Ultimate mechanical characteristics

- Strength
- Tensile load
- Specific strength
- Elongation
- Strain
- Moduli
- Breaking length
- Special types of load

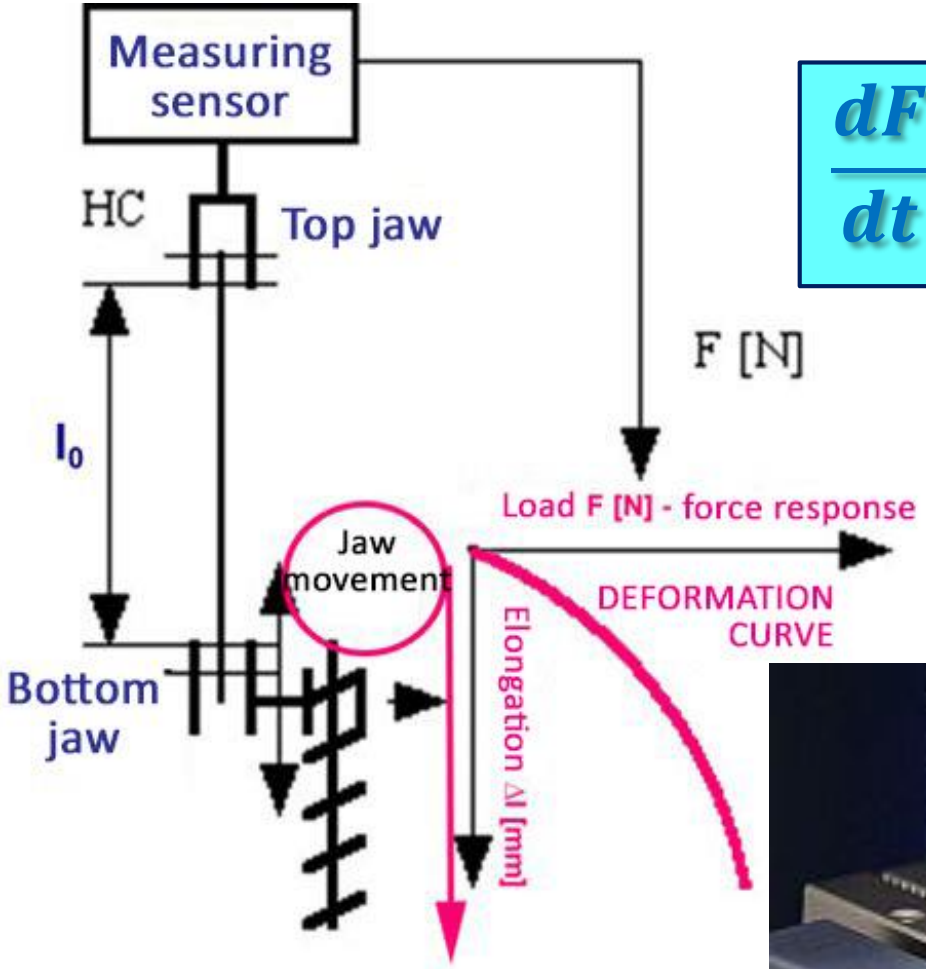
Ultimate mechanical properties

Physical quantity	Symbol	Unit
Breaking strength	F	N
Specific strength	σ	Pa
Elongation	Δl	m
Strain	ε	%
Moduli (materiál resistence to deformation)		
E [GPa]	**G [GPa]**	**K [GPa]**
tensile	*shear*	*compressive*

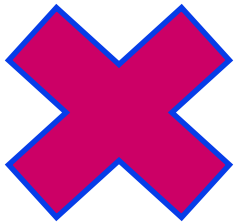
Special types of load

Physical quantity	Symbol	Unit
Specific force (yarns, fibers)	Fr f	[N/tex] [cN/dtex]
Breaking length	L_T	km
Strength in wet state Strength in knot	f_m, f_u [% z $F_{suchá}$]	
Tear and tear strength	$F_{střední}$ [N]	
Seam strength Layer adhesion	$F_{šev}$ [N] η_S [%]	
Tensile strength for nonwovens and geotextiles		

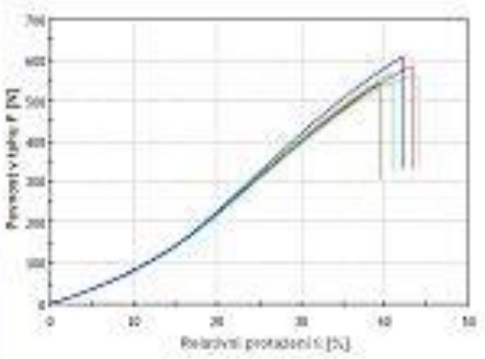
Tensile load



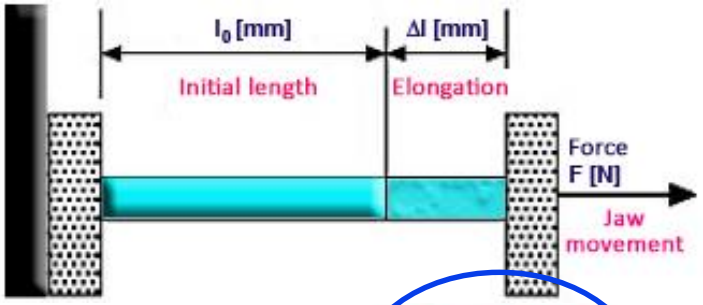
$$\frac{dF}{dt} = konst.$$

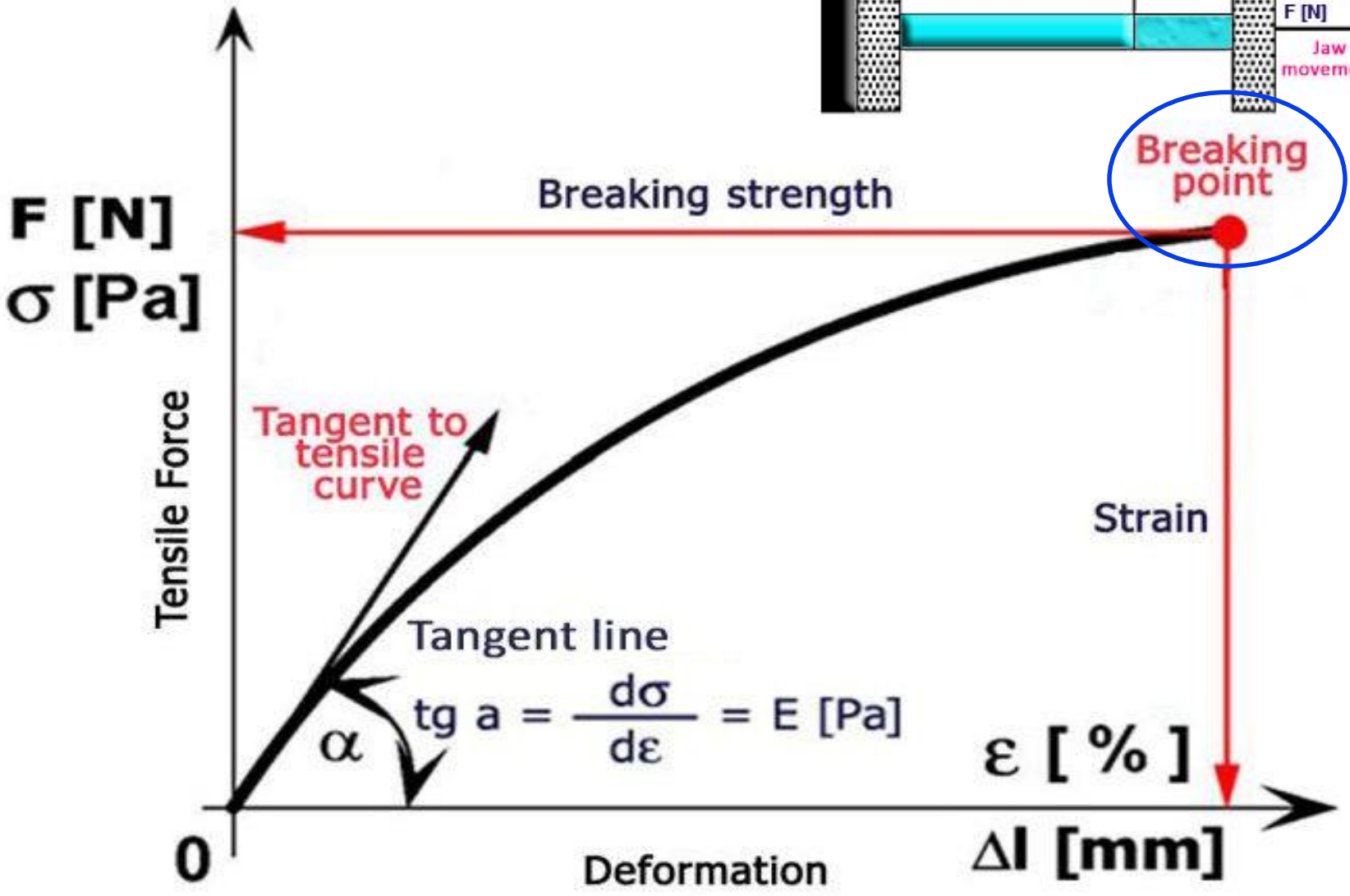


$$\frac{d\varepsilon}{dt} = konst.$$



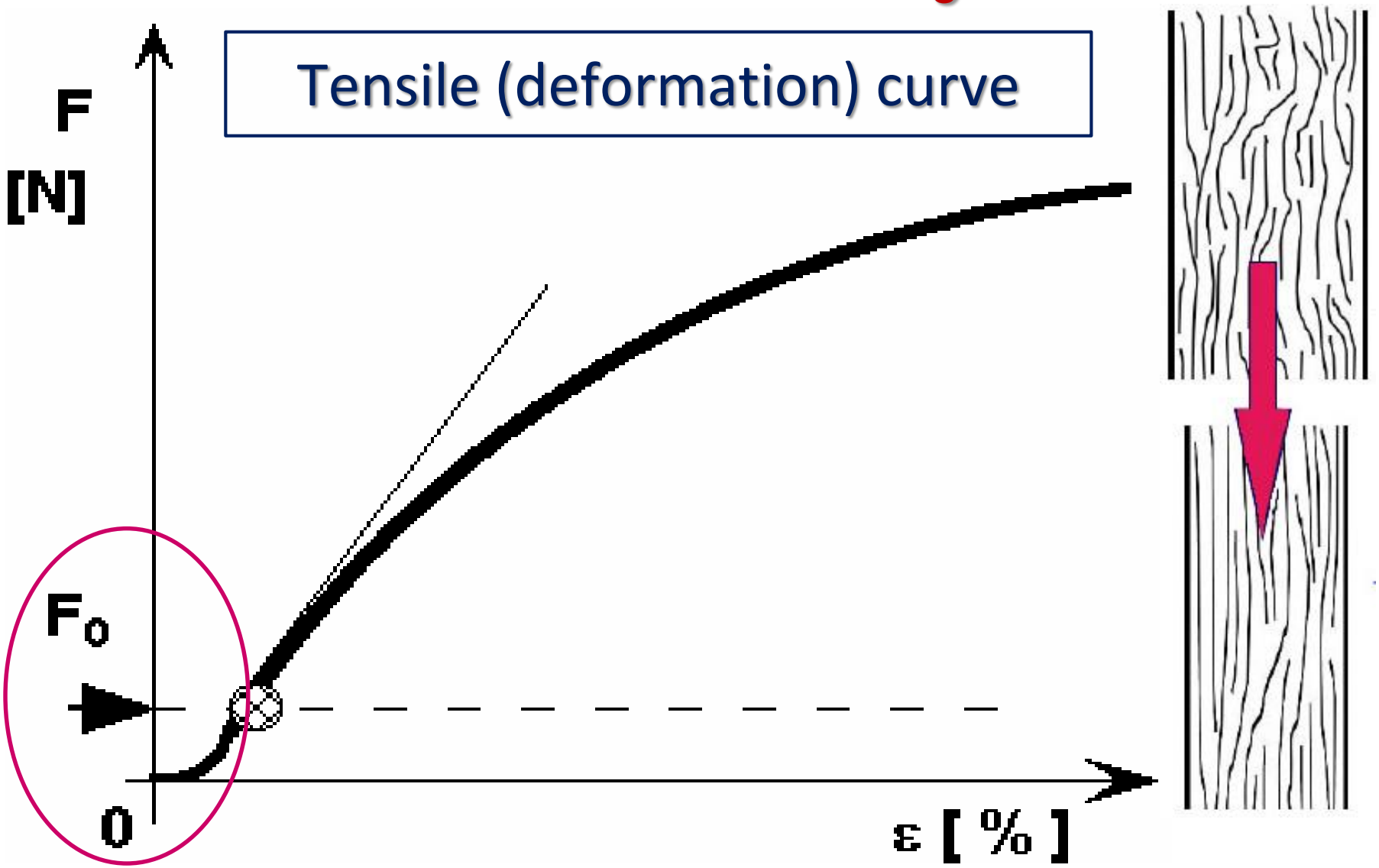
Tensile curve





Pre-tension F_0

Tensile (deformation) curve



Force (specific) strength

- Specific strength σ [Pa] ⟺ Specific force F_r [N/tex]

$$\sigma\ [Pa] = F\ [N] / S\ [m^2]$$

$$F_r\ (f)\ [N/tex] = F\ [N] / T\ [tex]$$

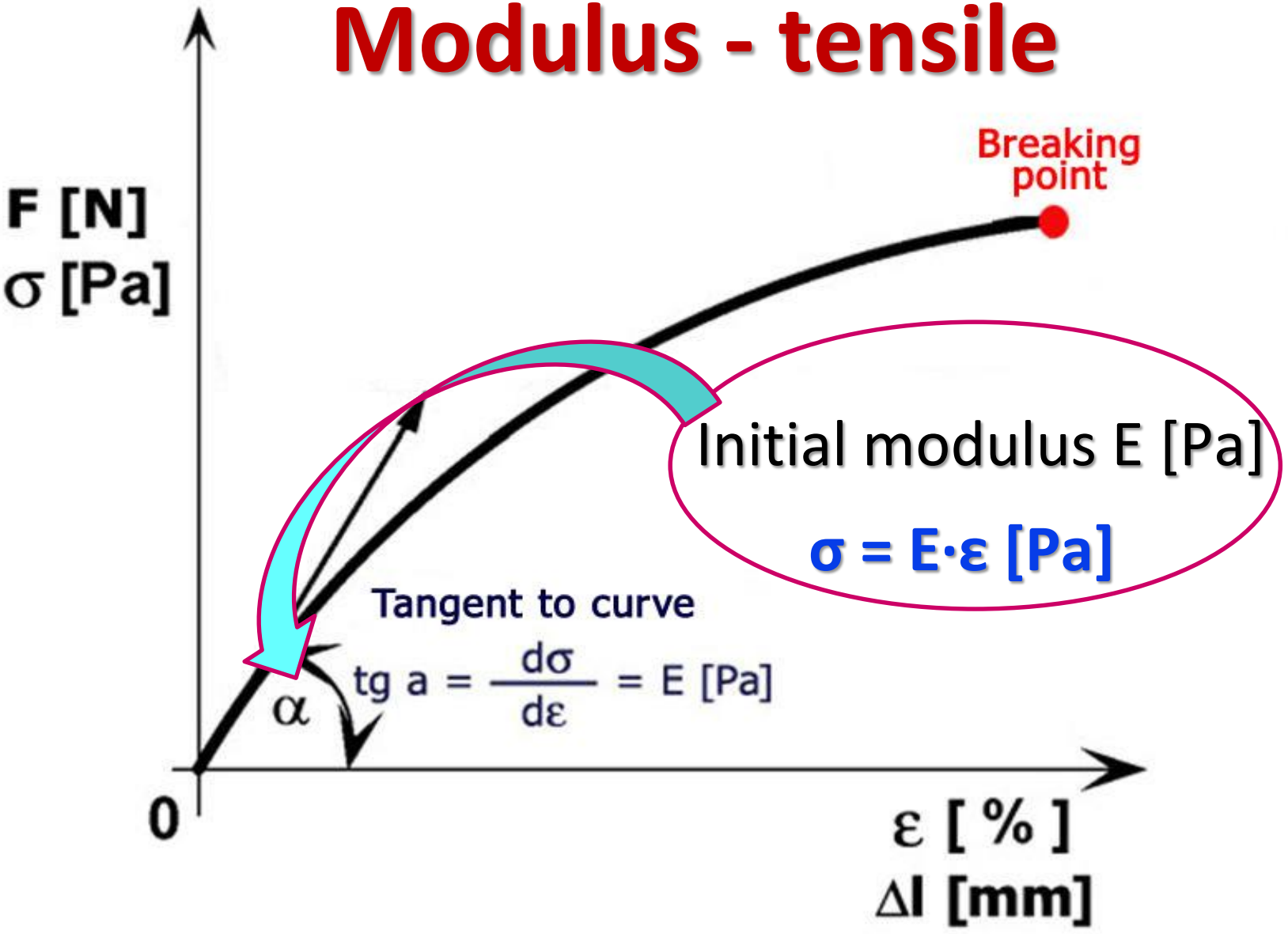
- units for fibers:

[cN/dtex], [cN/tex], [mN/dtex]

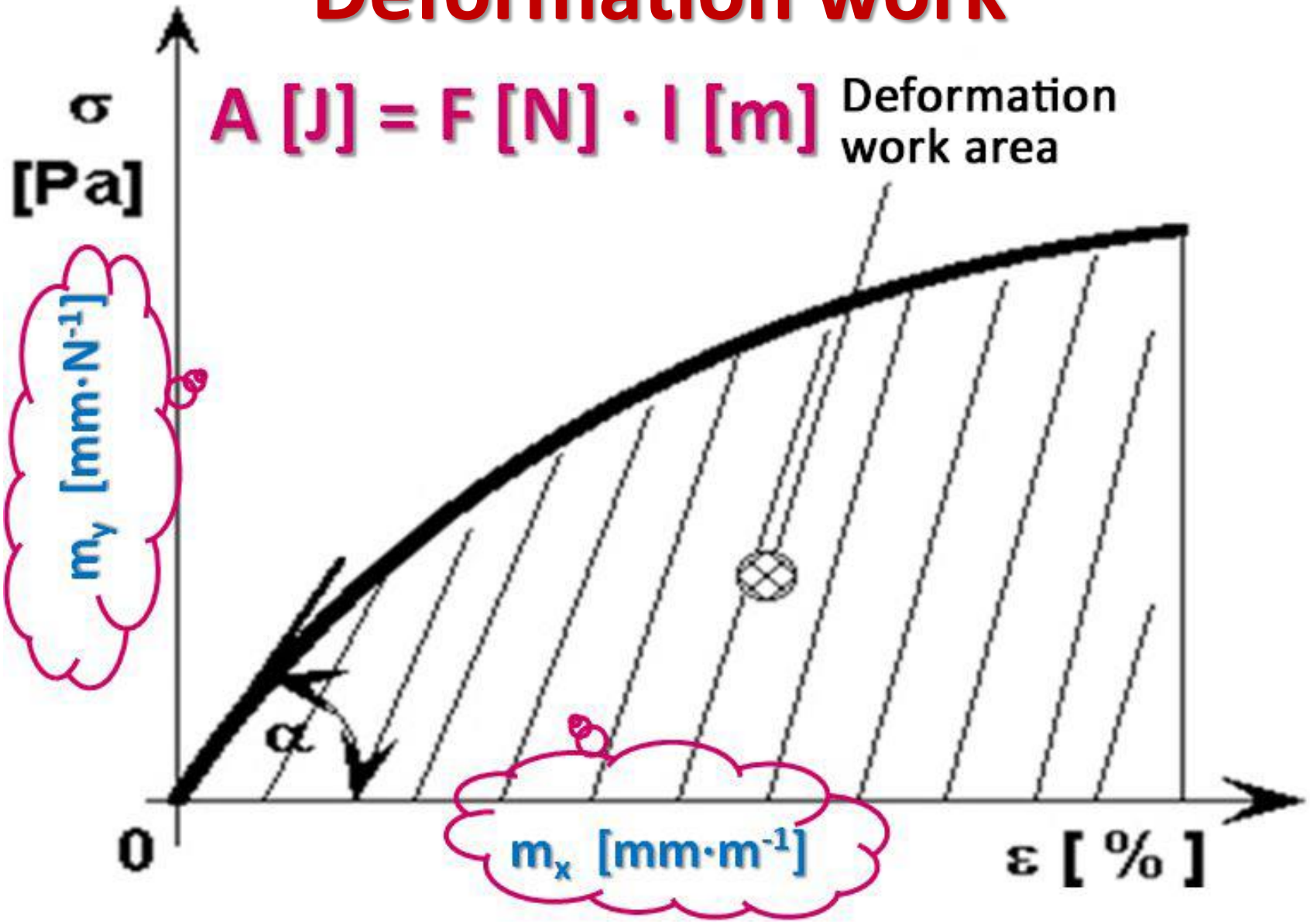
- Relation between σ a F_r :

$$\sigma = F\ [N] / S\ [m^2] = F\ [N] / (T\ [tex] \cdot 10^{-6} / \rho\ [kg \cdot m^{-3}]) =$$
$$= F_r\ [N/tex] \cdot \rho [kg \cdot m^{-3}] \cdot 10^6\ [Pa]$$

Modulus - tensile



Deformation work



Strain

- Elongation

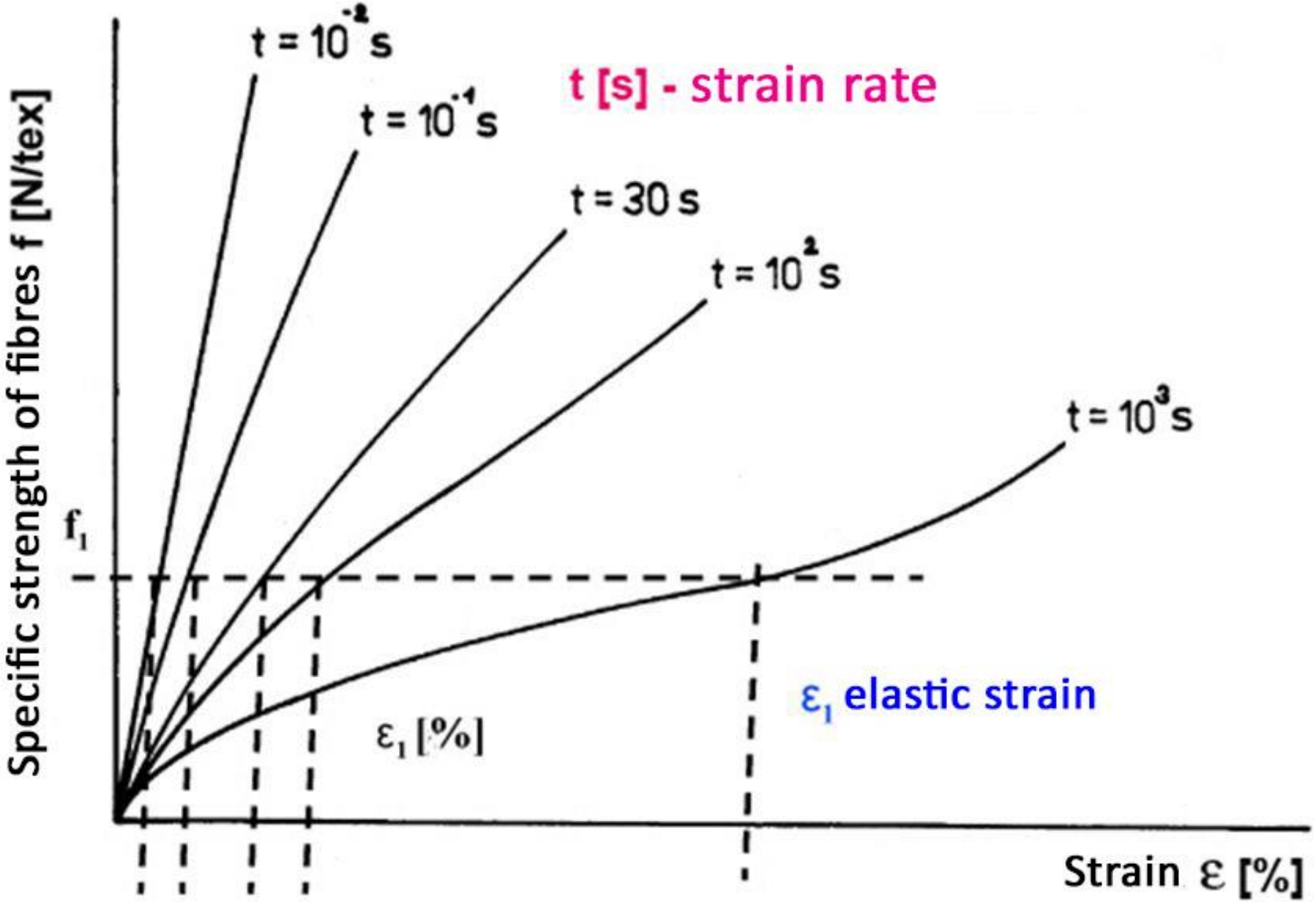
$$\Delta l = l - l_0 \text{ [mm], [m]}$$

- Deformation

$$\varepsilon = \Delta l \text{ [mm]} / l_0 \text{ [mm]} \text{ [-]}$$

$$\varepsilon = \Delta l / l_0 \cdot 100 \text{ [\%]}$$

- Strain ε [%]
  - **Elongation in break!!!**


t = 10⁻² s
t = 10⁻¹ s
t = 30 s
t = 10² s
t = 10³ s
t [s] - strain rate
Specific strength of fibres f [N/tex]
f1
ε1 [%]
ε1 elastic strain
Strain ε [%]

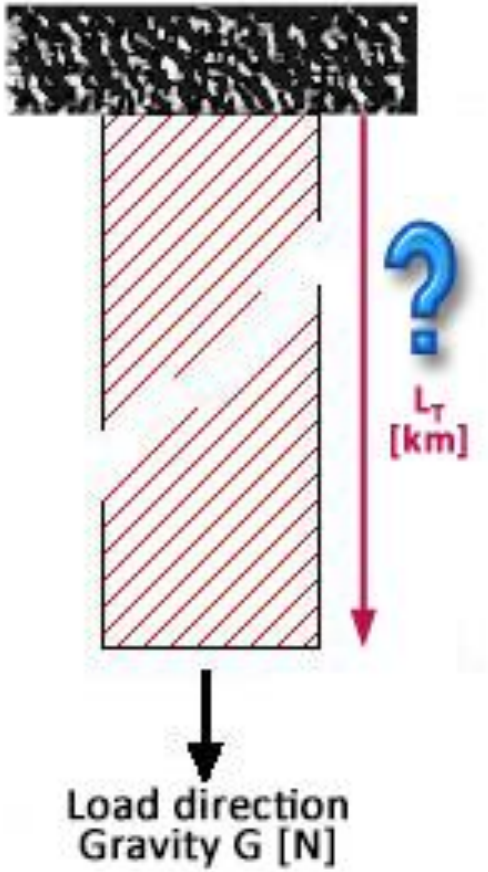
Breaking length

$$G = F = m_{textilie} \cdot g$$

$$m_{vlákno} = T_{vlákno} \cdot L_{vlákno}$$

$$L_{vlákno} = \frac{F \cdot 10^6}{g \cdot T} \; [m]$$

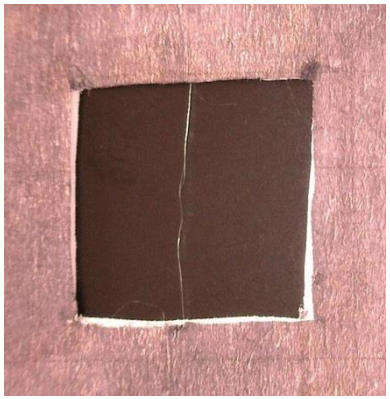
$$L_{Textilie} = {}^{F}/_{g \cdot 10^3 \cdot b \cdot \rho_S}$$

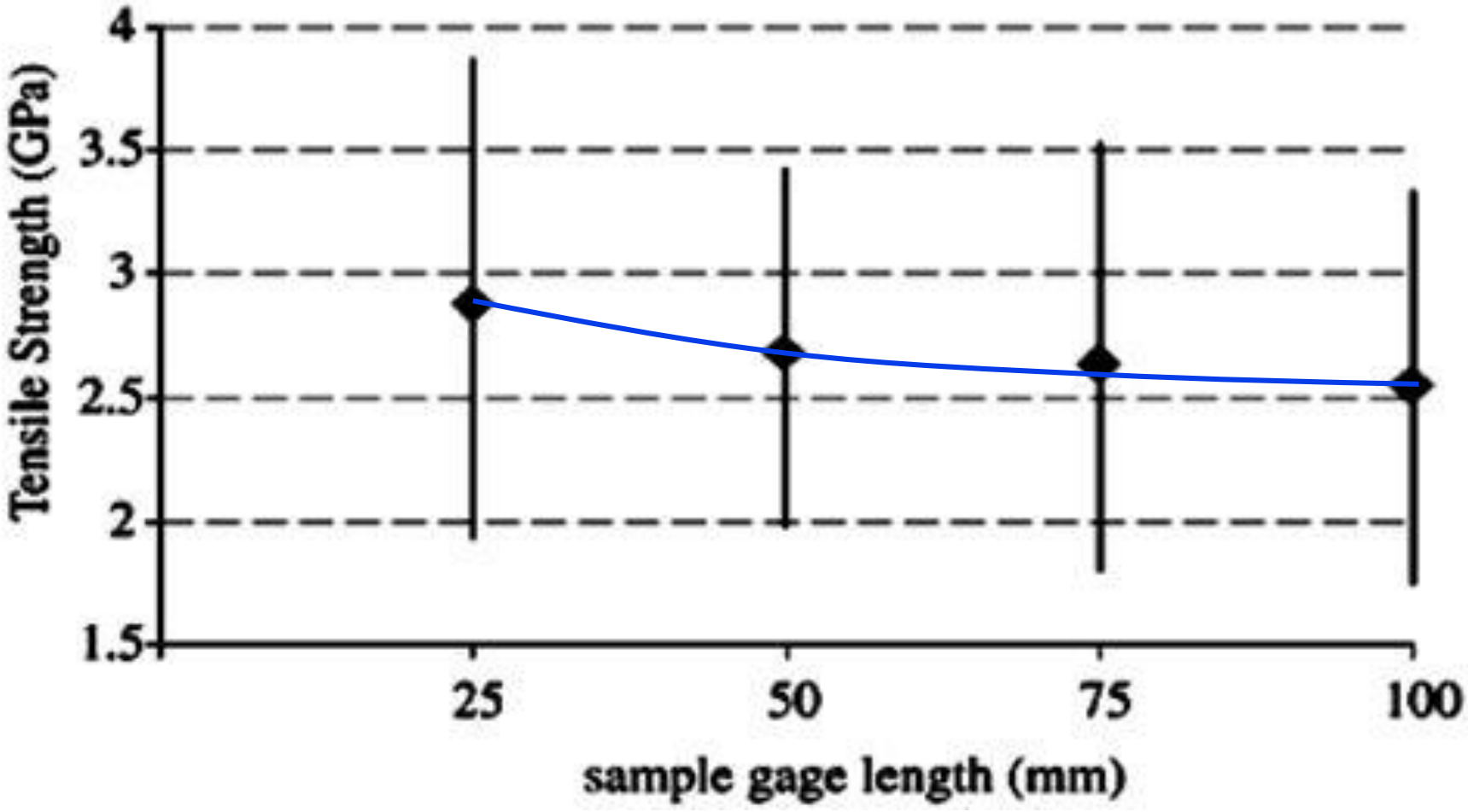


!!! Unit conversion !!!

Tensile strength of fibres

- Standard EN ISO 5079 "Textiles-Fibres-Determination of breaking force and elongation at break of individual fibres"
  - **Initial length l_0 = 10 mm (20 mm)**
  - 50 % initial length/min
    minimum strain < 8%
  - 100 % initial length/min
    minimum strain ≥ 8%



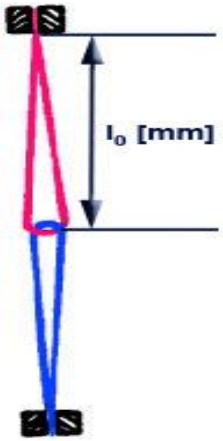

Tensile Strength (GPa)
4
3.5
3
2.5
2
1.5
25
50
75
100
sample gage length (mm)

Tensile strength of yarns

- ISO 2062:2009 "Textiles — Yarns from packages — Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester"
- Standard atmosphere:
  - T = 20 °C, ϕ = 65 %
- Initial length l_0 = *500 mm*
  - ***250 mm – range of device frame***
- Test speed *100 – 500 mm/min*
- Pre-stress
  - Conditioned specimen ***0,5 ± 0,1 cN/tex***
  - Wet specimen ***0,25 ± 0,05 cN/tex***

Special tensile tests for linear textiles

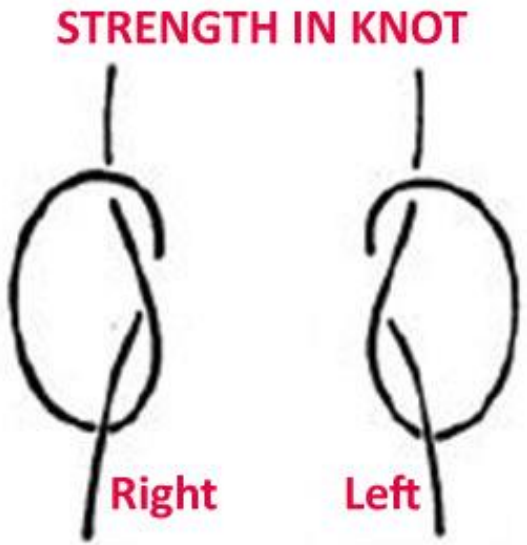
- **Tensile load on dry specimen**
  - Strength in dry state $f_s = F_s/F \cdot 10^2$ [%]
- **Tensile load on wet specimen**
  - Strength in wet state $f_m = F_m/F \cdot 10^2$ [%]
    - ba, ln, kn (+ up to 120 %), Vs (- 50%) syn (- 10%)



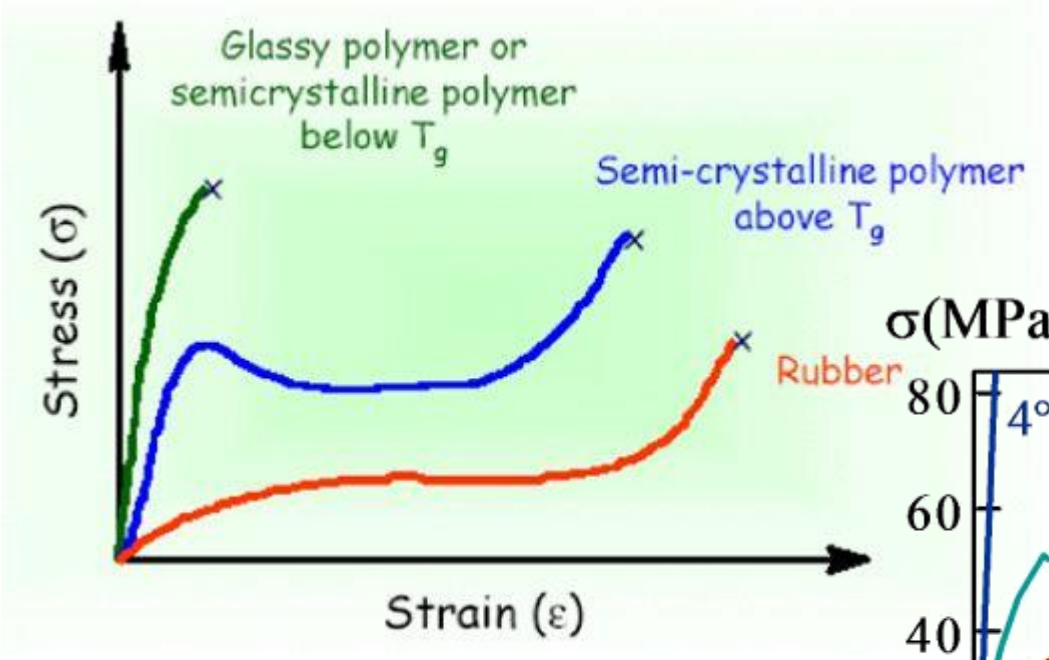
- **Strength in loop**

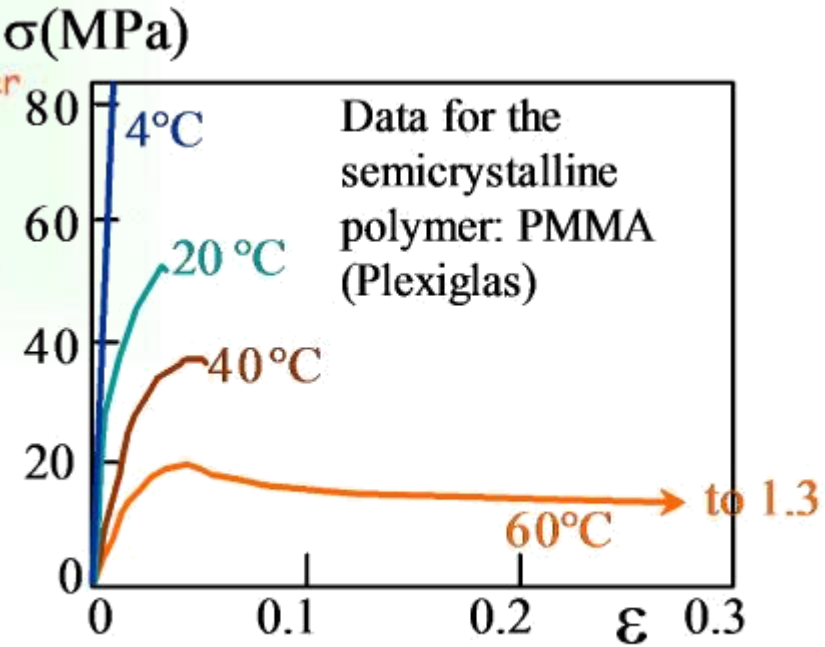
  $f_{sm} = F_{sm}/(2F) \cdot 10^2$ [%]
- **Strength in knot**

  $f_u = F_u/F \cdot 10^2$ [%]
- Speed of deformation
- Influence of temperature



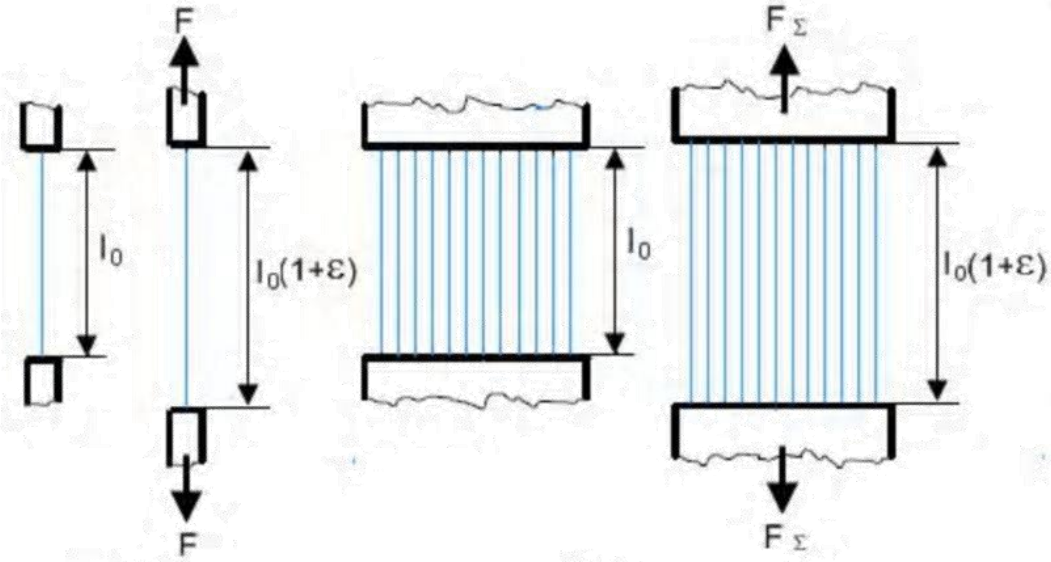
Influence of temperature

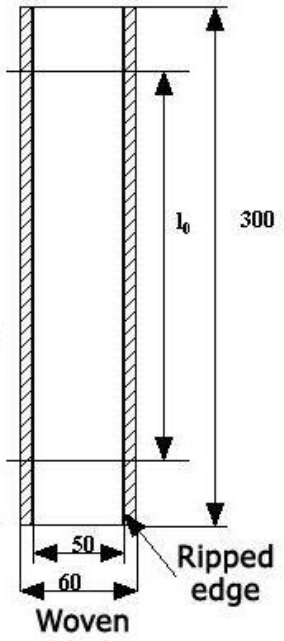


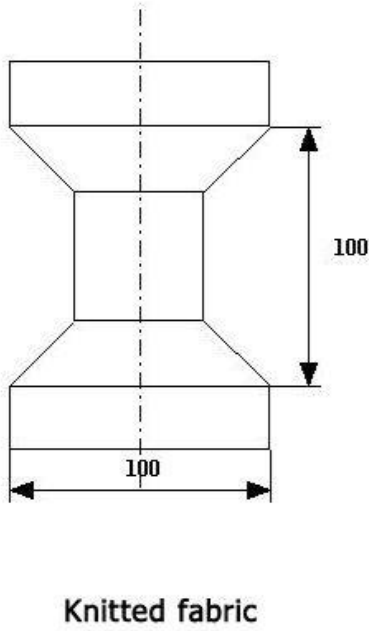


Testing of fabrics

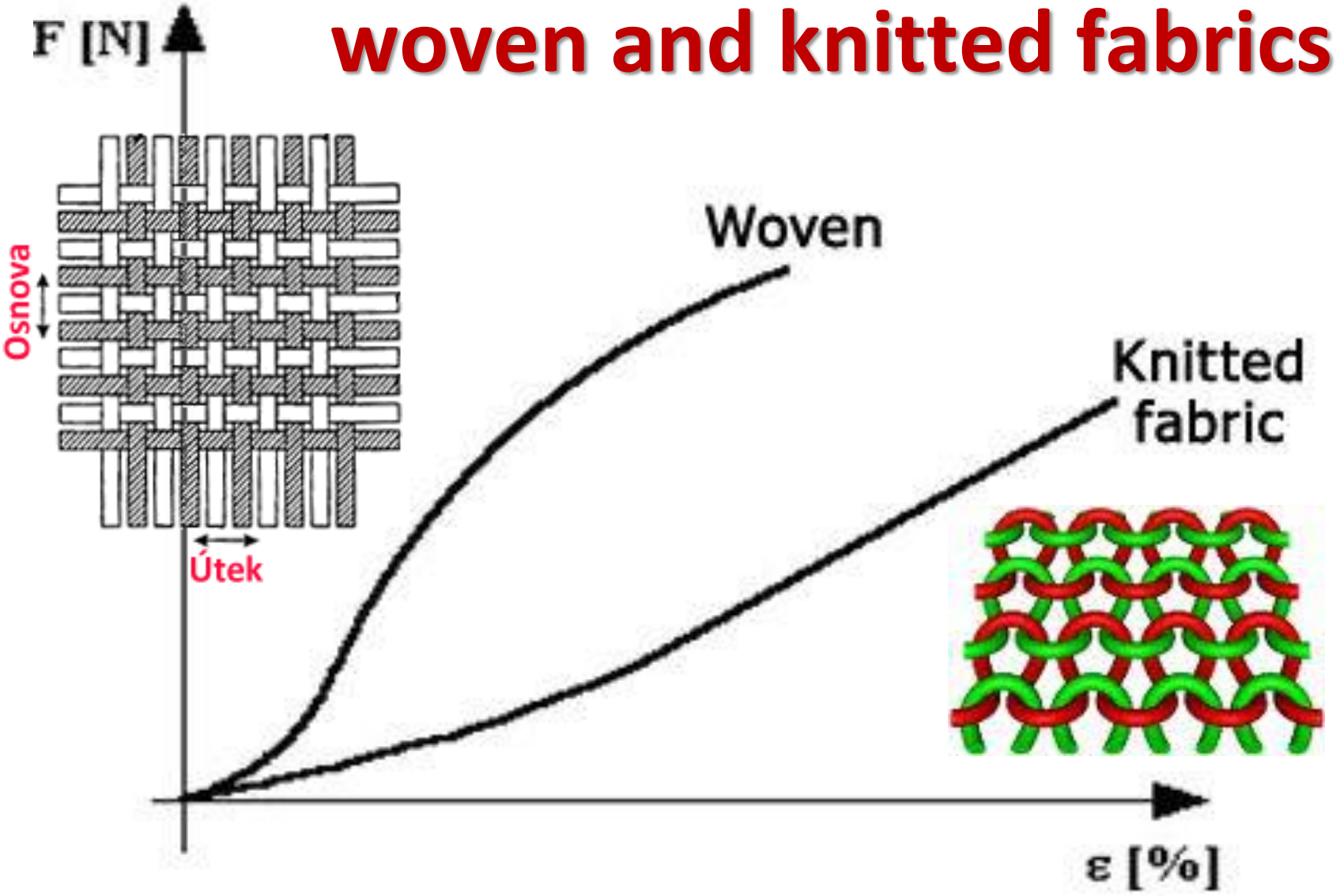
- **ISO 13934-1:2013** "Textiles — Tensile properties of fabrics — Part 1: Determination of maximum force and elongation at maximum force using the **Strip method**"
- **ISO 13934-2:2014** "Textiles — Tensile properties of fabrics — Part 2: Determination of maximum force using the **Grab method**"





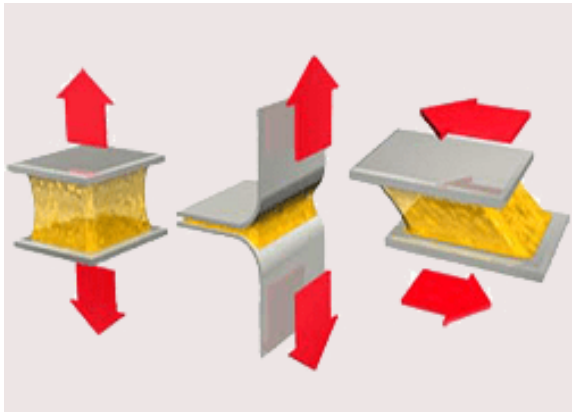


Tensile curves woven and knitted fabrics



Special tensile load for fabrics

- Tear and tear strength
- Rupture strength
- Seam strength
- Layer adhesion

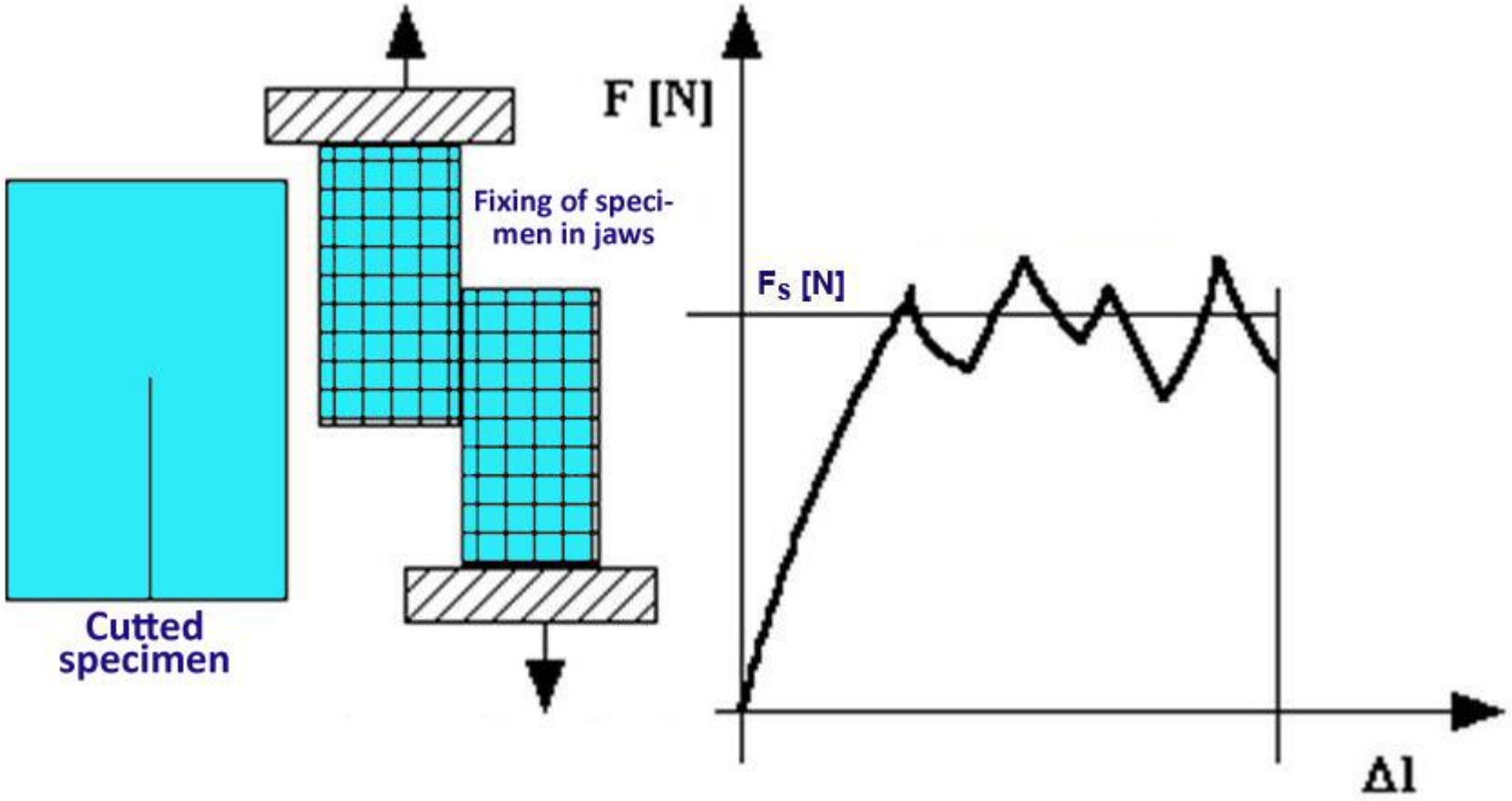


- **Rubber- or plastics-coated fabrics** ⇒
  Determination of tensile strength and elongation at break
- **Geotextiles** ⇒ Tensile strength on wide stripe
- **Tensile strength for nonwovens**
- **Fishing nets** ⇒ Determination of *mesh breaking force* of netting

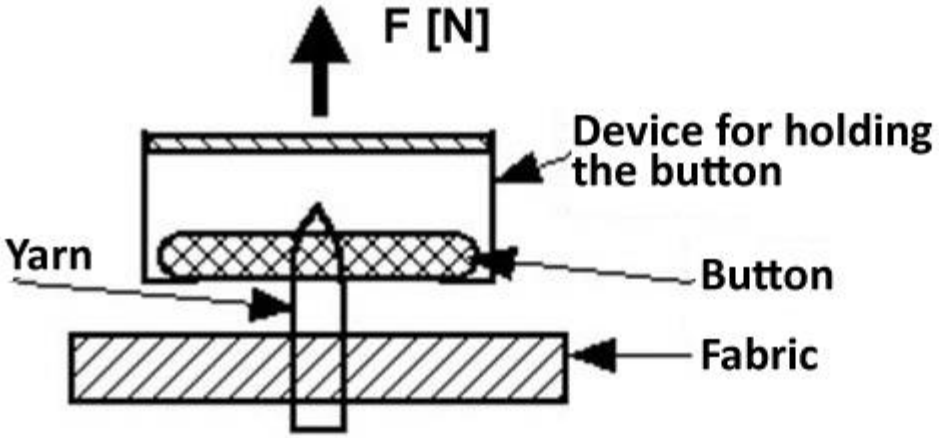
Tear and tear strength

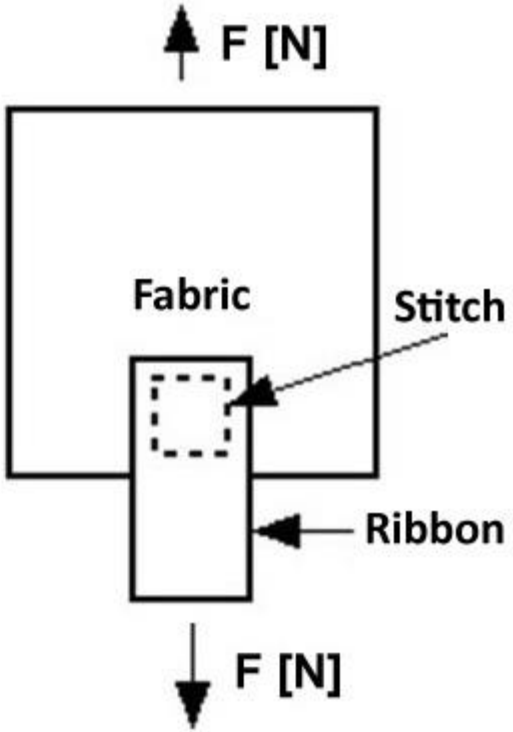
ISO 13937 (Part 1 – Part 4)

"Textiles — Tear properties of fabrics 1-4"

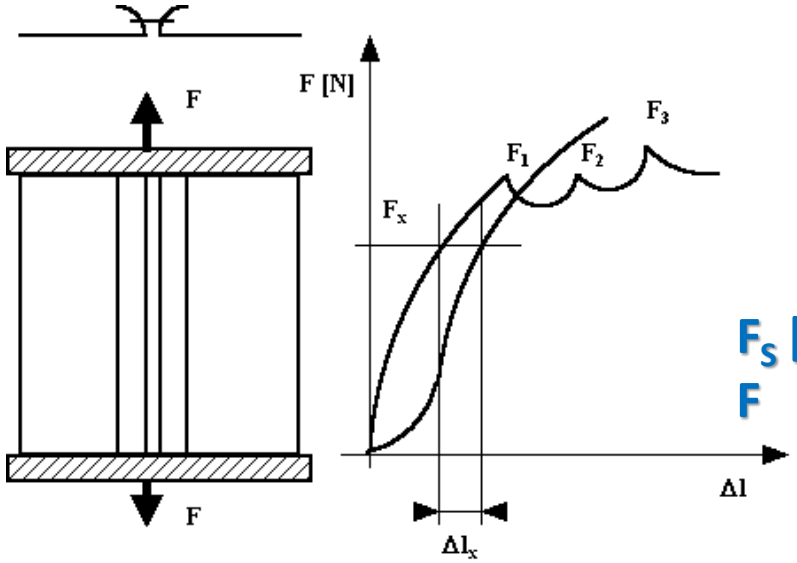


Rupture strength





Seam strength – parallel direction



$$\eta_S = F_S/F \cdot 10^2 \ [\%]$$

F_S [N] – strength of stiched fabric
F [N] – strength of free fabric

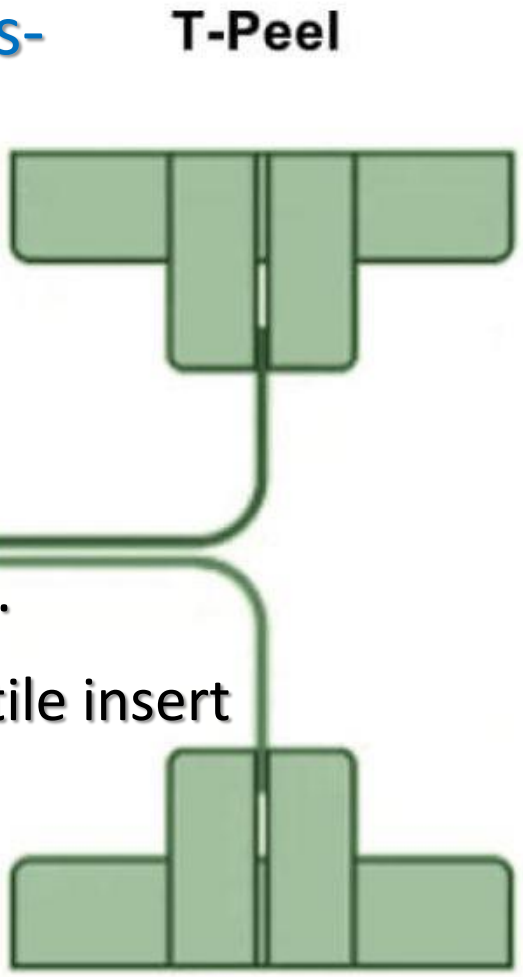
Seam strength – cross direction

- Seam efficiency η_S [%]
  - It is recomended to be up to 80 %

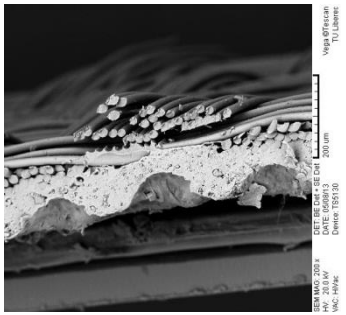
ISO 13935-1:2014 "Textiles — Seam tensile properties of fabrics and made-up textile articles — Part 1: Determination of maximum force to seam rupture using the strip method

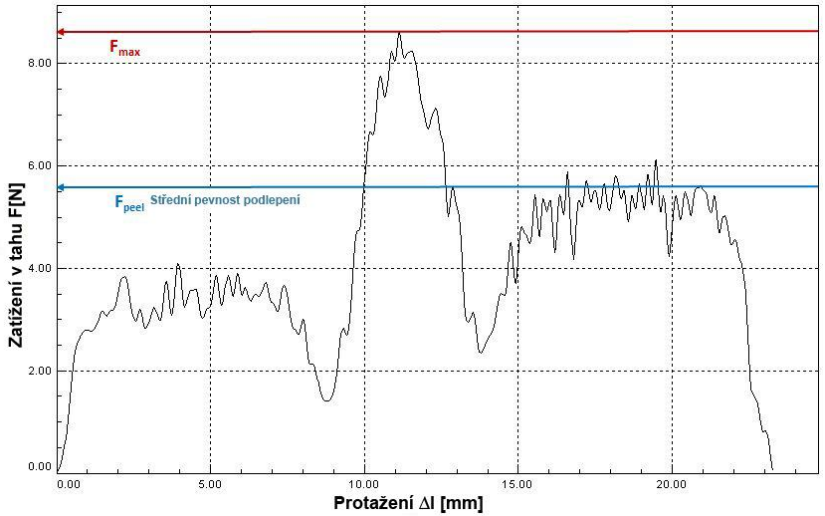
Strength of adhesion

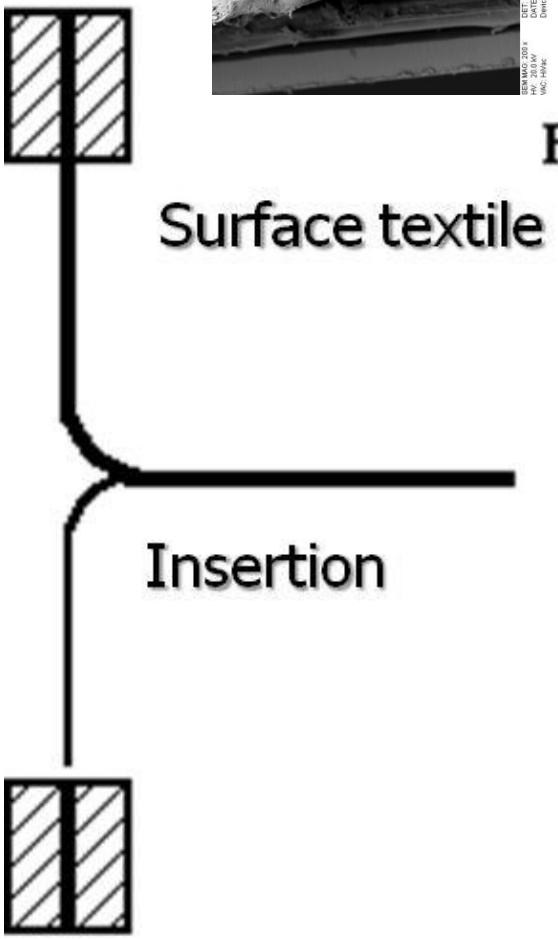
- **ISO 2411:2017** "Rubber- or plastics-coated fabrics — Determination of coating adhesion"



- Strength of coated fabrics:
  - coating of fabric with PUR, PVC etc.
  - coating of fabric with adhesive textile insert
  - other coatings adhesion



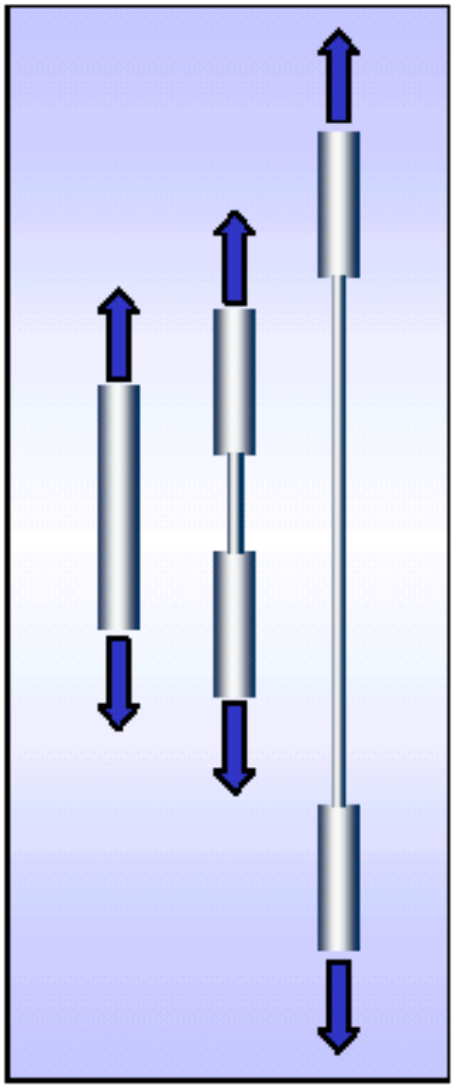

F_{max}
F_{peel} Střední pevnost podlepení
Zatížení v tahu F[N]
Protažení Δl [mm]
0.00
2.00
4.00
6.00
8.00
0.00
5.00
10.00
15.00
20.00


Surface textile
Insertion

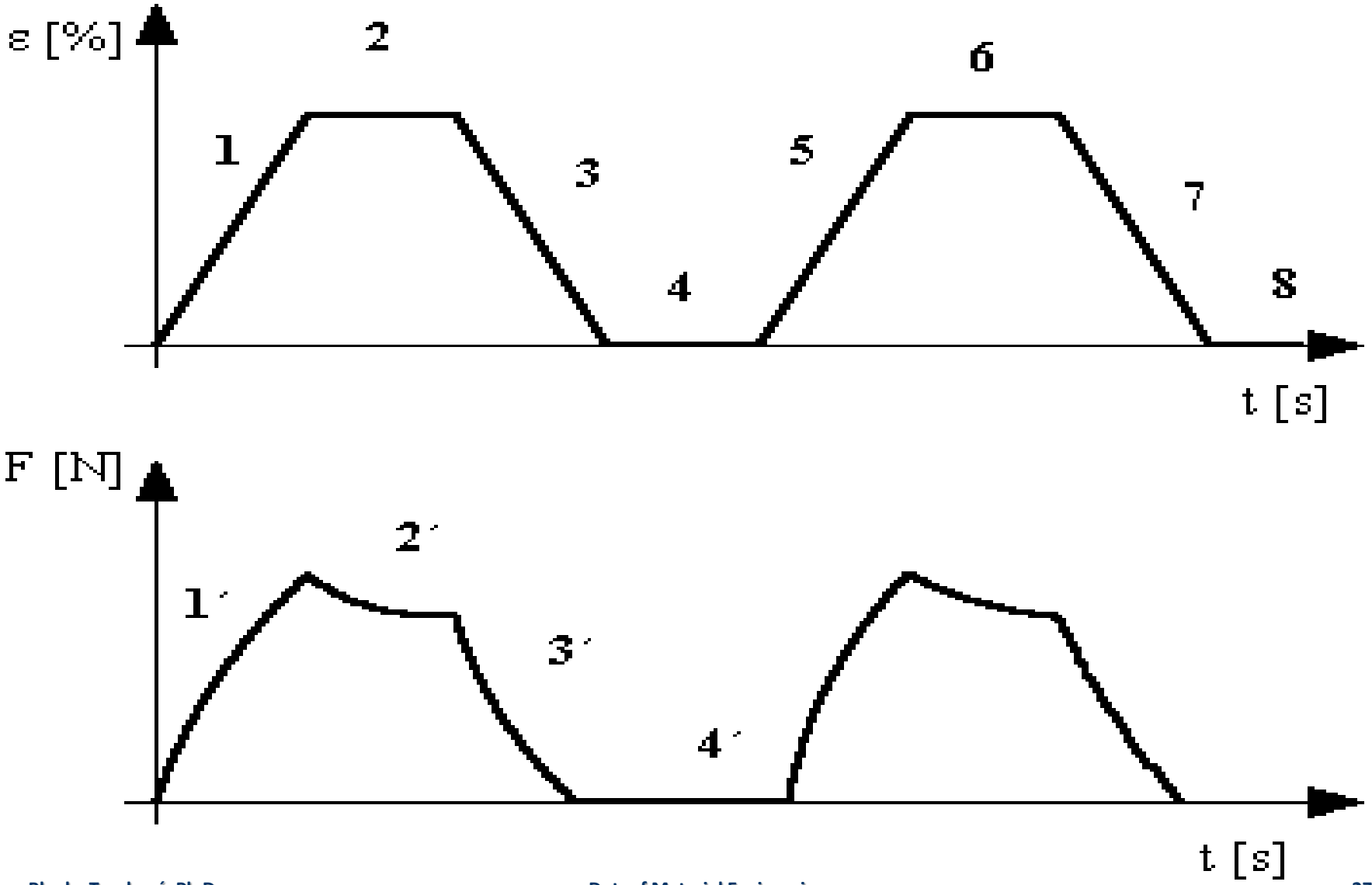
F [N]
$F_{average}$
Δl

Cyclic, semi-cyclic and dynamic load

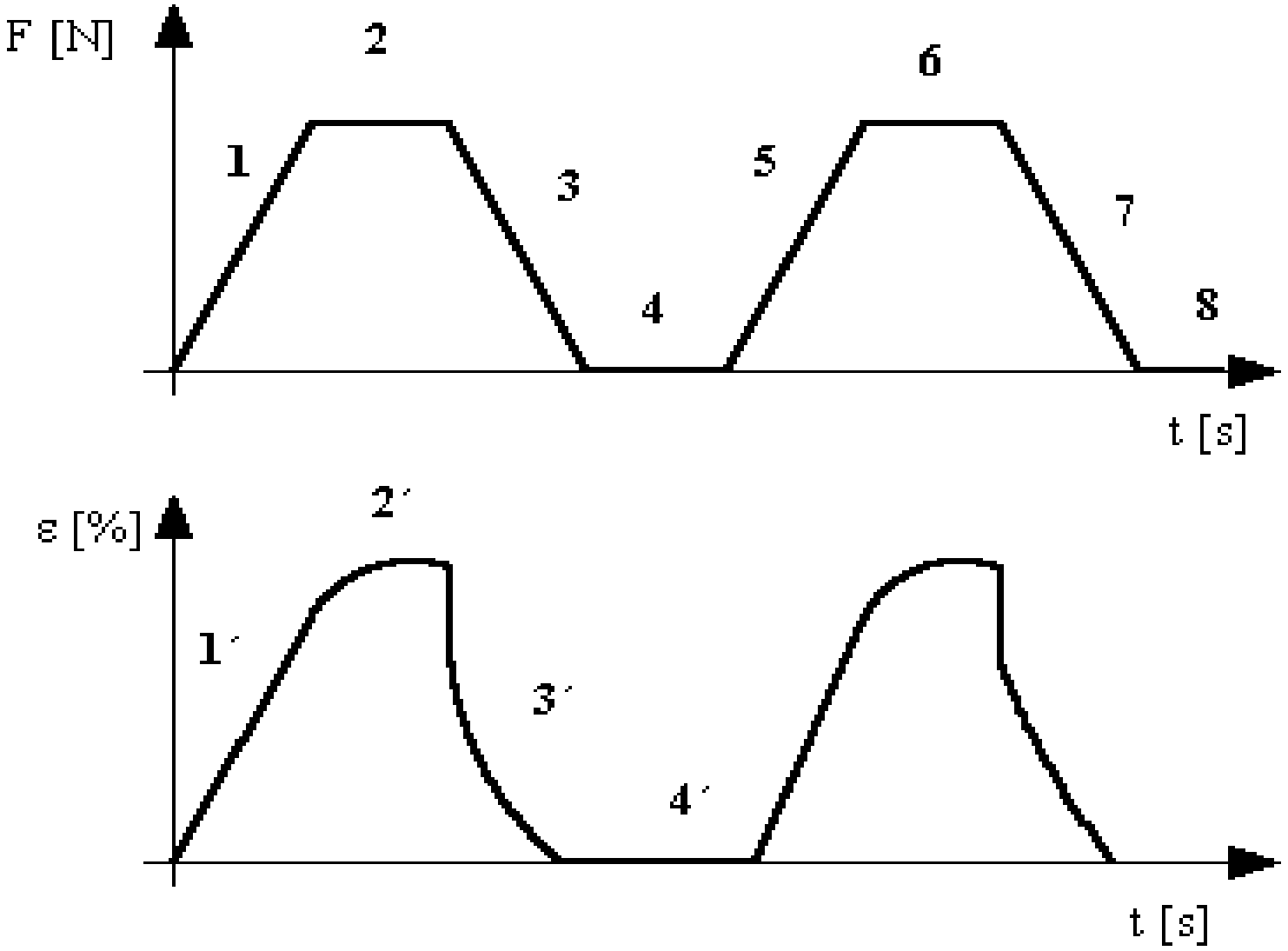
- uniaxial load (tensile, compression)
- multiaxial load (torsion, bending)
- Simple deformation (non-cycle)
- Cyklic load
- Static (time-independent) deformation
- Dynamic (time-dependent) deformation
  - Impact (extremely short time)
- Ultimative deformation (rupture)
- Non-destructive deformation
- Isothermal deformation
- Thermally dependant deformation



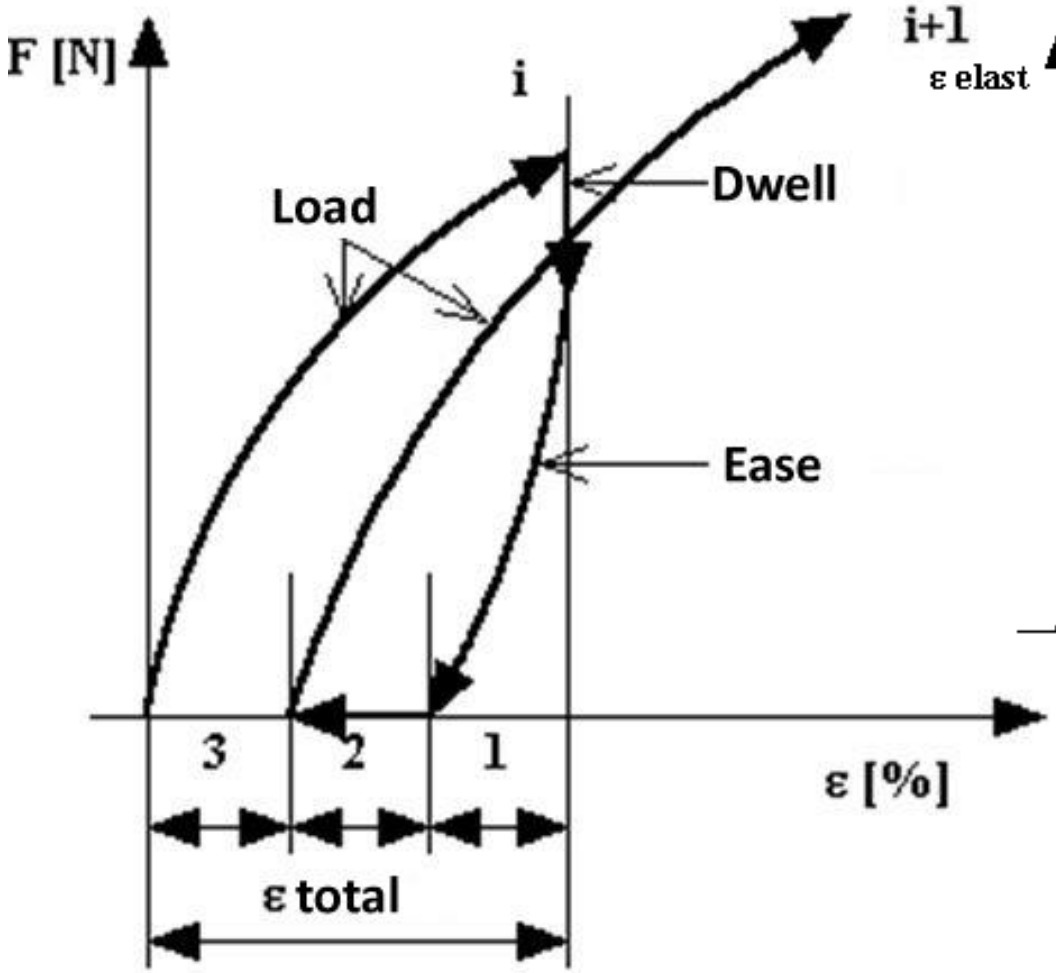
Cyclic load I.

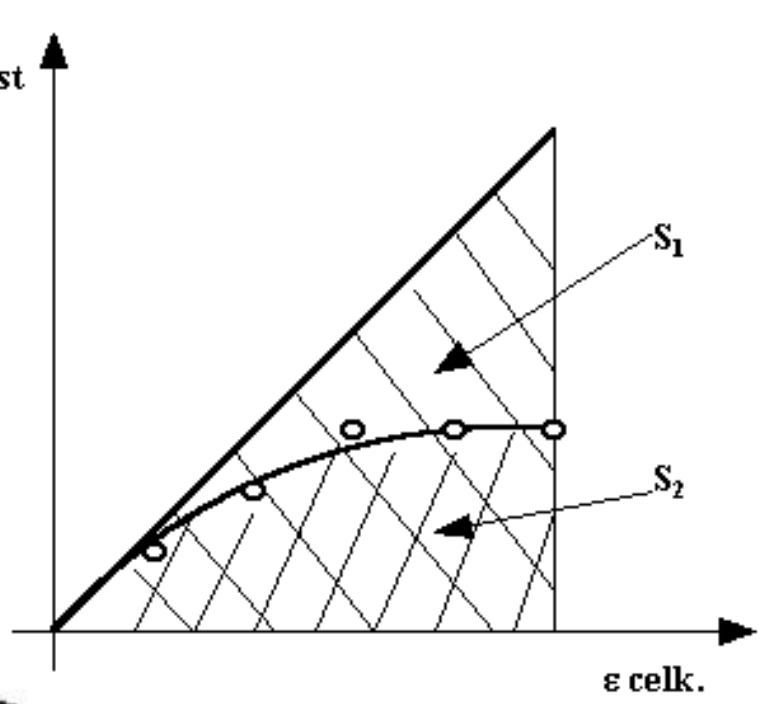


Cyclic load II.



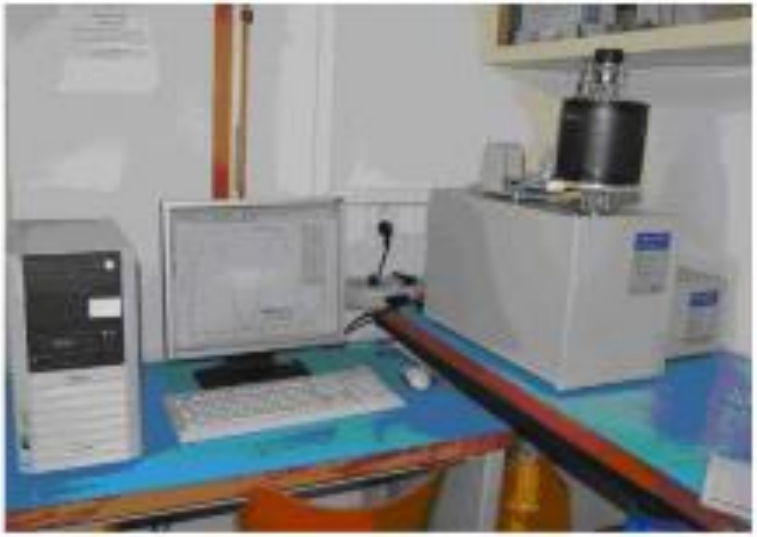
Cyclic load - elasticity of yarn

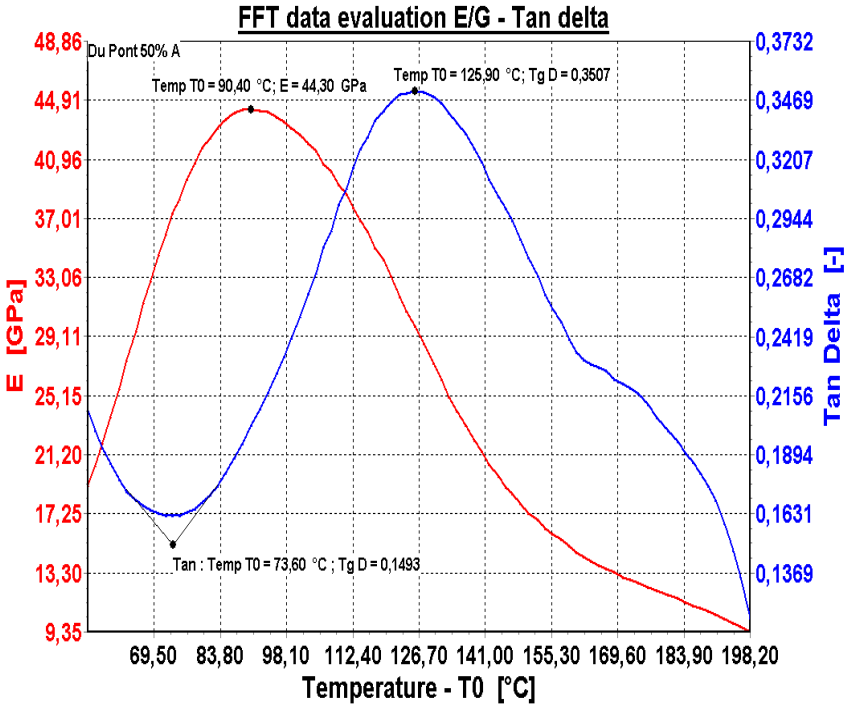


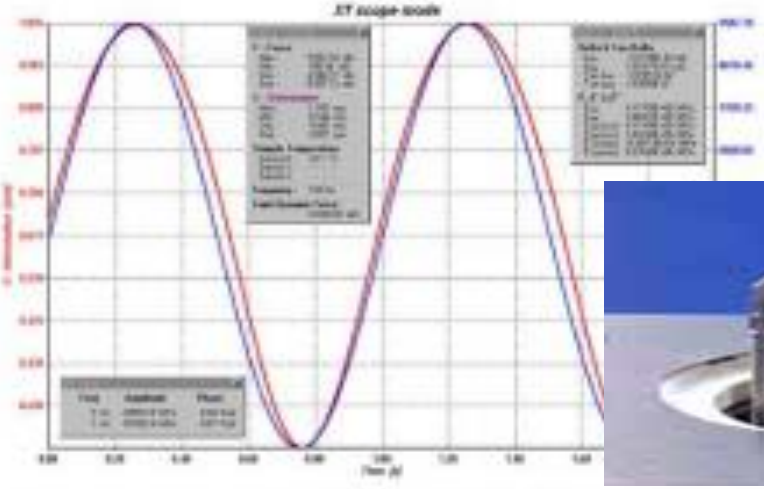


$$E = \frac{S_2}{S_1} \cdot 10^2 \ [\%]$$

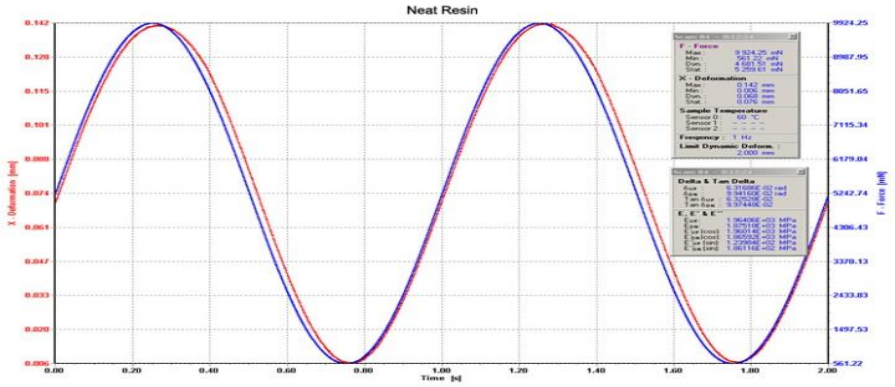
Dynamical-Mechanical Analysis

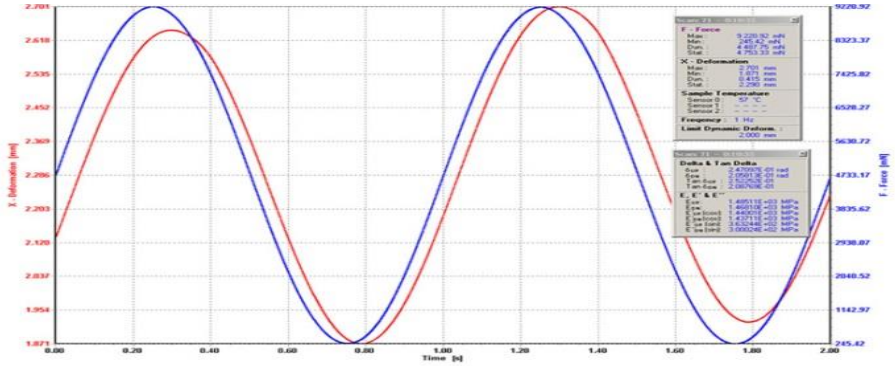


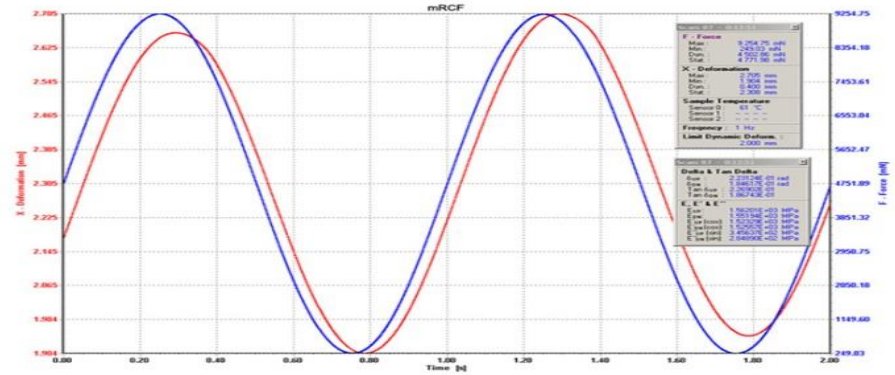


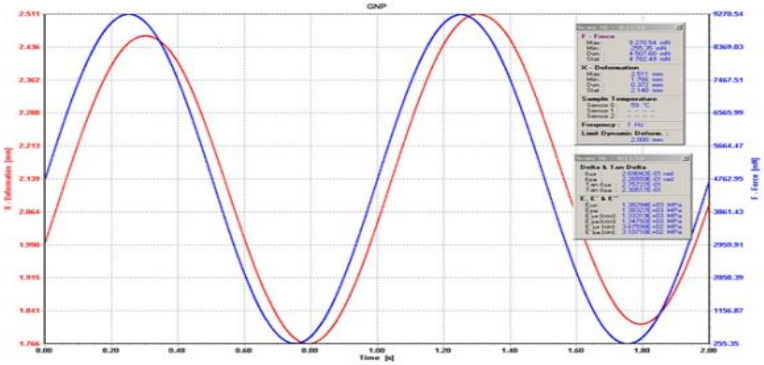


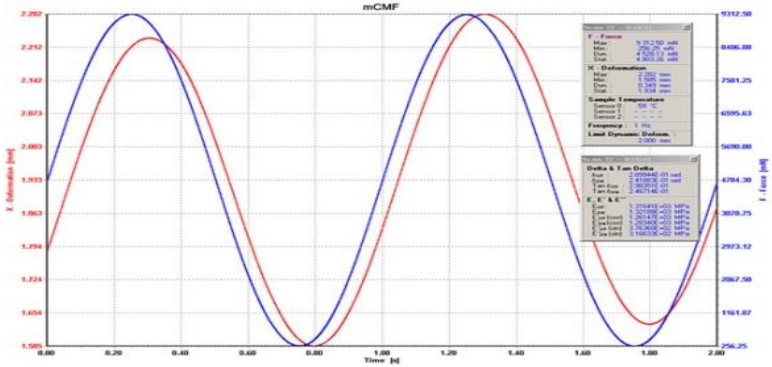
Dynamical-Mechanical Analysis



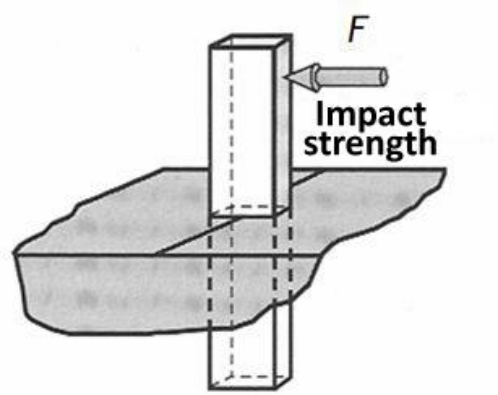


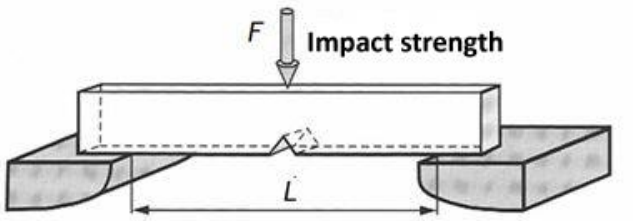






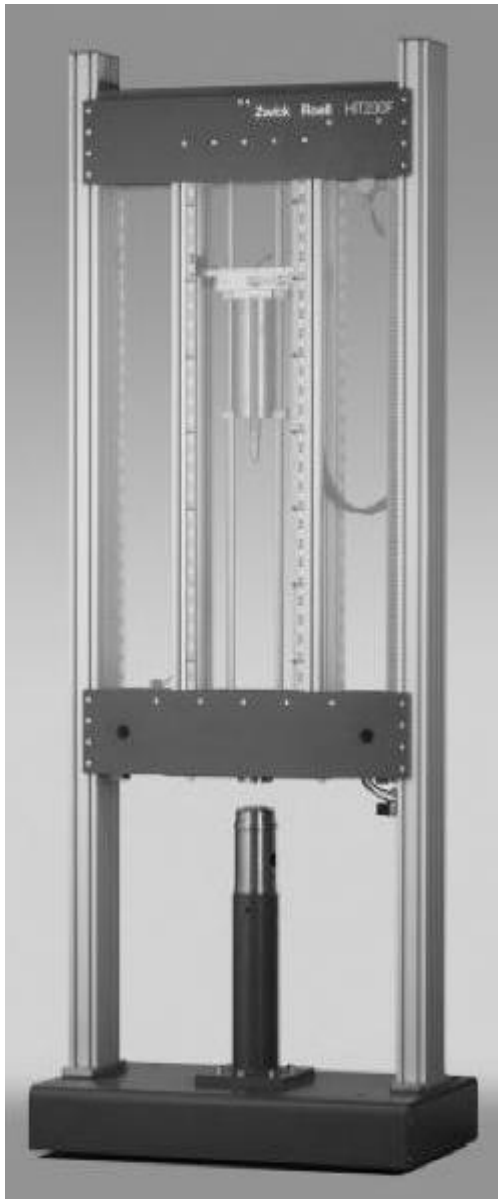
Impact Strength

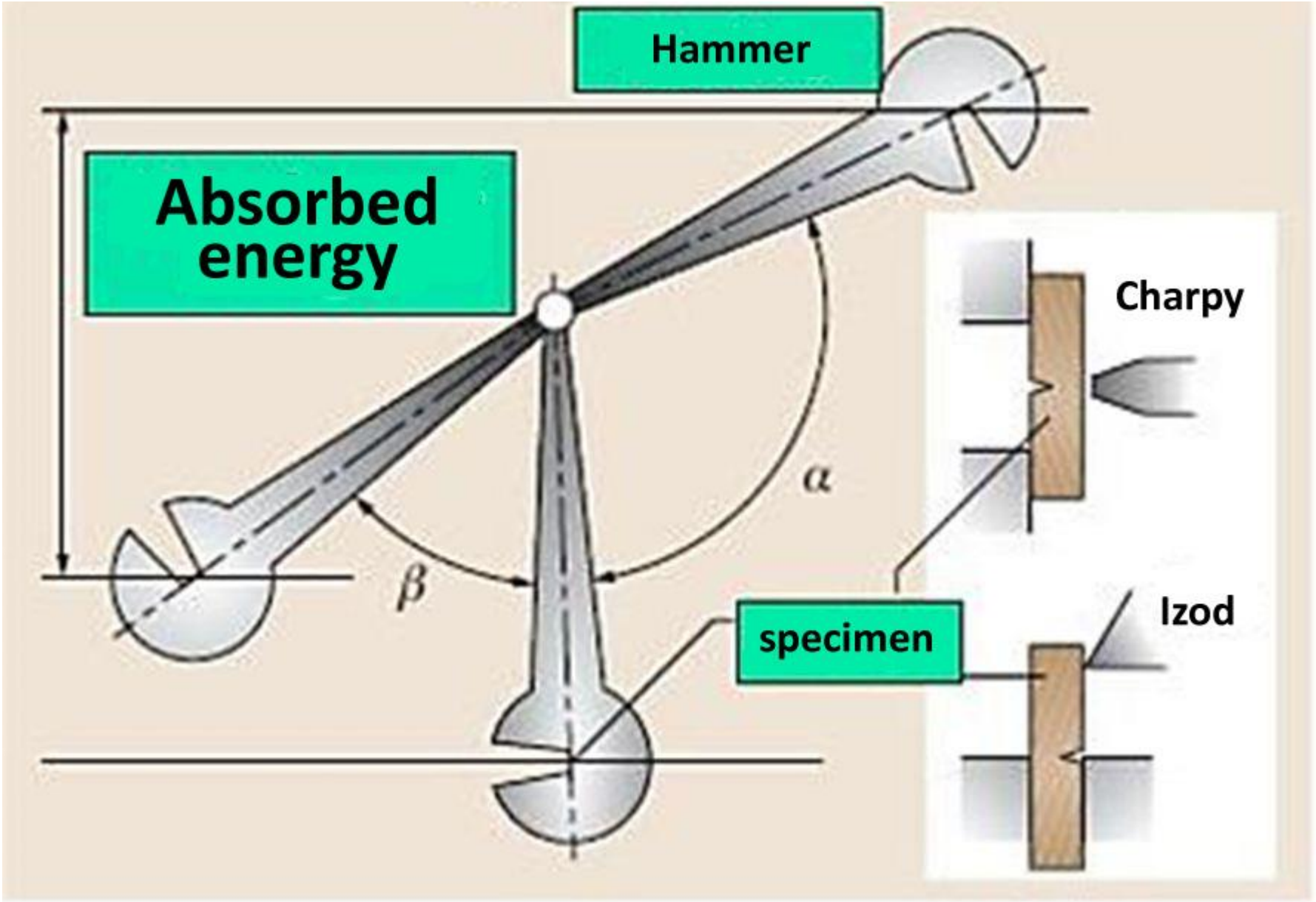




$$A_n = \frac{W}{b.h} \; [kJ.m^{-2}]$$

- *W* … deformation energy used for breakage of specimen
- *b* … width of specimen
- *h* … thickness of specimen




Hammer
Absorbed energy
α
β
specimen
Charpy
Izod