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Mathematical approach to sifting significant technological factors into the sewing industry

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The paper deals with damp–heating processing (DHP) in sewing industries. DHP is essential for the quality and productivity in clothing manufacture. This is a complex process where heat and mass transfer in ironing is realized through applying a plurality of physical processes like convection, radiation and diffusion. Their joint impact on DHP with steam-presses is not sufficiently examined. From this point of view, we can conclude that our subject should be thoroughly studied, as there is not enough research conducted. Therefore, statistical methods of analysis and assessment should be applied. The goal of this paper is to investigate the importance of factors influencing the quality criteria (the compressibility of textile materials after ironing with a steam-press), then to select the most significant factors, and finally to sort out factors by their degree of influence on the quality criterion. To achieve these goals we make use of a specialized statistical method - the method of classifying correlation.

Keywords: sewing industries, statistical methods, quality

INTRODUCTION

Damp – heating processing (DHP) is essential for the quality and productivity in clothing manufacture in sewing industries. This process is a complex process where heat and mass transfer in ironing is realized through applying a plurality of physical processes like convection, radiation and diffusion [1, 2]. Their joint impact on DHP in steam-presses is not sufficiently examined. From this point of view, we can conclude that our subject should be thoroughly studied, as there is not enough research conducted. Therefore, statistical methods of analysis and assessment should be applied [3-7].

The goal of this paper is to investigate the importance of factors influencing the quality criteria, then to select the most significant factors, and finally to sort out factors of their degree of influence on the optimization criteria. To achieve these goals we make use of a specialized statistical method - the method of classifying correlation.

Numerous scientific papers seek to reduce the number of manageable factors [8-10] and optimization criteria [11] in mathematical modelling of different processes.

The survey results in this study will make it possible to reduce the number of controlled factors in conducting a multifactor expertise for the mathematical modelling of the DHP.

Referring to the context above, it is important to choose the basic optimization criteria. In other papers when examining the DHP process as criteria for optimization [2, 10, 11] what is used is time (as a performance criterion) and degree of luster after DHP (as a quality criterion). In the recent years new different types of textile materials are increasingly used in the garment industry. Each textile material (TM) has different composition, structure and properties. They determine the different degree of compressibility of textile materials after the DHP. Therefore, the compressibility of the materials after the DHP is of particular interest as a quality criterion.

In our country no research has been conducted in mathematical modelling and optimizing the DHP process with a quality criterion - the compressibility of textile materials after DHP.

The results of the studies conducted in this field abroad are mainly commercial or confidential information.

Therefore, as a criterion for optimization after the DHP in the present article we will use the quality criterion - compressibility after the DHP.

EXPERIMENTAL

Following the analysis of the essence and technological features of the DHP process [1, 2, 10-13] 15 factors were proposed which influence the compressibility of textile materials after a DHP with a steam press. When formulating and synthesizing these factors the principles of the morphological method of analysis and synthesis should be applied [14, 15]. These factors are given in Table 1. The significance of all above listed factors and their influence on DHP is investigated in numerous publications. Correlation has been studied between time and temperature in DHP ofcotton textiles, as well as the correlation between the ironing surface and the composition of

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processed materials [10]. Also, a correlation has been examined between continuance of DHP and the number of processed layers [2].

Table 1. Inquiry card

Code of the factor	Factors which influence DHP and the compressibility of TM after ironing with a steam-press
X_1	Composition of the textile material
X_2	Mass per unit area of treated textile materials
X_3	Structure of processed textile materials / type of weave /
X_4	Linear density of warp threads and weft threads
X_5	Elasticity of warp and weft threads
X_6	Pressure
X_7	Temperature of steam
X_8	Amount of steam supplied to ironing pillows
X_9	Temperature of processed textiles
X_{10}	Continuance of the 1st stage – preparing the textiles to be molding
X_{11}	Continuance of the 2nd stage – molding up the textiles
X_{12}	Continuance of the 3rd stage – Part 1: Fixing the final shape - Drying
X_{13}	Continuance of the 3rd stage – Part 2: Fixing the final shape - Cooling
X_{14}	Number of layers
X_{15}	Correlation between ironing surface area and processed details' surface area

In terms of the compressibility of textile materials it is important to consider their composition. This is the reason why the composition of textile materials was chosen as factor X_1. The wide variety of textile materials and the emergence of more and more new ones require continuous experimentation to determine the nature of the compressibility of TM after ironing with a steam-press. For example, a tissue - a multilayer weave type "double cloth" [13] has increasingly been used in the sewing industry recently and this motivates the choice of factor X_3. The structure of processed textile materials / type of weave / was selected as factor X_3. In connection with the compressibility of textile materials, it is also important to consider the elasticity of textile materials. The boundary elastic values are graphically determined on experimental rheograms from dynamometric investigations [12, 13]. According to Hooke's law, at very low loads, there is proportionality between normal voltage and full relative elongation. Tear strength and yarn stretching is an important factor determining the quality criterion - compressibility after the DHP. Therefore, as factor X_5 elasticity of warp and weft threads was selected. Overall, the importance of the above factors was the subject of research. The problem was how to rank them in accordance to their influence on the criterion of "Quality".

For this purpose, we made use of the inquiry card which was filled in by 12 specialists in the sewing industry and lecturers at universities. The ranking closely matches the factors' significance. The only limitation set was that by filling in the inquiry card there should not be equal evaluations of the different factors.

EXPERIMENTAL RESULTS

A sample of results is shown in a matrix (table 2).

Table 2. Ranking matrix

Factor / Expert	1	2	...	i	…	N=15
1	$X_{11}=15$	$X_{21}=10$	…	$X_{i1}=X_{81}=14$	…	$X_{15\,1}=11$
2	$X_{12}=14$	$X_{22}=9$	...	$X_{i2}=X_{82}=15$	…	$X_{15\,2}=10$
…	…	…	…	…	…	…
j	$X_{1j}=X_{18}=15$	$X_{2j}=X_{28}=10$	…	$X_{ij}=X_{88}=13$	…	$X_{15\,j}=X_{15\,8}=11$
…	…	…	…	…	…	…
K=12	$X_{1k}=15$	$X_{2k}=11$	…	$X_{ik}=X_{8k}=13$	…	$X_{15\,k}=10$

The information was evaluated by using Kendall's informational and statistical methods that deal with the grade of concordance in ranking, conducted by more than two experts and by using a large number of factors [16]. For this purpose, we should first define Kendal's quotient of concordance:

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

$$W = 0{,}97561 \quad (2)$$

To calculate it we should define the sum of all factors evaluated:

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

where: k – number of experts; n – number of factors to be ranked; Xij - ranking evaluation; i-factor and j-th expert (table 2).

The average evaluation sum is defined by (4).

$$\overline{C} = \frac{\sum_{i=1}^{n} C_i}{n} \quad (4)$$

The value of each factor is stated in table 3.

Table 3. Sum of evaluations

Factor	Sum of evaluations C_i
X_1	175
X_2	119
X_3	141
X_4	87
X_5	94
X_6	160
X_7	112
X_8	167
X_9	52
X_{10}	17
X_{11}	26
X_{12}	29
X_{13}	56
X_{14}	73
X_{15}	133

The method for a statistical analysis of the quotient W was chosen in accordance with the values "n" and "k".

Subsequently, in our case it would be appropriate to use Pearson's Chi-Squared test for a statistical analysis of W [3, 4, 8, 17] calculated in accordance with (5).

$$\chi_R^2 = k(n-1)W \quad (5)$$

χ_T^2 is stated by means of statistical tables.

$$\chi_T^2 = f\begin{Bmatrix} f = n-1 \\ P = 0{,}95 \end{Bmatrix} \quad (6)$$

where: f - degree of freedom; P - confidence probability.

χ_R^2 and χ_T^2 are compared, and for the case:

$$\chi_R^2 > \chi_T^2 \quad (163.90389>23.685 \quad (7)$$

Therefore, the hypothesis of the statistical significance of the Quotient of Concordance is proven with a confidence probability P = 0.95.

This means that the experts' evaluations match with a confidence probability = 0.95.

CONCLUSION

A screening experiment was conducted to rank factors according to their degree of influence on the criterion of quality /the compressibility of textile materials/ after DHP.

These factors were ranked in accordance to their importance, as shown in Fig. 1.

Factors that significantly affect the compressibility of TM after DHP with a steam-press are determined: X_1 - composition of the textile material; X_6 – pressure; X_8 - amount of steam supplied to ironing pillows.

Results show that it is reasonable to reduce the number of controlled factors for the multifactor experiment in order for the DHP to be modelled mathematically.

Considering all of the above, we chose factors X_1, X_6, and X_8 for mathematical modelling of DHP with a quality criterion - the compressibility of textile materials.

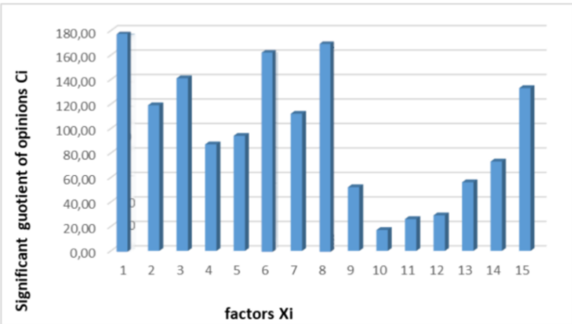

Fig.1. A histogram of experts' opinions.

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