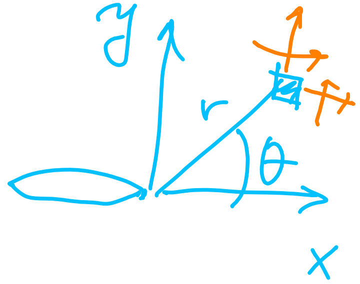
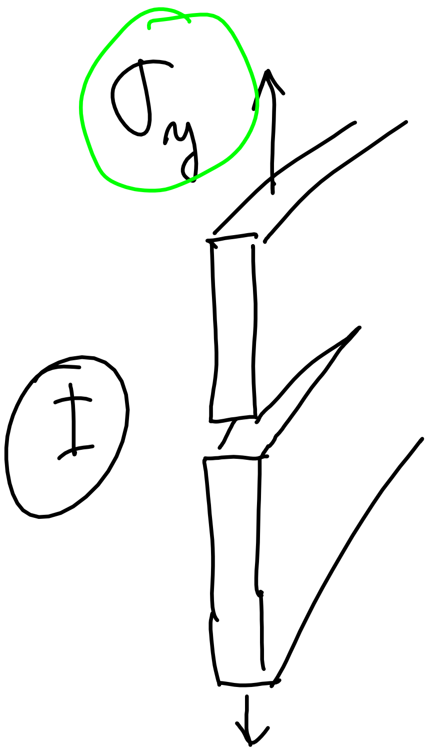
LLM – K-faktor (f. int. napětí)

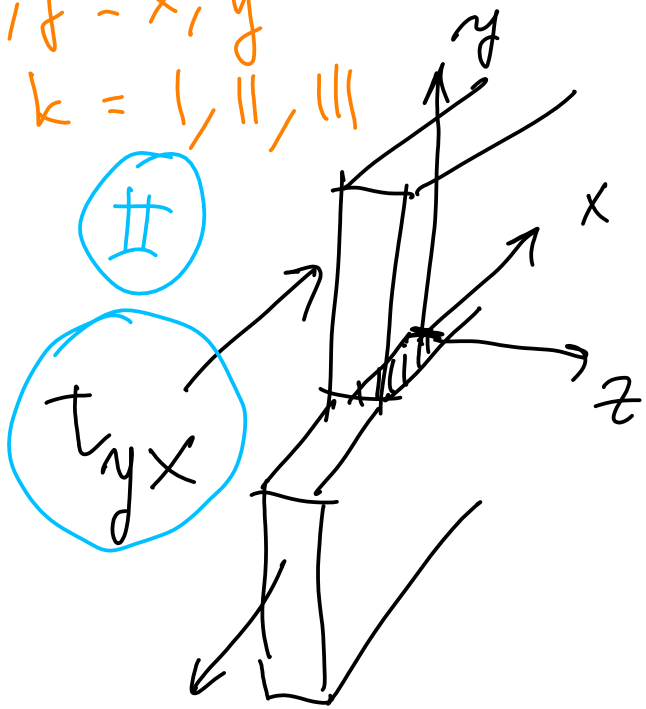


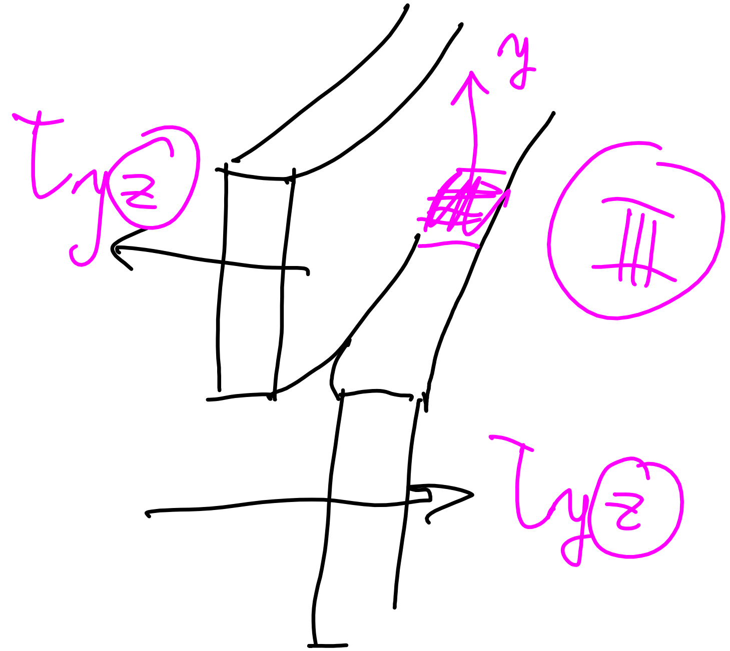
$$\sigma_{ij,k}(r,\theta) = \frac{\sigma_k\sqrt{a}}{\sqrt{2r}} f_{ij,k}(\theta)$$

$i,j = x,y$

$k = I, II, III$







(I)

$K_I = \sigma\sqrt{\pi a}$ – zavedením

STRESS INTENSITY FACTOR

$$\sigma_x(r,\theta) = \frac{K_I}{\sqrt{2\pi r}} \cdot \cos\frac{\theta}{2}\left(1 - \sin\frac{\theta}{2}\cos\frac{3\theta}{2}\right)$$

$$\sigma_y(r,\theta) = \frac{K_I}{\sqrt{2\pi r}}\, c \quad \left(1 + \quad\right)$$

$$\tau_{xy}(r,\theta) = \frac{K_I}{\sqrt{2\pi r}} \cos\frac{\theta}{2}\sin\frac{\theta}{2}\cos\frac{3\theta}{2}$$

FIN

$MPa\sqrt{mm}$ $Pa\sqrt{m}$

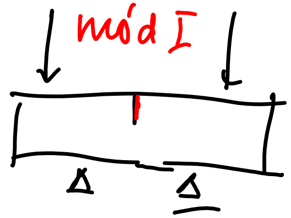
Faktor intenzity napětí K

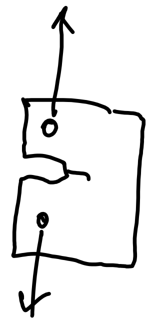
$$K_I = \lim_{r \to 0} \sqrt{2\pi r} \cdot \sigma_y(r,0) \Rightarrow K_I = \sigma\sqrt{\pi a}$$

$$K_{II} = \lim_{r \to 0} \sqrt{2\pi r} \cdot \tau_{yx}(r,0) \Rightarrow K_{II} = \tau\sqrt{\pi a}$$

$K_{I.c}$

$$K_{III} = \lim_{r \to 0} \sqrt{2\pi r} \cdot \tau_{yz}(r,0) \Rightarrow K_{III} = \tau\sqrt{\pi a}$$





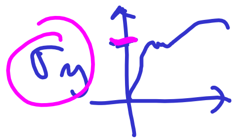
Mezní stav:

- kdy dojde k poškození **lomem**.
- $K_I < K_{I.c}$ – kritická h. FIN – **experimentálně**

$K_{II} < K_{II.c}$

$K_{III} < K_{III.c}$

viz: $\sigma_{red}(\sigma_x, \sigma_y, \dots) < \sigma_{mez}(\sigma_y)$ (σ_{ij})

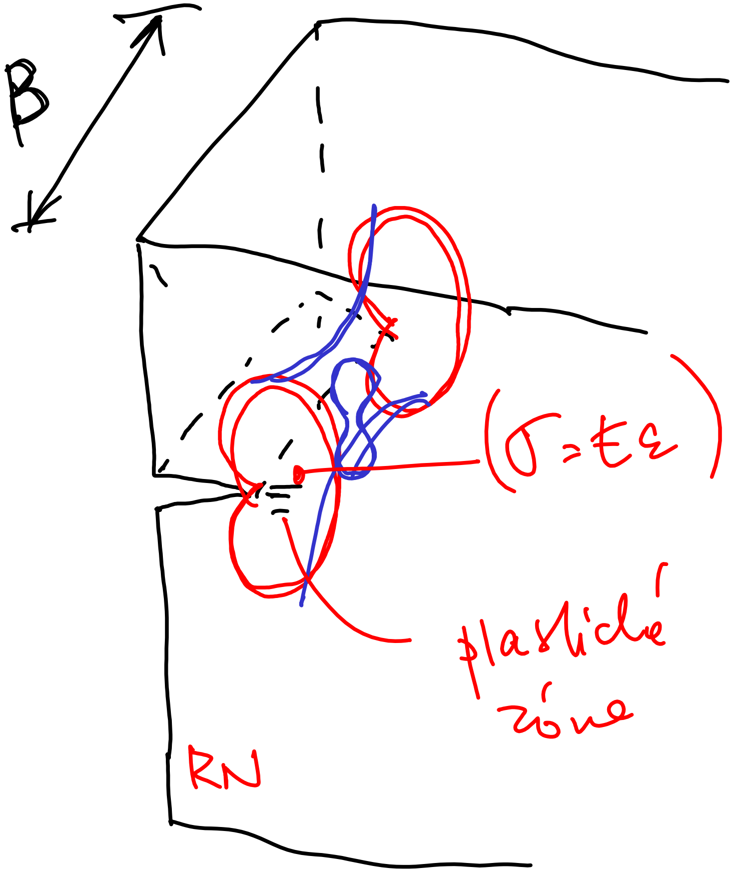


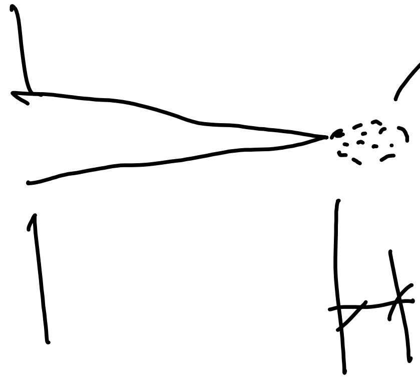
→ HMH Ran

předpoklad LLM ($\underline{\underline{K}}$)

× lineární el. mat → FPZ

fracture process zone





procesní zóna trhliny

není kontinuum

mikrotrhliny

$$\underset{\sim}{\sigma} = D \underset{\approx}{\varepsilon}$$

$$a_t = \frac{1}{\pi}\left(\frac{K_c}{R_g}\right)^2$$

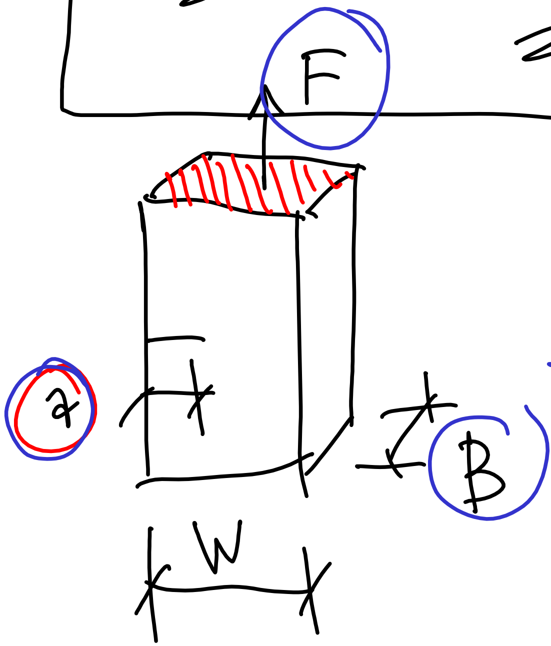
$$a_c = \frac{1}{\pi}\left(\frac{K_c}{\sigma_p}\right)^2$$

plastické def

lom

$$K = \sigma\sqrt{\pi a} \qquad \left(\tau\sqrt{\pi a}\right)$$

$$a_c = \frac{1}{\pi}\left(\frac{K_c}{\sigma_p}\right)^2$$



$$\sigma = \frac{F}{A} = \frac{F}{W \times B}$$

$$K = \frac{F}{W \times B}\sqrt{\pi a}$$ ✓

SHRNUTÍ: $K < K_c$; $K_I < K_{Ic}$ K_{IIc}, K_{IIIc}

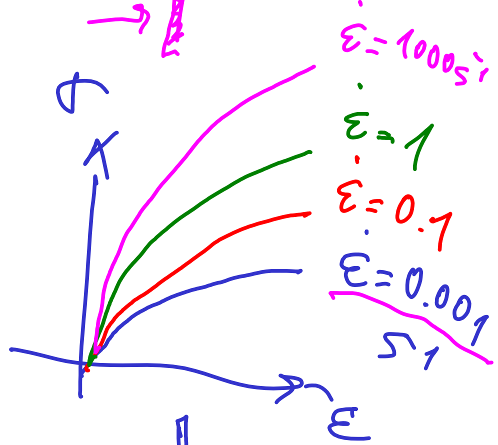
$$K_J < K_{Jc}$$

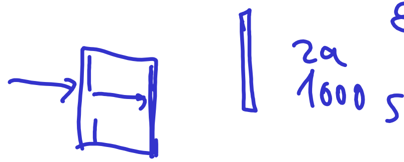
$K_J > K_{Jc}$ ... nastane nestab. šíření trhliny. (nevratné)

LOM. HOUŽEV. závisí:

- materiál
- rozměrech (B) → RD / RN
- teplotě
- agresivitě prostředí
- rychlosti deformace

$$\dot{\varepsilon} = \frac{d\varepsilon}{dt}$$

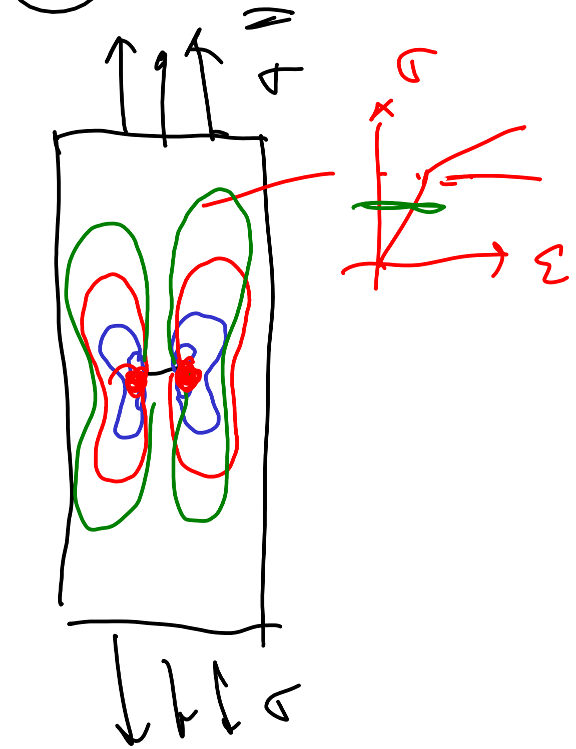


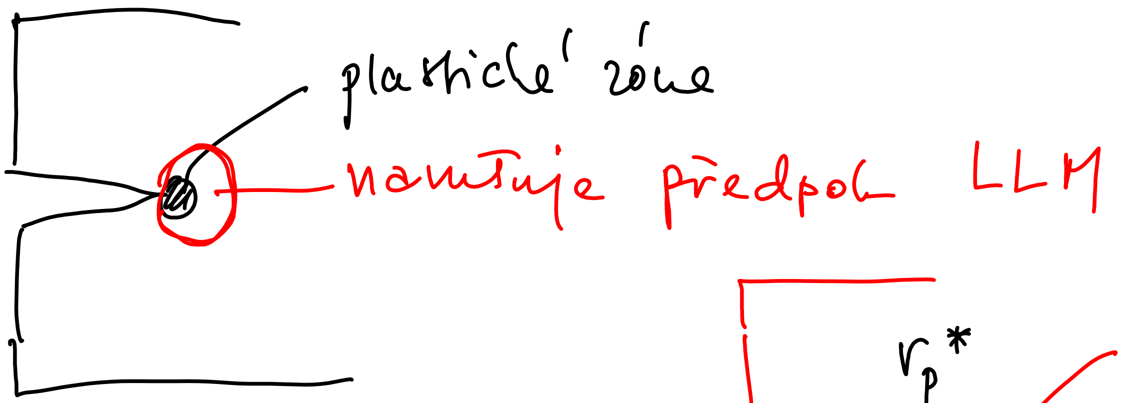


Obecně:

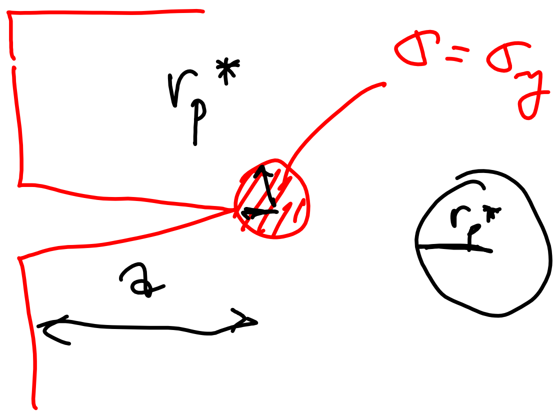
- čím vyšší je mez kluzu R_y, tím nižší je lom. houževnatost
- čím nižší je teplota, tím nižší je lom. houž.

Ⓚ = LLM





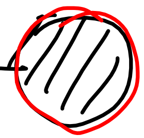
→ korekce:



$$a_{ef} = a + r_p^*$$

$$r_p^* = \alpha \left(\frac{K_I}{R_y}\right)^2 \qquad a = \frac{1}{\pi}\left(\frac{K_I}{R_y}\right)^2$$

pro kruh. plast. zónu



tvar tělesa

RN x RD

$$\alpha = \frac{1}{6\pi}$$

$$r_p^* = \frac{1}{6\pi}\left(\frac{K_I}{R_y}\right)^2$$

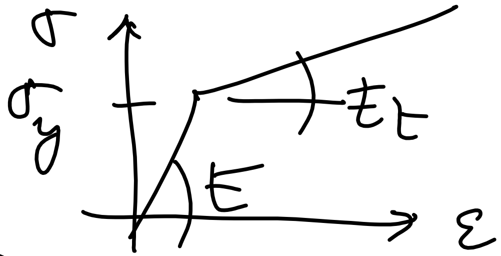
pro RD

$$a_{ef} = a + r_p^*$$

$$K_{I.corr} = \sigma_{nom} \cdot \sqrt{\pi a_{ef}}\; \underbrace{f\left(\frac{a}{W}\right)}_{\text{tvar. fce}}$$

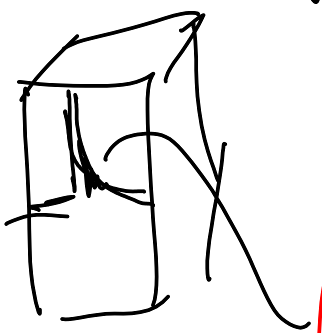
LLM ✓ → NLM nelinearita = materiálová

mater: elasto-plastický materiál



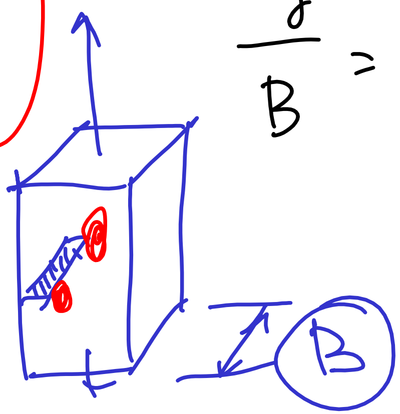
NLM [CTOD (Crack Tip Opening Displacement)
 J integrál

Podmínky LLM: $a, B, (W-a) \geq 2{,}5 \left(\frac{K_I}{R_e}\right)^2$

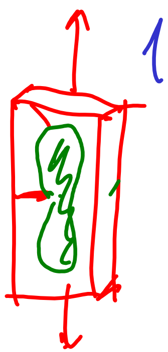


RD: $r_y^{RD} = \frac{1}{6\pi}\left(\frac{K_I}{R_e}\right)^2$

$\sigma_{ij,k} \approx \frac{1}{\sqrt{r}}$ $\frac{1}{\sqrt{r}}$



$$\frac{r_y}{B} = \frac{\frac{1}{6\pi}\left(\frac{K_I}{R_e}\right)^2}{2{,}5\left(\frac{K_I}{R_e}\right)^2} = \frac{1}{15\pi} \sim \frac{1}{50}$$

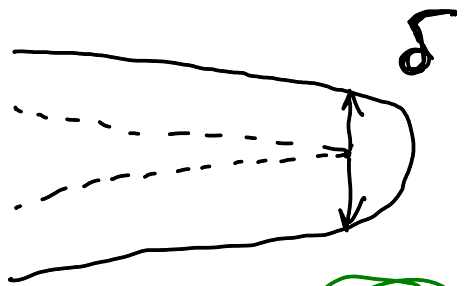


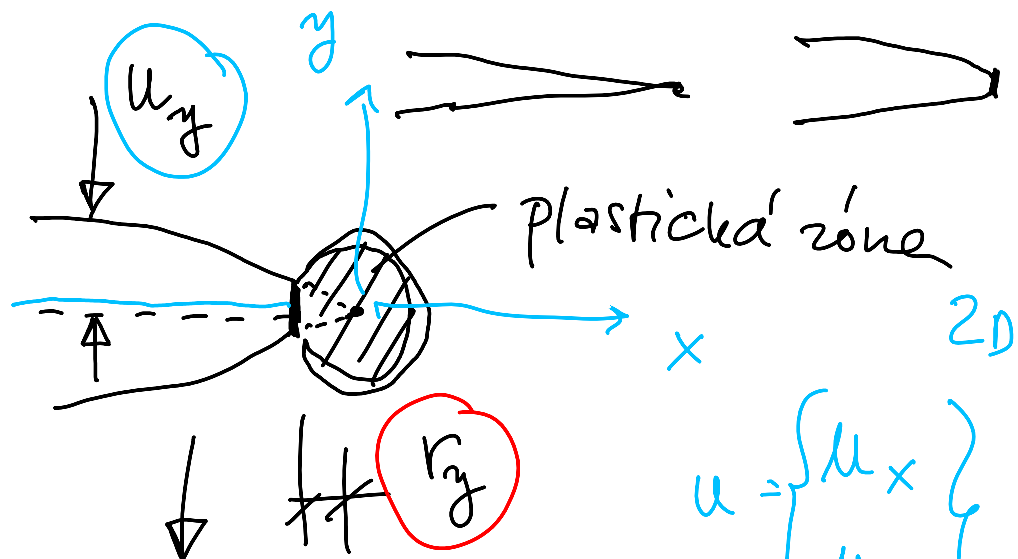
CTOD – Crack Tip Opening Displacement : 1963, Wells

$K_I = K_{I.c}$ $\quad (K_{II.} = K_{II.c}) \ldots$

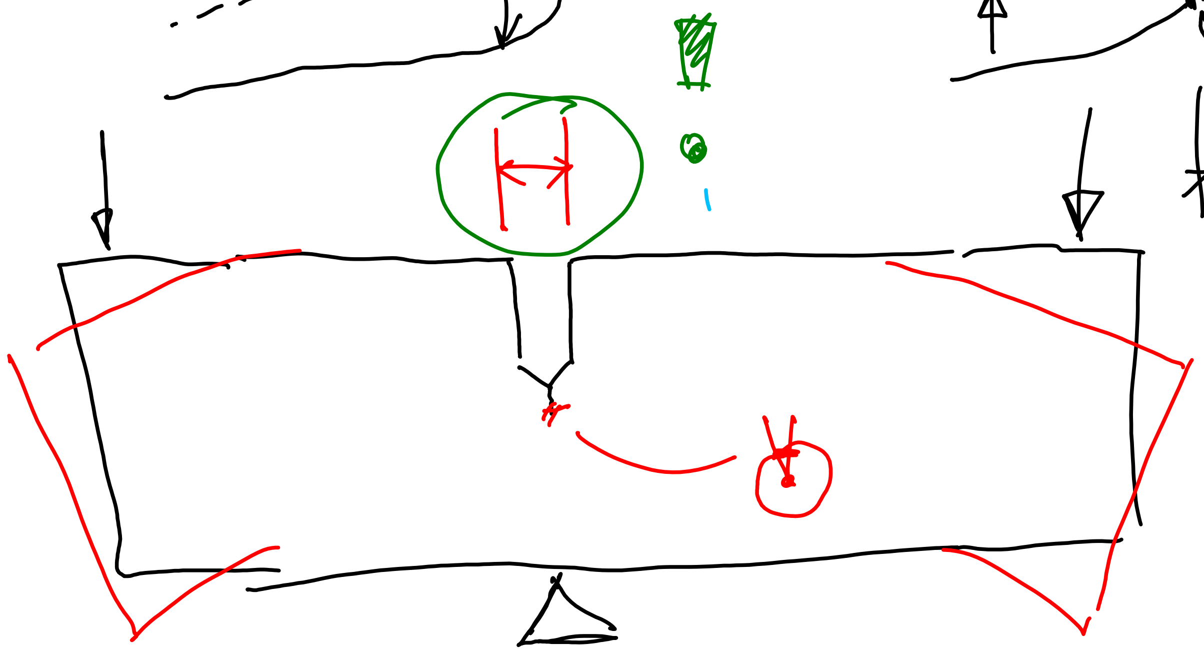
$$\delta = \delta_c$$

reálná trhlina :

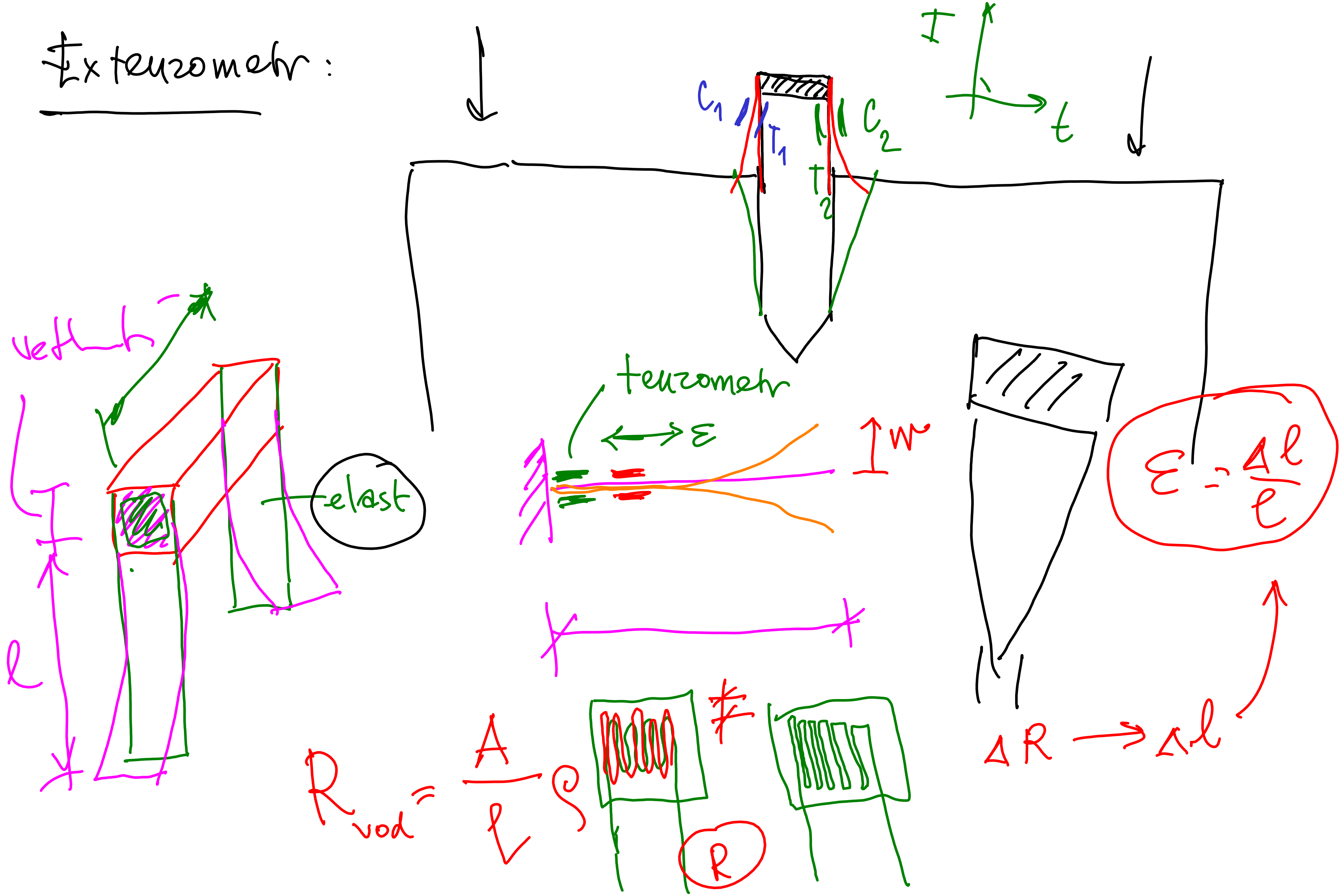


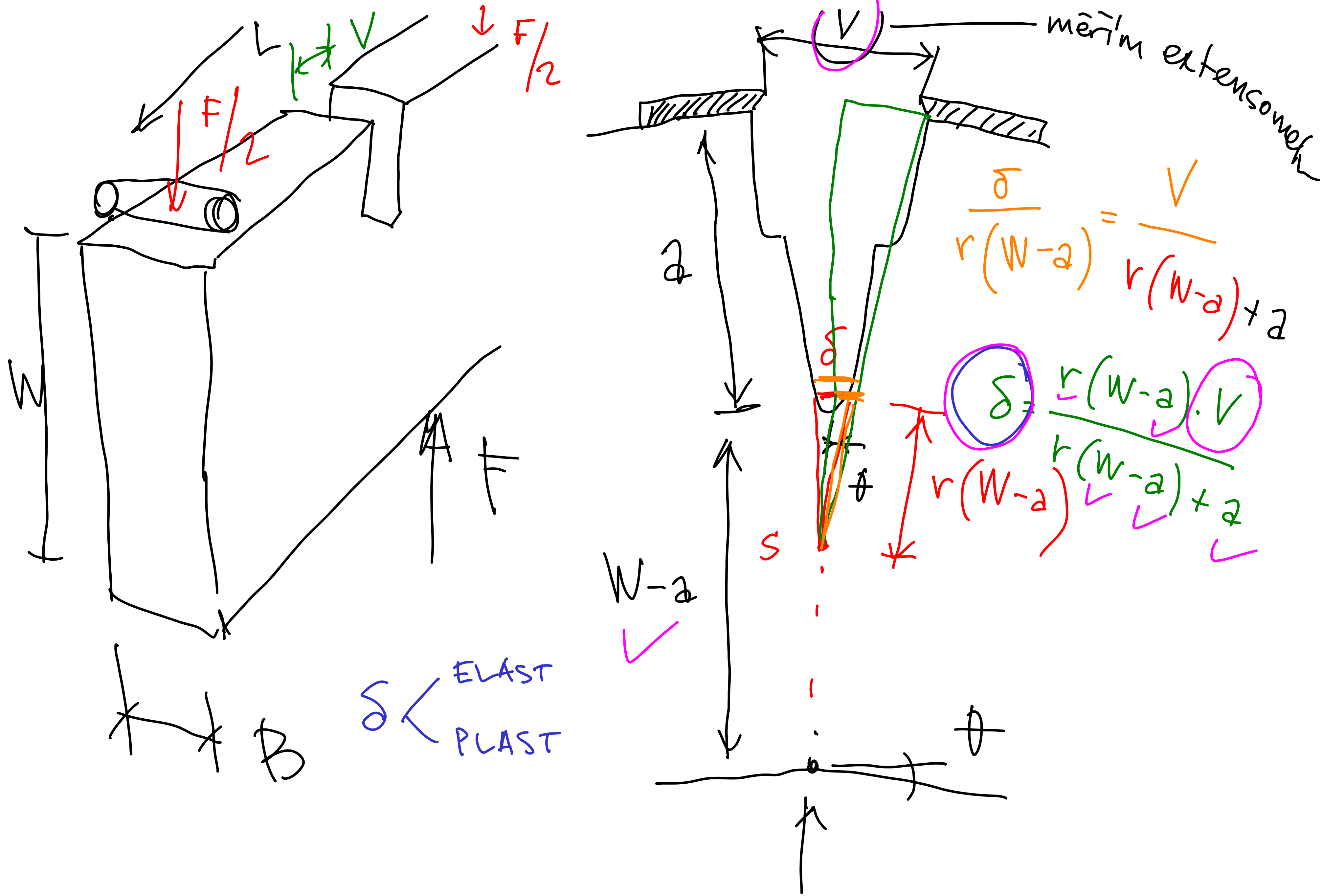


$$u = \begin{Bmatrix} u_x \\ u_y \end{Bmatrix}$$



Extenzometr:




L
V
F/2
F/2
W
B
F
δ ELAST
PLAST
V
měřím extensometrem
a
W-a
δ
s
θ
δ / r(W-a) = V / (r(W-a)+a)
δ = r(W-a) · V / (r(W-a)+a)
r(W-a)

$\delta < \delta_c$ $\quad \delta \dots \text{EXP} \dots \delta_c$

$$\delta = \delta_{el} + \delta_{pl} = \frac{K_I^2}{m R_e E'} + \frac{r_p (w-a) V}{r_p (w-a) + a}$$

NEXT

J-integral ✓