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Measurement of shearing stress in fabrics*

Měření smykového napětí v tkaninách

Eva Zajícová[1)], Zdeněk Kalousek[2)]

Abstract

At uniaxial strain of fabrics, tension rises in these fabrics that has, thanks to anisotropy of material's properties, meaningful as tensile as shear components. At deformation tests, the force is usually measured in direction deformation only. It is a tensile stress. A method has been designed and virtually well tried how to measure forces in perpendicular direction that rise in consequence of shear tension. This proposal is enclosed. It has been proved that in textures, cut below definite angle, both components of tension are seriously significant.

Keywords

fabric, warp, weft, thread, weave, set of fabric, elongation threads, strain, tensile stress, shear stress, tensile force, shear force, grip

1. Acting forces in fabric

In fabric, which is in abeyance, there is no force. As soon as a fabric begins deforming in upright direction, tensions arise, which appear on the edge of sample, as a force that can be split into two components: in vertical direction – tensile force and in horizontal direction – shear force.

Threads in the fabric, which is cut below definite angle, are being extended by acting tension about ε_o, it means from original longitude l to l_l. The total length of fabric will be changed from longitude d to d_l (Figure 1). The distance of threads x, metered in direction latitude grips, stay constant after action of the force.

For calculation of sizes of acting forces the simplified model was used. The system of warp and weft threads that are perpendicular upon themselves, but not interlaced, and only small deformations of sample were thought. It means that there is no structure created (interlacing warp and weft) [1].

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1 Department of Measurement, Technical University of Liberec, Hálkova 6, 461 17, Czech Republic.
E-mail: eva.zajicova@vslib.cz

2 Department of Applied Mathematics, Technical University of Liberec, Hálkova 6, 461 17
E-mail: zdenek.kalousek@vslib.cz

1.1 Calculation of elongation threads ε_o a ε_u

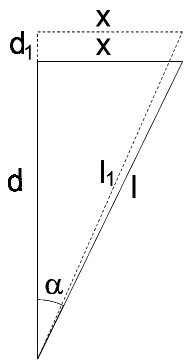

Figure 1

$$l_1 = \sqrt{(d + d \cdot \varepsilon_t)^2 + (d \cdot tg\alpha)^2}$$

$$\varepsilon_o = \frac{l_1 - l}{l}$$

$$l = \frac{d}{\cos\alpha}$$

$$\varepsilon_o = \varepsilon_t \cdot \cos^2\alpha$$

$$x = d \cdot tg\alpha$$

$$\varepsilon_u = \varepsilon_t \cdot \sin^2\alpha$$

where,
ε_o is elongation warp threads and ε_u is elongation weft threads.

1.2 Determination of forces in warp and weft threads and quantity of threads on given latitude of fabric

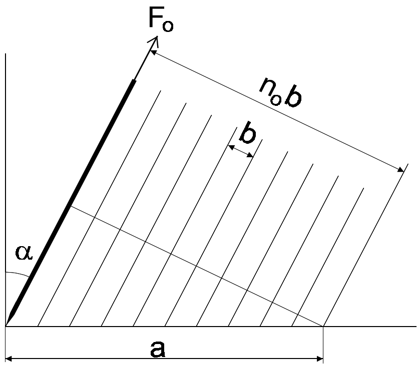

Figure 2

For warp thread:

$$F_o = E \cdot S \cdot \varepsilon_t \cdot \cos^2\alpha$$

$$n_o = \frac{a}{b} \cdot \cos\alpha$$

For weft thread:

$$F_u = E \cdot S \cdot \varepsilon_t \cdot \sin^2\alpha$$

$$n_u = \frac{a}{b} \cdot \sin\alpha$$

where a is latitude of the fabric, b is distance of threads, which is designated from set of fabric, E is Young's modulus, S is thread area.

1.3 Acting forces in horizontal and vertical direction

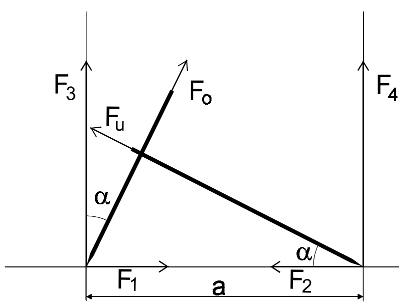

Figure 3

$$F_1 = F_o \cdot \sin\alpha$$

$$F_2 = F_u \cdot \cos\alpha$$

$$F_s = F_1 \cdot n_o - F_2 \cdot n_u$$

$$F_s = \frac{E \cdot S \cdot \varepsilon_t \cdot a}{4 \cdot b} \cdot \sin 4\alpha$$

$$F_3 = F_o \cdot \cos\alpha$$
$$F_4 = F_u \cdot \sin\alpha$$

$$F_T = F_3 \cdot n_o + F_4 \cdot n_u$$

$$F_T = \frac{E \cdot S \cdot \varepsilon_t \cdot a}{b} \cdot \left(1 - \frac{1}{2} \cdot \sin^2 2\alpha\right)$$

When *sin 4 α* = 1, the shear force is maximum.
When sin $\alpha = 0$ or $\alpha = 90$ it means in direction of warp and weft, the tension force is maximum.
Judgment was: the maximum of tensile force is four-times greater than maximum of shear force.
In real fabric the force is little bit lower because there will be acting for example a way of interlacing threads, it is structure of fabrics.

2. Measurement of shear force

At deformation examinations, the samples that are cut along warp or weft are used only. The problem begins with samples that are cut below other angle; the norm doesn't even allow this manner of preparation of the samples. It is possible to find shear forces in these samples. As far as occurs a need to measure the size of these forces, it is necessary to adjust jaws of the apparatus, to be possible to realize this measurement.

Shear force works in horizontal direction, that is why the possibility, how to scan forces, is releasing one of grips (upper or lower), to make possible movement to the sides only. At deformation examination the shear force is transferred into the vacation grip and it causes its swing to the sides. As far as we prevent this movement and measure the force, which hereto is needed, we will get the very inquired for the value of shear force.

2.1 Fasten grip

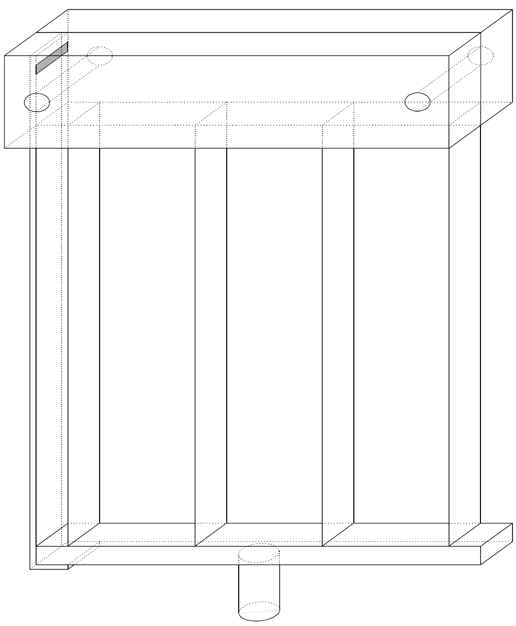

Figure 4: Lower fasten grip

Lower fasten grip is griped on plangetes that must be from elastic material, to enable grips swing to the sides. On jaws was screwed metal plate in movable groove, which make the possibility of its shift. This shift allows optimal setting of position of the sensor, fixed on this metal plate, in face of jaws, to make minimum of "deaf swing" during metering when jaws are not in contact with the sensor. The tensiometer sensor with range 3N+100% was used there.

The plangetes, which the lower fasten grip is griped on, must be as tough, not to happen their nonreversible deformation even when the maximum tensile force at experiment (i.e. on the limit of toughness of examined fabric samples), and at the same time so flexible, to be neglected the power that is needed to "deaf swing" of grip in an order tenths millimetres compared with expected shear forces.

The proportion of mechanism must allow its placing to the breaker (specifically TiraTest 2300). If we take *n* the plangetes of size about (axial length x latitude x longitude = *c x h x l*), there will be the highest allowed tensile force F_{max} and shear

$$F_{\max} = \sigma_D \cdot n \cdot c \cdot h$$

$$F_y = E \cdot \frac{c^3 \cdot h}{l^3} \cdot y \cdot n$$

force that is needed to get a deflection y for material of allowed straining σ_D.

At selection of four planzet from steel of class 15 230 and size 0,25 x 20 x 100mm with σ_D = 160 MPa and E = 200 GPa the force goes out F_{max}= 3,2kN, which exceeds the maximum toughness of common fabric samples of an order ten times, and F_y = 25mN at deflection y = 0,1mm; it is less than per cent of range used force sensor, and then this force is comparable with the others sources of errors of measuring.

2.2 Experiment

The signal from breaker is fetched to the control unit (CU) and from here to the PC, where's processed. Data and graphs are processed by output of every measuring.

The signal from the sensor of shear tension, which was added to the breaker, was led through tensiometer device on a dynamic signal analyser, where data were saved during measuring. Thanks to floppy disk the data could be processed later.

Two sets of data were gained from every test - one of the analyser and alternative from the Lab Test programme that processed data directly on PC from the sensor of tensile force.

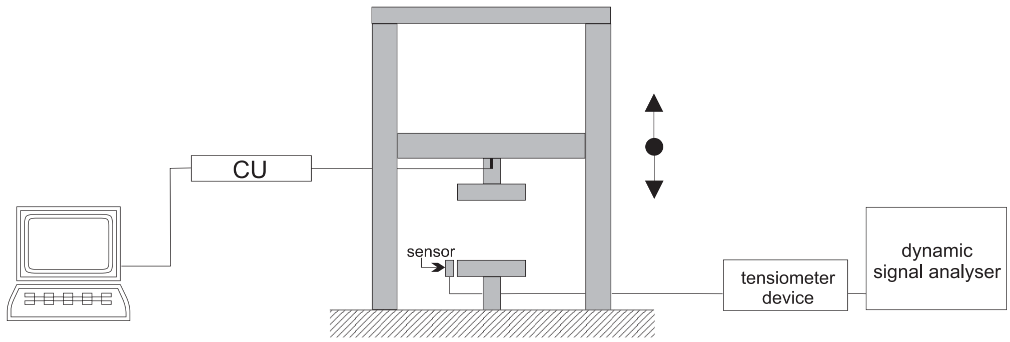

Figure 5: Measuring workplace

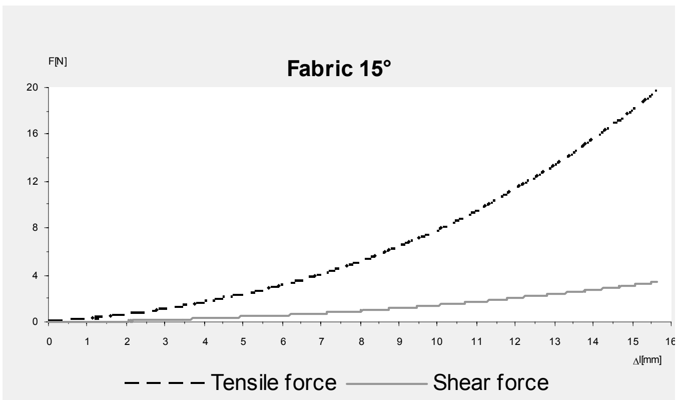

Figure 6: Force - elongation threads graph

The record of measuring illustrates enclosed graph made in MS Excel (exhibit of processed signals at Angle α =15°). We can see that the judgment of ratio sizes of shear and tensile forces is of an order right.

Reference

[1] Zajícová, E.: The Expansion of Shredder TiraTest 2300, Diploma Thesis, TU Liberec 2001
[2] Zehnula, K.: The sensores of nonelectric quantity, SNTL, Praha 1977