W < 20\%$ is almost the same, and in the temperature area $T > 60^\circ C$ the thermal conductivity of bare seeds begins to increase.



Picture 3: Dependence of thermal conductivity of lowered seeds on humidity at different temperatures. (temperatures (ºC): 1-40, 2-50, 3-60, 4-70, 5-80).



Picture 4: Dependence of thermal conductivity of bare seeds on humidity at different temperatures. (temperatures (0C): 1-40, 2-50, 3-60, 4-70, 5-80).

The thermal conductivity of bare seeds with humidity $W = 30\%$ in the area of drying temperature increases quite intensively.

Thus, the drying temperature of bare seeds with humidity $0 < W < 20\%$ has no significant effect on the thermal conductivity of the bare seeds. The high drying temperature significantly affects the thermal conductivity of bare seeds with humidity $W > 25\,\%$.

From the pic. 3 and 4, which show the curves of heat conductivity, humidity, temperature of sunken and bare seeds. From the results of numerous experimental studies, it follows that depending on the neglect and nakedness, humidity, volumetric density and temperature, the thermal conductivity of bare seeds may exceed the thermal conductivity of the sunken ones $1.2 \div 1.5$ times.

On the basis of experiments and results presented in Pic. 1-4, which show the dependence of thermal conductivity of raw cotton, fiber, omitted and bare seeds, respectively, on humidity and temperature, it was possible to establish the following conditions

$$\lambda(ог) > \lambda(оп) > \lambda(хл) > \lambda(в), \quad (1)$$

where $\lambda(хл)$, $\lambda(в)$, $\lambda(оп)$ и $\lambda(ог)$- the thermal conductivity of raw cotton, fiber, omitted seeds and bare seeds.

Conclusions

Thus, it is proved that cotton fibers have the least thermal conductivity in comparison with raw cotton, lowered and bare seeds.

Raw cotton, which consists of seeds and surrounded by fibers, has a higher thermal conductivity than fibers and less than lowered and bare seeds.

Lower seeds consisting of smaller number and length of fibers have lower thermal conductivity than bare seeds and greater than raw cotton and fibers.

Naked seeds that do not have fibers on their surface have a higher thermal conductivity than lowered seeds, raw cotton and fibers.

The dependence of thermal conductivity of raw cotton and its components on the temperature at different humidity is obtained, which allows to carry out calculations by the equation of heat and mass transfer during drying of raw cotton.

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