TECHNICKÁ UNIVERZITA V LIBERCI

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

Staple yarn and multifilament - internal structure by image analysis

Ing. Bc Monika Vyšanská, PhD.

Financováno Evropskou unií NextGenerationEU

Národní plán obnovy

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

Staple yarn and multifilament - internal structure by image analysis

Ing. Monika Vyšanská, PhD.

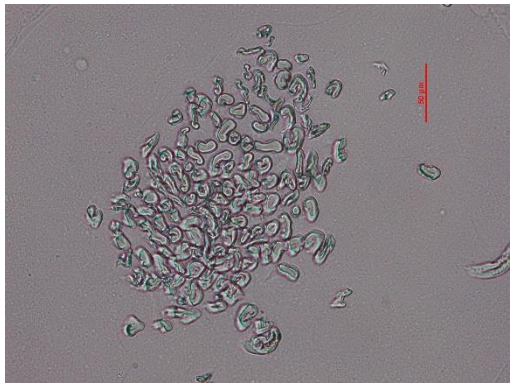
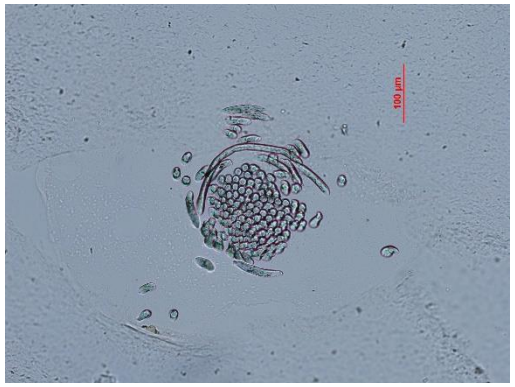
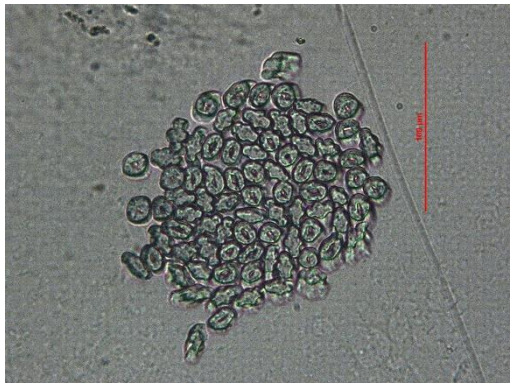
Thread - internal structure

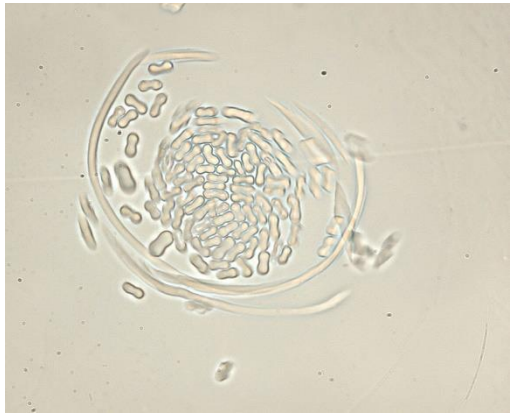
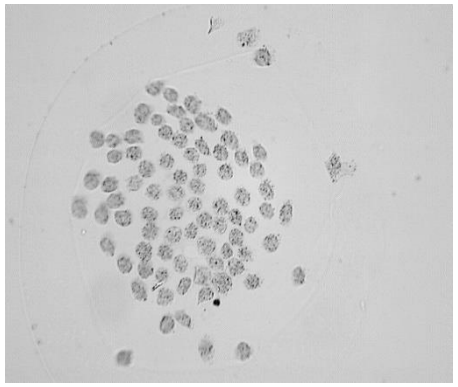
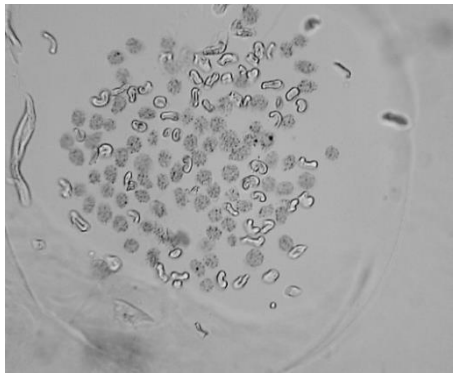
IMAGES:

Cross-sections - optical microscopy

Cross-sections - micro (nano) CT

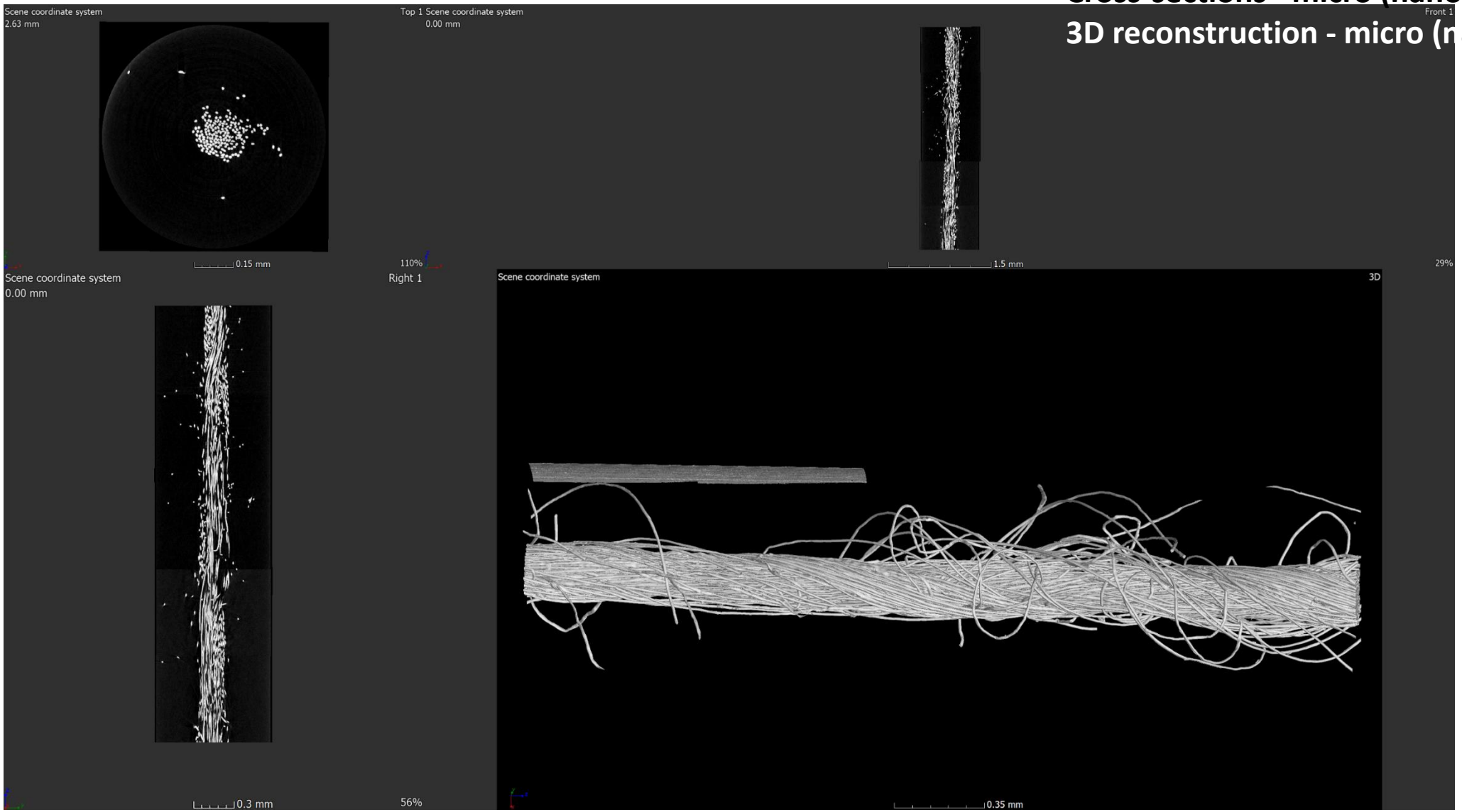
3D reconstruction - micro (nano) CT

Thread - internal structure

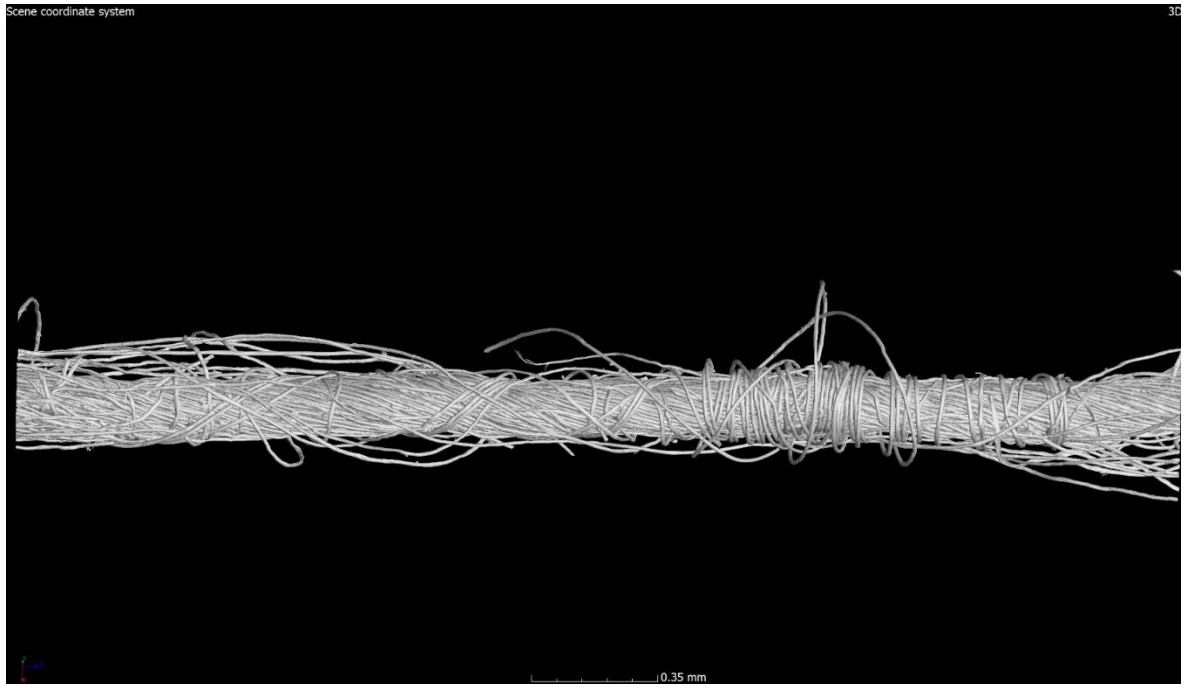
IMAGES:
Cross-sections - optical microscopy
Cross-sections - micro (nano) CT
3D reconstruction - micro (nano) CT



Thread - internal structure

IMAGES:
Cross-sections - optical microscopy
Cross-sections - micro (nano) CT
3D reconstruction - micro (nano) CT

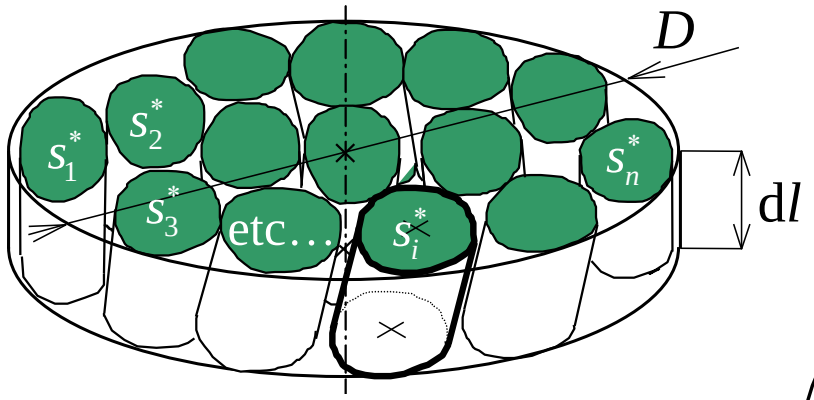
*.mp4 out of *.ppt



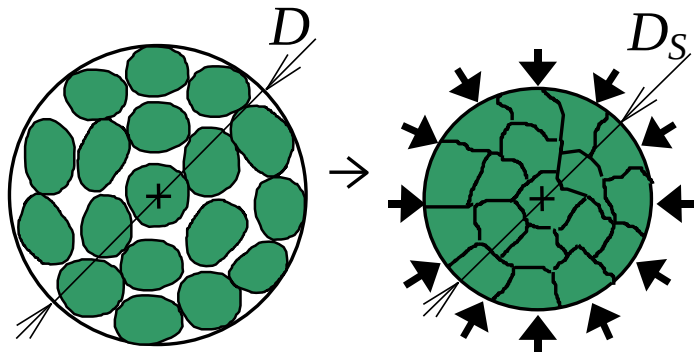
Parameters:
Scan length - 2.69 mm
Number of cross-sections 6129
Thickness of one cross-section ~ 0.44 mm
Resolution 0.5 mm

Detected parameters, see STR [1] :

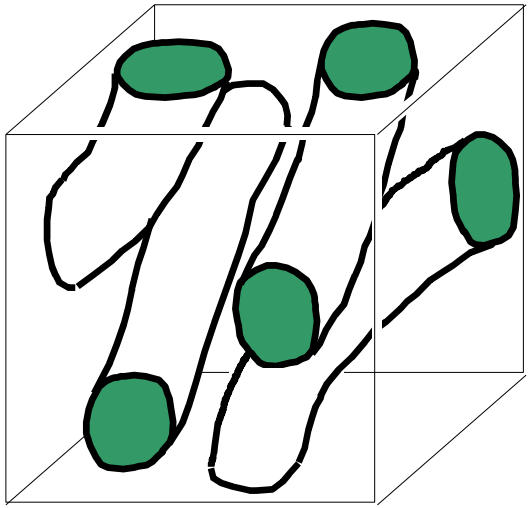
$$T = \mathrm{d}m/\mathrm{d}l = \rho\,\mathrm{d}l\,S/\mathrm{d}l = S\rho$$



$$D = \sqrt{\frac{4S}{\pi\mu}} = \sqrt{\frac{4T}{\pi\mu\rho}} = \frac{D_S}{\sqrt{\mu}} \qquad D_S = \sqrt{\frac{4S}{\pi}}$$



$$\mu = \frac{4S}{\pi D^2} = \frac{4T}{\pi D^2 \rho} \qquad \mu = \left(\frac{D_S}{D}\right)^2$$



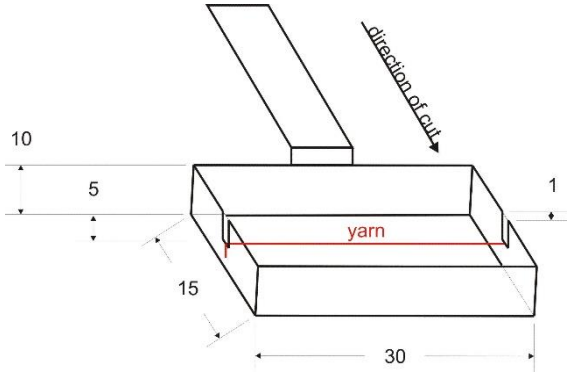
$$\mu = V/V_c \qquad \mu = \frac{S}{S_c} \qquad \mu = \frac{\gamma}{\rho}$$

Internal structure of single length fabrics - internal standards (see EXA_01):

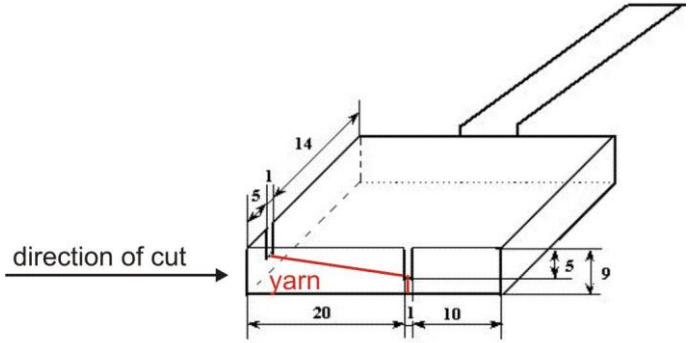
- IN 46-108-01/01 Recommended procedure for creating cross sections. Soft and hard cross sections
- IN 22-102-02/01 Transverse dimensions of two ply yarn and diameter of single yarn. Cross-sections.
- IN 22-103-01/01 Yarn fpacking density Direct method and Secant method
- IN 22-103-02/01 Yarn packing density - Direct method
- IN 22-103-03/01 Yarn packing density - Isoquantities
- IN 22-109-02/01 Directional arrangement of fibres in yarn - Oblique yarn cross sections
- IN 22-109-01/01 Directional arrangement of fibres in yarn - tracer fibres

General Approach by IS 46-108-01/01

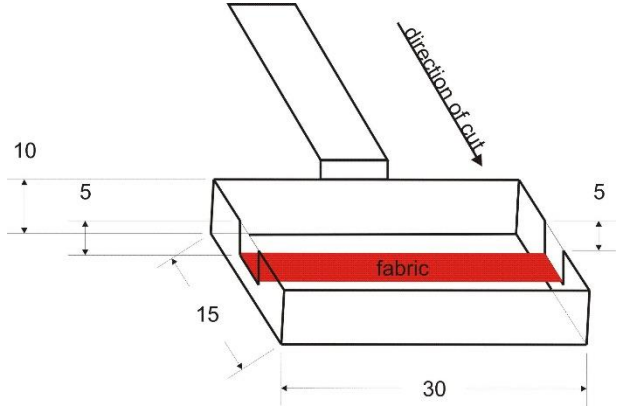
- Periodic taking of minimally 30 samples from yarn's hank with count nearest to mean count of ten yarn's hanks.
- 30 samples fixing in three steps by hardly diluted glue (by Spolion 8), softly diluted glue (by Spolion 8), concentrated glue in three days.
- Placing of each sample in a laboratory bath, adding mixture of vex and paraffin 2:3.



Single and two-ply yarn perpendicular cross-section

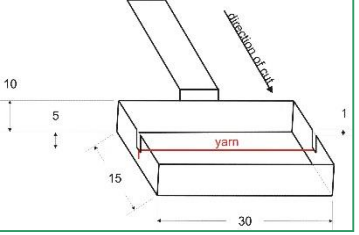


Single yarn oblique cross-section



Fabric perpendicular cross-section

- cooling, cutting (microtome knife – 16cm, microtome – Leica RM 2155), preparing for microscopy preparation (xylen)

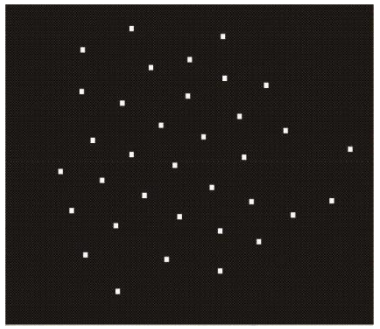


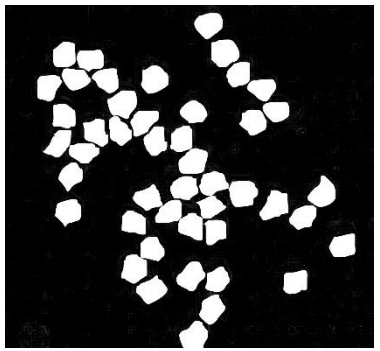
Single One Component Yarn Cross-section

IN 22-103-01/01 Zaplnění příze, Přímá metoda a metoda Secant
IN 22-103-02/01 Zaplnění příze – Metoda přímá

- Cross-section parameters:
  - Width of perpendicular cross-section **≈ 15µm**
  - Number of cross-sections for one yarn – **min. 30**

Image Analysis – IA





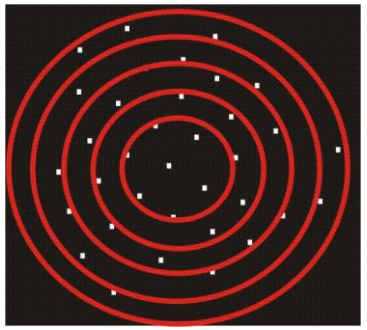
Magnification 200x

Fiber's regular shape
CentreX, CentreY

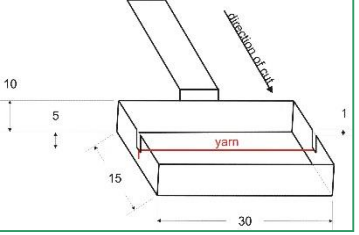
Fiber's irregular shape
CentreX, CentreY, Area

Prize.exe (REBOL)

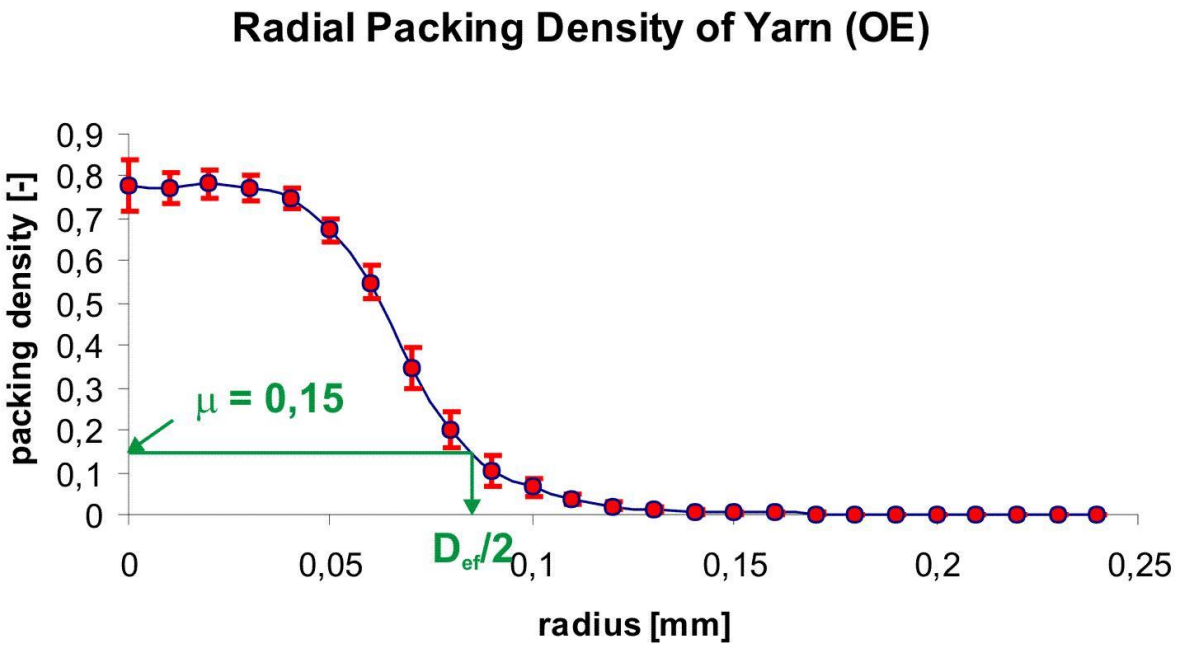
Input parameters:
Fiber count
Fiber density
Yarn count
Yarn twist
Annulus width



Output information:
Number of fibers in yarn
Effective yarn packing density
Effective yarn diameter
Radial packing density of yarn



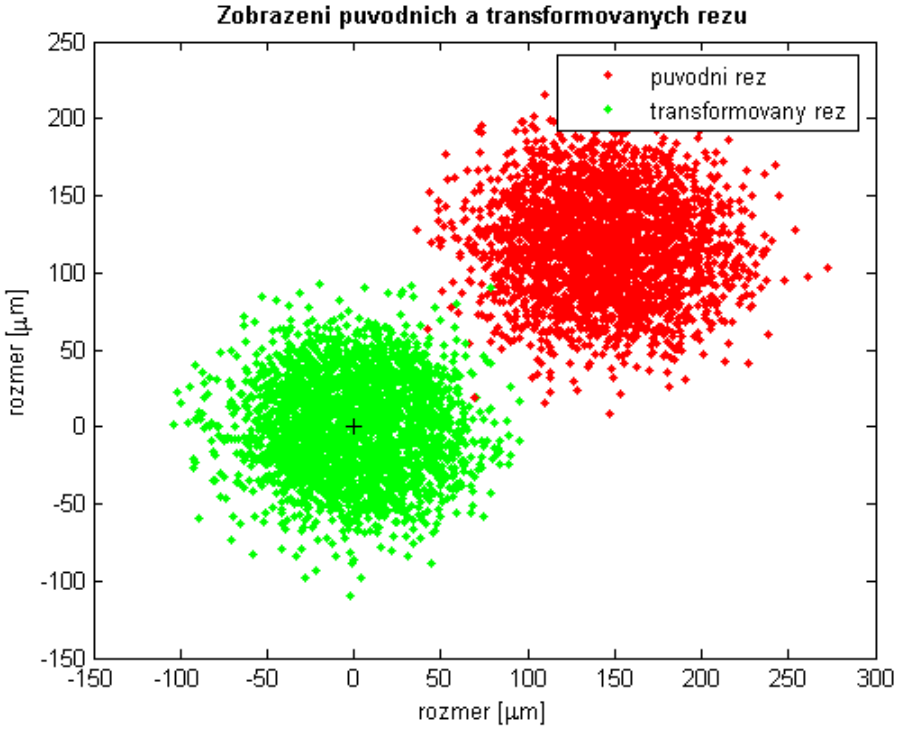
Single One Component Yarn Cross-section

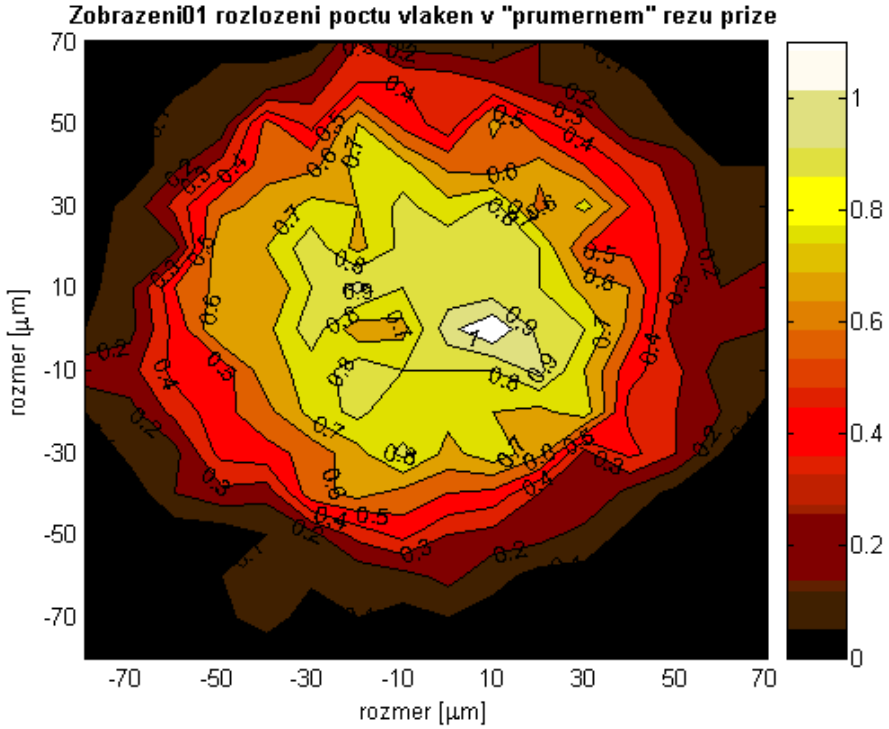


μ_{ef} = (area of the fibers)/
(area of the circle with radius ($D_{ef}/2$))

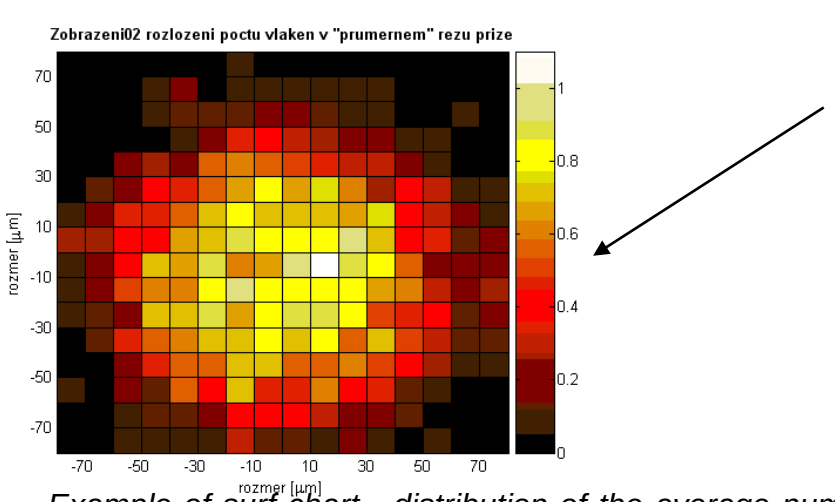
IN 22-103-03/01 Yarn packing density - Isoquantities

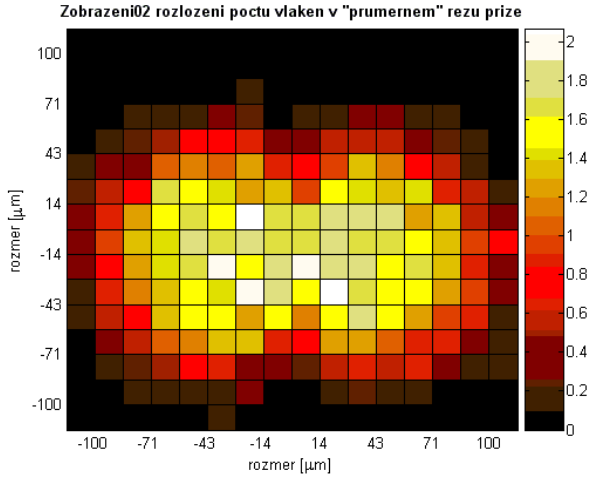
This standard specifies a procedure for calculating the density of fibre distribution in single and two-ply free, wefted or looped single component yarns. Image analysis (NIS Elements) is used to obtain images of the cross-sections and to evaluate them, and a program in the MatLab environment is used to process the data and to obtain data and graphical output.



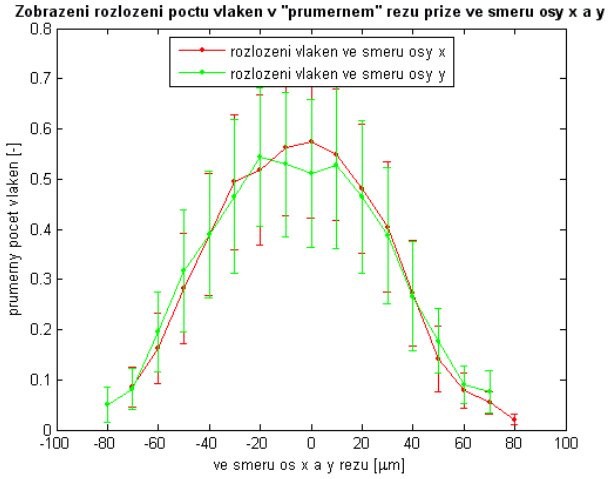


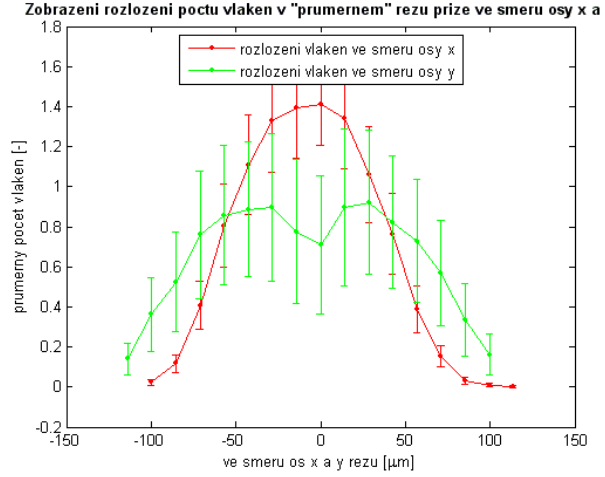
IN 22-103-03/01… continued …





Example of surf chart - distribution of the average number of fibres in an "average" cross-section for single (100%ba, worsted, 10tex) and two-ply yarn (100%CO, worsted, 2x10tex, 601 1/m)

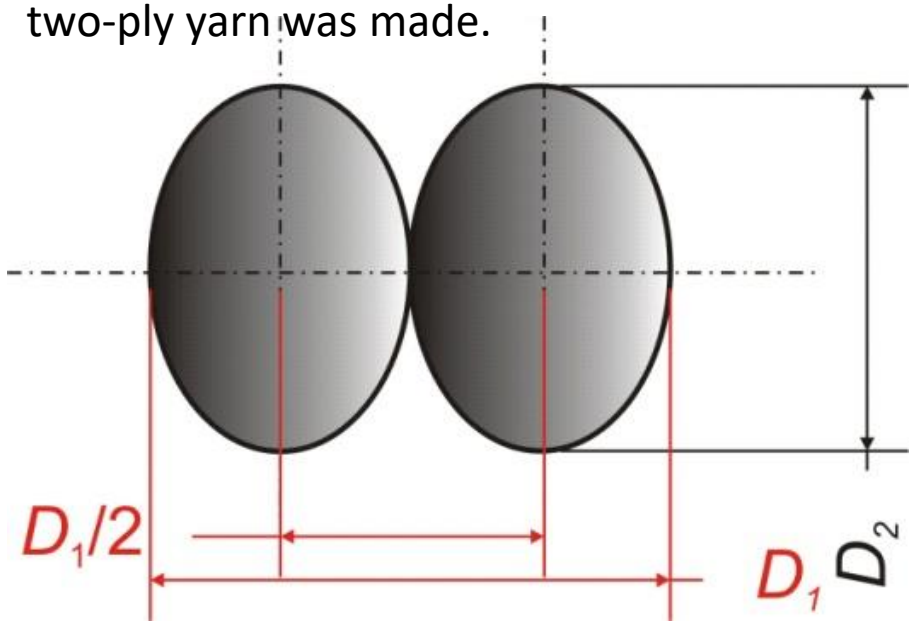




Example of graphical representation of the distribution of the average number of fibres in an "average" cross-section with single (100%CO, worsted, 10tex) and two-ply yarn (100%CO, worsted, 2x10tex, 601 1/m), always in the direction of the x and y axis (in the sense of an oriented cross-section)

IN 22-102-02/01 Cross-sectional dimensions of two-ply yarn and **diameter of single yarn, Cross-sections**

This standard specifies a procedure for determining the geometric parameters and shape characteristics of two- and single-ply yarns and a procedure for monitoring changes in the behaviour of single-ply yarns in two-ply yarns using laboratory equipment for preparing soft yarn cross-sections, image analysis software (e.g. NIS Elements) for obtaining images of the cross-sections and an evaluation program in the MatLab environment for obtaining data and graphical output. The method is suitable for two-ply yarns and single yarns from which the two-ply yarn was made.



Plan view of the two-ply yarn model with marked parameters D_1, D_2

Tab. 1: Znázornění možných stavů příze jednoduché v dvojmo skané srovnáváním jejích rozměrů s ekvivalentním průměrem příze jednoduché

$Stav1a: \frac{D_2 \cos \beta_s}{D_{ekvivalentní}} > 1$	Rozšíření jednoduché příze v dvojmo skané ve směru minimálního rozměru	$Stav1b: \frac{D_1}{2 D_{ekvivalentní}} > 1$	Rozšíření jednoduché příze v dvojmo skané ve směru maximálního rozměru
$Stav2a: \frac{D_2 \cos \beta_s}{D_{ekvivalentní}} = 1$	Žádná akce ve směru minimálního rozměru	$Stav2b: \frac{D_1}{2 D_{ekvivalentní}} = 1$	Žádná akce ve směru maximálního rozměru
$Stav3a: \frac{D_2 \cos \beta_s}{D_{ekvivalentní}} < 1$	Stlačení jednoduché příze v dvojmo skané ve směru minimálního rozměru	$Stav3b: \frac{D_1}{2 D_{ekvivalentní}} < 1$	Stlačení jednoduché příze v dvojmo skané ve směru maximálního rozměru

IN 22-102-02/01… continued …

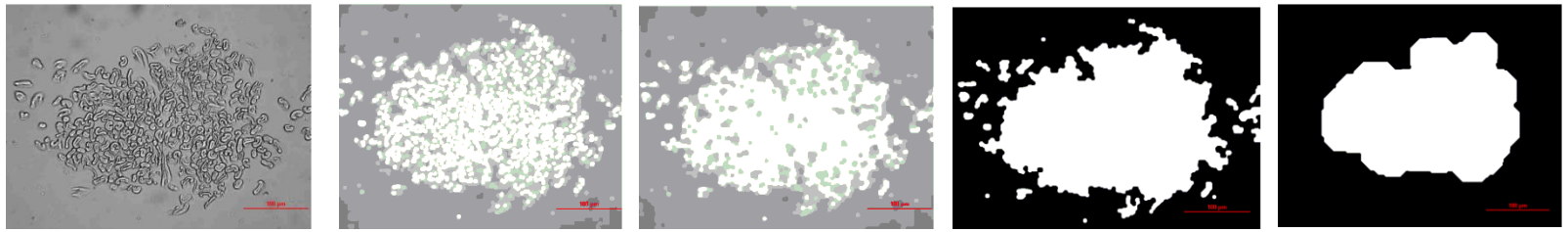
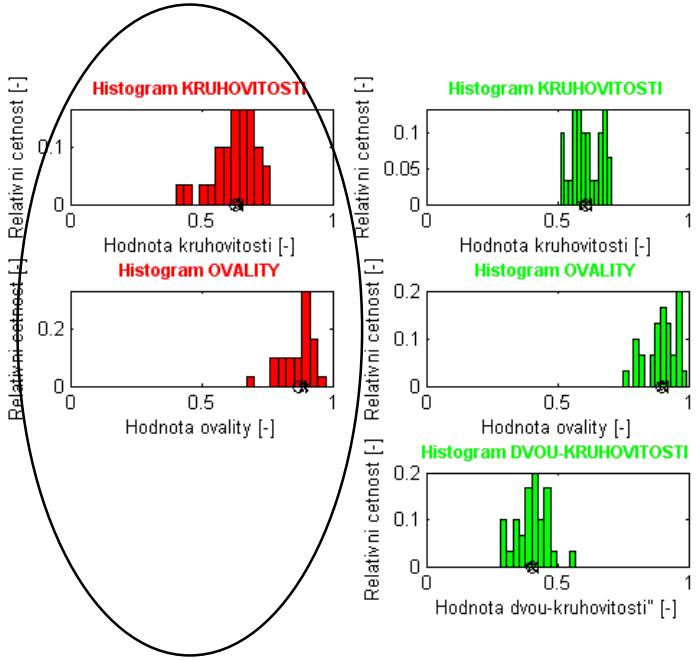
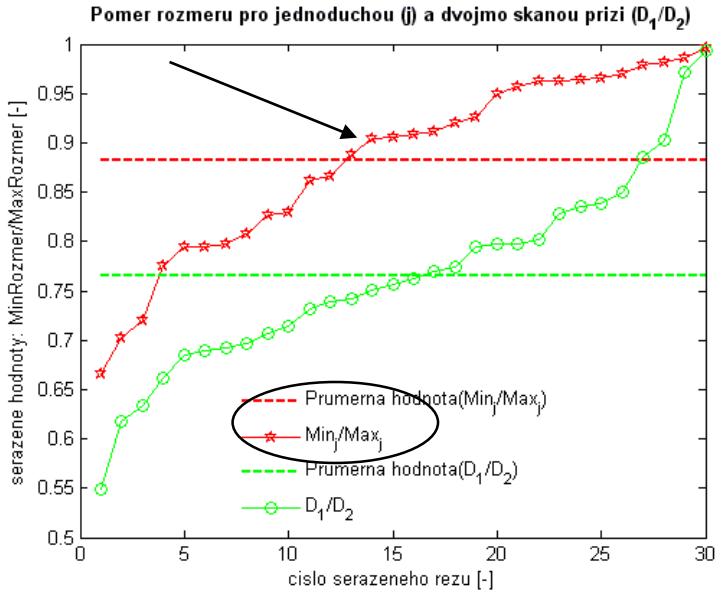
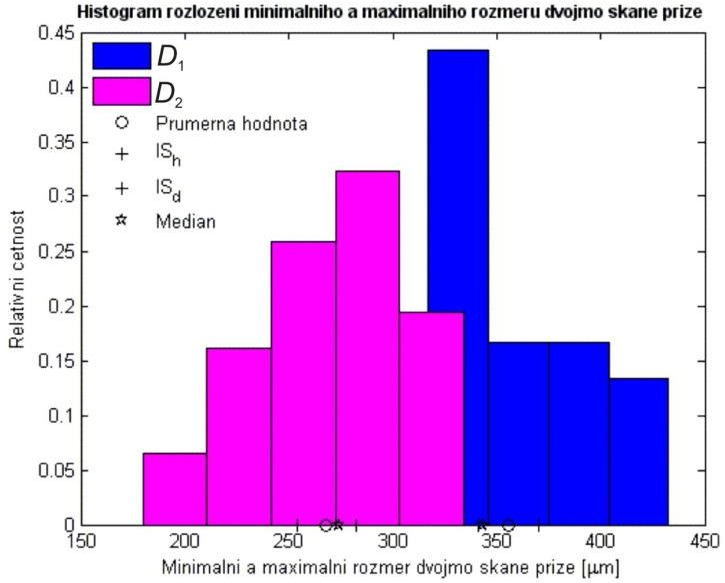
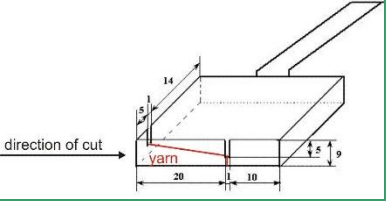


Illustration of the process of processing the cross-sectional image of the two-ply yarn (single yarn is subjected to exactly the same procedure)

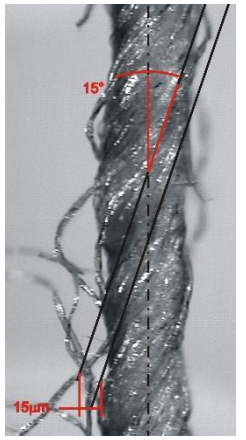








Single Yarn Cross-section - OBLIQUE

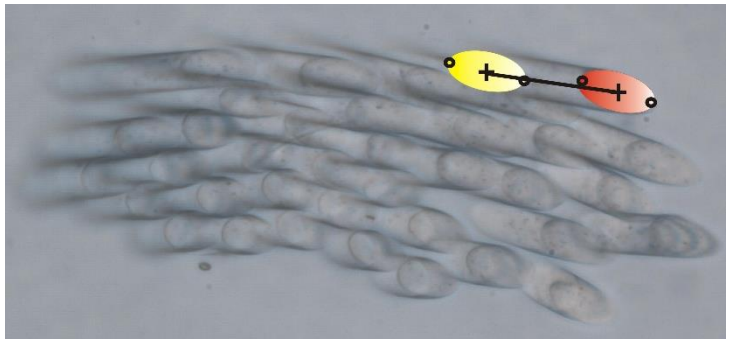


IN 22-109-02/01 Directional arrangement of fibres in yarn - oblique yarn cross sections

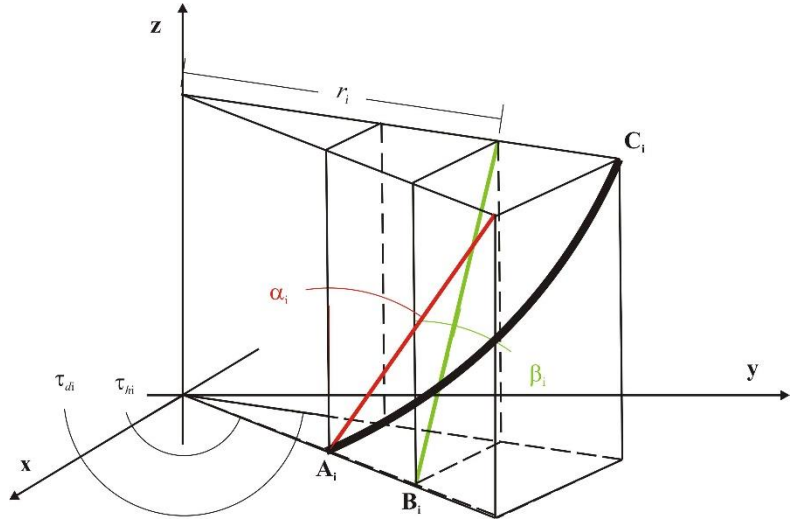
- Cross-section parameters:
  - Width of oblique cross-section **≈ 15µm**
  - Number of cross-sections for one yarn – **min. 30**
  - Slope angle of knife to the yarn axis **≈ 15°** (≈ slope angle of yarn surface fibers)

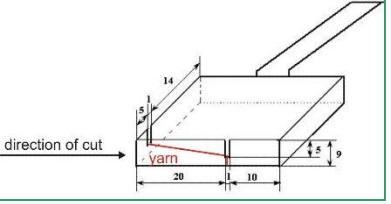
WHY?

- observation of upper and lower fiber's end
- description of fiber's directional assembly through the yarn radius by angles α and β



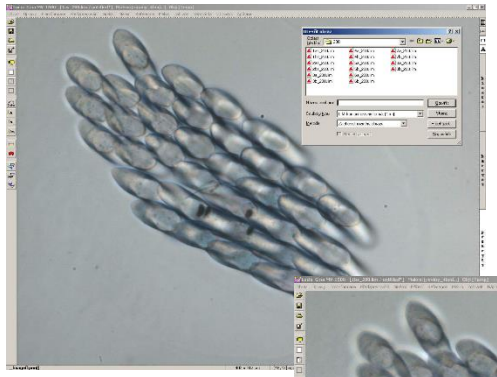
Magnification 200x



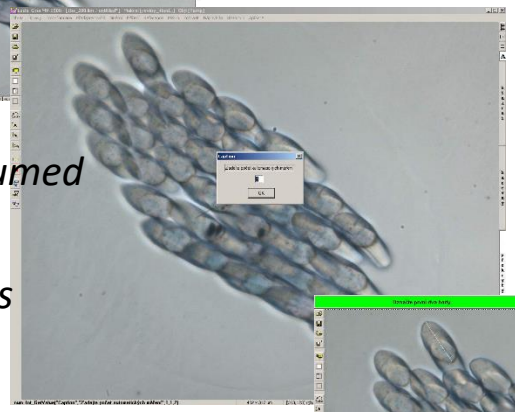


Single Yarn Cross-section - OBLIQUE

HOW? – by macro created in the IA

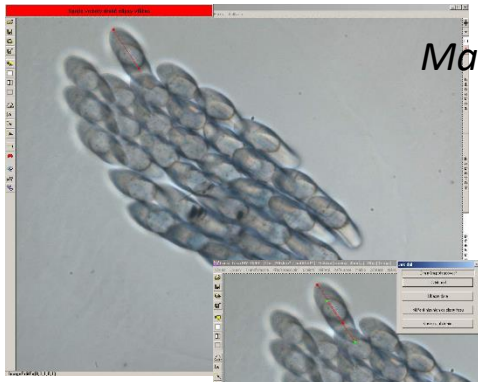


Scanning of images, focusing on their upper and lower plain



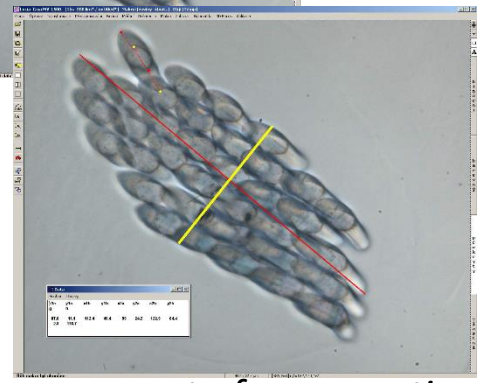
Choice of an assumed number of the measured objects

Connection of the furthermost points of fiber facets in upper plain of cross-section

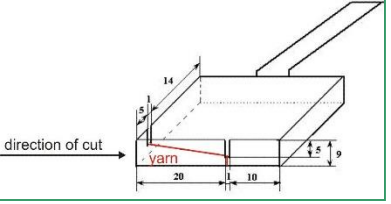


Marking of these points

The same for lower cross-section's + decision making

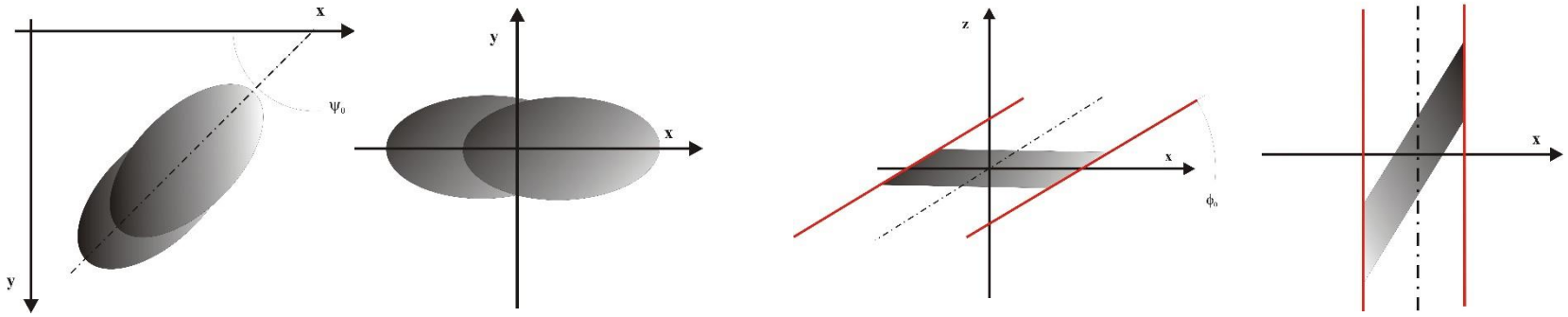


Control measurement of cross-section's ellipse axes + measured data saving



Single Yarn Cross-section - OBLIQUE

Basic transformations of oblique cross-sections



Input parameters:
Fiber count (diameter)

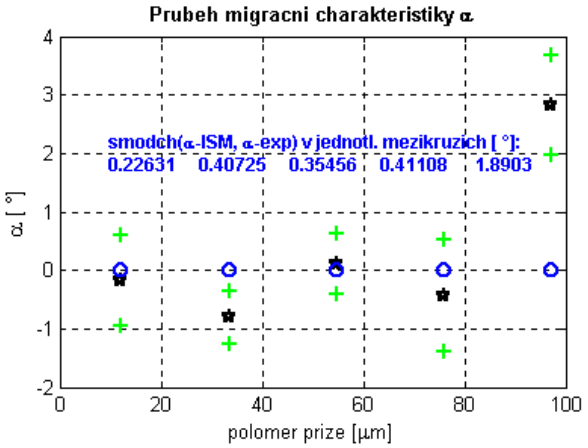
Yarn twist

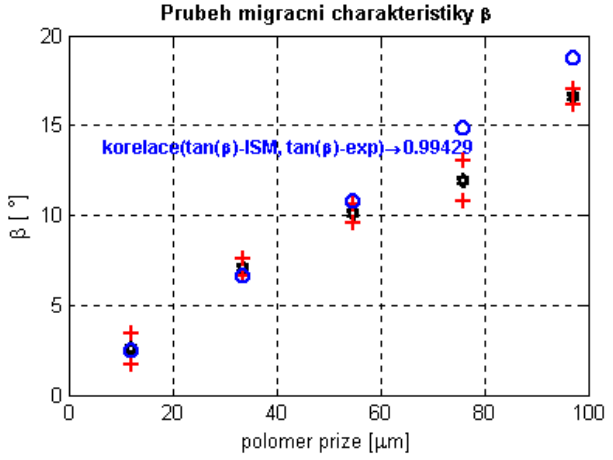
Output information:
Radial migration characteristic – angle α

Twist migration characteristic – angle β

The comparison of these characteristics with ideal helical model

The investigation of suitable statistical distribution (for these two migration characteristics) in the each annulus



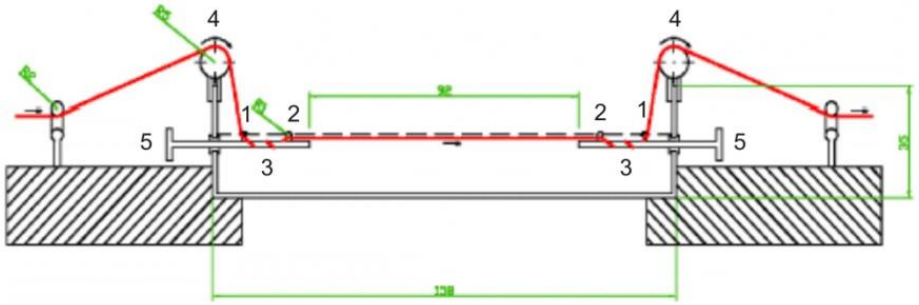


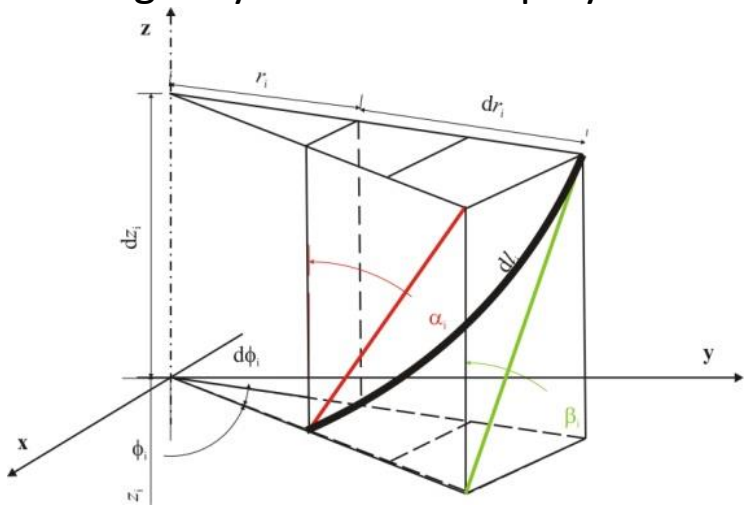
IN 22-109-01/01 Directional arrangement of fibres in yarn - tracer fibres

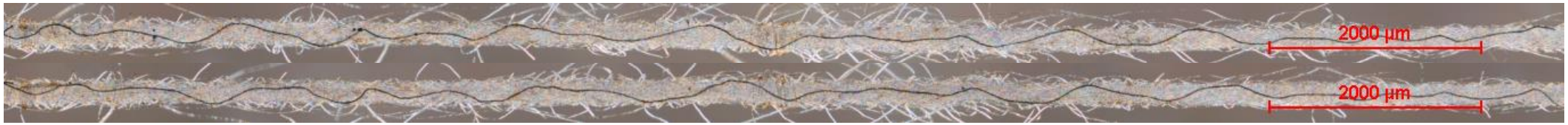
- 3D visualization of fiber in yarn
- Evaluation of spinning coefficient
- Percentage of fibers with knots
- Radial progress of directional angles α, β, γ

IN 22-109-01/01 Directional arrangement of fibres in yarn - tracer fibres

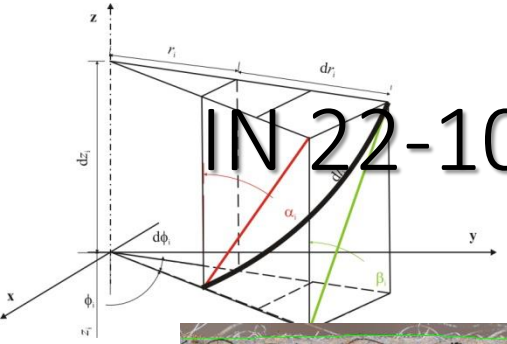
This standard specifies a procedure for taking and processing images of marked fibres in yarn and then evaluating the data to determine the directional arrangement of the fibres in the yarn by means of selected parameters. The method is suitable for yarns with labelled fibres of natural and synthetic materials which are free from any optically extraneous impurities, contaminants or matting (some of which can be removed by suitable preparation of yarn samples). The method gives the best results for glossy viscose and polyamide fibres.

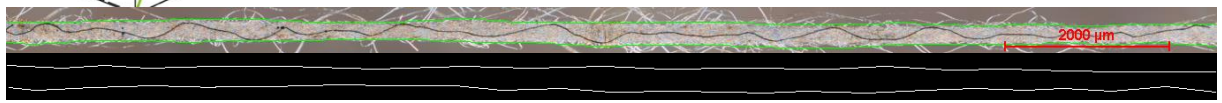


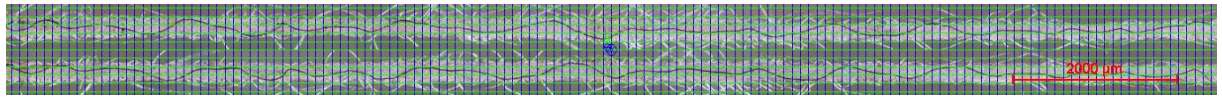


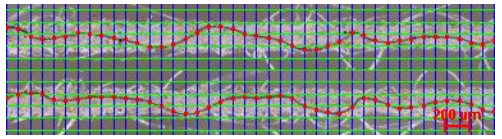


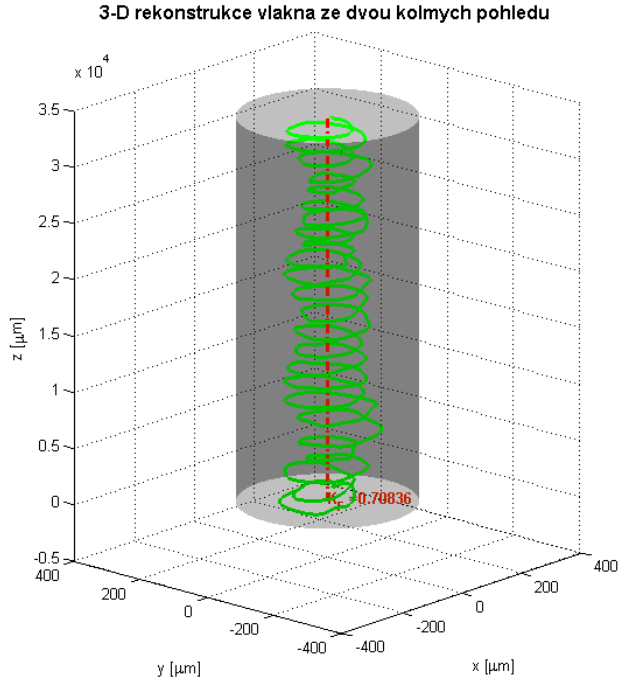
IN 22-109-01/01… continued…

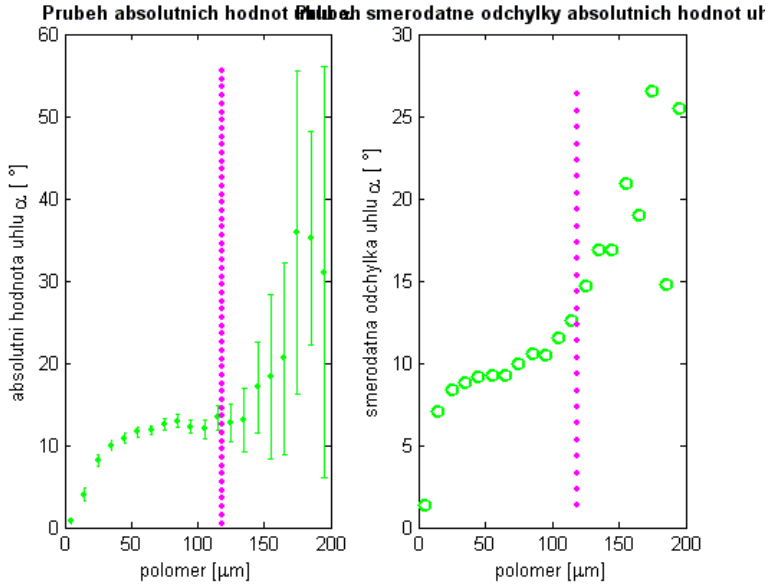


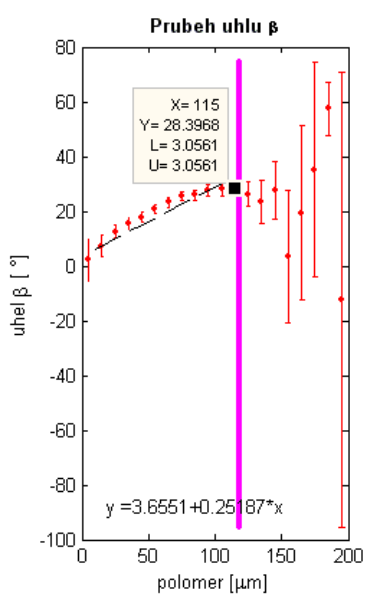


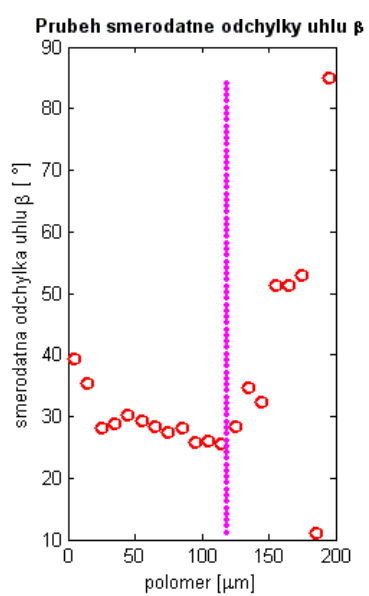


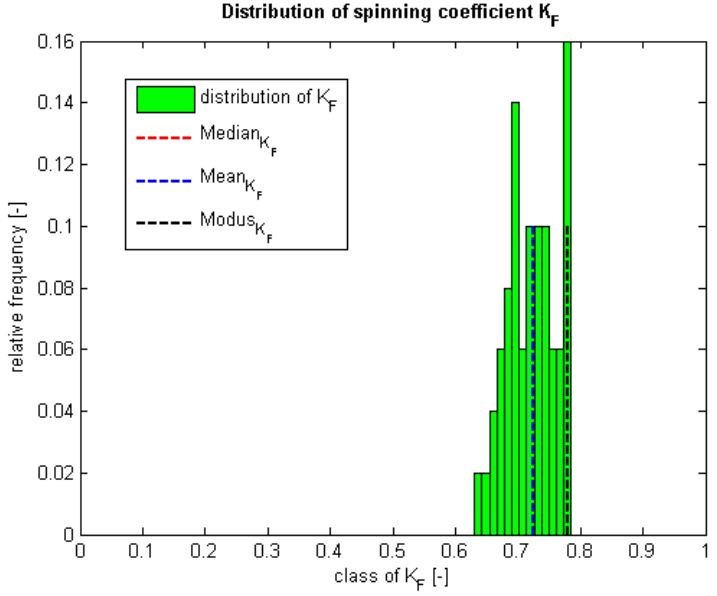




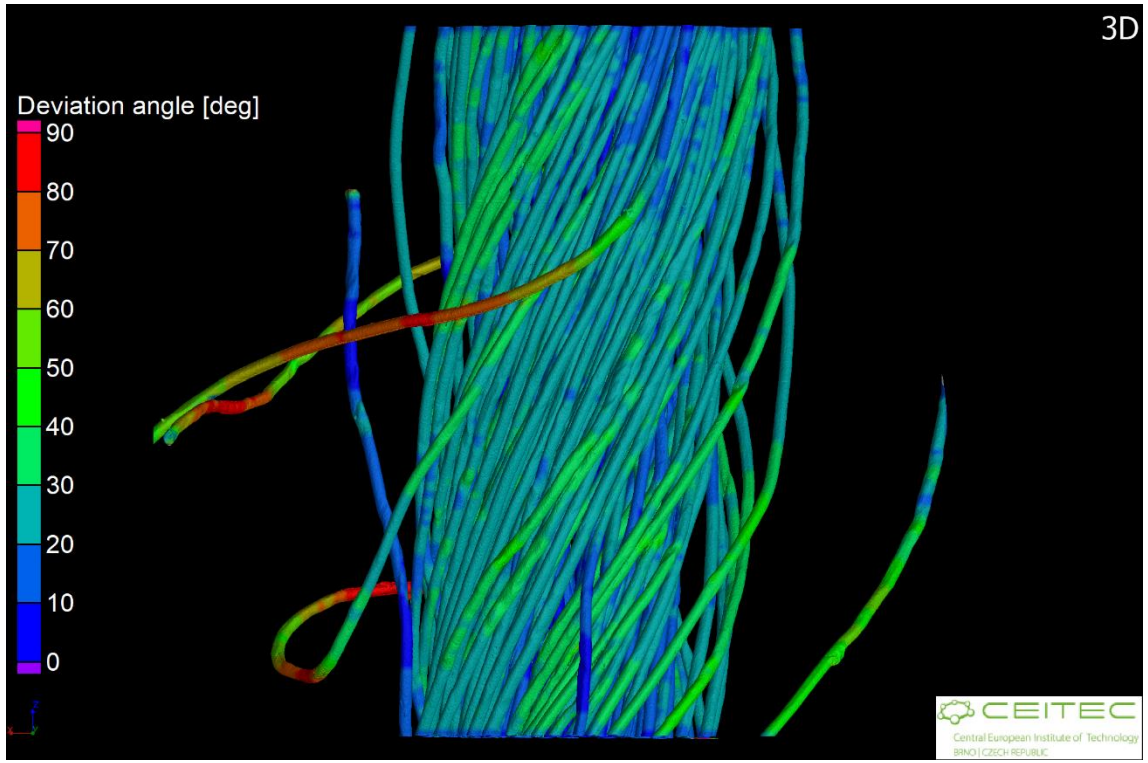


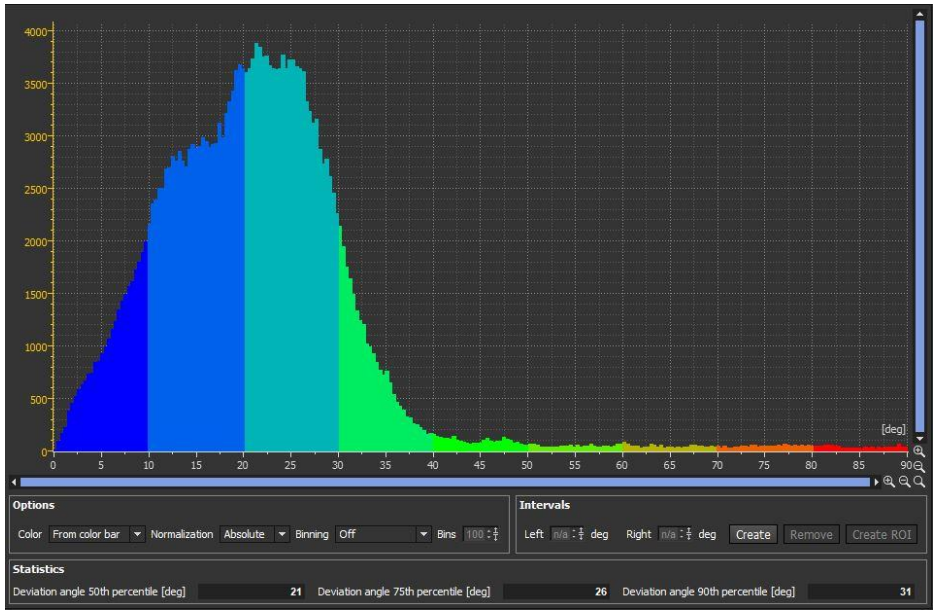






Directional arrangement of fibres via nanoCT



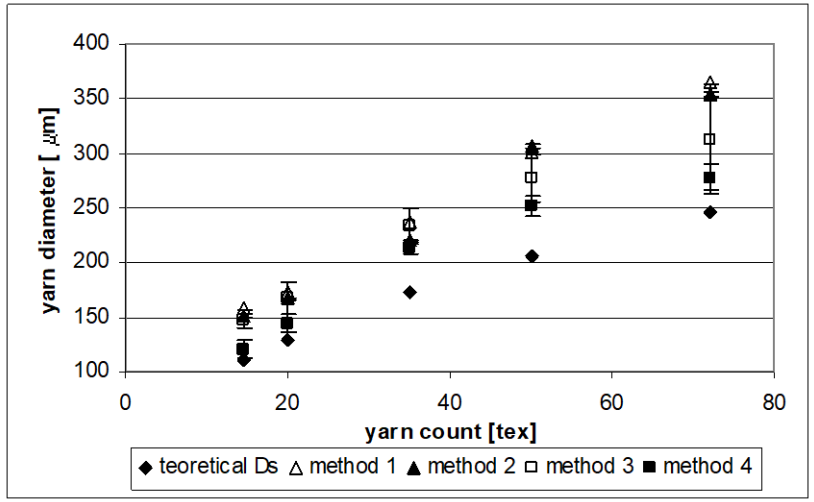


Experiment I - evaluation of yarn diameter by four methodologies + comparison with theoretical calculation

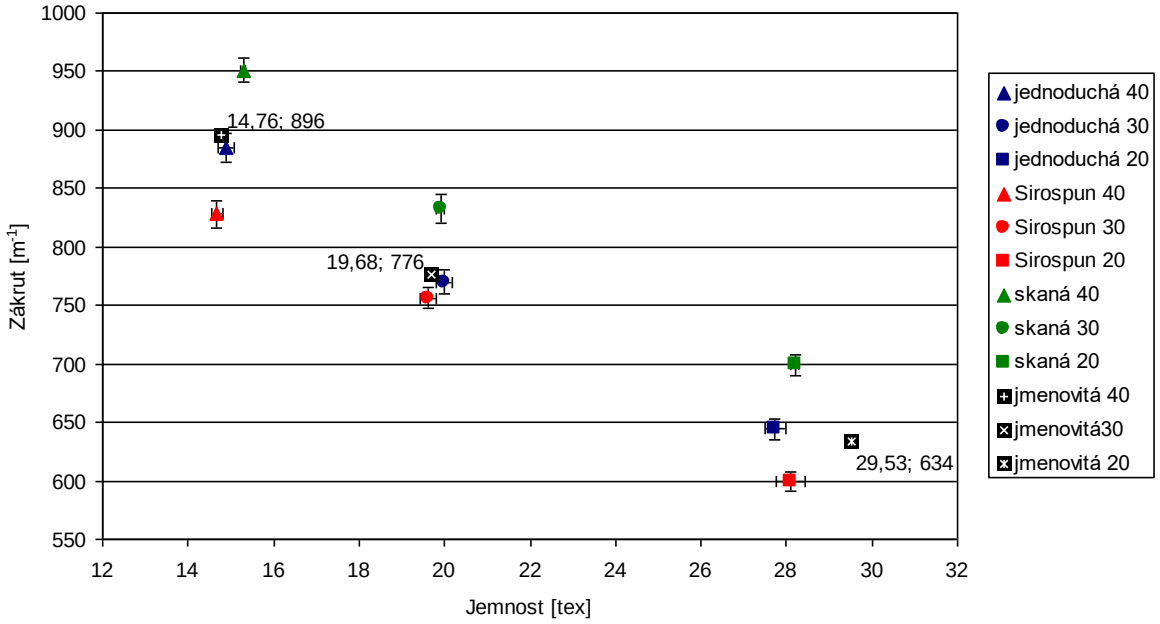
$$D_s = \sqrt{4S/\pi} = \sqrt{4T/\pi\rho}$$

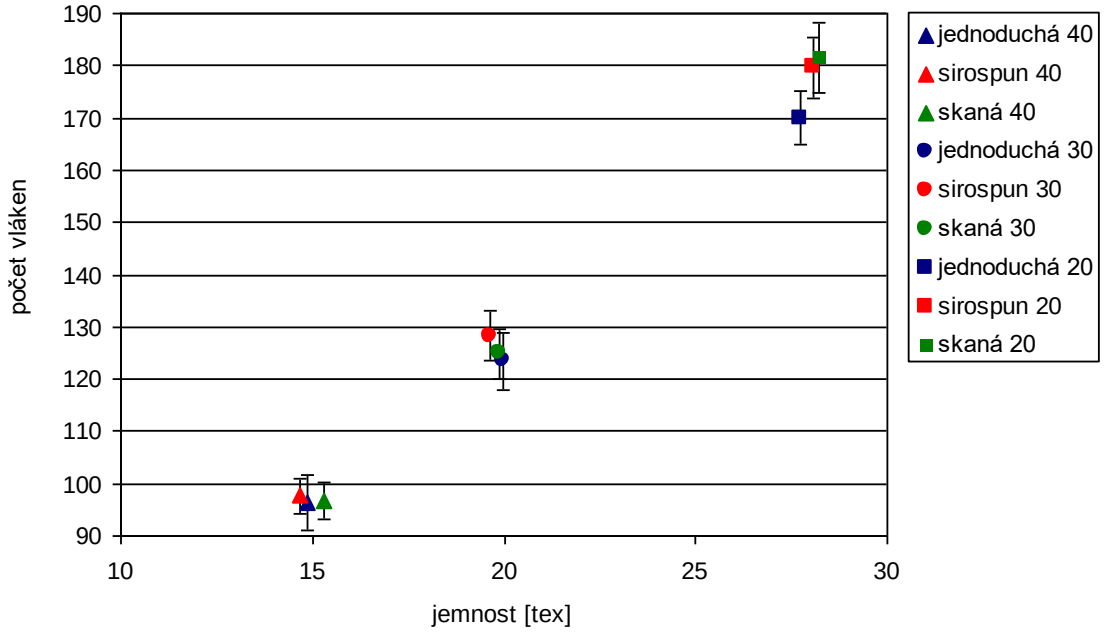
1. IN 22-102-01/01 Yarn diameter and hairiness
2. IN 32-102-01/01 Transverse dimensions of two-ply yarn and diameter of single yarn, Longitudinal views
3. **IN 22-103-01/01 Yarn packing density, Direct method and Secant method**
4. **IN 22-102-02/01 Transverse dimensions of two-ply yarn and diameter of single yarn. Cross-sections.**

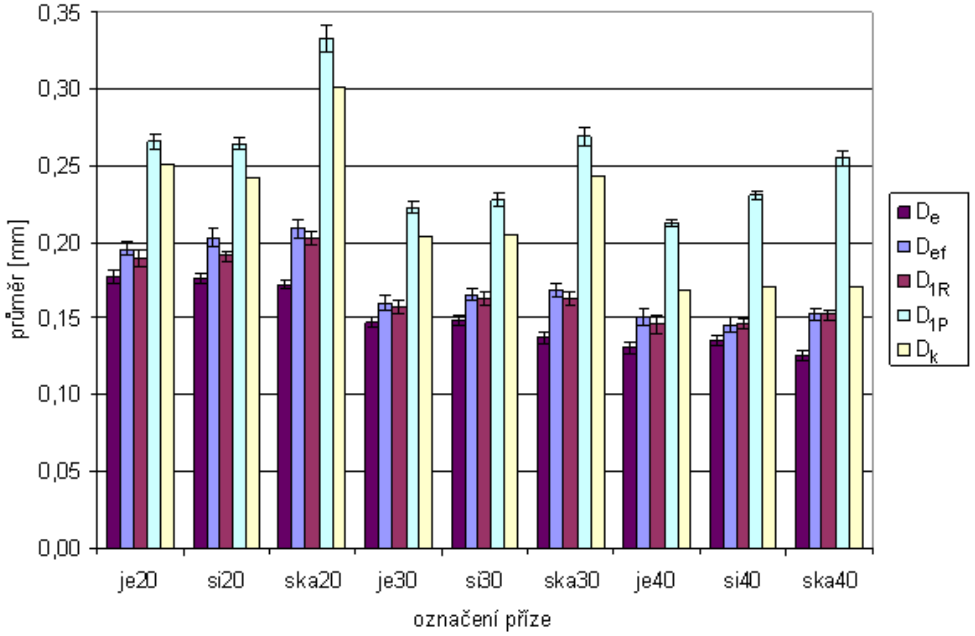
Yarns tested: 100% cotton rotor yarns with finenesses of 14.5tex, 20tex, 35.5tex, 50tex and 72tex and a twist factor of 85ktex$^{2/3}$m^{-1}.



Experiment II - diameter, packing density







D_e **equivalent diameter from IA - cross sections**

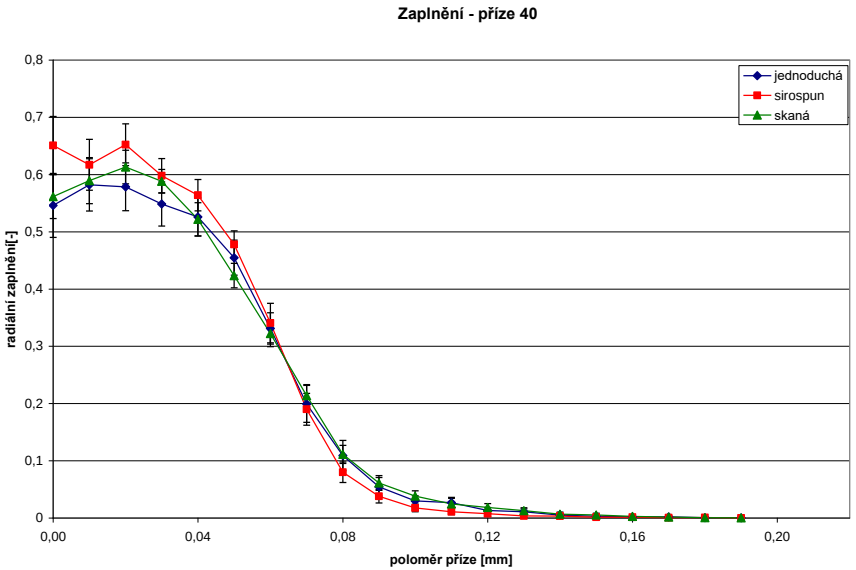
D_{ef} **effective diameter - equivalent to 0.15 of packing density - cross sections**

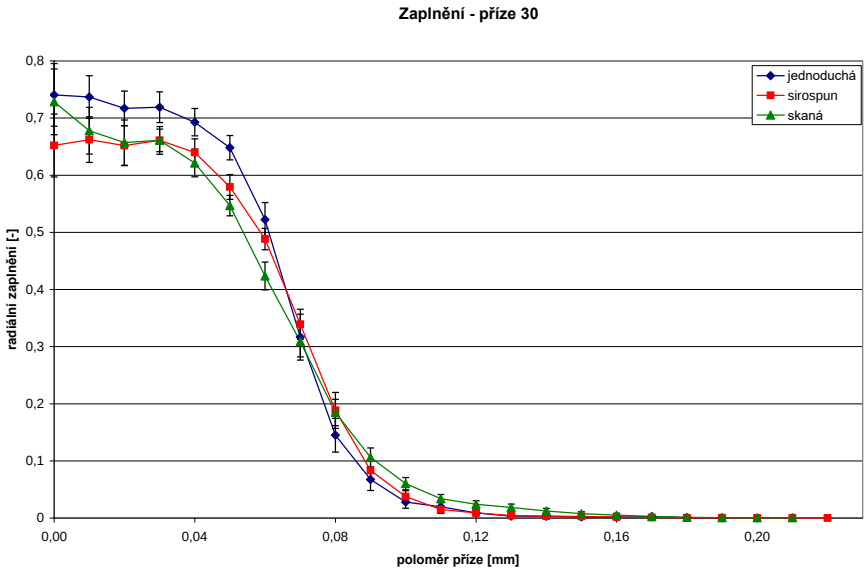
D_{1R} **maximum dimension from IA - cross-sections**

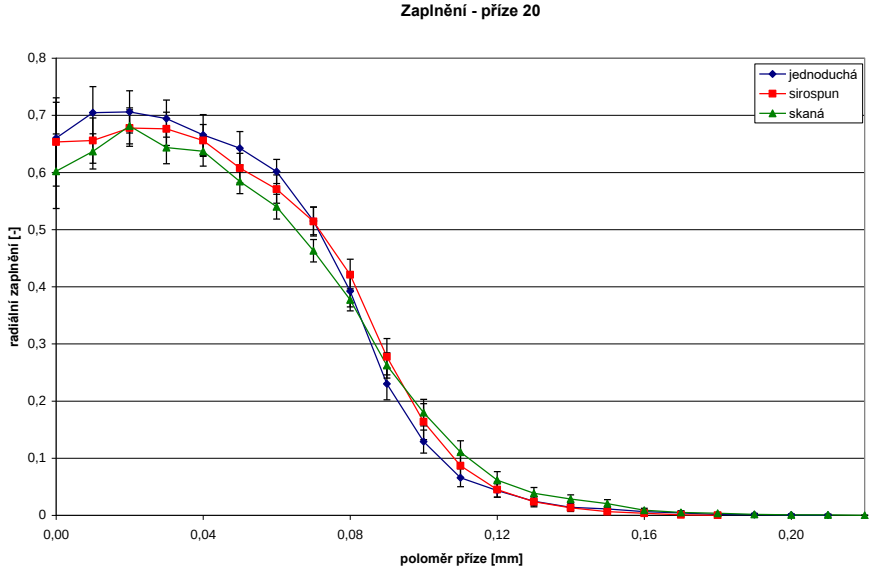
D_{1P} diameter of the smallest cylinder into which the two-ply yarn will fit - longitudinal views

D_k covering diameter - corresponding to 50% blackening - longitudinal views

Experiment II - diameter, packing density (continued)

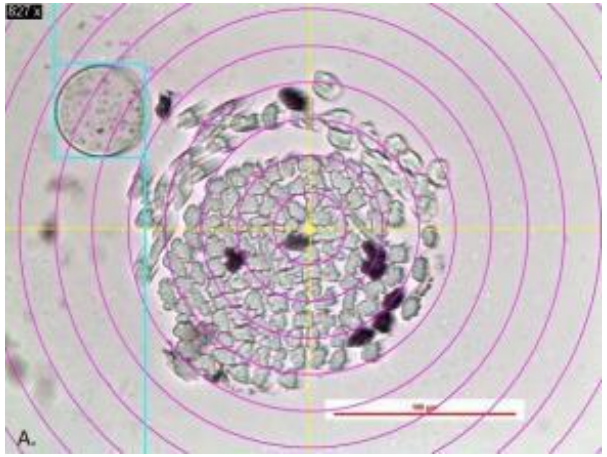




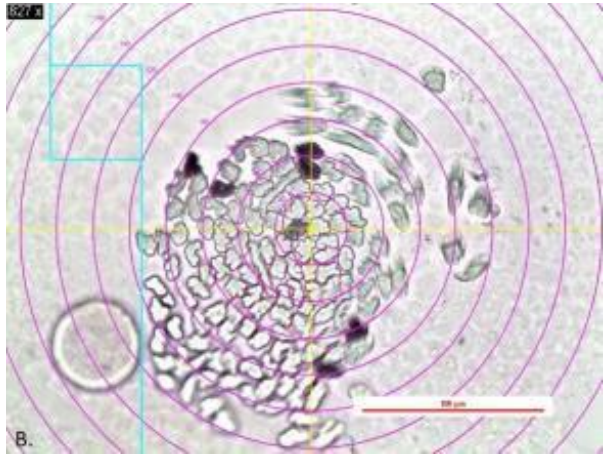


Experiment III - reconstruction of individual fibre trajectories in air-jet yarn

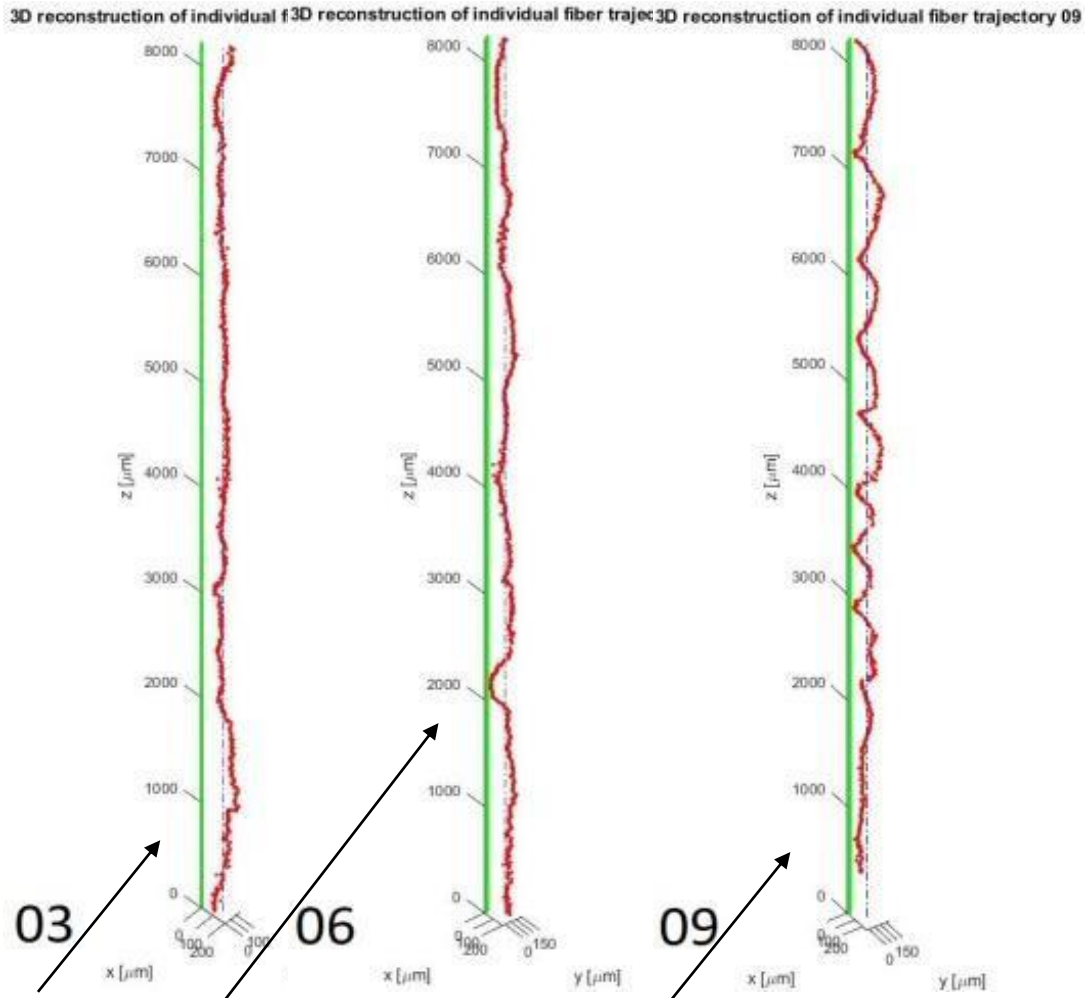
Property	Value	Verification	
		average	CV [%]
Count of yarn	20 tex	19,72 tex	2,74
Fineness of fibers	1,3 dtex	1,44 dtex	12,15
Length of fibers	40 mm	38,67 mm	6,93



Correct position



Bad position



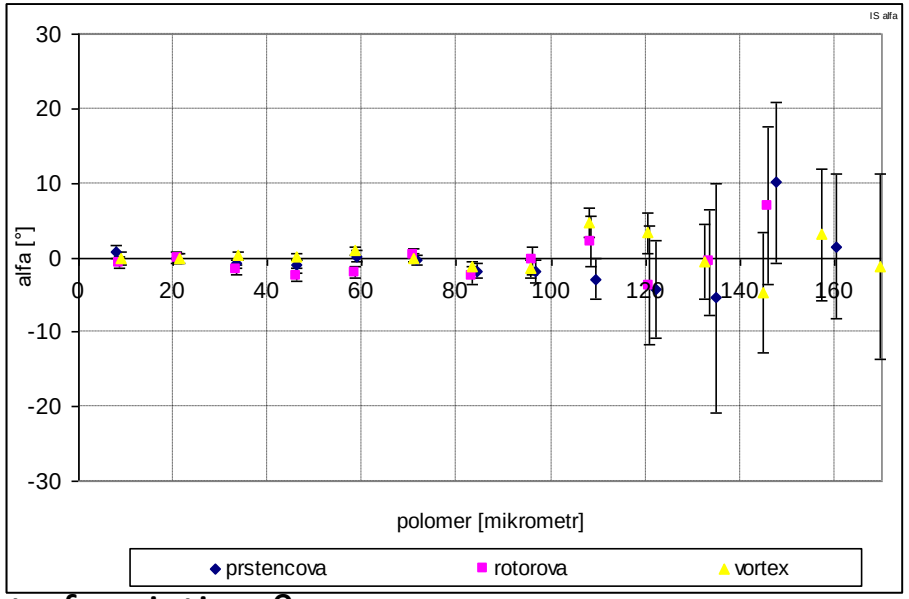
Fibre in the yarn core

Fibre in the surface ribbon

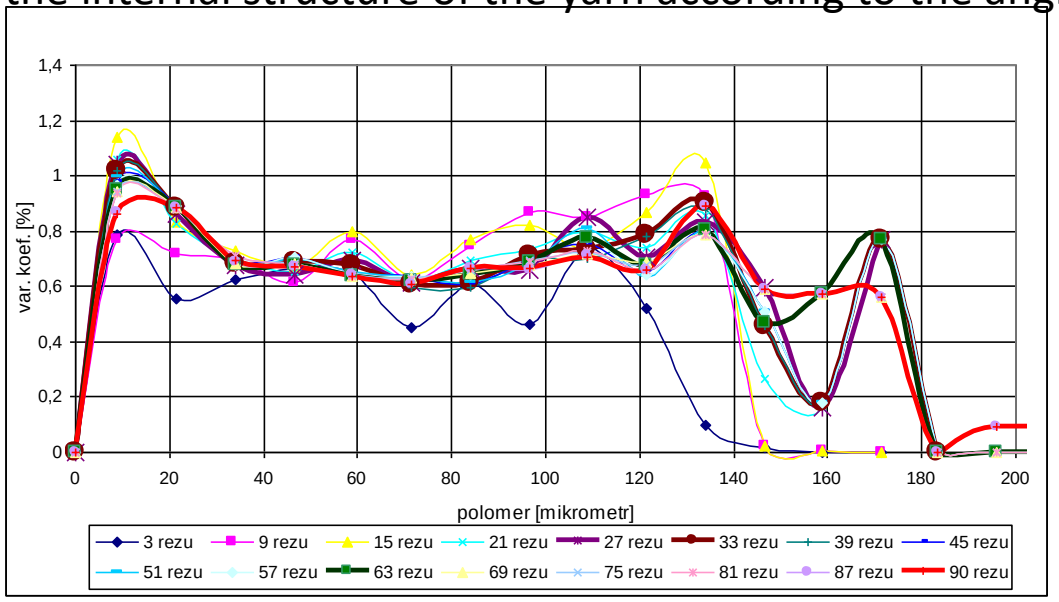
Fibre partly in the yarn core and partly in the surface ribbon

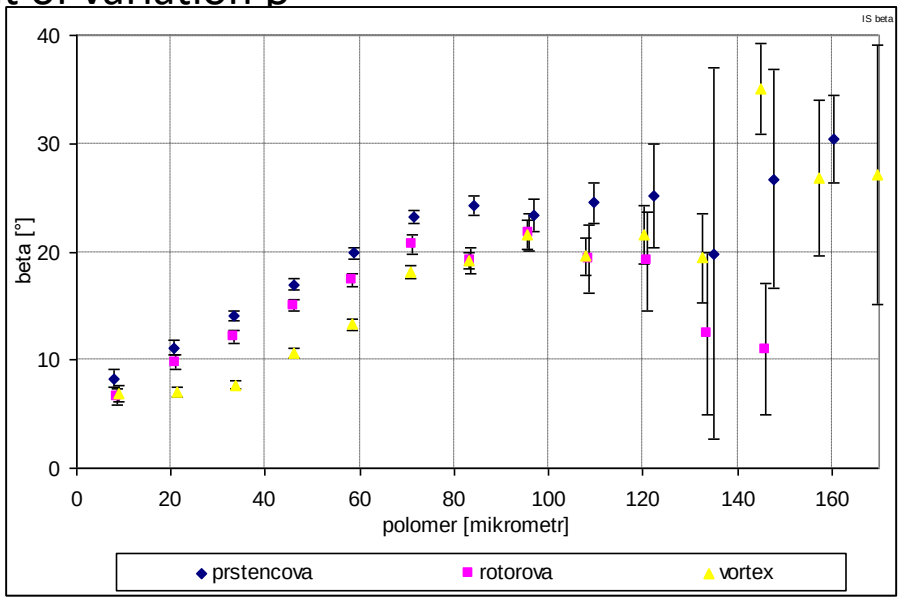
Experiment IV - testing the oblique cross-section methodology

Typ příze VS	Prstencová	Vortex	Rotorová
Průměr vlákna[μm]	12	12	12
Hustota vláken[kg/m^3]	1500	1500	1500
Jemnost příze[tex]	17,3	16,5	16,5
Zákrutový koeficient[m^{-1}.ktex$^{2/3}$]	62	68	68
Zákrut příze[m^{-1}]	926	1050	1050



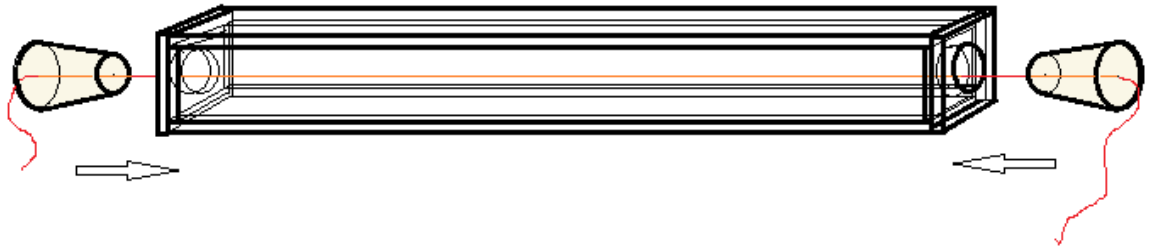
Representative number of cross-sections to describe the internal structure of the yarn according to the angle coefficient of variation ß

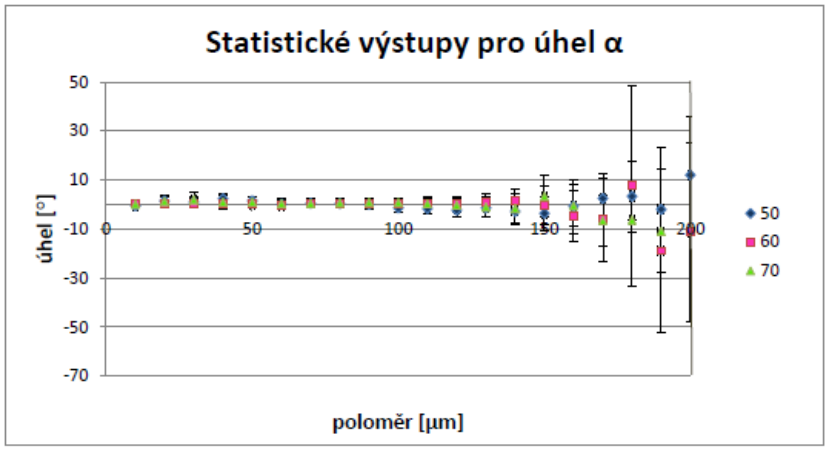


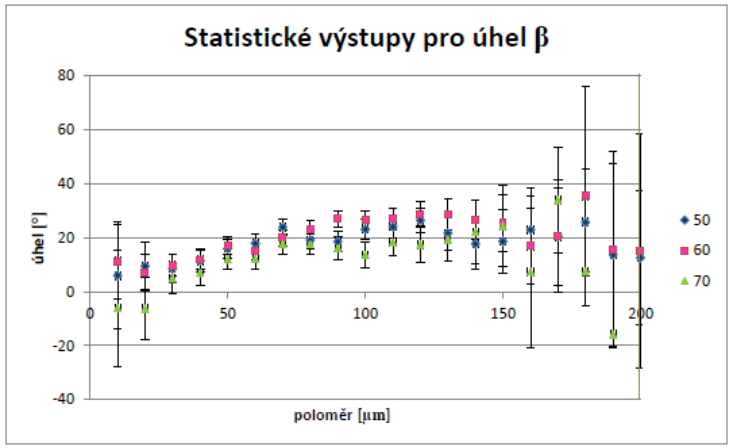


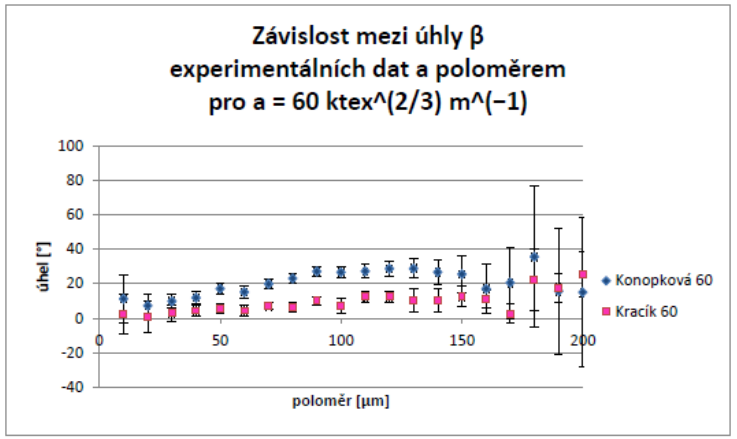
Experiment V - directional fibre arrangement - tracer fibre method

Přízové těleso	1	2	3
Zákrutový koeficient [ktex2/3 m-1]	50	60	70
Podíl značených vláken [%]	1,5	1,5	1,5





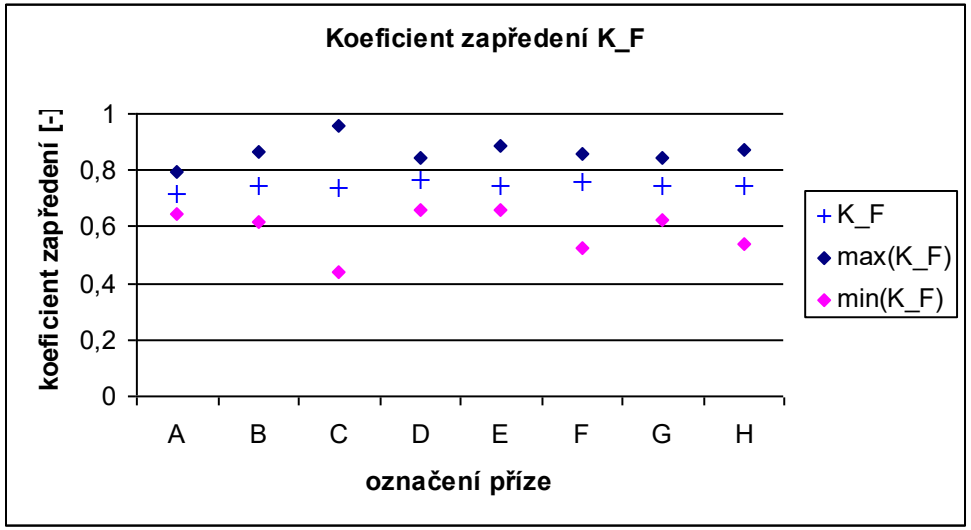


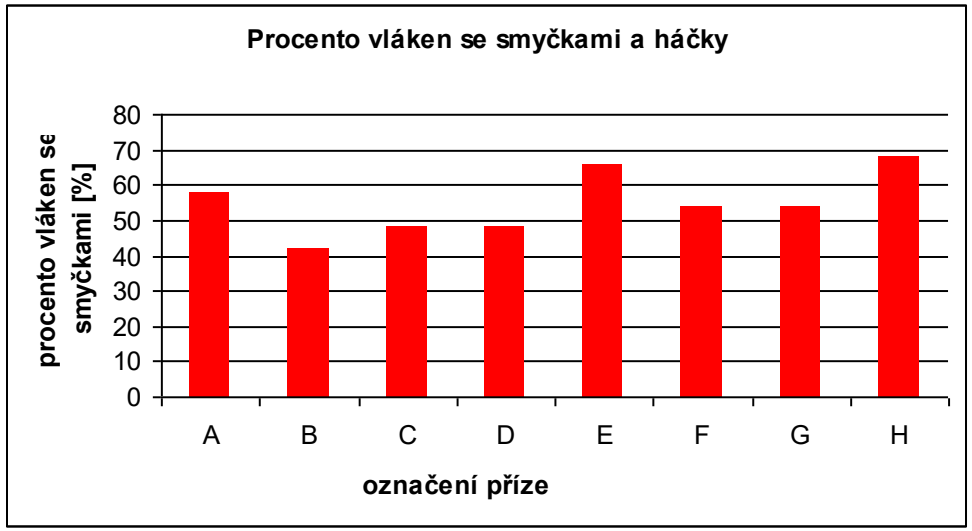


Experiment VI - internal structure of OE yarns (tracer fibres)

- 8 rotor yarns, nominal fineness 25 tex, twist coefficient 60 ktex$^{2/3}$m^{-1}

Označení vzorku	Typ povrchu rotoru	Otáčky rotoru [1/min]
ECK810/A	T34ND	80 000
ECK810/B	T34NDN	80 000
ECK810/C	T34NBD	80 000
ECK810/D	T34N	80 000
ECK810/E	T34ND	110 000
ECK810/F	T34NDN	110 000
ECK810/G	T34NBD	110 000
ECK810/H	T34N	110 000

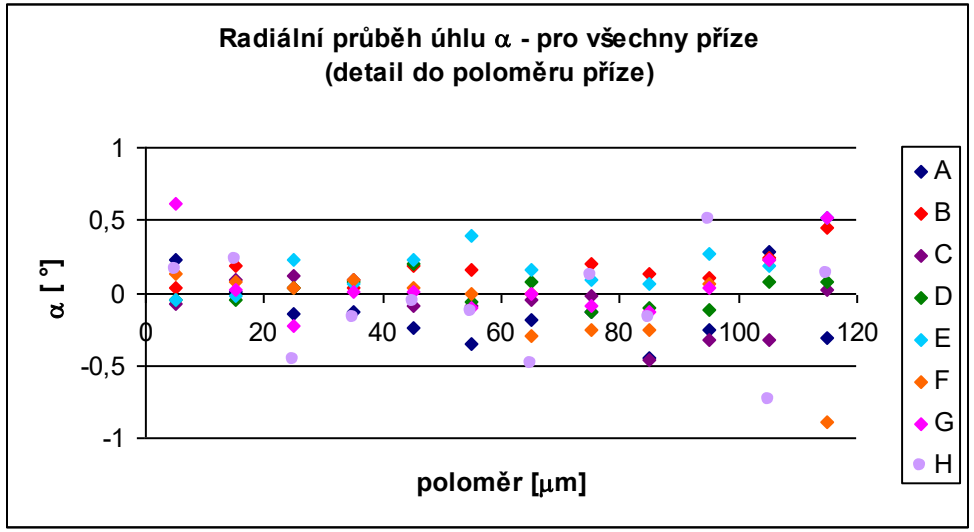


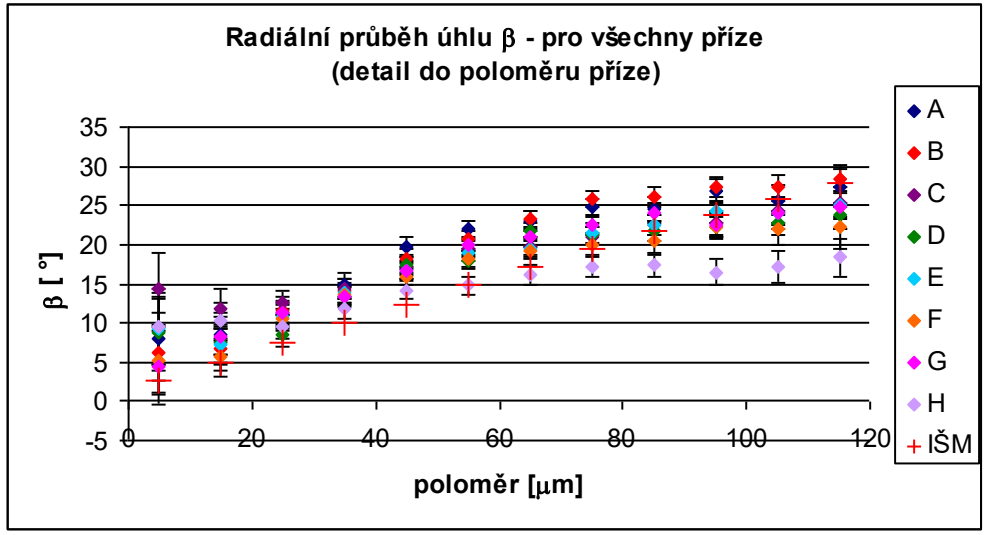


The values of the spinning coefficients for the individual yarns studied reach relatively high values - around 0.75, where, according to Kašpárek, ring carded yarns are commonly found.

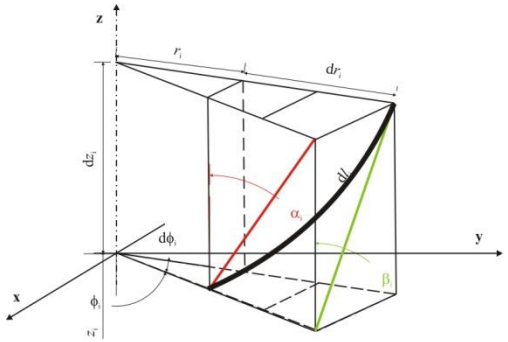
The evaluation of the percentage of threads with loops and hooks shows that it is more suitable to use lower speeds - 80 000 1/min when creating rotor yarns using used rotors.

Experiment VI - internal structure of OE yarns (tracer fibres)... continued

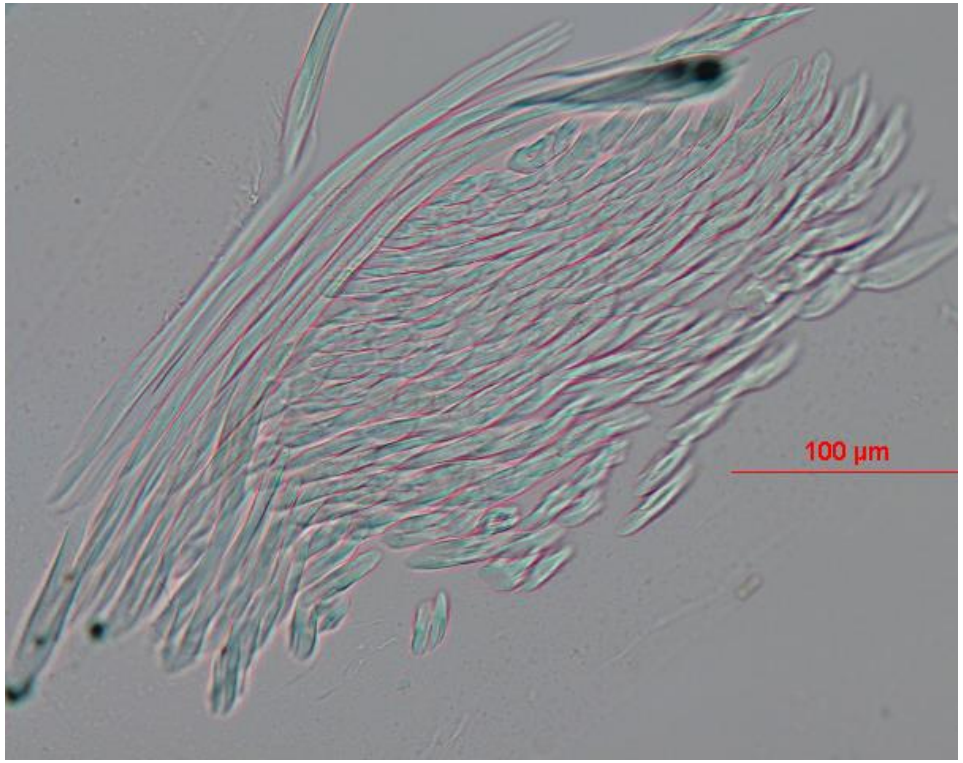


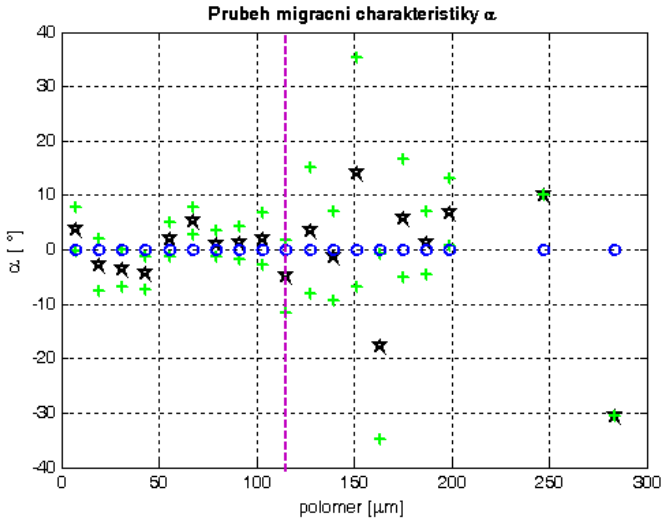


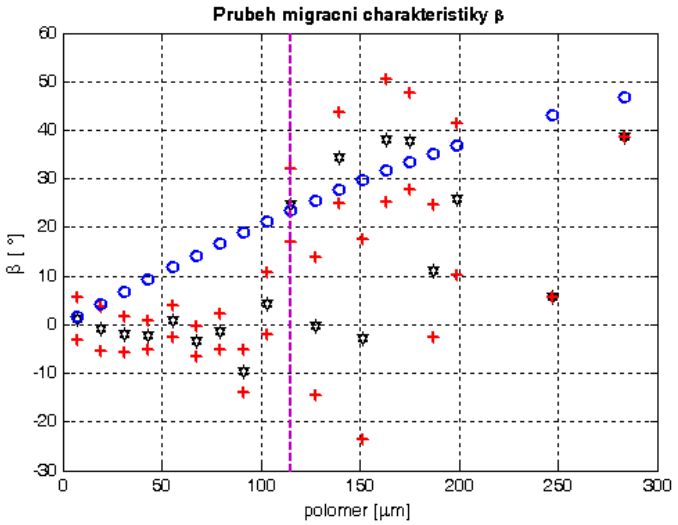
...the confidence intervals of the mean values of the individual yarns on the given intermediate rings do not always overlap, therefore it cannot be stated unequivocally that the differences within the radial course of angle β between the yarns are insignificant.

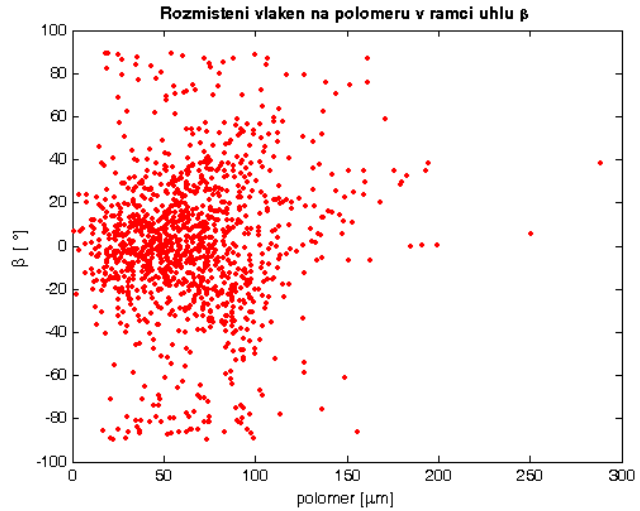


Experiment VII - Vortex-J yarn properties (oblique cross-sections)









References used:

1. Bohuslav Neckář: PŘÍZE A HEDVÁBÍ 1, TU Liberec, KTT, power point prezentace pro předmět STR
2. Neckář, B.: Příze – struktura, vlastnosti, výroba, SNTL, Praha, 1991
3. Výběr interních norem KTT – viz text prezentace
4. CEITEC – výsledky vyhodnocení textilií pomocí nanoCT
5. Výběr publikací a zpráv autorky, práce vedené autorkou