Qualify Exam. _ Principle of Machine Design

Date: 2016.03.24

1. The cantilevered bar in Figure 1 is made from AISI 1018 CD steel (S_{ut} = 440 Mpa, S_y = 370 Mpa) and is loaded with F_x = 1.2 kN, F_y = 1 kN, and F_z = -0.4 kN. The force F is applied as a repeated load. Determine the minimum factor of safety for fatigue in the small diameter at the shoulder at A, based on infinite life, using the modified Goodman criterion. Also find the factor of safety for yielding. Axial load can be negligible. $k_c = k_d = k_e = k_f = 1$. (25%)

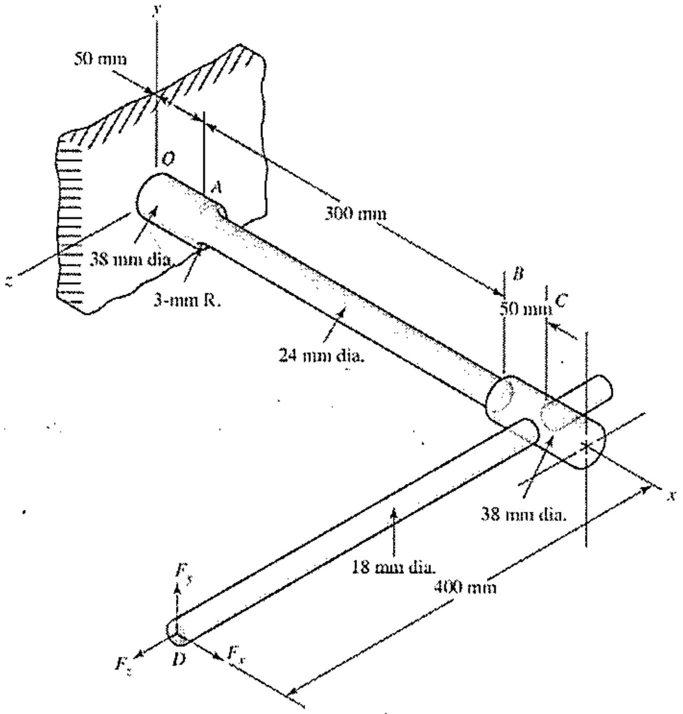


Figure 1

2. The cantilever bracket is bolted to a column with three M12×1.75 ISO 5.8 bolts as in Figure 2. The bracket is made from AISI 1020 hot-rolled steel with S_y = 210 Mpa. Assume the bolt threads do not extend into the joint. Find the factors of safety for the following failure modes: shear of bolts, bearing of bolts, bearing of bracket, and bending of bracket. $S_{sy} = 0.577\ S_y$. (25%)

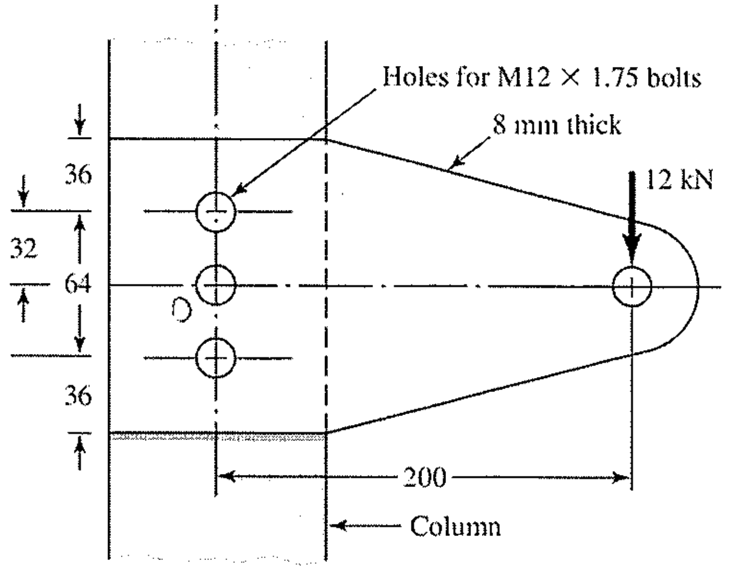


Figure 2

Dimensions in millimeters.

3. 請分別寫出下圖（a）與（b）中，那一個軸承承受軸向力（5%）

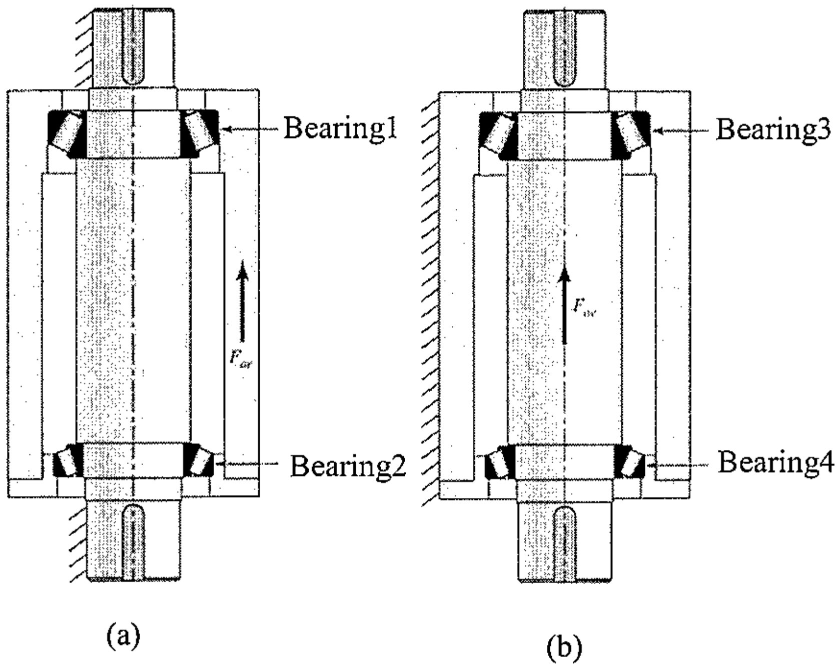


Figure 3

4. Figure 5 shows a rectangular member OB, made from 6-mm-thick plate, pinned to the ground at one end supported by a 12-mm-diameter steel rod with hooks formed on the ends. A load of 400 N is applied as shown. Use Castigliano's theorem to determine the vertical deflection at point B. For steel E = 207 Gpa. (20%)

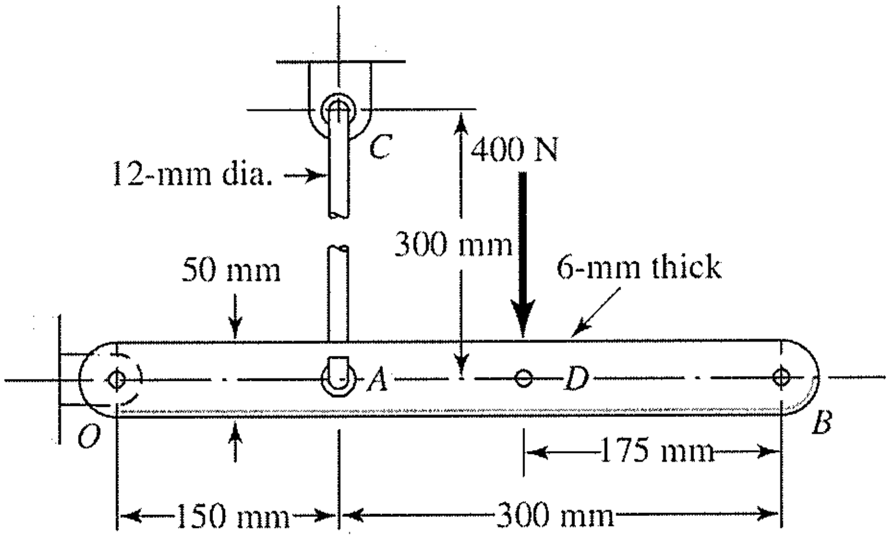


Figure 4

5. ***Bearing* 名詞解釋**

   Bearing Life (2%)

   Rating Life *(Minimum Life* or L_{10} *Life)* (2%)

   Median Life *(Average Life* or *Average Median Life)* (2%)

   C_{10} (Table 11-2 中) (2%)

   C_0 (Table 11-2 中) (2%)

Table 11–2

Dimensions and Load Ratings for Single-Row 02-Series Deep-Groove and Angular-Contact Ball Bearings

Bore, mm	OD, mm	Width, mm	Fillet Radius, mm	Shoulder Diameter, mm d_S	d_H	Load Ratings, kN Deep Groove C_{10}	C_0	Angular Contact C_{10}	C_0
10	30	9	0.6	12.5	27	5.07	2.24	4.94	2.12
12	32	10	0.6	14.5	28	6.89	3.10	7.02	3.05
15	35	11	0.6	17.5	31	7.80	3.55	8.06	3.65
17	40	12	0.6	19.5	34	9.56	4.50	9.95	4.75
20	47	14	1.0	25	41	12.7	6.20	13.3	6.55
25	52	15	1.0	30	47	14.0	6.95	14.8	7.65
30	62	16	1.0	35	55	19.5	10.0	20.3	11.0

6. Please simply give an example to briefly explain why you need to do the deflection analysis in the product design. (5%)

7. In the discussion of buckling problem, could you use the Euler equations for all range of slenderness ratio? Please also briefly make an explanation to your answer. (5%)

8. Please briefly explain the three stages for the generation of fatigue fracture. In the following fracture surface, what is the location of fatigue crack origin in this case. (5%)

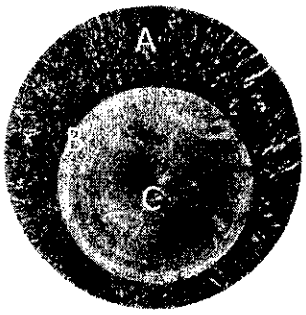


Figure 5

Reference

Table A-15

Charts of Theoretical Stress-Concentration Factors K_t^* (*Continued*)

Figure A-15-7

Round shaft with shoulder fillet in tension. $\sigma_0 = F/A$, where $A = \pi d^2/4$.

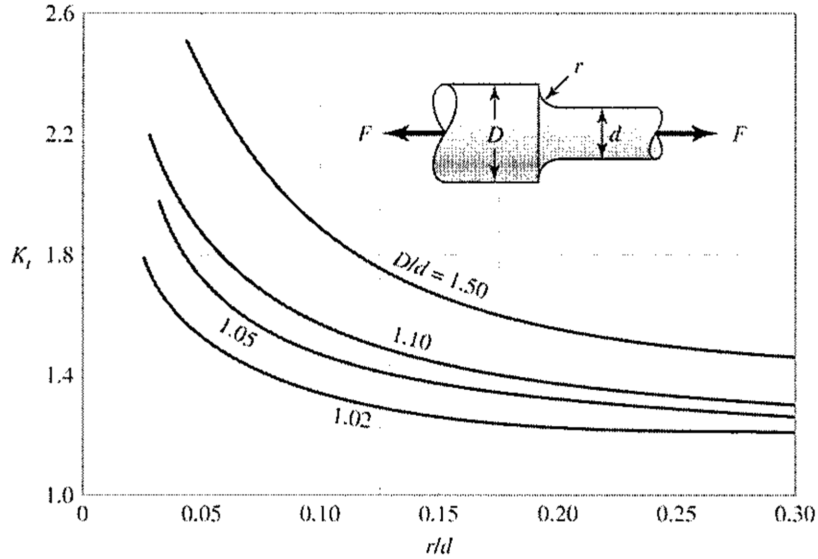


Figure A-15-8

Round shaft with shoulder fillet in torsion. $\tau_0 = Tc/J$, where $c = d/2$ and $J = \pi d^4/32$.

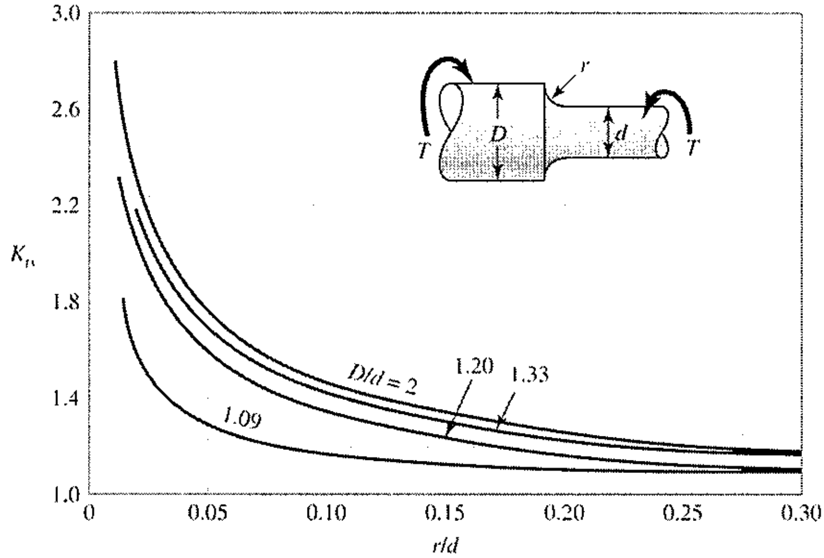


Figure A-15-9

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

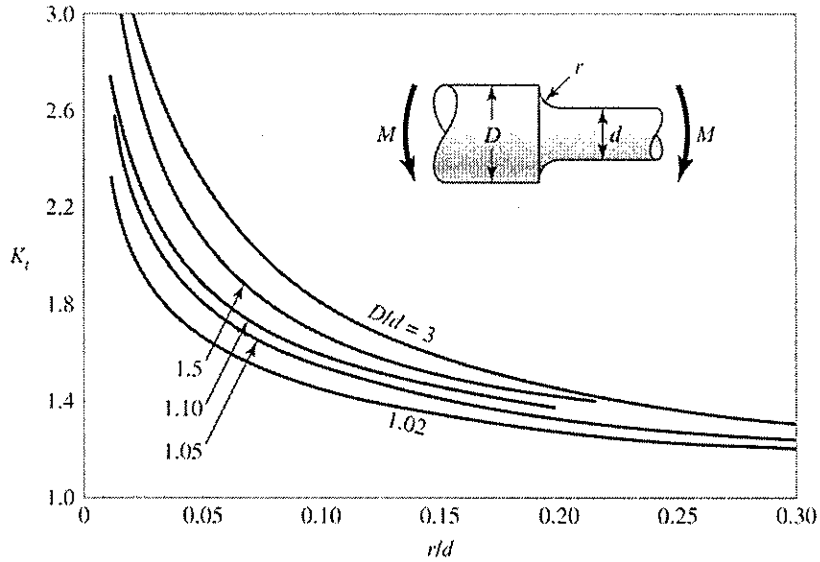


Figure 6–20

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. *(From George Sines and J. L. Waisman (eds.),* Metal Fatigue, *McGraw-Hill, New York. Copyright © 1969 by The McGraw-Hill Companies, Inc. Reprinted by permission.)*

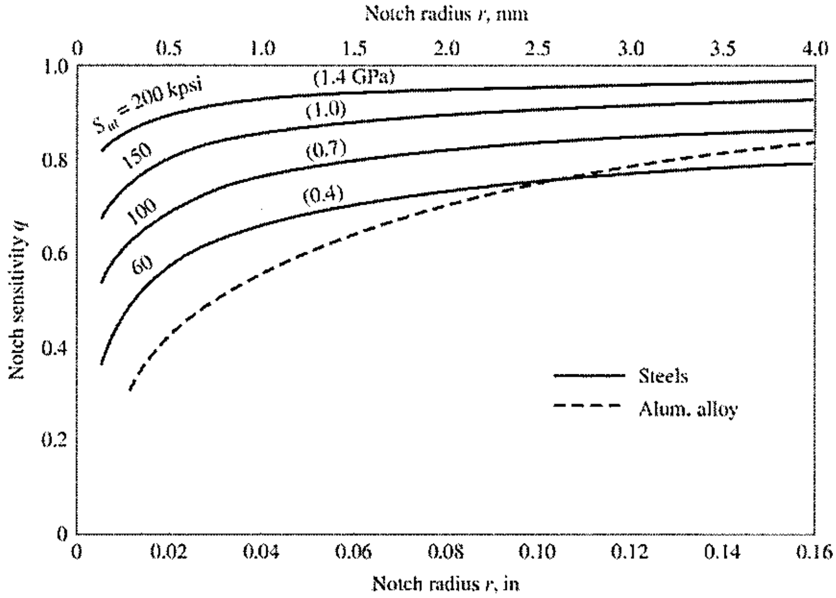
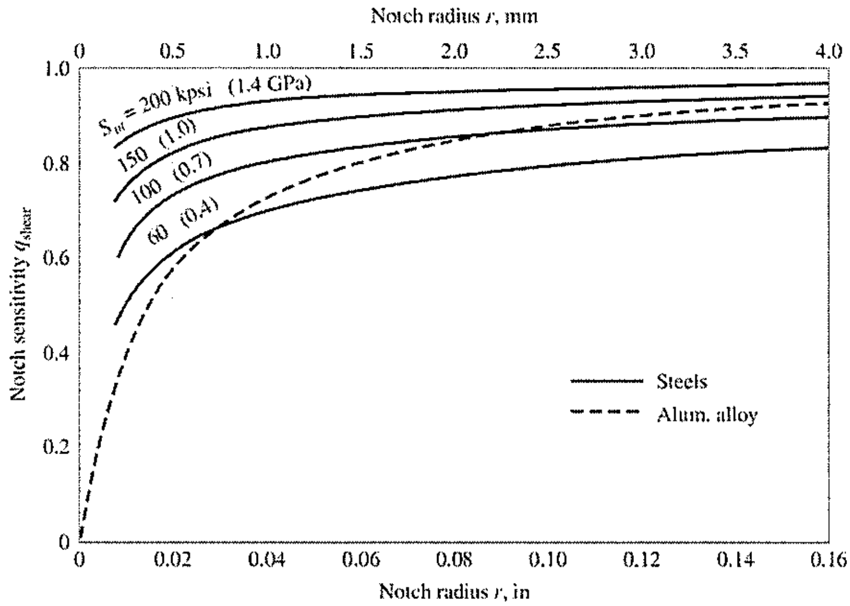


Figure 6–21

Notch-sensitivity curves for materials in reversed torsion. For larger notch radii, use the values of q_{shear} corresponding to r = 0.16 in (4 mm).



Langer static yield $\sigma_a + \sigma_m = \frac{S_y}{n}$ $\quad \sigma'_{max} = \left[(\sigma_a + \sigma_m)^2 + 3(\tau_a + \tau_m)^2\right]^{1/2}$ $\quad n_y = \frac{S_y}{\sigma'_{max}}$

mod-Goodman $\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{n}$

Primary Shear

$$F' = V_1/n$$

Secondary Shear

$$\frac{F''_A}{r_A} = \frac{F''_B}{r_B} = \frac{F''_C}{r_C} \qquad F''_n = \frac{M_1 r_n}{r_A^2 + r_B^2 + r_C^2 + \cdots}$$

$$\sigma_1, \sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad \tau_1, \tau_2 = \pm\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Distortion Energy theory (Von Mises Stress for plane stress)

$$\sigma' = \left(\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2\right)^{1/2}$$

$$S'_e = \begin{cases} 0.5S_{ut} & S_{ut} \le 200 \text{ kpsi } (1400 \text{ MPa}) \\ 100 \text{ kpsi} & S_{ut} > 200 \text{ kpsi} \\ 700 \text{ MPa} & S_{ut} > 1400 \text{ MPa} \end{cases}$$

$$S_e = k_a k_b k_c k_d k_e k_f S'_e$$

k_a = surface condition modification factor
k_b = size modification factor
k_c = load modification factor
k_d = temperature modification factor
k_e = reliability factor[13]
k_f = miscellaneous-effects modification factor
S'_e = rotary-beam test specimen endurance limit
S_e = endurance limit at the critical location of a machine part in the geometry and condition of use

$$k_a = aS_{ut}^b$$

Table 6–2

Parameters for Marin Surface Modification Factor.

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

$$k_b = \begin{cases} (d/0.3)^{-0.107} = 0.879d^{-0.107} & 0.11 \le d \le 2 \text{ in} \\ 0.91d^{-0.157} & 2 < d \le 10 \text{ in} \\ (d/7.62)^{-0.107} = 1.24d^{-0.107} & 2.79 \le d \le 51 \text{ mm} \\ 1.51d^{-0.157} & 51 < d \le 254 \text{ mm} \end{cases}$$

Axial load $k_b = 1$

Table 8–11

Metric Mechanical-Property Classes for Steel Bolts, Screws, and Studs

Property Class	Size Range, Inclusive	Minimum Proof Strength,* MPa	Minimum Tensile Strength,* MPa	Minimum Yield Strength,* MPa	Material	Head Marking
4.6	M5–M36	225	400	240	Low or medium carbon	4.6
4.8	M1.6–M16	310	420	340	Low or medium carbon	4.8
5.8	M5–M24	380	520	420	Low or medium carbon	5.8
8.8	M16–M36	600	830	660	Medium carbon, Q&T	8.8
9.8	M1.6–M16	650	900	720	Medium carbon, Q&T	9.8
10.9	M5–M36	830	1040	940	Low-carbon martensite, Q&T	10.9
12.9	M1.6–M36	970	1220	1100	Alloy, Q&T	12.9

*Minimum strengths are strengths exceeded by 99 percent of fasteners.

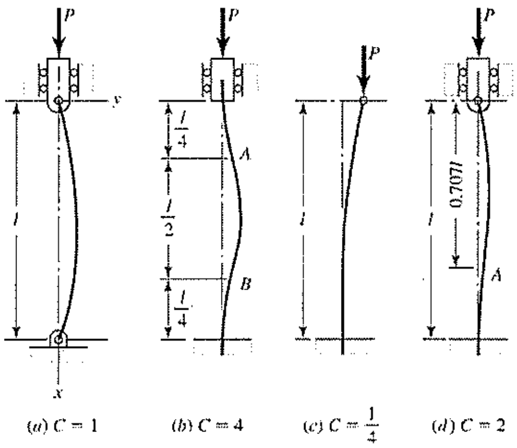
Castigliano'sTheorem

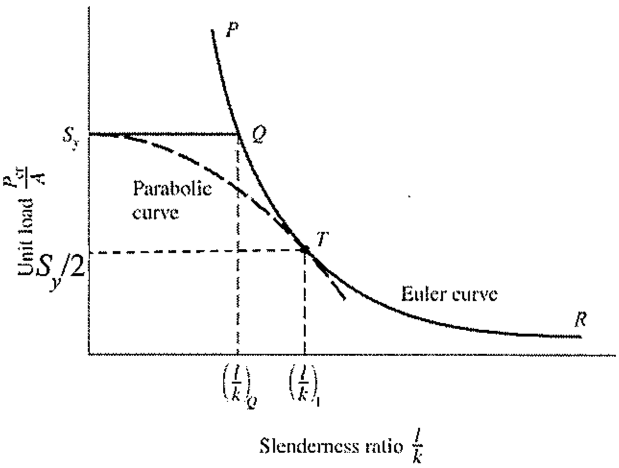
$$\delta_i = \frac{\partial U}{\partial F_i} = \int \frac{1}{AE}\left(F\frac{\partial F}{\partial F_i}\right)dx \qquad \text{tension and compression}$$

$$\theta_i = \frac{\partial U}{\partial M_i} = \int \frac{1}{GJ}\left(T\frac{\partial T}{\partial M_i}\right)dx \qquad \text{torsion}$$

$$\delta_i = \frac{\partial U}{\partial F_i} = \int \frac{1}{EI}\left(M\frac{\partial M}{\partial F_i}\right)dx \qquad \text{bending}$$

Compression Members





Long column with central loading
Euler column formula

$$P_{cr} = \frac{C\pi^2 EI}{l^2} \qquad I = Ak^2 \qquad \frac{P_{cr}}{A} = \frac{C\pi^2 E}{(l/k)^2} \qquad \left(\frac{l}{k}\right)_1 = \left(\frac{2\pi^2 CE}{S_y}\right)^{1/2}$$

Intermediate-Length Columns with Central Loading
Johnson formula

$$\frac{P_{cr}}{A} = S_y - \left(\frac{S_y}{2\pi}\frac{l}{k}\right)^2 \frac{1}{CE} \qquad \frac{l}{k} \le \left(\frac{l}{k}\right)_1$$