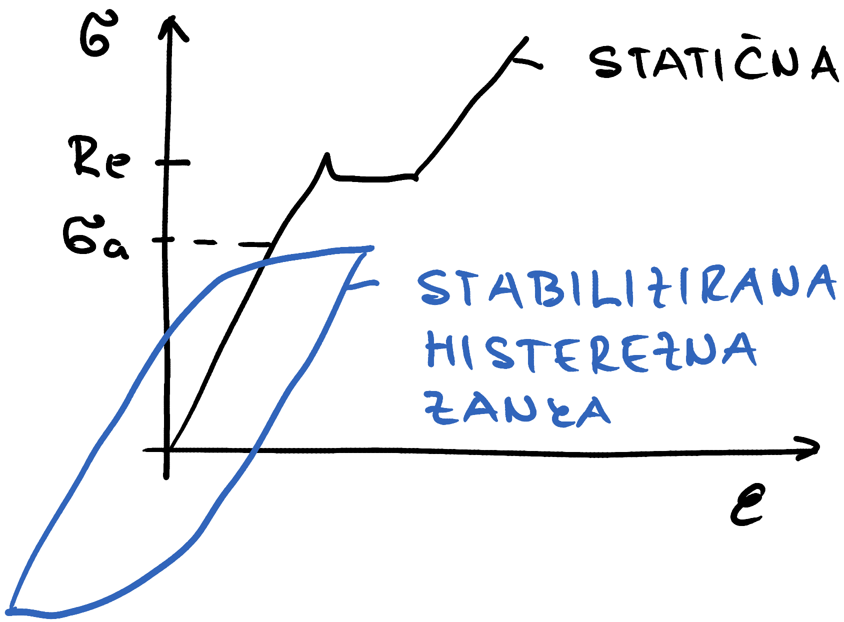
CIKLIČNO UTRJEVANJE IN MEHČANJE

STR 3

$$\sigma = \frac{F}{A}$$

A IMENSKI PREREZ

KONTROLIRAMO NAPETOST $R_\sigma = \frac{\sigma_{min}}{\sigma_{max}} = -1$



$Re = R_{p0.2} > \sigma_a$

CIKLIČNO MEHČANJE

NAPETOSTNA KONTROLA $R_\sigma = -1$ STR 4

$\sigma_a > R_{p0.2}$

CIKLIČNO UTRJEVANJE

DEFORMACIJSKA KONTROLA $R_\varepsilon = \frac{\varepsilon_{min}}{\varepsilon_{max}} = -1$ STR 5

$\varepsilon_a < 0,2\%$

CIKLIČNO MEHČANJE

DEFORMACIJSKA KONTROLA $R_\varepsilon = -1$ STR 6

$\varepsilon_a > 0,2\%$

CIKLIČNO UTRJEVANJE

CIKLIČNO UTRJEVANJE IN MEHČANJE POPIŠEMO Z ELASTOPLASTIČNIMI MATERIALNIMI MODELI.

CIKLIČNO LEZENJE IN RELAKSACIJA

STR 7

NAPETOSTNA KONTROLA $R_\sigma > -1$

CIKLIČNO MEHČANJE SUPERPONIRANO NA CIKLIČNO LEZENJE

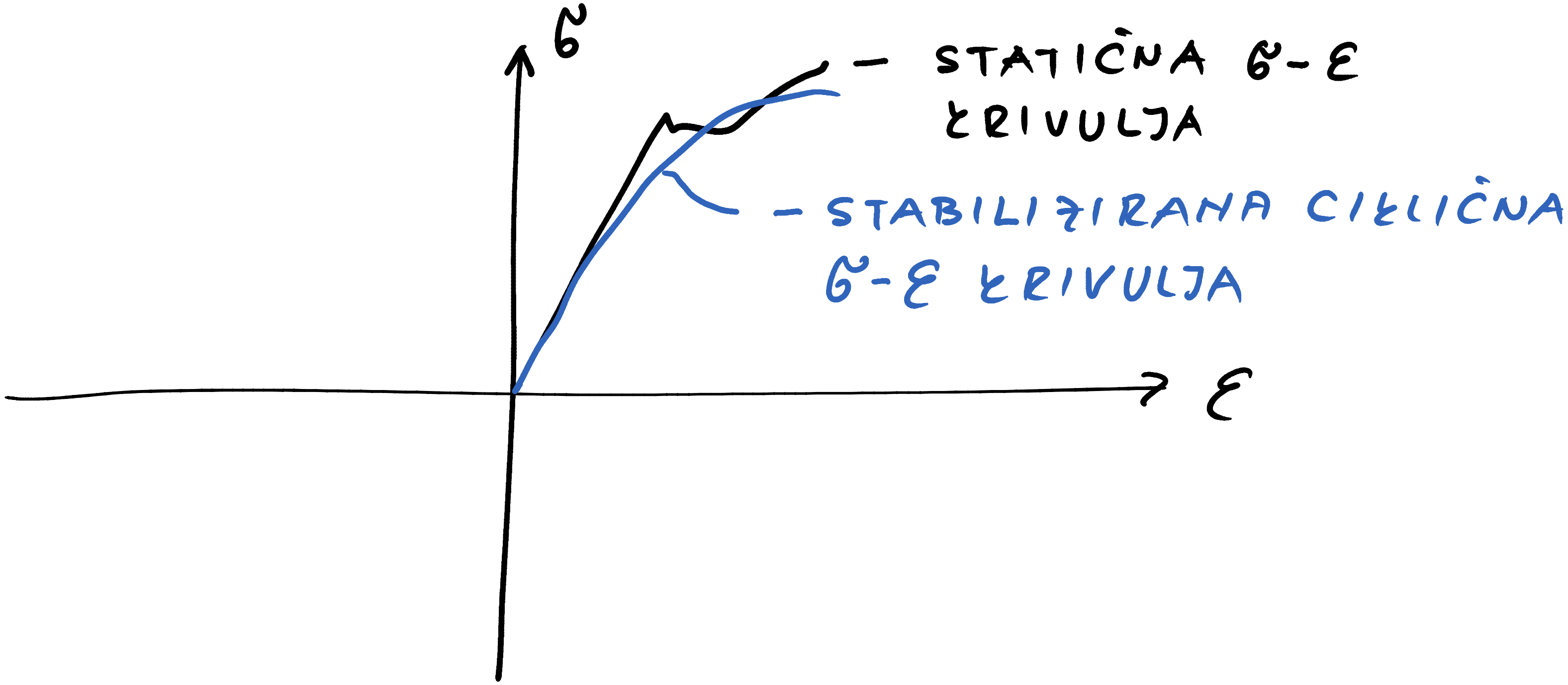
STR 8

DEFORMACIJSKA KONTROLA $R_\varepsilon > -1$

CIKLIČNO MEHČANJE SUPERPONIRANO NA CIKLIČNO RELAKSACIJO

CIKLIČNO LEZENJE IN RELAKSACIJO POPIŠEMO Z ELASTOVISKOPLASTIČNIMI MATERIALNIMI MODELI.

STABILIZIRANA CIKLIČNA σ-ε KRIVULJA

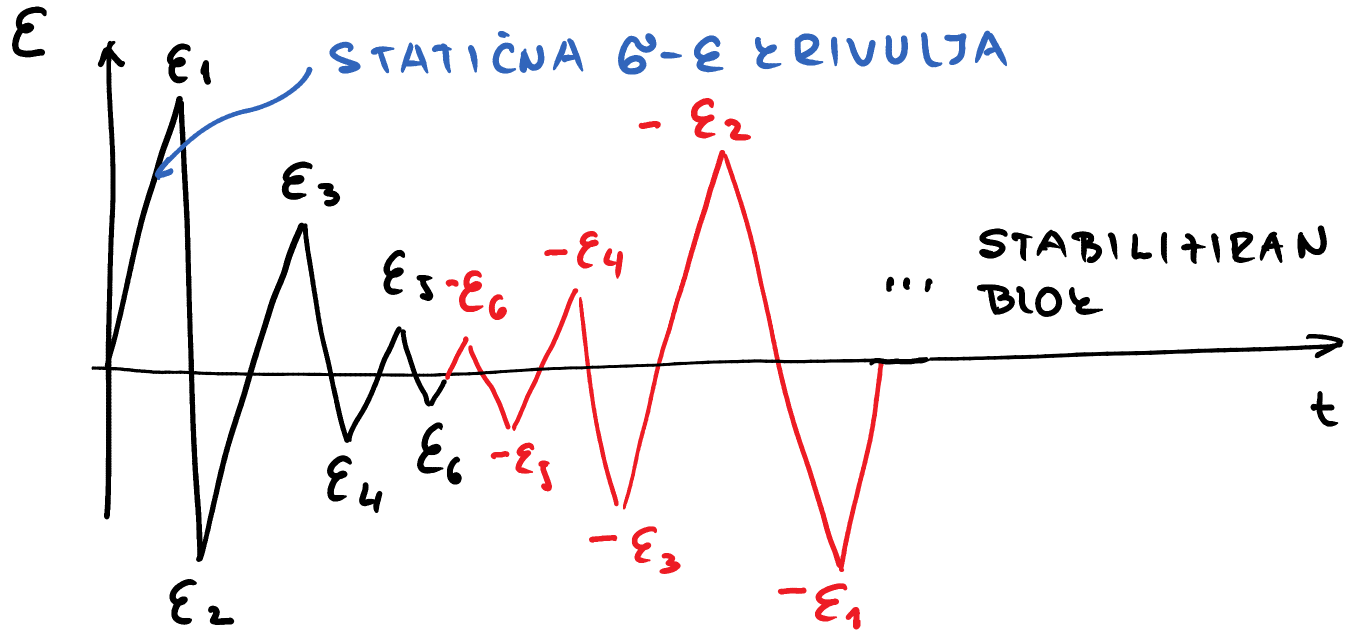


ANALITIČEN POPIS STABILIZIRANE CIKLIČNE σ-ε KRIVULJE

$$\varepsilon_a = \frac{\sigma_a}{E} + \left(\frac{\sigma_a}{K'} \right)^{\frac{1}{n'}}$$

RAMBERG-OSGOODOVA ENAČBA

INKREMENTALNI STEP TEST

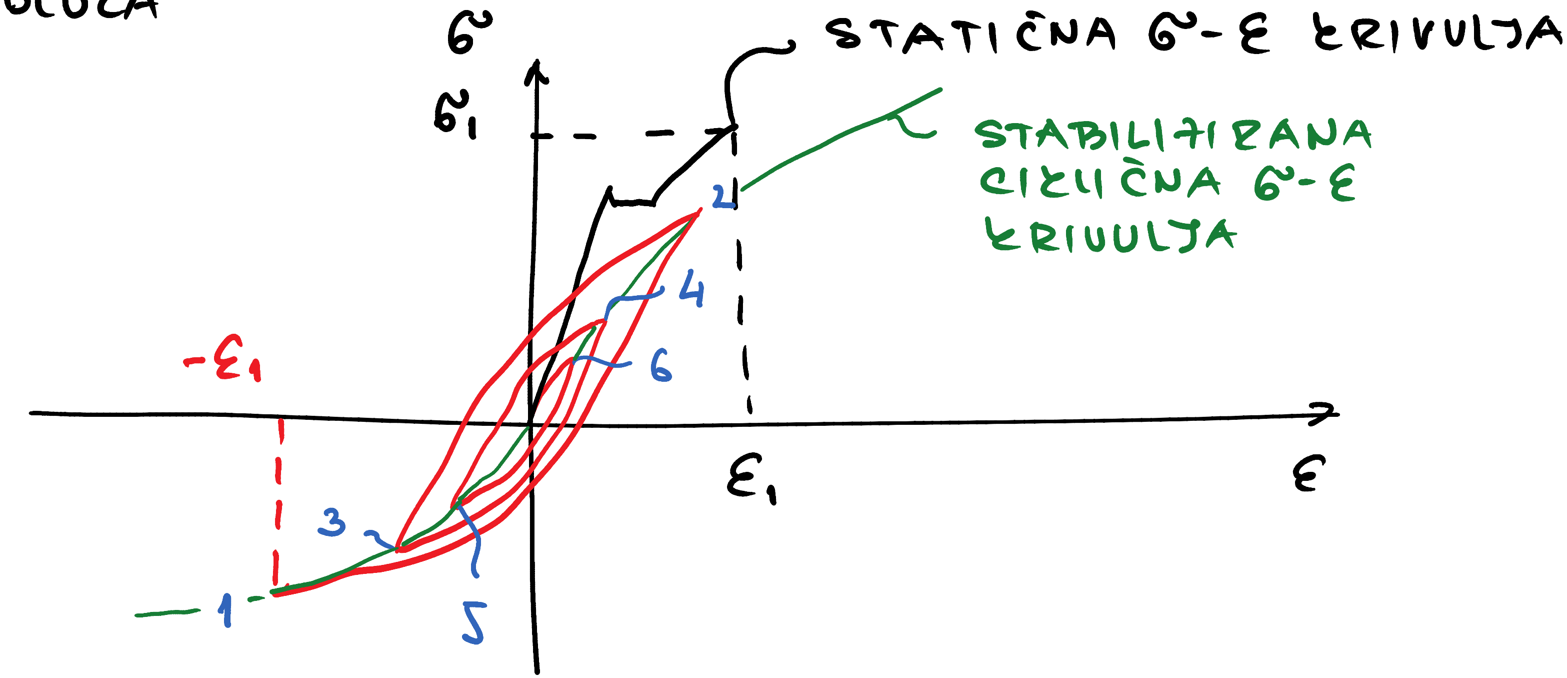


$$|\varepsilon_1| > |\varepsilon_2| > |\varepsilon_3| > |\varepsilon_4| > |\varepsilon_5| > |\varepsilon_6|$$

ε_1 DO ε_6 PREDSTAVLJA PADAJOČI BLOK OBREMENITEV

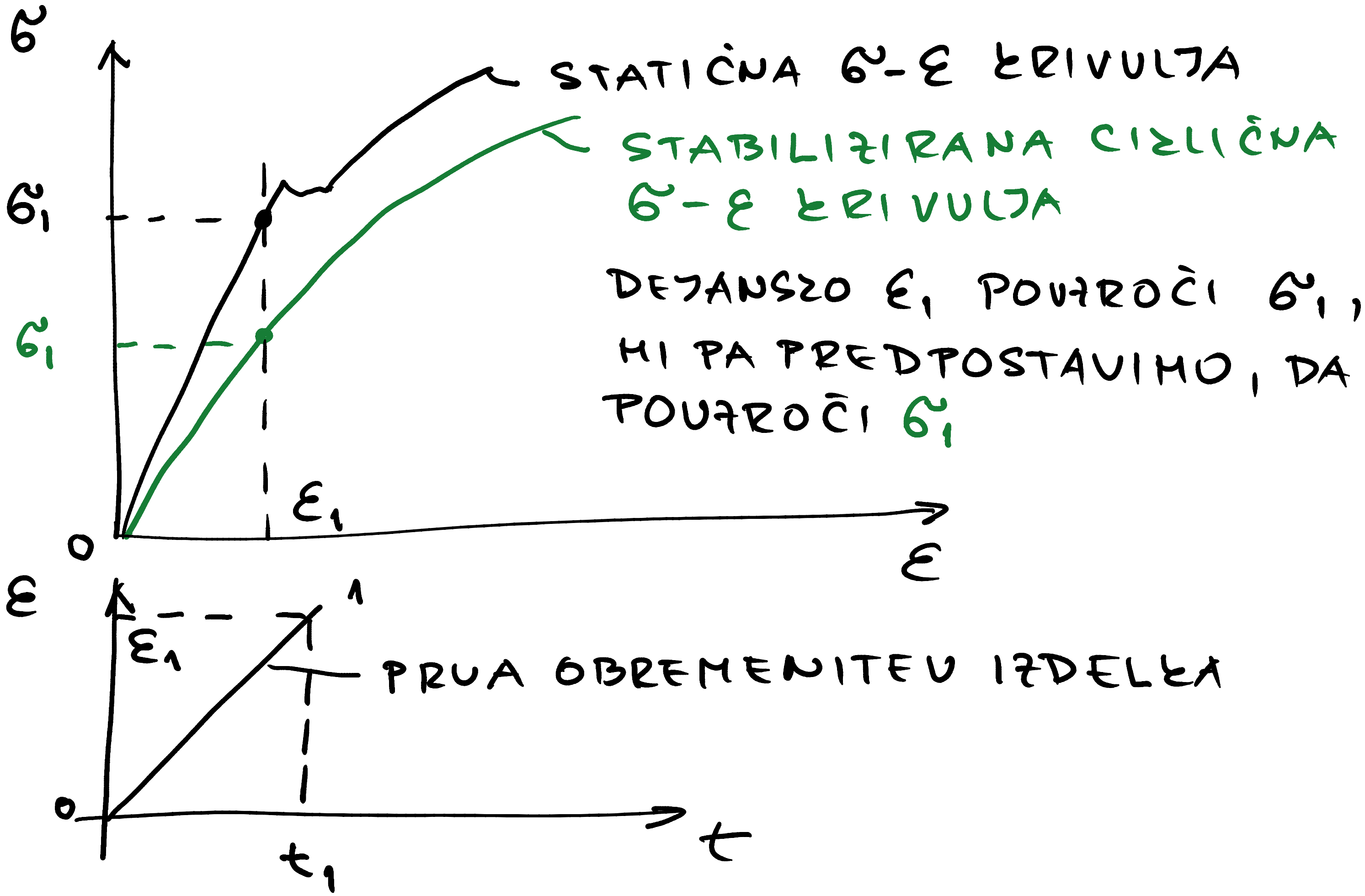
$-\varepsilon_1$ DO $-\varepsilon_6$ PREDSTAVLJA NARAŠČAJOČI BLOK OBREMENITEV

BLOKA PONAVLJAMO DO STABILIZACIJE NATO POSNAMEMO BLOKA



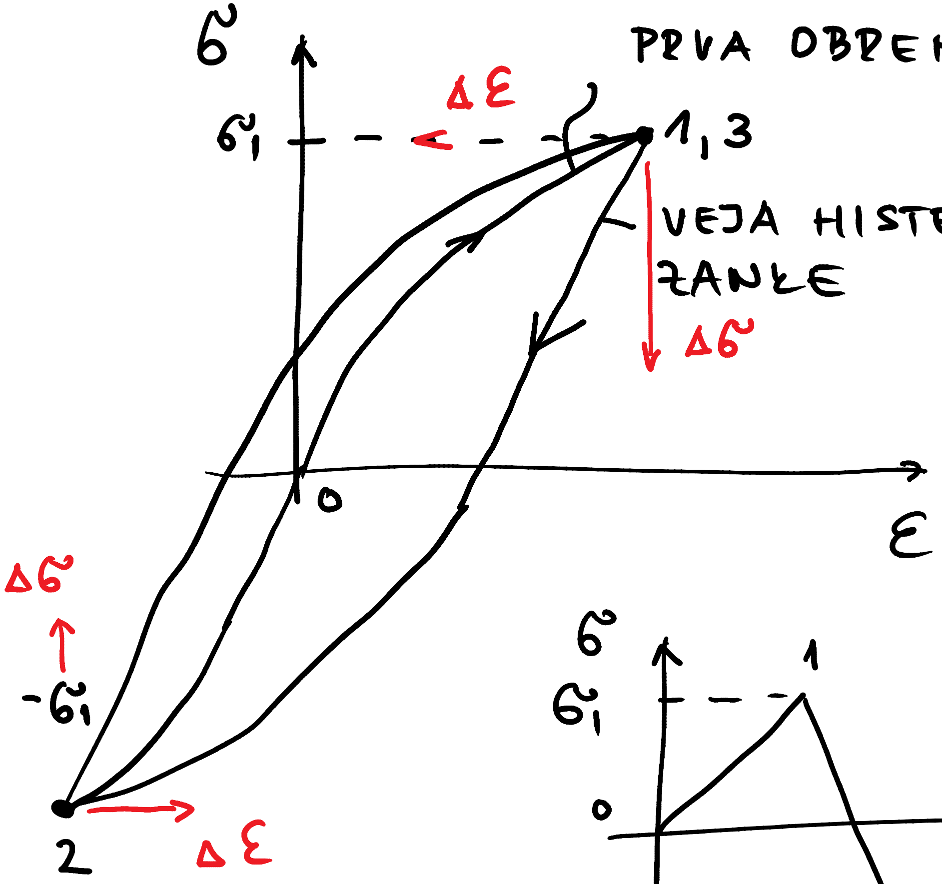
SKOZI TOČKE 1 DO 6 S POMOČJO REGRESIJE NAPNEMO RAMBERG OSGOODOVO ENAČBO IN DOLOČIMO PARAMETRE E, K' IN n'.

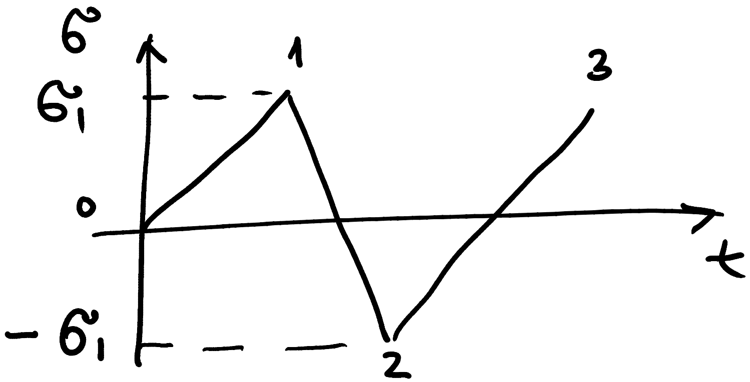
PREDPOSTAVKA O ENAKOSTI STABILIZIRANE CIKLIČNE $\sigma-\varepsilon$ KRIVULJE IN PRVE OBREMENITVENE KRIVULJE



STABILIZIRANA CIKLIČNA σ-ε KRIVULJA SE OD SEDAJ DALJE IMENUJE PRVA OBREMENITVENA KRIVULJA

MASINGOVO PRAVILO





OD 0 DO 1 VELJA RAMBERG OSGOODOVA ENAČBA

$$\varepsilon_a = \frac{\sigma_a}{E} + \left(\frac{\sigma_a}{K'}\right)^{\frac{1}{n'}}$$

$$\frac{\Delta\varepsilon}{2} = \varepsilon_a \quad \text{IN} \quad \frac{\Delta\sigma}{2} = \sigma_a$$

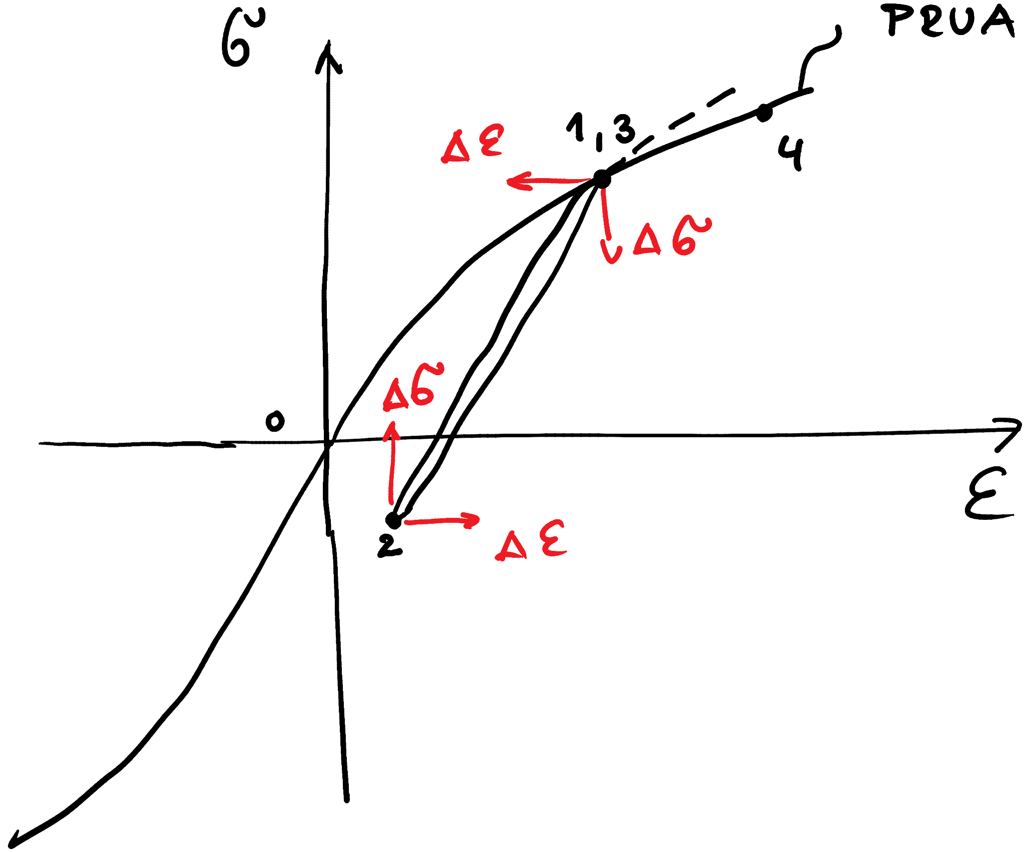
$$\frac{\Delta\varepsilon}{2} = \frac{\Delta\sigma}{2E} + \left(\frac{\Delta\sigma}{2K'}\right)^{\frac{1}{n'}} \quad \Big| \cdot 2$$

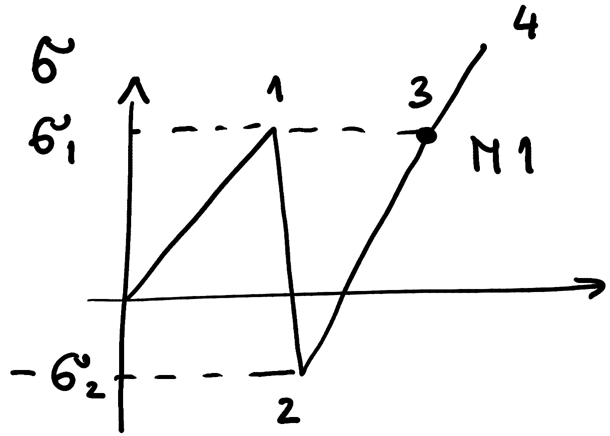
$$\Delta\varepsilon = \frac{\Delta\sigma}{E} + 2\left(\frac{\Delta\sigma}{2K'}\right)^{\frac{1}{n'}}$$

ENAČBA, KI VELJA OD 1 DO 2 IN OD 2 DO 3.

MEMORY PRAVILA

PRVA CIKLIČNA KRIVULJA





$$|\sigma_2| < |\sigma_1|$$

01 – RO RAMBERG OSGOOD

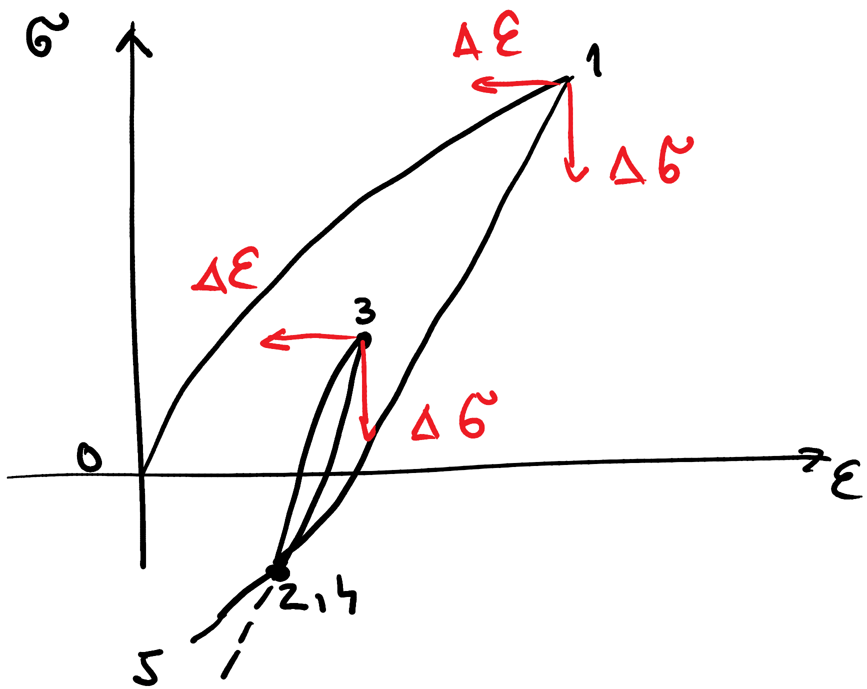
12 – M MASING

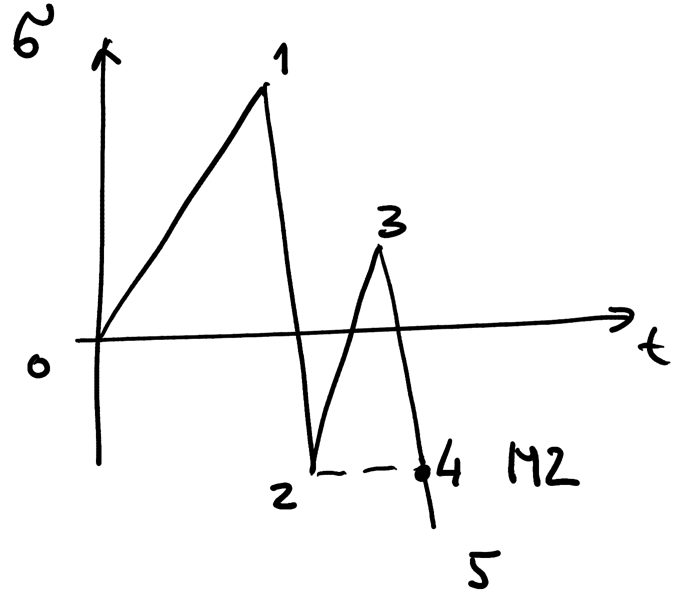
23 – M

34 – RO

M1 MEMORY 1

PO ZAKLJUČKU HISTEREZNE ZANKE (TOČKA 3), KI SE JE ZAČELA NA RO, SLEDI σ-ε POT PONOVNO RO.

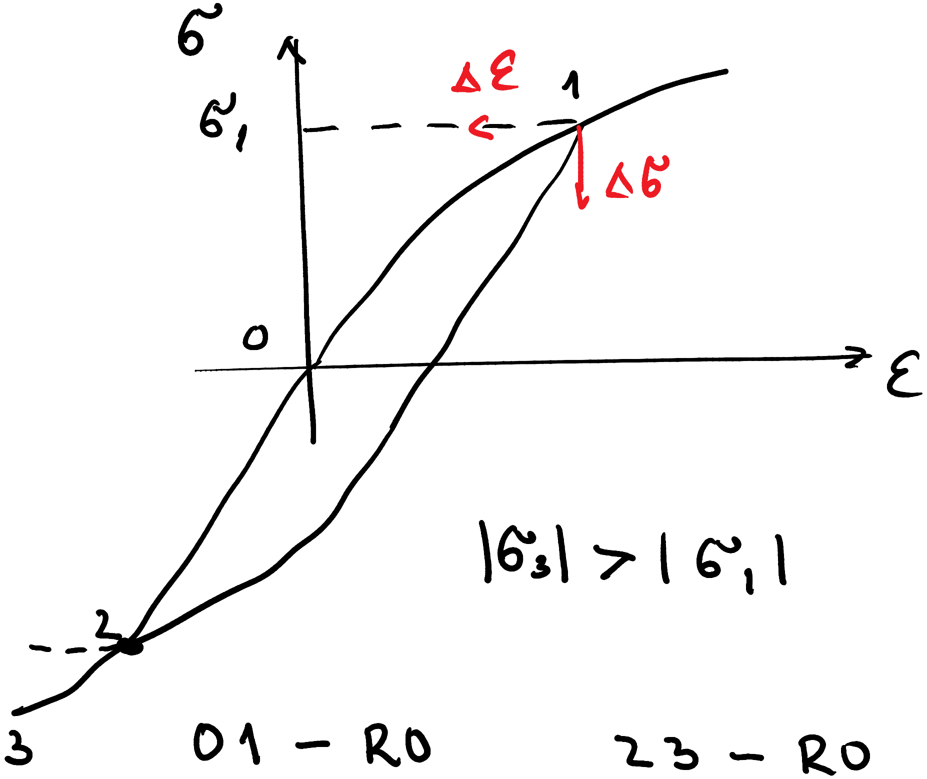




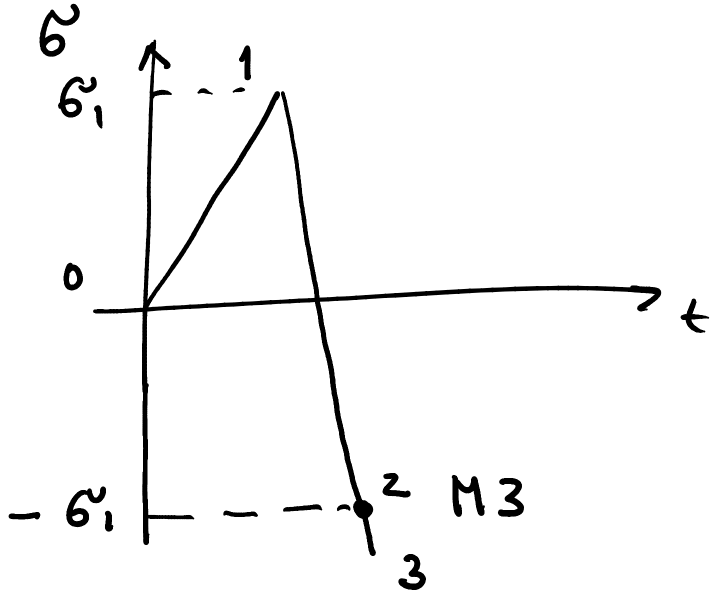
01 - RO ; 12 - M ; 23 - M ; 34 - M ; 45 - M

M2 - MEMORY 2

PO ZAKLJUČKU HISTEREZNE ZANKE (TOČKA 1), KI SE JE ZAČELA NA M_1 SLEDI σ-ε POT PONOVNO M.



$|\sigma_3| > |\sigma_1|$



01 – RO

12 – M

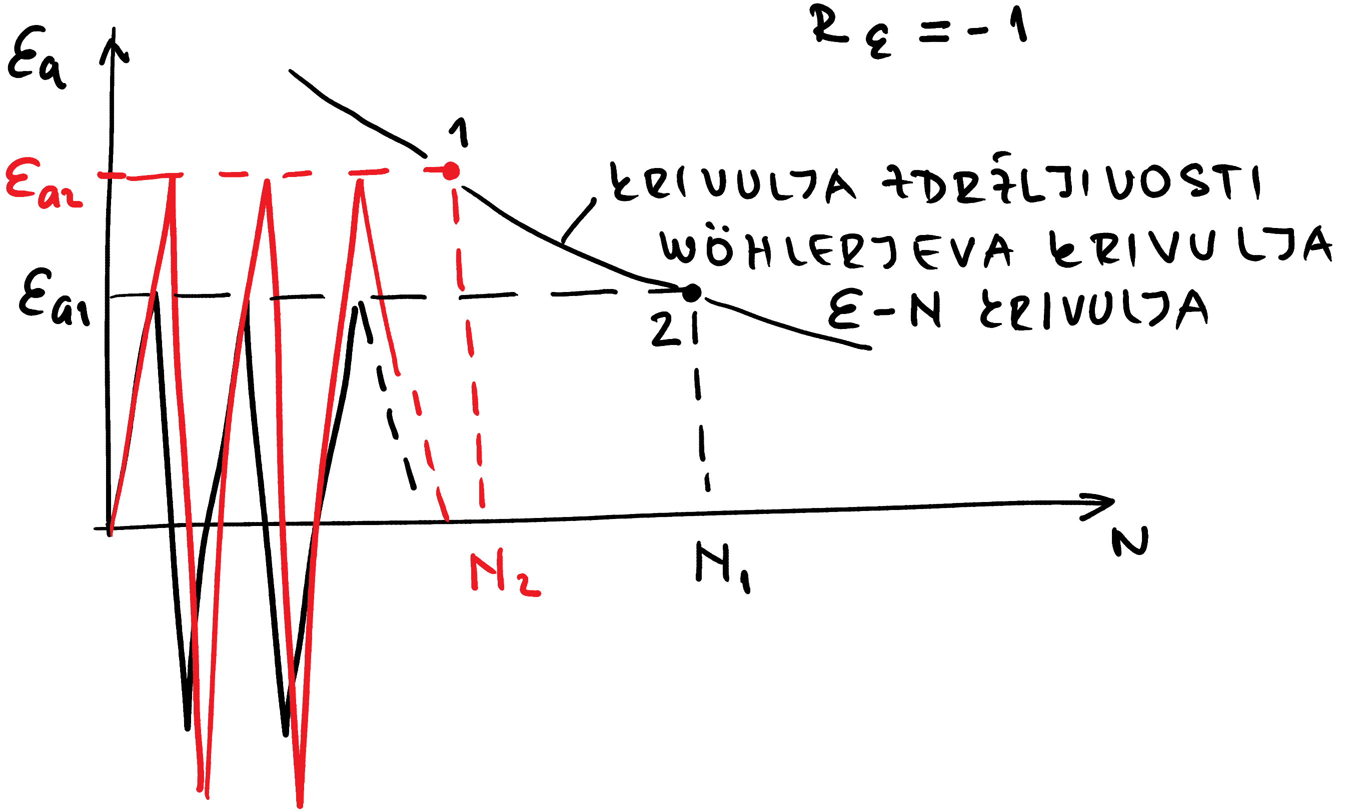
23 – RO

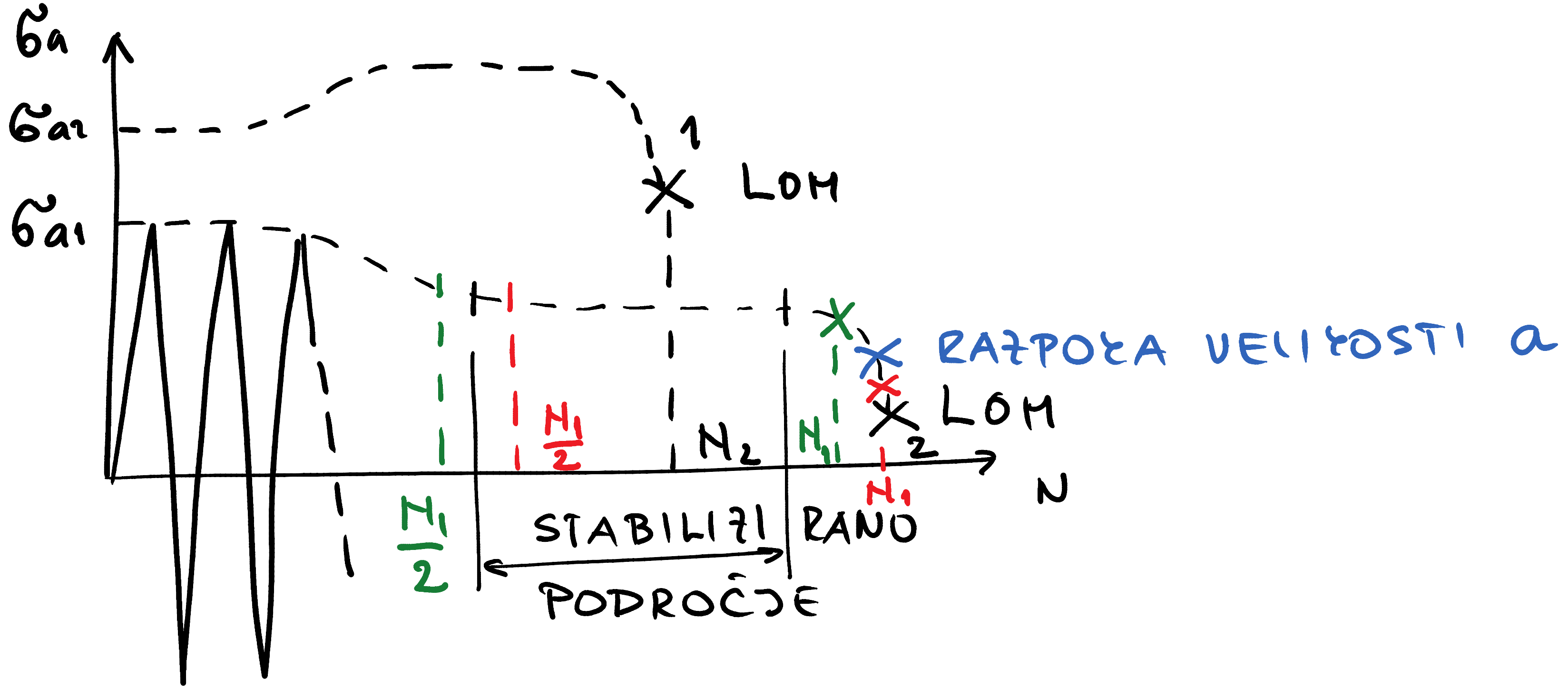
M3 MEMORY 3

KO PRESEŽEMO U NASPROTI LEŽEČEM KUADRANTU DO TEDAJ MAKSIMALNO ABSOLUTNO NAPETOST, SLEDI σ-ε POT PONOVNO RO.

KRITIČNA POŠKODBA PRI MALOCIKLIČNEM UTRUJANJU

$R_\varepsilon = -1$





KRITIČNA POŠKODBA JE LAHKO:

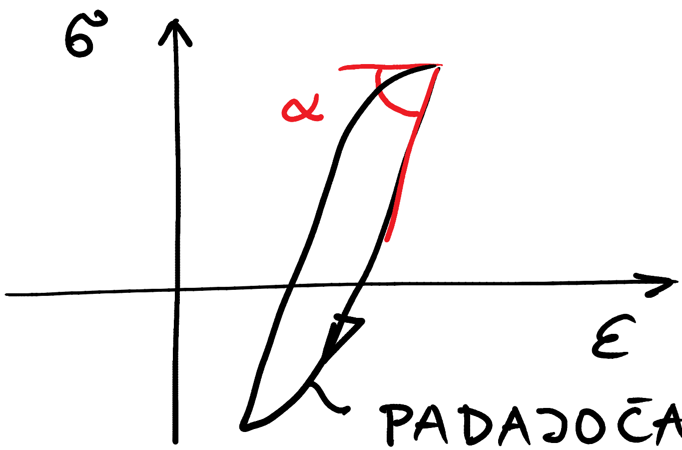
- LOM X
- RAZPOKA DOLOČENE VELIKOSTI a X
- PADEC NAPETOSTI δσ ZA DOLOČEN ODSTOTEK X
- PADEC MODULA ELASTIČNOSTI δE ZA DOLOČEN % X

$$\delta\sigma = \frac{\sigma_a(N_1/2) - \sigma_a(N_1)}{\sigma_a(N_1/2)} \cdot 100 \geq 5\%$$ POMENI, DA

JE NASTOPILA KRITIČNA POŠKODBA

$$\delta E = \frac{E(N=1) - E(N_1)}{E(N=1)} \cdot 100 \geq 10\%$$ POMENI, DA

JE NASTOPILA KRITIČNA POŠKODBA

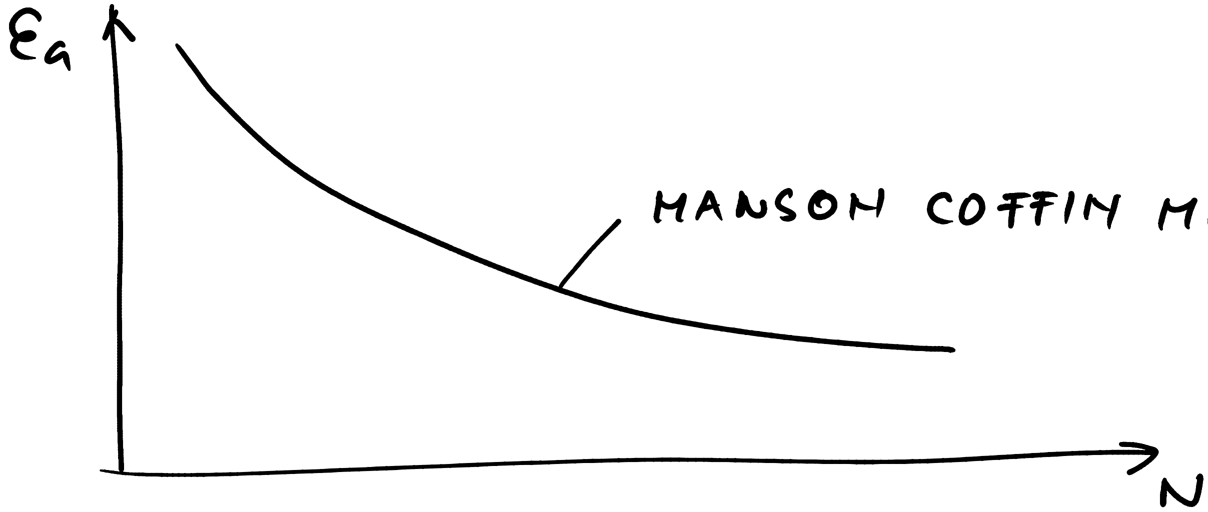


$E(N) = \tan\alpha$

MODUL ELASTIČNOSTI MERIMO U NATEZNEM DELU PADAJOČE VEJE HISTEREZNE ZANKE.

STABILIZIRANA HISTEREZNA ZANKA JE VEDNO PRI $N_1/2$ IN $N_2/2$

ANALITIČEN POPIS ε-N KRIVULJE



$$\varepsilon_a = \underbrace{\frac{\sigma_f'}{E}(2N)^b}_{\substack{\varepsilon_{a,e} \\ \text{ELASTIČNA}}} + \underbrace{\varepsilon_f'(2N)^c}_{\substack{\varepsilon_{a,p} \\ \text{PLASTIČNA}}}$$

KOMPATIBILNOSTNI ENAČBI

$$\varepsilon_a = \varepsilon_{a,e} + \varepsilon_{a,p} = \frac{\sigma_a}{E} + \left(\frac{\sigma_a}{K'}\right)^{\frac{1}{n'}}$$

$$\varepsilon_a = \frac{\sigma_f'}{E}(2N)^b + \varepsilon_f'(2N)^c = \varepsilon_{a,e} + \varepsilon_{a,p}$$

$$\frac{\sigma_a}{\cancel{E}} = \frac{\sigma_f'}{\cancel{E}}(2N)^b \rightarrow 2N = \left(\frac{\sigma_a}{\sigma_f'}\right)^{\frac{1}{b}}$$

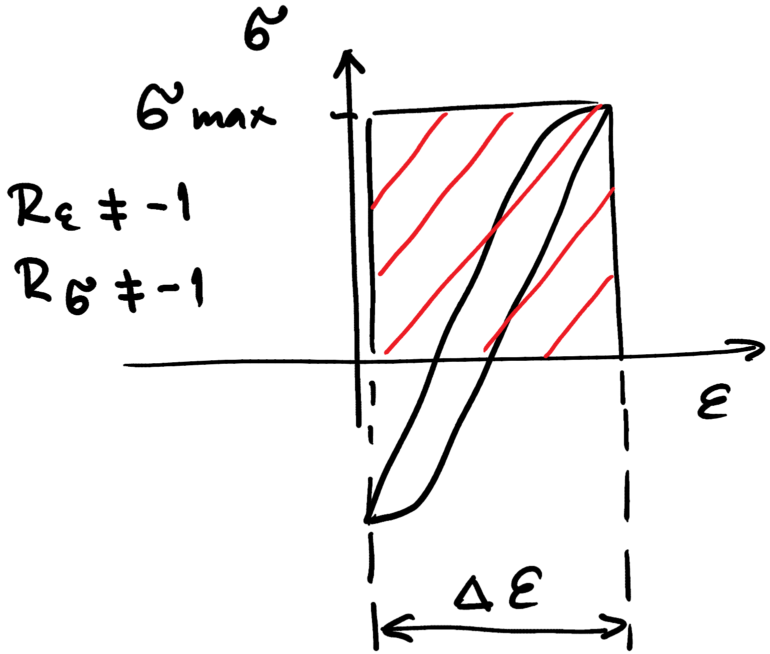
$$\left(\frac{\sigma_a}{K'}\right)^{\frac{1}{n'}} = \varepsilon_f'(2N)^c = \varepsilon_f'\left(\frac{\sigma_a}{\sigma_f'}\right)^{\frac{c}{b}} = \left(\frac{\sigma_a}{\sigma_f' \, \varepsilon_f'^{-\frac{b}{c}}}\right)^{\frac{c}{b}}$$

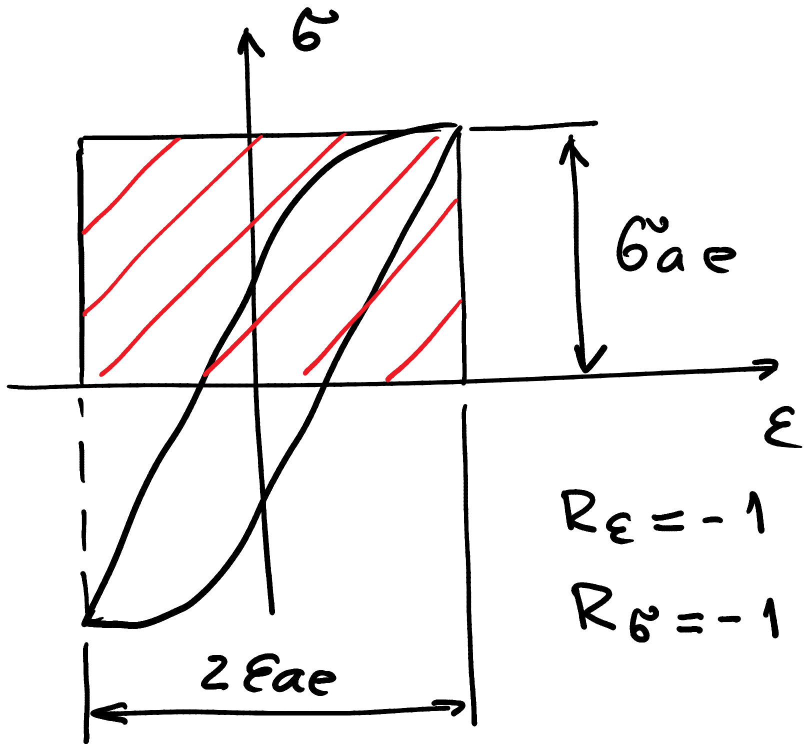
$$\frac{1}{n'} = \frac{c}{b} \rightarrow n' = \frac{b}{c}$$

$$K' = \sigma_f' \, \varepsilon_f'^{-\frac{b}{c}}$$

VPLIV SREDNJEGA NIVOJA OBREMENITVENIH CIKLOV

SMITH – WATSON – TOPPER PRAVILO





$$\Delta \varepsilon = 2\varepsilon_a$$

$$W = \sigma_{max} \cdot \Delta \varepsilon$$

$$W_e = \sigma_{ae} \, 2\varepsilon_{ae}$$

$$W = W_e$$

$$\sigma_{max}\,\varepsilon_a \cancel{\tfrac{1}{2}} = \sigma_{ae}\,\varepsilon_{ae} \cancel{\tfrac{1}{2}}$$

$$\sigma_{max}\,\varepsilon_a = \sigma_{ae}\left(\underbrace{\frac{\sigma_f'}{E}(2N)^b}_{\varepsilon_{ae,e}} + \varepsilon_f'(2N)^c \right)$$

$$\varepsilon_{ae} = \underbrace{\frac{\sigma_{ae}}{E}}_{\varepsilon_{ae,e}} + \left(\frac{\sigma_{ae}}{K'}\right)^{\frac{1}{n'}}$$

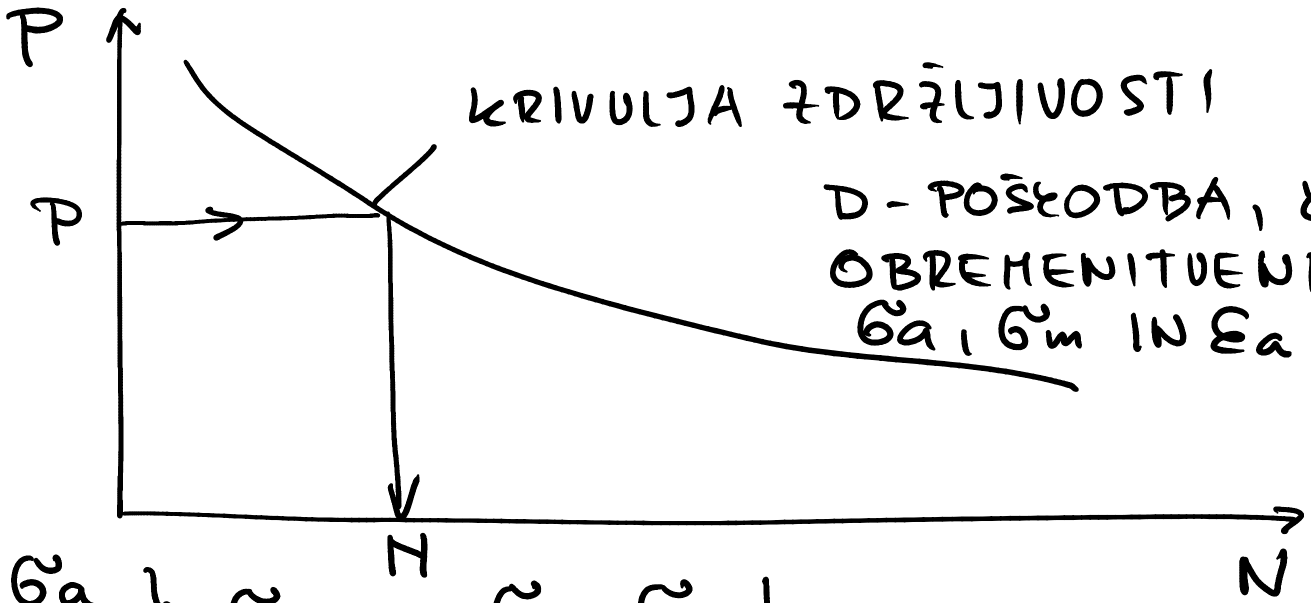
$$\frac{\sigma_{ae}}{\cancel{E}} = \varepsilon_{ae,e} = \frac{\sigma_f'}{\cancel{E}}(2N)^b$$

$$\sigma_{max}\,\varepsilon_a = \sigma_f'(2N)^b\left(\frac{\sigma_f'}{E}(2N)^b + \varepsilon_f'(2N)^c \right) \Big| \cdot E$$

$$\sigma_{max}\,\varepsilon_a\,E = \sigma_f'^{\,2}(2N)^{2b} + \sigma_f'\,\varepsilon_f'\,E\,(2N)^{b+c}$$

$$P = \sqrt{\sigma_{max}\, \varepsilon_a\, E}$$ POŠKODBENI PARAMETER

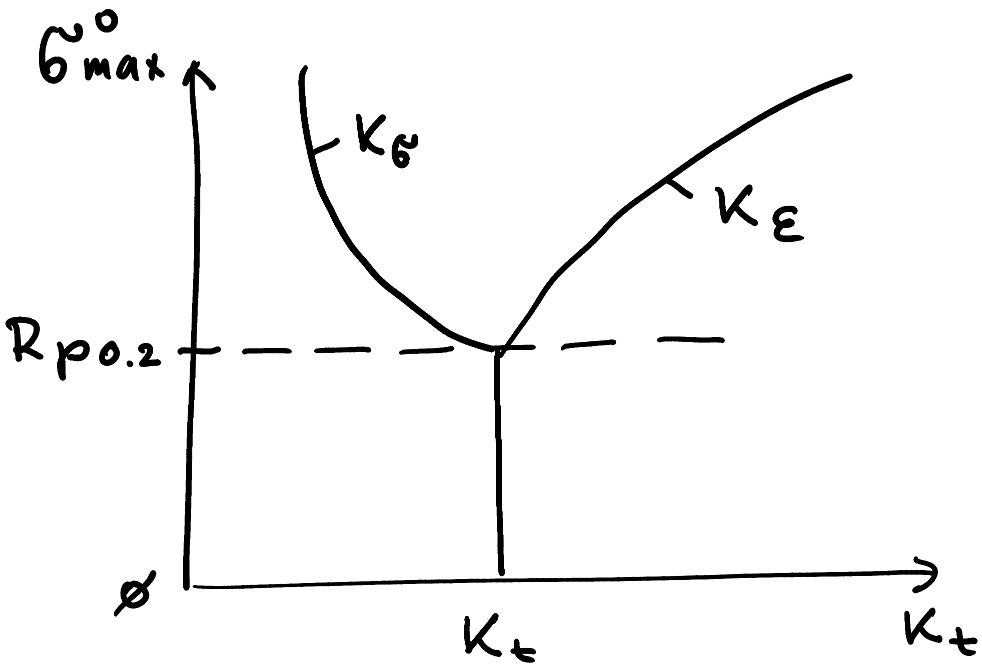
$$P = \sqrt{\sigma_f'^2 (2N)^{2b} + \sigma_f' \varepsilon_f' E (2N)^{b+c}}$$



D - POŠKODBA, KI JO POVZROČI OBREMENITVENI CIKEL Z σ_a, σ_m IN ε_a

$$\left.\begin{matrix} \left.\begin{matrix}\sigma_a \\ \sigma_m\end{matrix}\right\} \to \sigma_{max} = \sigma_a + \sigma_m \\ \varepsilon_a, E \end{matrix}\right\} \to P \to D = \frac{1}{N}$$

OBLIKOVNA ŠTEVILA



$$K_t = \frac{\sigma^{O}_{max}}{\bar{\sigma}}$$

$$K_\sigma = \frac{\sigma^{D}_{max}}{\bar{\sigma}}$$

$$K_\varepsilon = \frac{\varepsilon^{D}_{max}}{\bar{\varepsilon}}$$

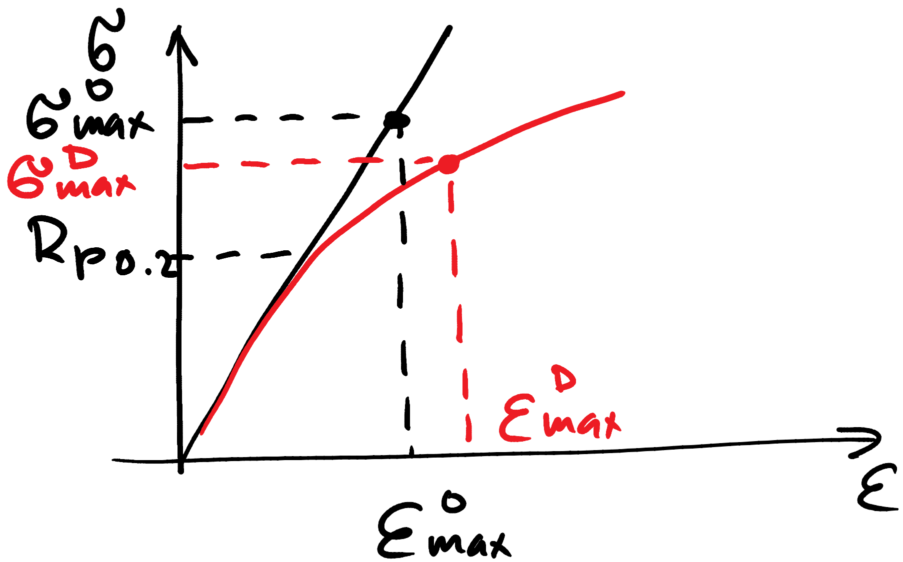
$\bar{\sigma}$ – IMENSKA NAPETOST

$\bar{\varepsilon}$ – IMENSKA SPECIFIČNA DEFORMACIJA

O – OCENJENA NAPETOST
SE NANAŠA NA ELASTIČNI MATERIALNI MODEL V MKE

D – DEJANSKA NAPETOST
SE NANAŠA NA DEJANSKI MATERIALNI MODEL

NEUBERJEVA APROKSIMACIJSKA FORMULA



$$\sigma^{0}_{max}\,\varepsilon^{0}_{max} = \sigma^{D}_{max}\,\varepsilon^{D}_{max}$$

NEUBERJEVA HIPOTEZA

$$\varepsilon^{0}_{max} = \frac{\sigma^{0}_{max}}{E}$$

$$\frac{\left(\sigma^{0}_{max}\right)^2}{E} = \sigma^{D}_{max}\,\varepsilon^{D}_{max}$$

$$\varepsilon^{D}_{max} = \frac{\sigma^{D}_{max}}{E}\left(\frac{\sigma^{0}_{max}}{\sigma^{D}_{max}}\right)^2$$

$$\varepsilon^{D}_{max} \rightarrow \varepsilon$$

$$\sigma^{D}_{max} \rightarrow \sigma$$

$$\sigma^{0}_{max} \rightarrow \sigma_e$$ – ELASTIČNA MEJE

$$\varepsilon = \frac{\sigma}{E}\left(\frac{\sigma_e}{\sigma}\right)^2$$

$$\varepsilon = \frac{\sigma}{E} + \left(\frac{\sigma}{K'}\right)^{\frac{1}{n'}}$$

REŠIMO Z NEWTON RHAPSON METODO

NEUBERJEVA POSPLOŠENA APROKSIMACIJSKA FORMULA

$$K_t^2 = K_\sigma K_\varepsilon$$

$$\left(\frac{\sigma^0_{max}}{\bar{\sigma}}\right)^2 = \frac{\sigma^D_{max}}{\bar{\sigma}} \; \frac{\varepsilon^D_{max}}{\bar{\varepsilon}}$$

$$\varepsilon^D_{max} = \frac{\sigma^D_{max}}{E} \left(\frac{\sigma^0_{max}}{\sigma^D_{max}}\right)^2 \frac{\bar{\varepsilon}}{\bar{\sigma}/E}$$

$$\varepsilon^D_{max} \to \varepsilon$$

$$\sigma^D_{max} \to \sigma$$

$$\sigma^0_{max} \to \sigma_e$$

$$\varepsilon = \frac{\sigma}{E} \left(\frac{\sigma_e}{\sigma}\right)^2 \frac{\bar{\varepsilon}}{\bar{\sigma}/E}$$

$$\varepsilon = \frac{\sigma}{E} + \left(\frac{\sigma}{K'}\right)^{\frac{1}{n'}}$$

$$\bar{\varepsilon} = \frac{\bar{\sigma}}{E} + \left(\frac{\bar{\sigma}}{K'}\right)^{\frac{1}{n'}}$$

$$\bar{\sigma} < R_{p0.2} \to \frac{\bar{\varepsilon}}{\bar{\sigma}/E} = 1$$

$$\bar{\sigma} \geq R_{p0.2} \to \frac{\bar{\varepsilon}}{\bar{\sigma}/E} > 1$$