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EVALUATING THE COMFORT CHARACTERISTICS OF KNITTED PRODUCTS

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Abstract: *For any range of products, the main requirements requested by the beneficiaries, refer to the presentation value, the commercial one, behavior during use (functionality), durability and maintainability. For clothing products, improving the comfort function is an essential requirement, which aims at: moisture absorption and transfer, ventilation capacity, thermal insulation capacity, electro-static charging, touch, structure, etc.*

The design, evaluation and improvement of product quality involves the inclusion of representative quality characteristics, which best meet the demands of the beneficiaries, as levers to control the desired quality. Obtaining the predetermined quality characteristics requires directing the manufacturing process by: choosing the raw material in correlation with usage conditions of the products, stating structure and structural parameters, establishing knitting and finishing technologies. In the case of knitted products, the design, redesign, quality control and evaluation are based on the inclusion and appreciation of simple and complex structural parameters, as the most important indicators in assessing the functional characteristics of knitwear. For these reasons, the paper proposes to substantiate a method of rapid and correct assessment for coefficients values of structural parameters, depending on the beneficiary requirements, regarding clothing comfort (air permeability, desired compactness degree, thermal insulation capacity). The variation intervals of the two coefficients, for four groups of knitted structures, allow choosing the knitting structure according to its desired degree of compactness, adopting the optimal values for structural parameters in the knitting design stage and estimating the changes suffered by the knit during finishing operations.

Key words: *knitted, quality, comfort, parameters, structure, compactness.*

1. INTRODUCTION

Knitted have the largest industrial use, the primary purpose being manufacturing clothing products for all categories of wearers and for every season (hot, cold and transitional seasons).

Any step in quality approach is based on the correlation of beneficiary requirements to functions and the quality characteristics of the products.

In the case of clothing products, the main groups of beneficiary requirements solicited regard [1, 2]:

- ✓ the presentation value;
- ✓ the commercial value of the product;
- ✓ functionality (behaviour during use);
- ✓ product response to certain actions it is subjected to (availability);

Presentation value requirements derive from the fact that any product, in order to enter the sphere of interest of a potential customer, must transmit an aesthetic message through style, model, appearance, chromatic combination, novelty elements etc. These requirements determine the degree of product amenity and implicitly its success on the market.

Demands targeting the commercial value apply to the product's presentation approach in sales, as well as the information provided by it (or the packaging).

Functionality requirements target a products usage value, being determined by the fact that a product must protect the body from the harmful influence of the environment and give the user a comforting sensation.

Availability requirements derive from the fact that a clothing product must fulfill the functions for which is was created, in specific usage conditions, until the appearance of physical or moral ageing. During its usage period, the products must respond to the demands regarding its maintenance and remediation.

The interface between user requirements and quality characteristics is constituted by set of functions that products have to meet. Function share (their degree of importance in quality assurance) differs from one type of product to another, being determined by the requirements imposed during use.

Improving the comfort function of clothing products is an essential requirement, of prime importance and always timely, being addressed in both research and production. This function is in interdependence with the constructive, ergonomic, technological, protection and availability functions.

The comfort of clothing products, with its three components (thermophysiological, sensory and mental) aims at:

- moisture absorption and transfer (water, vapors);
- ventilation capacity;
- thermal insulation capacity;
- electro-static charging capacity;
- touch, chromatic, structure, transparency, etc.;

2. KNITTED SPECIFIC STRUCTURAL PARAMETERS

Designing, manufacturing, evaluating and improving product quality involves establishing the technical dimensions of the functions and implementing the representative quality characteristics that can best meet the beneficiary requirements, as levers for controlling the desired quality.

Obtaining the predetermined quality characteristics, depending on usage conditions of the products, requires a controlled management of the manufacturing process through:

- ✓ choosing the raw material characteristics in correlation with the usage conditions of the products;
- ✓ inclusion of specific structure and structural parameters;
- ✓ establishing knitting and finishing technologies;

In general, the design, redesign, control and assement of knitted quality is based on inclusion and evaluation of structural parameters: A – the step of the loop, B – the height of the loop, C – the density factor, l_o – loop thread length.

Nevertheless, an evaluation of knitted quality using only these simple structural paramenters is not complete, lacking an appreaciation of the characteristics of functionality.

Assessing the behavior of knitted products during use and evaluating the characteristics of thermophysiological comfort is possible by establishing and appreciating:

- compactness degree of the knitted;
- air permeability of the knitted;
- thermal insulation capacity.

These characteristics are evaluated by determining the variation intervals of the complex coefficients of the structural parameters. They establish the relationship between the structural elements of the knitted fabric (length of the stitch, surface area or volume of the loop), the properties of the thread (diameter of the thread F), the projection of the lateral surface of the loop into the knitted surface and the volume occupied by the thread.

The main complex coefficients for the structural parameters that influence the properties and behavior of knitted products during use, the calculus equation and some of their characteristics are presented in Table 1 [3, 4, 5].

Table 1: *Complex coefficients of structural parameters*

Coefficient	Characteristics	Calculus relation
Density coefficient C	• Offers information regarding the compactness degree of the knitted. • Varies in certain intervals, specific to each type of structure.	$C = \frac{D_o}{D_v} = \frac{B}{A}$
Linear cover coefficient δl	• Offers information regarding the air permeability of the knitted, as well as compactness degree. • Varies between certain limits, depending on structure type. Values placed near the inferior limit imply high surface density (low values for loop height and step, so **high compactness**), while those placed near the upper limit suggest low surface density. • Influence knitted resistance to different types of strain. • Influence dimensional stability of the knitted.	$\delta_l = \frac{l_o}{F}$
Volumetric filling factor δv	• Represents an expression of the filling capacity. • Offers information about the thermal isolation capacity of the knitted. • The more coefficient values are closer to 1, the more knitted compactness and thermal isolation capacity are higher.	$\delta_v = \frac{\pi \cdot F^2 \cdot l_o}{4 \cdot A \cdot B \cdot g_t}$

3. DETERMINING THE COEEFICIENTS OF STRUCTURAL PARAMETERS

In order to determine the variation intervals for the complex coefficients of structural parameters, for four variants of basic and derived structures, it was necessary to establish the calculus equations for:

- ✓ loop thread lenght, loop step and height;
- ✓ knitted thickness;
- ✓ the linear cover coefficient δl;
- ✓ volumetric filling coefficient δv;

In table 2 are presented the calculus relations for loop thread lenght, loop step and height, specific to the four variants of structures: single jersey, rib fabric, cross-mis 1:1 and interlock, according to the hypotheses from the literature [3, 5].

Table 2: *Equation for loop thread length for 4 variants of structure*

Structure	Hypothesis	Initial calculus relation	Final calculus relation
Single jersey (plain fabric)	**Dalidovici**	$l_o = 1{,}57 \cdot A + 2 \cdot B + 3{,}14 \cdot F$	$l_o = [(1{,}57 + 2 \cdot C) \cdot K_A + 3{,}14] \cdot F$
Rib fabric	**Hagiu**	$l_o = 1{,}57 \cdot A + 2 \cdot B + 3{,}39 \cdot F$	$l_o = [(1{,}57 + 2 \cdot C) \cdot K_A + 3{,}39] \cdot F$
Cross-mis 1:1 (plain structures)	**Dalidovici**	$l_o = 2{,}32 \cdot A + 2 \cdot B + \pi \cdot F$	$l_o = [(2{,}32 + 2 \cdot C) \cdot K_A + 3{,}14] \cdot F$
Interlock fabric	**Mihailov**	$l_o = 2{,}2 \cdot A + 2{,}8 \cdot B - 2{,}2 \cdot F$	$l_o = [(2{,}2 + 2{,}8 \cdot C) \cdot K_A - 2{,}2] \cdot F$
$A = K_A \cdot F \quad B = K_A \cdot F \cdot C$			

Calculus relations for the complex coefficients of structural parameters are presented in tables 3 and 4.

Table 3: *Equation for the linear cover coefficient for 4 variants of structure*

Structure	Calculus equation of the linear cover coefficient
Single jersey (plain fabric)	$\delta_l = (1{,}57 + 2 \cdot C) \cdot K_A + 3{,}14$
Rib fabric	$\delta_l = (1{,}57 + 2 \cdot C) \cdot K_A + 3{,}39$
Cross-mis 1:1 (plain structures)	$\delta_l = (2{,}32 + 2 \cdot C) \cdot K_A + 3{,}14$
Interlock fabric	$\delta_l = (2{,}2 + 2{,}8 \cdot C) \cdot K_A - 2{,}2$

Table 4: *Equations for the volumetric filling coefficient for 4 variants of structure*

Structure	Calculus equation for thickness	Calculus equation for the volumetric filling coefficient
Single jersey (plain fabric)	$g_t = 2 \cdot F$	$\delta_v = \frac{\pi \cdot [(1{,}57 + 2 \cdot C) \cdot K_A + 3{,}14]}{8 \cdot K_A^2 \cdot C}$
Rib fabric	$g_t = 4 \cdot F$	$\delta_v = \frac{\pi \cdot [(1{,}57 + 2 \cdot C) \cdot K_A + 3{,}39]}{16 \cdot K_A^2 \cdot C}$
Cross-mis 1:1 (plain structures)	$g_t = 3 \cdot F$	$\delta_v = \frac{\pi \cdot [(2{,}32 + 2 \cdot C) \cdot K_A + 3{,}14]}{12 \cdot K_A^2 \cdot C}$
Interlock fabric	$g_t = 4 \cdot F$	$\delta_v = \frac{\pi \cdot [(2{,}2 + 2{,}8 \cdot C) \cdot K_A - 2{,}2]}{16 \cdot K_A^2 \cdot C}$

4. DETERMINING THE VARIATION INTERVALS OF THE COMPLEX COEFFICIENTS FOR FOUR TYPES OF STRUCTURE

Based on the recommendations in specialty literature [3, 5], as well as on some practical determinations, there were established the variation intervals of:

- loop step coefficient: $K_A = 4 \div 7$
- density coefficient: for single jersey and rib fabric: C = 0,65 ÷ 1,00
- density coefficient for cross-mis 1:1and interlock: C = 0,65 ÷ 1,30.

Under these conditions, the variation intervals were determined for the complex coefficients of structural parameters, for two basic bonds (single jersey and rib fabric) and for their derived structures (cross-mis 1:1and interlock). The determined intervals are shown in Tables 5 and 6.

Table 5: *Variation intervals of complex coefficients for the structures single jersey and rib fabric*

Compactness degree	Variation intervals							
	K_A	C		δ_l		δ_V		
		Single jersey	Rib fabric	Single jersey	Rib fabric	Single jersey	Rib fabric	
Very high	4 - 5	0,65 – 0,75		14,6 – 18,5	14,9 – 18,7	0,55 – 0,39	0,30 – 0,20	
	5 - 6			17,5 – 21,6	17,7 – 21,8	0,42 – 0,31	0,22 – 0,16	
	6 - 7			20,4 – 24,6	20,6 – 24,9	0,34 – 0,26	0,18 – 0,13	
High	4 - 5	0,75 – 0,85		15,4 – 19,5	15,7 – 19,8	0,50 – 0,36	0,25 – 0,18	
	5 - 6			18,5 – 22,8	18,7 – 23,0	0,38 – 0,29	0,20 – 0,15	
	6 – 7			21,6 – 26,0	21,8 – 26,3	0,31 – 0,24	0,16 – 0,12	
Medium	4 - 5	0,85 – 0,95		16,2 – 20,5	16,5 – 20,8	0,47 – 0,34	0,23 – 0,17	
	5 - 6			19,5 – 24,0	19,8 – 24,2	0,36 – 0,27	0,18 – 0,14	
	6 - 7			22,8 – 27,5	23,0 – 27,7	0,29 – 0,23	0,14 – 0,12	
Low	4 - 5	0,95 – 1,00		17,0 – 21,0	17,3 – 21,3	0,44 – 0,33	0,22 – 0,16	
	5 - 6			20,5 – 24,5	20,7 – 24,8	0,34 – 0,26	0,17 – 0,13	
	6 - 7			24,0 – 28,1	24,2 – 28,4	0,27 – 0,22	0,13 – 0,11	

Table 6: *Variation intervals of complex coefficients for the structures cross-mis 1:1 and interlock*

Compactness degree	Variation intervals						
	K_A	C		δ_l		δ_V	
		Cross-mis 1:1	Interlock	Cross-mis 1:1	Interlock	Cross-mis 1:1	Interlock
Very high	4 - 5	0,65 – 0,75		18,0 – 22,2	13,9 – 19,3	0,13 – 0,08	0,3 – 0,2
	5 - 6			21,7 – 26,0	17,9 – 23,6	0,08 – 0,06	0,21 – 0,17
	6 - 7			25,5 – 29,9	21,9 – 25,8	0,06 – 0,04	0,18 – 0,15
High	4 - 5	0,75 – 0,85		18,4 – 23,2	15,0 – 20,7	0,12 – 0,07	0,24 – 0,19
	5 - 6			22,2 – 27,3	19,3 – 25,3	0,08 – 0,05	0,20 – 0,16
	6 – 7			26,0 – 31,3	23,6 – 27,6	0,05 – 0,04	0,17 – 0,14
Medium	4 - 5	0,85 – 0,95		19,2 – 24,2	16,1 – 22,1	0,11 – 0,07	0,23 – 0,18
	5 - 6			23,4 – 28,5	20,7 – 27,0	0,07 – 0,04	0,19 – 0,15
	6 - 7			27,3 – 32,7	25,3 – 29,4	0,05 – 0,03	0,16 – 0,13
Low	4 - 5	0,95 – 1,00		20,0 – 24,7	17,2 – 22,8	0,10 – 0,06	0,22 – 0,17
	5 - 6			24,2 – 29,0	22,1 – 27,8	0,07 – 0,04	0,18 – 0,15
	6 - 7			28,5 – 33,4	27,0 – 30,3	0,04 – 0,03	0,15 – 0,13
Compactness degree	4 - 5	1,00 – 1,30		21,2 – 27,7	17,8 – 25,6	0,10 – 0,06	0,20 – 0,16
	5 - 6			24,7 – 32,6	22,8 – 31,2	0,07 – 0,04	0,17 – 0,14
	6 - 7			29,0 – 37,5	27,8 – 34,0	0,04 – 0,03	0,15 – 0,12

5. CONCLUSIONS

Assesing the behavior of knitted products during use and evaluating the characteristics of thermophysiological comfort is possible by establishing and appreaciating the compactness degree of the knitted, the air permeability, as well as the thermal insulation capacity.

Establishing the variation intervals for the complex coefficients of the structural parameters is a necessity for different types of knited, which facilitates their design, redesign and qualitative evaluation.

The method proposed in this paper allows a quick assessment of the most important quality indicators of knitted products, based on the coefficients of structural parameters, regardless of the type or count of the yarn used. The established variation intervals can constitute a database containing the values of the complex structural parameters, in the case of basic structures like single jersey and rib jersey as well as for the derived jersey and interlock structures. This database allows:

- rapid determination of the coefficient values for structural parameters, depending on the beneficiary requirements, regarding the desired comfort of the clothing products (air permeability, degree of compactness, thermal insulation capacity);
- rapid determination of the coefficient values for structural parameters, in correlation with the purpose of clothing products;
- choosing the structure of the knitted according to its desired degree of compactness;
- adopting the optimal values of the structural parameters in the knitting design stage;
- testing and examining the knitted during the manufacture of the “zero series”, regarding the degree of compactness, before launching a fabrication order;
- estimating the intervening changes in the knitted during the finishing operation;

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