NOTCH STRESS CONCENTRATION (STATIC)

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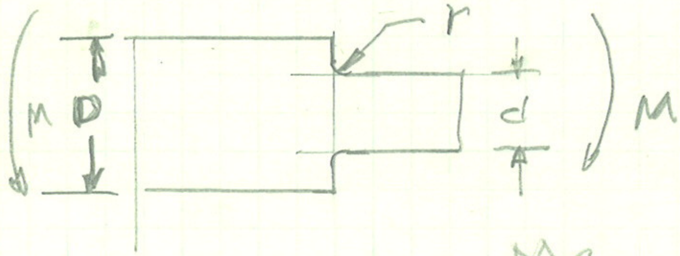
NOTCHES and changes in diameter of shafts cause stress concentrations.



The stress at the change in size is greater than the nominal stress

$$\sigma_{nom} = \frac{Mc}{I}$$

COMPUTE THE OUTER FIBER STRESS USING THE SMALLER d FOR THE CALCULATIONS

The max stress is computed using

$$\sigma_{max} = K_t \, \sigma_{nom}$$

K_t is computed from the equation

$$K_t = A\left(\frac{r}{d}\right)^b$$

where r = The radius of the fillet

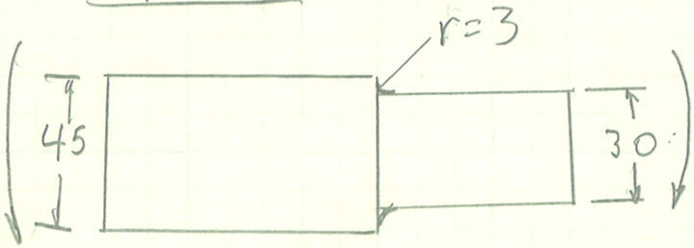
d = The smaller size of the shaft

A = A value from a table in Appendix C

b = Value from Appendix C

Please note that K_t is dimensionless

EXAMPLE



Dimensions in mm

$M = 1000$ N-M

$$\sigma_{nom} = \frac{Mc}{I}$$

$c = 15\text{mm} = .015 \text{ m}$

$D = 45\text{mm} = .045 \text{ m}$

$d = 30\,mm = .030\ m$

$$I = \frac{\pi d^4}{64} = \frac{\pi(.03)^4}{64} = 3.97 \times 10^{-8}$$

$$\sigma_{nom} = \frac{Mc}{I} = \frac{1000(.015)}{3.97 \times 10^{-8}} = 378\ MPa$$

$$K_t = A\left(\frac{r}{d}\right)^b$$

$r = 3\,mm = 0.003$

$b = -0.25759$

$A = 0.93836$

From Appendix C

$$K_t = .938\left(\frac{.003}{.03}\right)^{-.258}$$

$$K_t = 1.70$$

$$\sigma_{max} = K_t \sigma_{nom} = 1.70 \cdot 378 =$$

$$\underline{\sigma_{max} = 642\ MPa}$$

NOTCH SENSITIVITY (DYNAMIC LOADS)

Materials subject to varying loads are sensitive to stress concentrations. A notch or change in diameter of a shaft can cause stress concentrations that move the stresses above the yield point. If this is the case, the part may be subject to earlier fatigue failure.

Interestingly enough, as the notch radius approaches zero, the notch sensitivity of the material decreases and also approaches zero.

$$q = \frac{K_f - 1}{K_t - 1}$$

K_f: fatigue stress concentration factor

K_t: static stress concentration factor

K_t can be computed using the technique just demonstrated but we need to compute K_f for fatigue

static loading factor

Rewriting

$$K_f = 1 + q\left(K_t - 1\right)$$

where

from formulas or Table

$$q = \frac{1}{1 + \dfrac{\sqrt{a}}{\sqrt{r}}}$$

radius in inches

we can compute $\sqrt{a}$ with

Bending or axial (STEEL)

$$\sqrt{a} = 0.246 - 3.08(10^{-3})\,S_{ut} + 1.51(10^{-5})\,S_{ut}^2 - 2.67(10^{-8})\,S_{ut}^3$$

Torsion

$$\sqrt{a} = 0.190 - 2.51(10^{-3})\,S_{ut} + 1.35(10^{-5})\,S_{ut}^2 - 2.67(10^{-8})\,S_{ut}^3$$

S_{ut} must be expressed in kpsi

Note that you do not have to take the square root of a. It has already been done

After computing K_f use the formulas

$$\sigma = K_f\,\sigma_{nom}$$

$$\tau = K_{fs}\,\tau_{nom}$$

K_f and K_{fs} will be different.

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EXAMPLE

From the previous example compute the fatigue equivalent stresses.

$\sigma_{nom} = 378$ MPa
$r = 3$ mm
} Previous Results

Assume we are working steel

$S_{ut} = 130$ kpsi $= 896$ MPa

Using the equation.

$$\sqrt{a} = 0.246 - 3.08(10^{-3})S_{ut} + 1.51(10^{-5})S_{ut}^2 - 2.67(10^{-8})S_{ut}^3$$

$$\sqrt{a} = 0.246 - 3.08(10^{-3})130 + 1.51(10^{-5})130^2 - 2.67(10^{-8})S_{ut}^3$$

$$\sqrt{a} = 0.0421$$

Convert the radius to inches

$r = 3$ mm $= .12$ inches

$$q = \frac{1}{1 + \frac{.0421}{\sqrt{.12}}} = .8916$$

From the previous work

$$k_t = 1.69$$

so

$$k_f = 1 + .8916(1.69 - 1)$$

$$k_f = 1.615$$

Previously

$$\sigma_{nom} = 378 \text{ MPa}$$

$$\sigma = k_f \sigma_{nom} = (1.615)(378) = 610 \text{ MPa}$$

NOTE: If the material is ductile use k_f. If it is brittle, use k_t.

Local Yielding

If the materials is ductile and we have local yielding at a step or a notch, we must make further corrections.

1) No Yielding

$$K_f |\sigma_{max}| \le S_y$$

then

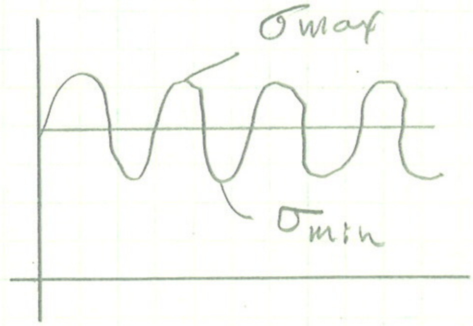
$$K_{fm} = K_f$$

2) Local Yielding

$$K_f |\sigma_{max}| > S_y$$

then

$$K_{fm} = \frac{S_y - K_f \sigma_a}{\sigma_m}$$



$$\sigma_{max} = \sigma_m + \sigma_a$$

$$\sigma_{min} = \sigma_m - \sigma_a$$

3) Large scale yielding

$$K_f |\sigma_{max} - \sigma_{min}| > 2S_y$$

$K_{fm} = 0$ <u>All hope is lost</u>

You should always try to avoid local yielding.