LOCAL MECHANICAL PROPERTIES – WHAT DOE´S IT MEAN?

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stress – strain

σ – ε

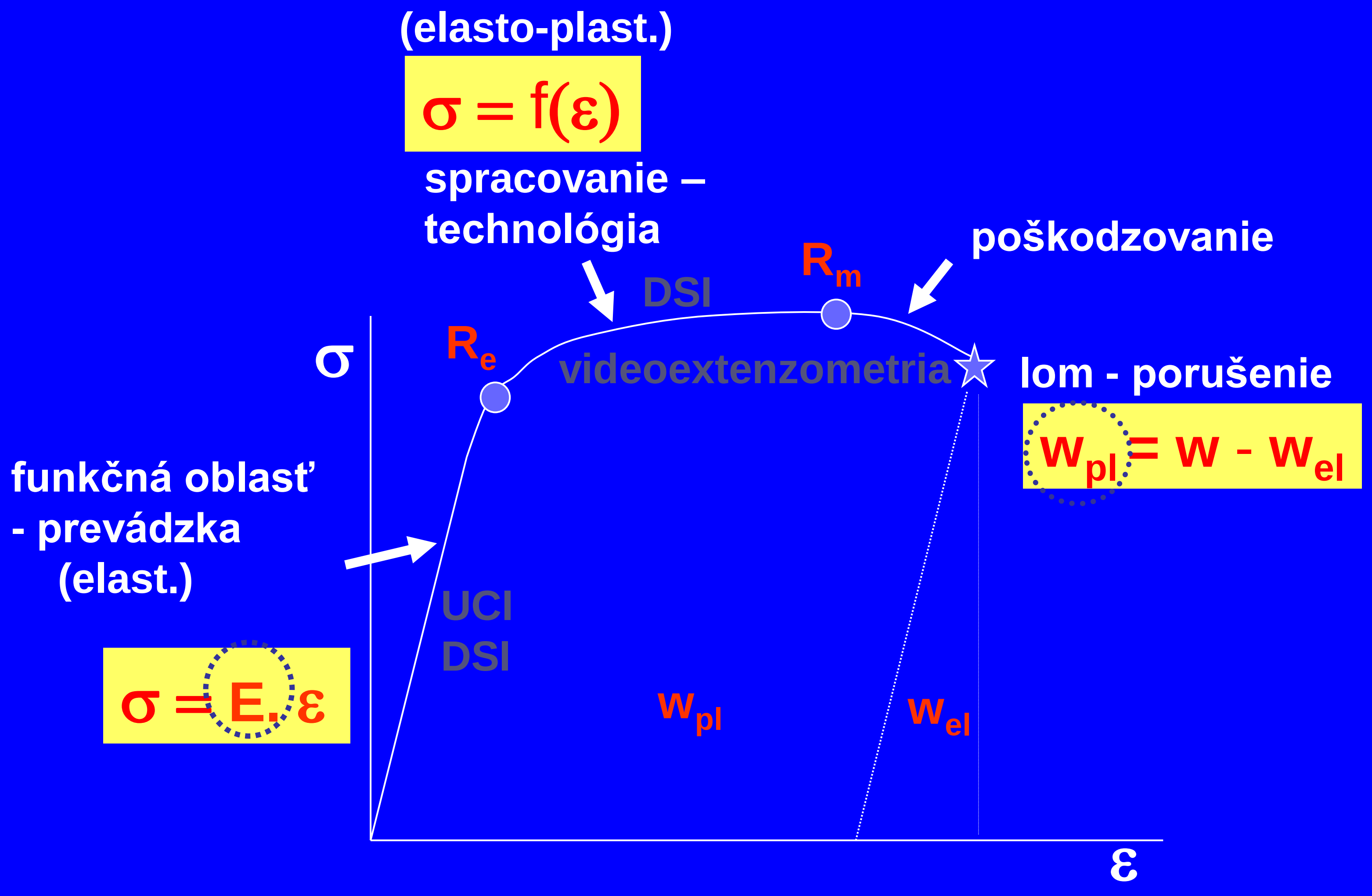
mechanisms:
elastic deformation (reversible) $\Delta V \neq 0$
plastic deformation (ireversible) $\Delta V = 0$ (dislocation movement)

uniform deformation
localised deformation

damage: voids initiation, growth, coalescence
fracturing: crack-initiation, -growth (stable, unstable), -arrest

thermal dilatation

Život (prevádzka) materiálu a jeho namáhanie



Veličiny charakterizujúce medzný stav (ťah, ohyb, tlak, krut, šmyk)

(zmena mechanizmu, koniec, začiatok, rozhranie)

napätie, deformácia, energia, čas, teplota

medza úmernosti	R_u	MPa
medza pružnosti fyzikálna	R_E	MPa
medza pružnosti technická (konvenčná)	$R_p0{,}005$	MPa
medza klzu: výrazná (horná, dolná)	R_e	MPa
nevýrazná	$R_p0{,}2$	MPa
medza pevnosti konvenčná (medza plastickej stability)	R_m	MPa
medza pevnosti skutočná = skutočné lomové napätie	σ_L	MPa
ťažnosť	A	%
rovnomerná ťažnosť	A_g	%
kontrakcia	Z	%

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húževnatosť	w_L(plast)	Jm^{-3}
vrubová húževnatosť	KCV, KCU	Jm^{-2}
lomová húževnatosť	K_{IC}	MPa $m^{1/2}$
lomová húževnatosť	J_{IC}	Jm^{-2}
kritické rozovretie trhliny	δ_c (CTOD)	mm
medza únavy	σ_C	MPa
časová medza únavy	σ_{CN}	MPa
životnosť	N_C	-
medza tečenia	R_{tT}	MPa
medza pevnosti pri tečení	R_{mT}	MPa
životnosť	t	h

Veličiny, ktoré necharakterizujú medzný stav, ale **vlastnosť** materiálu

Elastická oblasť

modul pružnosti **E, G, K** MPa

Poissonovo číslo ν alebo $\mu = -\varepsilon_{priečna} / \varepsilon_{pozdĺžna}$

tuhosť **k** = F/ΔL $N\ m^{-1}$

poddajnosť $\lambda = 1/k = \Delta L / F$ $m\ N^{-1}$

Tuhosť , poddajnosť = f(súčiastka) $k = E\ S_0 / L_0$

Elasto-plastická oblasť

exponent deformačného spevnenia **n**

$\sigma = k\ \phi^n$ ϕ = skutočná deformácia

tvrdosť ≠ medzný stav

Rýchlosť šírenia únavovej trhliny dc/dN

stress - strain

$\boldsymbol{\sigma}$ - $\boldsymbol{\varepsilon}$

- material (E)
- construction (stiffness)

1. Temperature transition behaviour: brittle - tough
2. Stress state triaxiality: compressing (plastic) → tensile (brittle)
3. Strain rate creep → static → dynamic (brittle)
4. Testing conditions specimen size, shape,...
5. Environment

Relationships: $\boldsymbol{\sigma} = f_1\,(T, \boldsymbol{\varepsilon}, d\boldsymbol{\varepsilon}/dt, x, y, z)$

$\boldsymbol{\varepsilon} = f_2\,(T, \boldsymbol{\varepsilon}, d\boldsymbol{\varepsilon}/dt, x, y, z)$

Mechanical properties = g(microstructure)

microscopy: optical, TEM, SEM, AFM, confocal,...

stress - strain

σ - ε

Bulk material ... „global“ properties

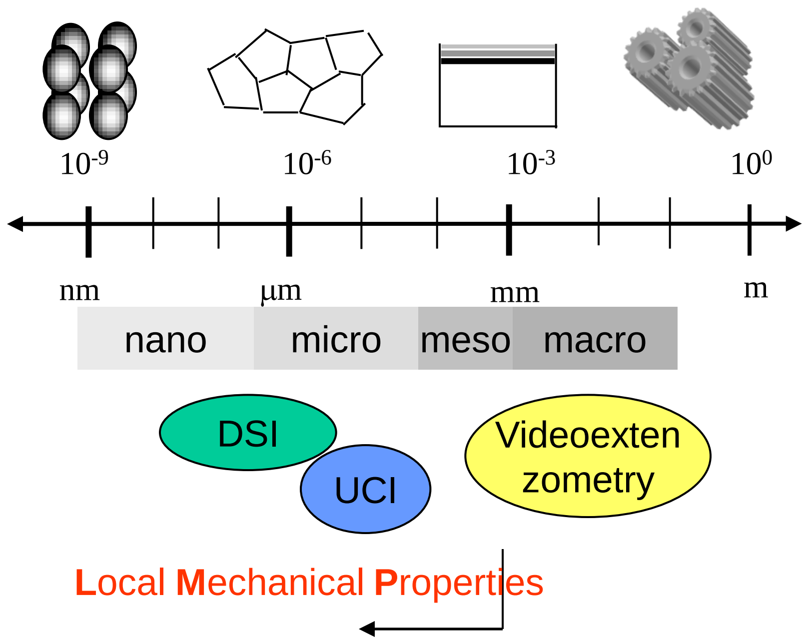
Standardized testing techniques tensile test, compression, toughness (Charpy, fracture t. K_{IC}), creep, bending, fatigue (S-N; da/dN – ΔK), hardness (macro)

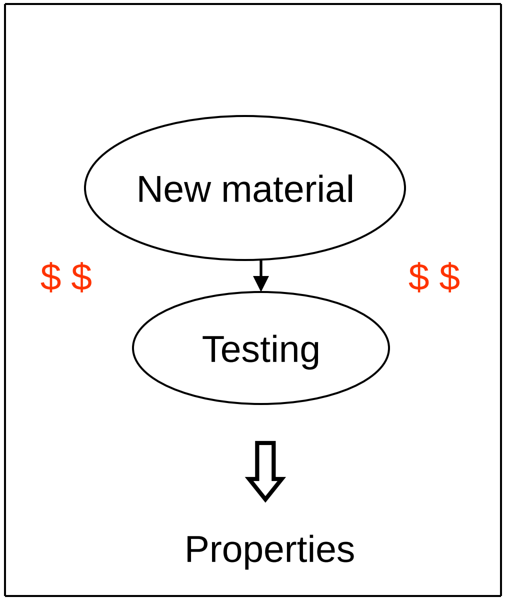
crack ↔ process zone

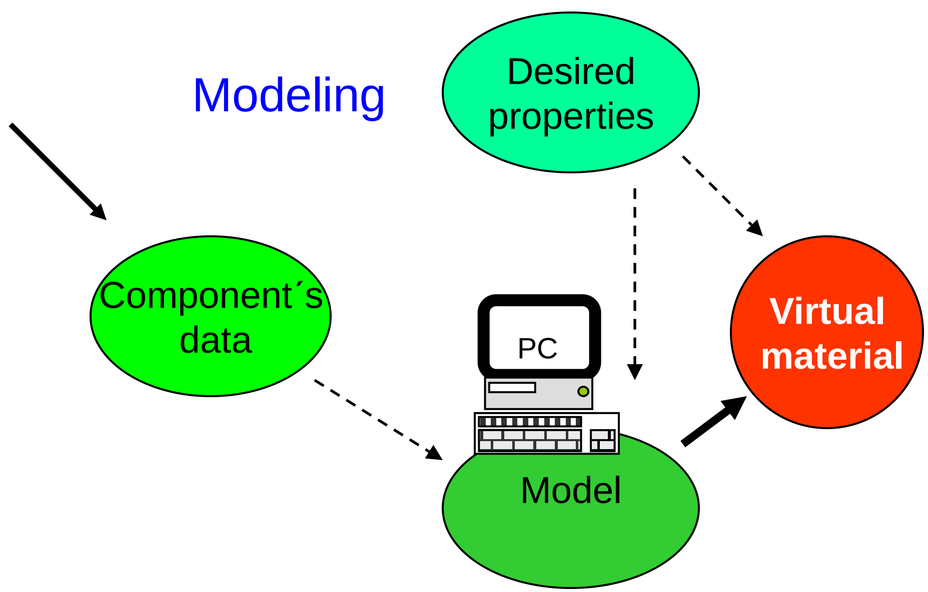
Microstructure objects ... „local“ properties

Experimental techniques in development

Local mechanical properties







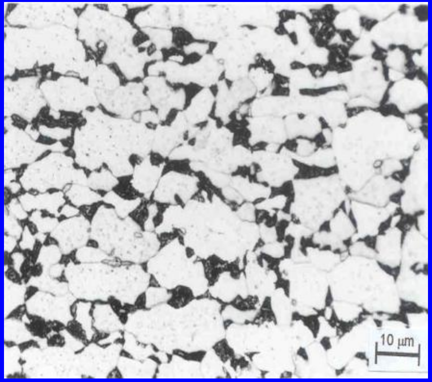
Importance:

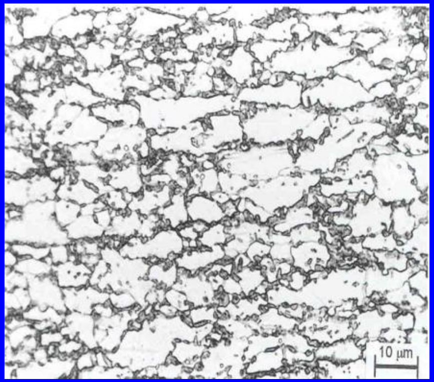
- Identification
- Characterization
- Input data for modeling
- Testing technique

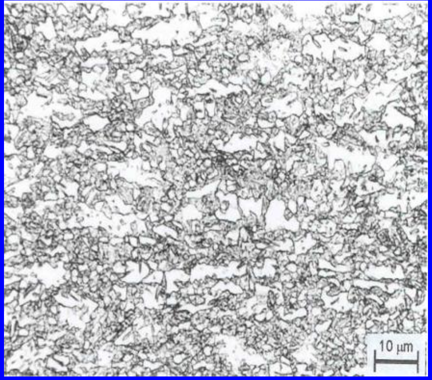
Modeling

- Physical models

  0,73 HM(ferrite) + 0,27 HM(martensite) = HM (mixed ferrite/martensite)







Microstructure of DP600, DP800 and DP1000 steels (from left to right)

Pešek, Vadasová, Zubko, Bláhová: Acta Metallurgica Slovaca, 13 (2007) spec. issue 1, 108-112

Modeling

- Finite element method
  Representative volume element

DSI

Tensile test

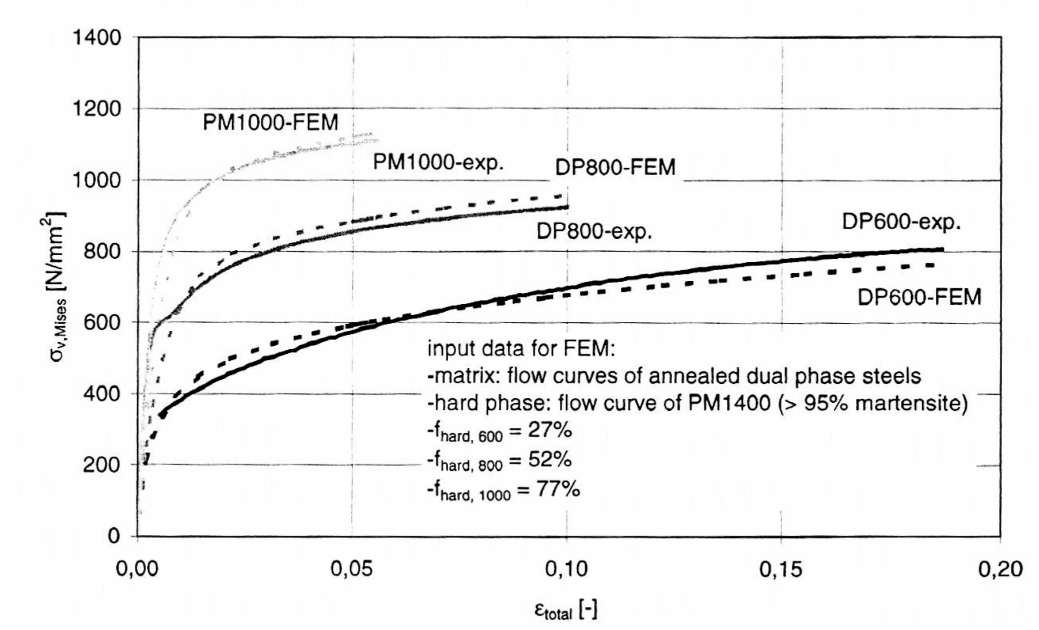
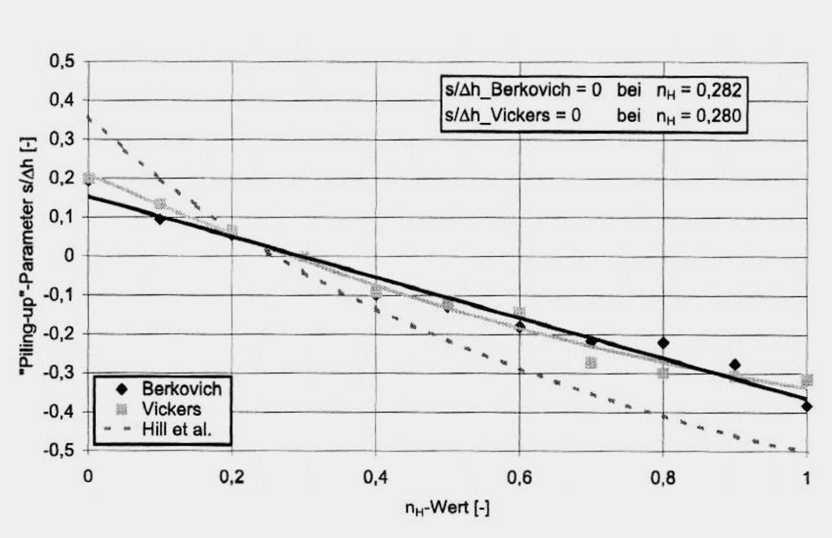
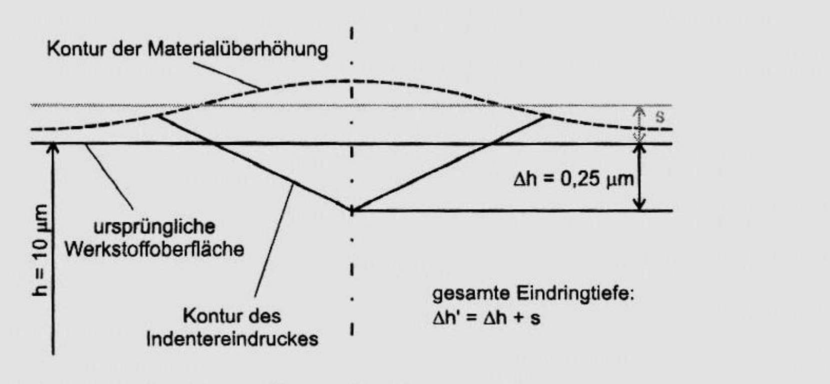


Fig. 4: Comparison between FEM results and experimental tensile tests





Kaluza, Lake, Pesek, Bleck: Modeling of Mechanical Properties and Local Deformation of Multi Phase High Strength Steels, In: Materials Week 2000, 25-28 Sept. 2000, Munich

Experimental techniques

IIT = Instrumented Indentation Testing
DSI = Depth Sensing Indentation

H, σ

IIT Instrumented Indentation Testing - instrumentovaná indentační zkouška
(skúška tvrdosti so záznamom, skúška tvrdosti s registráciou sily)

ISO 14577 – Metallic materials – Instrumented indentation test for hardness and materials parameters, 2002

nano - mikro

UCI – **U**ltrasonic **C**ontact **I**mpedance

micro - meso

Frequency change due to mechanical contact

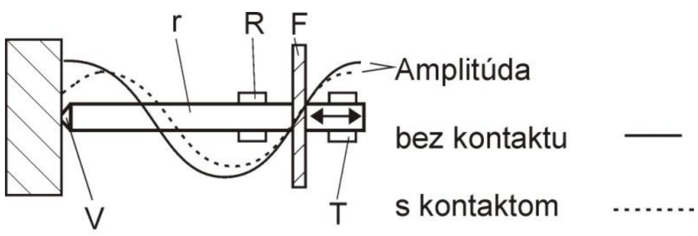
E, H

Videoextenzometry (non contact strain measurement)

meso - macro

ε

UCI – Ultrasonic Contact Impedance



V Vickersov indentor
r rezonančná tyč
F uchytenie
R snímač
T generátor kmitov

Principle: ultrasonic frequency change due to contact with specimen surface

specimen

$$\Delta f = f(A_S, E_P, \nu_P, E_d, \nu_d, f_0)$$

$$A_S = g(E_d, \nu_d, E_P, \nu_P) \cdot h(\Delta f / f_0)$$

contact

$$\Delta f \rightarrow A_S \rightarrow H \qquad HV = F / A_S$$

N – reference block
I – diamond (indentor)
P - specimen

$$HV = HV_{UCI} \left(\frac{1/E_N + 1/E_I}{1/E_P + 1/E_I} \right)^2 \Rightarrow E_P$$