Textile testing - Practicals

Course schedule

1. Safety rules, basic informations
2. Processing of experimental data I
3. Processing of experimental data II
4. Laboratory task 1
5. Laboratory task 2
6. Laboratory task 3
7. Laboratory task 4
8. Laboratory task 5
9. Laboratory task 6
10. Laboratory task 7
11. Laboratory task 8
12. Remaining tasks
13. Report control and corrections
14. Credits

Course informations:

Working tools: shoes for change, writing aids, calculator

Granting credits: submission and approval of laboratory reports

Processing of laboratory reports:

1. **Introduction: General information on studied material**
2. **Processing of laboratory tasks**
   - Brief description of the task
   - Description of measured parameters
   - Processing of experimental data
   - Final results
3. **Conclusion: Evaluation of analysed material**

Overview of laboratory tasks:

Laboratory task 1 - length of fibres (wool and synthetic)

Laboratory task 2 - linear density of fibres (wool and synthetic)

Laboratory task 3 - linear density of yarns (yarn from bobbin and 10 warp and weft yarns of 10 cm length)

Laboratory task 4 - yarn twist (number of twists per meter, 10 yarns of 30 cm length for warp direction and 10 yarns of 30 cm length for weft direction)

Laboratory task 5 - basic parameters of fabric - 3 specimen

Laboratory task 6 - strength and strain of fabric - 3 specimen for warp and 3 for weft directions

Laboratory task 7 - fabric stiffness (3 specimen for warp and 3 for weft directions) and drapability (3 specimen)

Laboratory task 8 - air permeability (13 specimen, 15 measurements each) and abrasivity of fabric (3x2 specimen)

Safety rules for students' laboratory work at Department of textile materials

Students are obliged to follow the instructions of the supervisors and work according to the instructions.

Students are forbidden to carry out work, which are not requested, and manipulate devices impropriate for a given task.

Students are obliged to keep the laboratory clear and not to block up the escape ways.

In laboratory it is forbidden to drink or eat. The laboratory glass must not be used for drinking and eating even out of laboratory.

While working with chemicals it is necessary to keep basic rules of chemical laboratory techniques.

If any damage occurs it is necessary to inform the supervisor or laboratory staff.

Students are informed where to find the first-aid kit, fire-extinguisher, and the rules for fire escape.

Long hairs must be fixed during the lab-work.

Basic statistical relations:

Two relations for arithmetic mean and variance are presented.
First are mentioned relations for small data set.
Second are mentioned relations for large data set (categorized data).

Arithmetic mean

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$\bar{x} = \frac{1}{n}\sum_{j=1}^{k} x_j n_j$$

Variance

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2$$

$$s^2 = \frac{1}{n-1}\left(\sum_{j=1}^{k} x_j^2 n_j - \left(\bar{x}^2 n\right)\right)$$

Standard deviation

$$s = \sqrt{s^2}$$

Coefficient of variation

$$v = \frac{s}{\bar{x}} \cdot 100 \quad [\%]$$

95% confidence interval.

$$95\% \quad IS = \bar{x} \pm t_{(n-1)} \cdot \frac{s}{\sqrt{n}}$$

t-paremeters of Student's distribution are enclosed

Modus

The measured value which has mostly occured
For categorized data it is characteristic value of the category.

Median

Mean value – average of data sorted by size.
For categorized data it is characteristic value of the category, where the cumulative density the 50 %

t-parameters of Student's distribution

n	$t_{0,025}$
1	12,7
2	4,30
3	3,18
4	2,78
5	2,57
6	2,45
7	2,36
8	2,31
9	2,26
10	2,23
11	2,20
12	2,18
13	2,16
14	2,14
15	2,13
16	2,12
17	2,11
18	2,10
19	2,09

n	$t_{0,025}$
20	2,09
21	2,08
22	2,07
23	2,07
24	2,06
25	2,06
30	2,04
40	2,02
50	2,01
60	2,00
100	1,98
120	1,98
150	1,96
∞	1,96

Volume densities of selected textile fibers

conditioned fiber	**ρ[kg.m^{-3}]**
cotton	1520
flax	1450
viscose	1490
acetate, triacetate	1320
wool	1310
silk	1340
casein	1300
polyamide 6, polyamide 6.6	1140
polyester	1390
polyacrylonitrile	1190
polypropylene	910
polyethylene	950
glass	2500
basalt	2800

Laboratory task 1
Length of fibres in yarn

Specification:

Measure the length of fibres using two methods:
1. Untwist the staple yarn, separate cca 50 fibres, and measure them by direct method on glass mat.
2. Wool fibres - the length of fibres is measured using ball measurement device (cca 150 fibres)

1. Estimate:
   - Mean length of fibres
   - Modal length of fibres
   - Median length of fibres
   - Standard deviation
   - Coeff. of variation
   - 95% confidence interval
2. Draw histogram of fibre lengthes
3. Draw staple diagram and staple curve

Analysed material
1. PES yarns of woven fabric
2. Wool fibres

Measurement device and aids
1. glass mat, glycerin,
2. scale of length, tweezers
3. ball measurement device

Climatic conditions:
- t =
- p =
- φ =

Basic relations:
1. Basic relations of statistics
2. Staple diagram – probability estimation of fibre occurence ***P***

$$P = \sum_{j=k}^{j} f_j$$

Table 1. Measured and calculated parameters:

<u>Fibres of PES yarn</u>

j	l_{jd} - l_{jh}	l_j [mm]	n_j	f_j [%]	F_j [%]	P_j [%]	$l_j n_j$	$l_j^2 n_j$
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

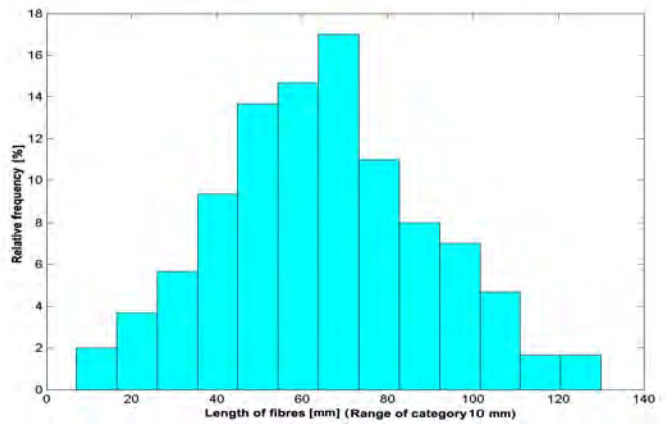
Wool fibres

j	l_{jd} - l_{jh}	l_j [mm]	n_j	f_j [%]	F_j [%]	P_j [%]	$l_j n_j$	$l_j^2 n_j$
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

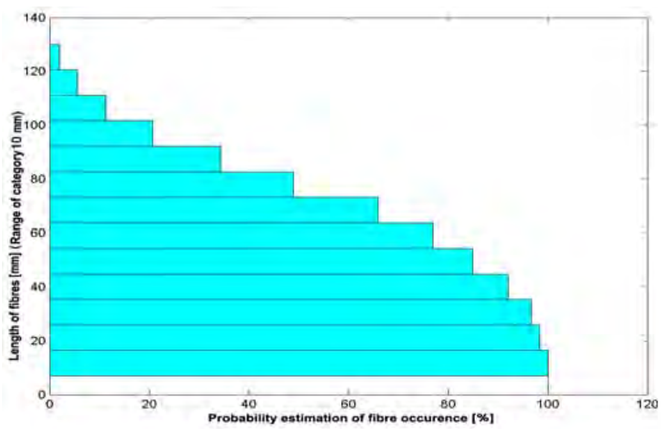
Results for PES and wool fibres:

- Mean length of fibres [mm]
- Modal length of fibres [mm]
- Median length of fibres [mm]
- Standard deviation [mm]
- Coeff. of variation [%]
- 95% confidence interval for mean value of lengthes [mm]

Histogram of fibre lengthes



Staple diagram and staple curve



Laboratory task 2
Estimation of linear density of fibres possessing circular cross-section

Specification:

Measure the diameter of cross-section of the fibres (PES, wool). For diameter determination use the device called Lanameter, analyse the PES and wool fibres separately. Number of measurements – 50 for PES fibres, 100 for wool fibres.

Estimate:

1. For both (PES, wool):
   - Average fibre diameter µm
   - Standard deviation µm
   - Coeff. of diameter variation %
   - 95% confidence interval (-) µm
2. Draw histogram of fibre diameters
3. Draw cumulative frequency diagram
4. Calculate mean linear density of fibres

Analysed material:
1. wool fibres from warp and weft yarns
2. PES fibres from warp and weft yarns

Climatic conditions:
- t =
- p =
- φ =

Measurement device and aids:
1. Lanameter
2. Aids for microscopical preparation

Basic relations:

$$\overline{T} = \frac{1}{4}\pi \cdot \overline{d}^{\,2} \cdot \rho \cdot 10^6 \text{ [tex]}$$

Linear density of fibres possessing circular cross-section

d – fibre diameter [m]

ρ – volume density of material [kg.m^{-3}]

Table: Measured and calculated parameters

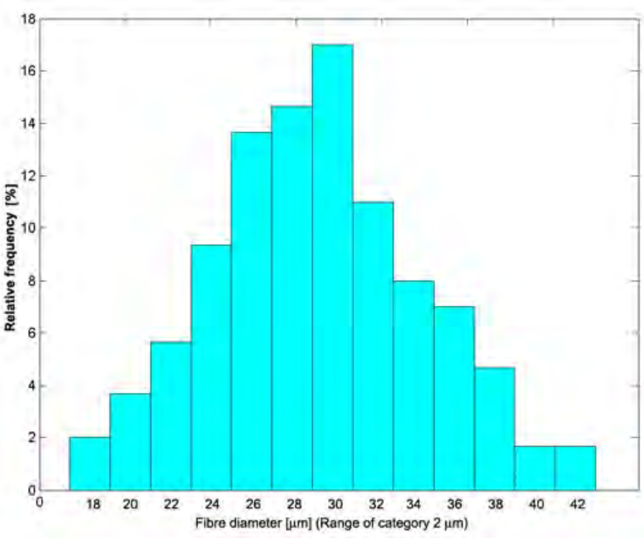
PES fibres:

j	d_{jd} - d_{jh}	d_j [µm]	n_j	f_j [%]	F_j [%]	$d_j n_j$	$d_j^2 n_j$
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

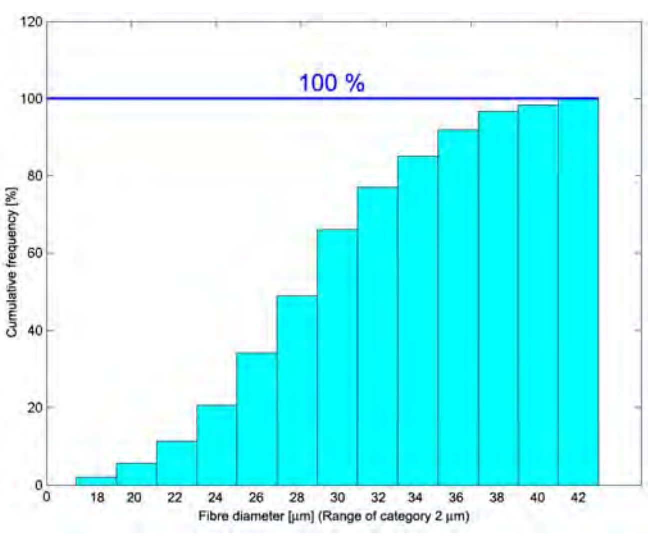
Wool fibres

j	d_{jd} - d_{jh}	d_j [µm]	n_j	f_j [%]	F_j [%]	$d_j n_j$	$d_j^2 n_j$
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

Histogram of fibre diameters



Cumulative frequency diagram



Laboratory task 3
Linear density of yarns

Specification:

1. Estimate linear density of warp and weft yarns (5 specimen each, specimen = 10 yarns of 10 cm length)
2. Calculate mean linear density of yarns
3. Estimate linear density of yarn using specimen of variable lengthes - 5, 10, 20, 30, 40, 50 metres
4. Draw diagram of linear density dependance on the length of specimen

Analysed material:

1. Warp and weft yarns of fabric
2. Yarn wound on bobbin

Climatic conditions

- t =
- p =
- φ =

Measurement device and aids:

1. Digital mass meter
2. Mat, razor blade, scale of length, tweezers
3. Scissors

Basic relations:

$$T = \frac{m}{l}[tex] \quad \left[\text{tex} \approx \frac{\text{g}}{\text{km}}\right]$$

m – mass of yarn [g]

l – length of yarn [km]

l = 1 m = 0,001 km

Table: Measured and calculated parameters

Warp yarns

Specimen	1	2	3	4	5	**Mean value**
m [g]						
T [tex]						

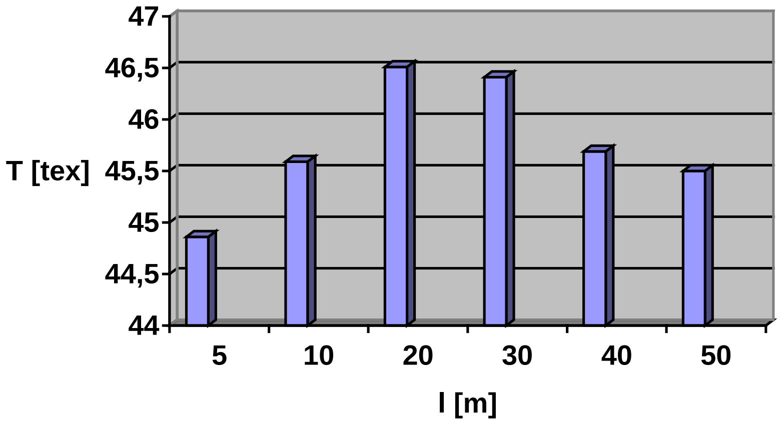
Weft yarns

Specimen	1	2	3	4	5	**Mean value**
m [g]						
T [tex]						

Yarn wound on bobbin

l [m]	5	10	20	30	40	50
m [g]						
T [tex]						

Results:



1. **Warp linear density: To = tex, s = tex , v = %**
2. **Weft linear density: Tu = tex, s = tex, v = %**
3. **Mean linear density of yarn wound on bobbin T = tex**

Laboratory task 4
Yarn twist analysis

Specification:

Measure out the number of folded and spun yarn twists from analysed material.
Folded yarn twist is measured by direct method.
Spun yarn twist is measured by indirect method using stretching device and limiter.

1. Draw yarn construction, estimate direction for both the folded yarn twist and the spun yarn twist.
2. Analyse:
   - Average number of twists
   - Standard deviation of twists
   - Coefficient of variation twists
   - Confidence interval for number of twists
3. Estimate average twist take-up and the level of twist take-up
4. Calculate average coefficient of folded yarn twist

Analysed material

Woolen type two-fold yarn

Measurement device and aids:

1. Twist counter
2. Scissors, needle

Climatic conditions:

- t =
- p =
- φ =

Basic relations:

Average number of folded yarn twists [z/1 m]

$$\bar{z}_S = \frac{\bar{x}_S}{l_0}$$

Average number of spun yarn twists [z/1 m]

$$\bar{z}_P = \frac{\bar{x}_P}{2 \cdot l_0}$$

Standard deviation of folded yarn twists [z/1 m]

$$s_S = \frac{1}{l_0} \cdot s_{XS}$$

Standard deviation of spun yarn twists [z/1 m]

$$s_P = \frac{1}{2 \cdot l_0} \cdot s_{XP}$$

Twist take-up [%]

$$\sigma = \frac{\Delta l}{l_0 + \Delta l} \cdot 100$$

Coeff. of twist take-up

$$P_\sigma = \frac{l_0}{l_0 + \Delta l}$$

Coeff. of twisting

$$\bar{\alpha} = \frac{\bar{z}_S}{\sqrt{\frac{1000}{T}}}$$

$\boldsymbol{l_0}$ – *clip length [m]* $\boldsymbol{\Delta l}$ - *change of length while the yarn is un-twisted [mm]*

$\bar{x}_S$ – *average number of folded yarn twists [z/0,25 m]* $\boldsymbol{T}$ – *folded yarn density [tex]*

$\bar{x}_P$ – *average number of spun yarn twists [z/0,5 m]*

Table 1. Measured and calculated parameters

	Xsi [z/0,25 m]	Zs [z/1 m]	Δl [mm]	Xpi [z/0,5 m]	Zp [z/1 m]
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Average					

Results:

- Drawn yarn construction
- Direction of folded yarn twists
- Direction of spun yarn twists
- Twist take-up σ **[%]**
- Coeff. of twist take-up P_σ
- Coeff. of spun yarn twists $\overline{\alpha}$

- *Average number of folded yarn twists* z_s **[z/1m]**
- Standard deviation s_s **[z/1m]**
- Coefficient of variation v_s **[%]**
- Confidence interval for z_s **(-) [z/1 m]**
- *Average number of folded yarn twists* z_p **[z/1m]**
- Standard deviation s_p **[z/1m]**
- Coefficient of variation v_p **[%]**
- Confidence interval for z_p **(-) [z/1 m]**

Laboratory task 5
Basic parameters of fabric

Specification:

Measure the thickness and the mass of three woven fabric specimens. Analyse the material composition using optical microscope. Estimate the warp and weft densities, and the crimp factor for both directions.

Estimate:

1. Mass of fabric $m[g]$
2. Thickness of fabric $h[m]$
3. Area density $\rho_s\left[kg.m^{-2}\right]$
4. Volume density $\rho\left[kg.m^{-3}\right]$
5. Porosity of the fabric weave P [%]
6. Warp and weft densities [No.of yarns/1m]
7. Crimp factor of warp and weft ε [%]
8. Level of crimp E [%]
9. Percentage of crimp P [%]
10. Analyse the weave

Analysed material :

3 specimens of woven fabrics – size 100 x 100 mm

Measurement device and aids:

1. Thickness meter
2. Digital mass meter
3. Lens
4. Scale

Climatic conditions:

- t =
- p =
- φ =

Basic relations:

Area density [kg.m^{-2}]

$$\rho_S = \frac{m}{a \cdot b}$$

Volume density [kg.m^{-3}]

$$\rho_V = \frac{m}{a \cdot b \cdot h}$$

Porosity [%]

$$P = \frac{\rho - \rho_V}{\rho} \cdot 100$$

Volume density of multi-component fabric ρ [kg.m^{-3}]

$$\rho = \frac{1}{100}\sum_{1}^{k} \rho_k \cdot v_k$$

Crimp factor [%]

$$\varepsilon_t = \frac{\Delta l}{l} \cdot 100$$

Level of crimp [1]

$$E_t = \frac{l + \Delta l}{l}$$

Percentage of crimp [%]

$$P_t = \frac{\Delta l}{l + \Delta l} \cdot 100$$

a – *width of specimen [m]*
b – *length of specimen [m]*
m – *mass of specimen – specimen size - a x b [g]*
h – *thickness of specimen [m]*
ρ – *volume density of material [kg.m^{-3}] – (wool 1310 kg.m^{-3} – PES 1360 kg.m^{-3})*
v_k - *percentage of material [%]*
l – *length of wave [mm]*
Δl – *(real length of yarn – length of wave) [mm]*

Table 1. Measured and calculated parameters

	Specimen 1	Specimen 2	Specimen 3
Thickness h [mm]			
Mass m [g]			
Warp density [yarns/1cm]			
Weft density [yarns/1cm]			
Δl of warp [mm]			
Δl of weft [mm]			
Weave			

Table 2. Results for analysed fabrics:

	Specimen 1	Specimen 2	Specimen 3
Area density [kg.m^{-2}]			
Volume density [kg.m^{-3}]			
Material composition			
Porosity [%]			
Crimp factor of warp [%]			
Crimp factor of weft [%]			
Level of warp crimp [1]			
Level of weft crimp [1]			
Percentage of warp crimp [%]			
Percentage of weft crimp [%]			

Laboratory task 6
Strength and strain of fabric

Specification:

Analyse the tensile strength and strain of three fabrics for both warp and weft directions (3 specimen for warp and 3 for weft directions) using strength dynamometer.

Estimate for both direction:

1. tensile strength
2. strain
3. deformation work
4. Young modulus
5. bending stiffness

Analysed material:

3 specimen for warp and 3 for weft directions – size of specimen 60 x 300 mm.
Yarns on side of specimen are ripped out up to 5 mm.
Clamp length of specimen – 200 mm.
Teared specimen final size - 50 x 200 mm.

Measurement device and aids:

1. dynamometer Tiratest
2. planimeter
3. sextant
4. scale of length
5. needle

Climatic conditions

- t =
- p =
- φ =

Basic relations:

Deformation work [J]

$$A = \frac{S}{m_x \cdot m_y}$$

Young modulus [Pa]

$$\mathrm{E} = \tan\alpha \frac{\mathrm{m_x}}{\mathrm{m_y}} \cdot \frac{\mathrm{l_0}}{\mathrm{h} \cdot \mathrm{b}}$$

Bending stiffness [N. m^2]

$$T_O = E \cdot \frac{1}{12} \cdot h^3 \cdot b$$

S – *area below the tensile curve [mm^2]*
m_x – *x-axis modulus modul [mm. m^{-1}]*
m_y – *y-axis modulus [mm. N^{-1}]*
m – *mass of teared specimen (size 50 x 200 mm) [g]*
g - *acceleration of gravity [m.s^{-2}]*
b – *width of specimen [mm]*
ρ_S – *area density of fabric [kg.m^{-2}]*
h – *thickness of specimen [m]*
l_0 – *clamp length [m]*
α – *angle of tensile curve elevation in Hook´s part [^{O}]*

Table 1. Measured and calculated parameters:

	Specimen A		Specimen B		Specimen C	
	Warp	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**
F [N]						
ε [%]						
S [mm^2]						
α [^{O}]						
m_x [mm. m^{-1}]						
m_y [mm. N^{-1}]						
ρ_S [kg.m^{-2}]						

Table 2. Results:

	Specimen A		Specimen B		Specimen C	
	Warp	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**
l_0 [m]						
h[m]						
m [g]						
A [J]						
tan α						
E[Pa]						
T [N. m^2]						

Laboratory task 7
Fabric stiffness and drapability

Specification:

Analyse the stiffness of 3 woven specimens in warp and weft directions.
Analyse the drapability of 3 large circular specimens.

Estimate:

1. Drapability
2. Stiffness of warp direction
3. Stiffness of weft direction

Analysed material:

Drapability - 3 circular specimens - diameter 300 mm
Stiffness - 3 specimens 150 x 30 mm for both warp and weft directions

Measurement device and aids

1. Device for drapability measurement
2. Paper of minimum A3-size, crayons
3. Planimeter
4. Device for stiffness analysis
   FLEXOMETR FF-20

Climatic conditions:

- t =
- p =
- φ =

Basic relations:

Drapability S:

$$S = \frac{A - A_P}{A_M} \cdot 100 \quad [\%]$$

$\boldsymbol{A}$ – *Area of circular specimen [mm^2]* $\qquad A = 70{,}69.10^3\ mm^2$
$\boldsymbol{A_P}$ – *Area of projection [mm^2]*
$\boldsymbol{A_M}$ – *Area of annulus [mm^2]* $\qquad A_M = 45{,}24.10^3\ mm^2$

Stiffness T:

$$T = b \cdot g \cdot \rho_S \cdot c^3 = b \cdot g \cdot \rho_S \cdot l^3 \cdot K \quad [\mathrm{N.\ m^2}]$$

$\boldsymbol{\alpha}$ - *angle of overhang [°]*

$$K = \frac{\cos 0{,}5\alpha}{8 \tan \alpha}$$

$\boldsymbol{b}$ – *width of specimen [m]*

$$c^3 = l^3 \cdot K$$

$\boldsymbol{c^3}$ – *overhang of measured direction [m^3]*

$\boldsymbol{g}$ - *acceleration of gravity [$m.s^{-2}$]*
$\boldsymbol{l}$ – *length of overhang [m]*
$\boldsymbol{K}$ – *constant for angle α [1]*
$\boldsymbol{\rho_S}$ – *area density [$kg.m^{-2}$]*

Table 1. Measured and calculated parameters - Drapability

Specimen	*Area of projection* [mm^2]	Drapability [%]
1		
2		
3		

Tables for measured and calculated parameters – Stiffness

Specimen 1

l [mm]	**α [º]** warp	**α [º]** weft	**K** warp	**K** weft	**T [N.m^2]** warp	**T [N.m^2]** weft
30						
40						
50						
60						
70						
80						
90						

Specimen 2

l [mm]	**α [º]** warp	**α [º]** weft	**K** warp	**K** weft	**T [N.m^2]** warp	**T [N.m^2]** weft
30						
40						
50						
60						
70						
80						
90						

Specimen 3

l [mm]	**α [º]** warp	**α [º]** weft	**K** warp	**K** weft	**T [N.m^2]** warp	**T [N.m^2]** weft
30						
40						
50						
60						
70						
80						
90						

Results:

- Average stiffness for warp $\mathbf{T_{warp}}$ **[N.m^2]**
- Average stiffness for weft $\mathbf{T_{weft}}$ **[N.m^2]**

- $\mathbf{T_{warp}}$ (1) = [N.m^2]
- $\mathbf{T_{warp}}$ (2) = [N.m^2]
- $\mathbf{T_{warp}}$ (3) = [N.m^2]
- $\mathbf{T_{weft}}$ (1) = [N.m^2]
- $\mathbf{T_{weft}}$ (2) = [N.m^2]
- $\mathbf{T_{weft}}$ (3) = [N.m^2]

Laboratory task 8
Air permeability and abrasivity of fabric

Specification:

Analyse the **abrasivity** (percentage of mass loss and number of revolutions till the first yarn is interupted, and **permeability** (measured 10 times on various areas of fabric) of 3 various fabric specimens.

Estimate:

1. Mean number of speed
2. Mean mass loss
3. Air permeability

Analysed material:

Abrasivity – 2 circular specimens for each fabric - diameter 95 mm
Air permeability – 10 times on the fabric sheets

Přístroje a pomůcky:

1. Rubbtester – abrasion
2. Digital mass meter
3. Emery paper, scissors
4. Air-permeability-tester

Climatic conditions:

- t =
- p =
- φ =

Basic relations:

<u>Abrasivity:</u>

Failure of first yarn interlacing point

Mass loss **U**:

$$U = \frac{m_1 - m_2}{m_1} \cdot 100 \quad [\%]$$

***m_1* –** *mass of new specimen [g]*

***m_2* –** *mass of abraded specimen [g]*

Table 1. Measured and calculated parameters - abrasivity:

Specimen	**m_1 [g]**	**m_2 [g]**	**U [%]**	**No. of revolutions**
1a				
1b				
2a				
2b				
3a				
3b				

Basic relations:

Air permeability R:

Pressure gradient - 100 Pa **Area of measuring jaw** - 20 cm^2

$$R = \frac{\overline{q}_V}{A} \cdot 167 \quad [mm.s^{-1}]$$

q_V – *speed of air flow [$l.min^{-1}$]*
A – *area of measuring jaw [cm^2]*
167 – *conversion coeff. – conversion of [$l.min^{-1}.cm^2$] to [$mm.s^{-1}$]*

Table 2 . Measured parameters – air pemeability:

Measurement	q [l/hod]		
	Specimen 1	**Specimen 2**	**Specimen 3**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Results:

- **Average mass loss U [%]**
- **Average number of revolutions**
- **Average air permeability R [$mm.s^{-1}$]**

- **U (1) = [%]** **Number of revolutions (1) =**
- **U (2) = [%]** **Number of revolutions (2) =**
- **U (3) = [%]** **Number of revolutions (3) =**
-
- **R (1) = [$mm.s^{-1}$]**
- **R (2) = [$mm.s^{-1}$]**
- **R (3) = [$mm.s^{-1}$]**