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IMPROVEMENT OF THE ERGONOMIC FUNCTION – AN ESSENTIAL CONDITION FOR ENSURING KNITTED PRODUCTS QUALITY

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Abstract: *The evaluation products quality in general and particularly in knitted fabrics starts with determining their most important quality characteristics as an initial step in the multicriterial analysis used to establish the optimum ratio between the requirements of the users and the product's quality.*
The behaviour of the knitted products during use is essential for the beneficiaries, the ergonomic-constructive characteristics correlated with the comfort characteristics being used in the product quality evaluation. The quality evaluation implies establishing the representative characteristics as well as applying the standardized testing methods, in order to choose the optimum knitted variants for the required destination.
Extensibility is an essential quality characteristic for form – fitting knitted products or areas of the product, that during dressing – undressing or wearing process, must modify in a significant and positive way their initial dimensions. For these reasons it can be affirmed that the ergonomic function of a knitted product is determined greatly by extensibility. Measuring extensibility on two stress directions is a compulsory test effectuated in order to properly design knitted products. For this purpose, in knitted products, the minimal and maximal extensibility areas are established, for a precise selection of knitted structure, structural parameters as well as the position of the product elements.
The paper encompasses an experimental study on the comparative evaluation of the extensibility of eight knit variants used in the production of outer garments in order to assess their ergonomic function and implicitly the ability to guide the quality of the knitted products during their design.

Key words: *product, knitted, evaluation, quality, extensibility, ergonomics*

1. INTRODUCTION

One of the most important functions of a garment product is the constructive – ergonomic one, which refers to:

- the ability of the product to conform to the shape and dimensions of the human body (regardless of the state - static or dynamic in which it is at a certain moment);
- providing easy dressing - undressing of the product;
- the ability of the product to allow freedom of body movement.

Extensibility is an essential quality characteristic for form-fitting knitted products or areas of the product (collars, accents, cuffs, welts), that during dressing-undressing or wearing process, must modify in a significant and positive way their initial dimensions [1, 2, 5]. For these reasons it can be affirmed that the ergonomic function of a knitted product is determined greatly by extensibility.

2. GENERAL CONSIDERATIONS

Both during the technological processing and during the wearing and household maintenance, textile products are subjected to a set of stresses, of which the non-destructive ones (where the driving force is less than the breaking load of the P < PR specimen) highlight fatigue resistance of the product.

Of the most common non-destructive stresses during use, unidirectional or multidirectional stretching (static, dynamic, or cyclical) **highlights the extensibility and elasticity of textile products**.

The domain of unidirectional stretching stress is divided into:

- the field of elastic stresses (which cause reversible deformations);
- field of plastic or retentive stresses (which produce irreversible deformations); in turn, the field of plastic deformations is divided into non-destructive plastic deformations and destructive deformations completed by breaking the material.

In figure 1 the force – elongation diagram is presented in which three domains are marked:

- elastic elongation domain that reveals the elasticity $\boldsymbol{\varepsilon_{el}}$ (point A abscissa is the limit of the elastic domain);
- extensibility domain $\boldsymbol{\varepsilon_{ex}}$ (between point A abscissa and point B abscissa);
- plastic elongation domain $\boldsymbol{\varepsilon_{p}}$ (after point B abscissa).

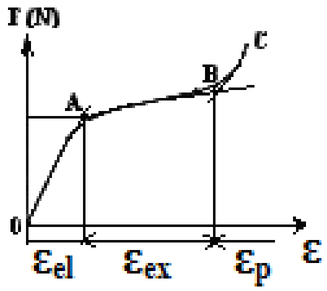

Fig. 1: *Force – elongation diagram*

Knitted fabrics, in comparison to other textile surfaces (woven or unwoven materials) have a greater capacity to elongate on the direction of a stretch strain, as a result of the migration of the yarn in the stitch.

Also knows as structural deformity, **extensibility** is the capacity of a knitted material to elongate under the action of a static strain, whose intensity is at the limit between the non-destructive plastic strain domain and the destructive one [1].

The extensibility of a knitted fabric or product is determined by:

- yarn characteristics (nature, extensibility grade, surface aspect, bending rigidity, yarn – yarn friction coefficient);
- knitted characteristics (structure, count, compactness coefficient);
- parameters of the finishing process applied to the knitted (temperature, strain).

By contrast to extensibility, elasticity is the capacity of the material (especially knitted) to store up reversible energy during static stretching loads and to revert to its initial dimension after ceasing the elastic stretching loads. If the knitted fabric returns completely to its original dimensions, the deformation is elastic. In the case of a partial recovery, it means that the stretching force exceeded the elastic domain – is the case of extensibility.

The extensibility of a knitted must be analyzed in relation with its elasticity.

By combining the extensibility and elasticity values, we get four possible variants of knitted fabrics:

- knitted fabrics with high values for extensibility and elasticity (recommended for collars, fittings at the base of neck, hose gusset, fitting bands, form-fitting products);
- knitted fabrics with high extensibility and low elasticity (that deform under stretch strains and have a low quality level);
- knitted fabrics with low values of both elasticity and extensibility (compact structures made out of very low elasticity yarns); recommended for products that keep their shape and dimensions during wearing.
- knitted fabrics with low extensibility but high enough elasticity (compact structures that present a low elongation on the strain solicitation and return to their initial shape and dimensions because of the high elasticity yarns [1, 2, 4].

In the design of a knitted product, the extensibility values on different directions determine the choice of structure and structural parameters, the shape, dimensions and position of the reference components of the knitted product, the type and parameters for the applied seams, as well as the finishing operations parameters.

3. EXPERIMENTAL METHODS OF EVALUATING THE EXTENSIBILITY

For studying the fabric behaviour under stretching, with a force less than the breaking load, three methods may be used with specific equipment:

- standardized method based on textile relaxometer;
- dynamometric method (on textile dynamometer);
- the method based on the use of Fryma extensometer.

3.1 Standardized method

This method involves straining the test sample, with standard dimensions, on a textile relaxometer and calculating the maximum deformation εt1, the elastic deformation ε / and the plastic deformation ε // (with formulas 1, 2, 3):

Relative elastic elongation $$\varepsilon^{/} = \frac{l_t - l_r}{l_0} \cdot 100 = \frac{\Delta l^{/}}{l_0} \cdot 100 \ [\%] \qquad \textbf{(1)}$$

Relative retentive elongation $$\varepsilon^{//} = \frac{l_r - l_0}{l_0} \cdot 100 = \frac{\Delta l^{//}}{l_0} \cdot 100 \ [\%] \qquad \textbf{(2)}$$

Relative total elongation $$\varepsilon_{t1} = \frac{l_t - l_0}{l_0} \cdot 100 = \frac{\Delta l_{t1}}{l_0} \cdot 100 \ [\%] \qquad \textbf{(3)}$$

where: 1_0 - represents the initial length of the specimen;
l_t - the final length of the specimen under the action of the deformation force;
l_r - the length of the specimen after removal of the force.

3.2 Dynamometric method

The method implies straining a test sample with standard dimensions on a dynamometer that has the capacity to record an effort - elongation diagram. By analyzing this diagram (figure 1) we can determine the point (B) that divides the curb into 2 zones: low rigidity zone (0 – B) – coincides with the extensibility domain; high rigidity zone (B – C) – coincides with the domain in which stretches are destructive.

3.3 Method based on the use of Fryma extensometer

This method is used to determine the extensibility of knitted materials under the action of a constant stretching force. The purpose of the test is to establish the degree of stretching and rebound of a material with the precision required by British Standard BS 4292/1968 [3].

The device allows measuring the extensibility of knitted with a maximum value of 300%, or of wefts with a maximum elongation of 50%.

The Fryma extensometer scheme is shown in Figure 2.

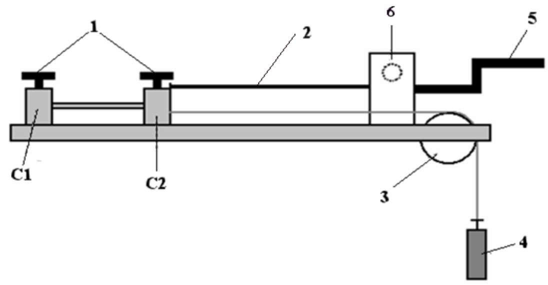

***Fig. 2** Construction of Fryma extensometer*
C1 – fixed clamp; C2 – moving clamp; 1 – tee screws; 2 – screw shaft; 3 – sustain wheel of the weighted cable 4; 5– winding handle; 6 – quick return button

4. EXPERIMENTAL DETERMINATIONS OF EXTENSIBILITY

In this paper were taken into study eight variations of knitted structures, of different counts, made out of 100% cotton yarns, with 19 tex linear count, intended for exterior clothing products. The extensibility testing was done on two directions (stitch rows and stitch wells respectively), with the use of the Fryma extensometer.

The samples with standard dimensions (75x85 mm), cut on the two directions were acclimated and put under a 3 daN force stretch load. The determinations were executed on a 5 samples specimen (on each direction), for each structure analyzed, after which the medium values of extensibility were calculated, as read on the machines graded scale.

In table one are presented and characterised the adopted structure variants.

***Table 1:** Characterization of knitted structures variants*

Variant number	Analyzed structure	Adapted raw material	Medium value of extensibility [%]	
			On the direction of stitch wells	On the direction of stitch rows
V1	**Jersey**	**100% Cotton Ttex = 19**	27	98
V2	**Jersey with miss stitches**		24	67
V3	**Plain pique**		25	117
V4	**Rib 1:1**		28	240
V5	**Rib 2:2**		34	262
V6	**Rib 1:1 with miss stitches**		20	190
V7	**Rib 2:2 with tuck stitches**		29	282
V8	**Interlock**		14	163

The comparative analysis of extensibility in two directions for the analyzed and tested structures is illustrated in Figures 4, 5, 6, 7, 8.

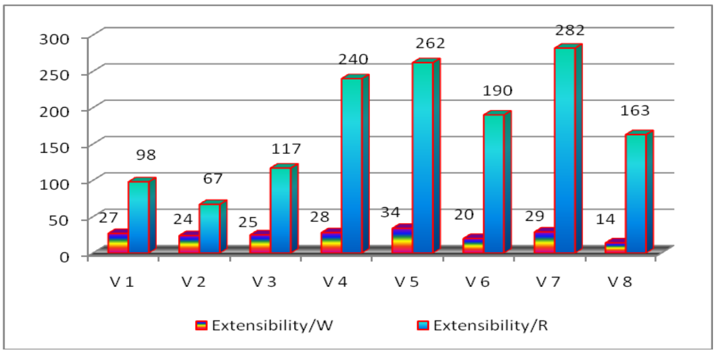

***Fig. 4**: Comparative variation of extensibility for the eight knitted variants on the directions of stitch wells and stitch rows.*

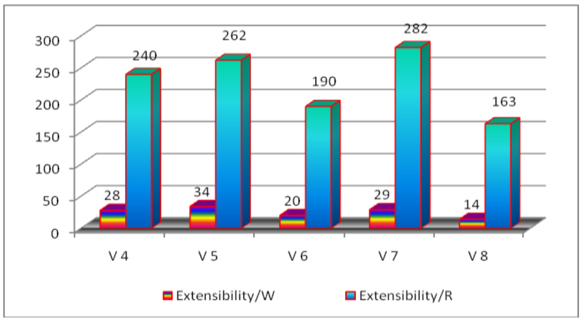

***Fig. 5**: Comparative variation of extensibility for the knitted variants rib and interlock*

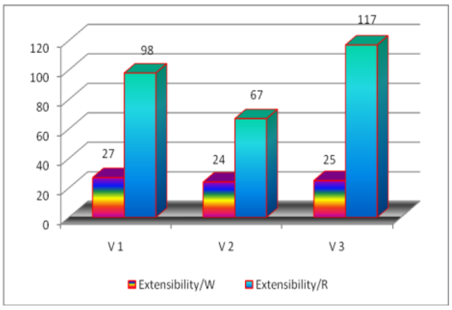

***Fig. 6**: Comparative variation of extensibility for the knitted variants type jersey.*

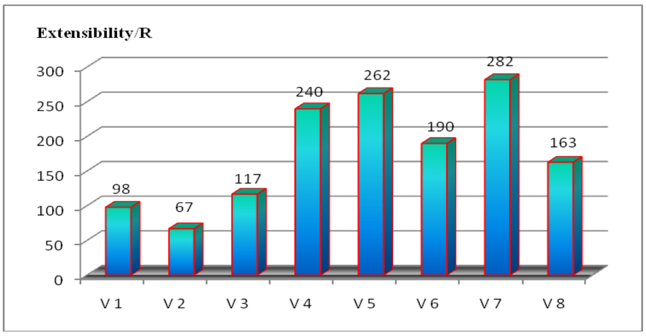

***Fig. 7**: The variation of extensibility on the direction of stitch rows in the eight structure variants*

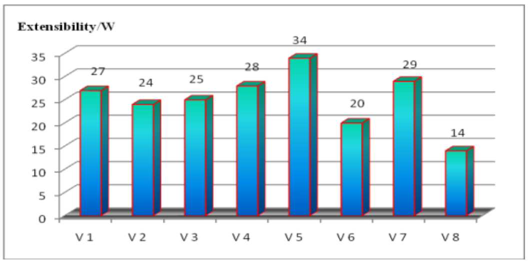

***Fig. 8**: The variation of extensibility on the direction of stitch wells in the eight structure variants*

Results interpretation

Based on the comparative analysis of extensibility for all the knitted variants analyzed, the following aspects were observed:

- significant differences occur between the extensibility values registered in the two directions;

- transversal extensibility (in the direction of the stitch rows) has net values higher than the longitudinal extensibility (in the direction of stitch wells) (Figure 4);
- due to the formation of the rib type knitted (V4, V5, V6, V7) and the closeness tendency of stitch wells with different aspects, their transversal extensibility is much higher (varies between 190% and 282%), compared to the similar extensibility recorded on jersey type knitted (V1, V2, V3), where the values vary between 67% and 117% – Figures 5, 6;
- in both jersey and rib type, the presence of miss stitches in the structure (V2, V6) gives stability to the structure and thus reduces the extensibility (Figures 5, 6);
- the lowest values of longitudinal extensibility are for: V8 variant (interlock - 14% due to compactness and distinct stability), variant V2 (jersey with miss stitches) and variant V6 (rib 1:1 with miss stitches);
- on all jersey and rib variants the presence of tuck stitches in the structure (V3, V7) determines an increase of transversal extensibility and decrease of longitudinal extensibility; this is explained by the greater mobility of the yarn withing tuck stitches (figures 5, 6);
- among the jersey variant, the highest value of the transversal extensibility was recorded in V3 variant (jersey with tuck stitches);
- among the rib variants, the highest value of the transversal extensibility was recorded in variant V7 (rib 2:2 with tuck stitches).

5. CONCLUSIONS

Measuring extensibility on two stress directions is a compulsory test effectuated in order to properly design knitted products. For this purpose, in knitted products, the minimal and maximal extensibility areas are established, for a precise selection of knitted structure, structural parameters as well as the position of the product elements. Only the optimal choice of structure and structural parameters for the same variant of yarn concur greatly to a quality improvement of the knitted products. For the structures analyzed in this paper it can be concluded that:

- the variant with the highest extensibility on the stitch well direction (34%) is rib 2:2; and the variant with minimal extensibility (14%) is interlock;
- maximal extensibility on the stitch row direction (282%) corresponds to V7 variant (rib 2:2 with tuck stitches, and minimal extensibility (67%) is valid for the V2 variant (jersey with miss stitches).

Only an exact knowledge of extensibility allows judicious choice of optimal knit variants, depending on the intended use of the product and in strict correspondence with the requirements of the beneficiaries.

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