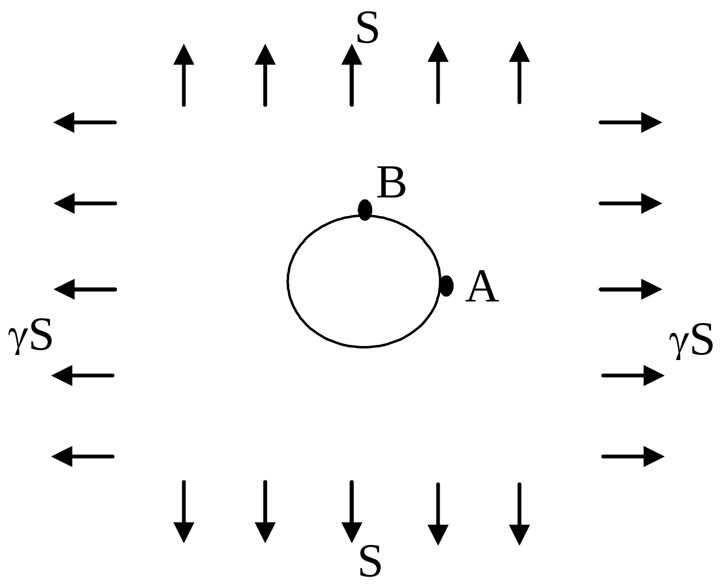
Exercises

Fatigue Analysis Course at TMC (13 & 27 september 2019)

Exercise

- Circular hole in biaxial stress field
  - γ=0.5
  - Calculate K_t at A



- Solution
  - "Vertical" stresses

$$\sigma_A = 3S \qquad \sigma_B = -S$$

  - "Horizontal" stresses

$$\sigma_B = 3\gamma S = 1.5S \qquad \sigma_A = -\gamma S = -0.5S$$

  - Location A

$$\sigma_A = 3S - 0.5S = 2.5S \quad \Rightarrow \quad K_t = 2.5$$

Exercise

a) What is the stress concentration factor of a circular hole (D = 11.6 mm) in an infinite sheet?

- $K_t = 3$

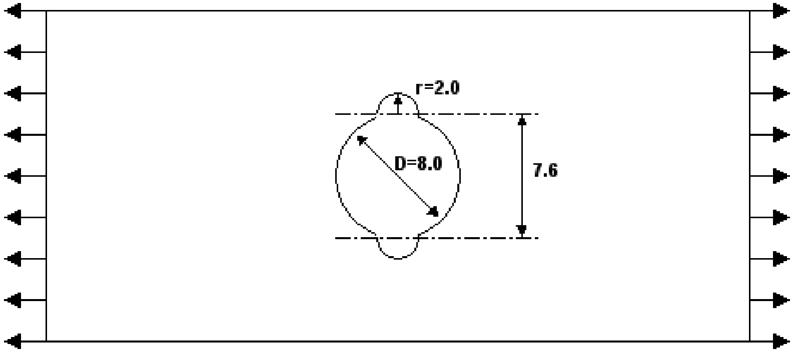
b) Make an estimation of the K_t value of this notch for the case the notch is in a finite sheet with width of 40mm. Use the expression for the K_t in a finite width sheet with a circular hole according to Heywood:

$$K_t = 2 + \left(1 - \frac{d}{W}\right)^3 = 2 + \left(1 - \frac{11.6}{40}\right)^3 = 2.4$$

c) Consider a specimen with notch in an infinite sheet as in the figure below. What is the stress concentration factor for that notch?

$$K_t = 1 + 2\sqrt{\frac{a}{\rho}}$$

$$K_t = 1 + 2\sqrt{\frac{5.8}{2}} = 4.4$$

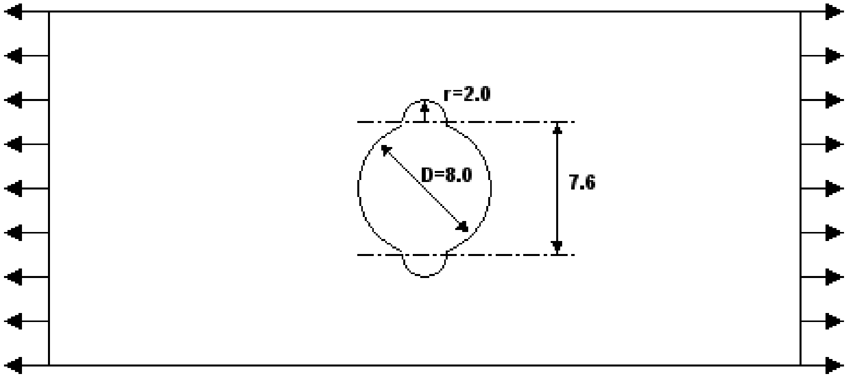


Exercise

d) Now assume a sheet width of 40 mm. Estimate the K_t value of the notch in the figure below based upon the previous questions

- Estimation using:
  - width effect for circular hole
  - notch, infinite sheet

$$K_t = \frac{2.36}{3} \cdot 4.41 = 3.46$$



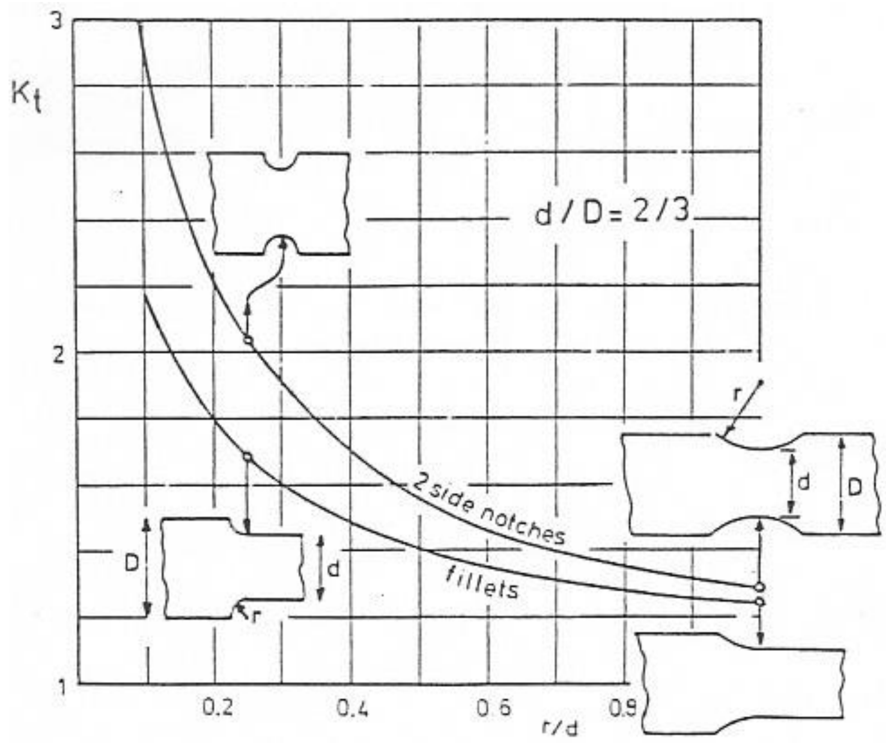
e) Calculate the theoretical (elastic) value of the maximum stress at the notch for case d), with:

- Tensile load: P = 24 kN
  Sheet thickness: t = 5 mm

$$\sigma_{\max} = K_t \frac{P}{(W-2a)\cdot t} = 3.46 \frac{24000}{(40-11.6)\cdot 5} = 585 MPa$$

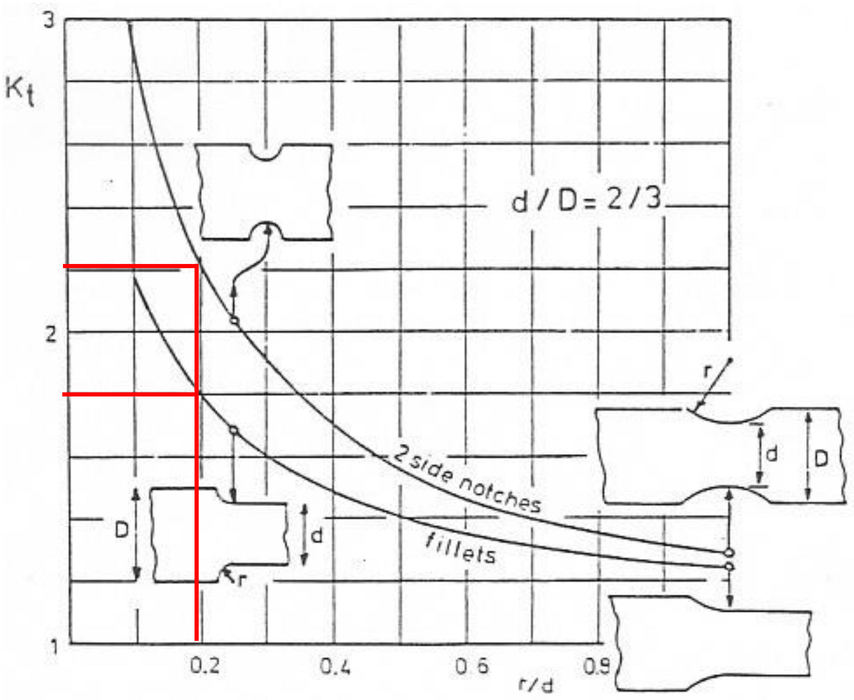
Exercise

Discuss using the diagram below what is better for fatigue: Letters forged <u>on</u> the surface of a component or letters forged <u>in</u> the surface.
The letters can be considered as either a protruding fillet or a rounded groove with r/d = 0.2.



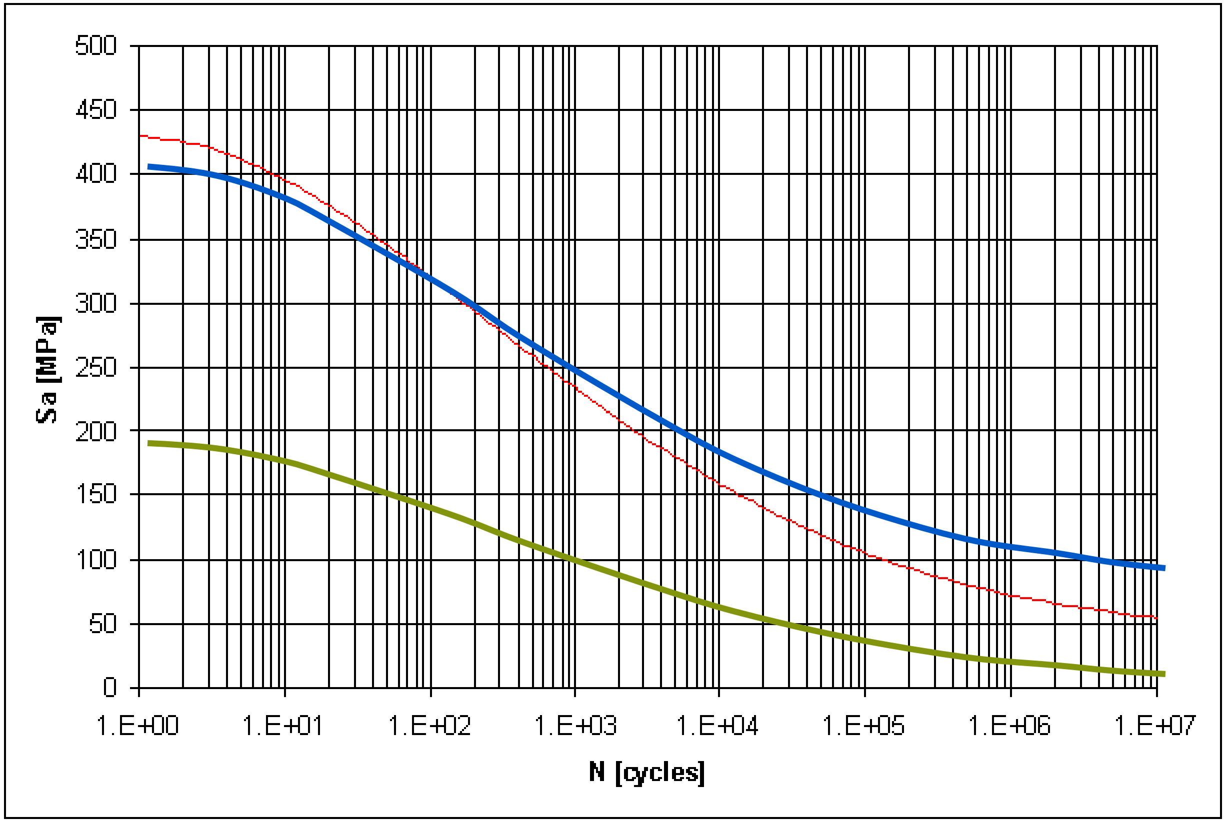
Exercise

- Letters forged on the surface: K_t = 1.8
- Letters forged in the surface: K_t = 2.2
- Letters forged on the surface lead to lower peak stresses and therefore a better fatigue life.



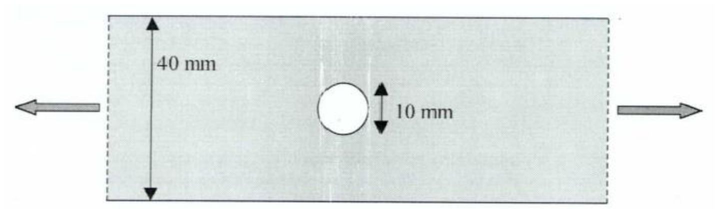
Exercise

- An S-N curve is given for 2024-T351, $K_t = 2.5$, $S_m = 0$ MPa. Make a sketch that indicates where the S-N curve would lie compared to the curve in the figure below for the following two cases:
  - 2024-T351, $K_t = 1$, $S_m = 0$ MPa
  - 2024-T351, $K_t = 2.5$, $R = 0$.



Exercise

- Estimate the fatigue limit for the strip with a central hole (Kt = 2.42) as shown in the figure. Use the Neuber notch sensitivity (why not Siebel?). The material is Al 7075-T6, R_m = 570 MPa.
  a) Fatigue limit for R=-1 (S_m = 0 MPa)
  b) Fatigue limit for R=0 using the Goodman relation



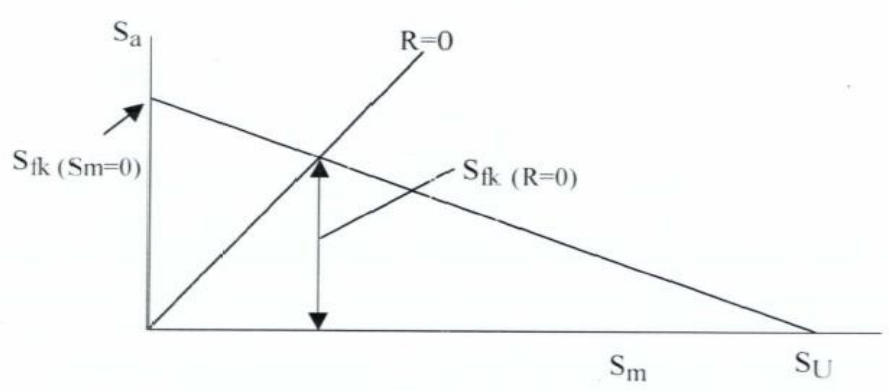
- S_f = 0.3*570 = 171 MPa for R=-1, un-notched
  (for aluminium: $S_f/R_m \approx 0.3$)
- Neuber notch sensitivity:

$$K_f = 1 + q \cdot (K_t - 1) \qquad q_{Neuber} = \frac{1}{1 + \sqrt{A/\rho}}$$

- A = 0.5; ρ = D/2 = 5; q = 0.76 $\Rightarrow$ K_f = 2.08
- $S_{fk(Sm=0)} = S_{f(Sm=0)} / K_f$ = 171/2.08 = 82 MPa

Exercise

- Because S_{fk} should be obtained for R = 0, the effect of the mean stress S_m should be accounted for. This is with the Goodman relation (brittle material).



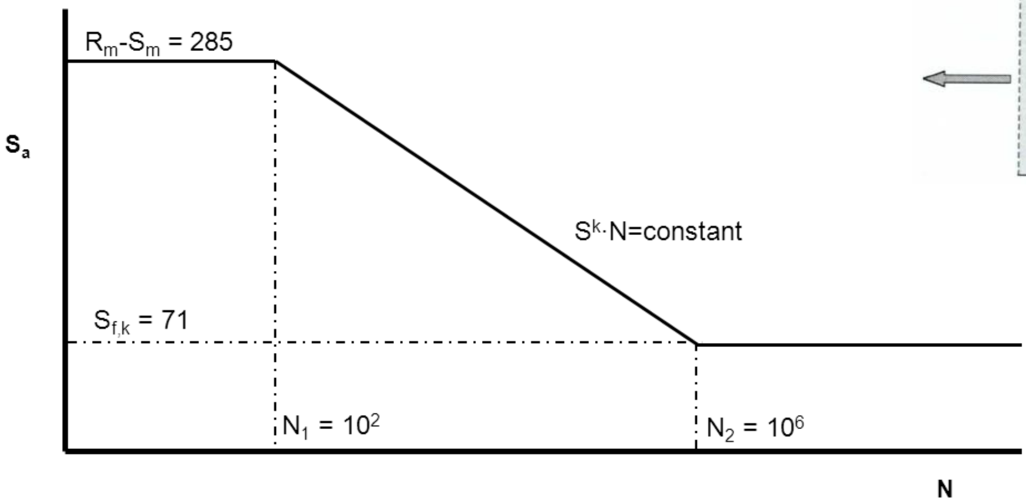
- Goodman relation:

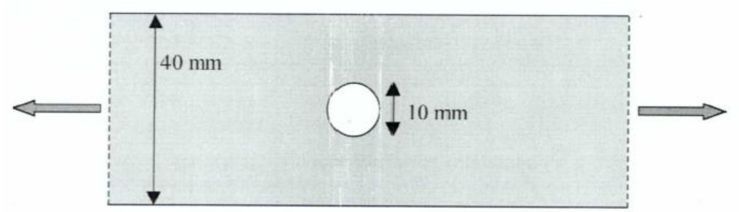
$$\frac{S_f}{\left(S_f\right)_{S_m=0}} = 1 - \left(\frac{S_m}{R_m}\right)$$

- R=0: $S_m = S_a$
- Intersection of lines for R=0 and Goodman gives:
- $S_{fk(R=-1)}$ = 82 MPa & R_m = 570 MPa $\Rightarrow$ $S_{fk(R=0)}$ = 71 MPa

Exercise

- Estimate the S-N curve for R=0 for the strip with a central hole (K_t = 2.42) as shown in the figure. The material is Al 7075-T6, R_m = 570 MPa.
  - From previous exercise: $S_{fk(R=0)}$ = 71 MPa





- Upper asymptote: $R_m = S_{max} = S_m + S_a \Rightarrow S_a = R_m - S_m$
  For R=0: $S_a = S_m \Rightarrow S_a = R_m - S_a \Rightarrow S_a = R_m/2 = 570/2 = 285$ MPa
- Lower asymptote: S_{fk} = 71 MPa