Scientific Research Publishing

Engineering, 2022, 14, 578-590
https://www.scirp.org/journal/eng
ISSN Online: 1947-394X
ISSN Print: 1947-3931

Theoretical Optimization of the Production of Heating Layers Using Local Wool Fibers

Matluba Abdurashid Kizi Nazarova[1], Juramirza Abdiramatovich Kayumov[2,3], Axtam Akramovich Qosimov[4], Abdulrasul Abdumajitovich Mahmudov[5]

[1]Department of "Construction and Technology of Light Industrial Products", Namangan Institute of Engineering and Technology, Namangan, Uzbekistan
[2]Department of Textile Engineering, Zhejiang Sci-Tech University, Hangzhou, China
[3]Department of Technology of Goods of Textile Industry, Namangan Institute of Engineering and Technology, Namangan, Uzbekistan
[4]Department of "Metrology, Standardization and Quality Management", Namangan Institute of Engineering and Technology, Namangan, Uzbekistan
[5]Department of General Technics, Fergana Polytechnics Institute, Fergana, Uzbekistan
Email: matluba.nazarova91@gmail.com, juramirza@gmail.com, axtamqosimov@gmail.com, abdurasul8448@gmail.com

How to cite this paper: Nazarova, M.A.K., Kayumov, J.A., Qosimov, A.A. and Mahmudov, A.A. (2022) Theoretical Optimization of the Production of Heating Layers Using Local Wool Fibers. *Engineering*, **14**, 578-590.
https://doi.org/10.4236/eng.2022.1412043

Received: October 20, 2022
Accepted: December 27, 2022
Published: December 30, 2022

Abstract

Science is the basis of the country's development and wealth. In particular, it is necessary to effectively use advanced scientific developments and technical achievements in order to strengthen the economy in the period when the desire for innovation in all fields is still growing. In theoretical-experimental Scientific Research work, both theoretical and experimental results are achieved, and it is more useful to withstand more theoretical-experimental loads for a longer period of time. The occurrences in the production process of natural wool fiber technologists are a complex of physical and mechanical phenomena, which can be used only by the modern achievements of science and technology. In most cases, the parameter relationship with the factors influencing the technological process or the object can open a curve without any other things.

Keywords

Wool, Polyester, Fiber Content, Heating Layer, Surface Density, Result Unwanted Factors, Chemical Fiber, Experiments, Heat Storage, Determine

1. Introduction

Science is the basis of the country's development and prosperity. Especially in today's era, when the desire for innovations and competition is increasing in all areas, it is necessary to effectively use advanced scientific developments and technical achievements to strengthen the economic potential [1].

Scientific research works are divided into the following types depending on the methods of implementation: Theoretical, experimental and theoretical-experimental.

Theoretical studies are analyzed on the basis of a previously known law, technological process or object parameters interrelationship is studied theoretically, and experimental studies are carried out by conducting experiments.

A regression model obtained as a result of a full factorial experiment of such a connected technological process or object is unbalanced and cannot adequately represent the connection [2].

It is desirable to use multi-factor mathematical modeling effectively in researching the input parameters that determine the characteristics of heating layers of different proportions obtained with local wool fibers and chemical fibers.

The main task of mathematical modeling in the study was to determine the deviation diagrams of isolines on the basis of computational models in order to determine the changes in the amount of wool in the nonwoven using factors affecting the heat retention and air permeability properties of the weave.

2. Research Planning Matrix and Processing of Results

It is desirable to theoretically optimize the production of heating layers with different proportions of local wool fibers and chemical fibers. Although the influence of the change in the mixture composition of our characteristic x_1 is a little less than that of the x_2 characteristic, the values in both of our properties are from 30% to 71%, taking into account the actual values of the mixture composition of the fiber. When these processes are taken into account, our highest values are seen in our values with 65% wool content.

As influencing factors, the input factors x_1—share of chemical fiber with wool (percentage), x_2—thickness, (mm), x_3—surface density, (gr/m^2) indicators were taken. The choice of levels and intervals of the studied factors is presented in **Table 1**.

In order to determine the regression coefficients, Student and Fisher's criteria were used to check the adequacy of the mathematical model.

Y_1—thermal conductivity (impermeability), Y_2—hygroscopicity (percentage) were selected as output factors.

Table 1. Choice of levels and intervals of change of factors under investigation.

Name and designation of factors		Change surfaces			Change interval
		−1	0	+1	
Percentage of wool fiber in the mixture (percent)	x_1	50 (50/50)	60 (40/60)	70 (70/30)	10
Thickness (mm)	x_2	1.4	1.8	2.2	0.4
Surface density (gr/m^2)	x_3	185	215	275	60

In the research, the main issue put forward from mathematical modeling, when the amount of wool in the non-woven fabric changes, the isoline deviation drawings were obtained based on the computational models in order to determine with the help of the factors affecting the properties of the non-woven fabric's heat storage and air permeability. (**Table 2**)

From the results of the full-factor experiment, it became clear that the studied process is represented by a higher order equation. Therefore, in order to obtain a second-order regression mathematical model, the central non-composite experiment (MNCT), which is somewhat simpler and convenient compared to other methods, and widely used in the research of mathematical modeling of light industrial technological processes, was selected and implemented [3].

Based on the results of the experiment, we look for a second-order regression multifactorial mathematical model. As a result of this experiment, the regression model of the following general form can be obtained:

$$Y_R = b_0 + \sum_{i=1}^{M} b_i x_i + \sum_{\substack{i=j=1 \\ j\neq 1}}^{n} b_{ij} x_i x_j + \sum_{i=1}^{M} b_{ii} x_i^2 \quad (1)$$

Or, since three factors are involved in our experiment, the above expression takes the following form:

$$Y_R = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 \quad (2)$$

In the Equation (2),

Table 2. Central non-composite experimental matrix.

№	Factors			x_1x_2	x_1x_3	x_2x_3	x_1^2	x_2^2	x_3^2	Y_1	$S_u^2(Y_1)$
	x_1	x_2	x_3								
1	+	+	0	+	0	0	+	+	0	65.9	3.5
2	+	−	0	−	0	0	+	+	0	69	3.1
3	−	+	0	−	0	0	+	+	0	69.2	2.9
4	−	−	0	+	0	0	+	+	0	63.7	1.9
5	+	0	+	0	+	0	+	0	+	75.4	3.4
6	+	0	−	0	−	0	+	0	+	73.2	4.2
7	−	0	+	0	−	0	+	0	+	62.8	2.4
8	−	0	−	0	+	0	+	0	+	72.9	2.6
9	0	+	+	0	0	+	0	+	+	72.6	1.9
10	0	+	−	0	0	−	0	+	+	73.4	1.8
11	0	−	+	0	0	−	0	+	+	67.8	4.9
12	0	−	−	0	0	+	0	+	+	68.9	2.8
13	0	0	0	0	0	0	0	0	0	72.9	0.8
14	0	0	0	0	0	0	0	0	0	73.9	1.7
15	0	0	0	0	0	0	0	0	0	74.6	0.5

The matrix should use the values (+), (−) and 0.

$b_0, b_1, \cdots$—regression coefficients,

x_1, x_2, x_3—the coded value of the factors,

Y_1—calculation of regression models for optimizing thermal conductivity (impermeability):

Regression coefficients are determined:

$$b_0 = \frac{1}{N_s}\sum_{u=1}^{N_s}\bar{Y}_{\bar{u}} = \frac{1}{3}(72.9+73.9+74.6) = 73.8 \quad (3)$$

$$b_i = g_3\sum_{u=1}^{N} x_{iu}\bar{Y}_u \quad (4)$$

$g_2 = 0.166 \quad g_5 = 0.125$

$g_3 = 0.125 \quad g_6 = 0.0625$

$g_4 = 0.25 \quad g_7 = 0.3125$

$b_1 = 0.125(69.5+69+(-69.2)+(-63.7)+75.4+73.2+(-62.8)+(-72.9))$
$= 1.86$

$b_2 = 0.125(69.5+(-69)+69.2+(-63.7)+72.6+73.4+(-67.8)+(-68.9))$
$= 1.46$

$b_3 = 0.125(75.4+(-73.2)+62.8+(-72.9)+72.6+(-73.4)+67.8+(-68.9))$
$= -1.23$

$$b_{ij} = g_4\sum_{u=1}^{N} x_{iu}x_{ju}\bar{Y}_u \quad (5)$$

$b_{12} = 0.25(65.9+(-69)+(-69.2)+63.7) = -2.15$

$b_{13} = 0.25(75.4+(-73.2)+(-62.8)+72.9) = 3.8$

$b_{23} = 0.25(72.6+(-73.4)+(-67.8)+68.9) = 0.07$

$$b_{ii} = g_5\sum_{u=1}^{N} x_{iu}^2\bar{Y}_u + g_6\sum_{i=1}^{M}\sum_{u=1}^{N} x_{iu}^2\bar{Y}_u - g_2\sum_{u=1}^{N}\bar{Y}_u \quad (6)$$

$\sum x_1^2\bar{Y}_u = 65.9+69+69.2+63.7+75.4+73.2+62.8+72.9 = 552.10$

$\sum x_2^2\bar{Y}_u = 65.9+69+69.2+63.7+72.6+73.4+67.8+68.9 = 550.50$

$\sum x_3^2\bar{Y}_u = 75.4+73.2+62.8+72.9+72.6+73.4+67.8+68.9 = 567.00$

$\sum \bar{Y}_u = 65.9+69+69.2+63.7+75.4+73.2+62.8+72.9+73.9+74.6 = 1056.2$

$\sum_{i=1}^{M} x_i^2\bar{Y}_u = 552.1+550.5+567 = 1669.60$

$b_{11} = 0.125\times552.1+0.0625\times1669.6-0.166\times1056.2 = -1.97$

$b_{22} = 0.125\times550.5 + 0.0625\times1669.6-0.166\times1056.2 = -2.17$

$b_{33} = 0.125\times567+0.0625\times1669.6-0.166\times1056.2 = -0.10$

The equation is written taking into account the determined regression coefficients:

$$Y_{R1} = 73.8+1.86x_1+1.46x_2-1.23x_3-2.15x_1x_2+3.08x_1x_3+0.07x_2x_3 -1.97x_1^2-2.17x_2^2-0.1x_3^2$$

The significance of the regression coefficients is determined. To do this, the variance of the output parameter is determined.

$$S^2\{Y\} = S_m^2\{Y\} = \frac{1}{N_s - 1}\sum_{u=1}^{N_s} S^2\{\bar{Y}\} = 3 \tag{7}$$

$$S^2\{\bar{Y}\} = \frac{1}{3-1} \times 3 = 1.5 \tag{8}$$

and on this basis the variance in determining the regression coefficients is calculated:

$$S^2\{b_0\} = g_1 S^2\{\bar{Y}\} = 0.2 \times 1.5 = 0.3$$

$$S^2\{b_i\} = g_3 S^2\{\bar{Y}\} = 0.125 \times 1.5 = 0.19$$

$$S^2\{b_{ij}\} = g_4 S^2\{\bar{Y}\} = 0.25 \times 1.5 = 0.375$$

$$S^2\{b_{ii}\} = g_7 S^2\{\bar{Y}\} = 0.3125 \times 1.5 = 0.47$$

The standard deviation in determining the regression coefficients is found:

$$S\{b_0\} = 0.55;\quad S\{b_i\} = 0.43;\quad S\{b_{ij}\} = 0.61;\quad S\{b_{ii}\} = 0.68$$

Then the calculated value of the Student Criterion is determined using the following equation:

$$t_R\{b_i\} = \frac{|b_i|}{S\{b_i\}} \tag{9}$$

$$t_R\{b_0\} = \frac{73.8}{0.55} = 134.18,\quad t_R\{b_{12}\} = \frac{2.15}{0.61} = 3.52$$

$$t_R\{b_1\} = \frac{1.86}{0.43} = 4.33,\quad t_R\{b_{13}\} = \frac{3.08}{0.61} = 5.05$$

$$t_R\{b_2\} = \frac{1.46}{0.43} = 3.40,\quad t_R\{b_{23}\} = \frac{0.07}{0.61} = 0.11$$

$$t_R\{b_3\} = \frac{1.23}{0.43} = 2.86,\quad t_R\{b_{11}\} = \frac{1.97}{0.68} = 2.90$$

$$t_R\{b_{22}\} = \frac{2.17}{0.68} = 3.19,\quad t_R\{b_{33}\} = \frac{0.1}{0.68} = 0.15$$

The table value of the student criterion is taken from Appendix 3 [4]:

$$t_j\left[P_D = 0.95;\ f\{S_s^2\} = 3 - 1 = 2\right] = 2.77$$

It is known that if the calculated value of a criterion is less than the table value, that coefficient is not significant and is deducted from the equation [4] [5].

In the study, the coefficients b_{23}, b_{33} were found to be insignificant for the studied parameters:

Rewrite the equation with significant coefficients:

$$Y_{R1} = 73.8 + 1.86x_1 + 1.46x_2 - 1.23x_3 - 2.15x_1x_2 + 3.08x_1x_3 - 1.97x_1^2 - 2.17x_2^2$$

Regression models for optimizing the hygroscopicity (Y_2) of heating layers obtained by a mixed method from local wool fibers:

Regression coefficients are determined:

$$b_0 = \frac{1}{N_s}\sum_{u=1}^{N_s} \bar{Y}_{\bar{u}} = \frac{1}{3}(3.06 + 3.14 + 3.12) = 3.11$$

$$b_1 = 0.125\left(2.91 + 1.82 + (-1.64) + (-1.15) + 2.98 + 1.09 + (-0.95) + (-1.36)\right) = 0.46$$

$$b_2 = 0.125\left(2.91 + (-1.82) + 1.64 + (-1.15) + 2.98 + 1.69 + (-1.72) + (-0.91)\right) = 0.45$$

$$b_3 = 0.125\left(2.98 + (-1.09) + 0.95 + (-1.36) + 2.98 + (-1.69) + 1.72 + (-0.91)\right) = 0.45$$

$$b_{12} = 0.25\left(2.91 + (-1.82) + (-1.64) + 1.15\right) = 0.15$$

$$b_{13} = 0.25\left(2.98 + (-1.09) + (-0.95) + 1.36\right) = 0.58$$

$$b_{23} = 0.25\left(2.98 + (-1.69) + (-1.72) + 0.91\right) = 0.12$$

$$\sum x_1^2 \overline{Y}_u = 2.91 + 1.82 + 1.64 + 1.15 + 2.98 + 1.09 + 1.36 = 13.90$$

$$\sum x_2^2 \overline{Y}_u = 2.91 + 1.82 + 1.64 + 1.15 + 2.98 + 1.69 + 1.72 + 0.91 = 14.82$$

$$\sum x_3^2 \overline{Y}_u = 2.98 + 1.09 + 0.95 + 1.36 + 2.98 + 1.69 + 1.72 + 0.91 = 13.68$$

$$\begin{aligned}\sum \overline{Y}_u &= 2.91 + 1.82 + 1.64 + 1.15 + 2.98 + 1.09 + 0.95 + 1.36 \\ &\quad + 2.98 + 1.69 + 1.72 + 0.91 + 3.06 + 3.14 + 3.12 \\ &= 30.5\end{aligned}$$

$$\sum_{i=1}^{M} \sum x_i^2 \overline{Y}_u = 13.09 + 14.82 + 13.68 = 4240$$

$$b_{11} = 0.125 \times 13.9 + 0.0625 \times 42.4 - 0.166 \times 30.52 = -0.68$$

$$b_{22} = 0.125 \times 14.82 + 0.0625 \times 42.4 - 0.166 \times 30.52 = -0.56$$

$$b_{33} = 0.125 \times 13.68 + 0.0625 \times 42.4 - 0.166 \times 30.52 = -0.71$$

Taking into account the determined regression coefficients, the equation is written:

$$\begin{aligned}Y_{R2} &= 3.11 + 0.46 * x_1 + 0.45 * x_2 + 0.45 * x_3 + 0.15 * x_1 x_2 + 0.58 * x_1 x_3 \\ &\quad + 0.12 * x_2 x_3 + (-0.68) * x_1^2 + (-0.56) * x_2^2 + (-0.71) * x_3^2\end{aligned}$$

Optimization of Y_1—thermal conductivity (impermeability) determines the significance of regression coefficients. To do this, the variance of the outgoing parameter is determined.

$$S^2\{Y\} = S_m^2\{Y\} = \frac{1}{N_s - 1} \sum_{u=1}^{N_s} S^2\{\overline{Y}\} = 3 \tag{10}$$

$$S^2\{\overline{Y}\} = \frac{1}{3-1} \times 3 = 1.5$$

and on this basis the variance in determining the regression coefficients is calculated:

$$S^2\{b_0\} = g_1 S^2\{\overline{Y}\} = 0.2 \times 1.5 = 0.3$$

$$S^2\{b_i\} = g_3 S^2\{\overline{Y}\} = 0.125 \times 1.5 = 0.19$$

$$S^2\{b_{ij}\} = g_4 S^2\{\overline{Y}\} = 0.25 \times 1.5 = 0.375$$

$$S^2\{b_{ii}\} = g_7 S^2\{\overline{Y}\} = 0.3125 \times 1.5 = 0.47$$

The mean squared deviation in determining the regression coefficients is found:

$$S\{b_0\} = 0.55; \quad S\{b_i\} = 0.43; \quad S\{b_{ij}\} = 0.61; \quad S\{b_{ii}\} = 0.68$$

After that, the calculated value of Student's criterion is determined using the following equation:

$$t_R\{b_i\} = \frac{|b_i|}{S\{b_i\}} \tag{11}$$

$$t_R\{b_0\} = \frac{73.8}{0.55} = 134.18,\quad t_R\{b_{12}\} = \frac{2.15}{0.61} = 3.52$$

$$t_R\{b_1\} = \frac{1.86}{0.43} = 4.33,\quad t_R\{b_{13}\} = \frac{3.08}{0.61} = 5.05$$

$$t_R\{b_2\} = \frac{1.46}{0.43} = 3.40,\quad t_R\{b_{23}\} = \frac{0.07}{0.61} = 0.11$$

$$t_R\{b_3\} = \frac{1.23}{0.43} = 2.86,\quad t_R\{b_{11}\} = \frac{1.97}{0.68} = 2.90$$

$$t_R\{b_{22}\} = \frac{2.17}{0.68} = 3.19,\quad t_R\{b_{33}\} = \frac{0.1}{0.68} = 0.15$$

The table value of the student criterion is obtained from Appendix 3 [4]:

$$t_j\left[P_D = 0.95; f\{S_s^2\} = 3-1 = 2\right] = 2.77$$

It is known that if the calculated value of the criterion is smaller than the table value, then that coefficient is not significant and it is removed from the equation. In the studies, it was found that the coefficient b_{23}, b_{33} is insignificant for the studied parameters:

The equation with significant coefficients is rewritten:

$$Y_{R1} = 73.8 + 1.86x_1 + 1.46x_2 - 1.23x_3 - 2.15x_1x_2 + 3.08x_1x_3 - 1.97x_1^2 - 2.17x_2^2$$

After determining the adequacy of the regression equations for the obtained output parameters, we proceed to their analysis.

The significance of the regression coefficients for the optimization of the hygroscopicity (Y_2) of heating layers obtained by a mixed method from local wool fibers was determined. For this, the variance of the outgoing parameter was determined.

$$S^2\{\bar{Y}\} = \frac{1}{3-1} \times 0.2 = 0.1$$

The variance in the determination of the regression coefficients for the optimization of the hygroscopicity (Y_2) of the heating layers obtained by a mixed method from local wool fibers was calculated:

$$S^2\{b_0\} = g_1 S^2\{\bar{Y}\} = 0.2 \times 0.12 = 0.02$$

$$S^2\{b_i\} = g_3 S^2\{\bar{Y}\} = 0.125 \times 0.12 = 0.02$$

$$S^2\{b_{ij}\} = g_4 S^2\{\bar{Y}\} = 0.25 \times 0.12 = 0.03$$

$$S^2\{b_{ii}\} = g_7 S^2\{\bar{Y}\} = 0.3125 \times 0.12 = 0.04$$

The mean square deviation in determining the regression coefficients for the optimization of the hygroscopicity (Y_2) of heating layers obtained by a mixed method from local wool fibers was found:

$$S\{b_0\} = 0.15,\quad S\{b_i\} = 0.12,\quad S\{b_{ij}\} = 0.17,\quad S\{b_{ii}\} = 0.19$$

After that, the calculated value of Student's criterion is determined using the following equation:

$$t_R\{b_i\} = \frac{|b_i|}{S\{b_i\}} \tag{12}$$

$$t_R\{b_0\} = \frac{3.11}{0.15} = 20.73,\quad t_R\{b_{22}\} = \frac{0.56}{0.19} = 2.95$$

$$t_R\{b_1\} = \frac{0.46}{0.12} = 3.83,\quad t_R\{b_{13}\} = \frac{0.58}{0.17} = 3.41$$

$$t_R\{b_2\} = \frac{0.45}{0.12} = 3.75,\quad t_R\{b_{23}\} = \frac{0.12}{0.17} = 0.71$$

$$t_R\{b_3\} = \frac{0.45}{0.12} = 3.75,\quad t_R\{b_{11}\} = \frac{0.68}{0.19} = 3.58$$

$$t_R\{b_{12}\} = \frac{0.15}{0.17} = 0.88,\quad t_R\{b_{33}\} = \frac{0.71}{0.19} = 3.74$$

The table value of the student criterion is obtained from Appendix 3 [4]:

$$t_j\left[P_D = 0.95;\ f\left\{S_s^2\right\} = 3-1 = 2\right] = 2.77$$

In the research, it was found that the coefficient of hygroscopicity b_{12}, b_{23} of heating layers obtained by a mixed method from local wool fibers is insignificant for the parameters under study:

The equation with significant coefficients is rewritten:

$$Y_{R2} = 3.11 + 0.46*x_1 + 0.45*x_2 + 0.45*x_3 + 0.58*x_1x_3 - 0.68*x_1^2 - 0.56*x_2^2 - 0.71*x_3^2$$

Adequacy checks of the obtained Y_1-thermal conductivity (impermeability), Y_2-hygroscopicity (%) equations. The test was performed using Fisher's test. The estimated value of Fisher's criterion was determined. The estimated value of the optimized factor Y_1 was calculated by putting the coded values of all the columns of the table in the matrix (−1, 0 and +1) of the equation 3.3. Values are taken by row, not column. The calculations for formula Y are as follows, and the calculation results are included in **Table 3** and **Table 4**.

Calculation of Y_1—heat conductivity (impermeability) by putting coded values into the equation:

$$Y_{R1.1} = 73.8 + 1.86 + 1.46 + (-2.15) + (-1.97) + (-2.17) = 67.83$$

$$Y_{R1.2} = 73.8 + 1.86 + (-1.46) + 2.15 + (-1.97) + (-2.17) = 70.71$$

$$Y_{R1.3} = 73.8 + (-1.86) + 1.46 + 2.15 + (-1.97) + (-2.17) = 70.31$$

$$Y_{R1.4} = 73.8 + (-1.86) + (-1.46) + (-2.15) + (-1.97) + (-2.17) = 64.19$$

Table 3. Calculation results of values coded into the equation for adequate dispersion.

№	Thermal conductivity (impermeability)				Hygroscopicity (%)			
	Y_{1i}	Y_{1i}	$(Y_{1i} - Y_{R1i})$	$(Y_{1i} - Y_{R1i})^2$	Y_{2i}	Y_{2i}	$(Y_{2i} - Y_{R2i})$	$(Y_{2i} - Y_{R2i})^2$
1	65.9	64.2	0.21	0.0	2.91	2.78	−0.13	0.0
2	69	51.2	1.21	1.46	1.82	1.88	0.06	0.00
3	69.2	53.7	2.71	7.34	1.64	1.86	0.22	0.05
4	63.7	40.7	1.71	2.92	1.15	0.96	−0.19	0.04
5	75.4	68.5	0.46	0.21	2.98	3.21	0.23	0.05
6	73.2	50	0.96	0.92	1.09	1.15	0.06	0.00
7	62.8	52	−1.04	1.08	0.95	1.13	0.18	0.03
8	72.9	45.5	−0.54	0.29	1.36	1.39	0.03	0.00
9	72.6	62.2	2.21	4.88	2.98	2.74	−0.24	0.06
10	73.4	54.7	1.71	2.92	1.69	1.84	0.15	0.02
11	67.8	54.2	2.21	4.88	1.72	1.84	0.12	0.01
12	68.9	36.7	1.71	2.92	0.91	0.94	0.03	0.3

Table 4. Calculation results of values coded into the equation for adequate dispersion.

№	Thermal conductivity (impermeability)				Hygroscopicity (%)			
	Y_{1i}	Y_{1i}	$(Y_{1i} - Y_{R1i})$	$(Y_{1i} - Y_{R1i})^2$	Y_{2i}	Y_{2i}	$(Y_{2i} - Y_{R2i})$	$(Y_{2i} - Y_{R2i})^2$
1	65.9	64.2	0.21	0.0	2.91	2.78	−0.13	0.0
2	69	51.2	1.21	1.46	1.82	1.88	0.06	0.00
3	69.2	53.7	2.71	7.34	1.64	1.86	0.22	0.05
4	63.7	40.7	1.71	2.92	1.15	0.96	−0.19	0.04
5	75.4	68.5	0.46	0.21	2.98	3.21	0.23	0.05
6	73.2	50	0.96	0.92	1.09	1.15	0.06	0.00
7	62.8	52	−1.04	1.08	0.95	1.13	0.18	0.03
8	72.9	45.5	−0.54	0.29	1.36	1.39	0.03	0.00
9	72.6	62.2	2.21	4.88	2.98	2.74	−0.24	0.06
10	73.4	54.7	1.71	2.92	1.69	1.84	0.15	0.02
11	67.8	54.2	2.21	4.88	1.72	1.84	0.12	0.01
12	68.9	36.7	1.71	2.92	0.91	0.94	0.03	0.3

$$Y_{R1.5} = 73.8 + 1.86 + (-1.23) + 3.08 + (-1.97) = 75.54$$

$$Y_{R1.6} = 73.8 + 1.86 + 1.23 + (-3.08) + (-1.97) = 71.84$$

$$Y_{R1.7} = 73.8 + (-1.86) + (-1.23) + (-3.08) + (-1.97) = 63.66$$

$$Y_{R1.8} = 73.8 + (-1.86) + 1.23 + 3.08 + (-1.97) = 74.28$$

$$Y_{R1.9} = 73.8 + 1.46 + (-1.23) + (-2.17) = 71.86$$

$$Y_{R1.10} = 73.8 + 1.46 + 1.23 + (-2.17) = 74.32$$

$$Y_{R1.11} = 73.8 + (-1.46) + (-1.23) + (-2.17) = 69$$

$$Y_{R1.12} = 73.8 + (-1.46) + 1.23 + (-2.17) = 69$$

In order to check the adequacy of the regression mathematical model mentioned above, it was determined using the calculated value of Fisher's criterion [5] [6].

$$F_R = \frac{S_{nad}^2\{Y\}}{S^2\{\bar{Y}\}}; \quad (13)$$

here

$$S^2\{\bar{Y}_1\} = \frac{\sum_{u=1}^{N} S^2\{Y\}}{N_s - 1} = \frac{3}{2} = 1.5$$

$$S_{nad}^2\{Y\} = \frac{\sum_{u=1}^{N-N_s+1}\left(Y_{Ru} - \bar{Y}_u\right)^2}{N - N_{k.en} - \left(N_s - 1\right)^2}; \quad (14)$$

$$N - N_{k.en} - \left(N_s - 1\right)^2 = 15 - 7 - (3-1)^2 = 4$$

$$N - N_s + 1 = 15 - 3 + 1 = 13$$

$$\sum_{u=1}^{N-N_s+1}\left(Y_{R1.u} - \bar{Y}_{1u}\right)^2 = 16\sum_{u=1}^{N-N_s+1}\left(Y_{R2.u} - \bar{Y}_{2u}\right)^2 = 0$$

$$S_{nad}^2\{Y_1\} = \frac{16.4}{4} = 4$$

It is known that if the calculated value of the criterion is smaller than the table value, then that coefficient proves that the calculations were carried out correctly.

$$F_{R1} = \frac{S_{nad}^2\{Y\}}{S^2\{\bar{Y}\}} = \frac{3.89}{1.5} = 2.59$$

$$F_j\left[P_D = 0.95;\ f\left\{S_{nad}^2\{Y\}\right\} = 15 - 6 - (3-1) = 5;\ f\left\{S_u^2\right\} = 3 - 1 = 2\right] = 4.74$$

$$F_{R1} = 2.59 < 4.74 = F_j \quad (15)$$

Therefore, the obtained regret mathematical models represent the researched process with sufficient accuracy.

Y_2—hygroscopicity of heat layers (Y_2) is calculated by putting coded values into the equation:

$$Y_{R1.1} = 3.11 + 0.46 + 0.45 + (-0.68) + (-0.56) = 2.78$$

$$Y_{R1.2} = 3.11 + 0.46 + (-0.45) + (-0.68) + (-0.56) = 1.88$$

$$Y_{R1.3} = 3.11 + (-0.46) + (-0.45) + (-0.68) + (-0.56) = 1.86$$

$$Y_{R1.4} = 3.11 + (-0.46) + (-0.45) + (-0.68) + (-0.56) = 0.96$$

$$Y_{R1.5} = 3.11 + 0.46 + 0.45 + 0.58 + (-0.68) + (-0.71) = 3.21$$

$$Y_{R1.6} = 3.11 + 0.46 + (-0.45) + (-0.58) + (-0.68) + (-0.71) = 1.15$$

$$Y_{R1.7} = 3.11 + (-0.46) + 0.45 + (-0.58) + (-0.68) + (-0.71) = 1.13$$

$$Y_{R1.8} = 3.11 + (-0.46) + (-0.45) + 0.58 + (-0.68) + (-0.71) = 1.39$$

$$Y_{R1.9} = 3.11 + 0.45 + 0.45 + (-0.56) + (-0.71) = 2.74$$

$$Y_{R1.10} = 3.11 + 0.45 + (-0.45) + (-0.56) + (-071) = 1.84$$

$$Y_{R1.11} = 3.11 + (-0.45) + 0.45 + (-0.56) + (-0.71) = 1.84$$

$$Y_{R1.12} = 3.11 + (-0.45) + (-0.45) + (-0.56) + (-0.71) = 0.94$$

In order to check whether the above-mentioned regret mathematical model is adequate or not, we determine using the calculation value of Fisher's criterion [5] [6].

$$F_R = \frac{S_{nad}^2\{Y\}}{S^2\{\bar{Y}\}}; \tag{16}$$

Here,

$$S^2\{\bar{Y}_1\} = \frac{\sum_{u=1}^{N} S^2\{Y\}}{N_s - 1} = \frac{38.4}{2} = 19.2$$

$$S^2\{\bar{Y}_2\} = \frac{\sum_{u=1}^{N} S^2\{Y\}}{N_s - 1} = \frac{0.2}{2} = 0.12$$

$$S_{nad}^2\{Y\} = \frac{\sum_{u=1}^{N-N_s+1}(Y_{Ru} - \bar{Y}_u)^2}{N - N_{k.en} - (N_s - 1)^2};$$

$$N - N_{k.en} - (N_s - 1)^2 = 15 - 7 - (3-1)^2 = 4$$

$$N - N_s + 1 = 15 - 3 + 1 = 13$$

$$\sum_{u=1}^{N-N_s+1}(Y_{R1.u} - \bar{Y}_{1u})^2 = 238, \quad \sum_{u=1}^{N-N_s+1}(Y_{R2.u} - \bar{Y}_{2u})^2 = 0$$

$$S_{nad}^2\{Y_1\} = \frac{238}{4} = 59.61, \quad S_{nad}^2\{Y_2\} = \frac{23615}{4} = 0.07$$

It is known that if the calculated value of the criterion is smaller than the table value, then that coefficient proves that the calculations were carried out correctly.

$$F_{R1} = \frac{S_{nad}^2\{Y\}}{S^2\{\bar{Y}\}} = \frac{238}{4} = 59.61$$

$$F_{R2} = \frac{S_{nad}^2\{Y\}}{S^2\{\bar{Y}\}} = \frac{0.07}{0.12} = 0.58$$

$$F_j\left[P_D = 0.95; f\{S_{nad}^2\{Y\}\} = 15 - 6 - (3-1) = 5; f\{S_u^2\} = 3 - 1 = 2\right] = 4.74$$

$$F_{R1} = 3.1 < 4.74 = F_j, \quad F_{R2} = 0.58 < 4.74 = F_j$$

Therefore, the obtained regret mathematical models represent the researched process with sufficient accuracy.

Y_1—analysis of regression models for optimization of thermal conductivity (impermeability). It is usually not possible to analyze 3 factors in the equation obtained on the basis of the central non-composite experiment and express them in a graph. Therefore, we rewrite the equation in the value of one of the factors in the central (average, $x_i = 0$) state.

In this case, the equation takes 3 forms and is analyzed as follows. The effect of the change of x_2—mixture composition of the obtained non-woven fabric on the value of the thickness of the fabric in the range of 1.4 ÷ 2.2 (mm) and the property of surface density in the range of x_3—185 ÷ 275 is expressed on the property of thermal conductivity (impermeability).

The second factor is the appearance of our mathematical model, taking the average (x_2 = 0, 0.5 mm) state of the surface density of knitted fabric as follows. (**Figure 1**)

$$Y_R = 212 + 17.25x_1 + 18x_3 + 5.26x_1x_3 - 8.57x_1^2$$

In the graphic plot, when the incoming second (x_2) and third (x_3) factors vary from the accepted minimum (−1) value to the maximum (1) value, and the first factor $x_1 = 0$, using the average value (Y_1) of thermal conductivity (impermeability) property (by height) values are described. The x_2 mixture composition of

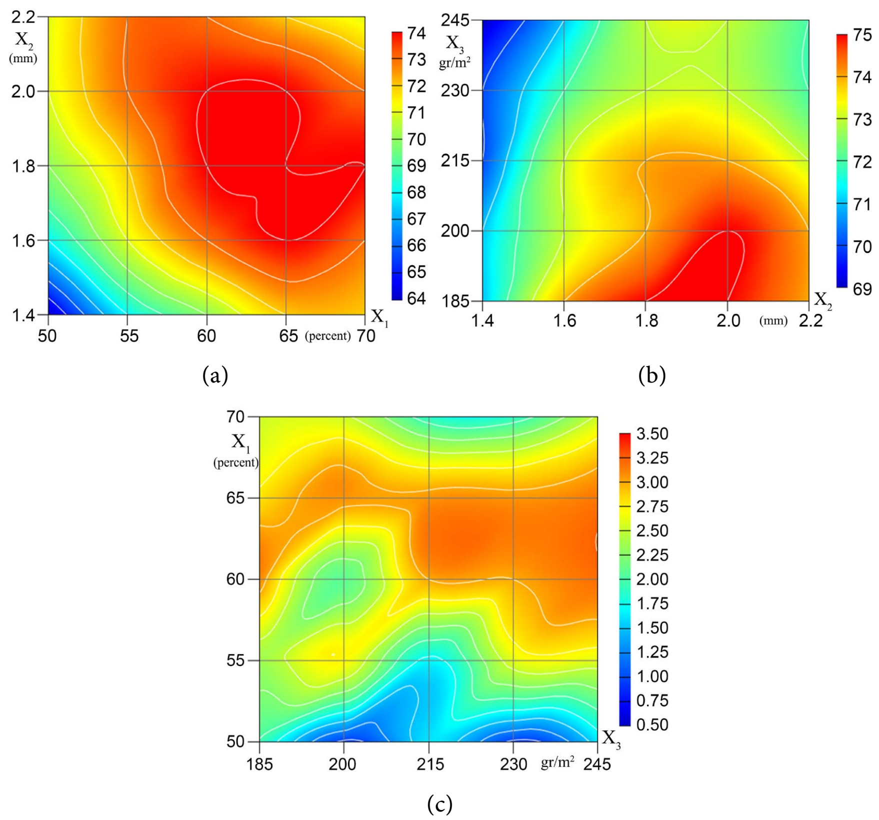

Figure 1. Graphical analysis of the regression equation on the property of thermal conductivity (impermeability) of fabric. (a) X_3 = 0 is the surface density (g/m²); (b) X_1 = 0 is the percentage of wool fibers in the mixture; (c) X_2 = 0 is the thickness (mm). (a) $Y_{R1} = 73.8 + 1.86x_1 + 1.46x_2 - 2.15x_1x_2 - 1.97x_1^2 - 2.17x_2^2$; (b) $Y_{R1} = 73.8 + 1.86x_1 - 1.23x_3 + 3.08x_1x_3 - 1.97x_1^2$; (c) $Y_{R1} = 73.8 + 1.46x_2 - 1.23x_3 - 2.17x_2^2$.

the obtained non-woven fabric reaches the highest values of the fabric thickness of 40/60 in the range of 1.8 (mm), surface density property in the range of x_3—215 g/m^2, and (Y_1) thermal conductivity (impermeability).

According to the statistical analysis of the experimental results and the drawing result of the optimization solutions, it can be seen in the graphic drawing 1 above that the 3-dimensional graphic image is depicted in the 2-dimensional view to represent the heat storage property of the non-woven fabric. Here, the coded values from −1 to 1 represent the changes in the fiber fraction of the x_1 property and the surface density of the x_2 property. In the case of −1 and −1 x_1 1 x_2, our value is 65%, and this indicator reaches its highest value in the form of coded value 1, +1, +1. It can be seen that it maintains a hot storage property of over 70%. Although the influence of the change in the mixture composition of our characteristic x_1 is a little less than that of the x_2 characteristic, the values in both of our properties are from 30% to 71%, taking into account the actual values of the mixture composition of the fiber. When these processes are taken into account, our highest values are seen in our values with 65% wool content.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Meliboev, U.Kh. (2020) Fundamentals of Modeling Technological Processes of the Textile Industry. Adabiyot Uchqunlari, Namangan.

[2] Amzaev, L.A., Jumaniyazov, Q.J. and Matismailov, S.L. (2008) Scientific Basis of Research and Alternative Technological Processes. Tashkent Institute of Textile and Industry, Tashkent, 147 p.

[3] Sevostyanov, A.G. (2007) Methods and Means of Studying the Mechanical and Technological Processes of the Textile Industry. Legkayaindustriya, Moscow, 648 p.

[4] Raxmankulova, B.O., Ziyaeva, SH.K. and Kubyashev, E.K. (2020) Mathematical Modeling of Information Technologies and Processes. Sharq, Tashkent.

[5] Michael, A. (2001) An Introduction to Mathematical Modeling of Infectious Diseases. Springer, Canada.

[6] Eshkobilov, Y.X., Yusupov, M. and Bobonazarov SH.P. (2003) Numerical Methods in Mathematical Modeling. Uzbekistan, Tashkent.