Inequality of Fabric Tensile Behaviour in Width

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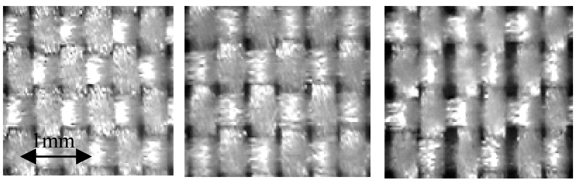
Received 30 September 2004; accepted 23 January 2005

Earlier experimental investigations have shown a particular regularity of warp projections inequality in the loom-state fabric width, while the projections of wefts were steady in the whole width of fabric. The changes of warp projections have high influence up on some properties of fabric. Variation of strength and elongation in warp direction in the fabric width is within the limits of error, while the variation of presented properties in weft direction is more signally. The reason of such phenomena can be the inequality of warp cross-section. So, the extension of specimens from different places in fabric width under the same loads is unequal. This means, that porosity of fabric under tension is different and herewith influences its filtration characteristics.

Keywords: warp projections, fabric cross-section, strength, elongation.

INTRODUCTION

Technical fabrics are widely used in various areas of application and thus concrete values of they properties are very important for usage. It is important to know if these properties are steady in the whole fabric width or if they vary. Early a significant inequality of different loom-state fabric structure and air permeability was determined in width [1]. The investigations of 16 different loom-state fabrics (various weaves, raw materials, sets, looms and etc.) show the particular regularity of fabric structure and air permeability inequality in width. The investigations of fabric images in the different places in width show the significant inequality of fabric structure, also (see Fig. 1).



a b c

Fig. 1. Image of fabric at distances of 5 cm (a), at 25 cm (b), and 70 cm (c) from its edge [13]

As it can be seen in Fig. 1, the images of fabric at different places in width are not the same. One can see, the warps are more flat in the border part of the fabric (Fig. 1, a, b), while in the central part of the fabric the projections of the warps in the plane of the fabric are signally lower (Fig. 1, c).

As it was mentioned earlier, for some fabrics (such as filter or aviation fabrics, or fabrics for protective clothing) it is very important to have a steady characteristics in the whole width [2, 3]. The main aim of theoretical analysis of an air permeability of textile materials is usually to find a relationship between an air permeability and structure of textiles.

In this case textile structure is usually represented by its porosity [4].

A number of theoretical and experimental methods exist for a porosity determination. Each of these methods includes some simplifying assumptions, what causes an inaccuracy. So, it is very important to know characteristics of pores (pore size, shape, position and etc.) Fabric porosity and air permeability depend on many factors, such as fabric weave, the yarn stock, the set of yarns and other parameters [5 – 7].

Besides, fabric is stretched under the certain loads during usage, and its porosity changes, also [8 – 11]. Fabric strength and elongation depend not only on yarn stock, but on fabric structure, too [12]. That's why inequality of fabric structure can effect also its tensile behaviour. On the other hand the tensile behaviour influences fabric porosity under loading.

The main aim of this article – to investigate and analize inequality of fabrics tensile behaviour in its width.

MATERIALS AND METHODS

The measurements of yarn projections were carried out using PC and the microscope Technik Rathenow (accuracy of measurements is ±0.001 mm). Ten warp projection measurements at a certain distance from the left fabric edge were carried out at each experimental point.

The properties of fabric were determined according to EN ISO 13934-1 standard (air permeability was determined with the pressure difference of 200 Pa).

The tensile characteristics of polyester fabrics were measured on Zwick/Z005. The extension rate of specimen was 100 mm/min, the pre-load was 2 N, distance between clamps was 200 mm. The tensile curves of fabric were obtained by values of five specimens in every experimental point in weft and warp direction. The distance from medium point of a specimen strip is taken as the distance from fabric edge (Fig. 2).

The plain weave polyester fabric of 158 cm width was chosen for property investigation. The warps of fabric were from multifilament 29.4 tex yarns (set 244 cm^{-1}) and the wefts were from 27.7 tex multifilament yarns (set 184 cm^{-1}).

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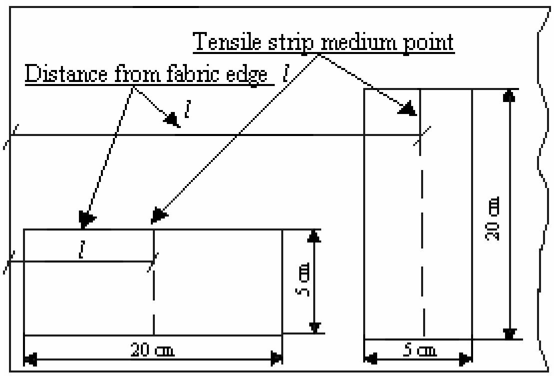

Fig. 2. The determination of tensile strip medium point

RESULTS AND DISCUSSIONS

Earlier experimental investigations have show a particular regularity of warp projections inequality in the loom-state fabric width (see Fig. 3), while the projections of wefts were steady in the whole width of a fabric.

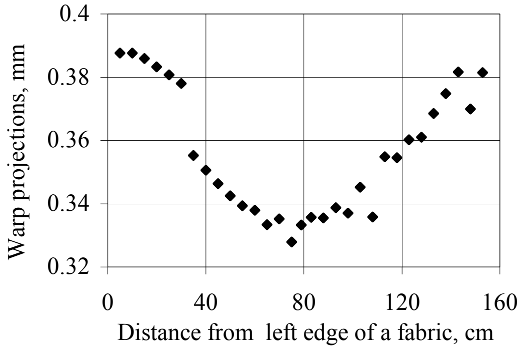

Fig. 3. Inequality of warp projections in fabric width

The warp projections have a high influence on some properties of fabric – at first on the inequality of air permeability, which is affected by fabric porosity [8 – 15].

It is also known, that parameters of yarns (linear density, set) have an influence on tensile strength of fabric in opposite direction [16]. So, the construction of fabric in one direction influences on strength of fabric in another direction. As it is shown in Fig. 3, the shape of warp projections in fabric width is unequal. So, the strength of fabric in weft direction also can be unequal.

In this stage of the investigation fabric strength and elongation in different places of the fabric were investigated. It was found, that variation of warps strength and elongation in fabric width is within the error limits, while the variation of wefts is not steady. The reason of such phenomena can be the inequality of warps cross-sections. In Fig. 4 the inequality of the fabric strength and elongation in weft direction from the edge to medium point are presented.

As it can be seen in Fig. 4, the particular regularities of presented properties inequality can be noted, also (the coefficients of variation in each experimental points of both dependences are not higher than 10 %). The reason of such phenomena also can be explained by warp cross-section inequality. It is evident that yarns in fabric are squeezed and the geometry of their cross-section becomes more sophisticated. Peculiarities of raw material, fabric set and weaving parameters are the deciding factors on the fabric cross-section shape.

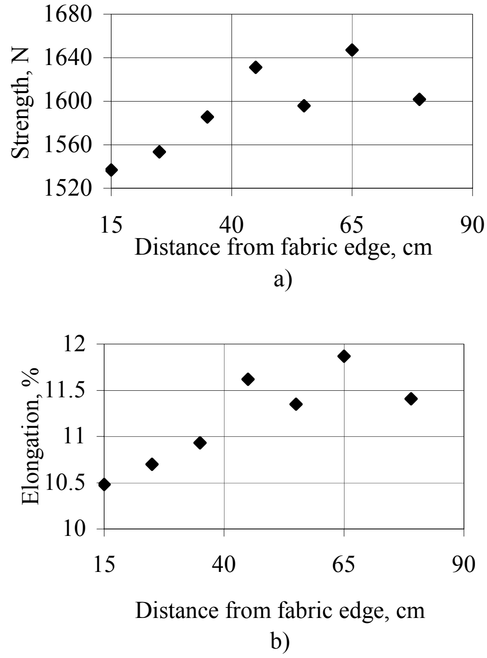

Fig. 4. Inequality of fabric strength (a) and elongation (b) in weft direction

The cross-section of the yarns is approximated by a certain geometrical shape. In this investigation it was offered to approximate it as a lens [6, 7, 17, 18]. While horizontal axis of warp cross-section decreases, the vertical one increases and the crimp of opposite system of yarns (wefts) increases, too. Therefore the elongation of fabric in weft direction is higher. The higher crimp of yarns also can be a reason of higher fabric strength.

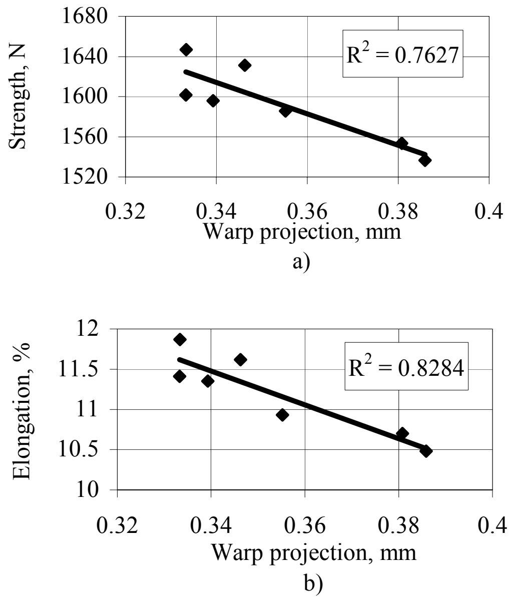

Fig. 5. Dependencies of fabric strength (a) and elongation (b) up on warp projections

In Fig. 5 the dependencies of fabric strength and elongation up on warp projections are presented. The linear regression equations describe the changes of fabric strength and elongation in weft direction with significant accuracy (the coefficients of determination are high $R^2 = 0.7627 \div 0.8284$).

So, it is possible to assert that inequality of fabric strength and elongation depends on warp projections inequality.

Experimental investigations confirmed that inequality of fabric strength and elongation at break in the different places of fabric depends on unequal fabric structure – the tensile curves of fabric vary from the first zone (see Fig. 7), which depends only on fabric structure (see Fig. 6).

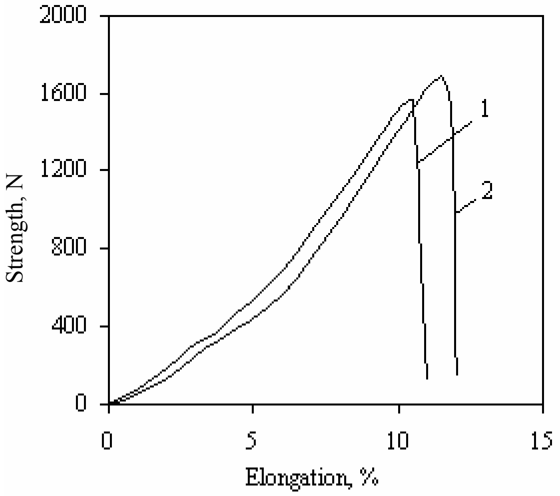

Fig. 6. Tensile curves of fabrics: 1 – at a distance of 15 cm from fabric edge, 2 – at a distance of 45 cm from fabric edge

The initial zone *OA* of a curve (see Fig. 7) shows a process, which need to overbear the friction forces during yarn straightening. This zone is characterized by a rather big stiffness. In the zone *AB* the yarns of fabric became more straight and the elements of opposite system crimps more intensively, i.e. process of crimp changing takes place. In *BC* zone forces which defeat resistance to binding increase. Further fabric extends only due to yarn extension (zone *CD*) and finally fabric specimen breaks.

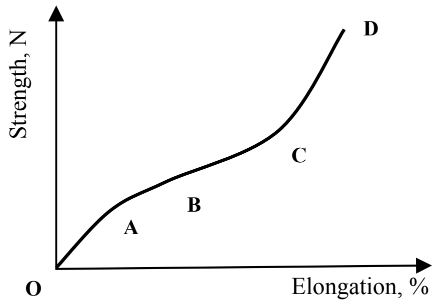

Fig. 7. Typical tensile curve

As it can be seen in Fig. 7, the typical tensile curve of fabric shows that only fabric structure changes can be observed in zone *OB*. The changes of yarns structure is seen further and the yarns begin extent. Besides, fabric extension in the initial tension stage is higher in the central part of a fabric than in border parts (see Fig. 6).

In Fig. 8 the dependence of fabric elongation in the initial tension stage (under load of 400 N) on the distance from fabric edge is presented. The value of loading under which the elongation of fabric was measured is chosen considering to fabric behavior under tension – till this load specimen is extended only due to fabric structure changes (see Fig. 6 and Fig. 7).

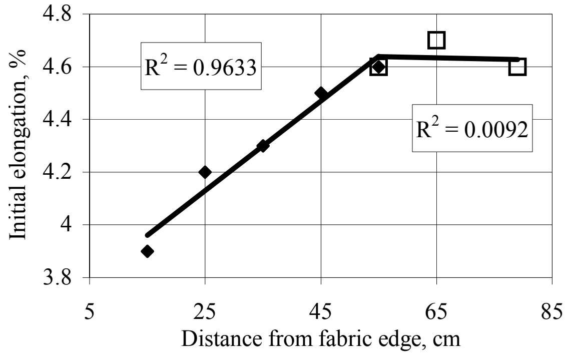

Fig. 8. Inequality of initial elongation in fabric width

As it can be seen in Fig. 8, the initial elongation of fabric increases intensively in the border part of the fabric and the linear equation confirms that (coefficient of determination is high $R^2 = 0.9627$). While in the central part of the fabric (55 – 79 cm from edge) the values vary very slightly. The low value of determination coefficient ($R^2 = 0.0092$) confirms non-existent dependence and initial elongation of this part of fabric can be described as $\varepsilon = \text{const}$.

Calculations of residual elongation (elongation at break minus initial elongation), which mostly depends on yarn properties, have shown the noncorrespondence between the residual elongation and distance from fabric edge – the coefficient of determination is low and values of elongation are in the limits of error (see Fig. 9).

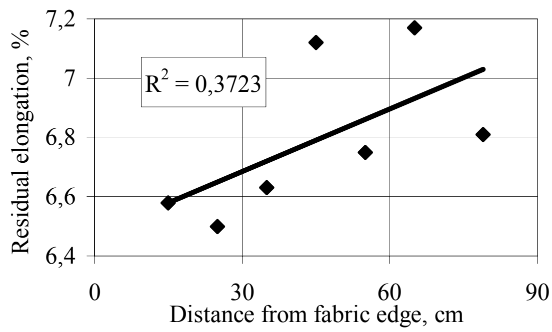

Fig. 9. Noncorrespondence between residual elongation and distance from fabric edge

So, we can assert that the regular inequality of strength and elongation of fabric in weft direction and of its tensile behaviour depends only on inequality of warp projections – the regular inequality only for initial part of tensile curve is observable.

Herewith, if the elongation of specimens from different places in fabric width under the same loads is unequal, the changes of fabric porosity in different places in width under tension are different and herewith may influence its filtration characteristics.

CONCLUSIONS

- The investigation proved the inequality of fabric structure in width - the warp projections are not equal in the whole fabric width. In a border parts they are larger than in a central part.

- The elongation and strength in weft direction of a fabric are higher in its central part than in the border parts. The dependences of presented properties on warp projections have high coefficients of determination ($R^2 = 0.7222 \div 0.8946$).
- The shape of yarns cross-section in one direction influences on fabric strength and elongation in the direction.
- The initial elongation of fabric increases intensively in the border part of the fabric ($R^2 = 0.9633$). The low value of coefficient of determination ($R^2 = 0.0092$) in central part of fabric confirm non-existence of dependence, and initial elongation of central part of fabric can be described as $\varepsilon = \text{const}$.
- The regular inequality in width of tensile behaviour of fabric in weft depends only on inequality of warp projections – the regular inequality only for initial part of stress-strain curve is observable.

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