STRESS CONCENTRATION EXAMPLES

MET 4501

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ROAD MAP FOR THE STRESS-LIFE METHOD – FULLY REVERSED SIMPLE LOADING

1. Determine S_e' either from test data or

$$S_e' = \begin{cases} 0.5S_{ut} & S_{ut} \leq 200 \text{ kpsi } (1400 \text{ MPa}) \\ 100 \text{ kpsi} & S_{ut} > 200 \text{ kpsi} \\ 700 \text{ MPa} & S_{ut} > 1400 \text{ MPa} \end{cases} \qquad (6\text{–}10)$$

2. Modify S_e' to determine S_e.

$$S_e = k_a k_b k_c k_d k_e S_e' \qquad (6\text{–}17)$$

   a. Surface factor, k_a

$$k_a = aS_{ut}^b \qquad (6\text{–}18)$$

Table 6–2 Curve Fit Parameters for Surface Factor, Equation (6–18)

Surface Finish	Factor a		Exponent b
	S_{ut}, kpsi	S_{ut}, MPa	
Ground	1.21	1.38	−0.067
Machined or cold-drawn	2.00	3.04	−0.217
Hot-rolled	11.0	38.6	−0.650
As-forged	12.7	54.9	−0.758

b. Size factor, k_b

Rotating shaft. For bending or torsion,

$$k_b = \begin{cases} (d/0.3)^{-0.107} = 0.879d^{-0.107} & 0.3 \le d \le 2 \text{ in} \\ 0.91d^{-0.157} & 2 < d \le 10 \text{ in} \\ (d/7.62)^{-0.107} = 1.24d^{-0.107} & 7.62 \le d \le 51 \text{ mm} \\ 1.51d^{-0.157} & 51 < 254 \text{ mm} \end{cases} \qquad (6\text{–}19)$$

For axial,

$$k_b = 1 \qquad (6\text{–}20)$$

Nonrotating member. For bending, use Table 6–3 for d_e and substitute into Equation (6–19) for d.

c. Load factor, k_c

$$k_c = \begin{cases} 1 & \text{bending} \\ 0.85 & \text{axial} \\ 0.59 & \text{torsion} \end{cases} \qquad (6\text{–}25)$$

b. Temperature factor, k_d

$$S_T/S_{RT} = 0.98 + 3.5(10^{-4})T_F - 6.3(10^{-7})T_F^2 \qquad \text{(6–26)}$$

$$S_T/S_{RT} = 0.99 + 5.9(10^{-4})T_C - 2.1(10^{-6})T_C^2$$

Either use the ultimate strength from Equation (6–26) to estimate S_e at the operating temperature, with $k_d = 1$, or use the known S_e at room temperature with $k_d = S_T/S_{RT}$ from Equation (6–26).

c. Reliability factor, k_e

Table 6–4 Reliability Factor k_e Corresponding to 8 Percent Standard Deviation of the Endurance Limit

Reliability, %	Transformation Variate z_a	Reliability Factor k_e
50	0	1.000
90	1.288	0.897
95	1.645	0.868
99	2.326	0.814
99.9	3.091	0.753
99.99	3.719	0.702

ROAD MAP FOR THE STRESS-LIFE METHOD – FULLY REVERSED SIMPLE LOADING

3. Determine fatigue stress-concentration factor, K_f or K_{fs}.

3 Determine fatigue stress-concentration factor, K_f or K_{fs}. First, find K_t or K_{ts} from Table A–15.

$$K_f = 1 + q(K_t - 1) \qquad \text{or} \qquad K_{fs} = 1 + q_s(K_{ts} - 1) \tag{6–32}$$

Obtain q from either Figure 6–26 or 6–27.

Alternatively,

$$K_f = 1 + \frac{K_t - 1}{1 + \sqrt{a/r}} \tag{6–34}$$

Bending or axial:

$$\sqrt{a} = 0.246 - 3.08(10^{-3})S_{ut} + 1.51(10^{-5})S_{ut}^2 - 2.67(10^{-8})S_{ut}^3 \quad 50 \le S_{ut} \le 250 \text{ kpsi}$$

$$\sqrt{a} = 1.24 - 2.25(10^{-3})S_{ut} + 1.60(10^{-6})S_{ut}^2 - 4.11(10^{-10})S_{ut}^3 \quad 340 \le S_{ut} \le 1700 \text{ MPa} \tag{6–35}$$

Torsion:

$$\sqrt{a} = 0.190 - 2.51(10^{-3})S_{ut} + 1.35(10^{-5})S_{ut}^2 - 2.67(10^{-8})S_{ut}^3 \quad 50 \le S_{ut} \le 220 \text{ kpsi}$$

$$\sqrt{a} = 0.958 - 1.83(10^{-3})S_{ut} + 1.43(10^{-6})S_{ut}^2 - 4.11(10^{-10})S_{ut}^3 \quad 340 \le S_{ut} \le 1500 \text{ MPa} \tag{6–36}$$

ROAD MAP FOR THE STRESS-LIFE METHOD – FULLY REVERSED SIMPLE LOADING

4. Apply K_f to the nominal completely reversed stress, $\sigma_a = K_f \sigma_{a0}$.
5. Determine f from Figure 6-23 or Equation (6-11). For S_{ut} lower than the range, use $f = 0.9$.

$$f = 1.06 - 2.8(10^{-3})S_{ut} + 6.9(10^{-6})S_{ut}^2 \qquad 70 < S_{ut} < 200 \text{ kpsi}$$
$$f = 1.06 - 4.1(10^{-4})S_{ut} + 1.5(10^{-7})S_{ut}^2 \qquad 500 < S_{ut} < 1400 \text{ MPa} \tag{6–11}$$

$$a = (f S_{ut})^2 / S_e \tag{6–13}$$

$$b = -[\log (f S_{ut}/S_e)]/3 \tag{6–14}$$

6. Determine fatigue strength S_f at N cycles, or, N cycles to failure at a reversing stress σ_{ar}.

(*Note:* This only applies to purely reversing stresses where $\sigma_m = 0$.)

$$S_f = aN^b \tag{6–12}$$

$$N = (\sigma_{ar}/a)^{1/b} \tag{6–15}$$

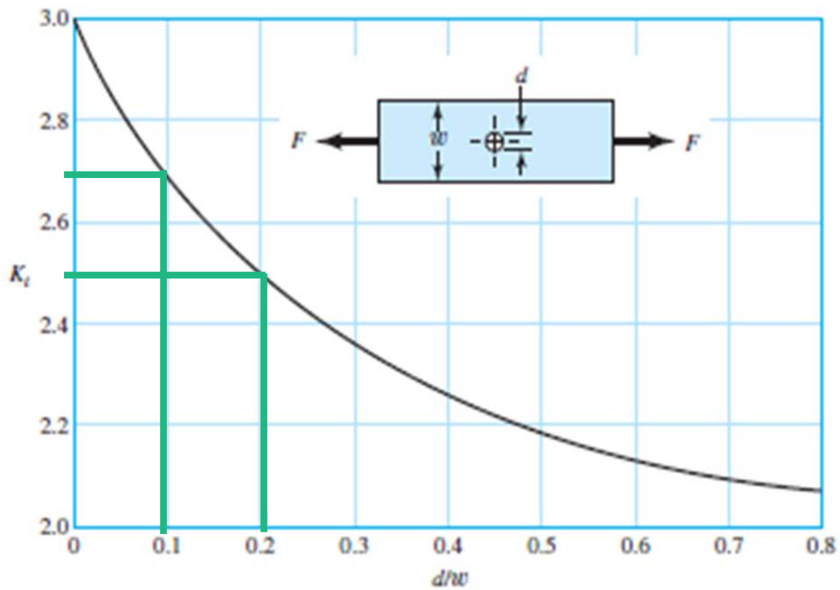
EXAMPLE 1

Table A–15

Charts of Theoretical Stress-Concentration Factors K_t^*

Figure A–15–1

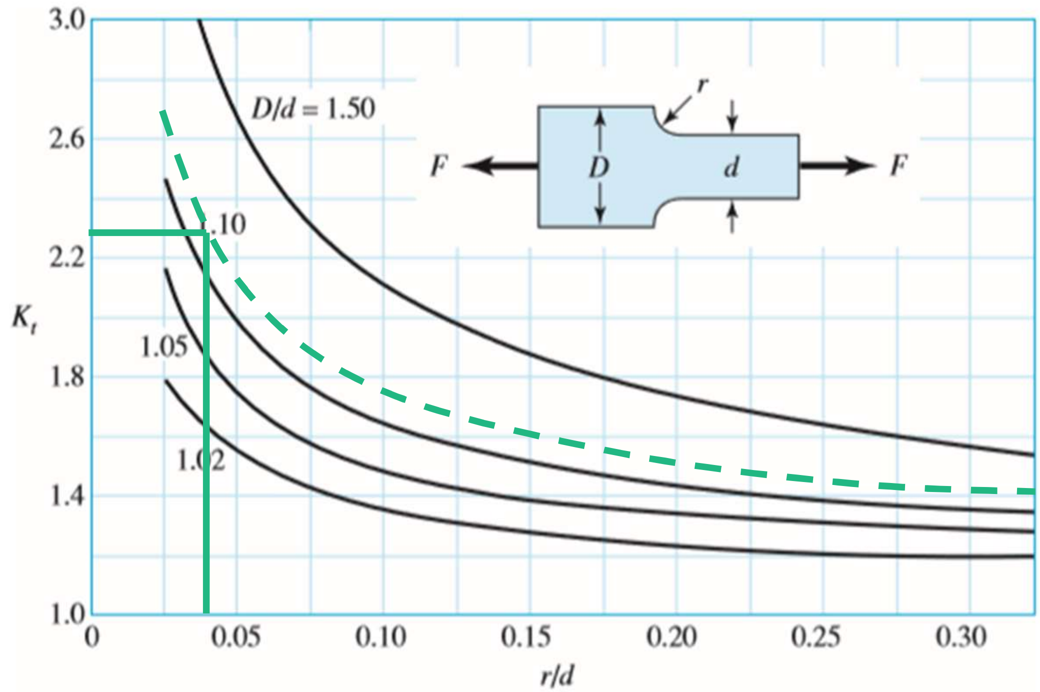
Bar in tension or simple compression with a transverse hole. $\sigma_0 = F/A$, where $A = (w - d)t$ and t is the thickness.



EXAMPLE 1

Figure A–15–5

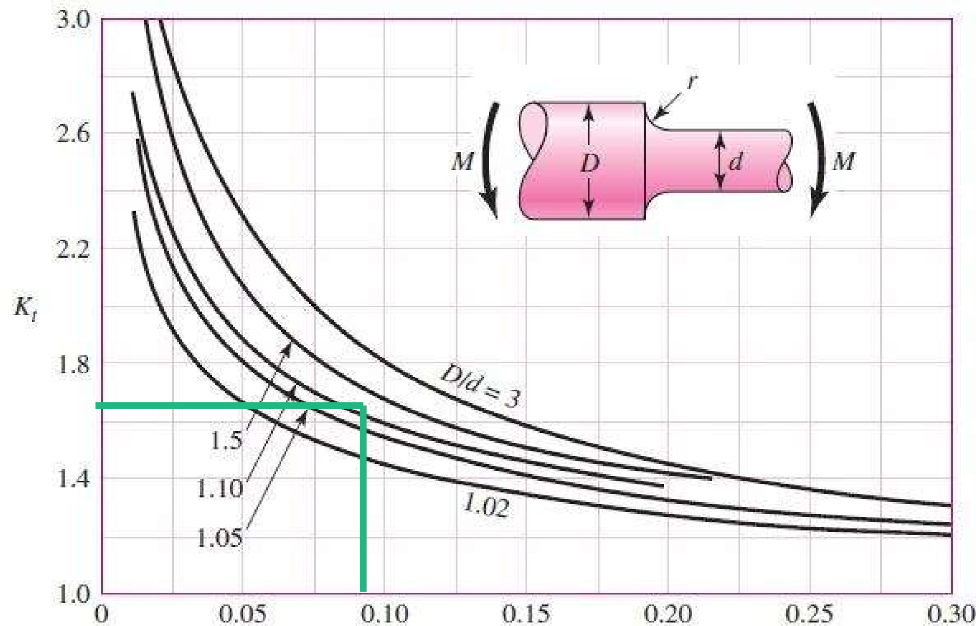
Rectangular filleted bar in tension or simple compression. $\sigma_0 = F/A$, where $A = dt$ and t is the thickness.



EXAMPLE 2

Figure A–15–9

Round shaft with shoulder fillet in bending. $\sigma_0 = Mc/I$, where $c = d/2$ and $I = \pi d^4/64$.



EXAMPLE 2

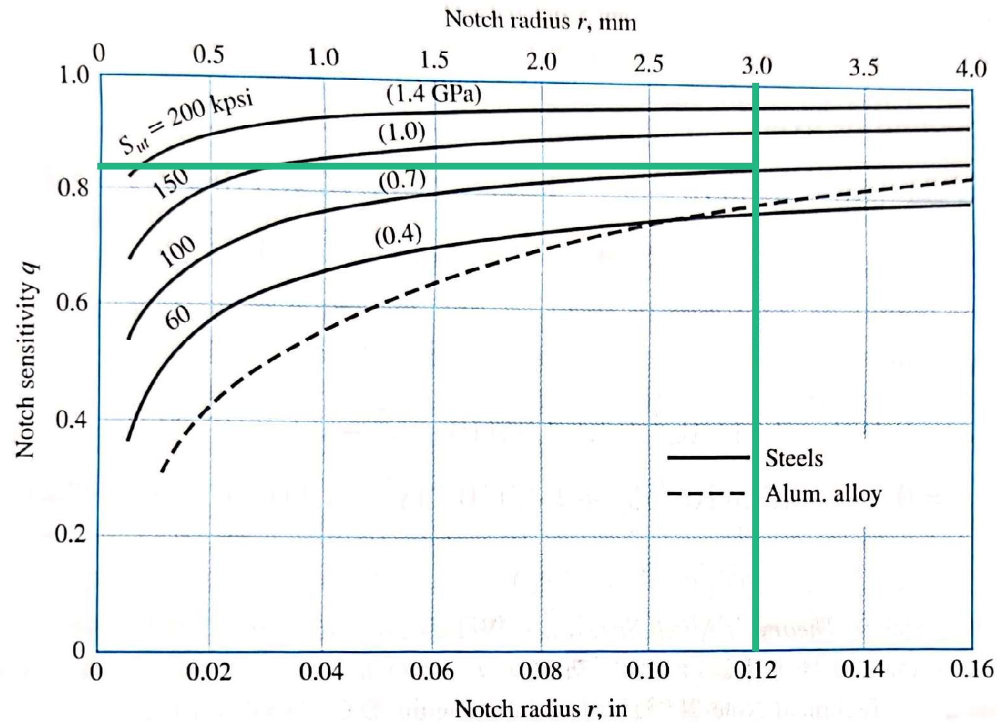


Figure 6–26

Notch-sensitivity charts for steels and UNS A92024-T wrought aluminum alloys subjected to reversed bending or reversed axial loads. For larger notch radii, use the values of q corresponding to the $r = 0.16$-in (4-mm) ordinate. Source: Sines, George and Waisman, J. L. (eds.), *Metal Fatigue*, McGraw-Hill, New York, 1969.

EXAMPLE 3

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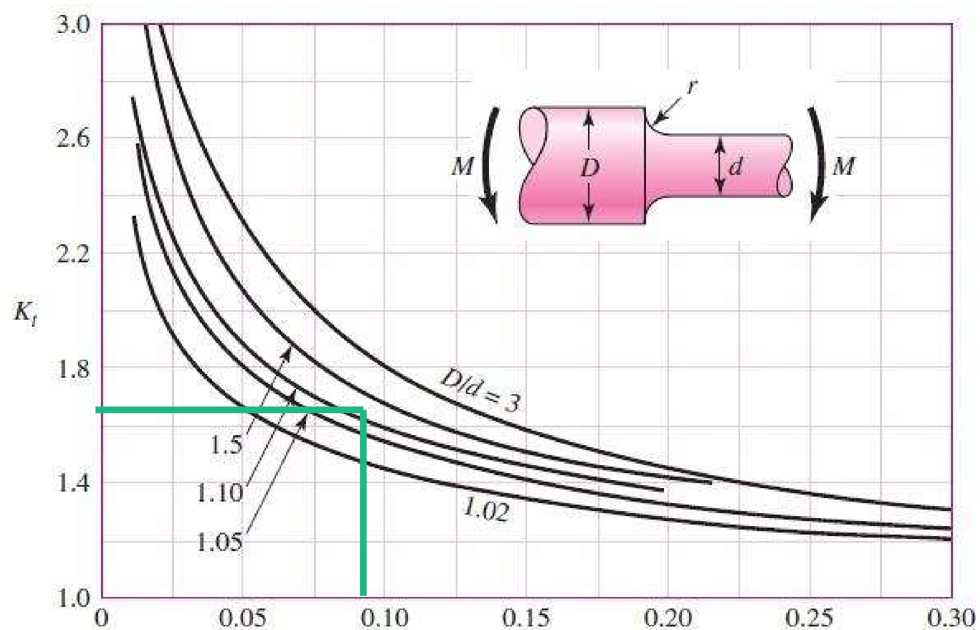

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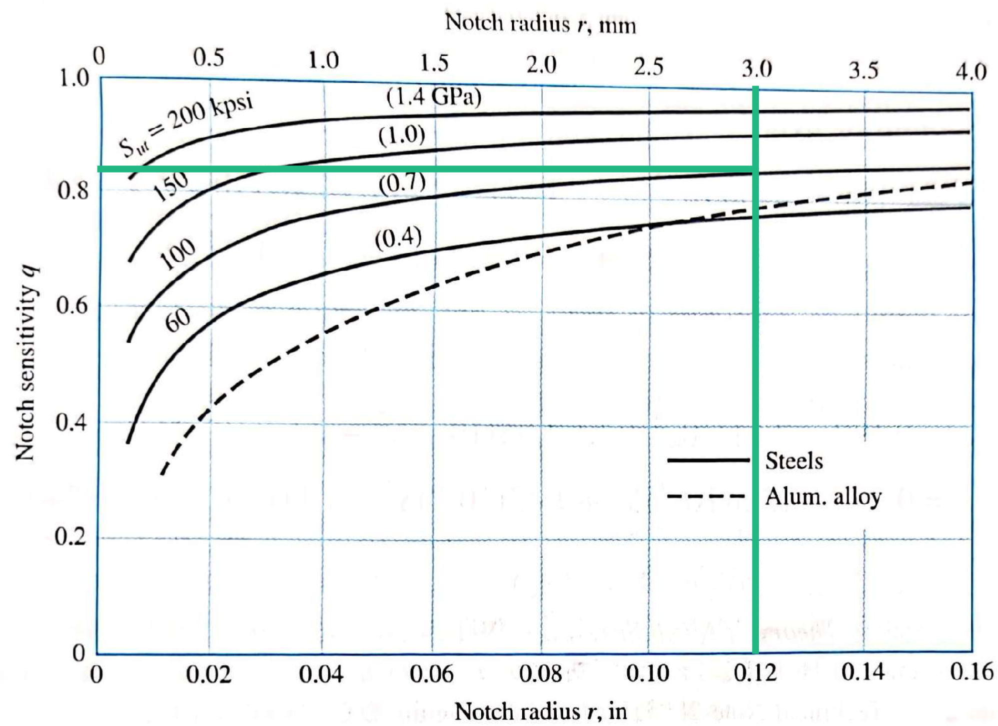

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