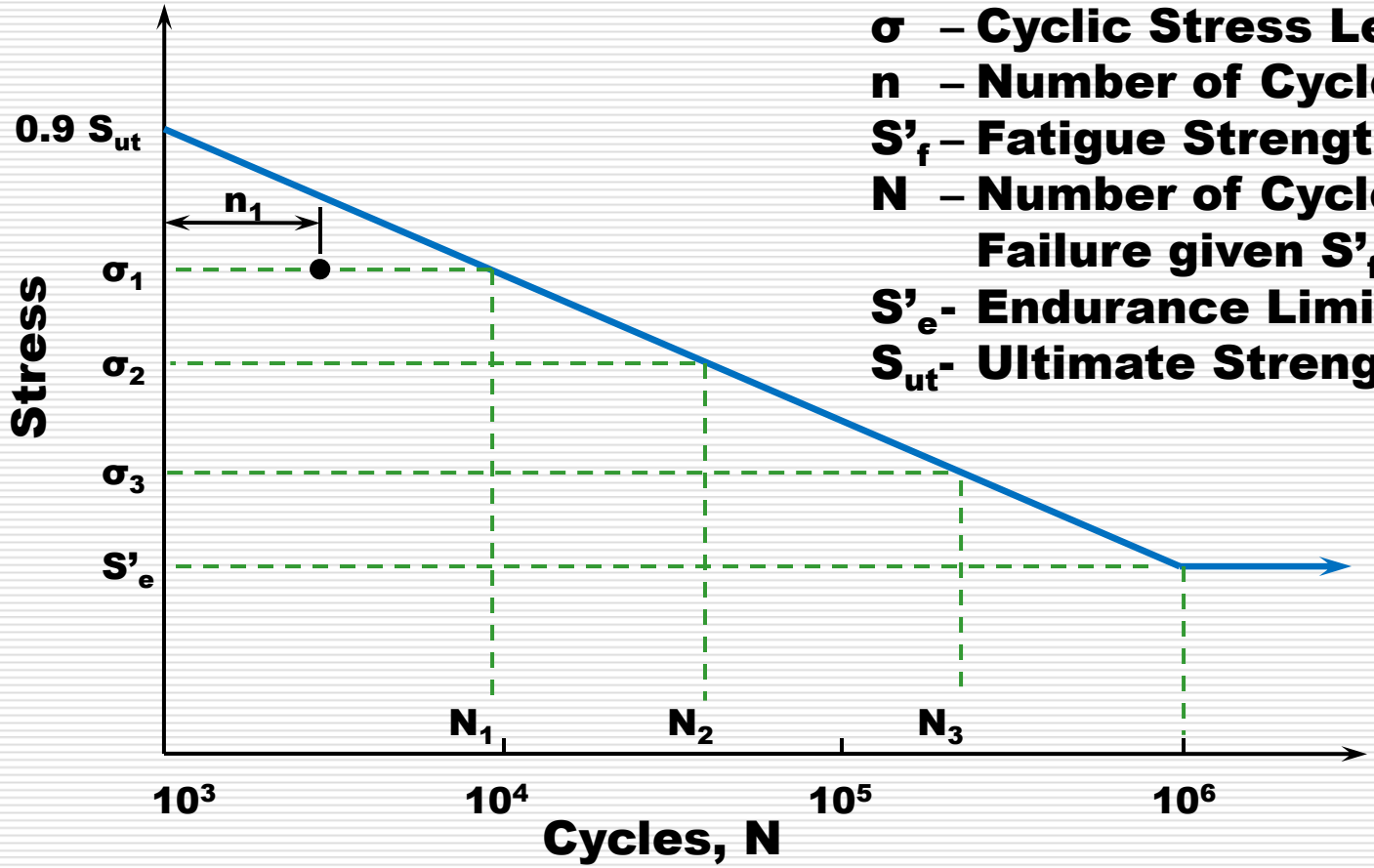
FATIGUE

Endurance Limit Modifying Factors

Cumulative Damage
Log-Log Plot For Test Sample



σ – Cyclic Stress Level
n – Number of Cycles
S'_f – Fatigue Strength at N
N – Number of Cycles to Failure given S'_f
S'_e - Endurance Limit
S_{ut} - Ultimate Strength

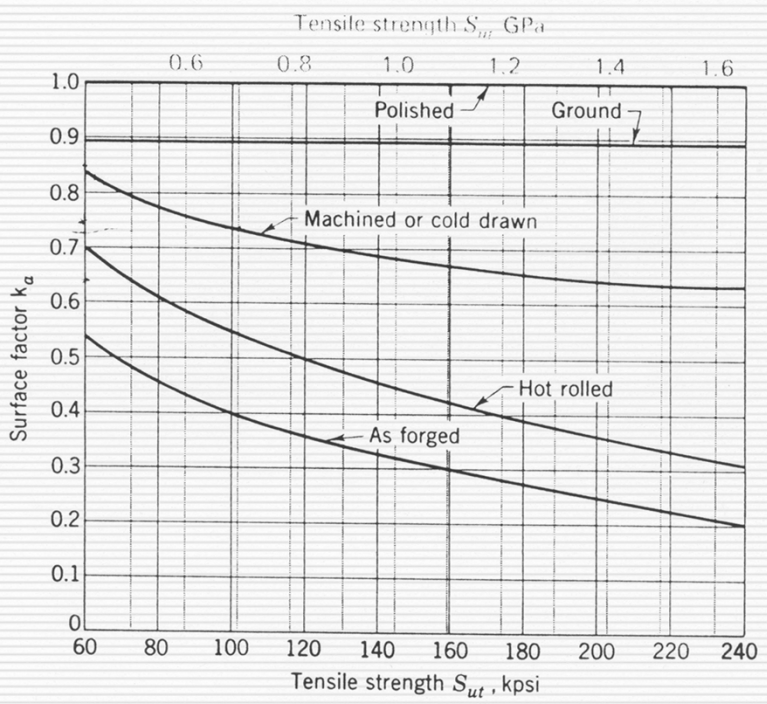
Endurance Limit Modifying Factors

- $S_e = k_a k_b k_c k_d k_e k_f S'_e$
  - k_a-surface factor
  - k_b-size factor
  - k_c-reliability factor
  - k_d-temperature factor
  - k_e-modifying factor for stress concentrations
  - k_f-miscellaneous effects factor

k_a – Surface factor

$$k_a = a \cdot S_{ut}^{b}$$

Surface Finish	Factor a S_{ut}, kpsi	Factor a S_{ut}, MPa	Exponent b
Ground	1.34	1.58	−0.085
Machined or cold-drawn	2.70	4.51	−0.265
Hot-rolled	14.4	57.7	−0.718
As-forged	39.9	272.	−0.995



k_b – Size Effect

- Rotating beam test specimen is 0.3 in in diameter
- Large specimens
  - 2in dia -> 10 to 25% reduction in S_e
  - Dia > 2in -> 25% reduction
- For bending and torsion, k_b
  - $d \leq 0.3$in (7.6mm) -> $k_b=1$
  - $0.3 \leq d \leq 2.0$ -> $k_b=0.85$
  - $d>2.0$in -> $k_b=0.75$
- For Axial loading, $k_b=1$

k_c- Loading Factor

- Bending k_c=1
- Axial k_c=0.85
- Torsion k_c=0.59

k_d - Temperature

- For steel
  - T < 160 °F -> k_d=1
  - T > 160 °F -> k_d=620/(460+T)

Stress Concentration

- K_t – theoretical or geometric static stress concentration factor
- K_f – fatigue strength reduction factor
  - (endurance limit of notch free specimen)/(endurance limit of notched specimens)
  - $K_f = 1+q(K_t-1)$, q-notch sensitivity
  - $k_e = 1/K_f$

Stress Concentration

- K_t – theoretical or geometric static stress concentration factor
- K_f – fatigue strength reduction factor

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

- Notch Sensitivity Factor

$$q = \frac{K_f - 1}{K_t - 1} = \frac{1}{1 + \sqrt{\rho'} / \sqrt{r_n}} \qquad r_n = \frac{r}{d_{\min}}$$

Neuber Constants, $\sqrt{\rho'}$

Steel Loaded in Tension

S_{ut} (ksi)	50	60	70	80	90	100	120	140	160	180	200	220	240
S_{ut} (Msi)	345	414	483	552	621	689	827	965	1103	1241	1379	1517	1655
$\sqrt{\rho'}\ (\sqrt{in})$	0.130	0.108	0.093	0.080	0.070	0.062	0.049	0.039	0.031	0.024	0.018	0.013	0.009

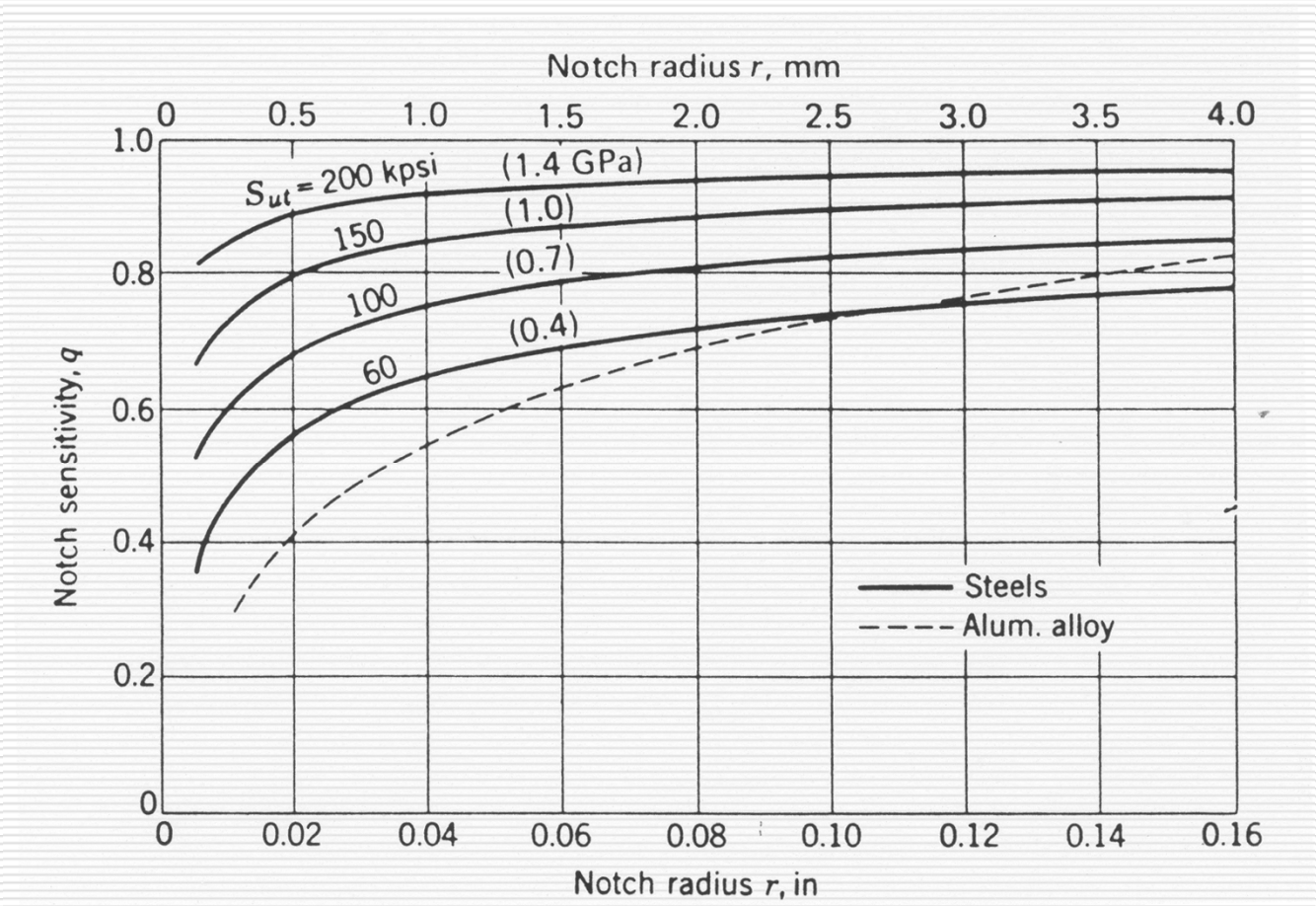
Annealed Aluminum

S_{ut} (ksi)	10	15	20	25	30	35	40	45
S_{ut} (Msi)	69	103	138	172	207	241	276	310
$\sqrt{\rho'}\ (\sqrt{in})$	0.500	0.341	0.264	0.217	0.180	0.152	0.123	0.111

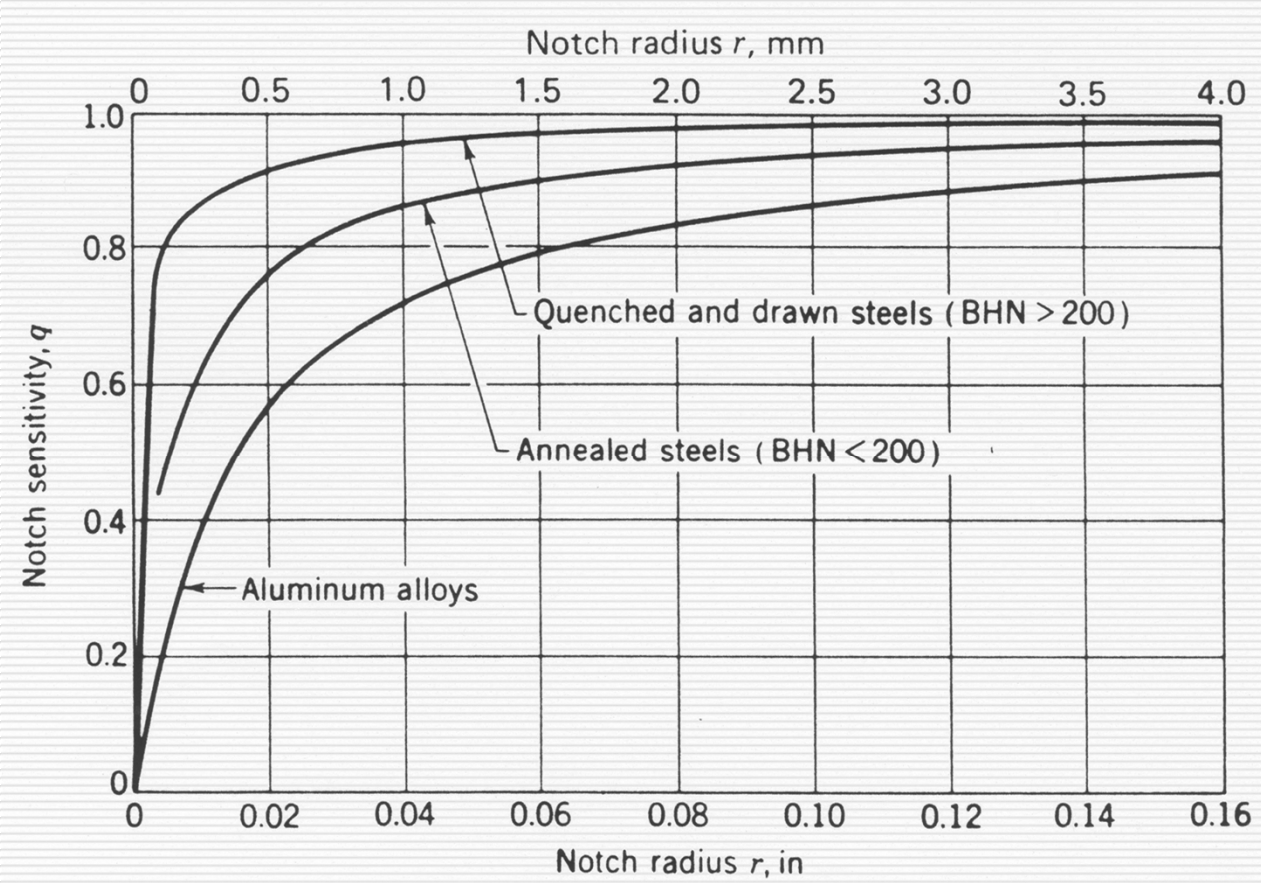
Hardened Aluminum

S_{ut} (ksi)	15	20	30	40	50	60	70	80	90
S_{ut} (Msi)	103	138	207	276	345	414	483	552	621
$\sqrt{\rho'}\ (\sqrt{in})$	0.175	0.380	0.278	0.219	0.186	0.162	0.144	0.131	0.122

Notch Sensitivity Curves



Additional Notch Sensitivity Curves



k_e - Reliability

Reliability, R	Standardized Variable, z_R	k_c
0.50	0	1.000
0.90	1.288	0.897
0.95	1.645	0.868
0.99	2.326	0.814
0.999	3.091	0.753
0.999 9	3.719	0.702
0.999 99	4.265	0.659
0.999 999	4.753	0.620
0.999 999 9	5.199	0.584
0.999 999 99	5.612	0.551
0.999 999 999	5.997	0.520

Example

A rotating shaft is supported by ball bearings at A and D and loaded by the non-rotating force F. Estimate the life of this part.

S_{ut}=103ksi

S_{yt}=72ksi

Shaft is drawn

UNS G10350 steel, drawn at 1000 C

Machined finish