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

Two-ply Yarn, Folded Yarn

Ing. Bc Monika Vyšanská, PhD.

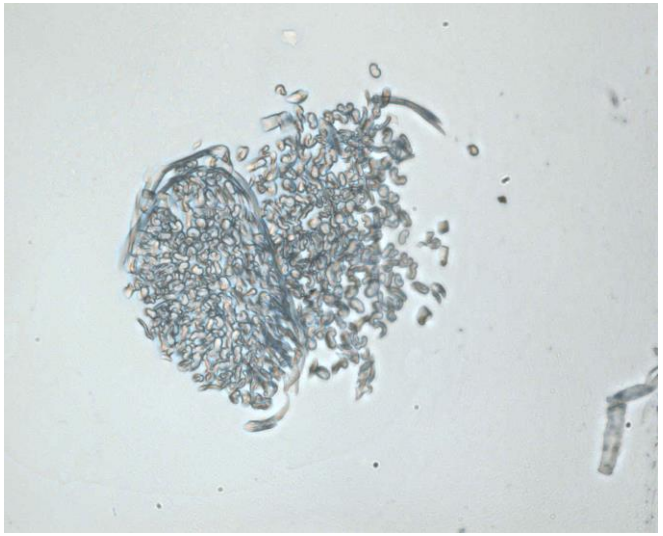
Financováno Evropskou unií NextGenerationEU

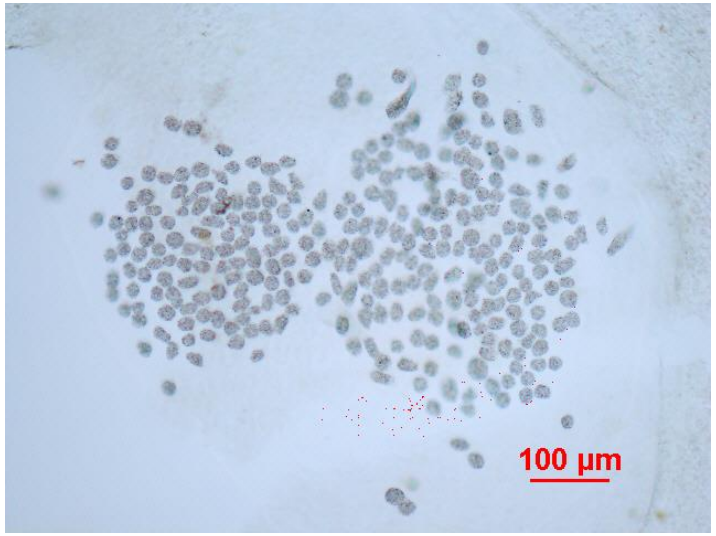
Národní plán obnovy

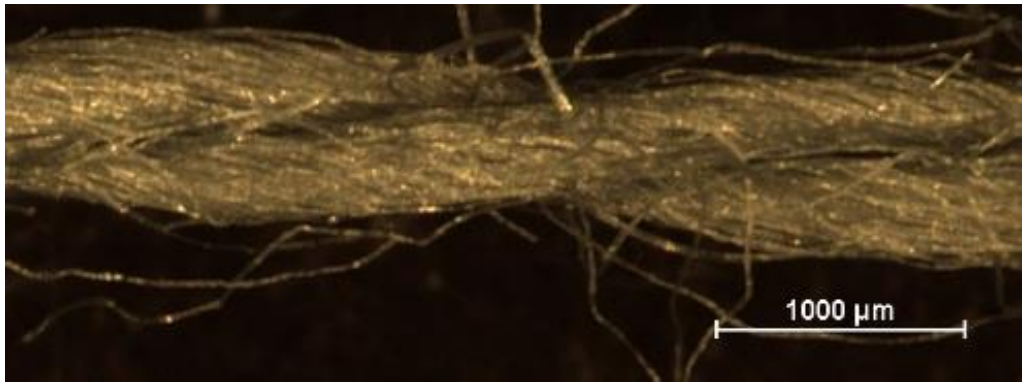
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

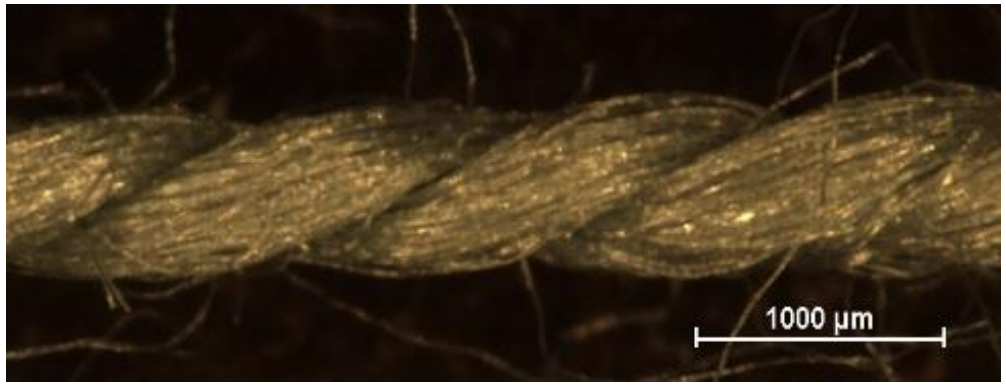
Two-ply yarn - inner and outer structure

IMAGES:
Cross-sections - optical microscopy
Longitudinal views - optical microscopy, macroscopy









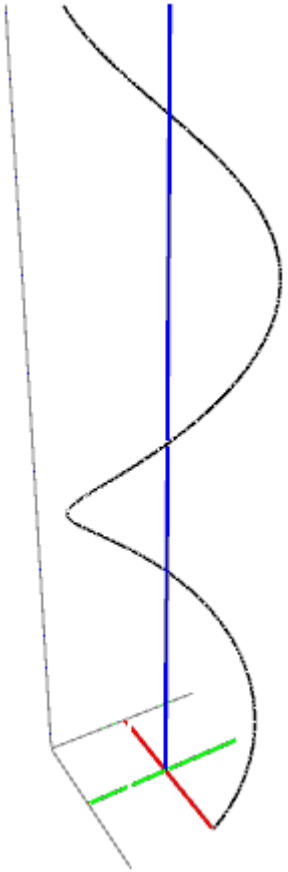
Two-ply yarn - geometry

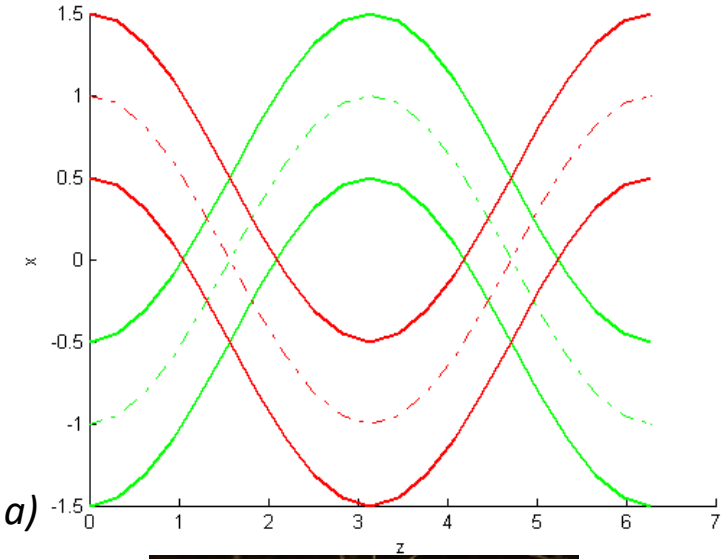
$$\vec{s}(x) = (a\cos(x), a\sin(x), b\,x)$$

kde ***x*** [rad]… rotation size

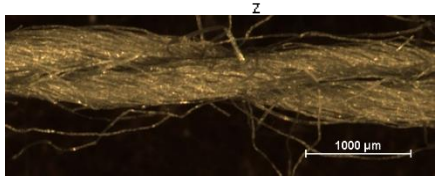
a [m]… radius of the cylindrical surface on which the helix lies

b [m]… reduced thread height of the screw movement.

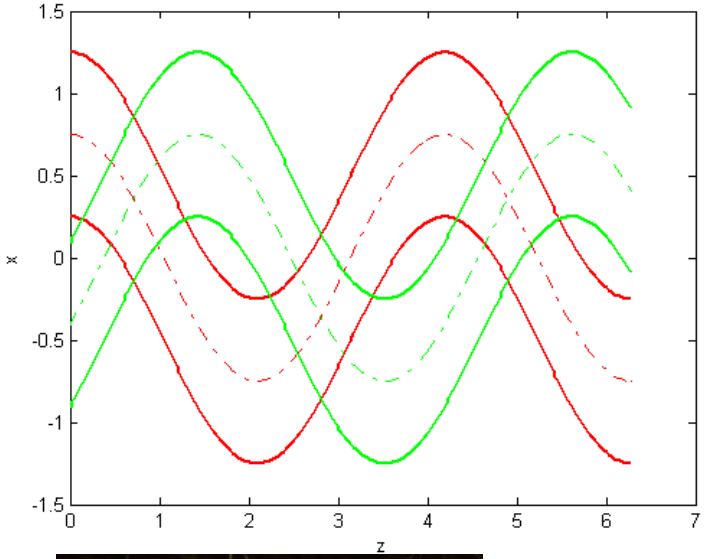




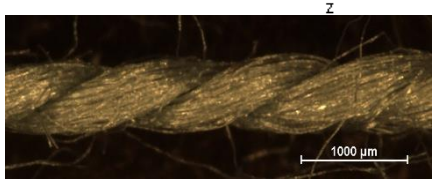
a)



c)



b)

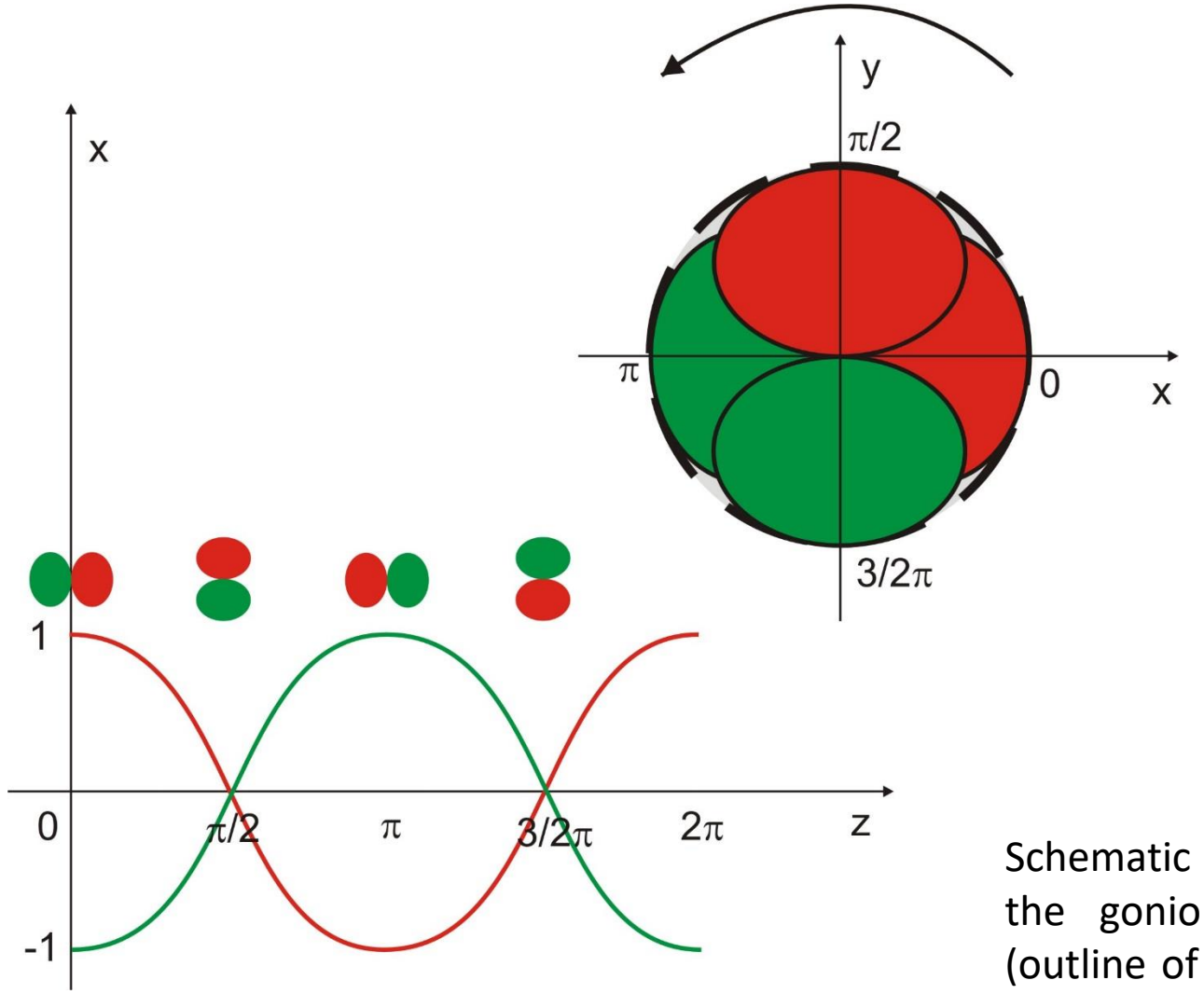


d)

Amplitude ↓
Phase shift ↑
Period ↓

Schematic representation of (a) extreme, (b) real position of single yarn axes in double yarn, c) - d) corresponding real yarns (2x45tex, 200 1/m, 600 1/m)

Two-ply yarn - geometry



Schematic display of single yarns in two-ply yarn through the goniometrical function (±cos(z)) in one period (outline of single yarn axes, ground plan of single yarns' bodies in half of one period).

Two-ply Yarn – geometrical parameters

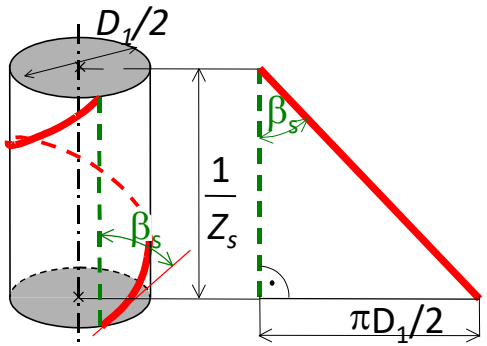
Max_s – the longest perpendicular distance between yarn boundaries
Min_s – the shortest perpendicular distance between yarn boundaries

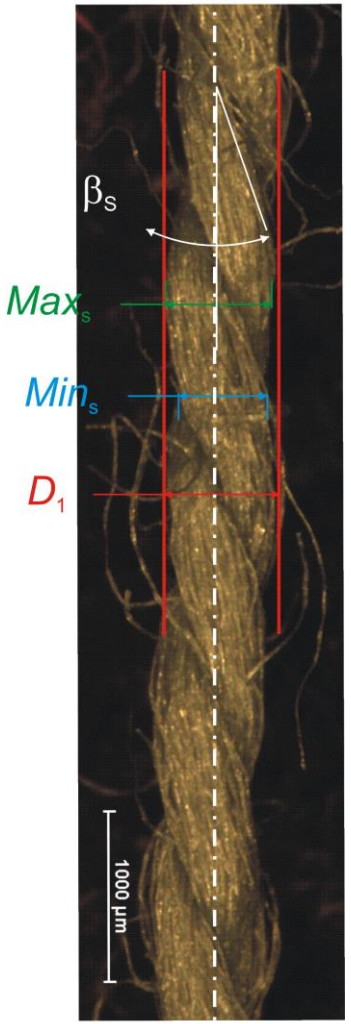
D_1 – the real diameter of cylinder, where can be two-ply yarn placed
($D_1/2$ distance of single yarns' axis in two-ply yarn)
β_s – angle between single yarn axis and two-ply yarn
D_2 – the shortest perpendicular distance between cross-section boundaries

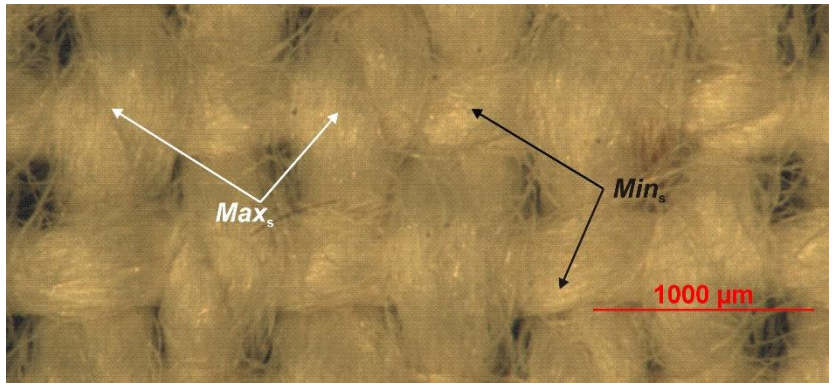
$$\tan \beta_s = \pi Z_s D_1/2$$

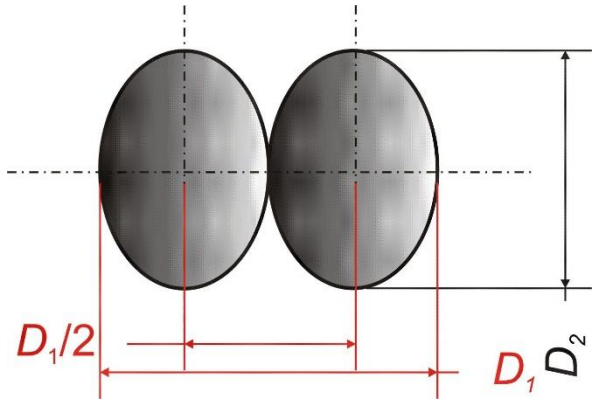
where… Z_s [1/m] is twist of two-ply yarn

One single yarn in two-ply yarn



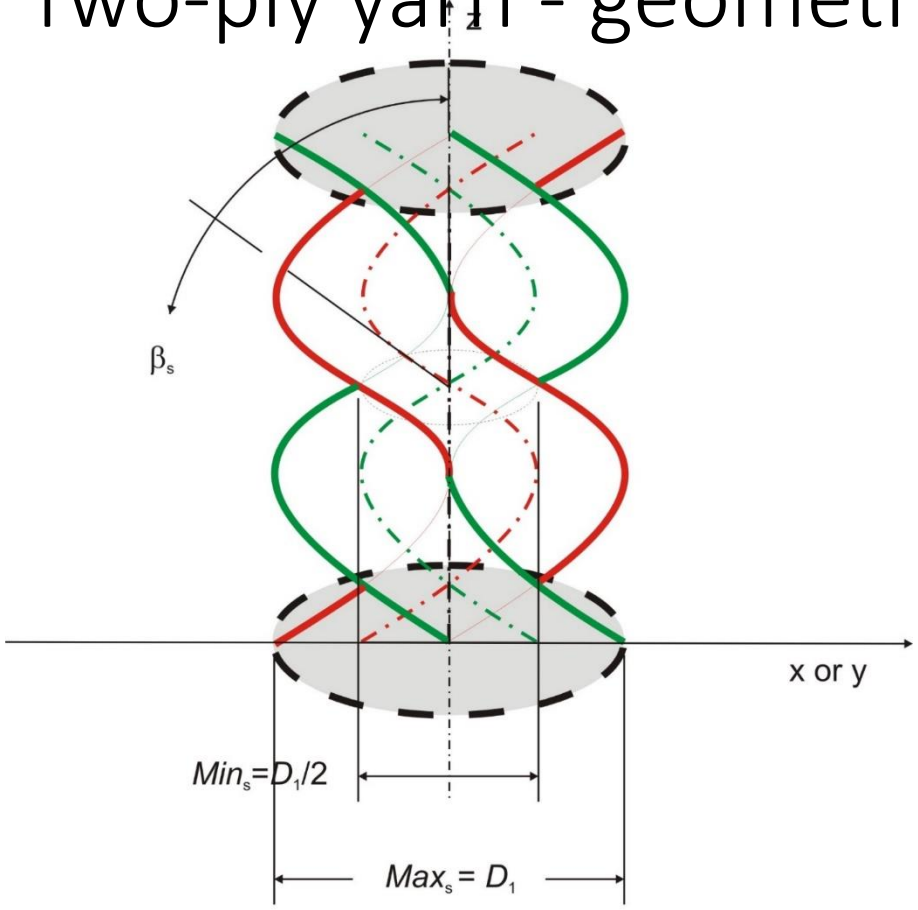


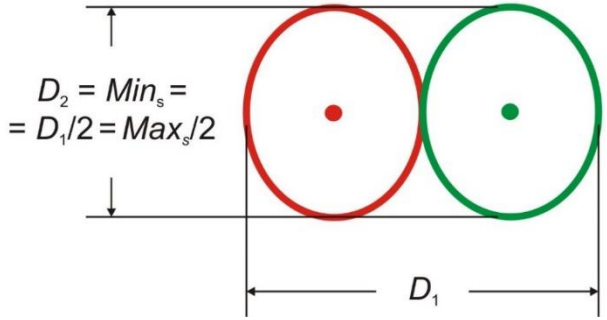




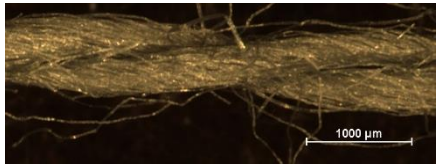
In extreme case the proportion D_1 is equal to Max_s. In other cases D_1 is longer than Max_s.
In extreme case D_2 is equal to Min_s, in other cases its value is shorter than Min_s (single yarns in two-ply yarn are not in the narrowest place of longitudinal view in sequence).

Two-ply yarn - geometry



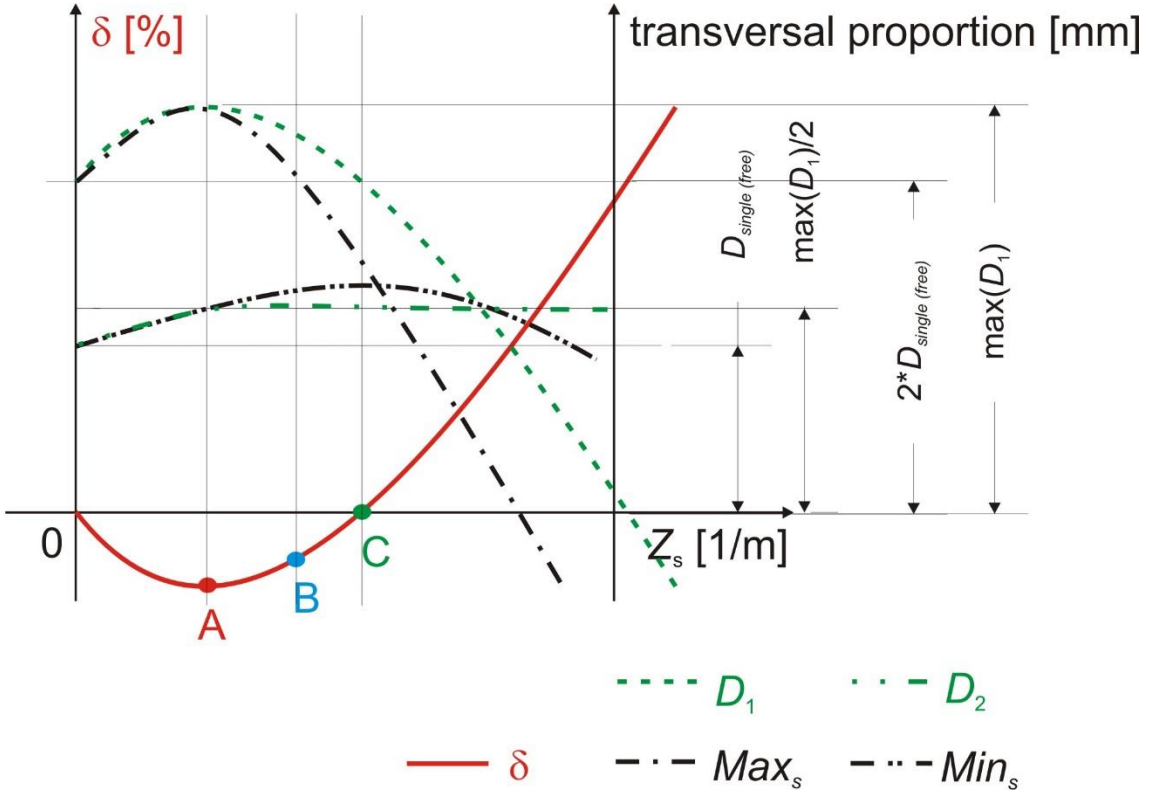


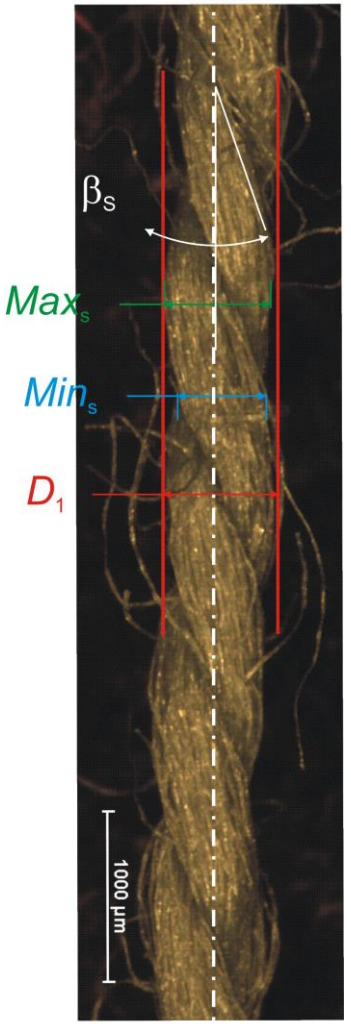
In the extreme case, the D1 dimension is equal to Maxs. In other cases, D1 is greater than Maxs.In the extreme case, D2 is equal to Mins, in other situations its value is less than Mins (single yarns in double skein are not completely concealed in the longitudinal view at the thinnest point).



An extreme state of two-ply yarn assembly in 2D (single yarns lie in a certain situation parallel, i.e., side by side or one after another).

Two-ply yarn - geometric parameters





Relation between retraction, ply twist and transversal proportions of two-ply yarn.

Two-ply Yarn – shape of cross-section

The most used shape characteristic is ***a circularity C***

$$C = \frac{real\ area\ 4\pi}{real\ perimeter^2}$$

Let's define ***ovality O*** on a basement of previous equation

$$O = \frac{real\ area}{area\ of\ ellipse\ with\ proportions\ of\ D_1\ D_2} = \frac{real\ area\ 4}{D_1\ D_2\ \pi}$$

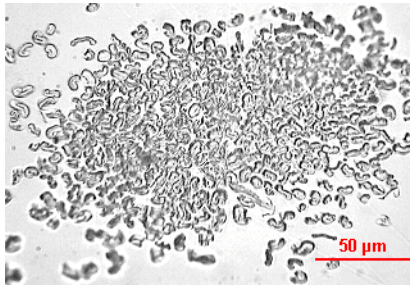
For two-ply and also single yarn.

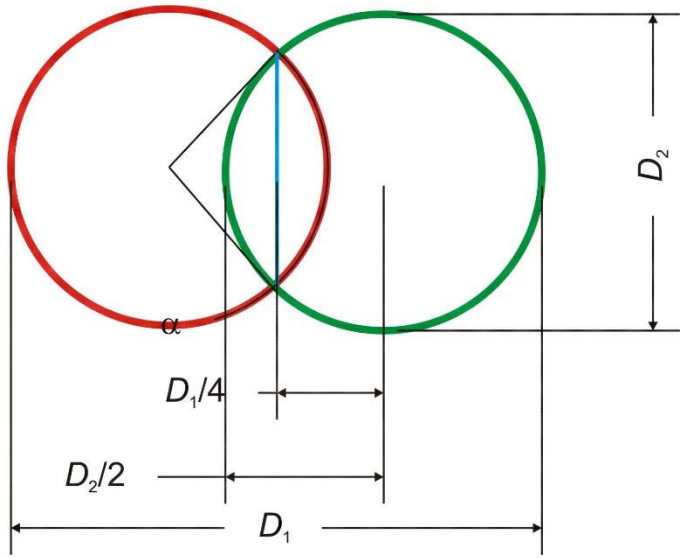
Two-circularity TC

$$S_u = \frac{\pi r^2}{360}\alpha - \frac{1}{2}r^2 \sin\alpha,$$

$$r = \frac{D_2}{2},$$

$$\alpha = 2\left[\arccos\left(\frac{D_1}{2D_2}\right)\right].$$





$$2\left[Area\ of\ circle - S_u\right] = \ldots = \frac{D_2^2}{2}\left[\frac{\pi}{2} - \frac{\pi}{180}\arccos\left(\frac{D_1}{2D_2}\right) + \frac{1}{2}\sin\left(2\arccos\left(\frac{D_1}{2D_2}\right)\right)\right].$$

$$TC = \frac{real\ area}{2\left[Area\ of\ circele - S_u\right]}.$$

For *C*, *O* and *TC* is valid – the closer to 1, the closer to circle, ellipse, two circles.

Two-ply Yarn – shape of cross-section, changes of single yarn diameter in the directions of D_1, D_2

If the observed formation (cross-section of single or two-ply yarn) doesn't have too broken boundaries, is possible to characterize its shape like ratio between the shortest ***(D_2)*** and longest perpendicular distance ***(D_1)***. If the ratio is equal to 1, formation with non-broken boundaries has circular shape, if is equal to 0.5, the given formation is ellipse.

If we know diameter or equivalent diameter (i.e. diameter of circle, which has the same area like real cross-section area) of single yarn D_{eq}, we can observe ***changes of this proportion in two direction of two-ply yarn proportions*** – D_1, D_2.

$Stage1a: \frac{D_2 \cos\beta_s}{D_{eq}} > 1$	Extension of single yarn in two-ply yarn in a direction of minimal proportion	$Stage1b: \frac{D_1}{2\,D_{eq}} > 1$	Extension of single yarn in two-ply yarn in a direction of maximal proportion
$Stage2a: \frac{D_2 \cos\beta_s}{D_{eq}} = 1$	No action in a direction of minimal proportion	$Stage2b: \frac{D_1}{2\,D_{eq}} = 1$	No action in a direction of maximal proportion
$Stage3a: \frac{D_2 \cos\beta_s}{D_{eq}} < 1$	Compression of single yarn in two-ply yarn in a direction of minimal proportion	$Stage3b: \frac{D_1}{2\,D_{eq}} < 1$	Compression of single yarn in two-ply yarn in a direction of maximal proportion

Internal and external structure of two-ply yarns - internal standards (see EXA_01):

- IN 46-108-01/01 Recommended procedure for creating cross sections. Soft and hard cuts
- IN 32-102-01/01 Transverse dimensions of two-ply yarn and diameter of single yarn. Longitudinal views.
- IN 22-102-02/01 Transverse dimensions of two-ply yarn and diameter of single yarn. Cross sections.
- IN 22-103-03/01 Yarn packing density - Isoquantities

Two-ply Yarn and Single Yarn – processing of cross-section

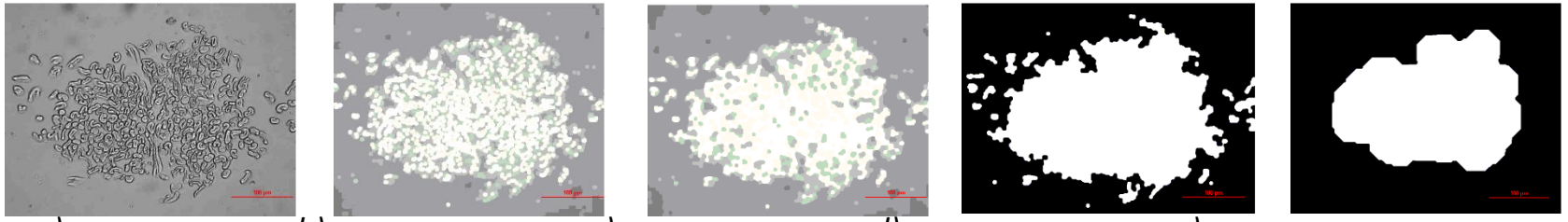
Preparation of cross-sections according to IS 46-108-01/ Recommended procedure for preparation of samples. Soft and hard sections (slices).

Input data to program in MatLab:

- Files with images of single yarn cross-sections.
- Calibration of images of single yarn cross-sections.
- Files with images of two-ply yarn cross-sections.
- Calibration of images of two-ply yarn cross-sections.
- Twist of two-ply yarn [1/m].

Principle:

Processing of each image of single and two-ply yarn cross-section proceeds by the following way.



a) *b)* *c)* *d)* *e)*

Download of color image (RGB), fig. a).

– Dilation [1] on intensity of color image components by structural element (SE) [1] with shape of disc (circle) with radius of 5 pixels. Dilation is executed for increasing of contrast between cross-section and background, in the same time the size of fibers is a little enlarged, fig. b).

– Close [1] of color image again by the same SE like in previous step. Morphological operation close is defined like dilation followed by erosion. In our case the area of fiber cross-section is a little enlarged for elimination the holes in yarn cross-section and in the same the size of yarn cross-section doesn't change, fig. c).

– Segmentation of preprocessed RGB image through the gray to binary (BW), Otsu's method is used [2], which is available in MatLab library. In the same time holes are filled up on BW image – black background surrounded by white color is filled also by white color, fig. d).

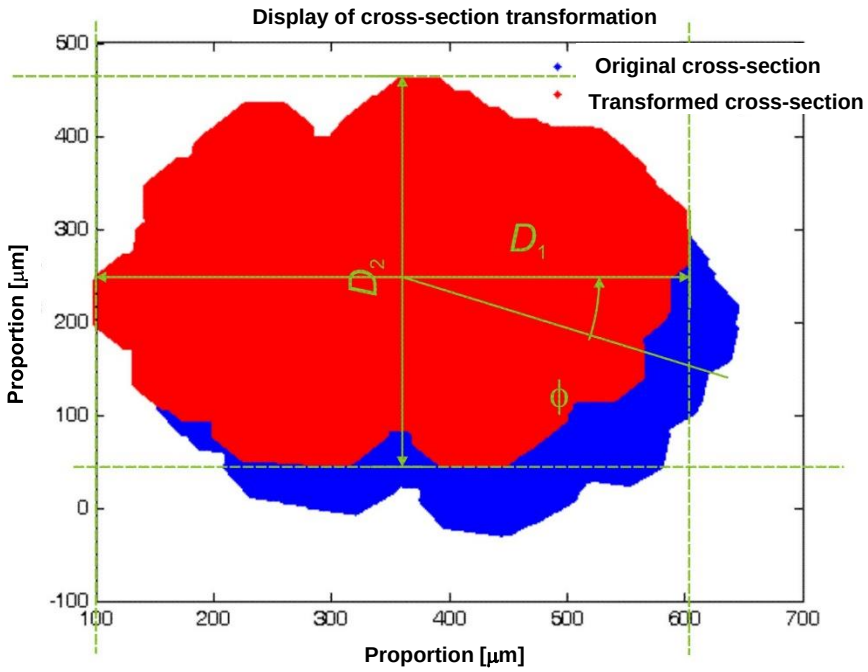
– Evaluation of all areas on image – object with the biggest area is defined like cross-section, which is finally smoothened by morphological operation close (erosion followed by dilation) wit using of structural element disc with radius of 40 pixels, fig. e).

Two-ply and Single Yarn – treatment of cross-section

Each cross-section (of two-ply and also of single yarn) is transformed to parallel direction with axis x.

For single yarn cross-section the following parameters are calculated:
- orientation (scalar – angle φ between axis x and main ellipse axis),
- equivalent diameter D_{eq}
- maximal and minimal perpendicular distance of cross-section borders (analogy to D_1 and D_2 by two-ply yarn),
- perimeter,
- filled area,
- circularity – C,
- ovality – *O*,
- ratio between minimal and maximal perpendicular distances of cross-section borders.

For two-ply yarn cross-section the following parameters are calculated:
- orientation (scalar – angle φ between axis x and main ellipse axis),
- maximal and minimal perpendicular distance of cross-section borders D_1 and D_2,
- perimeter,
- filled area,
- circularity – C,
- ovality – *O*,
- two-circularity – *TC*,
- ratio between minimal and maximal perpendicular distances of cross-section borders.

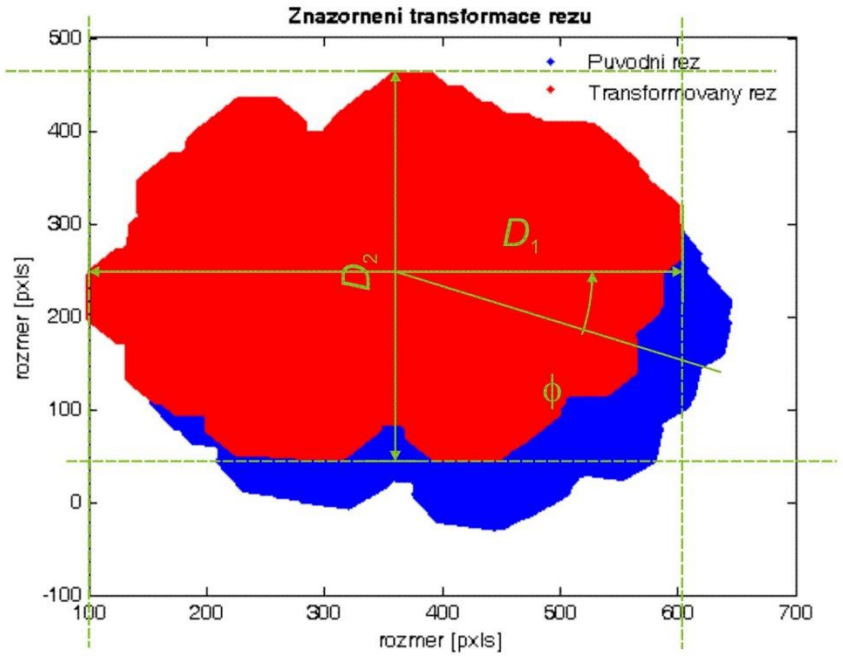


In confrontation of single and two-ply yarn cross-sections the changes of single yarn equivalent diameter D_{eq} in a direction of the maximal D_1 and minimal D_2 perpendicular distance of two-ply yarn cross-section borders, see previous table.

Dvojmo skaná a jednoduchá příze – zpracování příčného řezu

U řezů dvojmo skanou přízí je vypočtena:

- orientace (skalár – úhel φ mezi osou x a hlavní osou elipsy),
- maximální a minimální kolmá vzdálenost hranic řezu D_1 a D_2,
- obvod,
- zaplněná plocha,
- cirkularita – kruhovitost *K*,
- ovalita – *O*,
- dvou-kruhovitost – *DK*,
- poměr minimální a maximální kolmé vzdálenosti hranic řezu.

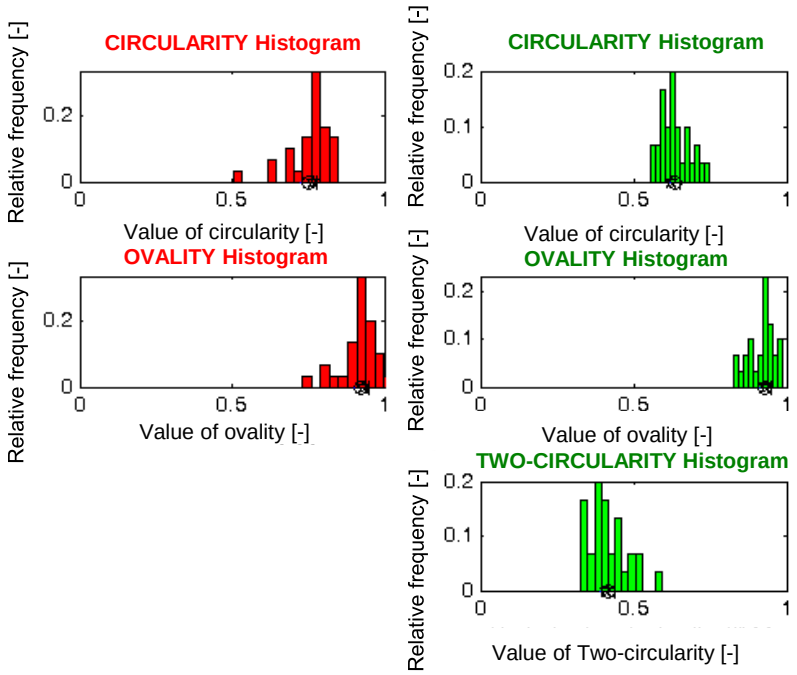


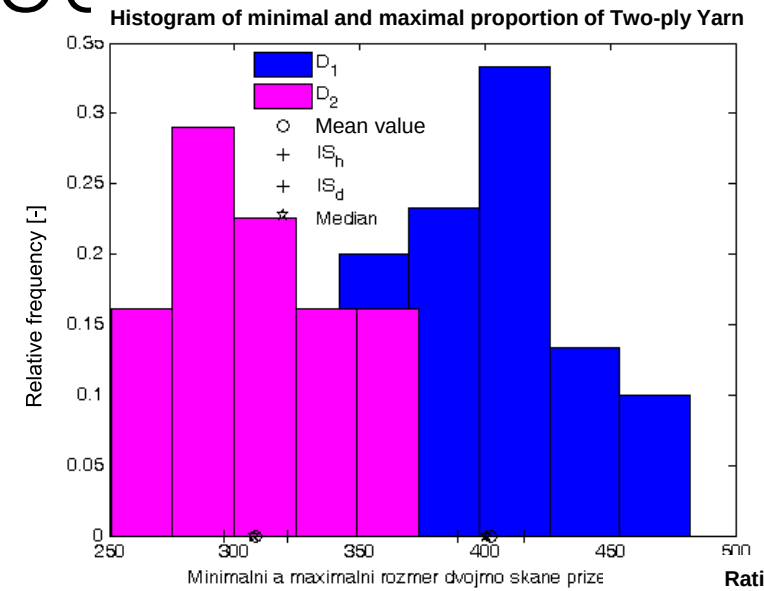
V rámci konfrontace řezů jednoduchou přízí s řezy dvojmo skanou přízí je sledována změna ekvivalentního průměru jednoduché příze $D_{ekvivalentní}$ ve směru nejdelší kolmé vzdálenosti hranic řezu dvojmo skanou přízí D_1 a ve směru nejmenší kolmé vzdálenosti hranic řezu dvojmo skanou přízí D_2, viz předchozí tabulka.

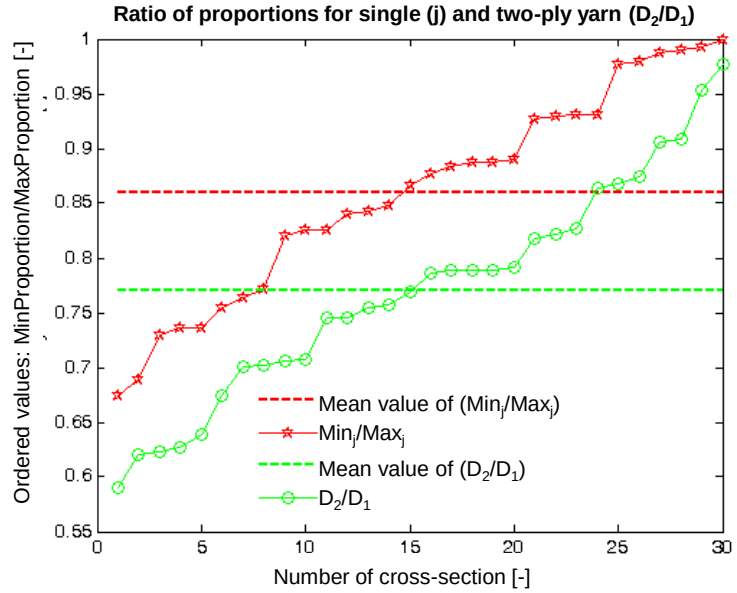
Two-ply and Single Yarn – processing of cross-section OUTPUTS

Data output – see previous slide

Graphical

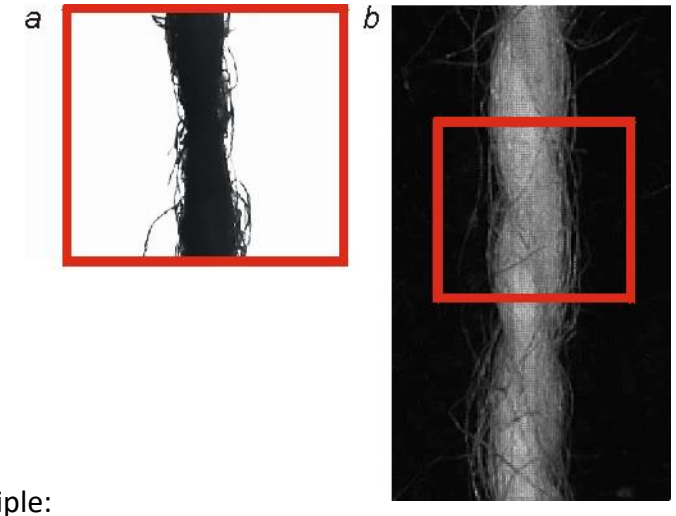






Two-ply Yarn – processing of longitudinal view

Image preparation according to IS 22-102-01/01 Hairiness and yarn diameter.

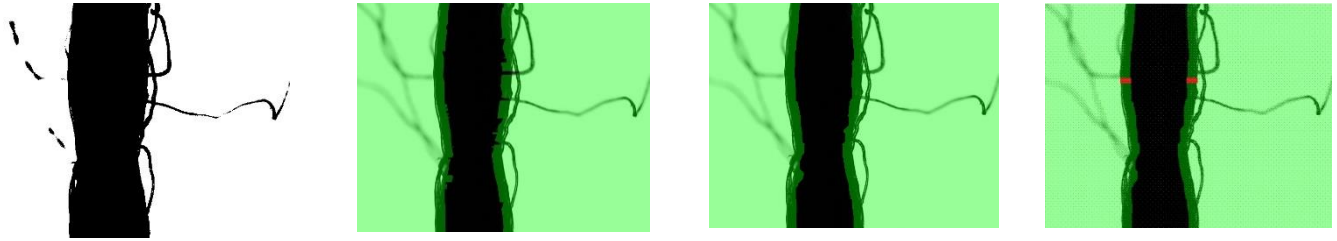


Input data:

- Files with images of two-ply yarn longitudinal views.
- Calibration of images.
- Initial choice of structural element length (is explained below).

Principle:

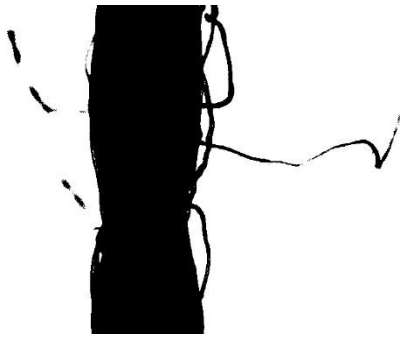
Correctly prepared color images of two-ply yarn longitudinal views are downloaded by program and following operations are executed on each.



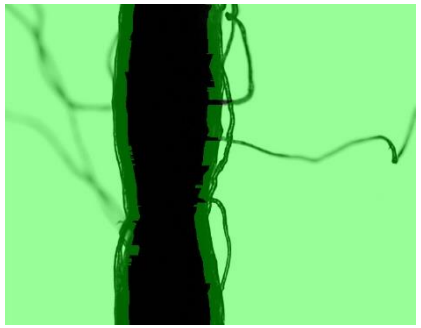
a) *b)* *c)* *d)*

Show of morphological operations executed on image: a) binary image, b) linear dilation, c) close, d) open (morphological operations are executed on binary image – here for illustration binary image overlays color image)

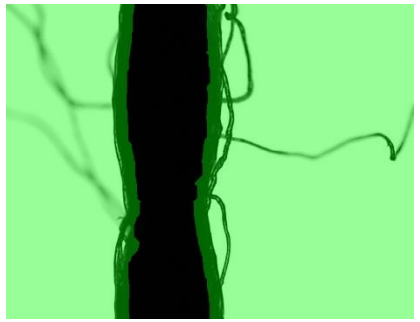
Two-ply Yarn – processing of longitudinal view



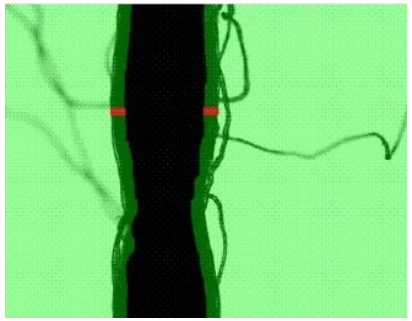
a)



b)



c)



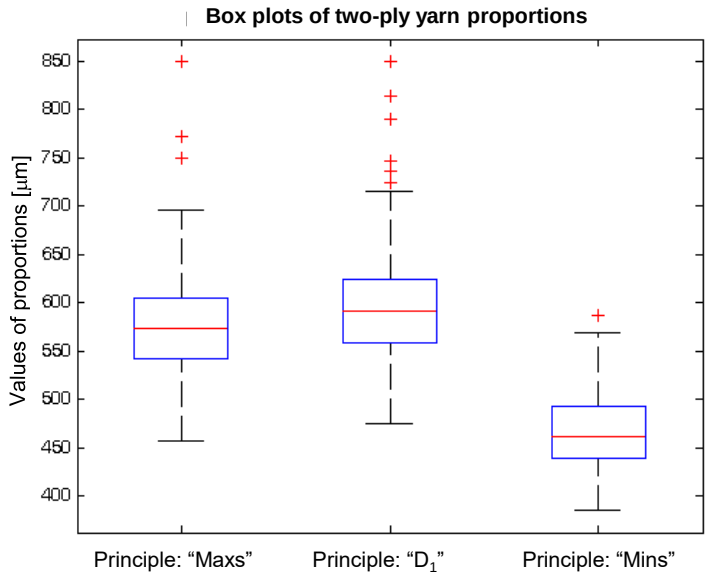
d)

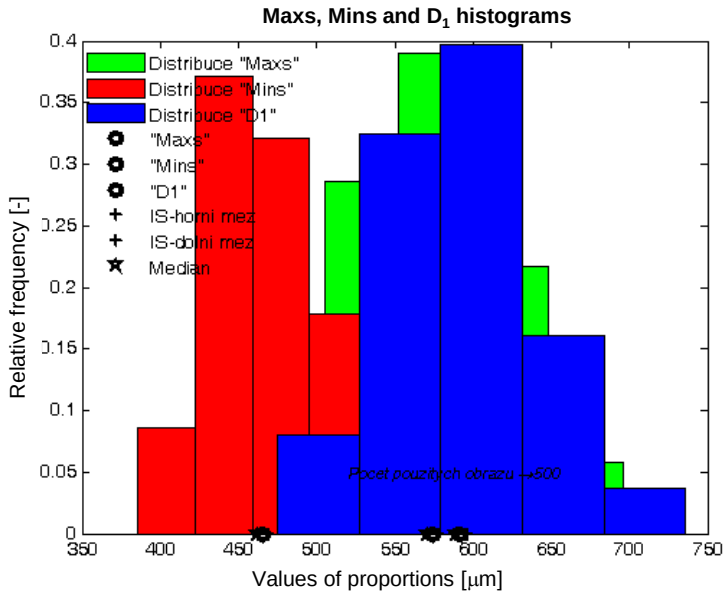
Representation of morphological operations performed on the image: a) binary image, b) linear dilation, c) closure, d) opening (morphological operations are performed on the binary image - here overlaid on the colour image for illustration)

Two-ply Yarn – processing of longitudinal view OUTPUTS

Data outputs – Max_s, Min_s, D_1 + their statistics

Graphical

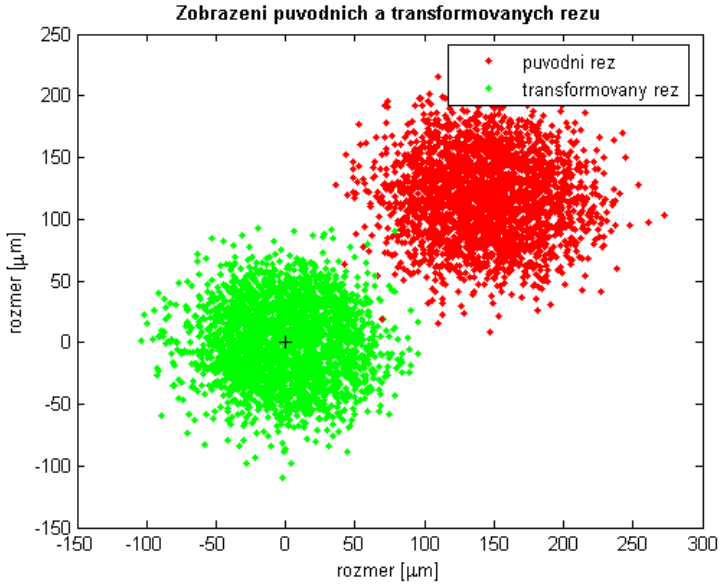


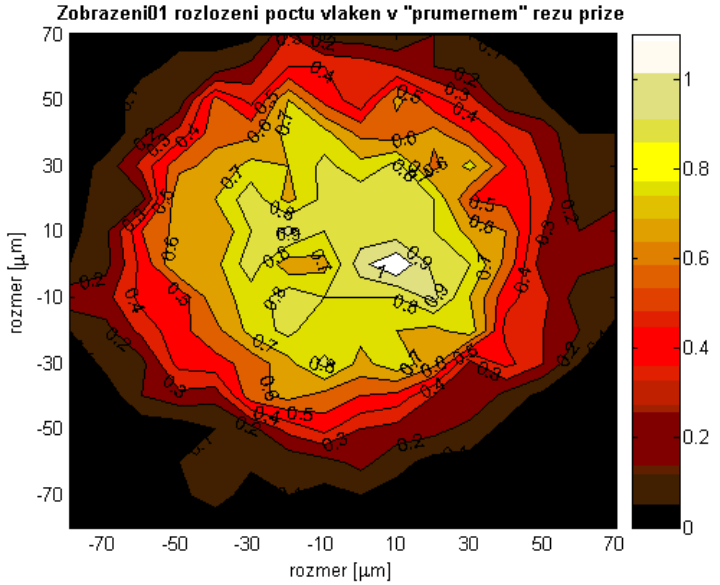


Program allows also processing of **single yarn** longitudinal view images, which doesn't have periodically repeated "thick" and "thin" places. Principle of processing is the same like by two-ply yarn images, all rows in image are evaluated, the statistic is calculated, box plots and histogram of single yarn diameter is displayed.

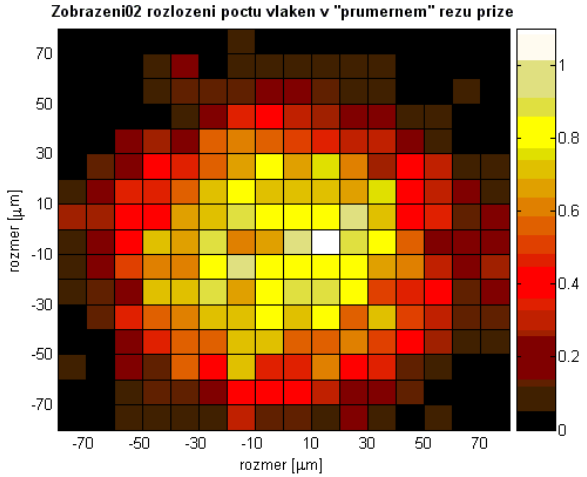
IN 22-103-03/01 Yarn packing density - Isoquantities

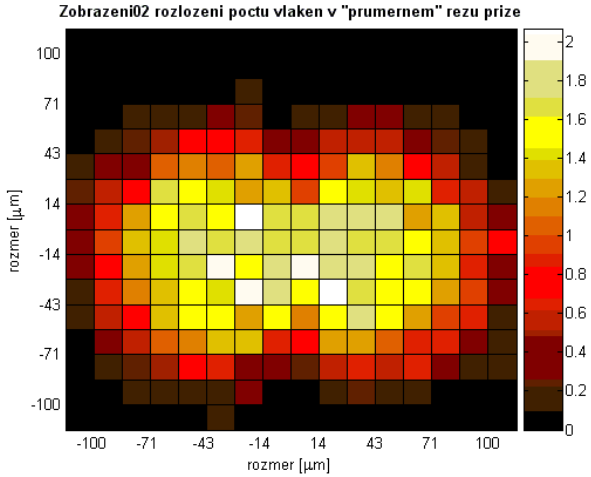
This standard specifies a procedure for calculating the density of fibre distribution in single and double twisted single component loose, twisted or braided yarns. Image analysis (NIS Elements) is used to obtain images of the sections and their evaluation, and a program in the MatLab environment is used to process the data and obtain data and graphical output.



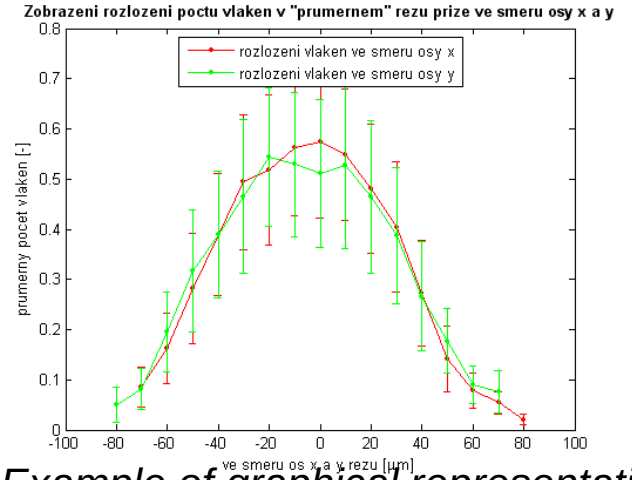


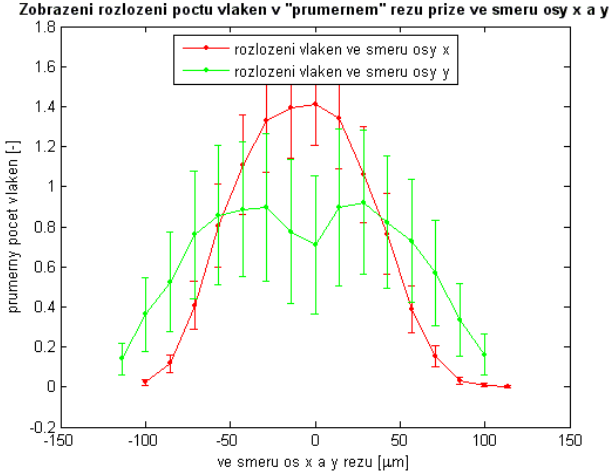
IN 22-103-03/01 Yarn packing density - Isoquantities





Example of surf chart - distribution of the average number of fibres in an "average" cut for single yarn (100%ba, combed, 10tex) and double skein yarn (100%ba, combed, 2x10tex, 601 1/m)

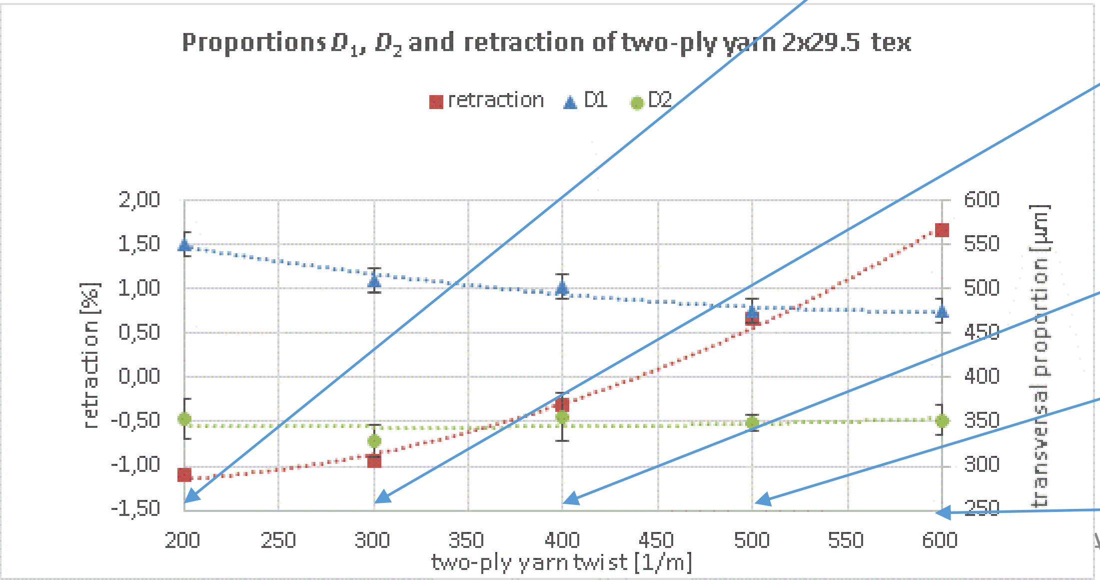


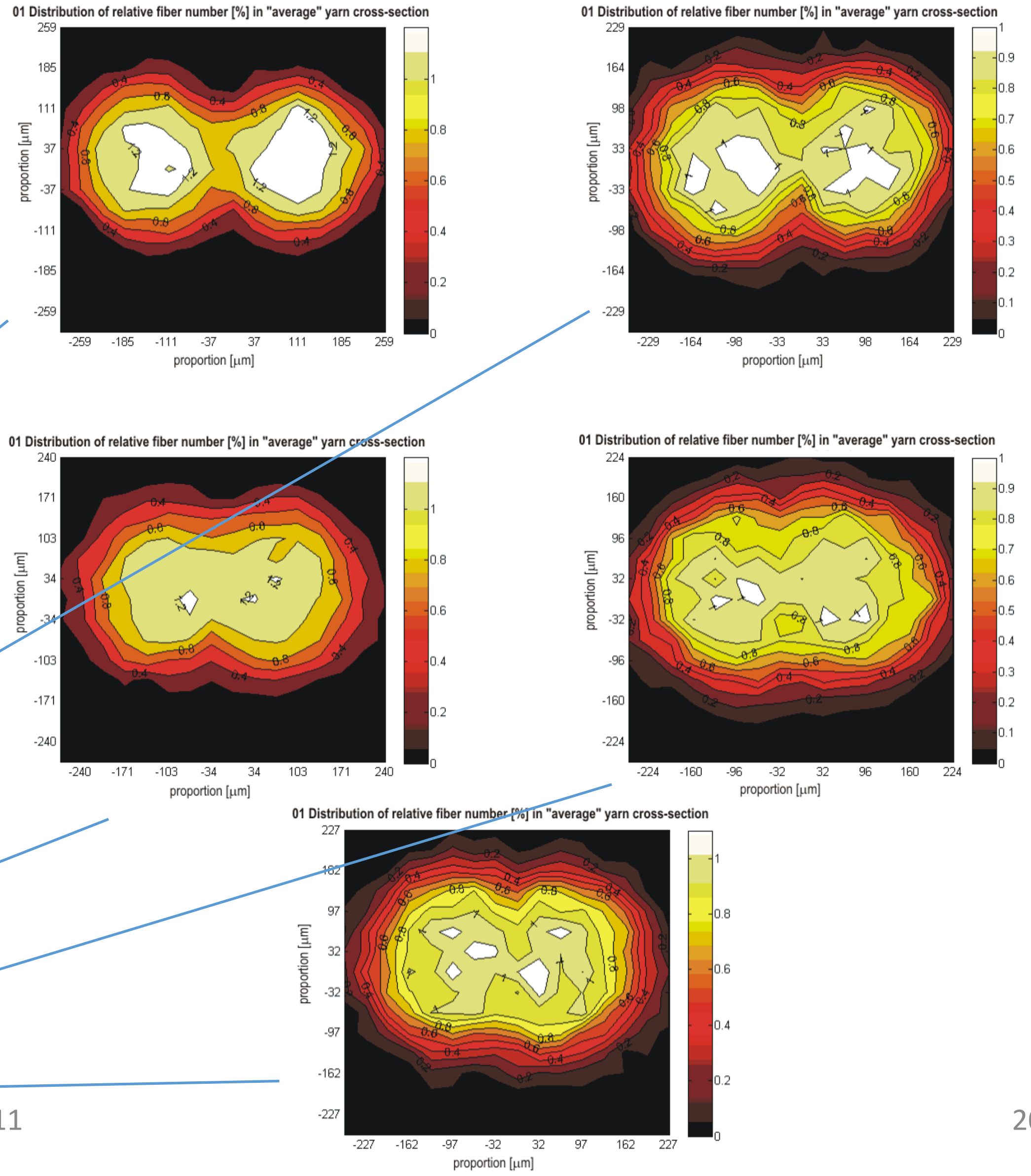


Example of graphical representation of the distribution of the average number of fibres in an "average" cut with single (100%ba, combed, 10tex) and double skein (100%ba, combed, 2x10tex, 601 1/m), always in the direction of the x and y axis (in the sense of an oriented cut)

Experiment I - the effect of the twist on the internal structure of the two-ply yarn

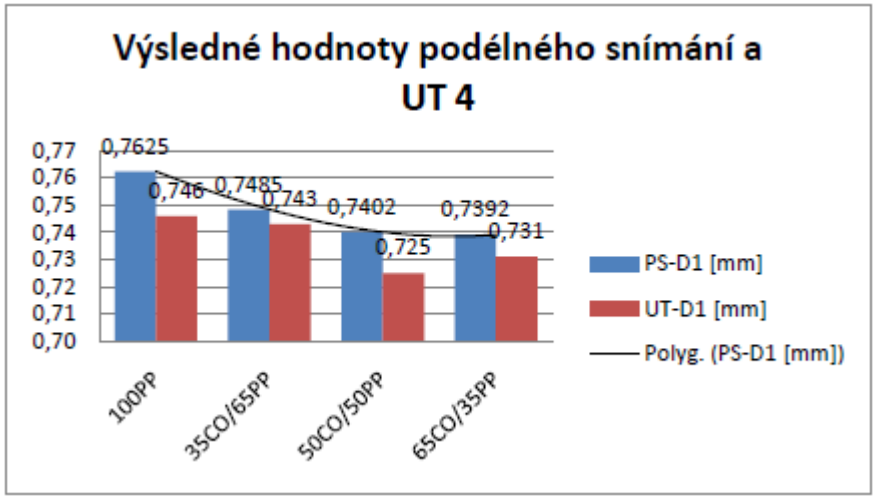
nominal fineness [tex]/ply twist [1/m]	2x29.5/200	2x29.5/300	2x29.5/400	2x29.5/500	2x29.5/600
real fineness [tex]	58.22±0.30	57.81±0.21	59.41±0.22	59.19±0.12	59.56±0.13
real ply twist [1/m]	192±8	273±8	415±10	493±11	547±20
D_1 [mm]	549.53±21.66	510.32±23.42	502.84±21.90	475.12±26.08	475.46±18.13
number of fibers [-]	238±8	221±10	233±8	227±4	234±9

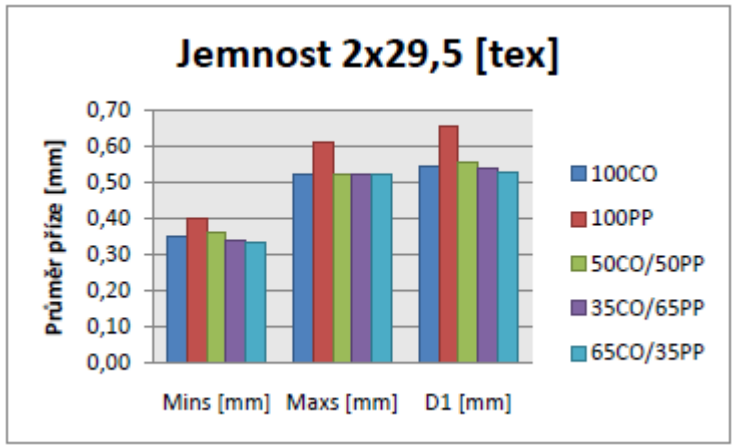


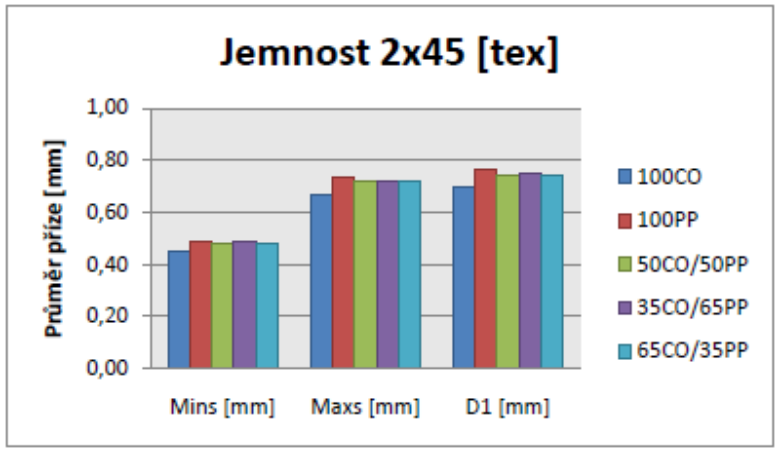


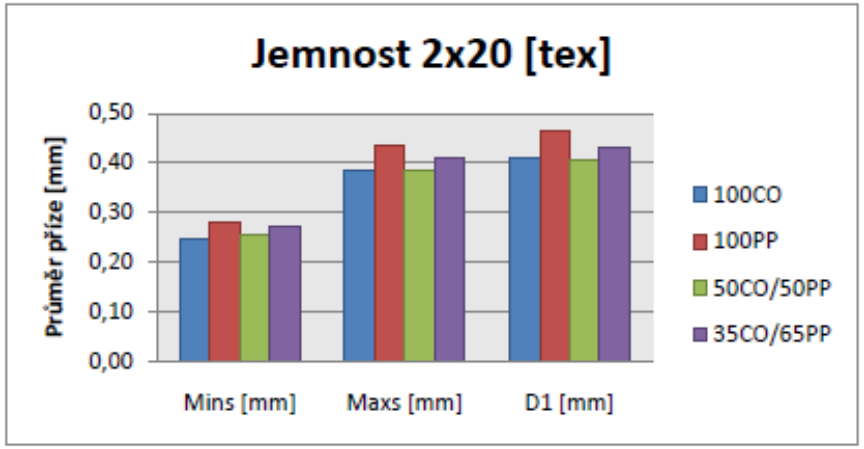
Experiment II - transverse dimensions of two-ply yarns of different materials

složení [%	jmenovitá jemnost [tex]	Mins [µm]	IS Mins [µm]	Maxs [µm]	IS Maxs [µm]	D1 [µm]	IS D1 [µm]
100CO	2x45	450,3450	9,4675	668,9500	12,7275	696,0500	12,5525
100PP	2x45	489,9850	9,6020	734,8500	12,7115	762,5000	13,2460
50CO/50P	2x45	480,9650	8,2540	717,9500	9,4705	740,1500	11,3275
35CO/65P	2x45	487,7600	7,5435	716,7500	11,3375	748,5000	11,8980
65CO/35P	2x45	479,8550	8,7165	715,8000	12,2500	739,2000	13,0180
100CO	2x29,5	352,9131	8,0971	522,0575	12,6572	546,5364	13,0518
100PP	2x29,5	403,8112	8,1533	611,2960	13,3277	656,6364	15,1783
50CO/50P	2x29,5	362,4859	7,8670	525,6541	10,3261	555,9865	10,5122
35CO/65P	2x29,5	341,0100	7,9050	526,3600	10,6250	439,8700	11,2650
65CO/35P	2x29,5	333,6700	7,3950	522,2900	10,2500	431,1100	10,2850
100CO	2x20	247,2550	5,1790	384,4200	8,7820	409,3700	9,0875
100PP	2x20	279,3650	5,8660	433,9700	8,1560	463,6950	9,0090
50CO/50P	2x20	255,9400	5,5580	384,4050	7,7415	405,8000	8,0795
35CO/65P	2x20	271,9250	6,1310	411,5150	8,3730	432,2850	9,1520

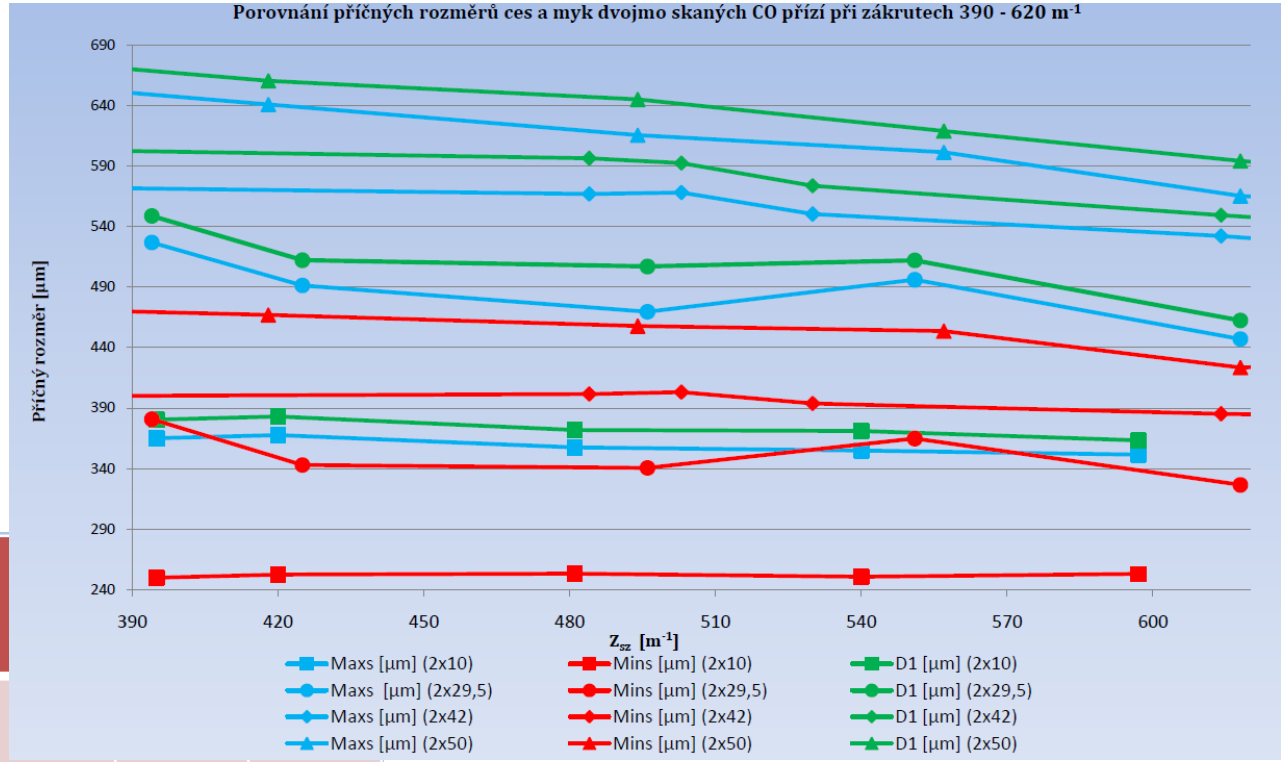






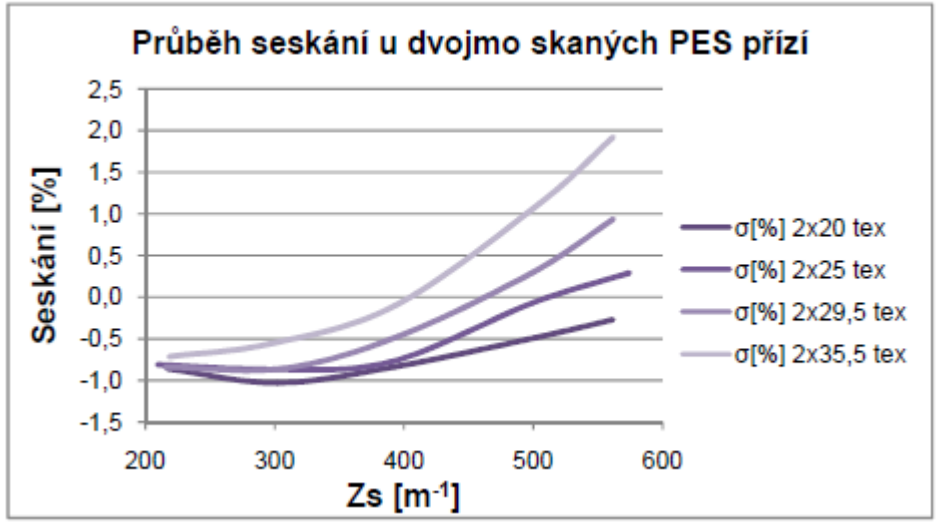


Experiment III - transverse dimensions of two-ply yarns (different single yarn technologies)



Jed. příze 100% CO	T_j [tex]	Z_s jmenovitá [m^{-1}]									
ČESANÁ	10	370	425	486	537	601					
	29,5	370	425	486	537	601					
MYKANÁ	42	300	370	425	486	537	601	681	783	861	1014
	50	300	370	425	486	537	601	681	783	861	1014

Experiment IV - transverse dimensions of two-ply yarns and slumping (polyester yarns)

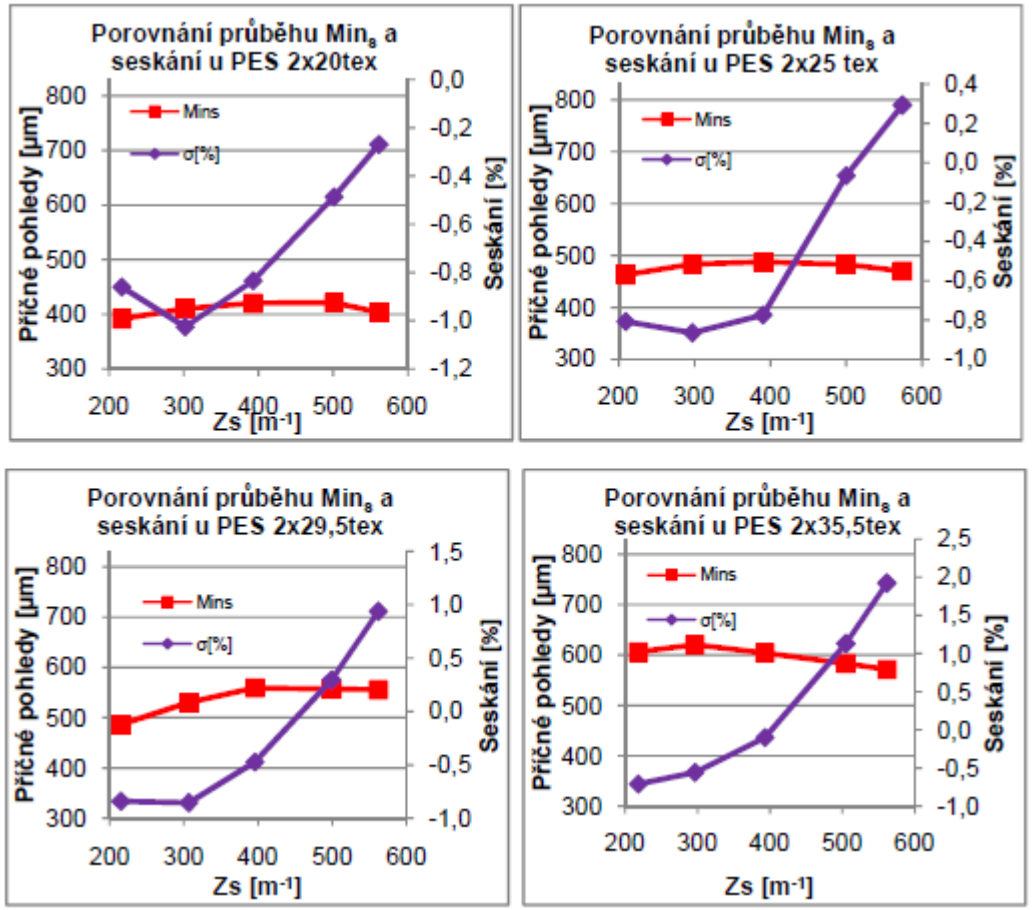


$$\delta = \frac{l - l_s}{l} 100$$

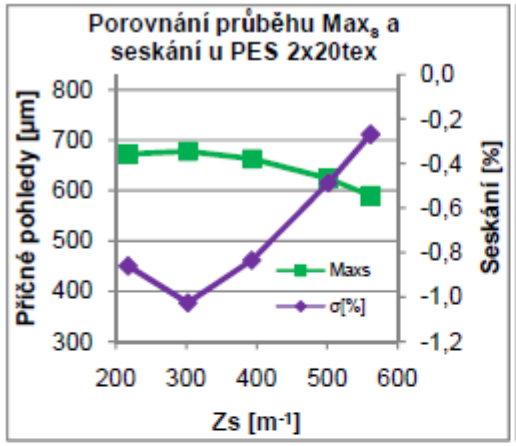
δ … seskání [%]

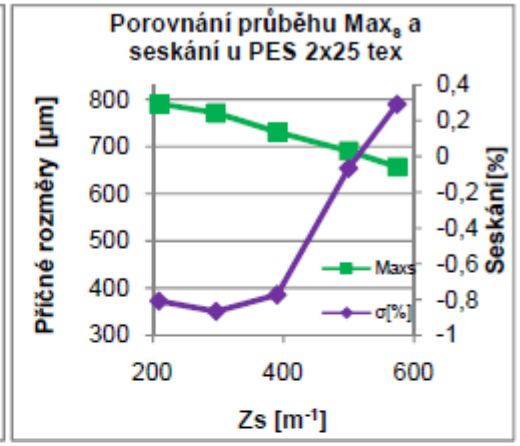
l_s … délka skané příze [m]

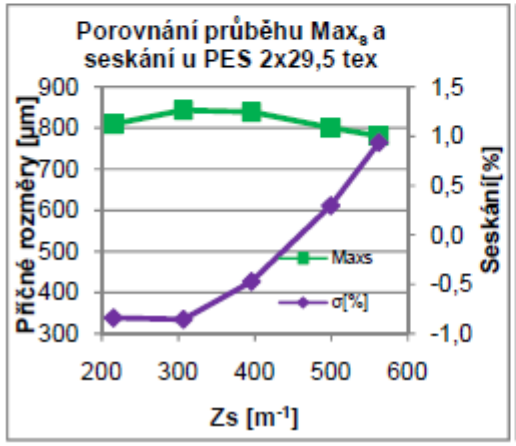
l … délka jednoduché příze [m]

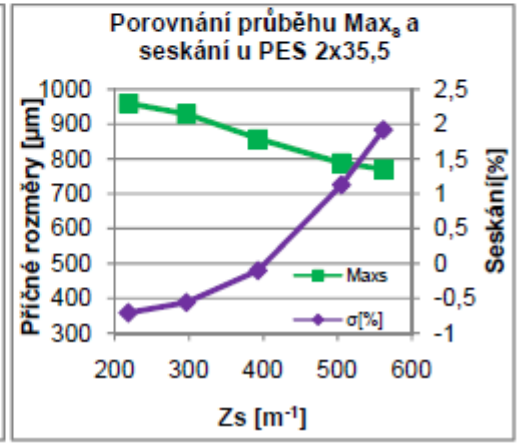


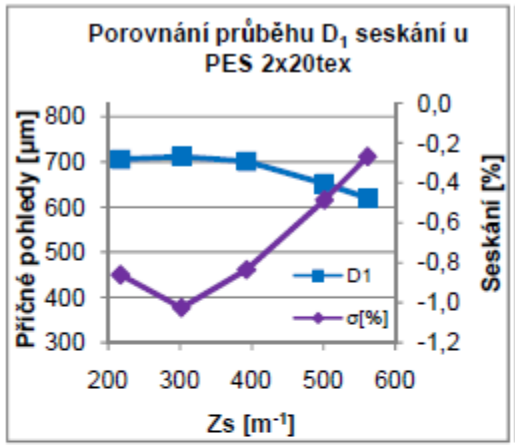
Experiment IV - transverse dimensions of two-ply yarns and slumping (polyester yarns) – continued

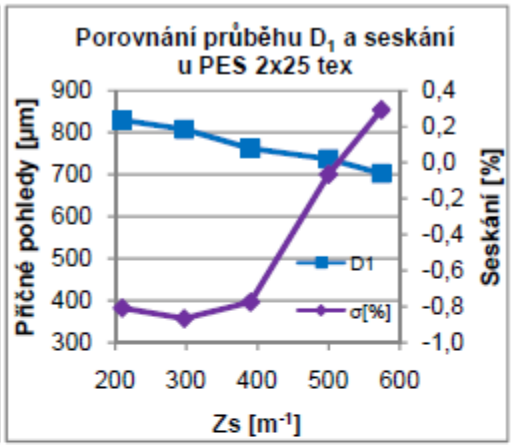


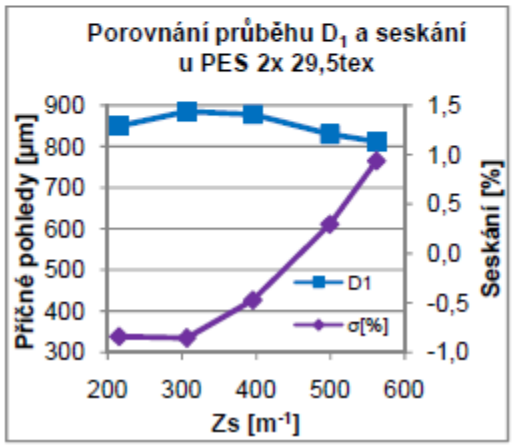


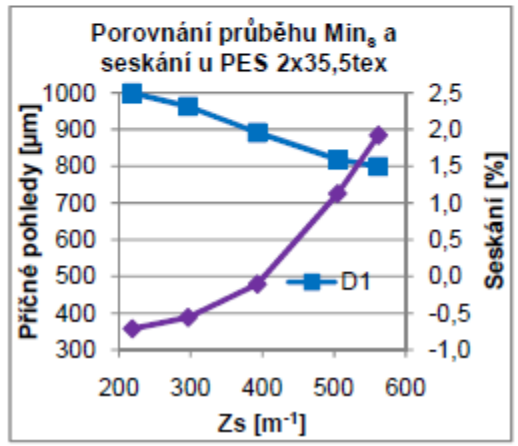












References used:

1. Výběr interních norem KTT – viz text prezentace
2. Výběr publikací a zpráv autorky, práce vedené autorkou