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Determining the deformation properties of jacquard single jersey for pattern designing dresses, by the percentage of Elastane in the yarn

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Abstract. The article presents a method for determining for deformation properties of knitted fabrics in the process of pattern making of women's outerwear, by the percentage of elastomeric threads in their composition. To develop the method, a study of the deformation properties of a group of jacquard single jersey fabrics was performed, depending on their content of elastomeric threads. A model for their determination in the process of clothing design pattern through reduction factors is proposed. The dependence on the reduction factors and the percentage of elastomeric threads in the composition of the knitted fabrics was studied. Strong statistically significant dependences were found. Using the method of linear regression, mathematical models have been developed, by which the reduction factor is determined on the basis of the percentage of elastomeric threads in the knitted fabrics. The obtained results are applied to improve the methodology for pattern designing women's dresses.

1. Introduction

A major point in the production of knitted garments is the determination of the exact pattern design parameters of the details of the clothing. They depend on the deformation properties of the knitted fabrics, which change as a result of the type of knit and yarn. In recent years, there has been a trend of increasing the comfort of clothing by using elastomeric threads in the yarn of knitted fabrics [1]. This fact is an additional factor for changing the deformation properties of knitted fabrics. There is a need to study the properties of knitted fabrics with elastic threads and look for a depending between their deformation properties and the percentage of elastomeric threads in the knitted fabrics. It was found in the study that the most appropriate method for determining the deformation properties of knitted fabrics in the process of constructing women's dresses is through a reduction factors [2]. To determine the reduction factors, laboratory tests must be performed on each material, which increases the costs of manufacturers and prolongs the process of designing knitwear.

The aim of the research is to develop a method for taking into account the deformation properties of knitted fabrics, influencing the pattern design parameters of women's dresses through the percentage of elastomeric threads in the knitted fabric.

2.Materials and methods

2.1.Materials

The object of study are a group of jacquard single jersey fabrics with similar yarn composition, differing elastomeric thread content. The choice of knits is made by analyzing the main characteristics of 687 articles, including 1956 patterns which were presented on the European market in the period from 2016 to 2020. It was found that jacquard single jersey knits are the most used stitch structures -36.6% of the total number of items. During the analysed period, knitted fabrics for women's dresses were produced with a content of elastomeric threads from 1% to 9%, as 86.7% of them were in the range from 2% to 6%. Due to their high aesthetic qualities, jacquard single jersey are suitable for the production of women's dresses, which were found in research and analysis of fashion collections of world-famous designers from the past 5 years, to be an item with an increasing amount of use and distribution. [3].

2.2. Methods

A T-shaped test stand was used to determine the deformation properties of the fabrics. Out of every type of fabric have been cut out 5 samples with size 200mm by 50mm. One end of the sample is folded. The fold is sewn 10 mm from its end with stitch type 401. A gap of 8mm length is cut out at the center of the fold. A section of length 100mm is marked at 1cm over the stich of the fold, in the middle of the sample. At the middle of the marked section, perpendicular to it is marked a section of length 40mm. The samples are left on a horizontal surface for 30 min. Before carrying out the tests all samples are condition for 4 hours in an atmosphere of 20 ± 2˚C with relative moisture 65±4%RH.

The sample is fixed onto the stand. The fixing dowel is pushed through the stitched part of the sample and the weight is applied. The samples are stretched for a duration of 60 seconds. The lengths of the marked sections are measured. The samples are taken down from the stand and placed on a horizontal surface for 60s. The marked sections are then measured again. The stretch and the residual deformation are measured according to the following formulae:

$$\varepsilon = \frac{L_1 - L_0}{L_0} . 100 [\%] \tag{1}$$

$$\varepsilon_r = \frac{L_2 - L_0}{L_0} . 100 [\%] \tag{2}$$

where:
L_0 - the initial size of the sample; L_1 – the length during the loading, L_2- the length after the 60 seconds of relaxation, ε – the relative stretch, $\varepsilon_{у.д}$ – residual deformation.

3. Determining the deformation properties of the fabrics

Ten jacquards single jersey articles have been studied, divided into 5 groups based on their percentage content of elastomeric threads. Each group contains two samples marked as sample 1 and sample 2. The main characteristics of the studied knitted fabrics are shown in table 1.

Table 1. Main characteristics of jacquards single jersey fabrics.

Group №	Sample №	Article	Fabric weight [g/m^2]	Yarn content - [%]
I (2%El)	S 1	Ginny4Col2	231,25	Viscose 73%, Polyester 25%, Elastane 2%
	S 2	Kortina	210,00	Viscose 66%, Polyester 32%, Elastane2%
II (3%EL)	S 1	Mestre	314,81	Viscose 68%, Polyester 29%, Elastane 3%
	S 2	Beatrix	295,00	Viscose 63%, Polyester 34%, Elastane 3%
III (4%EL)	S1	Mayer	276,00	Viscose 69%, Polyester 27%, Elastane 4%
	S 2	Marley	257,14	Viscose 63%, Polyester 33%, Elastane 4%
IV (5%EL)	S 1	Giarion	295,00,	Viscose 65%, Polyester 30%, Elastane 5%
	S 2	Ginny 2	260,13	Viscose 61%, Polyester 34%, Elastane 5%
V (6%EL)	S 1	GinnyLux2	215,15	Viscose 62%, Polyester 32%, Elastane 6%
	S 2	Aroma3	203,00	Viscose 73%, Polyester 21%, Elastane 6%

3.1. Analysis of the results
The study results are organized according to the stretch and residual deformation along each direction – along the course, wale and bias (45˚). The average values are presented in table 2.

Table 2. Average values of stretch and residual deformation.

Elastomeric thread content - [%]	Stretch along the specific direction - [%]			Residual deformation along the specific direction - [%]		
	Course - $\overline{x}$	Wale - $\overline{x}$	Bias 45˚- $\overline{x}$	Course- $\overline{x}$	Wale - $\overline{x}$	Bias 45˚- $\overline{x}$
2%EL	25,1	20,1	30,1	1,0	0,4	0,6
3%EL	31,4	26,4	36,4	1,5	1,7	0,4
4%EL	36,4	31,4	41,2	1,9	1,4	1,7
5%EL	39,9	35,3	45,2	1,0	1,0	0,9
6%EL	45,2	40,7	50,5	0,2	0,5	0,6

The results show that these types of knitted fabrics have the biggest stretch along the bias (45˚), followed by along the course and wale. The residual deformation is not considered as a part of the pattern design parameters as its value is less than 2% for each sample [1, 4]. Therefore, stretch is the property that will be used to determine the deformation of the studied group of fabrics. A graphical analysis is performed in order to examine its relation to the percentage content of elastomeric threads in the knitted fabric – figure 1.
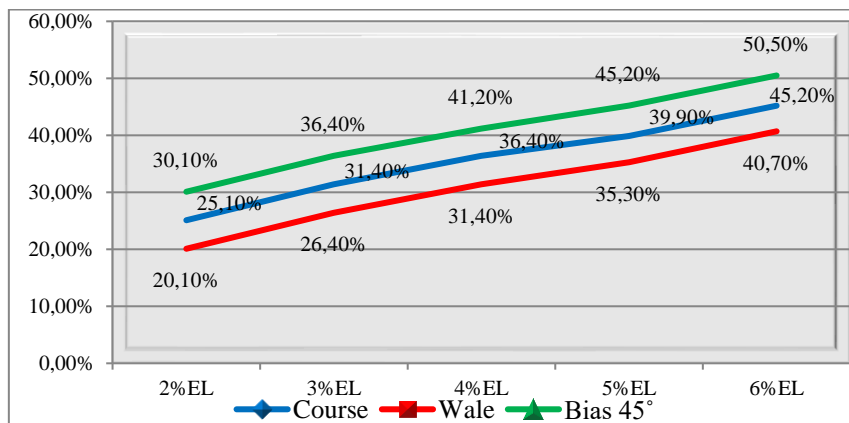
Figure 1. Correlation between stretch and content of elastomeric threads [%].

The analysis shows a linear correlation between the two variables. Correlational analysis is performed to determine the strength of the correlation. The statistical analysis was performed using the Statistica 7.0 software. Statistical significance is achieved when the value of the result p is less than 0.05.

3.2. Determining the strength of the correlation between the stretch and percentage content of elastomeric threads of knitted fabrics
The Pearson coefficient $-r_{xy}$ is used to determine the strength of relationship between the two variables. The statistical significance is tested with n-2 degrees of freedom and the statistical significance α =0.05. The correlation coefficients and analysis of the statistical significance are presented in table 3.

Table 3. Analysis of the correlation coefficients between the stretch and elastomeric thread content [%].

Stretch	r_{xy}	r^2	k^2	t_R	t_T	$t_R > t_T$
Along the course -%	0,98	96,04	3,96	33,96	2,011	33,96>2.011
Along the wale - %	0,98	96,04	3,96	33,96	2,011	33,96>2.011
Along the bias 45˚ - %	0,98	96,04	3,96	33,96	2,011	33,96>2.011

Note: *The critical value of the Pearson coefficient with n=50 and* α=0.05 *equals 0.27.*
were:r_{xy}- Pearson coefficient;r^2- coefficient of determination; k^2- undetermined coefficient.

The correlation between the variables is high according to Cohen's d. [5]

4. Stretch reduction factors used to determine the stretch of knitted fabrics as part of the design as part of the pattern design parameters
During clothing construction, the reduction factor helps determine the deformation properties of the material and to establish the connection between the human body and the clothing by ensuring high aesthetics, good fit and comfort. This can be accomplished by using ease [6,7].

4.1. Stretch reduction factor
A specific percentage of the available stretch is needed in determining the value of the correction coefficient for pattern making. Analyzing the pattern making methodologies for women's knitted fabrics outerwear show that some of the scientists [8,9,10] use 100% of it. Others [11, 12] use specific values: 20% for transverse measurements and 20%-25% for the longitudinal. I-Chin Tsai follows a rule [4]

according to which stretch should not be higher that what makes its residual deformation not higher than 5% [1]. The high recovery ability of knitted fabrics makes this method inapplicable. P. Watkins reduces the value of laboratory extensibility in a reduction factor, for this purpose introduces the terms - TRF (Tension release factor) and AR (axis ratio) [12]. Based on the studied marches, it was decided to reduce the laboratory-determined extensibility by the values of the minimum required allowance for freedom of dynamics. According to Myazina, the stretch of the clothing in the area of the shoulders is from 13 to 16%, along the knees 35 - 45%, and on the thighs 25 - 30% [13]. Other scientists have found that in some areas clothing stretches from 20 to 22% [14]. This corresponds to 35-40% laboratory established stretch of the fabrics. The differences in the values of the laboratory established and the stretch of the knitted fabric in the sewn garment are due to the fact that when worn the garment is subjected to a load of 0.5 to 3N. [14] Kartseva found that with increasing residual deformation of knitted fabrics, their deformation increases when wearing clothes from them. According to the results of her research, casual wear made of knitted fabric with an extensibility of up to 40% is stretched to 35%, and fabrics with a higher initial stretch - up to 55% [15].

Based on the analysis of the studies, coefficients of reduction of extensibility are determined, in which the following will be taken into account: the minimum necessary garment ease to ensure vital functions of the human body with a value of 4.1 cm, which corresponds to 5% stretching while wearing clothing; the dynamic (wearing) ease, which is the stretch while wearing the garment of 35-55%.

Values of the stretch factor are: along the course -60%q along the wale- 50%; along the bias 45˚- 60%. The stretch reduction factor value will be calculated according to the equations:

$$K_{srf}^{c} = \frac{\varepsilon}{100} . K_{sf}^{c} . \tag{3}$$

$$K_{srf}^{w} = \frac{\varepsilon}{100} . K_{Sf}^{w} \tag{4}$$

$$K_{srf}^{b45°} = \frac{\varepsilon}{100} . K_{sf}^{b45°} . \tag{5}$$

where:

K_{srf}^{c} , K_{srf}^{w} , $K_{srf}^{b45°}$ - stretch reduction factor along the course, along the wale and along the bias 45˚;

K_{sf}^{c} , K_{sf}^{w} , $K_{sf}^{b45°}$ - – stretch factor along the course, along the wale and along the bias 45˚

4.2. Determining the value of the correction coefficients of the garment construction parameters

Determining the values of coefficients with which the garment construction parameters will be adjusted goes through the following stages:

1. Determination of the fabric deformation - according to equation 1.
2. Determining the stretch factor value of the stretch of the fabric along the course, along the wale and along the bias 45˚- according to equations 5, 6, 7.
3. Determination the reduction factors value of stretch in garment construction parameters.

Each point of the main structure changes its parameters after determining value the stretch of the fabric according to the following equations:

$$x_n = x_i\left(1 - K_{srf}^{c} \right) \tag{6}$$

$$y_n = y_i\left(1 + K_{srf}^{w}\right) \tag{7}$$

$$z_n = z_i\left(1 - K_{srf}^{b45°}\right) \tag{8}$$

where:

x_i, y_i and z_i are the coordinates of the i - th point of the contour of the part without taking into account the deformation properties of the fabric

Therefore, the value by which each point of the structure changes its initial position can be defined as a reduction factor. Its values depending on the extensibility in course, wale and bias 45˚are determined by the equations ((9)), ((10)), ((11)):

$$K_R^c = \left(1 - K_{srf}^c\right) \tag{9}$$
$$K_R^w = \left(1 + K_{srf}^w\right) \tag{10}$$
$$K_R^{b45°} = \left(1 - K_{srf}^{b45°}\right) \tag{11}$$

where:

K_R^c , K_R^w , $K_R^{b45°}$ - reduction factors along the specific direction.

5. Research on the relation between the percentages of elastomeric treads of the jacquard single jersey fabrics and the reduction factors

It was found that there is a strong correlation between the stretch and the percentage of elastomeric threads in the composition of the studied group of knitted fabrics. The existence of a causal relationship between the extensibility and the correction factors gives reason to assume that there is a similar relationship between them and the percentage of elastomers. Based on the empirical data, correlation coefficients were calculated according to equations 10, 11, 12. Their average values are presented in table 4.

Table 4. Average values of reduction factors.

Reduction factors	Elastane content in the fabric[%] [%]				
	2%	3%	4%	5%	6%
Along the course - $\bar{x}$	0,9	0,87	0,85	0,84	0,82
Along the wale - $\bar{y}$	1,08	1,11	1,13	1,14	1,16
Along the bias 45° - $\bar{z}$	0,88	0,85	0,84	0,81	0,8

A graphical analysis of the type of dependence and the distribution of empirical data was made. Presented in Figures 2, 4 and 6 histograms prove the normal distribution of the studied quantities and the scatter plots (Figures 3, 5, and 7) - the presence of linear correlation. The values of the Pearson correlation coefficient (r_{xy}.) are determined at a significance level of 0.05. The results obtained for the relationship between the percentage of elastomeric threads and reduction factors are: along the course - $r_{xy} = -0,98$; along the wale - $r_{xy} = 0,98$ and along the bias 45° - $r_{xy} = -0,98$. The coefficient of determination and uncertainty shows that 96.04% of the changes in the stability of the reduction factors are prolonged by a change in the percentage of elastomeric threads in the composition of knitted fabrics, and remain 3.96% in factors not included in the analysis. The test of the statistical significance of the correlation information is defined as large, depending on the Cohen scale.
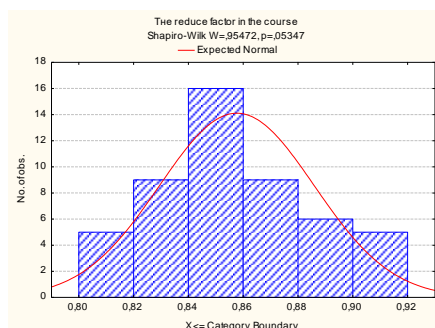

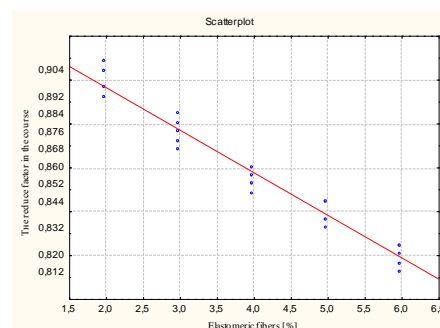**Figure 2.** Histogram of the distribution of the reduction factor along the course.

Figure 3. Correlation between the content [%] of the elastomeric threads and the reduction factor along the course.
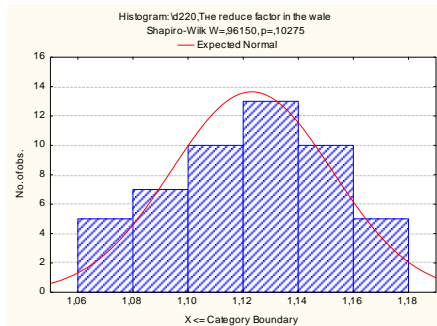
Figure 4. Histogram of the distribution of the reduction factor along the wale.
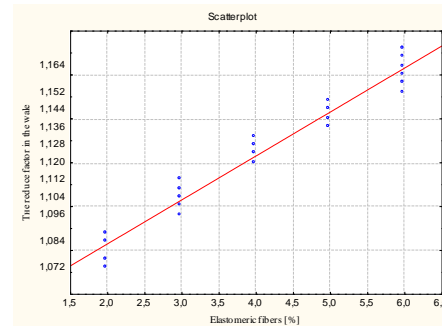

Figure 5. Correlation between the content [%] of the elastomeric threads and the reduction factor along the course.
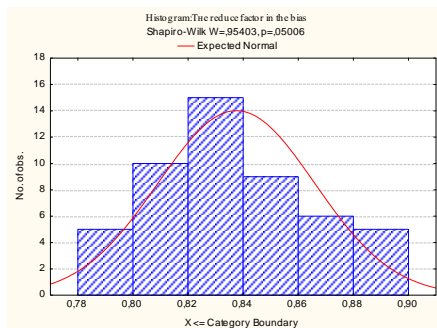

Figure 6. Histogram of the distribution of the reduction factor along the bias (45˚).
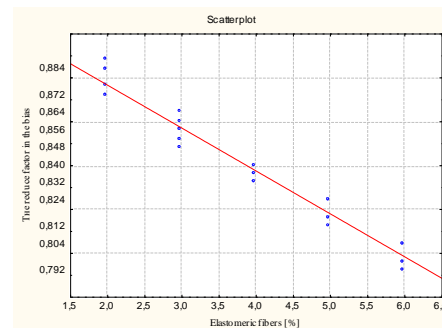

Figure 7. Correlation between the content [%] of the elastomeric threads and the reduction factor along the bias (45˚).

5.1. Mathematical model of the correlation between the content [%] of the elastomeric threads of the studied fabrics and the reduction factors

A linear regression model is proposed for analytical presentation of the studied correlation between the reduction factors and the percentage content of elastomeric threads in the studied knitted fabrics. The reduction factor along a specific direction is chosen as the dependent variable and as an independent variable – the percentage content of elastomeric threads.

The linear regression model is as follows:

Regression model:

$$K_R^i = \beta_0 + \beta_1 . Ef\%_i + e_i \tag{12}$$

Regression equation:

$$\widehat{K_R} = \beta_0 + \beta_1 . Ef\% \tag{13}$$

where:

K_r^i– empirical values of reduction factor along a specific direction; β_0 и β_1 - parameters of the linear regression model; $Ef\%$ - the percentage content of elastomeric threads; e_i – residual; $\widehat{K_R}$ - predicted value of the dependent variable.

The result is estimated using simple least squares regression. The calculation is performed using Microsoft Excel 2007 and Statistica 7.

5.1.1. Results

The following regression equations are derived from the analysis:

Reduction factor along the course:

$$K_R^c = 0,935 - 0,02Ef\% \tag{14}$$

Reduction factor along the wale:

$$K_R^w = 1{,}043 + 0{,}02 Ef\% \tag{15}$$

Reduction factor along the bias (45°):

$$K_R^{b45°} = 0{,}916 - 0{,}02 Ef\% \tag{16}$$

where:

K_R^c − reduction factor along the course, K_R^w −reduction factor along the wale, $K_R^{b45°}$- reduction factor along the bias (45˚), $Ef\%$ −content of elastomeric threads in the knitted fabric [%].

The results show a high value of statistical significance p ≤ 0,000 and determination coefficients: reduction factors along the course 0.958, along the wale 0.965, and along the bias 0.963. The standard deviations are derived- 0.006. The analysis is performed using the method of Fisher The analysis has shown that the regression models are adequate. The results are shown in table 5.

Table 5. Analysis of the adequacy of the models.

Reduction factors	Fisher analysis		Analysis of the model parameters		
	$F_{emp} = \dfrac{\sigma_1^2}{\sigma_2^2}$	F_{tab}	$t_{emp} = \dfrac{\|\beta_0\|}{\mu_{\beta_0}}$	$t_{emp} = \dfrac{\|\beta_1\|}{\mu_{\beta_1}}$	t_{tab}
K_R^c − along the course	1179,98	4,08	389,84	-34,31	2,02
K_R^w − along the wale	1130,53	4,08	412,45	33,62	2,02
$K_R^{b45°}$- along the bias (45˚)	1267	4,08	392,84	-35,60	20,2

The parameters of the regression equations are statistically significant with risk of error 0.05%. The interval values β_1 are determined on the basis of the standard error of the coefficient μ_{β_1}. The interval scores are determined with probability of 95% and the value of Student's coefficient $t_{табл..} = 2{,}02$. The interval scores of the regression coefficients for each model are as follows:

Reduction factor along the course:

$$-0{,}021 \le \beta_1 \le -0{,}017 \tag{17}$$

Reduction factor along the wale:

$$0{,}019 \le \beta_1 \le 0{,}021 \tag{18}$$

Reduction factor along the bias (45˚):

$$-0{,}021 \le \beta_1 \le -0{,}019 \tag{19}$$

6. Application of reduction factors in the process of women's dresses pattern making

It is proposed to use the reduction factors determined depending on the persentage content ot elastomeric threads in the knitted fabric for determine garment ease in pattern construction process. A basic pattern of a women's dress for standard size 170/88/92 (according to BDS 8371-89) was draft, which should be sewn from a single jacquard knitted fabric with an elastane content of 4%. The geometrical parameters of each pattern point are determined by the corresponding reduction factor. The modeling of the article is done using the method of arcs, which is presented in [16, 17]. The pattern making was shown in Fig. 8.

The dress prototype 1 is sewn (figure 9). On it are marked in green the lines of the chest, waist and hips, determined by the body measurements, and in red - their respective lines, after taking into account the stretch of the knitted fabric with the correction factor for stitch row, stitch column and angle of 45˚– Fig.9. It was found that the constructive lines shift in the direction of the line length: chest line - 3.5 cm, waist line - 5 cm and hip line - 7.2 cm. The side and shoulder seams are located in the middle of the respective sections. No change or distortion of the fabric pattern is observed. A second basic pattern has been made, in which only the transverse dimensions have been corrected with the reduction factor along the course. When superimposing the two structural bases on each other, it was found that the displacement of the structural lines of the sewn dress is equal to the reduce value along the course of the

pattern parameters - Fig.10. This fact imposes the conclusion that when reducing the transverse dimensions of the parts it is not necessary to increase their values in length. To verify this statement, a second dress was sewn (prototype 2), in which the pattern parameters were adjusted only with the reduction factor along the course. A correspondence was found between the constructive lines of this dress and its dimensional features. The side and shoulder seams are located correctly, there is no deformation and distortion of the pattern on the plate - Fig.11.

Figure 8. Pattern making.

Figure 9. Prototype 1.
Figure 10. Analysis of basic patterns.
Figure 11. Prototype 2.

7. Conclusion

A method for determining the deformation properties of knitted fabrics by the percentage of elastomeric threads in the knitted fabric in the designing and pattern making of women's knitted dresses is proposed. Equations for calculating the reduction factors depending on the percentage of elastane in the knitted fabric are derived. The results have been applied in the construction of women's knitted dresses. A prototype was made on a constructive basis of a women's dress made of single jacquard fabric. It has been found that when reducing the transverse dimensions of the garment, it is not necessary to increase the longitudinal dimensions. A second prototype was made, in which only the deformation along the course was taken into account. In this case, the coincidence of the pattern construction lines and the seams are good. The developed method presents a new approach for determining the values of the reduction factors using for initial information the data on the composition of the knitted fabrics according to the current standards. Its use ensures a good fit of the clothing and would reduce the costs of manufacturers.

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