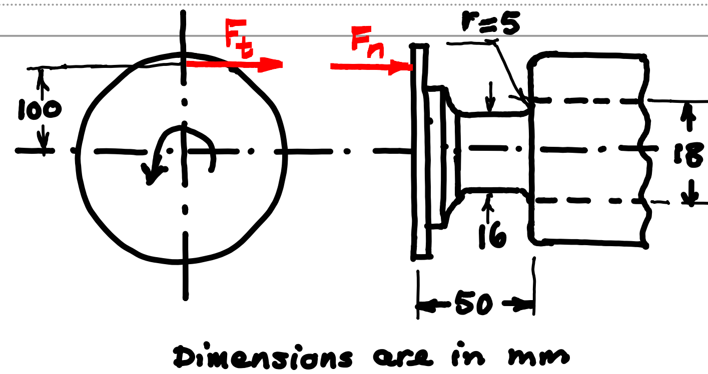
ME 314 - Engineering Design : Mechanical Components
Lecture 17

Note Title



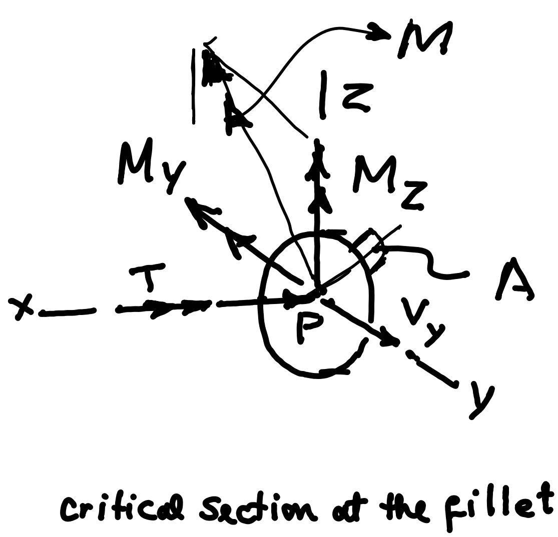
Example: The shaft of a disk sander has a machined surface and is made of SAE 1340 (quench & temper) steel alloy. The most severe loading occurs when an object is held near the periphery of the disk (100-mm radius) with sufficient force to develop a friction torque of 12 N.m. Assume a coefficient of friction of 0.6 between the object and the disk, and neglect the effect of transverse shear loading on the critical section. What is the factor of safety guarding against the fatigue failure of the shaft?

Solution:

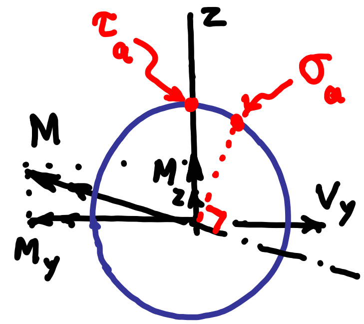
1) Material & Geometrical Properties

From Table A-10 (p. 993):

2) Applied Stresses



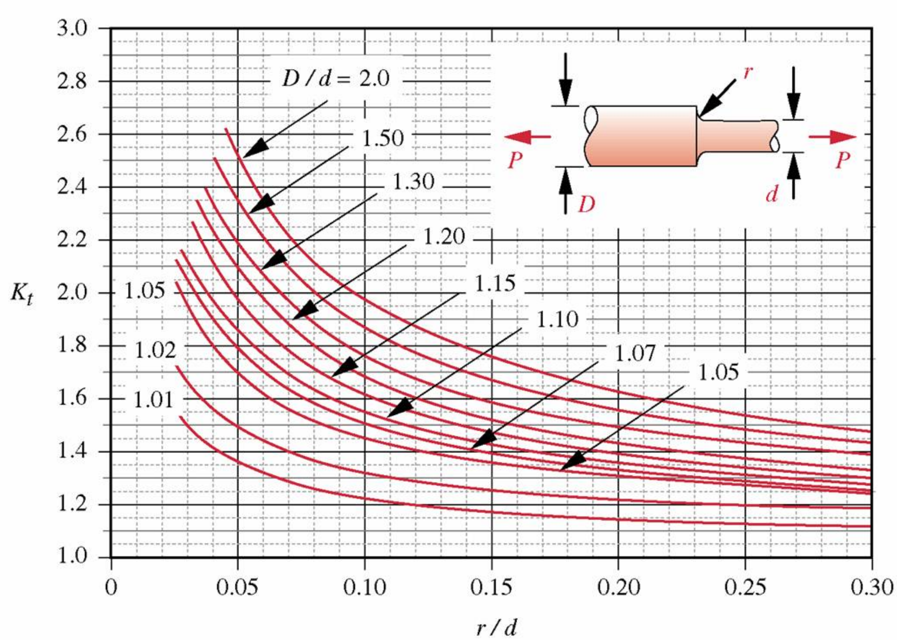
Under steady-state operating conditions, the torsional and axial stresses are constant while the bending stress is completely reversed (because, at any point on the fillet, it goes from tension-to-compression-to-tension during each shaft revolution). Hence,



Theoretical stress concentration factors for axial, bending, and torsion loads are found from Figs. C-1, C-2, and C-3, respectively.

$$\frac{r}{d} = \frac{5}{16} = 0.3125, \quad \frac{D}{d} = \frac{18}{16} = 1.125, \quad A = 0.98267 \quad b = -0.216515$$

$$(K_t)_{axial} = (0.98267)(0.3125)^{-0.216515} = 1.26$$



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

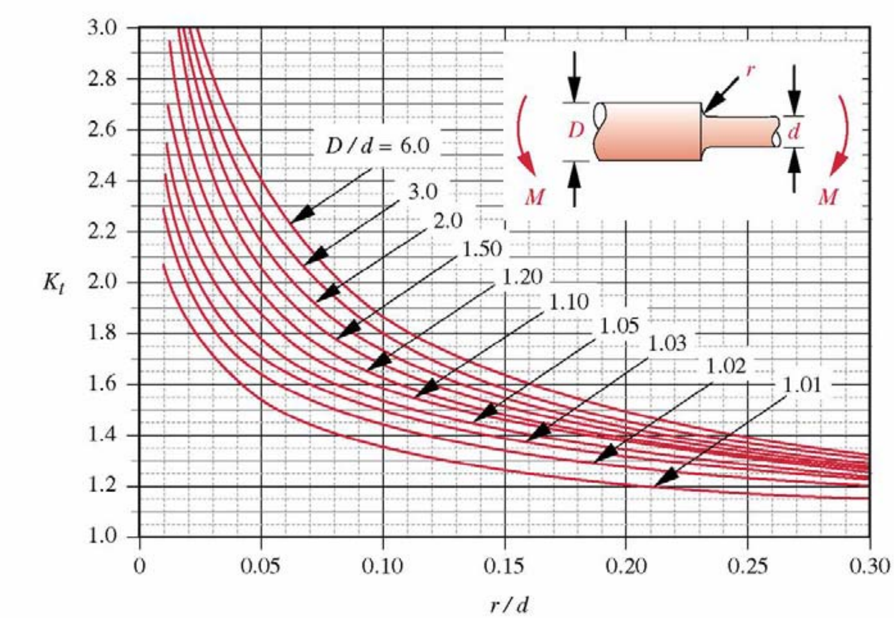
where :

D/d	A	b
2.00	1.014 70	–0.300 35
1.50	0.999 57	–0.282 21
1.30	0.996 82	–0.257 51
1.20	0.962 72	–0.255 27
1.15	0.980 84	–0.224 85
1.10	0.984 50	–0.208 18
1.07	0.984 98	–0.195 48
1.05	1.004 80	–0.170 76
1.02	1.012 20	–0.124 74
1.01	0.984 13	–0.104 74

Figure E-1
Geometric Stress-Concentration Factor K_t for a Shaft with a Shoulder Fillet in Axial Tension.

$$\frac{r}{d} = \frac{5}{16} = 0.3125, \quad \frac{D}{d} = \frac{18}{16} = 1.125, \quad A = 0.96109, \quad b = -0.227765$$

$$(K_t)_{bend} = (0.96109)(0.3125)^{-0.227765} = 1.25$$



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

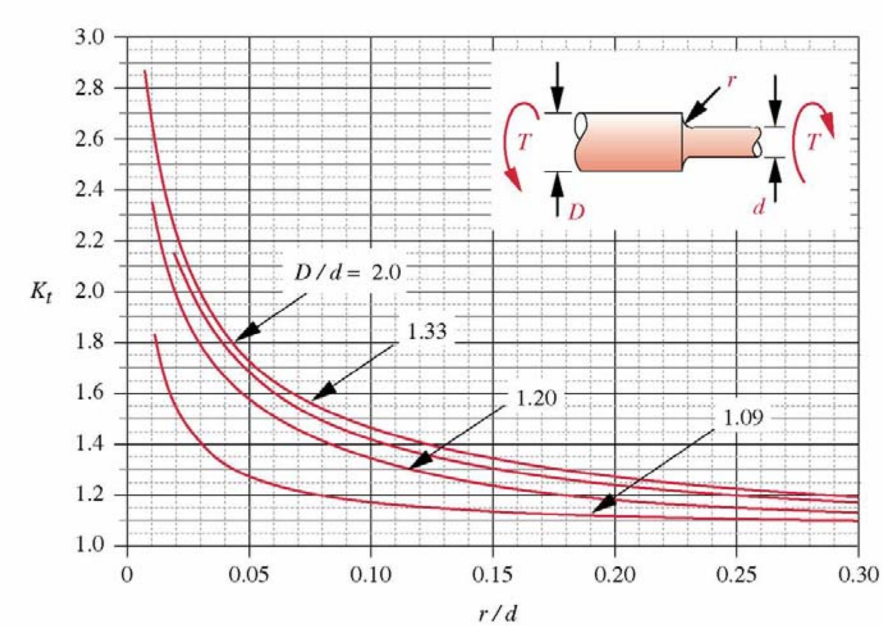
where :

D/d	A	b
6.00	0.878 68	−0.332 43
3.00	0.893 34	−0.308 60
2.00	0.908 79	−0.285 98
1.50	0.938 36	−0.257 59
1.20	0.970 98	−0.217 96
1.10	0.951 20	−0.237 57
1.07	0.975 27	−0.209 58
1.05	0.981 37	−0.196 53
1.03	0.980 61	−0.183 81
1.02	0.960 48	−0.177 11
1.01	0.919 38	−0.170 32

Figure E-2
Geometric Stress-Concentration Factor K_t for a Shaft with a Shoulder Fillet in Bending.

$$\frac{r}{d} = \frac{5}{16} = 0.3125, \quad \frac{D}{d} = \frac{18}{16} = 1.125, \quad A = 0.90117, \quad b = -0.15542$$

$$(K_{ts})_{torsion} = (0.90117)(0.3125)^{-0.15542} = 1.08$$



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

where :

D/d	A	b
2.00	0.863 31	−0.238 65
1.33	0.848 97	−0.231 61
1.20	0.834 25	−0.216 49
1.09	0.903 37	−0.126 92

Figure E-3
Geometric Stress-Concentration Factor K_t for a Shaft with a Shoulder Fillet in Torsion.

To find the notch sensitivity coefficient we can use Fig. 6-35.

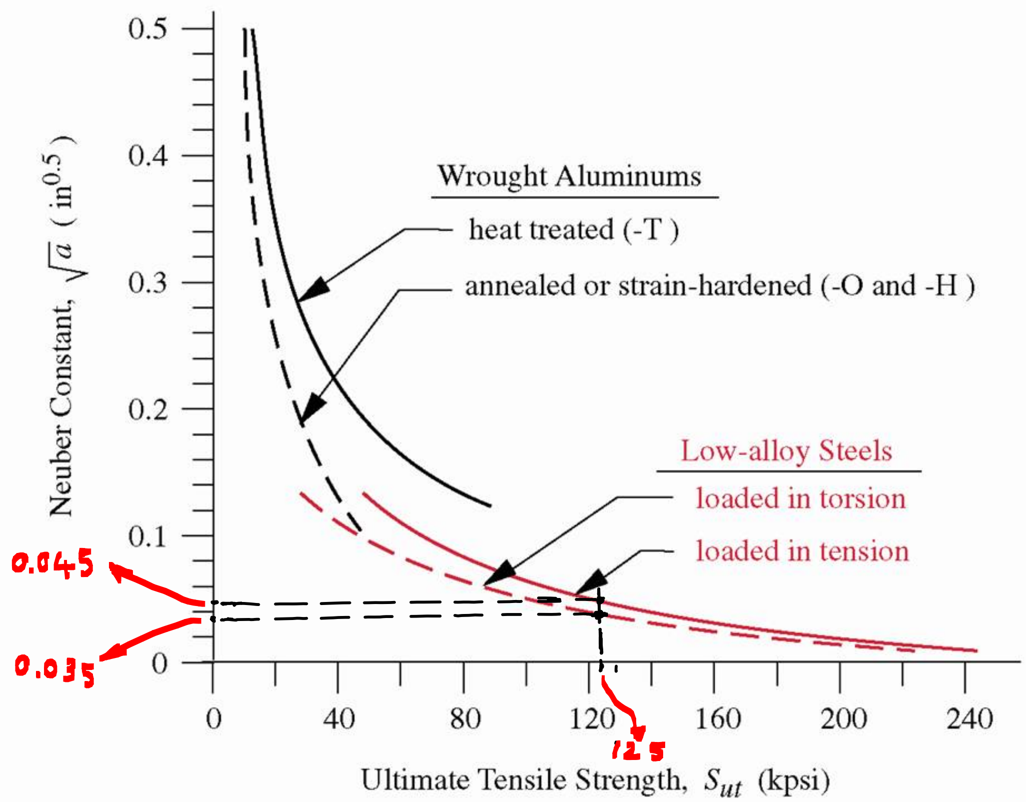


Figure 6-35

Neuber Constants for Steel and Aluminum. (From *ASME Paper* 843c, "The Prediction of Notch and Crack Strength under Static or Fatigue Loading," by P. Kuhn, April 1964).

Now S_{ut} = 862 MPa = 125 kpsi , r = 5 mm = 0.19685 in

So $\sqrt{a}$ = 0.045 $\sqrt{in}$ for tension (axial & bending)

and $\sqrt{a}$ = 0.035 $\sqrt{in}$ for torsion

Some Remarks about finding $\sqrt{a}$ and q: Table 6-6 can also be used to find $\sqrt{a}$. The value of $\sqrt{a}$ for tension is obtained using S_{ut}=125 kpsi. We find $\sqrt{a}$=0.046. For torsion, we must use S_{ut} + 20 kpsi = 145 kpsi. The result is $\sqrt{a}$=0.037.

A more accurate way that can also be solved numerically, is to use the cubic equation below that is fitted to the data in Fig. 6-35:

$$\sqrt{a} = 0.245799 - 0.307794(10^{-2})S_{ut} + 0.150874(10^{-4})S_{ut}^{2} - 0.266978(10^{-7})S_{ut}^{3}$$

For tension, use S_{ut} = 125 kpsi to find $\sqrt{a}$ = 0.045 $\sqrt{in}$. For torsion, use S_{ut} = 125 + 20 = 145 kpsi to find $\sqrt{a}$ = 0.035 $\sqrt{in}$.

Eq.(6.13):

3) Endurance Limit

Load Factor: For combined axial & any other type of loading, C_{load} = 0.7

Remark: For combined torsion and bending C_{load} = 1. For axial, or for combined axial and any other type of load use the axial load factor: C_{load} = 0.7 (see the second paragraph after Eq. (6.21b) on page 378 of text.

Size Factor:

Surface Factor:

Temperature:

Reliability:

$$S_e = C_{load}\, C_{size}\, C_{surf}\, C_{temp}\, C_{reliab}\, S_e'$$