

Nové možnosti rozvoje vzdělávání na Technické univerzitě v Liberci

Specifický cíl A2: Rozvoj v oblasti distanční výuky, online výuky a blended learning

NPO_TUL_MSMT-16598/2022

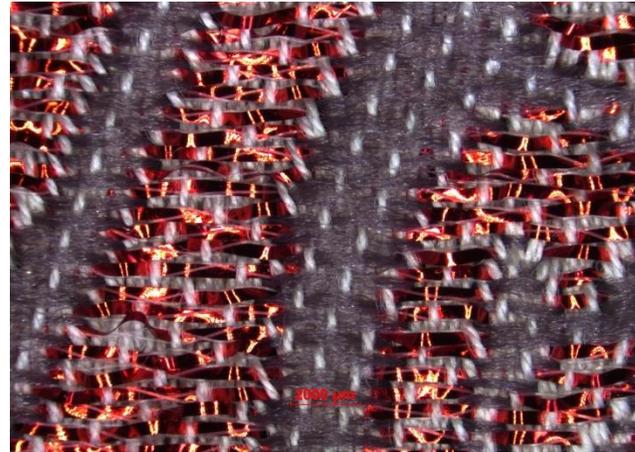
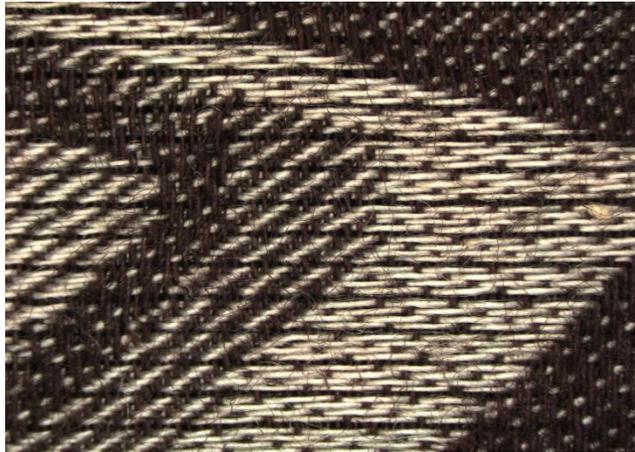
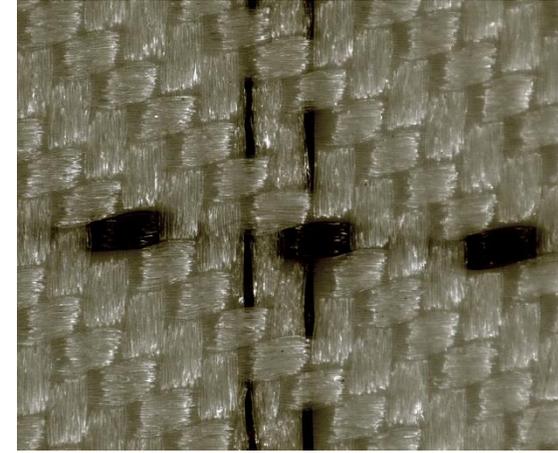
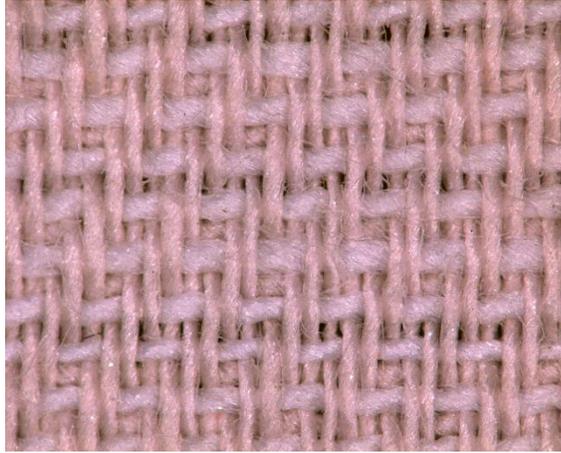


Fabric - surface structure by image analysis

Ing. Bc Monika Vyšanská, PhD.



Fabric - external structure, identification



Detected parameters, see STR [1]:

$$z_o \in \langle 4, v \rangle$$

$$Z_o = D_o d_o$$

$$z_u \in \langle 4, v \rangle$$

$$Z_u = D_u d_u$$

$$z = (z_o + z_u) \in \langle 8, 2v \rangle$$

$$Z = Z_o + Z_u - Z_o Z_u$$

$$\kappa_o = z_o / v \leq 1$$

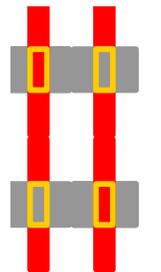
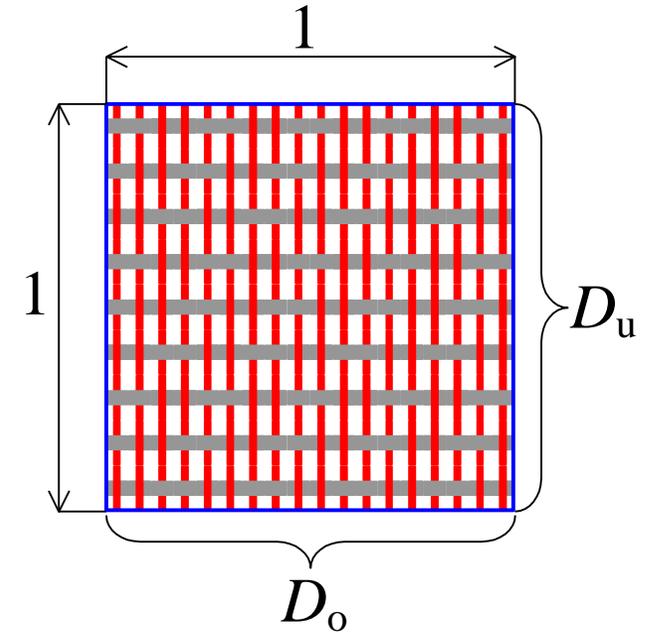
$$C_{f,o} = D_o \sqrt{T_o}$$

$$\kappa_u = z_u / v \leq 1$$

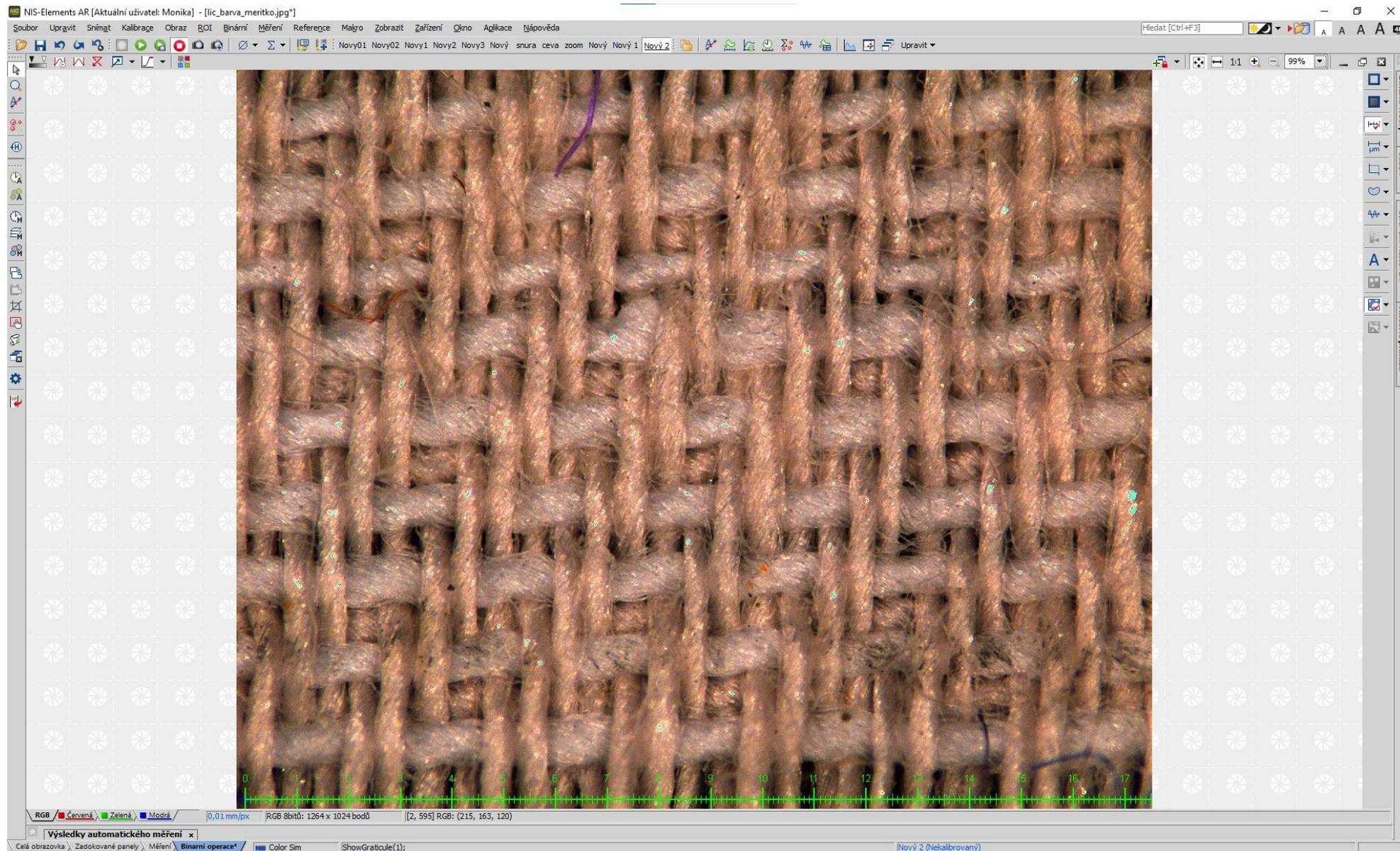
$$C_{f,u} = D_u \sqrt{T_u}$$

$$\kappa = \frac{\kappa_o + \kappa_u}{2}$$

$$C_f = C_{f,o} + C_{f,u}$$



Parameters - interactively in IA...



Parameters - interactively in IA...

The screenshot displays the NIS-Elements AR software interface. The main window shows a close-up image of a brown woven fabric. A measurement tool window titled "Anotace a měření" is overlaid on the image. The window contains various measurement tools and a table for recording data.

Anotace a měření

Anotace: [Tools for annotation]

Délka: [Tools for length measurement]

Plocha: [Tools for area measurement]

Úhel: [Tools for angle measurement]

Poměry: [Tools for ratios]

Počty a Taxonomie: [Tools for counting and taxonomy]

Počty

	Zdroj	Cíle	Komentář
Průměr			
St. odchylka			
Min			
Max			

At the bottom of the interface, there is a status bar with the following information: RGB / Červená / Zelená / Modrá, 0,01 mm/px, RGB 8bitů: 1264 x 1024 bodů, [N/A]. The taskbar at the very bottom shows "Výsledky automatického měření" and "Nový 2 (Nekalibrovaný)".

Parameters - interactively in IA...

The screenshot displays the NIS-Elements AR software interface. The main window shows a close-up image of a brown woven fabric. A semi-transparent measurement tool window titled "Anotace a měření" is overlaid on the image. This tool includes various measurement icons for length, area, angle, and radius, as well as a table for recording data.

The table within the tool window is structured as follows:

	Zdroj	Čísla	Komentář
Průměr			
St. odchylka			
Min			
Max			

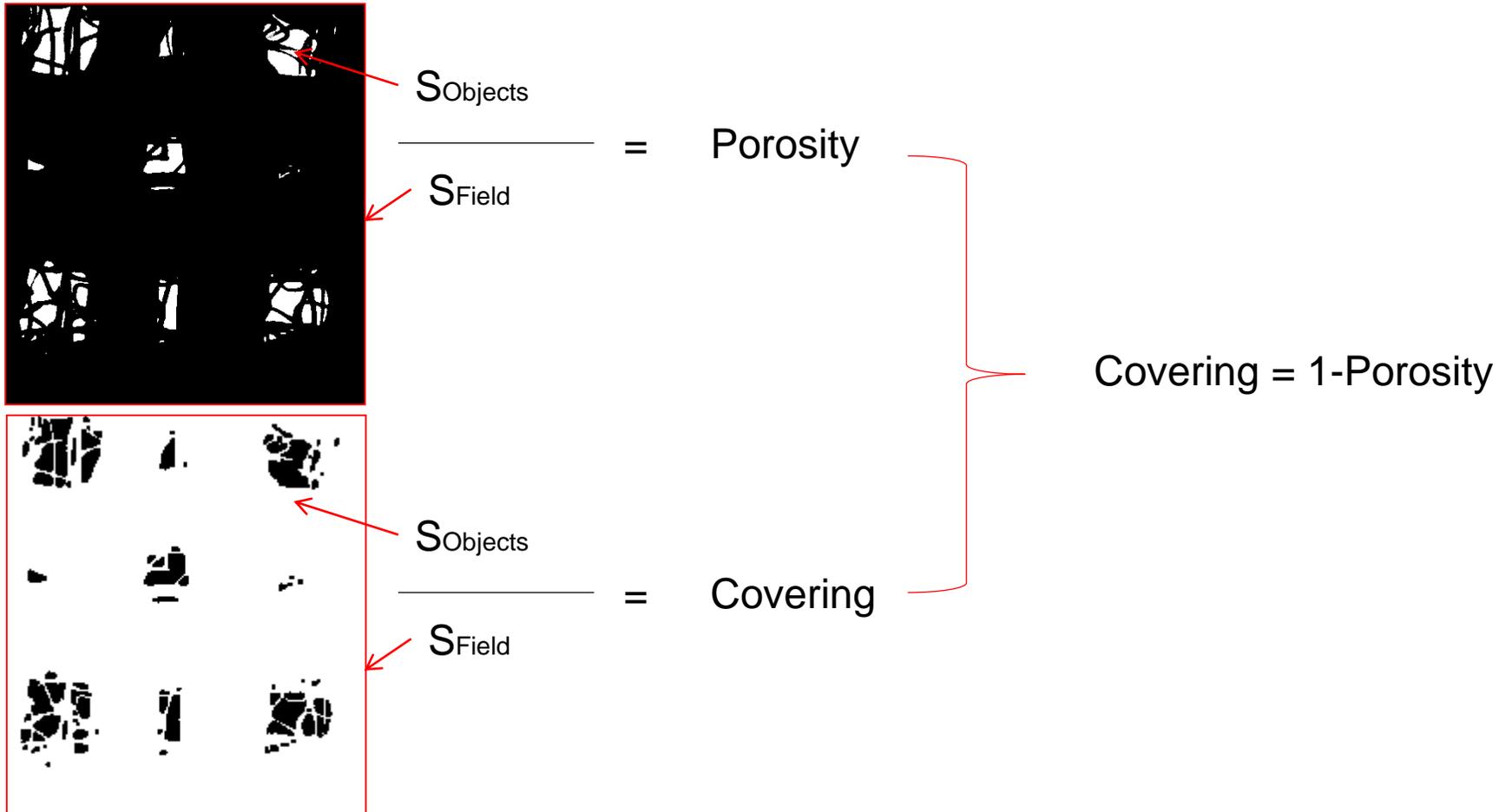
At the bottom of the interface, there is a status bar with the following information: "RGB Červená Zelená Modrá", "0,01 mm/px", "RGB 8bit: 1264 x 1024 bodů", and "[N/A]". A small window at the bottom left shows "Výsledky automatického měření".

External fabric structure - internal standards (see EXA_01):

- IN 23-107-01/01 Fabric covering
- IN 23-110-01/01 Comprehensive evaluation of the surface structure of textiles
- IN 23-111-01/01 Methodology for detecting non-uniformity of fabric images
- IN 23-203-01/01 Objective determination of the degree of wrinkling of fabrics

IN 23-107-01/01 Fabric covering

The standard specifies a procedure for measuring the area coverage of fabrics by projection on a microscope in transmitted light. The method is not suitable for densely finished fabrics.



IN 23-110-01/01 Comprehensive evaluation of the surface structure of textiles

- The test is based on the principle of optical detection of the transverse profile of the surface of the textile material.
- The measurement and evaluation of the surface roughness is performed by scanning virtual cross-sections of the textile or the interface between the surface of the transverse profile of the textile and the background in a randomly selected section of the textile sample.
- The scanning of individual virtual cross-sections is performed at defined, constant distances of the sample displacement in the measurement direction.
- The image of the textile surface relief on the measuring edge is subsequently recorded and processed after each frame. From a series of images of virtual cross-sections of textile samples, standard characteristics of the geometric texture of the surface are calculated, including the replacement of the curves describing the interface of the virtual cross-sections of the textile sample by a Fourier series.
- The standard geometric texture characteristics describe surface roughness, unevenness and shape heterogeneity. The output of the measurements are standardized surface roughness values such as MAD, SD, TP and other characteristics specified in the IN.

IN 23-110-01/01 Comprehensive evaluation of the surface structure of textiles - continued (theory)



Obr. 15: Výstupky profilu



Obr. 16: Prohlubně profilu

Střední aritmetická odchylka profilu MAD / R_a

je základní charakteristikou drsnosti povrchu. Je to střední absolutní odchylka profilu na délce l definovaná pro spojitý profil:

$$MAD = \frac{1}{l} \int_0^l |R(x) - \bar{R}| dx \quad (4)$$

nebo pro diskretní profil:

$$MAD \approx \frac{1}{N} \sum_{i=1}^N |R_i - \bar{R}| \quad (5)$$

kde

- x x-ová souřadnice profilu
- $R(x)$ výška profilu v místě x
- \bar{R} průměrná hodnota výšky profilu
- R_i souřadnice N bodů profilu povrchu v mezích základní délky; $i = 1, 2, 3, \dots, N$
- l délka profilu
- N počet bodů profilu povrchu na délce profilu

Výška nerovnosti profilu z deseti bodů TP / R_z

je definována jako průměr z absolutních výšek pěti nejvyšších výstupků profilu a hloubek pěti nejnižších prohlubní profilu v rozsahu délky profilu:

$$TP = \frac{\sum_{i=1}^5 |R_{pmi}| + \sum_{i=1}^5 |R_{vmi}|}{10} \quad (6)$$

kde

- R_{pmi} výška i -tého nejvyššího výstupku profilu
- R_{vmi} hloubka i -té nejhlubší prohlubně

IN 23-110-01/01 Comprehensive evaluation of the surface structure of textiles - continued (theory)

Střední kvadratická odchylka profilu SD / R_q

V rozsahu své délky je určena vztahem pro spojitý profil:

$$SD = \sqrt{\frac{1}{l} \int_0^l (R(x) - \bar{R})^2 dx} \quad (13)$$

nebo pro diskrétní profil:

$$SD \approx \sqrt{\frac{1}{N} \sum_{i=1}^N (R_i - \bar{R})^2} \quad (14)$$

kde

l délka profilu

N počet vybraných bodů na délce profilu

and more...

IN 23-110-01/01 Comprehensive evaluation of the surface structure of textiles - continued (theory)

An alternative method suitable for non-contact evaluation of surface relief is represented by the use of spatial statistics tools (autocorrelation function, variogram) and fractal dimension.

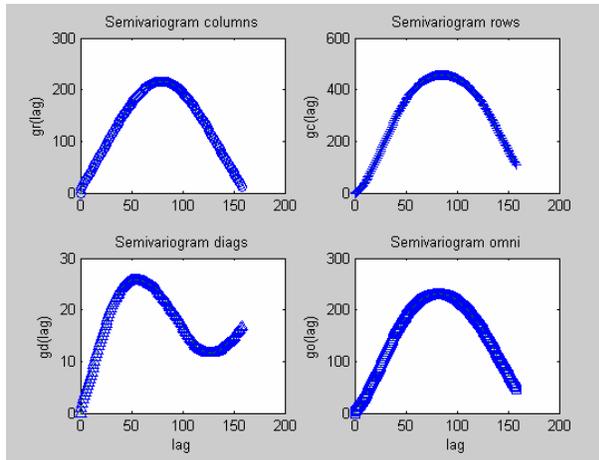
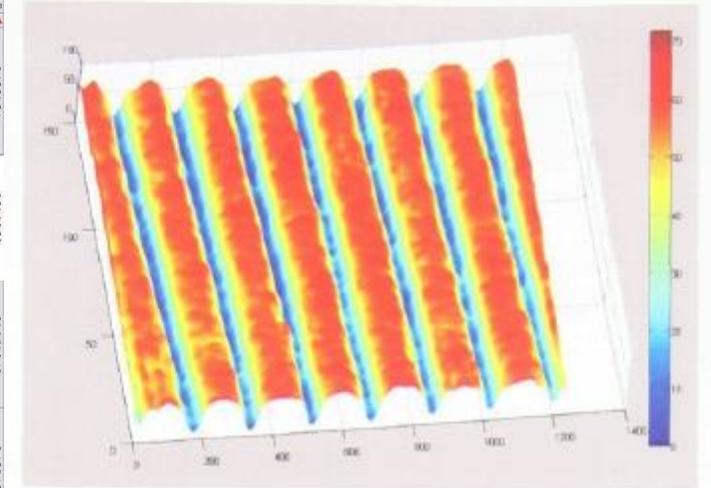
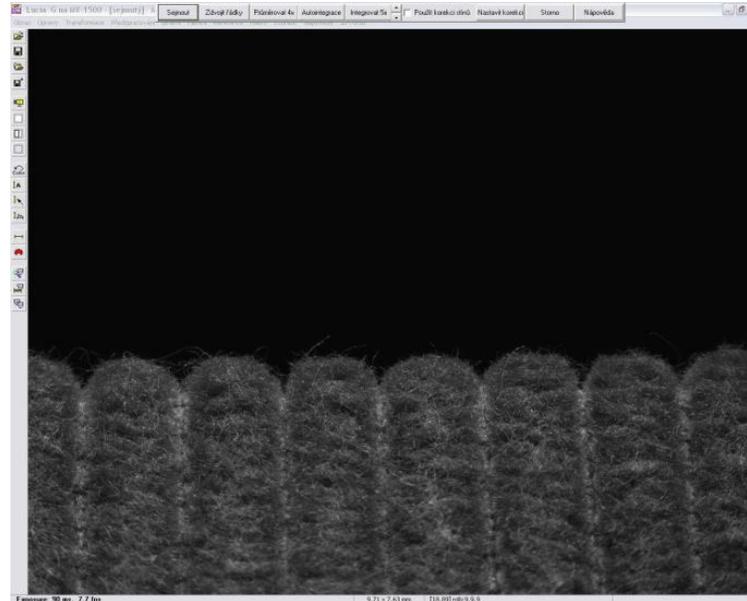


Illustration of semivariograms constructed in column (warp), row (weft), diagonal and omnidirectional directions

IN 23-110-01/01 Comprehensive evaluation of the surface structure of textiles - continued (theory)

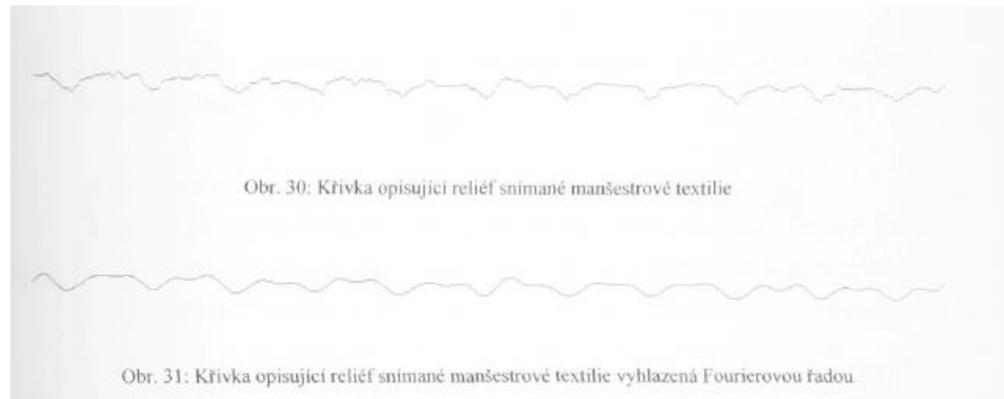


Obr. 3: Detail RCM systému s popisky jednotlivých funkčných častí



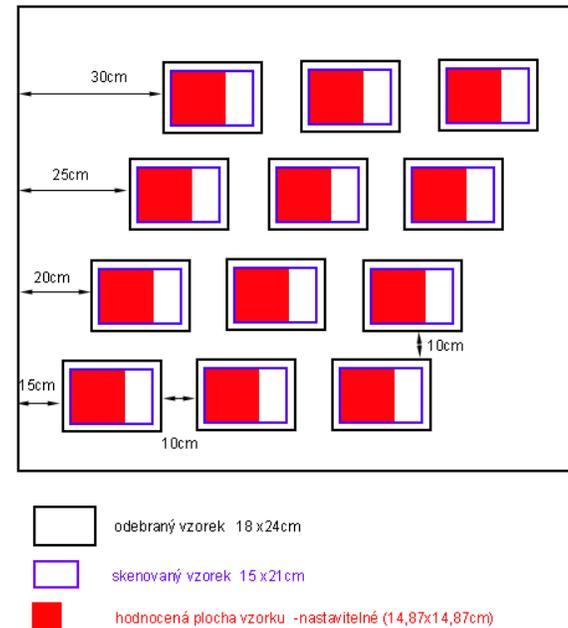
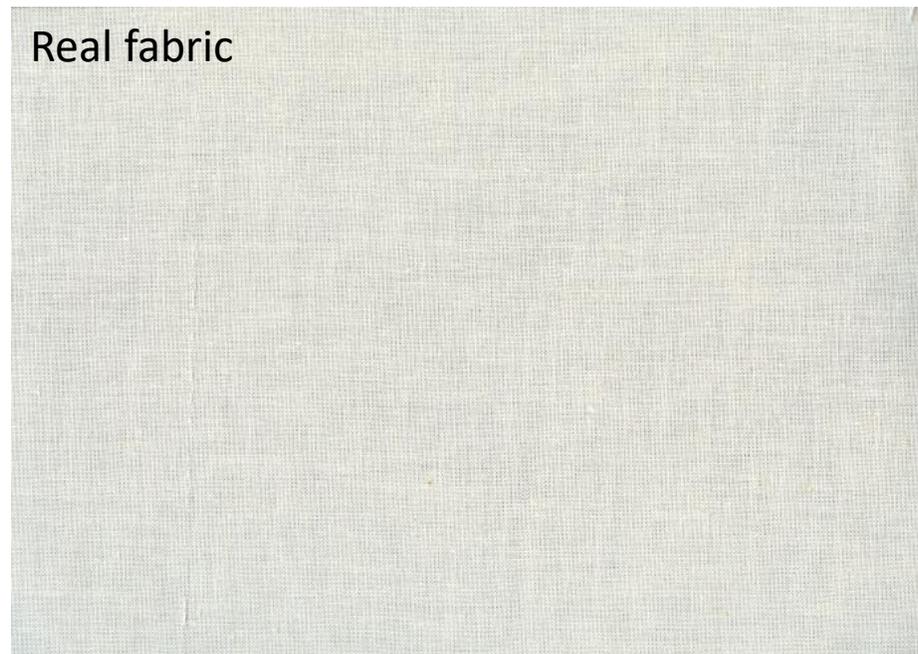
Příklad rekonstrukce 3D obrazu reliéfu povrchu snímaného textilního vzorku

RCM –
Roughness
Contactless
Measurement



IN 23-111-01/01 Methodology for detecting non-uniformity of fabric images

The standard describes a methodology for detecting the visual non-uniformity of a fabric based on the variation of grey levels in the fabric image. The fabric image can be obtained by taking a photograph of the fabric sample or the fabric appearance generated by the Uster-Tester IV can be used.



Recommended fabric sampling

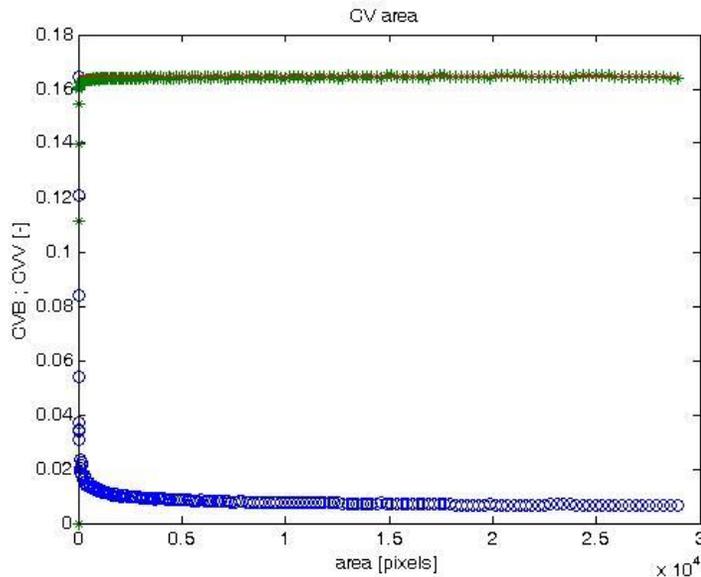
IN 23-111-01/01 Methodology for detecting non-uniformity of fabric images - continued

Vnější plošná variační křivka

Křivka, která vyjadřuje závislost variačního koeficientu stupňů šedi mezi čtverci v obrazu tkaniny na velikosti plochy čtverce. Je definována vztahem:

$$CVB(A) = \frac{\sqrt{S^2}}{\bar{X}} \quad (1)$$

- kde: $CVB(A)$ vnější variační koeficient průměrných stupňů šedi mezi čtverci o ploše A v obrazu tkaniny,
 S směrodatná odchylka průměrných stupňů šedi ve čtvercích o ploše A obsažených v obrazu,
 \bar{X} průměrná hodnota středních stupňů šedi ve čtvercích o ploše A obsažených v obrazu,
 A plocha čtverce.



Area Variation Curve

EXA_12

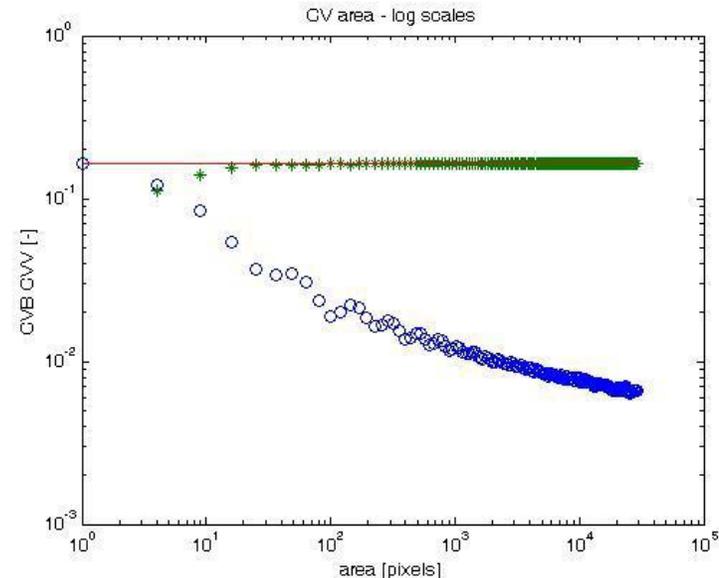
Vnitřní plošná variační křivka

Křivka, která vyjadřuje závislost průměrného variačního koeficientu stupňů šedi uvnitř čtvercových ploch obrazu tkaniny na velikosti sledované plochy čtverce. Je definována vztahem:

$$CVV(A) = \frac{\sum_{i=1}^N CV_i}{N} \quad (2)$$

$$\text{kde: } CV_i = \frac{\sqrt{Sv_i^2}}{\bar{X}_i} \cdot 100 \quad (3)$$

- $CVV(A)$... průměrný variační koeficient stupňů šedi uvnitř čtvercového pole o ploše A ,
 CV_i variační koeficient stupňů šedi v i -tém čtvercovém poli o ploše A ,
 N počet čtvercových ploch,
 Sv_i směrodatná odchylka stupňů šedi v i -tém čtvercovém poli,
 \bar{X}_i průměrná hodnota stupňů šedi v i -tém čtvercovém poli.

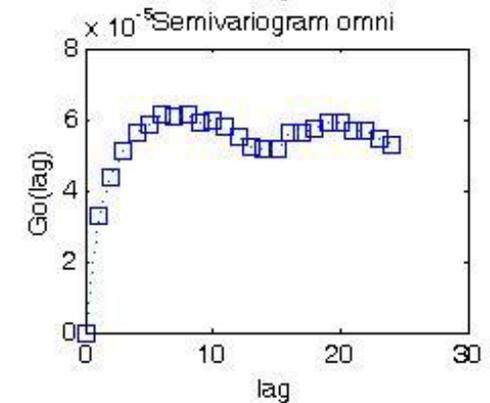
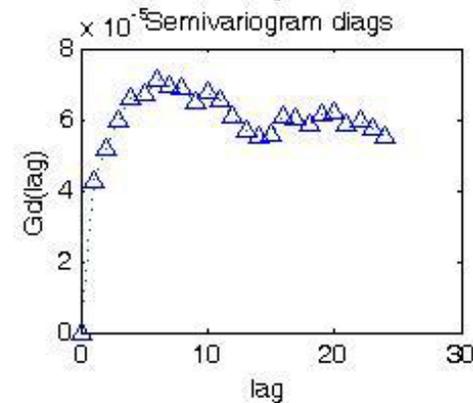
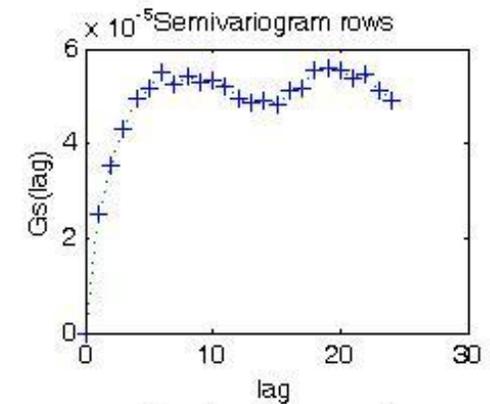
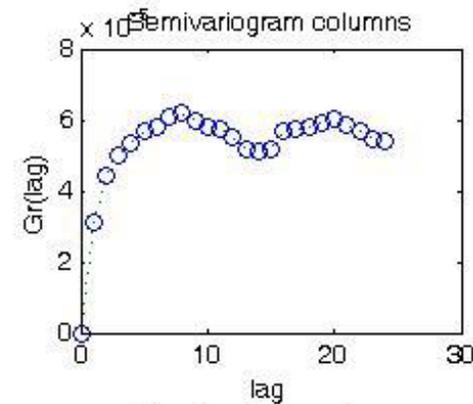


IN 23-111-01/01 Methodology for detecting non-uniformity of fabric images - continued

Semivariogram

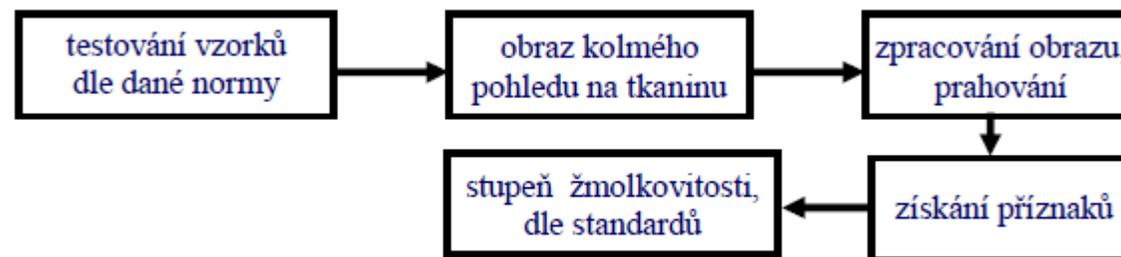
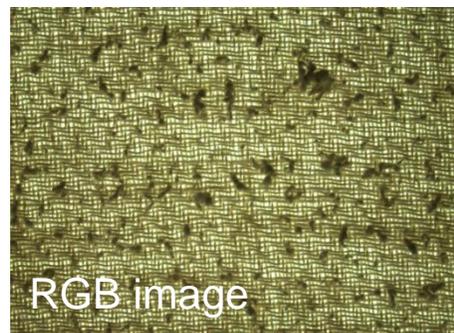
Zde vyjadřuje prostorovou nepodobnost mezi hodnotami průměrných stupňů šedi v místech x_i a x_j . Obraz tkaniny je rozdělen na síť se čtvercovými poli. Středů polí jsou místa x , místu x je přiřazena průměrná hodnota stupně šedi v daném čtverci $z(x_i)$. Semivariogram je obecně definován jako polovina rozptylu rozdílů ($z(x_i) - z(x_i+lag)$) [1]:

Veličina lag zde vyjadřuje směrový (posunový) vektor (0° ; 90° , 45°).

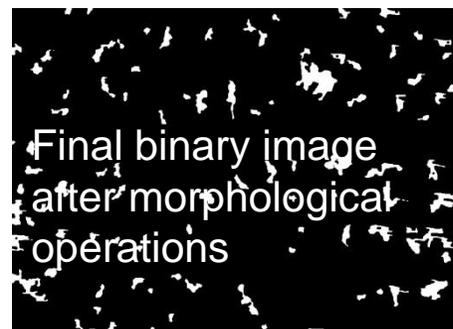
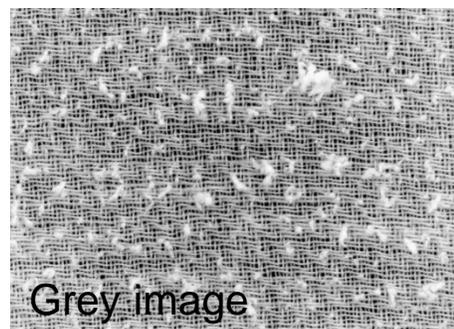


IN 23-203-01/01 Objective determination of the degree of pilling of fabrics

The standard specifies a procedure for measuring the wrinkling of fabrics by projection on a microscope in transmitted light. The method is not suitable for very dark fabrics and fabrics with a distinctive pattern.

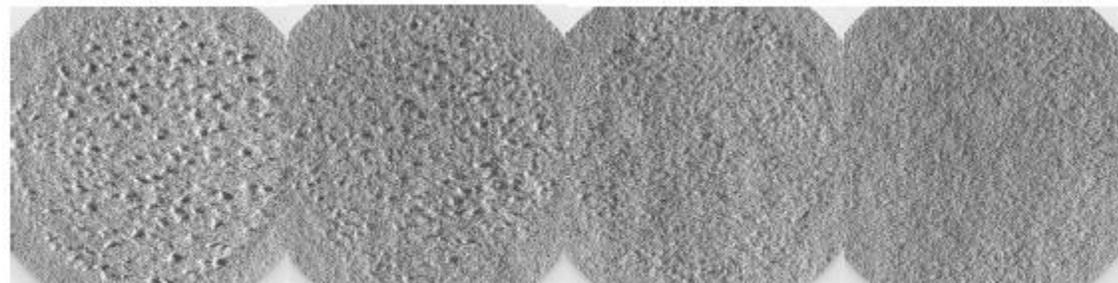


Obr. 2 Schéma objektivního hodnocení žmolkovitosti tkanin v ploše textilie



označení tkaniny	průměrný počet žmolků	celková plocha žmolků [cm ²]	podíl plochy žmolků [%]	hustota žmolků na 100cm ²	průměrná plocha žmolku [mm ²]	ekvivalent. průměr žmolku [mm]	průměrný obvod žmolku [mm]
0 PP	25 <15;35>	1,66 <0,91;2,41>	2,30 <2,09;2,51>	15 <12;18>	6,994 <6,506;7,482>	0,851 <0,822;0,88>	3,41 <2,62;3,12>

IN 23-203-01/01 Objective determination of the degree of wrinkling of fabrics - continued



Etalon W12 Etalon W23 Etalon W34 Etalon W45

Obr. 3 Etalony Martindale



Stupeň 1 Stupeň 3 Stupeň 5

Obr. 4 Etalony, komorový žmolkovací přístroj

Tabulka 1 Charakteristiky etalonů přístroje Martindale

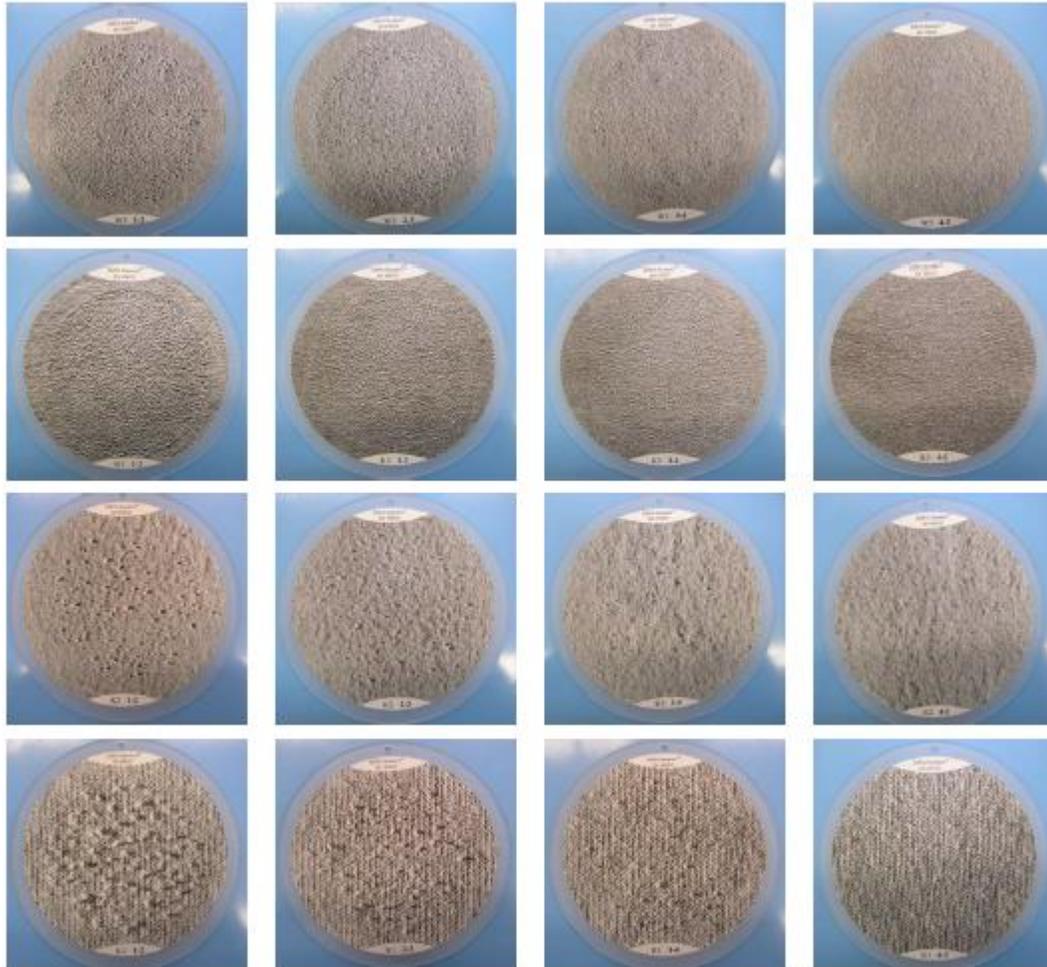
Označení etalonu	Průměrný počet žmolků	Celková plocha žmolků, cm ²	Podíl plochy žmolků, %	Hustota žmolků na 100cm ²	Průměrná plocha žmolku, mm ²	Ekvivalentní průměr žmolku, mm	Průměrný obvod žmolku, mm
W12	99	1,96	2,54	128	1,54	1,42	4,74
W23	75	1,85	2,4	97	2,33	1,72	5,98
W34	41	0,66	0,85	53	1	1,13	3,72
W45	18	0,23	0,3	23	0,77	0,99	3,16

Tabulka 2 Charakteristiky etalonů komorového žmolkovacího přístroje

označení etalonu	průměrný počet žmolků	Celková plocha žmolků, cm ²	Podíl plochy žmolků, %	Hustota žmolků na 100cm ²	Průměrná plocha žmolku, mm ²	Ekvivalentní průměr žmolku, mm	Průměrný obvod žmolku, mm
stupeň 1	74	0,7	0,76	80	0,72	0,96	2,97
stupeň 2	51	0,47	0,51	55	0,68	0,93	2,87
stupeň 3	27	0,23	0,25	29	0,64	0,9	2,77
stupeň 4	16	0,13	0,14	17	0,58	0,86	2,63
stupeň 5	4	0,02	0,02	4	0,52	0,82	2,48

The data are compared to the benchmarks using modus and median.

An objective system for assessing friability using the gradient field method and spatial data analysis – Ing. L. Techniková, PhD. [4]



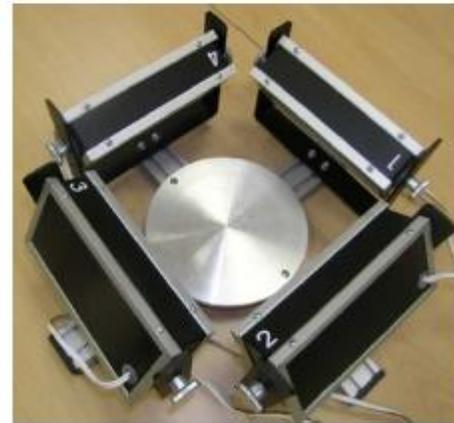
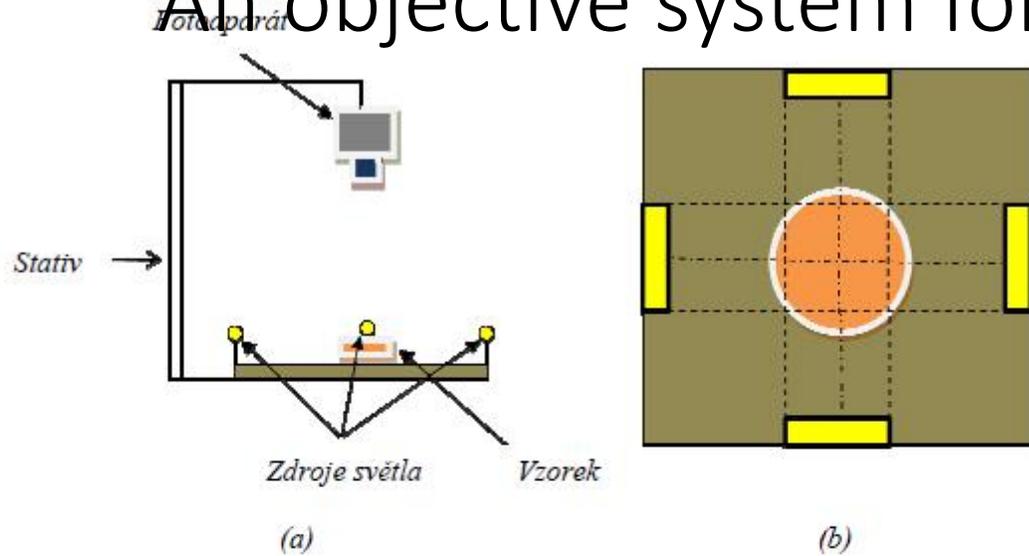
Obr. 5 Obrázky čtyř sad fotografických etalonů pro stanovení mezistupně žmolkovitosti vzorků různých typů textilií z přístroje Martindale.



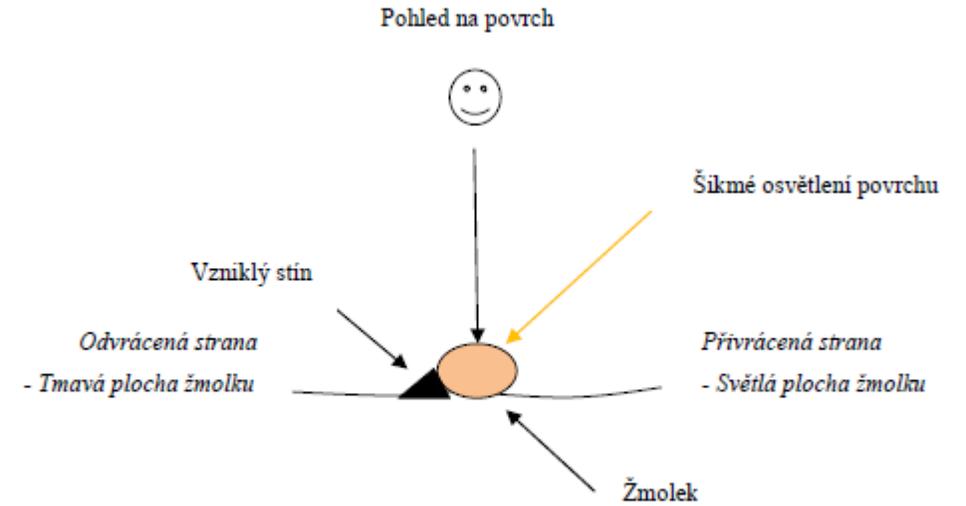
Obr. 7 Tři sady fotografických etalonů pro stanovení stupně žmolkovitosti vzorků různých typů textilií testovaných na Komorového žmolkovacího přístroje.

An objective system for the assessment of wrinkling...

[4] - continued

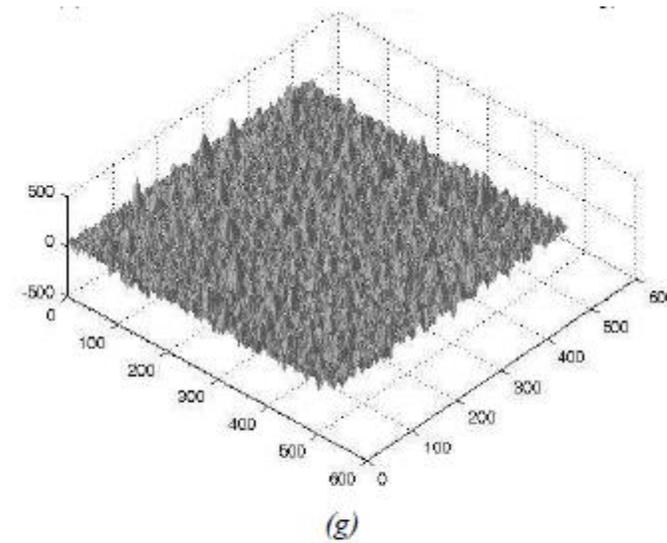
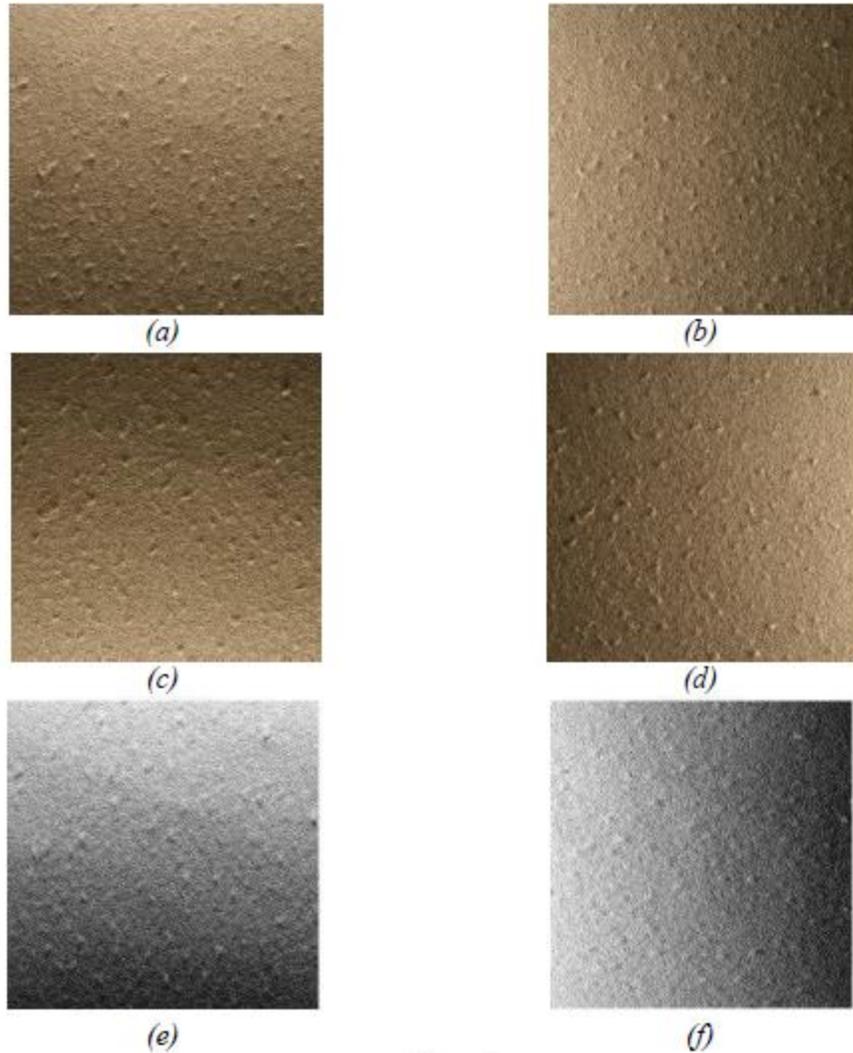


Obr. 12 Schéma systému pořízení obrazu vzorků se žmolky, (a) bokorys a (b) půdorys systému. (c) Reálný systém snímání obrazu vzorků a (d) reálný světelný systém.



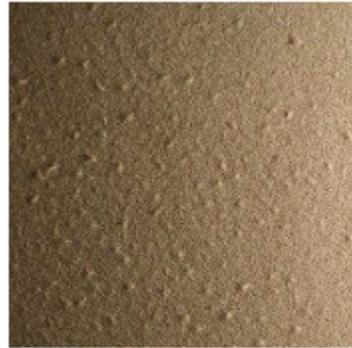
Obr. 17 Princip metody pro tvorbu 3D povrchu textilie se žmolky na základě formování tvaru reliéfu ze šikmého osvětlení vzorku.

An objective system for the assessment of pilling... [4] - continued

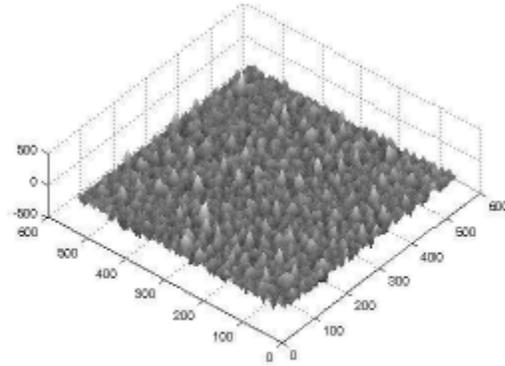


Obr. 20 Sada čtyř obrázků vzorku B9 osvětleného (a) shora I_a , (b) zleva I_l , (c) ze spodu I_b , (d) zprava I_r , výsledné obrázky po odečtení obrázků v příslušných směrech (e) g_y a (f) g_x . (g) 3D povrch vzorku B9 získaný pomocí metody gradientních polí ze sady 4 obrázků.

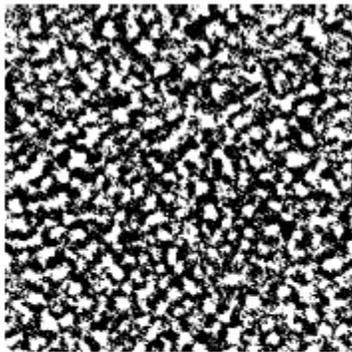
An objective system for the assessment of pilling... [4] - continued



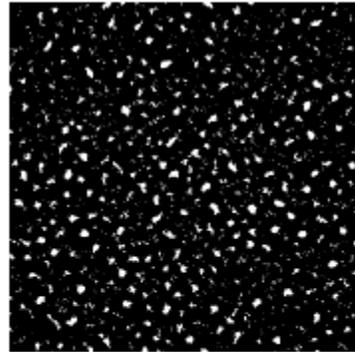
(a)



(b)

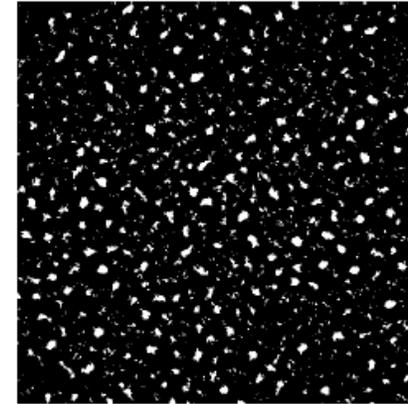


(c)

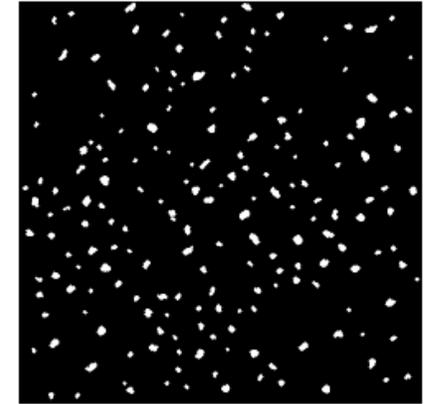


(d)

Obr. 22 (a) Barevný obraz vzorku B9 osvětlený zprava, (b) jeho 3D povrch, (c) binární obraz vzorku po segmentaci obrazu Otsuovou metodou a (d) po lokálním prahování podle Niblacka.



(a)

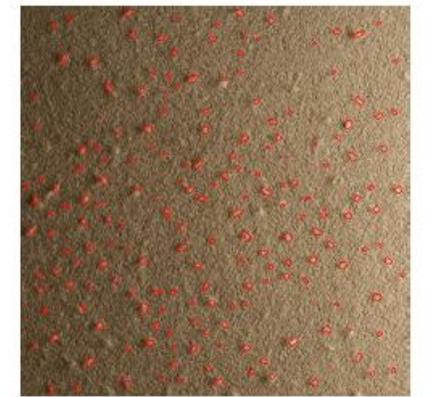


(b)

Obr. 25 (a) Binární obraz vzorku B9 bez úprav a (b) finální binární obraz vzorku B9 po všech aplikovaných úpravách objektů.



(a)



(b)

Obr. 26 (a) Původní barevný obraz vzorku B9 osvětlený zprava a (b) barevný obraz vzorku s detekovanými žmolky ohraničenými červenou barvou.

The samples are processed by the proposed algorithm, for each sample, the characteristics of the wrinkling are calculated from the binary image: number of wrinkles, average, total wrinkle area, average wrinkle perimeter, wrinkle density and wrinkle contrast.

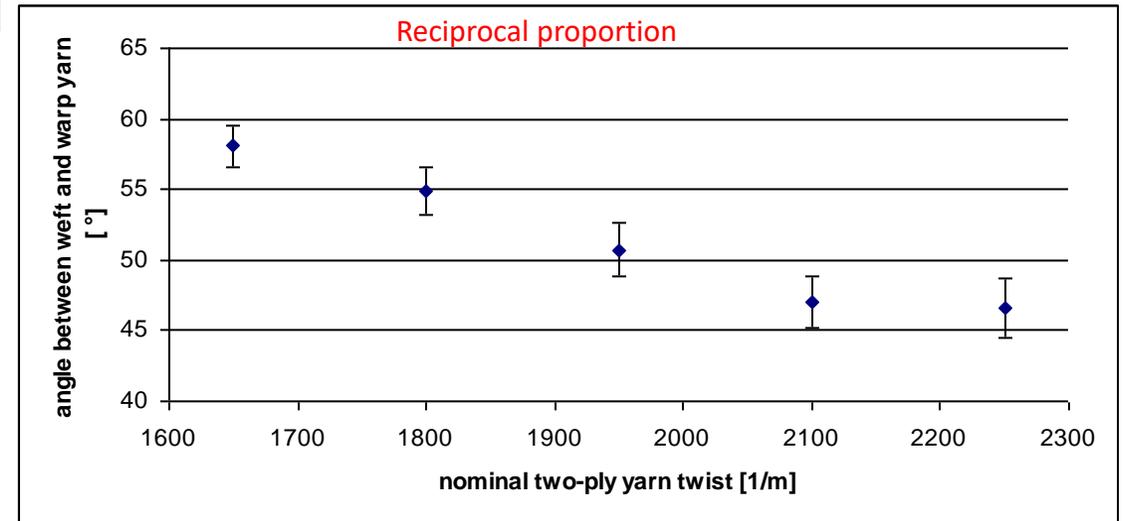
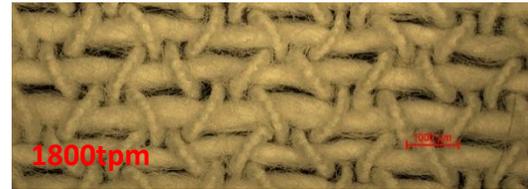
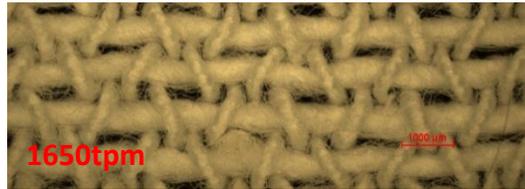
Experiment I - structure of cotton bandages

Bandage: *Idealbinden*

Plane wave

Warp: 2x20tex, cotton, 2250tpm (zz/S, ss/Z – periodic variation), ring spun

Weft: 50tex, cotton, 600tpm, open end spun



Experiment I - structure of cotton bandages - continued

- Specific deformation D [%]:
$$D[\%] = \frac{l_1 - l_0}{l_0} \cdot 100$$
- Elastic deformation R [%]:
$$R[\%] = \frac{l_1 - l_2}{l_1 - l_0} \cdot 100$$

- l_0 ... non-stressed length of bandage on measuring bench
- l_1 ... pre-tensioned length of bandage by 5kg (for 10cm wide bandage)
- l_2 ... length of bandage after 1minute of tensioning and 2 minutes of relaxation without pre-tension

	l_0 [m]	l_1 [m]	D [%]	l_2 [m]	R [%]
IB 1650	2	3,31	65,6 <65,2;66,01>	2,39	69,9 <69,68;70,33>
IB 1800	2	3,7	85,3 <84,41;85,65>	2,49	71,4 <71,14;71,67>
IB 1950	2	3,93	96,3 <95,87;96,63>	2,52	72,8 <72,53;72,98>
IB 2100	2	4,08	103,9 <103,37;104,39>	2,65	68,7 <68,29;69,12>
IB 2250	2	4,11	105,3 <104,83;105,73>	2,68	68,7 <68,45;68,95>

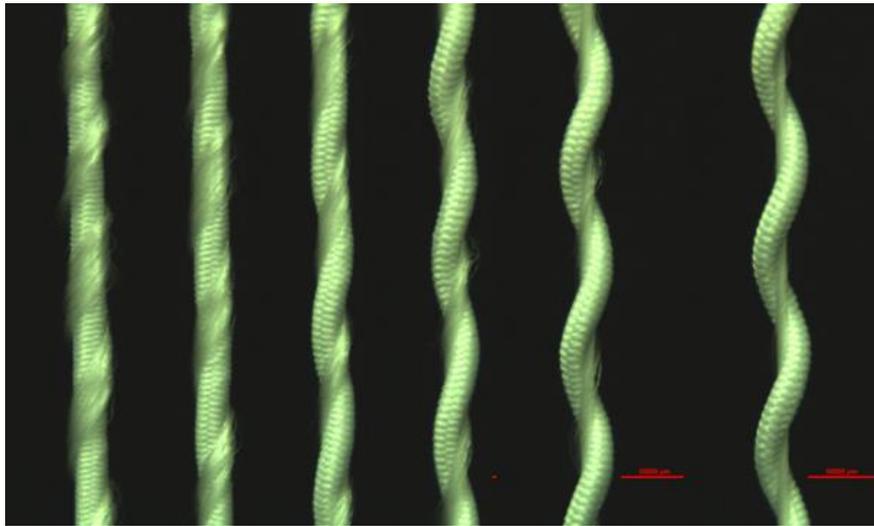
L&R guarantees more than 90% of specific elongation and more than 60% of elastic deformation of bandage after its rolling.

Footnote:
just three samples of five fulfill tolerance given by the company.

Experiment II - AUXETIC WOVEN FABRICS – PORES' PARAMETERS OBSERVATION

Helix Auxetic Yarn – HAY (patent by Hook and col. 2006)

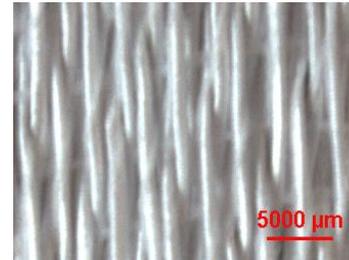
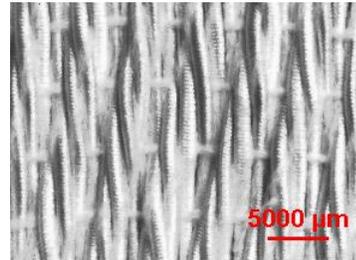
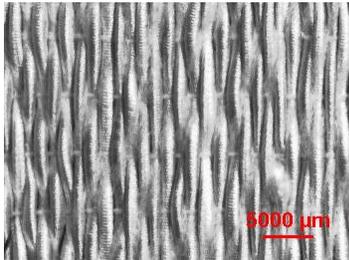
- core – industrially produced polyester elastic band with the fineness of 922 tex
- sheet – polypropylene multifilament yarn 2x72 tex with preventive twist



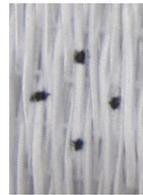
Experiment II – AUXETIC WOVEN FABRICS – PORES' PARAMETERS OBSERVATION – pokračování

Woven fabrics

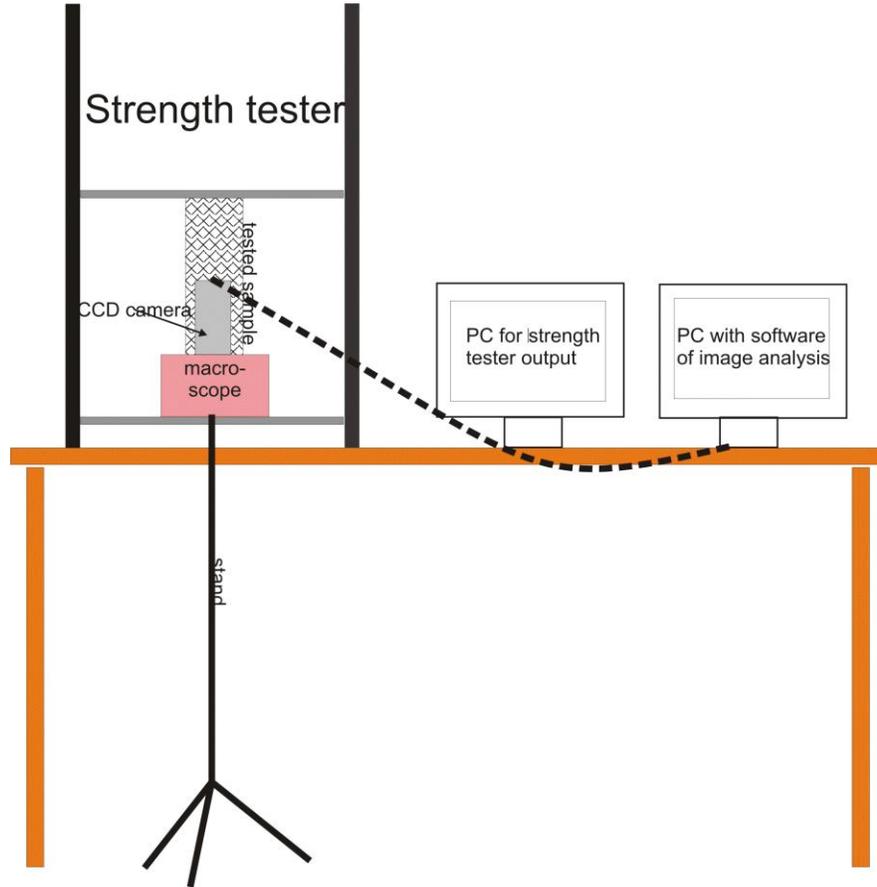
- **Material:**
 - Weft – HAY (sett - 2 threads/cm)
 - Warp - polypropylene two ply multifilament yarn 2x72 tex (9 threads/cm)
- **Patterns:** plain, 2/2 twill and 3/5 (3) satin
- **Machine:** hand weaving loom with eight shafts



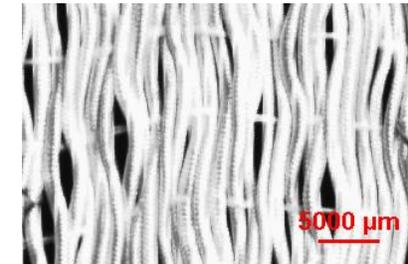
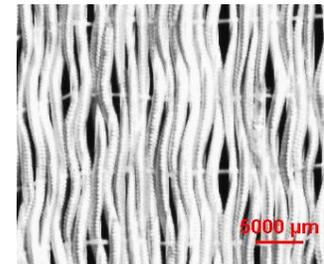
Experiment II – AUXETIC WOVEN FABRICS – PORES' PARAMETERS OBSERVATION – continued



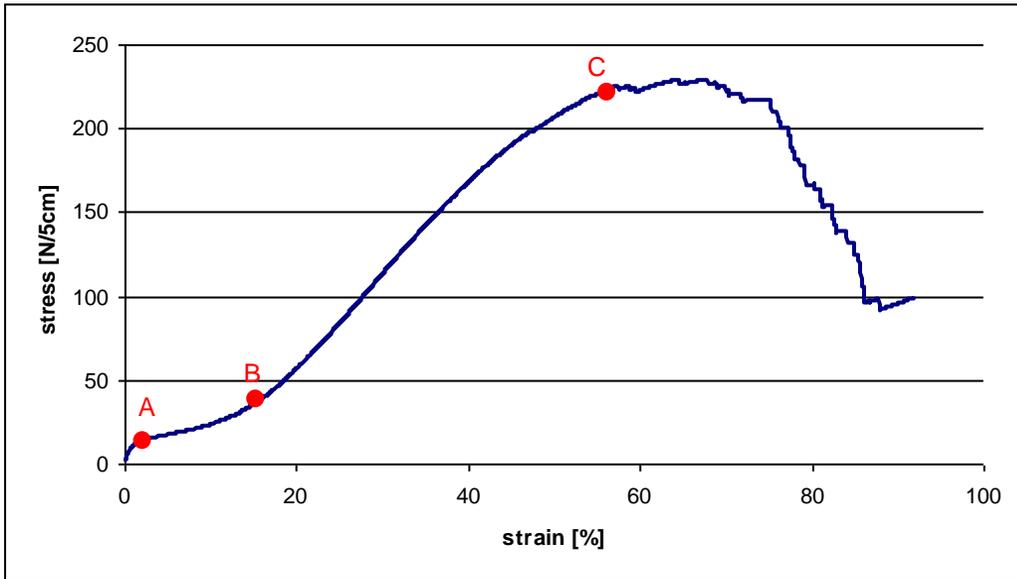
Test



- each 10th second captured by CCD camera to the system of image analysis NIS Elements
- Images of the fabrics in deformation of about 40%



Experiment II – AUXETIC WOVEN FABRICS – PORES' PARAMETERS OBSERVATION – continued

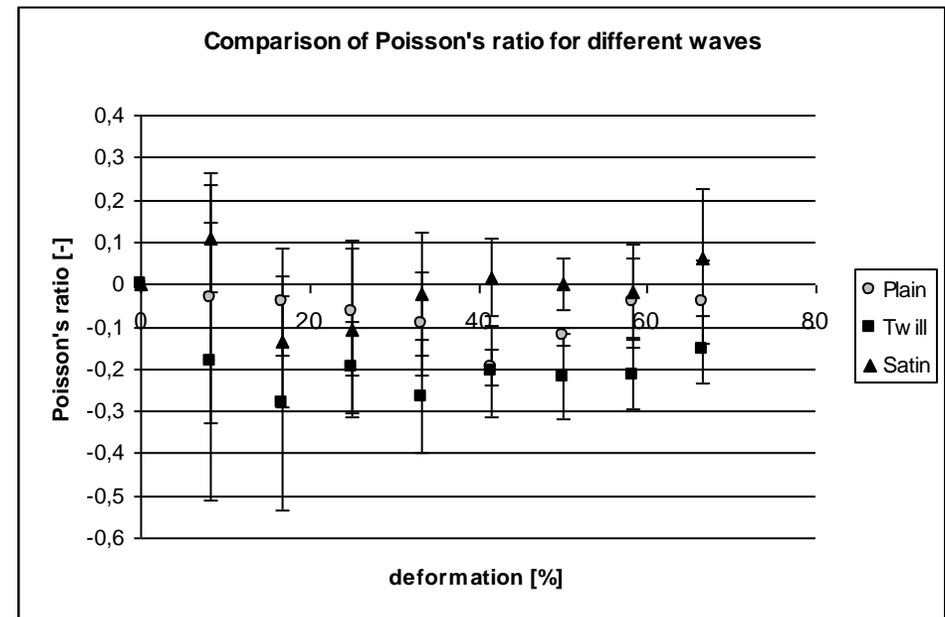


Stress-strain curve of twill pattern:

- 0 – A, the fabric is stiff, caused by friction between two constituents of the HAY
- linear region A – B, represents decrimping of weft threads
- B – C the second linear part, the HAYs are strained themselves and pores' size is expanded
- after C – breakage of thinner yarn in the HAY and related straightening of the second part of the HAY

Results I
– Poisson's ratio

- the most auxetic and stable (in all tested deformations) - twill wave followed by plain and satin waves

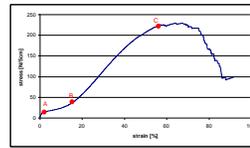


Experiment II – AUXETIC WOVEN FABRICS – PORES' PARAMETERS OBSERVATION – continued

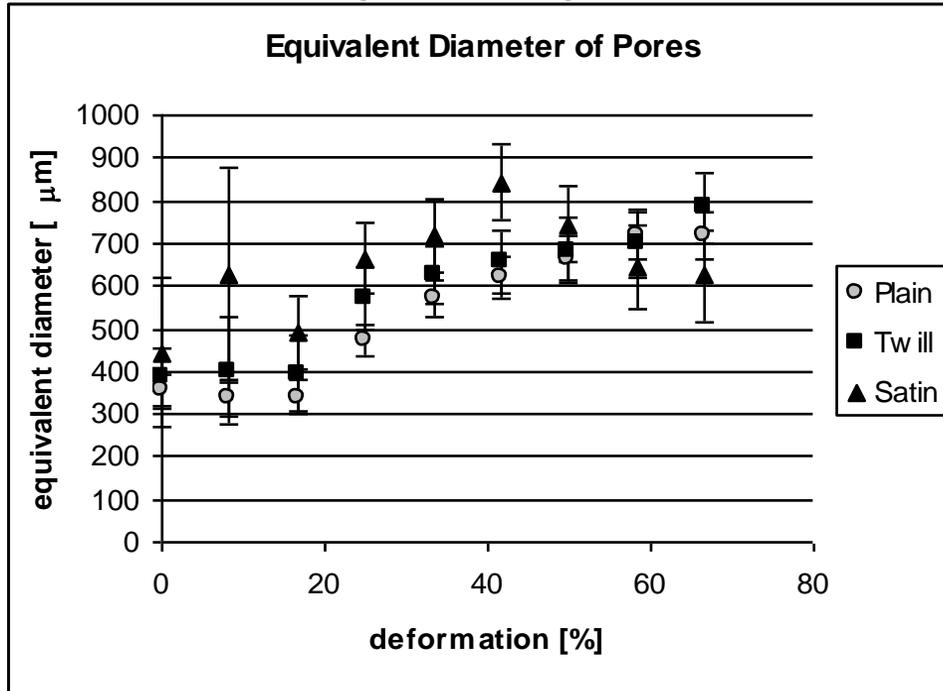
Results II – pores' parameters

- **Porosity** – areal fraction, means total pores' area divided by measured area of woven fabric
- **Number of pores in m^2**
- **Equivalent diameter of pore** – diameter of circle with the same area like the pore has
- **Minimal Feret diameter** – minimal perpendicular distance of tangents to the pore's border
- **Maximal Feret diameter** – maximal perpendicular distance of tangents to the pore's border
- **Circularity of pore** – ratio between real area of pore and area of circle with the same perimeter like the real pore has. Circularity of circle is equal to 1.

Experiment II – AUXETIC WOVEN FABRICS – PORES' PARAMETERS OBSERVATION – continued

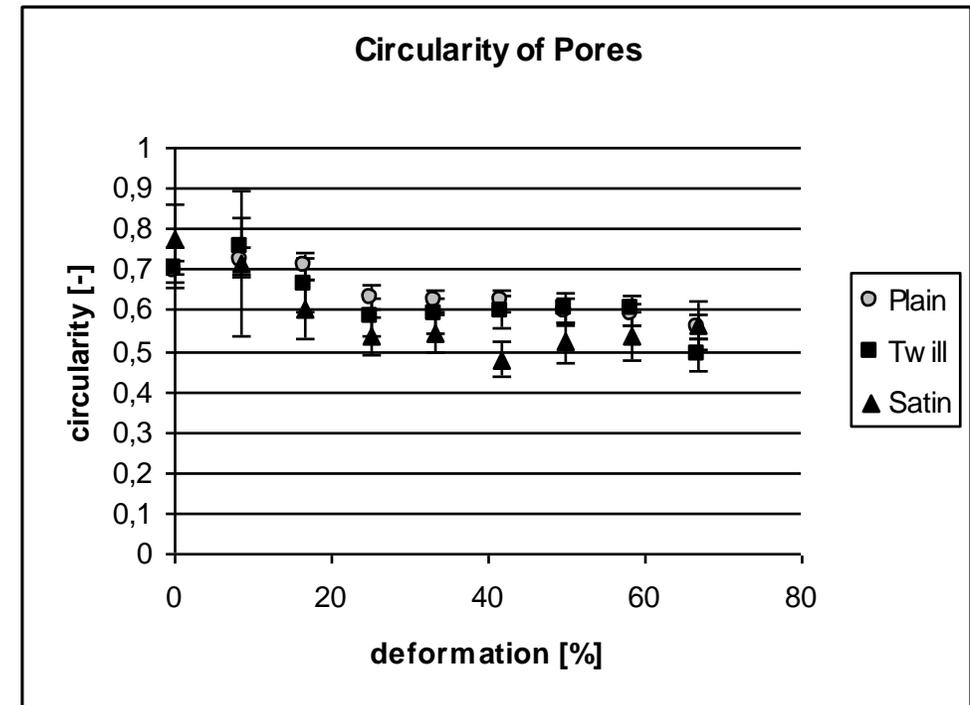


Results II – pores' parameters

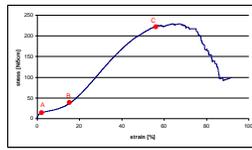


- during decrimping – equivalent diameter is constant
- during pores' expansion – equivalent diameter increases

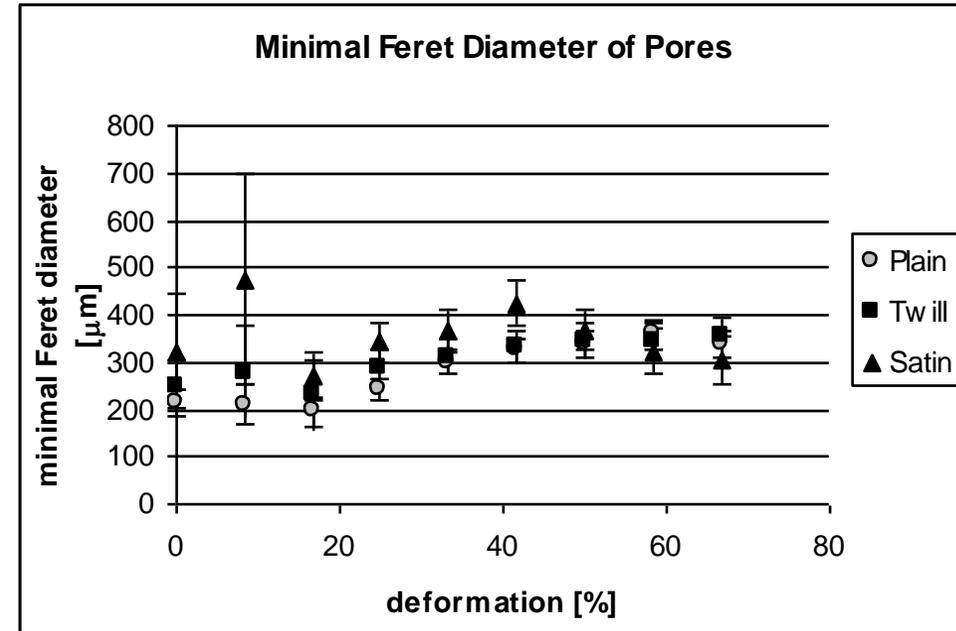
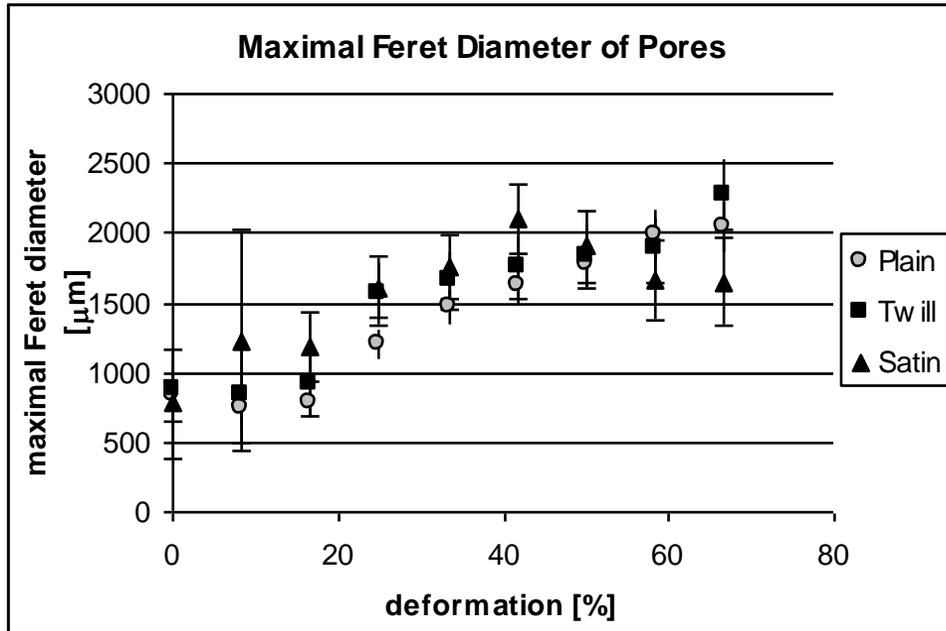
- till aprox. 20% of deformation – threads' decrimping => decreasing of circularity
- after that pores' expansion – circularity is constant



Experiment II – AUXETIC WOVEN FABRICS – PORES' PARAMETERS OBSERVATION – continued

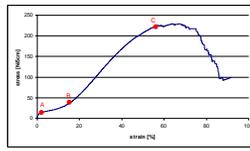


Results II – pores' parameters

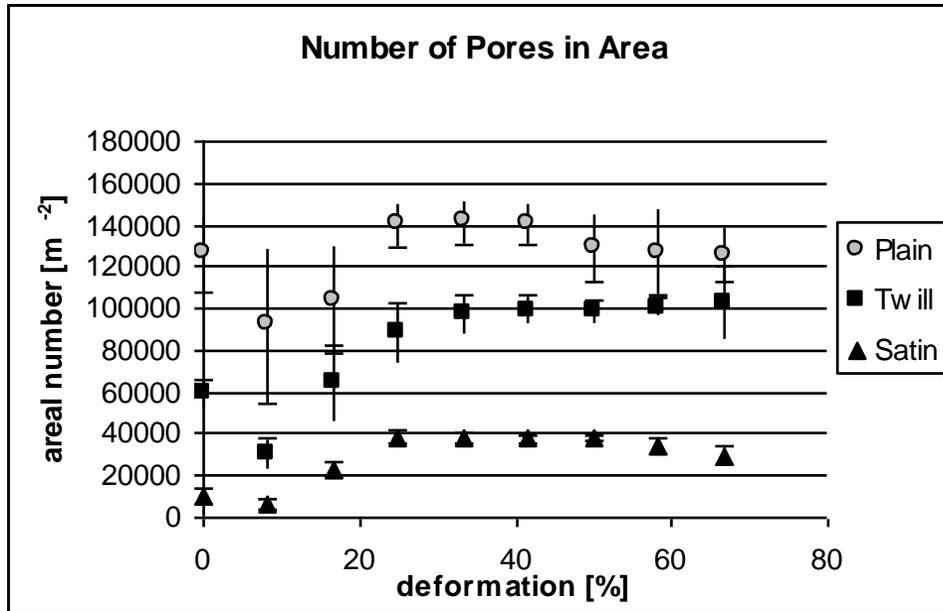


- during decrimping – maximal and minimal Feret's diameter is constant
- during pores' expansion – these diameters increase

Experiment II – AUXETIC WOVEN FABRICS – PORES' PARAMETERS OBSERVATION – continued

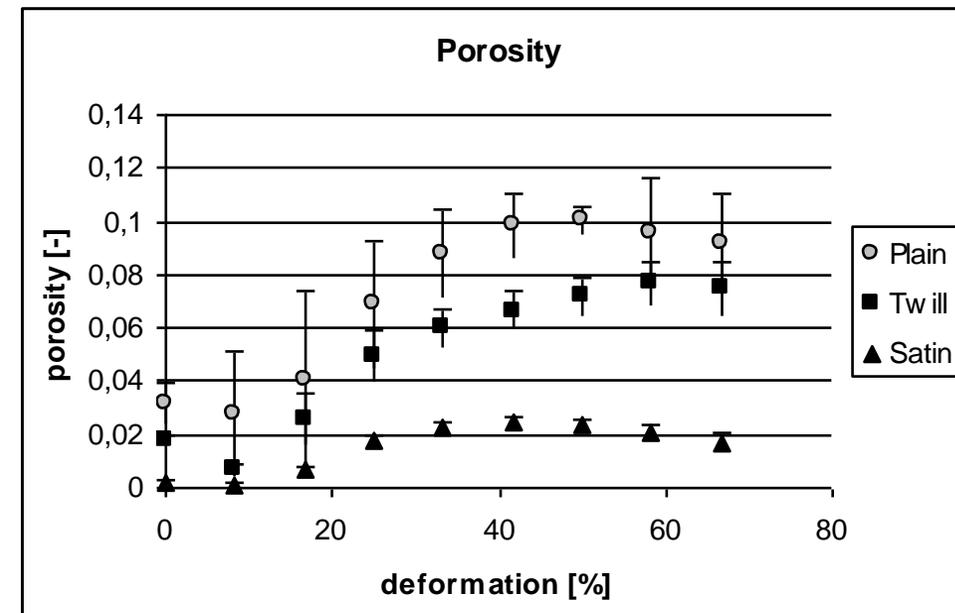


Results II – pores' parameters

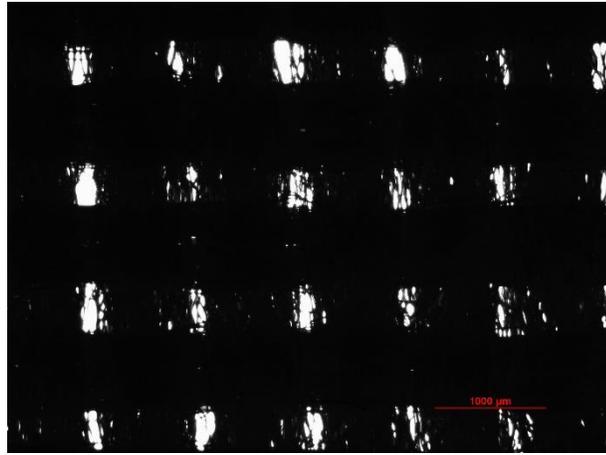


- during decrimping – number of pores generally increases
- during pores' expansion – this parameter is almost constant

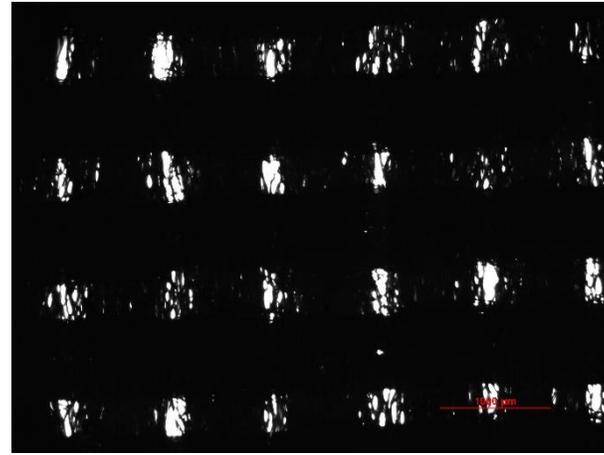
- during decrimping – porosity is almost constant
- during pores' expansion – these parameter increases



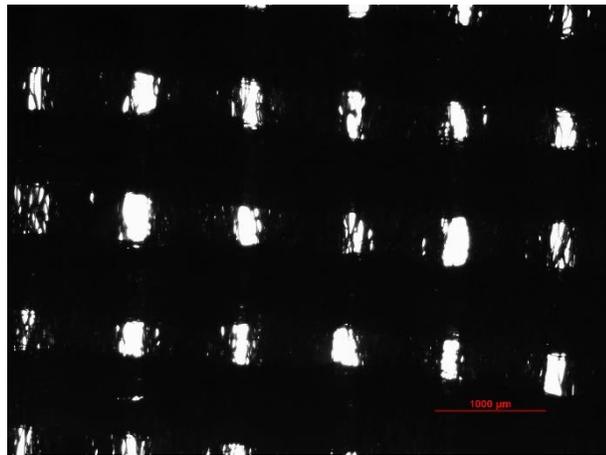
Experiment III - Fabric analysis - porosity before and after fabric relaxation



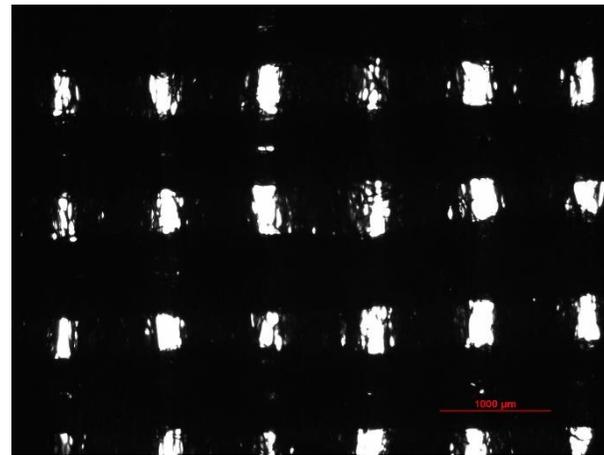
vz 01



vz 01_relax

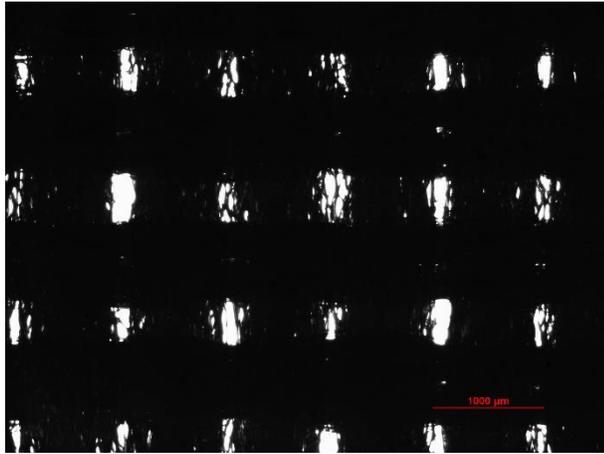


vz 02

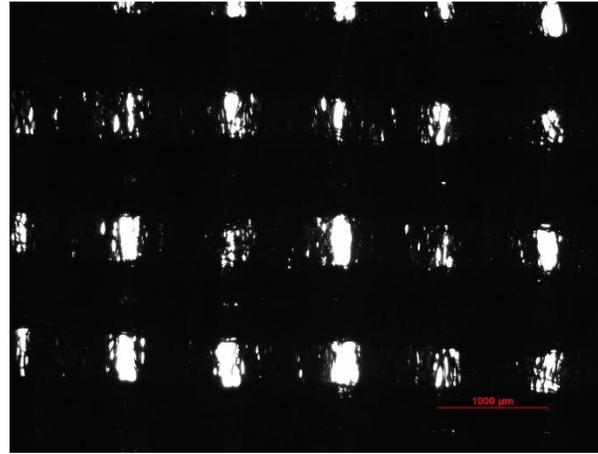


vz 02_relax

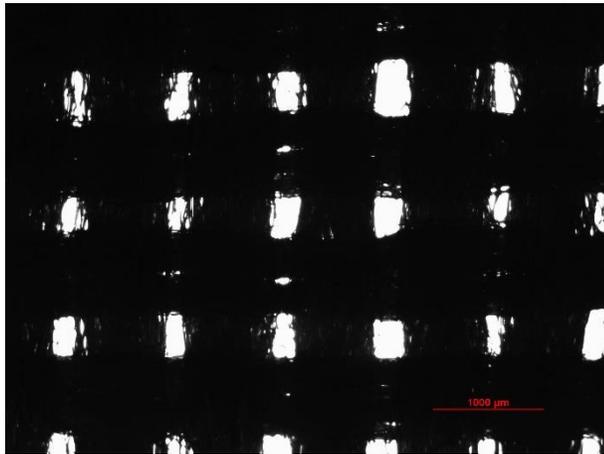
Experiment III - Fabric analysis - porosity before and after fabric relaxation – continued



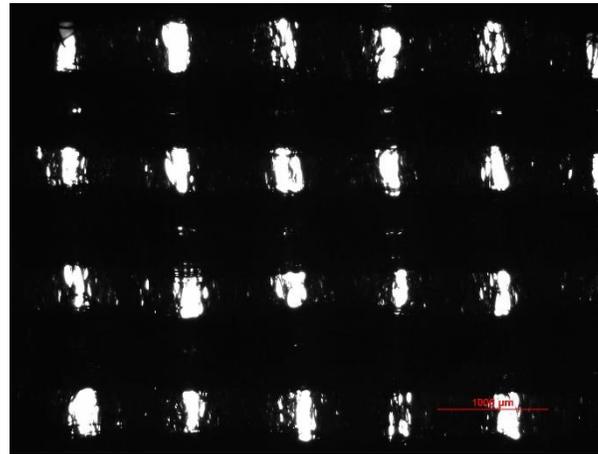
vz 03



vz 03_relax

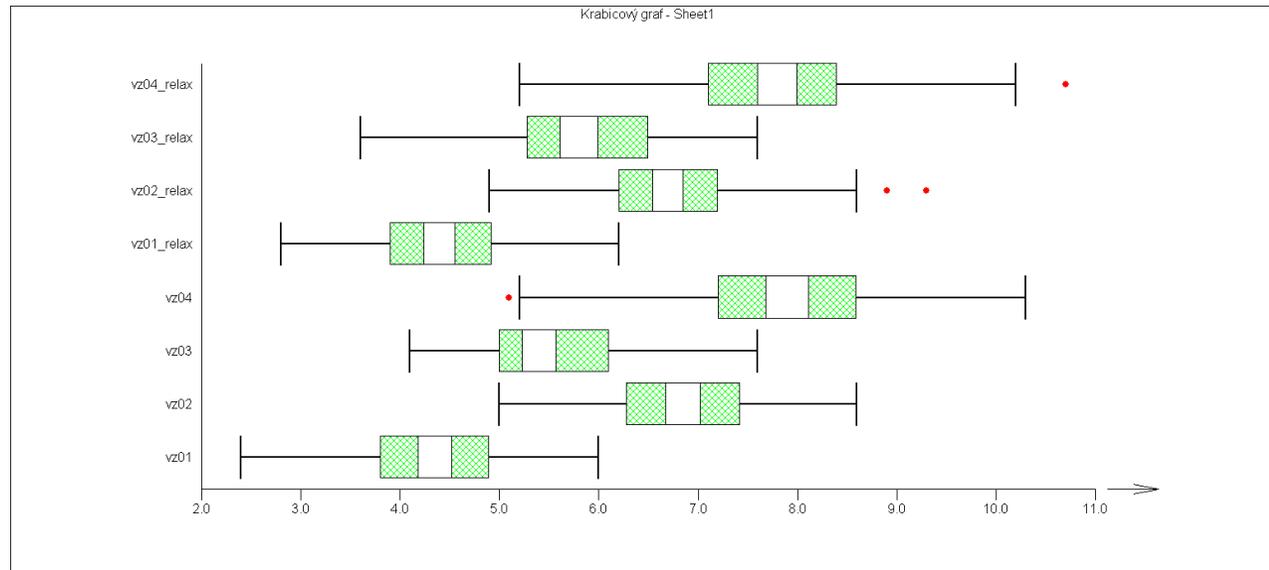


vz 04



vz 04_relax

Experiment III - Fabric analysis - porosity before and after fabric relaxation – continued



From the graphical representation and statistical evaluation, it is clear that there are no statistically significant differences between the pre- and post-relaxation tests. Thus, the samples retain their original difference as they had before relaxation.

References used:

1. Bohuslav Neckář: TKANINY 1 – DEFINICE, SOUVISLOSTI, TU Liberec, KTT, power point prezentace pro předmět STR
2. Výběr interních norem KTT – viz text prezentace
3. Bleša, M.: Komplexní hodnocení povrchové struktury, disertační práce, FT, TUL, Liberec, 2009
4. Techniková, L.: OBJEKTIVNÍ SYSTÉM HODNOCENÍ ŽMOLKOVITOSTI S VYUŽITÍM METODY GRADIENTNÍCH POLÍ A PROSTOROVÉ ANALÝZY DAT, disertační práce, FT, TUL, Liberec, 2015
5. Výběr publikací a zpráv autorky, práce vedené autorkou