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Study on the Optimal Sealing Technological Regime for Making Officer Rain Clothes

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Abstract

The article focuses on the simultaneous influence of sealing technology factors: sealing temperature, sealing speed, and roller pressure on the quality of the sealing seam, which is evaluated through the tensile strength, the elongation of the sealing seam in the pre- and post-aging conditions and the waterproofing in the finishing process of office raincoat from 100% polyester coated fabric. In this research, authors used orthogonal experimental design method, Microsoft Excel 2010 and Design Expert 11.0 software to process and analyse experiment results. The result is identified sealing technological factors having important effects on the waterproofing, the tensile strength, and the elongation of the sealing seam, and the optimal sealing technology mode to improve the quality of bonding pieces' surface, to increase the aesthetic and durability of the product before use, in the process used; save time and costs in production. The result of this study is a useful guide in the actual production of raincoat garment enterprises in general and the raincoat of 19-5 One Member Limited Liability Company in particular.

Keywords: Raincoat, sealing technology, sealing technology factors, waterproof fabric.

1. Introduction

Raincoats in general and raincoats of the police force in particular play an important role in protecting the health and improving the work efficiency of users and officers, and soldiers during their duties, especially in harsh weather conditions such as heavy rain, when patrolling and controlling tasks must still be performed.

Vietnam is a country with a humid tropical monsoon climate, with the rainy season lasting from May to October. The Central and Southern regions face many storms and floods every year, officers and soldiers often have to use raincoats to serve the work of flood prevention, rescue, and relief. Therefore, raincoats of the police force are not only a part of the armed forces' uniforms but also play an essential role in ensuring health safety, supporting professional work, and maintaining the professional image of the force in all weather conditions. This is an important factor that helps the police force complete its task of protecting security and order in a harsh and continuous environment.

The waterproofness of an outer garment layer prevents water penetration from the outside [1]. This waterproof layer serves a critical function in a raincoat, specifically for officers, effectively preventing water from entering the external environment.

Some research has been done to determine and optimize the sealing parameters for waterproof fabrics [2-6]. Vlad Luminita *et al.* [5] studied the influence of the sealing parameters, namely temperature, work speed, and the pressure of the roller and of the air, on the resistance of specific assemblies for double and triple laminated materials and designed the correlation between the breaking load and the elongation and temperature.

The objective of this study is to optimize the sealing conditions for the raincoat. The thermo-adhesion process using thermo-adhesive tape was undertaken. The research was based on the tensile strength of the fabric before and after aging, which determines the seam sealing parameters, including temperature, sealing speed, and roller presser. The requirement for the optimization is that the tensile strength is maximum and suitable for resistance to water penetration.

2. Materials and Methods

2.1. Object of Research

The subject of this research is the raincoat of the police force, which is a specialized clothing used to serve the work requirements and perform the duties of the Vietnamese police force in harsh weather conditions. In this research, waterproof-coated fabric and sealing tape were used as experimental materials. The waterproof fabric used for the officer raincoat was selected from Yung Yaw Fabrictech Corporation (Taiwan). An image of an officer's raincoat is shown in Fig. 1. A wide range of influencing parameters that affect aging depends on the aim to simulate the environment and influences under which the material is expected to perform. In this study, the experiment for the

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aging of fabrics used for officer raincoats is defined following the TCVN 8833:2011 standard [7]. Therefore, the fabric was exposed to a temperature of 70 °C for 72 hours (3 days) to finish the aging process. The properties of the fabrics before and after aging are shown in Table 1.

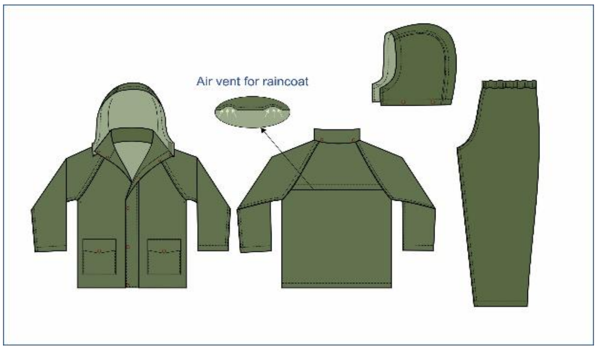

Fig. 1. Image of an officer raincoat

Table 1. Technical specifications required

No	Properties	Value
1.	Layer	2 (Base fabric and coated fabric)
2.	Width (cm)	150
3.	Fabric	100% PET
4.	Coating layer	PVC
5.	Area density (g/m^2)	165 (SD = - 3%, 5%)
6.	Fabric weave	Plain Weave
7.	Thickness (mm)	0.17 ± 0.01
8.	Resistance to water penetration (mmH$_2$0 ×1h)	
	Before aging	500
	After aging	500
9.	Tensile strength before aging (N)	
	Longitudinal direction	≥ 700
	Cross direction	≥ 370
10.	Tensile strength after aging (N)	
	Longitudinal direction	≥ 690
	Cross direction	≥ 390

To evaluate the optimal sealing technological regime for making officer rain clothes, the PVC sealing tape was chosen to seal seams of the waterproof fabrics to prevent water from leaking through the seams [8]. Table 2 provides the properties of polyvinyl chloride sealing tape.

Table 2. Thermal and physical properties of sealing tape

No.	Properties	Specification
1.	Composition	100% PVC
2.	Width (mm)	20
3.	Thickness (mm)	0.07
4.	Melting temperature (°C)	105 - 184

All seams were sewn at constant machine conditions. Each sample was sewn together in the weft direction, with a stitch density of 4 cm per centimeter, using a double chainstitch machine (ESSY Model: ES927D-PL). Then, the seamed fabrics were sealed with waterproof sealing tape on the hot air seam sealing machine (VIM, Model: V-1 Seri: 7090) with the maximum temperature of 730 °C and the speed range from 1 to 24 m/min. The scheme of stitched and sealed seams is shown in Fig. 2 [9]. The experiment was conducted at 19-5 One Member Limited Liability Company.

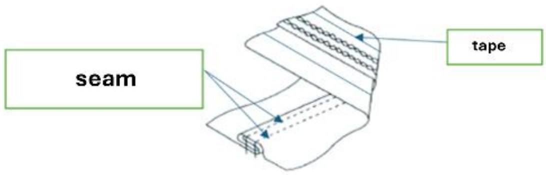

Fig. 2. Scheme of stitched and sealed seams test sample

2.2. Research Methodology

In this experimental research, the evaluation criteria for the quality of sealing seam include: Y_1 (N) – the tensile strength of the sealing seam before and after aging, Y_2 (%) – the elongation of sealing seam before and after aging, Y_3 – Water-proofness of sealing seam before aging, Y_4 – Appearance of sealing seam after aging, Y_5 – Water-proofness of sealing seam after aging.

An experimental design was applied for the investigation of the influence of factors of the sealing process with seam tape on tensile strength, elongation of the sealing seam and resistance to water properties of seams. There are many technology factors that have a great impact on the quality of sealing seam on waterproof fabrics. This is to examine the influence of the three most important factors on the quality of sealing seam, including: sealing temperature, sealing speed, and roller pressure. The tensile strength and the elongation of the sealing seam test were carried out by the standard ISO 13935-2:2014 [10]. The experiment was conducted by MESDANLAB machine in the Department of Textile - Leather and Fashion, School of Materials Science and Engineering, Hanoi University of Science and Technology.

The values of the factors are measurable and controllable variables. To ensure the total general and accurate experiments, the change in the value of these factors is based on the average, the upper, and lower values, which are wider than the value ranges commonly established in enterprises. The range of variations of the sealing technology factors chosen in this study is shown in Table 3.

Number of samples tested: The authors use the orthogonal planning level 2 for 3 influencing factors. The number of experiments is [11]:

$$N = 2^K + n_0 + 2K = 2^3 + 3 + 2x3 = 17 \quad (1)$$

17 experimental plans are shown in Table 4. The number of experimental samples of each option to adjust 3 factors is 6 samples (2 samples to measure tensile strength before aging condition, 2 samples to measure tensile strength after aging condition, 2 samples to measure waterproof strength). So, total number of tests: 17 × 6 = 102 (samples).

In this research, the authors use ANOVA variance analysis method with one factor based on Microsoft Excel 2010 and Design Expert 11.0 software. The data evaluate the simultaneous influence of technological factors of the sealing machine, such as sealing temperature (X_1), sealing speed (X_2), and roller pressure (X_3) on the tensile strength and the elongation of the sealing seam before and after aging to ensure the waterproof properties of the raincoat products of the police force. Based on that influence relationship, we can find the optimal set of technological parameters so that the quality of the sealing seam meets the requirements of resistance to water penetration.

Table 3. Identification of sealing process factors

No	Factor code	Variability levels				
		-1.68	-1	0	1	+1.68
1	X_1 - Sealing temperature (ºC)	500	547	615	683	730
2	X_2 - Sealing speed (m/min)	6	7	9	11	12
3	X_3 - Roller pressure (MPa)	0.24	0.27	0.31	0.35	0.38

Table 4. Experimental plans

No	x_1	x_2	x_3	X_1 (ºC)	X_2 (m/min)	X_3 (Mpa)
1	-1	-1	-1	547	7	0.27
2	+1	-1	-1	683	7	0.27
3	-1	+1	-1	547	11	0.27
4	+1	+1	-1	683	11	0.27
5	-1	-1	+1	547	7	0.35
6	+1	-1	+1	683	7	0.35
7	-1	+1	+1	547	11	0.35
8	+1	+1	+1	683	11	0.35
9	-1.68	0	0	500	9	0.31
10	+1.68	0	0	730	9	0.31
11	0	-1.68	0	615	6	0.31
12	0	+1.68	0	615	12	0.31
13	0	0	-1.68	615	9	0.24
14	0	0	+1.68	615	9	0.38
15	0	0	0	615	9	0.31
16	0	0	0	615	9	0.31
17	0	0	0	615	9	0.31

3. Results and Discussion

3.1. The Influence of Sealing Technology Factors on the Quality of the Sealing Seam before Aging

In order to determine the relevance of empirical equations, Fisher's criterion was calculated. With x_1: sealing temperature; x_2: sealing speed; x_3: roller pressure; and a_1, a_2, and a_3 stand for the linear coefficient values of x_i (i = 1÷3); a_{ij}: the correlation coefficient between two factors x_i and x_j; a_{ii}: the quadratic coefficient values of x_i (i = 1÷3). From the mathematical models, we can analyze the effect of temperature, sealing speed, and roller pressure on the tensile strength of the seam before and after aging (Y).

3.1.1. The tensile strength of the sealing seam before aging

Mathematical models are presented in the following form:

$$\begin{aligned} Y_1 &= 407.14 + 15.91x_1 + 20.51x_3 \\ &+ 0.56x_1x_2 + 19.19x_1x_3 - 21.69x_2x_3 - 16.88x_1^2 \\ &-7.25x_2^2 - 15.20x_3^2 + 4.94x_1x_2x_3 + 7.69x_1^2x_2 \\ &- 40.95x_1^2x_3 - 18.59x_1x_2^2 \end{aligned} \tag{2}$$

As seen from (2), the greatest absolute value of a_i is $|a_3|$ equal 20.51, which means that X_3 has the largest impact on the value of Y_1, corresponding to the value of roller pressure, which is the most important factor for the tensile strength of the sealing seam before aging. Table 5 shows the influence of one factor (x_i) on the tensile strength of the sealing seam before aging. The positive correlation between Y_1 and x_1/x_3 means when x_1/x_3 increases, it leads to Y_1 increasing. Therefore, to enhance the tensile strength of sealing seam before aging, it is necessary to increase the value of sealing temperature and roller pressure in sealing seam conditions.

From Table 6, the correlation between the tensile strength of sealing seam and the two factors was evaluated; the value a_{ij} was taken from (2). The correlation between sealing temperature and sealing speed/roller pressure is positive, which means the simultaneous increase or decrease of sealing temperature and sealing speed, or sealing temperature and roller pressure, corresponds to the increase of the tensile strength of the sealing seam. However, the increase in the tensile strength of the sealing seam happens when the sealing speed increases, and simultaneously, roller pressure is reduced or reversed.

The relationship between the tensile strength of the sealing seam and sealing technology factors as sealing temperature (°C), sealing speed (m/min), and roller pressure (MPa), is presented through 3D graphs in Fig. 3, Fig. 4, and Fig. 5, respectively.

Table 5. Correlation between the tensile strength of the sealing seam before aging and one factor

X_i	a_i	Correlation with Y_1
X_1 – Sealing temperature	+15.91	Positive
X_2 – Sealing speed	0.00	-
X_3 – Roller pressure	+20.51	Positive

Table 6. Correlation between the tensile strength of the sealing seam before aging and two factors

X_{ij}	a_{ij}	Correlation with Y_1
X_{12} – Sealing temperature and Sealing speed	+0.56	Positive
X_{23} – Sealing speed and Roller pressure	– 21.69	Negative
X_{13} – Sealing temperature and Roller pressure	+19.19	Positive

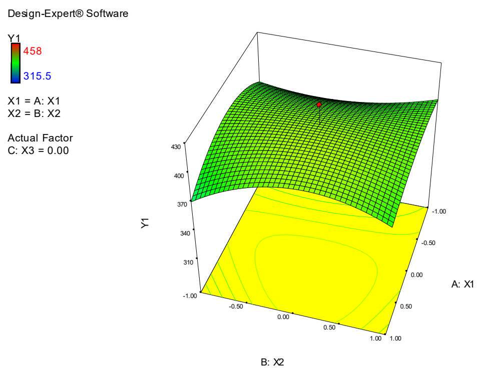

Fig. 3. The response of sealing seam tensile strength before aging - Y_1 (N) at different levels of sealing temperature - X_1 (°C) and sealing speed - X_2 (m/min).

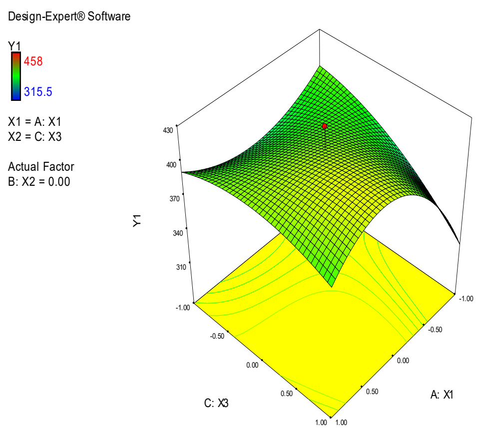

Fig. 4. The response of sealing seam tensile strength before aging - Y_1 (N) at different levels of sealing temperature - X_1 (°C) and roller pressure - X_3 (MPa)

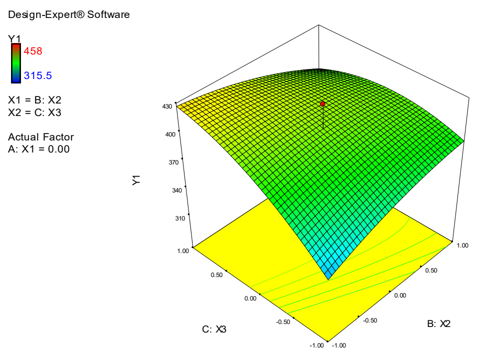

Fig. 5. The response of sealing seam tensile strength before aging - Y_1 (N) at different levels of sealing speed - X_2 (m/min) and roller pressure - X_3 (MPa)

3.1.2. The elongation of the sealing seam before aging

Mathematical models of the elongation of the sealing seam before aging with three factors are presented in the following form:

$$\begin{aligned} Y_2 = {} & 25.47 - 0.62x_1 + 0.40x_2 + 0.27x_3 \\ & - 0.58x_1x_2 + 1.18x_1x_3 - 1.44x_2x_3 - 0.30x_1^2 \\ & - 0.38x_2^2 - 0.19x_3^2 - 0.17x_1x_2x_3 + 0.74x_1^2x_2 \\ & - 1.19x_1^2x_3 - 0.41x_1x_2^2 \end{aligned} \quad (3)$$

As seen from (3), the greatest absolute value of a_i is $|a_1|$ equal 0.62, which means that the value of temperature is the most important factor for the elongation of the sealing seam before aging.

From (3), we can analyze the effect of sealing temperature, sealing speed and roller pressure on the elongation of the sealing seam before aging (Y_2).

Table 7 shows the influence of one factor (X_i) to the elongation of the sealing seam before aging. The negative correlation between Y_2 and x_1 means when x_1 goes up, it leads to Y_2 going down. The positive correlation between Y_2 and x_2/x_3 means when x_2/x_3 increases, it leads to Y_2 increasing. Therefore, to enhance the elongation of the sealing seam before aging when modifying one factor, it is necessary to decrease the value of x_1 - the sealing temperature of the sealing condition and increase the value of sealing speed and roller pressure.

From Table 8, the correlation between the elongation of the sealing seam and two factors was evaluated; the value a_{ij} was taken from (3). The correlation between sealing speed and sealing temperature/roller pressure is negative, which means increasing temperature and decreasing sealing speed/roller pressure, simultaneously, or reserved corresponds to the increase of the elongation of the sealing seam. The increase in the elongation of the sealing seam happens when the sealing speed and roller pressure increase or decrease simultaneously.

Table 7. Correlation between the elongation of the sealing seam before aging and three factors

X_i	a_i	Correlation with Y_2
X_1 – Sealing temperature	– 0.62	Negative
X_2 – Sealing speed	+ 0.40	Positive
X_3 – Roller pressure	+ 0.27	Positive

Table 8. Correlation between the elongation of the sealing seam before aging and two factors

X_{ij}	a_{ij}	Correlation with Y_1
X_{12} – Sealing temperature and Sealing speed	– 0.58	Negative
X_{23} – Sealing speed and Roller pressure	– 1.44	Negative
X_{13} – Sealing temperature and Roller pressure	+1.18	Positive

Relationship between the elongation of the sealing seam and sealing technology factors as sealing temperature (°C), sealing speed (m/min), and roller pressure (MPa), are presented through 3D graphs in Fig. 6, Fig. 7, and Fig. 8, respectively.

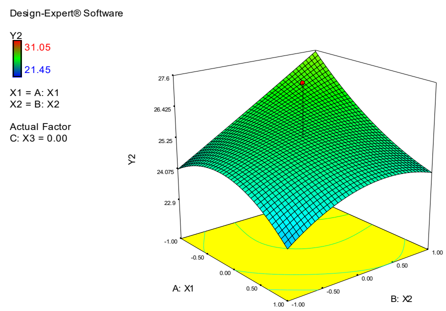

Fig. 6. The response of the elongation of the sealing seam before aging - Y_2 (%) at different levels of sealing temperature - X_1 (°C) and sealing speed - X_2 (m/min)

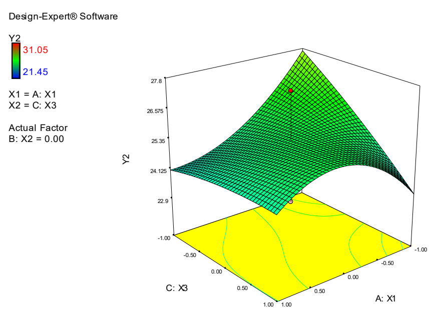

Fig. 7. The response to the elongation of the sealing seam before aging - Y_2 (%) at different levels of sealing temperature - X_1 (°C) and roller pressure - X_3 (MPa)

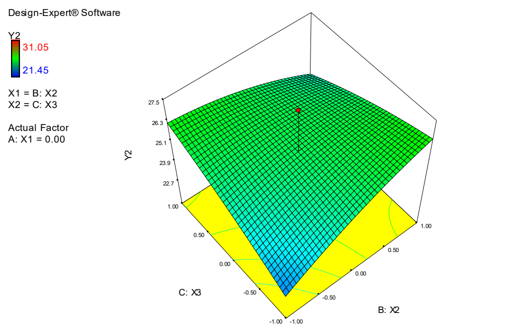

Fig. 8. The response of the elongation of the sealing seam before aging - Y_2 (%) at different levels of the sealing speed - X_2 (m/min) and roller pressure - X_3 (m/min)

3.2. The Influence of Sealing Technology Factors on the Quality of the Sealing Seam after Aging

3.2.1. The tensile strength of the sealing seam after aging

Mathematical models are presented in the following form:

$$Y_1 = 396.39 - 5.35x_1 + 2.08x_2 + 2.53x_3 - 9.88x_1x_2 + 21.50x_1x_3 + 2.37x_2x_3 - 12.79x_1^2 + 7.90x_2^2 - 13.23x_3^2 + 2.13x_1x_2x_3 + 2.79x_1^2x_2 + 20.47x_1^2x_3 + 8.85\,x_1x_2^2 \quad (4)$$

As seen from (4), the greatest absolute value of a_i is $|a_1|$ equal 5.35, which means that X_1 has the largest impact on the value of Y_1, corresponding to the value of temperature, which is the most important factor for the tensile strength of the sealing seam after aging.

Table 9 shows the influence of one factor (X_i) to the tensile strength of sealing seam after aging. The negative correlation between Y_1 and x_1 means when x_1 decreases, it leads to Y_2 decreasing. The positive correlation between Y_1 and x_2/x_3 means when x_2/x_3 increases, it leads to Y_1 increasing. Therefore, to enhance the tensile strength of seam after aging when modifying one factor, it is necessary to increase the value of sealing speed and roller pressure and reduce the value of temperature in sealing seam conditions.

From Table 10, the correlation between the tensile strength of sealing seam and the two factors was evaluated; the value aij was taken from (4). The correlation between roller pressure and sealing speed/sealing temperature is positive, which means the simultaneous increase or decrease of sealing temperature and roller pressure, or sealing speed and roller pressure, corresponds to the increase of the tensile strength of the sealing seam after aging. However, the increase in the tensile strength of the sealing seam after aging happens when the sealing speed increases, and simultaneously temperature is reduced or reversely.

Table 9. Correlation between the tensile strength of sealing seam after aging and three factors

X_i	a_1	Correlation with Y_1
X_1 – Sealing temperature	– 5.35	Negative
X_2 – Sealing speed	+ 2.08	Positive
X_3 – Roller pressure	+ 2.53	Positive

Table 10. Correlation between the tensile strength of sealing seam before aging and two factors

X_{ij}	a_{ij}	Correlation with Y_2
X_{12} – Sealing temperature and Sealing speed	– 9.88	Negative
X_{23} – Sealing speed and Roller pressure	+ 2.37	Positive
X_{13} – Temperature and Roller pressure	+ 21.50	Positive

Relationship between the tensile strength of sealing seam and sealing technology factors as sealing temperature (ºC), sealing speed (m/min), and roller pressure (MPa), are presented through 3D graphs in Fig. 9, Fig. 10, and Fig. 11, respectively.

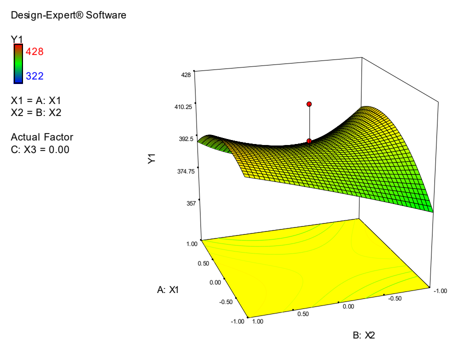

Fig. 9. The response of sealing seam tensile strength after aging Y_1 (N) at different levels of sealing temperature - X_1 (ºC) and Sealing speed - X_2 (m/min)

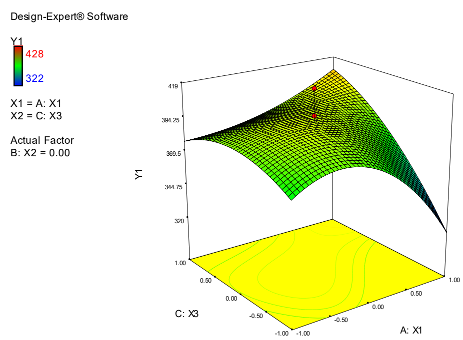

Fig. 10. The response of sealing seam tensile strength after aging Y_1 (N) at different levels of sealing temperature - X_1 (ºC) and roller pressure - X_3 (MPa)

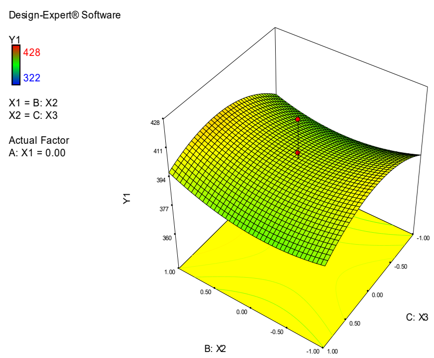

Fig. 11. The response of sealing seam tensile strength after aging - Y_1 (N) at different levels of sealing speed - X_2 (m/min) and roller pressure - X_3 (MPa)

3.2.2. The elongation of the sealing seam after aging

Mathematical models are presented in the following form:

$$Y_1 = 26.13 - 0.67x_1 + 0.18x_2 - 0.045x_3 - 0.92x_1x_2 + 1.82x_1x_3 + 0.21x_2x_3 - 0.79x_1^2 + 0.62x_2^2 - 1.10x_3^2 - 0.17x_1x_2x_3 - 0.047x_1^2x_2 + 0.81x_1^2x_3 + 0.39x_1x_2^2 \quad (5)$$

As seen from (5), the greatest absolute value of a_i is $|a_1|$ equal 0.67, which means that the value of sealing temperature is the most important factor for the elongation of the sealing seam after aging.

Table 11. Correlation between the elongation of the sealing seam after aging and three factors

X_i	a_i	Correlation with Y_2
X_1 – Sealing temperature	– 0.67	Negative
X_2 – Sealing speed	+ 0.18	Positive
X_3 – Roller pressure	– 0.045	Negative

Table 11 shows the influence of one factor (X_i) to the elongation of the sealing seam after aging. The negative correlation between Y_2 and x_1/x_3 means when x_1/x_3 goes up, it leads to Y_2 going down. The positive correlation between Y_2 and x_2 means when x_2 increases, it leads to Y_2 increasing. Therefore, to enhance the elongation of the sealing seam after aging, it is necessary to decrease the value of sealing temperature and roller pressure, and increase the value of sealing speed in the sealing seam conditions.

From Table 12, the correlation between the elongation of the sealing seam and two factors was evaluated; the value a_{ij} was taken from (5). The influence of two factors on the elongation of the sealing seam after aging is the same as the elongation of the sealing seam before aging.

Table 12. Correlation between the elongation of the sealing seam before aging and two factors

X_{ij}	a_{ij}	Correlation with Y_2
X_{12} – Sealing temperature and Sealing speed	– 0.92	Negative
X_{23} – Sealing speed and Roller pressure	+0.21	Positve
X_{13} – Sealing temperature and Roller pressure	+ 1.82	Positive

Relationship between the elongation of the sealing seam and sealing technology factors as sealing temperature (ºC), sealing speed (m/min), and roller pressure (MPa), are presented through 3D graphs in Fig. 12, Fig. 13, and Fig. 14, respectively.

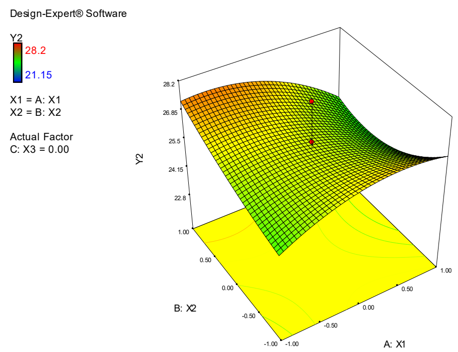

Fig. 12. The response of the elongation of sealing seam after aging - Y_2 (%) at different levels of sealing temperature - X_1 (ºC) and sealing speed - X_2 (m/min)

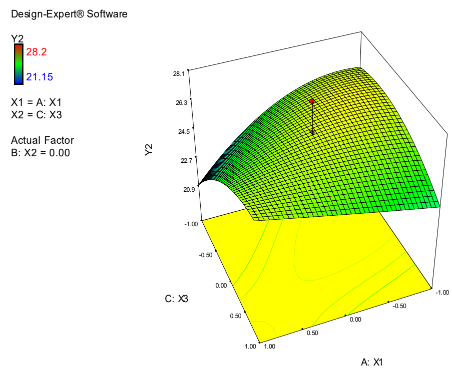

Fig. 13. The response of the elongation of sealing seam after aging - Y_2 (%) at different levels of sealing temperature - X_1 (ºC) and roller pressure - X_3 (MPa)

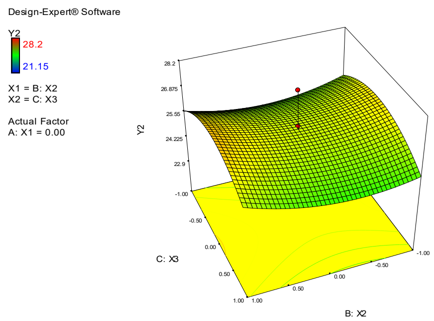

Fig. 14. The response of the elongation of sealing seam after aging - Y_2 (%) at different levels of Sealing speed - X_2 (m/min) and roller pressure - X_3 (m/min)

3.3. The influence of Sealing Technology Factors on the Appearance and Water-Proofness of Sealing Seam before and after Aging

Table 13 shows that:

- 12/17 experimental options achieved water-proofness both before and after aging.

- 9/17 experimental options had tensile strength post-aging greater than in pre-aging condition, which shows that the coated fabric and sealing tape have high quality due to good anti-aging ability, which is very suitable for actual usage conditions.

Table 13. The results of sealing seam appearance and water-proofness before and after aging

No	X_1 (°C)	X_2 (m/min)	X_3 (MPa)	Y_3	Y_4	Y_5
1	547	7	0.27	ok	ok	ok
2	683	7	0.27	ok	ok	ok
3	547	11	0.27	ok	ok	ok
4	683	11	0.27	ok	ok	ok
5	547	7	0.35	ok	ok	ok
6	683	7	0.35	ok	ok	ok
7	547	11	0.35	nok	nok	nok
8	683	11	0.35	ok	ok	ok
9	500	9	0.31	nok	nok	nok
10	730	9	0.31	ok	ok	ok
11	615	6	0.31	ok	ok	ok
12	615	12	0.31	ok	ok	ok
13	615	9	0.24	nok	nok	nok
14	615	9	0.38	ok	ok	ok
15	615	9	0.31	ok	nok	nok
16	615	9	0.31	nok	nok	nok
17	615	9	0.31	ok	nok	nok

3.4. Determining the Optimum Value of the Seal Technology Parameters

From the empirical regression equations expressing the influence of the three factors of sealing technology on the tensile strength and the elongation of the sealing seam on the studied waterproof fabric before and after aging, the optimization problem is solved using Design Expert software on the basis of the following:

- Harrington's multi-variable, single-objective optimization algorithm – Expected function method with acceptance range on both sides of the optimal point to be found.

- The optimal value of the sealing technology parameters found can be surveyed in the entire research domain of the variables.

- The optimal point must satisfy the objective function to achieve the largest value.

The real variable from was calculated as follows:

$$x_i = \frac{X_i - X_i^0}{\Delta X_i} \text{ with } \Delta \mathrm{X_i} = \frac{\overline{\mathrm{X_i}} - \underline{\mathrm{X_i}}}{2} \quad (6)$$

If

$$x_i = 1 \rightarrow X_i = \overline{X_i};\ x_i = 0 \rightarrow X_i = X_i^0;\ x_i = -1 \rightarrow X_i = \underline{X_i} \quad (7)$$

3.4.1. The optimal parameters for sealing seam before aging

Table 14 shows the solutions to optimize the parameters for sealing seam before aging.

Optimal value of variables x_1 = -1.00, x_2 = 1.00, and x_3 = -1.00 with the maximum value of tensile strength of sealing seam: Y_1 = 443.864 (N) and the maximum value of the elongation of sealing seam: Y_2 = 30.72 (%).

Therefore, the optimal parameters of sealing seam conditions for fabric before aging:

- Sealing temperature (X_1): 547 °C
- Sealing speed (X_2): 11 m/min
- Roller pressure (X_3): 0.27 MPa.

3.4.2. The optimal parameters for sealing seam after aging

Table 15 shows the solutions to optimize the parameters for sealing seams after aging.

Optimal values of variables are: x_1 = 1.00, x_2 = - 1.00, and x_3 = 1.00 with the maximum value of tensile strength of sealing seam: Y_1 = 426.77 (N) and the maximum value of the elongation of sealing seam: Y_2 = 27.91 (%).

Therefore, the optimal parameters of sealing seam conditions for fabric after aging are:

- Sealing temperature (X_1): 683 °C
- Sealing speed (X_2): 7 m/min
- Roller pressure (X_3): 0.35 MPa.

With the condition before aging - the realistic manufacturing condition, the actual operational parameters used by 19-5 One Member Limited Liability Company were a sealing temperature of 650 °C, a sealing speed of 7 m/min, and a roller pressure of 0.27 MPa. After optimization, the sealing temperature was reduced to 547 °C, while the sealing speed was increased to 11 m/min. However, the roller pressure remained unchanged. This adjustment led to improved performance, with a faster sealing speed enhancing overall efficiency and ensuring the quality of the seam sealing.

4. Conclusion

In summary, our experiments demonstrate that sealing temperature significantly impacts the tensile strength and the elongation of the sealing seam, both before and after aging. Optimal pre-aging sealing temperature was determined to be at 547 °C, sealing speed at 11 m/min, and roller pressure at 0.27 MPa. Post-aging, the optimal sealing temperature shifted to 683 °C, sealing speed at 7 m/min, and roller pressure at 0.35 MPa. Applying these parameters optimizes the tensile strength and the elongation of the sealing seam and ensures adequate water penetration resistance.

Table 14. Nine solutions to optimize the parameters for sealing seam before aging

No.	x_1	x_2	x_3	Y_1 (N)	Y_2 (%)	Desirability
1.	-1.00	1.00	-1.00	443.86	30.72	0.93
2.	-1.00	1.00	-0.96	442.48	30.61	0.92
3.	-1.00	1.00	-0.94	441.54	30.53	0.91
4.	0.14	-1.00	1.00	427.17	26.28	0.62
5.	0.12	-1.00	1.00	427.25	26.28	0.62
6.	0.15	-1.00	1.00	427.05	26.29	0.62
7.	0.10	-1.00	1.00	427.33	26.27	0.62
8.	0.18	-0.98	1.00	426.71	26.29	0.62
9.	0.22	-1.00	1.00	426.19	26.29	0.62

Table 15. Ten solutions to optimize the parameters for sealing seam after aging

No.	x_1	x_2	x_3	Y_1 (N)	Y_2 (%)	Desirability
1.	1.00	-1.00	1.00	426.77	27.91	0.97
2.	1.00	-1.00	0.96	426.17	27.89	0.97
3.	1.00	-0.98	1.00	426.18	27.86	0.96
4.	0.96	-1.00	1.00	425.18	27.81	0.95
5.	1.00	-0.95	0.99	424.82	27.76	0.95
6.	1.00	-1.00	0.61	419.56	27.62	0.91
7.	1.00	-1.00	0.58	418.79	27.58	0.91
8.	1.00	-0.81	1.00	420.94	27.43	0.91
9.	-0.57	1.00	-0.16	406.74	27.39	0.84
10.	-0.55	1.00	-0.14	406.85	27.38	0.84

References

[1] I. Padleckienė, D. Petrulis, V. Rubežienė, V. Valienė, A. Abraitienė, Breathability and resistance to water penetration of breathable-coated textiles after cyclic mechanical treatments, Materials Science (Medžiagotyra), vol. 15, no. 1, pp. 69–74, 2009.

[2] H. Zhang, Q. Zhai, Y. Cao, J. Hu, Q. Zhen, X. Qian, Design and facile manufacturing of tri-layer laminated polyolefin microfibrous fabrics with tailoring pore size for enhancing waterproof breathable performance, Materials & Design, vol. 228, Apr. 2023, Art. no. 111829. https://doi.org/10.1016/j.matdes.2023.111829

[3] T. T. Trang and P. T. Thao, Study on the optimal sealing technological regime for making sport wears from waterproof fabric, in Proceedings of the International Conference on Physics and Mechanics of New Materials and Their Applications, PHENMA 2019, Springer, Cham, 2020, pp. 141–156, 2020. https://doi.org/10.1007/978-3-030-45120-2_13

[4] P. T. Thao, Building data-sheet of amendment to correct the optimal sealing technological regime for making high quality garment products from waterproof fabrics in the tropical seasonal climate of Vietnam, in International Forum on Strategic Technology, IEEE, Oct. 13–15, 2010, Ulsan, Korea (South), 2010, pp. 111-115. https://doi.org/10.1109/IFOST.2010.5667901

[5] L. Vlad, M. Stan, and C. Buhai, The optimization of the assemblies applied to products made of waterproof fabrics, Tekstil ve Konfeksiyon, vol. 23, no. 2, pp. 273–279, 2013.

[6] S. Radhakrishnan and D. Kumari, Seams for protective clothing - an overview, World Journal of Textile Engineering and Technology, vol. 3, pp. 16–23, 2017.

[7] Standard TCVN 8833:2011 (ISO 1419:1995), Rubber or plastic coated fabrics - Accelerated ageing test, 2011.

[8] Bemis Associates, Thermoplastic adhesives coatings, Specialty Films & Seam Tape, 2025.

[9] Adhesive Films, Inc., Instruction Manual and Guide for Effective Waterproofing of Sewn Seams, 2005.

[10] Standard ISO 13935-2:2014, Textiles - seam tensile properties of fabrics and made-up textile articles, Part 2: Determination of maximum force to seam rupture using the grab method, 2014.

[11] N. Van Lan, Processing Statistical Data and Applied Examples in the Textile Industry, The Publishing House of Vietnam National University, Ho Chi Minh City, 2003. (In Vietnamese: Xử lý thống kê số liệu thực nghiệm và những ví dụ ứng dụng trong ngành dệt may, Nxb Đại học Quốc gia. TP. Hồ Chí Minh, 2003).