Analysis of Factors Influencing the Process of Thermo-mechanical Sticking in the Sewing Industry

Snezhina Angelova Andonova
South-West University "Neofit Rilski"
SWU
Blagoevgrad, Bulgaria
andonova_sn@abv.bg

***Abstract*—The process of thermo-mechanical sticking is one of the main technological processes in the sewing industry. The quality of the sewing product depends to a great extent on its precise realization. The goal of this paper is to analyze the significance of factors influencing optimization criteria in the thermo-mechanical sticking process and then to sort out factors of their degree of influence on optimization criteria, taking into account the modern ones conditions for analysis and research in the sewing industry. To achieve this goal we use a specialized method of analysis and evaluation - the method of the sorting experiment. Quality criteria and performance criteria are used as optimization criteria.**

Keywords—thermo-mechanical sticking; sewing companies

I. Introduction

The process of thermo-mechanical sticking (TMS) is one of the main technological processes in the sewing industry. The quality of the sewing product depends to a great extent on its precise realization.

In recent years in the garment industry are increasingly used new different types of textile materials. Each of the textile material (TM) has a different composition, structure and properties. They determine the different degree of influence of individual factors on one optimization criterion. For example, work at a number of sewing companies shows that the high hygroscopicity of wool textile materials is a reason for poor quality of the TMS process. On the other hand, the continuous development of natural science knowledge, measuring equipment and computerization of control systems greatly increase the reliability of control. Therefore, continuous updating of the research in the different fields of sewing production is necessary through the use of modern control and measuring equipment. For example, in some studies of the TMS process, the temperature of the TM is reported with a thermal paper [1]. The creation of various computer-integrated measuring systems enables continuous temperature reading at different points of processed textile materials.

In the context of the above, the goal of this paper is to analyze the significance of factors influencing optimization criteria in the TMS process and then to sort out factors of their degree of influence on optimization criteria, taking into account modern ones conditions for analysis and research in the sewing industry. To achieve this goal we use a specialized method of analysis and evaluation - the method of the sorting experiment (the sifting experiment).

Many scientific studies seek to reduce the number of controllable factors [2, 3] and optimization criteria [4] in mathematical modeling of different processes.

The survey results in this work will make it possible to reduce the number of controllable factors in conducting a multifactor experiment for mathematical modeling of the thermo-mechanical sticking process.

II. Discussion and Analysis

A. *Conditions to Execute the Experiment*

In order to achieve the main objective, it is necessary to first determine the basic criteria for optimization of the thermo-mechanical sticking process. The criteria for quality of this process in scientific works [5] are the shrinkage after TMS and the degree of color shade change. Time is used as a criterion for process performance [5]. Principles of the morphological method for analysis and synthesis [6] are applied in formulating and synthesizing the factors that influence above optimization criteria.

The subject of investigation in the present work is the process of thermo-mechanical sticking with an electric press. The main part of the process takes place when the pressing cushions are closed. The practical implementation of the process is related to the transfer of heat and mass. In this sense, it can be summarized that the process of thermo-mechanical sticking with an electric press is complex, insufficiently studied and represents a black box. For this reason, it is appropriate to apply mathematical methods of analysis and evaluation [7, 8]. In this work, the statistical method of the sifting experiment is used in the selection of significant controllable factors.

Following a review of the literature and analysis of the nature of the thermo-mechanical sticking process, this paper proposes 15 generalized factors that influence the criteria for optimization of this process. These factors are given in Table 1.

TABLE I. INQUIRY CARD

Code of the Factor	**Factors that Influence the Process Optimization Criteria of Thermo-mechanical Sticking**
X_1	The temperature between the basic and the subjected textile material
X_2	The temperature between the bottom cushion of the press and the basic textile material
X_3	The temperature difference measured between the temperature below the upper cushion and the temperature between the basic and the subjected textile material
X_4	The temperature difference measured between the temperature between the basic and the subjected textile material and the temperature between the lower pillow and the basic textile material
X_5	The pressure between press cushions
X_6	The absorbed moisture from textile materials prior to the thermo-mechanical sticking process
X_7	A composition of the basic textile material
X_8	A composition of the subjected textile material
X_9	A structure of the basic textile material
X_{10}	A structure of the subjected textile material
X_{11}	A surface mass of the basic textile material
X_{12}	A surface mass of the subjected textile material
X_{13}	A method of application of the polymeric binder on the subjected textile material
X_{14}	The amount of polymer binder applied per unit area
X_{15}	The melting point of the polymer binder

With the development of science and technology, tools for measuring and controlling various controllable factors of the process are developing.

This makes it possible to more accurately monitor the technology of a thermo-mechanical sticking. For example, in some scientific studies [1], the temperature of textile materials in the thermo-mechanical sticking is reported with thermal paper. This allows only the maximum temperature reached by textile materials to be taken into account. With the development of the technique, many other means have been created to measure the temperature of textile materials during the thermo-mechanical sticking process. For example, work [9] proposes a computer-integrated measurement system for temperature measurement during the damp-heating processing. This system can also find an extremely good application in the measurement of temperature during the thermo-mechanical sticking process. This will create conditions to monitor the temperature change at different points of processed textile materials throughout the technological process. There will be continuous feedback on the sticking material between two closed press countertops. This is a prerequisite for exploring many more manageable factors. For example, the study of the temperature change between the basic and the subjected textile material over the whole process will allow to clarify its technological nature. Therefore, the temperature between the basic and the subjected textile material is chosen as one of the manageable factors influencing criteria for optimization of the thermo-mechanical sticking process (factor X_1 in Table I).

As another factor is selected the temperature between the bottom cushion of the press and the basic textile material (factor X_2 in Table I).

It is also appropriate to investigate the temperature difference measured between:

- the temperature below the upper cushion and the temperature between the basic and the subjected textile material (factor X_3 in Table I);
- the temperature between the basic and the subjected textile material and the temperature between the lower pillow and the basic textile material (factor X_4 in Table I).

Another important controllable factor for the thermo-mechanical sticking process is the pressure between the press cushions (factor X_5 in Table I).

From the experience gained in conducting experiments in this field, it has been found that the more hygroscopic the Textile material is, the easier it is to absorb moisture from the environment. The content of additional moisture in textile materials necessitates an increase in temperature in order to evaporate the additional moisture, and then the actual thermo-mechanical sticking takes place. Therefore, the absorbed moisture from textile materials prior to the thermo-mechanical sticking process is indicated in Table I as a factor X_6.

In recent years, more and more diverse textile materials have come in [10]. Each has a different composition, structure and surface mass. In this connection, the factors X_7 to X_{12} in Table I are also selected.

High technology also enters the process of applying the polymer binder to the subjected textile material. Therefore, it is important to investigate the impact of factors as well:

- method of application of the polymeric binder on the subjected textile material (factor X_{13} in Table I);
- the amount of polymer binder applied per unit area (factor X_{14} in Table I);
- the melting point of the polymer binder (factor X_{15} in Table I).

The impact of some of the above factors has been the subject of various studies. In this case, however, it is important to arrange them according to their influence on optimization criteria.

To this end, 10 sewing industry experts or university educators complete a special inquiry card. Each expert classifies individual factors according to their degree of influence on the thermo-mechanical sticking process optimization criteria. The limitation set is that by filling in the inquiry card there should not be equal evaluations of different factors.

B. *Experimental results*

Ratings of each expert are completed in a rank matrix. Results obtained are completed in a table in the form of Table II.

After processing estimates given by each expert, overall estimates for each factor are obtained.

Summary results obtained for the level of each factor are given in Table III.

The information was evaluated by using Kendall's informational and statistical methods that deal with the grade of concordance in ranking completed by more than two experts and by using a large number of factors [3. 11].

C. *Discussion of experimental results*

Define for this purpose, should define Kendal's quotient of concordance:

$$W = \frac{12\sum_{i=1}^{n}\left(C_i - \overline{C}\right)^2}{k^2 n\left(n^2 - 1\right)} \qquad (1)$$

After the calculations are made, the value of the Kendal's quotient of concordance given in (2) is obtained.

$$W = 1,1679 \qquad (2)$$

To calculate it we should define the sum of each factor evaluated:

$$C_i = \sum_{j=1}^{k} x_{ij} \qquad (3)$$

where: k – number of experts; n – number of factors to be ranked; Xij – ranking evaluation; i – factor and by j-th expert.

TABLE II. RANKING MATRIX

experts	Factors				
	1	**…**	***i***	**…**	***n=15***
1	$X_{1,1}$	…	$X_{i,1}$	…	$X_{15,1}$
2	$X_{1,2}$	..	$X_{i,2}$	…	$X_{15,2}$
…	…	…	…	…	…
j	$X_{1,j}$	…	$X_{i,j}$	…	$X_{15,j}$
…	…	…	…	…	…
K=10	$X_{1,k}$	…	$X_{i,k}$	…	$X_{15,k}$

TABLE III. SUM OF EVALUATIONS

Factor	**Sum of evaluations, C_i**
X_1	158
X_2	122
X_3	109
X_4	99
X_5	154
X_6	42
X_7	146
X_8	56
X_9	87
X_{10}	33
X_{11}	23
X_{12}	14
X_{13}	78
X_{14}	66
X_{15}	131

For the statistical analysis of W [3, 11, 12], Pearson's criterion, as given in (4), is used.

$$\chi_R^2 = k(n-1)W \qquad (4)$$

χ_T^2 is stated by means of statistical tables.

$$\chi_T^2 = f\left\{\begin{matrix} f = n-1 \\ P = 0,95 \end{matrix}\right\} \qquad (5)$$

where: f – grade of freedom ; P – trustful probability.

$$\chi_R^2 \triangleright \chi_T^2 \qquad (163,5 \triangleright 23,685) \qquad (6)$$

Therefore the hypothesis of the statistical significance of the Quotient of Concordance is proven.

III. CONCLUSION

A sorting experiment (sifting experiment) was conducted to rank the controllable factors according to their degree of influence on the thermo-mechanical sticking process optimization criteria.

Factors are ranked in accordance to their significance, as shown in Table III.

The factors whose influence on the process optimization criteria for thermo-mechanical sticking are most significant have been identified. These are the factors X_1 – the temperature between the basic and the subjected textile material, X_5 – the pressure between the press cushions, X_7 – the composition of the basic textile material.

Obtained results make it possible to reduce the number of controlled factors when conducting a multifactor experiment for mathematical modeling of the process of thermo-mechanical sticking with an electric press.

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