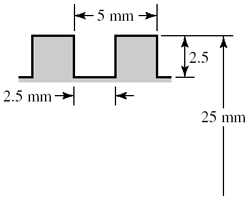
**Chapter 8**

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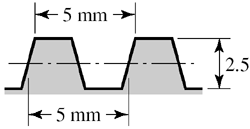
**8-1** **(a)**Thread depth= 2*.*5 mm *Ans.*

Width = 2*.*5 mm *Ans.*

*dm*= 25 - 1*.*25 - 1*.*25 = 22*.*5 mm

*dr*= 25 - 5 = 20 mm

*l* = *p* = 5 mm *Ans.*

 **(b)**Thread depth = 2.5 mm *Ans.*

Width at pitch line = 2.5 mm *Ans.*

*dm*= 22*.*5 mm

*dr*= 20 mm

*l* = *p* = 5 mm *Ans.*

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**8-2** From Table 8-1,





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**8-3** From Eq. (*c*) of Sec. 8-2,







Using *f* = 0*.*08, form a table and plot the efficiency curve.

|  |  |
| --- | --- |
| λ, deg. | *e* |
| 0 | 0 |
| 0 | 0.678 |
| 20 | 0.796 |
| 30 | 0.838 |
| 40 | 0.8517 |
| 45 | 0.8519 |

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**8-4** Given *F* = 5 kN, *l* = 5 mm, and *dm* = *d*−*p*/2 = 25 − 5/2 = 22.5 mm, the torque required to raise the load is found using Eqs. (8-1) and (8-6)



The torque required to lower the load, from Eqs. (8-2) and (8-6) is



Since *TL* is positive, the thread is self-locking. From Eq.(8-4) the efficiency is



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**8-5** Collar (thrust) bearings, at the bottom of the screws, must bear on the collars. The bottom segment of the screws must be in compression. Whereas, tension specimens and their grips must be in tension. Both screws must be of the same-hand threads.

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**8-6** Screws rotate at an angular rate of

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**(a)** The lead is 6.35 mm, so the linear speed of the press head is

*V* = 28.67(6.35) = 182.118mm/min *Ans.*

**(b)** *F* = 11 120 N/screw



Eq. (8-5):



Eq. (8-6):



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**8-7** AISI 1006 CD steel. Table A-20: *Sy* = 280 MPa.

**(a)** The handle has maximum bending moment where it enters the screw body.   
 *M* = (89 − 9.525) *F* = 79.375 *F*

****

*F* = 302 N *Ans.*

**(b)** Using Fig. 8-3 for the Acme thread, *p = l =* 25.4/152.4 = 4.23 mm

,

*α* = 29°/2 = 14.5°, sec 14.5° = 1.033

From Eqs. (8-5) and (8-6),



From part (a), *T*total = 89 *F* = 89(302) = 26855 N۰mm



**(c)** Using Eqs. (8-11), (8-8), (8-7), and (8-12):

Bending stress in first thread, with the force on the first thread being 0.38*F* and *nt*= 1,



Axial stress in body of screw,



Torsion in body of screw:



The tangential shear stress given by Eq. (8-12) with one thread carrying 0.38 *T*:



From Eq. (5-14),



 *Ans.*

**(d)** The column has one end fixed and the other end pivoted in the swivel joint of the anvil striker, so from Table 4-2, *C* = 1.2. We will use the root diameter of the screw body to check buckling, neglecting the effect of the threads.

*A* = π(0.0.014812)/4 = 0.000172 m2, *Sy*= 280 MPa, *E* = 207(109) GPa, *L* = 0.2032 m,

*, L/k* = 203.2/3.7 = 54.9

From Eq. (4-45),



Since 54.9 < 131.7, the J.B. Johnson formula is applicable. From Eq. (4-48), the critical clamping force for buckling is 

 *Ans.*

It is confirmed that the weak link is the yielding of the handle.

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**8-8** *T* = 35.58(88.9) = 3163 N ⋅ mm



*l* =  = 4.23 mm, *α* =  = 14.50, sec 14.50 = 1.033

From Eqs. (8-5) and (8-6)





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**8-9** *dm*= 38.1 − 6.35/2 = 34.925 mm, *l* = 2(6.35) = 12.7 mm

From Eq. (8-1) and Eq. (8-6),



Since *n* = *V/l* = 50.8*/*12.7 = 4 rev/s = 240 rev/min

so the power is



**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**8-10** *dm*= 40 − 4 = 36 mm, *l* = *p* = 8 mm

From Eqs. (8-1) and (8-6)

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**8-11** (**a**) Table A-31, nut height *H* = 12.8 mm. *L*≥*l + H* = 2(15) + 12.8 = 42.8 mm. Rounding up,

*L* = 45 mm *Ans.*

(**b**) From Eq. (8-14), *LT* = 2*d* + 6 = 2(14) +6 = 34 mm

From Table 8-7, *ld* =*L − LT* = 45*−* 34 = 11 mm, *lt = l −ld*= 2(15) − 11 = 19 mm,

*Ad* =*π*(142) / 4 = 153.9 mm2. From Table 8-1, *At* = 115 mm2. From Eq. (8-17)



(**c**) From Eq. (8-22), with *l* = 2(15) = 30 mm



**8-12** (**a**) Table A-31, nut height *H* = 12.8 mm. Table A-33, washer thickness *t* = 3.5 mm. Thus, the grip is *l* = 2(15) + 3.5 = 33.5 mm. *L*≥*l + H* = 33.5 + 12.8 = 46.3 mm. Rounding up

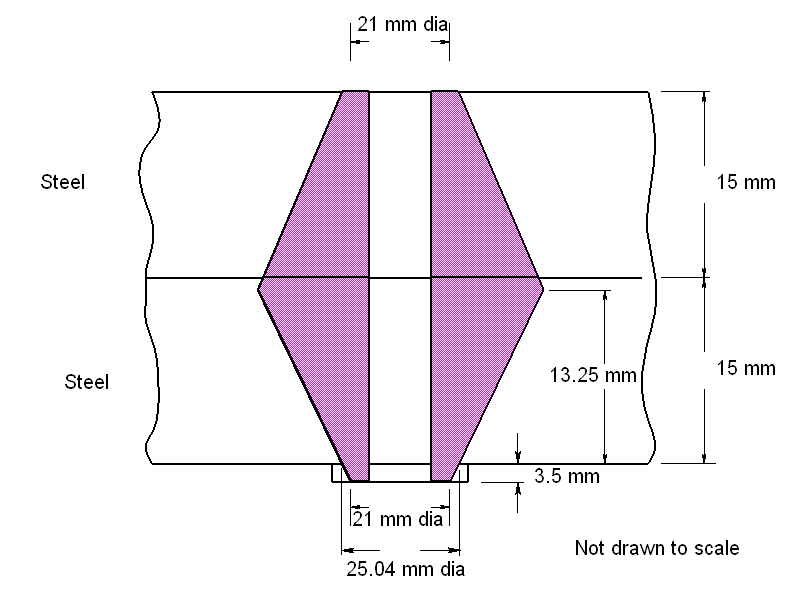
*L* = 50 mm *Ans.*

(**b**) From Eq. (8-14), *LT* = 2*d* + 6 = 2(14) +6 = 34 mm

From Table 8-7, *ld* =*L − LT* = 50*−* 34 = 16 mm, *lt = l −ld*= 33.5 − 16 = 17.5 mm,

*Ad* =*π*(142) / 4 = 153.9 mm2. From Table 8-1, *At* = 115 mm2. From Eq. (8-17)





(**c**)

From Eq. (8-22)



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**8-13** (**a**) Table 8-7, *l*= *h* + *d* /2 = 15 + 14/2 = 22 mm. *L*≥*h* + 1.5*d* = 36 mm. Rounding up

*L* = 40 mm *Ans.*

(**b**) From Eq. (8-14), *LT*= 2*d* + 6 = 2(14) +6 = 34 mm

From Table 8-7, *ld* =*L − LT* = 40*−* 34 = 6 mm, *lt = l −ld*= 22 − 6 = 16 mm

*Ad*= *π*(142) / 4 = 153.9 mm2. From Table 8-1, *At* = 115 mm2. From Eq. (8-17)



(**c**) From Eq. (8-22), with *l* =22 mm



**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**8-14** (**a**) From Table A-31, the nut height is *H*= 12.8 mm. *L ≥ l + H* = 50.8 + 25.4 + 12.8 = 89.3 mm. Rounding up, *L*= 89.9 mm *Ans.*

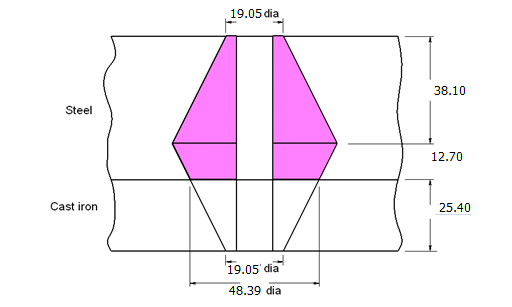
(**b**) From Eq. (8-14), *LT=* 2*d +* 6 = 2(12.7) + 6 = 31.4 mm

From Table 8-7, *ld = L − LT* = 89.9 − 31.4 = 57.9 mm, *lt = l* −*ld* = 77.1 − 57.9 =19.2 mm

*Ad= π* (12.72)/4 = 126.65 mm2. From Table 8-2, *At*= 115 mm2. From Eq. (8-17)



(**c**)



Top steel frustum: *t* = 38.1 mm, *d* = 12.7 mm, *D* = 19.05 mm, *E* = 207 GPa. From Eq. (8-20)



Lower steel frustum: *t* = 12.7 mm, *d* = 12.7 mm, *D* = 19.05 + 2(25.4) tan 30° = 48.38 mm, *E* = 207 GPa. Eq. (8-20) ⇒*k*2 = 36 918 MN/m

Cast iron: *t* = 25.4 mm, *d* = 12.7 mm, *D* = 19.05 mm, *E* = 100 GPa (Table 8-8). Eq. (8-20) ⇒

*k*3 = 2149 MN/m

From Eq. (8-18),

*km* = (1/*k*1 + 1/*k*2 +1/*k*3)−1 = (1/3969.6 + 1/36918 + 1/2149)−1 = 1343.4 MN/m *Ans.*

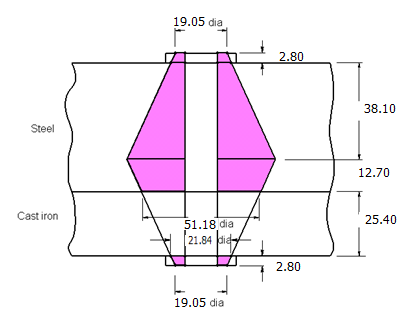
**8-15** (**a**) From Table A-33 (14N), the washer thickness is 2.80 mm . Thus, *l* = 50.8 + 25.4 + 2(2.8) = 81.8 mm. From Table A-31, the nut height is *H*= 12.8 mm. *L ≥ l + H* = 81.38 + 12.88 = 94.26 mm. Rounding up, *L*= 95.25 mm *Ans.*

(**b**) From Eq. (8-13),*LT=* 2*d +* 6 = 2(12.7) + 6 = 31.4 mm

From Table 8-7, *ld = L − LT* = 95.25 − 31.4 = 63.85 mm, *lt = l* −*ld* = 81.8 − 63.85 = 17.95 mm

*Ad= π* (12.72)/4 = 126.65 mm2. From Table 8-2, *At*= 115 mm2. From Eq. (8-17)



 (**c**)

Each steel washer frustum: *t*= 2.80 mm, *d*= 15.25 mm (Table A-33), *D*= 19.05 mm, *E* = 207 GPa . From Eq. (8-20)



Top plate,top steel frustum: *t*= 38.1 mm, *d*= 12.7 mm, *D*= 19.05 + 2(2.8)tan 30° =22.28 mm, *E* = 207 GPa. Eq. (8-20)⇒*k*2= 5257 MN/m

Top plate, lower steel frustum: *t*= 12.7 mm, *d*= 12.7 mm, *D* = 21.84 + 2(25.4) tan 30° =49.81 mm, *E* = 207 GPa. Eq. (8-20) ⇒*k*3 = 38997 MN/m

Cast iron: *t* = 25.4 mm, *d* = 12.7 mm, *D* = 19.05 + 2(2.8) tan 30° = 22.28 mm, *E* = 100 GPa (Table 8-8). Eq. (8-20) ⇒*k*4 = 2906 MN/m

From Eq. (8-18)

*km*= (2/*k*1 + 1/*k*2 +1/*k*3+1/*k*4)−1 = (2/10891 + 1/5257 + 1/38997 + 1/2906)−1

= 1534 MN/m *Ans.*

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**8-16** (**a**) From Table 8-7, *l* = *h* + *d* /2 = 50.8 + 12.7/2 = 57.15 mm.

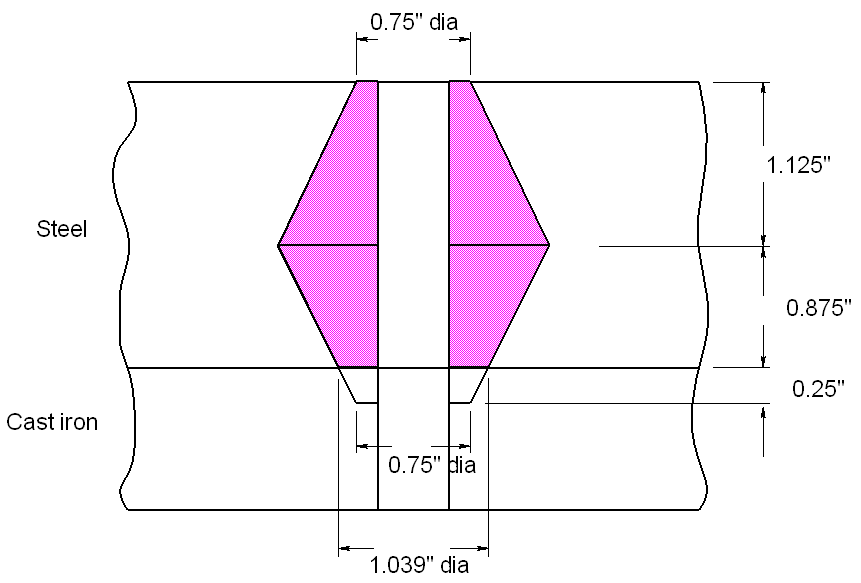
*L*≥ *h* + 1.5 *d* = 50.8 + 1.5(12.7) = 69.85 mm *Ans.*

(**b**) From Table 8-7, *LT =* 2*d +* 6 = 2(12.7) + 6 = 31.4 mm

*ld = L − LT* = 69.85 − 31.4 = 38.45 mm, *lt = l* −*ld* = 57.15 − 38.1 = 18.7 mm

*Ad= π* (12.72)/4 = 126.65 mm2. From Table 8-2, *At*= 115 mm2. From Eq. (8-17)



 (**c**)

Top steel frustum: *t*= 28.58 mm, *d*= 12.7 mm, *D*= 19.05 mm, *E*= 207 GPa. From Eq. (8-20)



Lower steel frustum: *t*= 22.23 mm, *d*= 12.7 mm, *D* = 19.05 + 2(6.35) tan 30° = 26.38 mm, *E* = 207 GPa. Eq. (8-20) ⇒*k*2 = 8642 MN/m

Cast iron: *t*= 6.35 mm, *d*= 12.7 mm, *D*= 19.05 mm, *E*= 100 GPa (Table 8-8). Eq. (8-20) ⇒

*k*3 = 4113 MN/m

From Eq. (8-18)

*km*= (1/*k*1 + 1/*k*2 +1/*k*3)−1 = (1/4289 + 1/8642 + 1/4113)−1 = 1689.34 MN/m *Ans.*

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**8-17** **a**) Grip, *l* =2(50.8 + 2.41) = 106.42 mm. *L ≥*106.42 + 11.11 = 117.55 mm.

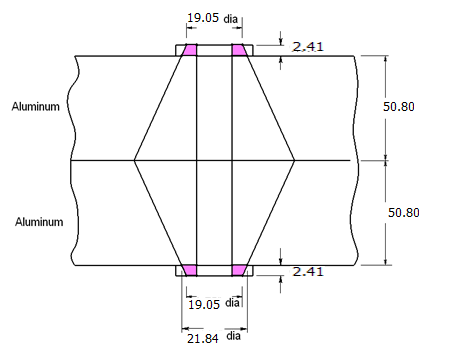
Rounding up, *L*= 120.6 mm *Ans.*

(**b**) From Eq. (8-13), *LT=* 2*d +* 6 = 2(12.7) + 6 = 31.4 mm

From Table 8-7, *ld = L − LT* = 117.55 − 31.4 = 86.15 mm, *lt = l* −*ld* = 106.4 −86.15 = 20.28 mm

*Ad= π* (14.72)/4 = 126.65 mm2. From Table 8-2, *At*= 115 mm2. From Eq. (8-17)



 (**c**)

Upper and lower halves are the same. For the upper half,

Steel frustum: *t* = 2.41 mm, *d* = 13.48 mm, *D* = 19.05 mm, and *E* = 207 GPa. From Eq. (8-20)



Aluminum: *t* =50.8 mm, *d* = 12.7 mm, *D*=19.05 + 2(2.41) tan 30° = 21.83 mm, and *E* =71.02 GPa. Eq. (8-20)⇒ *k*2 = 1616.5 MN/m

For the top half,  = (1/*k*1 + 1/*k*2)−1 =(1/15658.5 + 1/1616.5)−1 = 1465.25 MN/m

Since the bottom half is the same, the overall stiffness is given by

*km* = (1/ + 1/)−1 = /2 = 1465.25/2 = 732.62 MN/m *Ans*

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**8-18** (**a**) Grip, *l* = 2(50.8 + 2.41) = 106.42 mm. *L ≥* 106.42 + 11.11 = 117.55 mm.

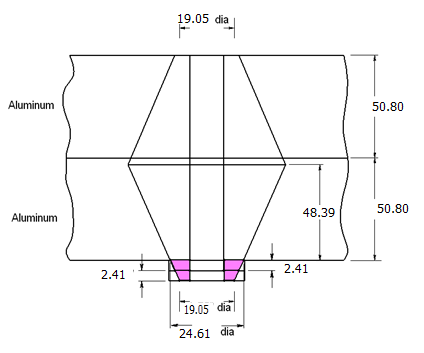
Rounding up, *L* = 120.6 mm *Ans.*

(**b**) From Eq. (8-13), *LT =* 2*d +* 6 = 2(12.7) + 6 = 31.4 mm

From Table 8-7, *ld = L − LT* = 120.6 − 31.4 = 89.2 mm, *lt = l* −*ld* = 106.42 − 89.2 = 17.22 mm

*Ad = π* (12.72)/4 = 126.65 mm2. From Table 8-2, *At* = 115 mm2. From Eq. (8-17)



 (**c**)

Upper aluminum frustum: *t*= [101.6 +2(2.41)] /2= 53.21 mm, *d*= 12.7 mm, *D*= 19.05 mm, and

*E*= 71.02 GPa. From Eq. (8-20)



Lower aluminum frustum: *t* = 101.6 − 53.21 = 48.39 mm, *d*= 12.7 mm,

*D*= 19.05 +4(2.41) tan 30° = 21.83 mm, and  *E*= 71.02 GPa. Eq. (8-20) ⇒*k*2 = 1635.3 MN/m

Steel washers frustum: *t* = 2(2.41) = 4.83 mm, *d*=13.49 mm, *D* = 19.05 mm, and *E*=207 GPa. Eq. (8-20) ⇒*k*3 = 9594.2 MN/m

From Eq. (8-18)

*km*= (1/*k*1 + 1/*k*2 +1/*k*3)−1 = (1/1266.9 + 1/1635.3 + 1/9594.2)−1 = 664.4 MN/m *Ans.*

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**8-19** (**a**) From Table A-31, the nut height is *H*= 8.4 mm. *L > l + H*= 50 + 8.4 = 58.4 mm.

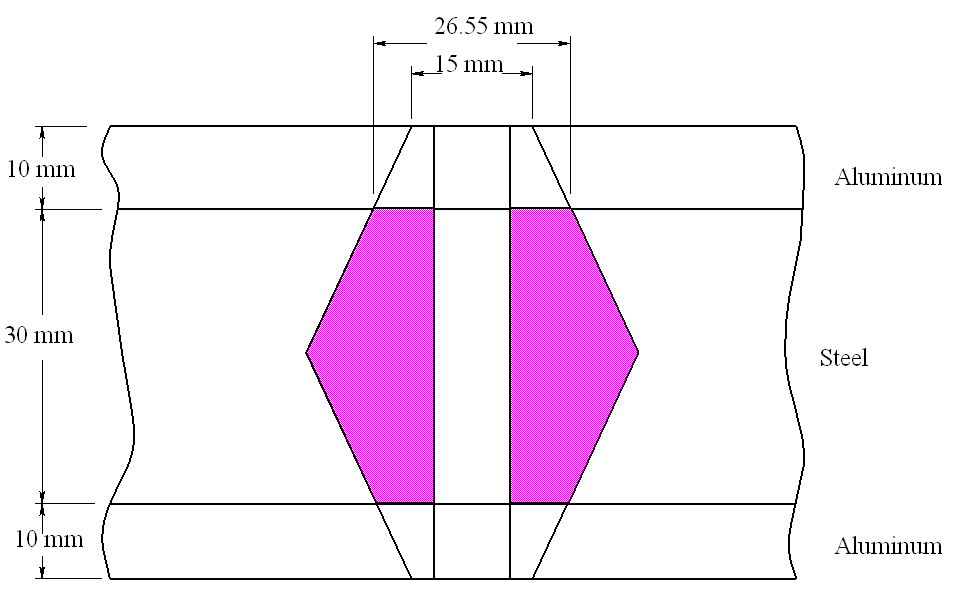
Rounding up, *L*= 60 mm *Ans.*

(**b**) From Eq. (8-14), *LT=* 2*d* + 6 = 2(10) + 6 = 26 mm, *ld= L* −*LT*= 60 − 26 =

34 mm, *lt= l −l*= 50 − 34 = 16 mm. *Ad*= *π* (102) / 4 = 78.54 mm2. From Table 8-1,

*At* = 58 mm2. From Eq. (8-17)



 (**c**)

Upper and lower frustums are the same. For the upper half,

Aluminum: *t*= 10 mm, *d*= 10 mm, *D*= 15 mm, and from Table 8-8, *E*= 71 GPa. From Eq. (8-20)



Steel: *t* = 15 mm, *d* = 10 mm, *D* = 15 + 2(10) tan 30° = 26.55 mm, and *E* = 207 GPa. From Eq. (8-20)



For the top half,  = (1/*k*1 + 1/*k*2)−1 = (1/1576 + 1/11 440)−1 = 1385 MN/m

Since the bottom half is the same, the overall stiffness is given by

*km* = (1/ + 1/)−1 = /2 = 1385/2 = 692.5 MN/m *Ans.*

**8-20** (**a**) From Table A-31, the nut height is *H*= 8.4 mm. *L > l + H*= 60 + 8.4 = 68.4 mm.

Rounding up, *L*= 70 mm *Ans.*

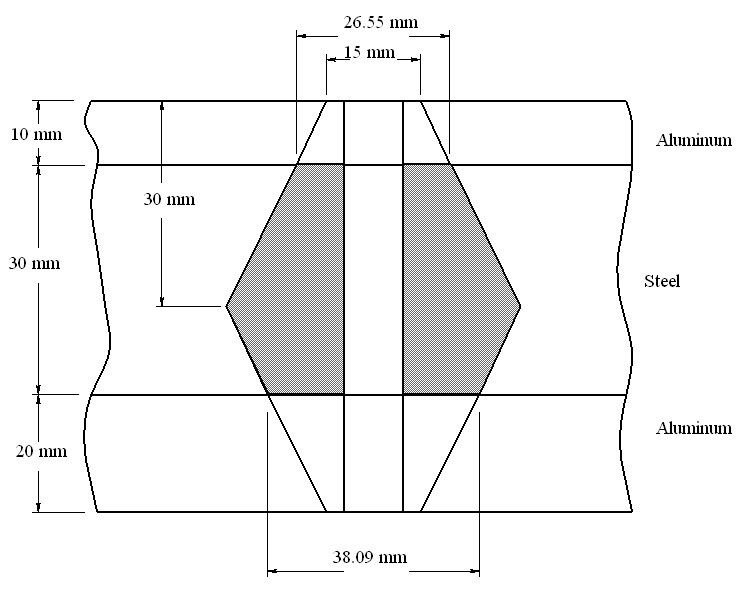
(**b**) From Eq. (8-14), *LT=* 2*d* + 6 = 2(10) + 6 = 26 mm, *ld= L* −*LT*= 70 − 26 =

44 mm, *lt= l −ld*= 60 − 44 = 16 mm. *Ad*= *π* (102) / 4 = 78.54 mm2. From Table 8-1,

*At* = 58 mm2. From Eq. (8-17)



(**c**)



Upper aluminum frustum: *t*= 10 mm, *d*= 10 mm, *D*= 15 mm, and *E*= 71 GPa. From Eq. (8-20)



Lower aluminum frustum: *t* = 20 mm, *d*= 10 mm, *D*= 15 mm, and *E*= 71 GPa. Eq.

(8-20) ⇒*k*2 = 1 201 MN/m

Top steel frustum: *t* = 20 mm, *d*= 10 mm, *D*= 15 + 2(10) tan 30° = 26.55 mm, and *E*= 207 GPa. Eq. (8-20) ⇒*k*3 = 9 781 MN/m

Lower steel frustum: *t* = 10 mm, *d*= 10 mm, *D*= 15 + 2(20) tan 30° = 38.09 mm, and *E*= 207 GPa. Eq. (8-20) ⇒*k*4 = 29 070 MN/m

From Eq. (8-18)

*km*= (1/*k*1 + 1/*k*2 +1/*k*3+1/*k*4)−1 = (1/1 576 + 1/1 201 + 1/9 781 +1/29 070)−1

= 623.5 MN/m *Ans.*

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**8-21** (**a**) From Table 8-7, *l* = *h* + *d* /2 = 10 + 30 + 10/2 = 45 mm. *L*≥ *h* + 1.5 *d* =

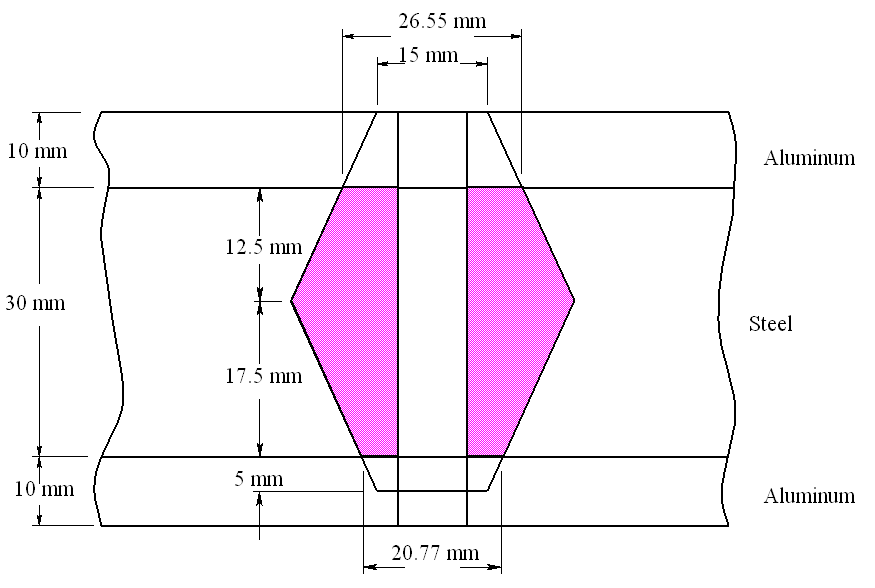
10 + 30 + 1.5(10) = 55 mm *Ans.*

(**b**) From Eq. (8-14), *LT =*2*d* + 6 = 2(10) + 6 = 26 mm, *ld = L* −*LT* = 55 − 26 =

29 mm, *lt = l −ld* = 45− 29 = 16 mm. *Ad* = *π* (102) / 4 = 78.54 mm2. From Table 8-1,

*At* = 58 mm2. From Eq. (8-17)





(**c**)

Upper aluminum frustum: *t*= 10 mm, *d*= 10 mm, *D*= 15 mm, and *E*= 71 GPa. From Eq. (8-20)



Lower aluminum frustum: *t* = 5 mm, *d*= 10 mm, *D*= 15 mm, and *E*= 71 GPa. Eq.

(8-20) ⇒*k*2 = 2 300 MN/m

Top steel frustum: *t* = 12.5 mm, *d*= 10 mm, *D*= 15 + 2(10) tan 30° = 26.55 mm, and *E*= 207 GPa. Eq. (8-20) ⇒*k*3 = 12 759 MN/m

Lower steel frustum: *t* = 17.5 mm, *d*= 10 mm, *D*= 15 + 2(5) tan 30° = 20.77 mm, and *E*= 207 GPa. Eq. (8-20) ⇒*k*4 = 6 806 MN/m

From Eq. (8-18)

*km*= (1/*k*1 + 1/*k*2 +1/*k*3+1/*k*4)−1 = (1/1 576 + 1/2 300 + 1/12 759 +1/6 806)−1

= 772.4 MN/m *Ans.*

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**8-22** Equation (*f* ), Sec. 8-7: 

Eq. (8-17): 

Eq. (8-22): 

See Table 8-7 for other terms used.

Using a spreadsheet, with coarse-pitch bolts (units are mm, mm2, MN/m):

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *d* | *At* | *Ad* | *H* | *L >* | *L* | *LT* |
| 10 | 58 | 78.53982 | 8.4 | 48.4 | 50 | 26 |
| 12 | 84.3 | 113.0973 | 10.8 | 50.8 | 55 | 30 |
| 14 | 115 | 153.938 | 12.8 | 52.8 | 55 | 34 |
| 16 | 157 | 201.0619 | 14.8 | 54.8 | 55 | 38 |
| 20 | 245 | 314.1593 | 18 | 58 | 60 | 46 |
| 24 | 353 | 452.3893 | 21.5 | 61.5 | 65 | 54 |
| 30 | 561 | 706.8583 | 25.6 | 65.6 | 70 | 66 |

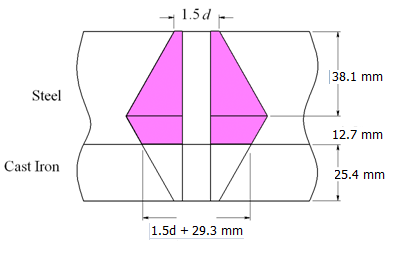
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *d* | *l* | *ld* | *lt* | *kb* | *km* | *C* |
| 10 | 40 | 24 | 16 | 356.0129 | 1751.566 | 0.16892 |
| 12 | 40 | 25 | 15 | 518.8172 | 2235.192 | 0.188386 |
| 14 | 40 | 21 | 19 | 686.2578 | 2761.721 | **0.199032** |
| 16 | 40 | 17 | 23 | 895.9182 | 3330.796 | 0.211966 |
| 20 | 40 | 14 | 26 | 1373.719 | 4595.515 | 0.230133 |
| 24 | 40 | 11 | 29 | 1944.24 | 6027.684 | 0.243886 |
| 30 | 40 | 4 | 36 | 2964.343 | 8487.533 | 0.258852 |

Use a M14 × 2 bolt, with length 55 mm. *Ans.*

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**8-23** Equation (*f* ), Sec. 8-7: 

Eq. (8-17): 



For upper frustum, Eq. (8-20), with  *D* = 1.5 *d* and *t* = 38.1 mm:



Lower steel frustum, with *D* = 1.5*d*+ 2(25.4) tan 30° = 1.5*d* + 29.3 mm, and *t* = 12.7 mm:



For cast iron frustum, let *E* = 100 GPa, and *D* = 1.5 *d*, and *t* = 25.4 mm:



Overall, *km* = (1/*k*1 +1/*k*2 +1/*k*3)−1

See Table 8-7 for other terms used.

Using a spreadsheet, with coarse-pitch bolts (units are mm, mm2, MN/m):

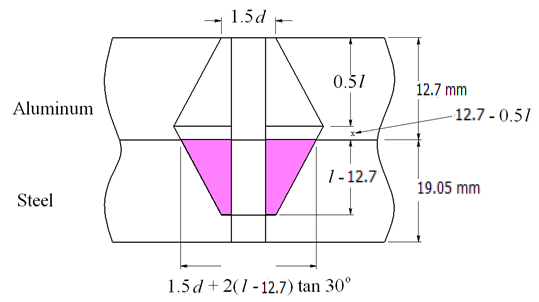
|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *d* | *At* | *Ad* | *H* | *L >* | *L* | *LT* | *l* |  |
| 9.53 | 50.0 | 71.3 | 8.33 | 84.53 | 88.90 | 25.40 | 76.20 |  |
| 11.11 | 68.6 | 97.0 | 9.53 | 85.73 | 88.90 | 28.58 | 76.20 |  |
| 12.70 | 91.5 | 126.7 | 11.11 | 87.31 | 88.90 | 31.75 | 76.20 |  |
| **14.29** | 117.4 | 160.3 | 12.30 | 88.50 | **88.90** | 34.93 | 76.20 |  |
| 15.88 | 145.8 | 197.9 | 13.89 | 90.09 | 95.25 | 38.10 | 76.20 |  |
| 19.05 | 215.5 | 285.0 | 16.27 | 92.47 | 95.25 | 44.45 | 76.20 |  |
| 22.23 | 298.1 | 387.9 | 19.05 | 95.25 | 95.25 | 50.80 | 76.20 |  |
|  |  |  |  |  |  |  |  |  |
| *d* | *ld* | *lt* | *kb* | *k*1 | *k*2 | *k*3 | *km* | *C* |
| 9.53 | 63.50 | 12.70 | 180.6 | 2792.6 | 31309.2 | 1481.9 | 939.1 | 0.161309 |
| 11.11 | 60.33 | 15.88 | 242.4 | 3365.1 | 34056.0 | 1804.8 | 1135.6 | 0.175884 |
| 12.70 | 57.15 | 19.05 | 313.8 | 3967.2 | 36883.2 | 2148.6 | 1343.0 | 0.189383 |
| **14.29** | 53.98 | 22.23 | 393.3 | 4598.7 | 39790.7 | 2513.2 | 1561.3 | **0.20121** |
| 15.88 | 57.15 | 19.05 | 493.2 | 5259.4 | 42778.7 | 2898.4 | 1790.4 | 0.215976 |
| 19.05 | 50.80 | 25.40 | 698.5 | 6667.4 | 48996.3 | 3730.2 | 2280.6 | 0.234476 |
| 22.23 | 44.45 | 31.75 | 935.5 | 8190.0 | 55536.3 | 4643.3 | 2813.2 | 0.24956 |

Use a M14 , with length 88.9 mm. *Ans.*

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**8-24** Equation (*f* ), Sec. 8-7: 

Eq. (8-17): 



Top frustum, Eq. (8-20), with*E* = 71 GPa, *D* = 1.5 *d*, and *t* = *l* /2:



Middle frustum, with *E* = 71 GPa, *D* = 1.5*d* + 2(*l*− 12.7) tan 30°, and *t* = 12.7 −*l* /2



Lower frustum, with *E* = 207 GPa, *D* = 1.5*d*,*t* = *l*− 12.7



See Table 8-7 for other terms used.

Using a spreadsheet, with coarse-pitch bolts (units are mm, mm2, MN/m)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Size | *d* | *At* | *Ad* | *L >* | *L* | *LT* | *l* | *ld* |
| 1 | 1.85 | 1.70 | 2.70 | 15.48 | 19.05 | 10.06 | 13.63 | 8.99 |
| 2 | 2.18 | 2.39 | 3.75 | 15.98 | 19.05 | 10.72 | 13.79 | 8.33 |
| 3 | 2.51 | 3.14 | 4.97 | 16.47 | 19.05 | 11.38 | 13.96 | 7.67 |
| 4 | 2.84 | 3.90 | 6.36 | 16.97 | 19.05 | 12.04 | 14.12 | 7.01 |
| 5 | 3.18 | 5.14 | 7.92 | 17.46 | 19.05 | 12.70 | 14.29 | 6.35 |
| 6 | 3.51 | 5.86 | 9.65 | 17.96 | 19.05 | 13.36 | 14.45 | 5.69 |
| 8 | 4.17 | 9.03 | 13.63 | 18.95 | 19.05 | 14.68 | 14.78 | 4.37 |
| 10 | 4.83 | 11.29 | 18.29 | 19.94 | 25.40 | 16.00 | 15.11 | 9.40 |
| Size | *d* | *lt* | *kb* | *k*1 | *k*2 | *k*3 | *km* | *C* |
| 1 | 1.85 | 4.64 | 34.1 | 189.9 | 342.3 | 1242.4 | 111.2 | 0.23478 |
| 2 | 2.18 | 5.46 | 45.9 | 231.4 | 429.0 | 1463.7 | 136.3 | **0.251687** |
| 3 | 2.51 | 6.29 | 58.3 | 275.0 | 524.2 | 1684.9 | 162.9 | 0.263647 |
| 4 | 2.84 | 7.11 | 70.6 | 320.6 | 628.3 | 1906.2 | 191.0 | 0.27 |
| 5 | 3.18 | 7.94 | 88.1 | 368.0 | 741.6 | 2127.4 | 220.5 | 0.285535 |
| 6 | 3.51 | 8.76 | 99.3 | 417.2 | 864.4 | 2348.7 | 251.3 | 0.28315 |
| 8 | 4.17 | 10.41 | 140.4 | 520.8 | 1140.7 | 2791.2 | 317.0 | 0.306931 |
| 10 | 4.83 | 5.72 | 202.8 | 630.9 | 1460.9 | 3233.7 | 387.8 | 0.343393 |

Use a 2−56 UNC × 0.75 in(19.05mm) long bolt. *Ans.*

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**8-25** For half of joint, Eq. (8-20): *t*= 20 mm, *d*= 14 mm, *D* = 21 mm, and *E*= 207 GPa



*km*= (1/*k*1 + 1/*k*1)−1 =*k*1/2 = 5523/2 = 2762 MN/m *Ans.*

From Eq. (8-22) with *l*= 40 mm



which agrees with the earlier calculation.

For Eq. (8-23), from Table 8-8, *A*= 0.787 15, *B* = 0.628 73

*km*= 207(14)(0.78 715) exp [0.628 73(14)/40] = 2843 MN/m *Ans.*

This is 2.9% higher than the earlier calculations.

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**8-26** (**a**) Grip, *l* = 254 mm. Nut height, *H* = 18.0 mm (Table A-31).

*L* ≥ *l* + *H* = 254 + 18 = 272 mm. Let *L* = 273 mm.

Table 8-7, *LT* = 2*d* + 25 = 2(19.05) + 25 = 63.1 mm , *ld* = *L*−*LT* = 273 − 63.1 = 209.95 mm, *lt* = *l*−*ld* = 254 − 209.95 = 44 mm

*Ad* = π(19.052)/4 = 285 mm2, *At* = 245 mm2 (Table 8-1)

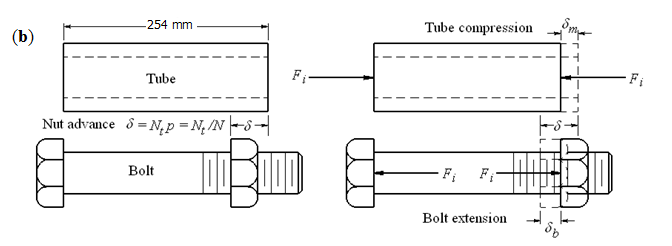
Eq. (8-17),



Eq. (4-4),



Eq. (*f*), Sec. 8-7, *C* = *kb*/(*kb* + *km*) = 226/(226 + 290) = 0.439 *Ans.*



Let:*Nt* = no. of turns, *p* = pitch of thread (in), *N* = no. of threads per in = 1/*p*. Then,

*δ* = *δb* + *δm*= *Ntp* = *Nt* /*N* (1)

But, *δb* = *Fi* /*kb*, and, *δm* = *Fi* /*km*. Substituting these into Eq. (1) and solving for *Fi*gives



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**8-27** Proof for the turn-of-nut equation is given in the solution of Prob. 8-26, Eq. (2), where

*Nt* =*θ* / 360°.

The relationship between the turn-of-nut method and the torque-wrench method is asfollows.



Eliminate *Fi*



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**8-28** **(a)** From Ex. 8-4, *Fi*= 64050 N, *kb*= 912.4(106) N/m, *km*= 1567.4(106) N/m

Eq. (8-27): *T* = *kFid*= 0*.*2(64050)(0.0158) = 203.36 N· m *Ans.*

From Prob. 8-27,



Bolt group is (38.1)/(15.88) or (1*.*5)*/*(5*/*8) = 2*.*4 diameters. Answer is much lower than RB&Wrecommendations.

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**8-29** *C*= *kb* / (*kb* + *km*) = 0.52/(0.52+2.1) = 0.2, *P* = *P*total/*N* = 355840/6 = 59 kN/bolt

Table 8-2, *At*= 9.15(10-5) m2; Table 8-9, *Sp*= 827 MPa; Eqs. (8-31) and (8-32),

*Fi*= 0.75 *At Sp*= 0.75(9.15(10-5))(827(106)) = 56.8 kN

(**a**) From Eq. (8-28), the factor of safety for yielding is



(**b**) From Eq. (8-29), the overload factor is



(**c**) From Eq. (8-30), the joint separation factor of safety is



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**8-30** 1/2 − 13 UNC Grade 8 bolt, *K* = 0.20

(**a**)Proof strength, Table 8-9, *Sp* = 827 MPa

Table 8-2,*At* = 9.15 (10-5) m2

Maximum, *Fi = SpAt* = 827(106)(9.15)(10-5) = 75.6 kN *Ans.*

(**b**) From Prob. 8-29, *C*= 0.2, *P* = 59 kN

Joint separation, Eq. (8-30) with *n*0 = 1

Minimum *Fi = P* (1 −*C*) = 59(106)(1 − 0.2) = 47.4 kN *Ans.*

(**c**)  = (75.6 + 47.4)/2 = 61.3 kN

Eq. (8-27), *T = KFid* = 0.2(61.3)103(12.7) = 13 kN⋅ mm *Ans.*

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**8-31** (**a**) Table 8-1, *At* = 20.1 mm2. Table 8-11, *Sp* = 380 MPa.

Eq. (8-31), *Fi* = 0.75 *Fp*= 0.75 *AtSp* = 0.75(20.1)380(10−3) = 5.73 kN

Eq. (*f* ), Sec. 8-7, 

Eq. (8-28) with *np* = 1,



*P*total = *NP* = 8(6.869) = 55.0 kN*Ans.*

(**b**) Eq. (8-30) with *n*0 = 1,



*P*total = *NP* = 8(7.94) = 63.5 kN*Ans.* Bolt stress would exceed proof strength

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**8-32** (**a**) Table 8-2, *At* =9.15(10-5) m2. Table 8-9, *Sp* =827 MPa.

Eq. (8-31), *Fi* = 0.75 *Fp*= 0.75 *AtSp* = 0.75(9.15(10-5))827(106) = 56.8 kN

Eq. (*f* ), Sec. 8-7, 

Eq. (8-28) with *np* = 1,



Round to *N* = 5 bolts *Ans.*

(**b**) Eq. (8-30) with *n*0 = 1,



Round to *N* = 5 bolts *Ans.*

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**8-33** Bolts: From Table A-31, the nut height is *H*= 10.8 mm. *L*≥*l +H* = 40 + 10.8 = 50.8 mm.

Round up to *L*= 55 mm *Ans.*

Eq. (8-14): *LT*= 2*d* + 6 = 2(12) + 6 = 30 mm

Table 8-7: *ld = L −LT* = 55 − 30 = 25 mm, *lt*= *l* −*ld* = 40 − 25 = 15 mm

*Ad*=*π* (122)/4 = 113.1 mm2, Table 8-1: *At*= 84.3 mm2

Eq. (8-17):



Members: Steel cyl. head: *t*= 20 mm, *d*= 12 mm, *D* = 18 mm, *E* = 207 GPa. Eq. (8-20),



Cast iron: *t*= 20 mm, *d*= 12 mm, *D*= 18 mm, *E* = 100GPa (from Table 8-8). The only difference from*k*1 is the material

*k*2= (100/207)(4470) = 2159 MN/m

Eq. (8-18): *km*= (1/4470 + 1/2159)−1= 1456 MN/m

*C*= *kb* / (*kb* + *km*) = 518.8/(518.8+1456) = 0.263

Table 8-11: *Sp*=650 MPa

For a non-permanent connection, usingEqs. (8-31) and (8-32)

*Fi*= 0.75 *AtSp*= 0.75(84.3)(650)10−3 = 41.1 kN

The total external load is *P*total= *pg Ag*, where *Ag* is the effective area of the cylinder, based on the effective sealing diameter of 100 mm. The external load per bolt is *P = P*total /*N*. Thus

*P*= [6*π*(1002)/4](10−3)/10 = 4.712 kN/bolt

Yielding factor of safety, Eq. (8-28):



Overload factor of safety, Eq. (8-29):



Separation factor of safety, Eq. (8-30):



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**8-34** Bolts: Grip, *l*= 12.7 + 15.87 = 28.57 mm. From Table A-31 , the nut height is *H*= 11.11 mm.

*L*≥*l + H*= 28.57 + 11.11= 39.68 mm.

Round up to *L*= 44.45 mm  *Ans.*

Eq. (8-13): *LT*= 2*d* + 6.35 = 2(12.7) + 6= 31.75 mm

Table 8-7: *ld = L −LT* =44.45−31.75 = 12.7 mm, *lt*= *l* −*ld* = 28.57−12.7 = 15.87 mm

*Ad*=*π* (12.72)/4 = 126.65mm2, Table 8-1: *At* = 91.55 mm2

Eq. (8-17):



Members: Steel cyl. head: *t*= 12.7 mm, *d* =12.7 mm, *D* = 19.05,mm *E* =207 GPa. Eq. (8-20),



Cast iron: Has two frusta.Midpoint of complete joint is at (12.7 + 15.88)/2 = 14.3 mm.

Upper frustum, *t*= 14.3 −12.7 = 1.60 mm, *d*= 12.7 mm,

*D*= 19.05 + 2(12.7) tan 30° = 33.7 mm, *E*= 100 GPa

Eq. (8-20) ⇒*k*2 = 50900 MN/m

Lower frustum, *t* = 14.3 mm, *d*= 12.7 mm, *D*= 19.05 mm, *E*= 100 GPa

Eq. (8-20) ⇒*k*3 = 2671 MN/m

Eq. (8-18): *km*= (1/5834+ 1/50900 + 1/2671)−1= 1769 MN/m

*C*= *kb* / (*kb* + *km*) = 870/(870+1769) = 0.299

Table 8-9: *Sp*= 586 MPa

For a non-permanent connection, usingEqs. (8-31) and (8-32)

*Fi*= 0.75 *AtSp*= 0.75(9.155(10-5))(586)(106) = 40.2 kN

The total external load is *P*total= *pg Ag*, where *Ag* is the effective area of the cylinder, based on the effective sealing diameter of 88.9 mm(0.0889 m). The external load per bolt is *P = P*total /*N*. Thus,

*P*= [10343(103)*π*(0.08892)/4]/10 = 6.4 kN/bolt

Yielding factor of safety, Eq. (8-28):



Overload factor of safety, Eq. (8-29):



Separation factor of safety, Eq. (8-30):



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**8-35** Bolts: Grip: *l* = 20 + 25 = 45 mm. From Table A-31, the nut height is *H*= 8.4 mm.

*L*≥*l +H* = 45 + 8.4 = 53.4 mm.

Round up to *L*= 55 mm *Ans.*

Eq. (8-14): *LT*= 2*d* + 6 = 2(10) + 6 = 26 mm

Table 8-7: *ld = L −LT* = 55 −26 = 29 mm, *lt*= *l* −*ld* = 45− 29 = 16 mm

*Ad*=*π* (102)/4 = 78.5 mm2, Table 8-1: *At*= 58.0 mm2

Eq. (8-17):



Members: Steel cyl. head: *t*= 20 mm, *d*= 10 mm, *D* = 15 mm, *E* = 207 GPa. Eq. (8-20),



Cast iron: Has two frusta.Midpoint of complete joint is at (20 + 25)/2 = 22.5 mm

Upper frustum, *t*= 22.5 − 20 = 2.5 mm, *d*= 10 mm,

*D*= 15 + 2(20) tan 30° = 38.09 mm, *E*= 100GPa (from Table 8-8),

Eq. (8-20) ⇒*k*2 = 45 880 MN/m

Lower frustum, *t* = 22.5 mm, *d*= 10 mm, *D*= 15 mm, *E*= 100GPa

Eq. (8-20) ⇒*k*3 = 1632 MN/m

Eq. (8-18): *km*= (1/3503 + 1/45 880 + 1/1632)−1= 1087 MN/m

*C*= *kb* / (*kb* + *km*) = 320.8/(320.8+1087) = 0.228

Table 8-11: *Sp*= 830 MPa

For a non-permanent connection, usingEqs. (8-31) and (8-32)

*Fi*= 0.75 *AtSp*= 0.75(58.0)(830)10−3 = 36.1 kN

The total external load is *P*total= *pg Ag*, where *Ag* is the effective area of the cylinder, based on the effective sealing diameter of 0.8 m. The external load per bolt is *P = P*total /*N*. Thus,

*P*= [550*π*(0.82)/4]/36= 7.679kN/bolt

Yielding factor of safety, Eq. (8-28):



Overload factor of safety, Eq. (8-29):



Separation factor of safety, Eq. (8-30):



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**8-36**

Bolts: Grip, *l* =9.53 + 12.7 = 22.23 mm. From Table A-31, the nut height is *H*= 9.53 mm.

*L*≥*l + H*= 22.23 + 9.53= 31.75 mm.

Let *L*= 31.75 mm *Ans.*

Eq. (8-13): *LT*= 2*d* + 6.35 = 2(11.11) + 6.35 = 28.47 mm

Table 8-7: *ld = L −LT* =31.75−28.47 = 3.28 mm, *lt*= *l* −*ld* = 22.23−3.28 = 18.95 mm

*Ad*=*π* (11.11)2/4 = 96.96 mm2, Table 8-2: *At*= 68.58 mm2

Eq. (8-17),



Members: Steel cyl. head: *t*=9.52 mm, *d* =11.11 mm, *D* = 16.67 mm, *E* = 207 GPa. Eq. (8-20),



Cast iron: Has two frusta.Midpoint of complete joint is at (9.52 + 12.7)/2 = 11.11 mm.

Upper frustum, *t*= 11.11 −9.52 = 1.59 mm, *d*= 11.11 mm,

*D*= 16.67 + 2(9.52) tan 30° = 27.66 mm , *E*= 100 GPa (from Table 8-8)

Eq. (8-20) ⇒*k*2 = 34245 MN/m

Lower frustum, *t* = 11.11 mm, *d*= 11.11 mm, *D*= 16.67 mm , *E*= 100 GPa

Eq. (8-20) ⇒*k*3 = 2467 MN/m

Eq. (8-18): *km*= (1/5505 + 1/34245 + 1/2467)−1= 1623 MN/m

*C*= *kb* / (*kb* + *km*) = 667/(667 +1623) = 0.291

Table 8-9: *Sp*= 827 MPa

For a non-permanent connection, usingEqs. (8-31) and (8-32)

*Fi*= 0.75 *AtSp*= 0.75(6.85(10-5))(827(106)) = 42.6 kN

The total external load is *P*total= *pg Ag*, where *Ag* is the effective area of the cylinder, based on the effective sealing diameter of 82.55 mm.The external load per bolt is *P = P*total /*N*. Thus,

*P*= [827(106)*π*(0.082552)/4]/8 = 5.53 kN/bolt

Yielding factor of safety, Eq. (8-28):



Overload factor of safety, Eq. (8-29):



Separation factor of safety, Eq. (8-30):



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**8-37**

From Table 8-7, *h = t*1= 20 mm

For *t*2>*d*, *l = h + d* /2 = 20 + 12/2 = 26 mm

*L* ≥ *h* + 1.5 *d* = 20 + 1.5(12) = 38 mm. Round up to *L* = 40 mm

*LT* = 2*d* + 6 = 2(12) + 6 = 30 mm

*ld* = *L*−*LT* = 40 − 20 = 10 mm

*lt*= *l* −*ld* = 26 − 10 = 16 mm

From Table 8-1, *At*= 84.3 mm2.*Ad*= *π* (122)/4 = 113.1 mm2

Eq. (8-17),



Similar to Fig. 8-23, we have three frusta.

Top frusta, steel: *t*= *l* / 2 = 13 mm, *d*= 12 mm, *D*= 18 mm, *E* = 207 GPa. Eq. (8-20)



Middle frusta, steel: *t*= 20 − 13 = 7 mm, *d*= 12 mm, *D*= 18 + 2(13− 7) tan 30° = 24.93 mm, *E* = 207 GPa. Eq. (8-20) ⇒*k*2 = 15 660 MN/m

Lower frusta, cast iron: *t*= 26 − 20 = 6 mm, *d*= 12 mm, *D*= 18 mm, *E* = 100GPa (see Table 8-8). Eq. (8-20)⇒*k*3 = 3 887 MN/m

Eq. (8-18), *km*= (1/5316 + 1/15660 + 1/3 887)−1 = 1 964 MN/m

*C = kb /* (*kb + km*) = 744.0/(744.0 + 1 964) = 0.275

Table 8-11: *Sp*= 650 MPa. For a non-permanent connection, usingEqs. (8-31) and (8-32)

*Fi*= 0.75 *AtSp*= 0.75(84.3)(650)10−3 = 41.1 kN

The total external load is *P*total= *pg Ag*, where *Ag* is the effective area of the cylinder, based on the effective sealing diameter of 100 mm. The external load per bolt is *P = P*total /*N*. Thus

*P*= [6*π*(1002)/4](10−3)/10 = 4.712 kN/bolt

Yielding factor of safety, Eq. (8-28)



Overload factor of safety, Eq. (8-29)



Separation factor of safety, Eq. (8-30)



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**8-38**

From Table 8-7, *h = t*1= 12.7 mm

For *t*2>*d*, *l = h + d* /2 = 12.7 + 12.7/2 = 19.05 mm

*L* ≥ *h* + 1.5 *d* = 12.7 + 1.5(12.7) = 31.75 mm. Let *L* = 31.75 mm

*LT* = 2*d* + 6.25 = 2(12.7) + 6.25 = 31.75 mm. All threaded.

From Table 8-1, *At*= 91.55 mm2. The bolt stiffness is

*kb= At E / l*= 9.15(10-5)(207(106))/0.01905=994 MN/m

Similar to Fig. 8-23, we have three frusta.

Top frusta, steel: *t*= *l* / 2 = 9.53 mm, *d*= 12.7 mm, *D*= 19.05 mm, *E* = 207 GPa



Middle frusta, steel: *t*= 12.7 − 9.53 = 3.18 mm, *d*= 12.7 mm,

*D*= 19.05 + 2(19.05−12.7) tan 30° = 26.4 mm, *E*= 207 GPa.

Eq. (8-20) ⇒*k*2 = 32273 MN/m

Lower frusta, cast iron: *t*= 19.05−12.7 = 6.35 mm, *d*= 12.7 mm, *D*= 19.05 mm, *E*= 100 GPa. Eq. (8-20)⇒*k*3 = 4113 MN/m

Eq. (8-18), *km*= (1/6735 + 1/32273 + 1/4113)−1= 2366 MN/m

*C = kb /* (*kb + km*) = 994/(994 + 2366) = 0.296

Table 8-9,*Sp*=586 MPa. For a non-permanent connection, using Eqs. (8-31) and (8-32)

*Fi*= 0.75 *AtSp*= 0.75(9.15(10-5))(586(106)) = 40.2 kN

The total external load is *P*total= *pg Ag*, where *Ag* is the effective area of the cylinder, based on the effective sealing diameter of 88.90 mm. The external load per bolt is *P = P*total /*N*. Thus

*P*= [10.34(106)*π*(0.08892)/4]/10 = 6.42 kN/bolt

Yielding factor of safety, Eq. (8-28)



Overload factor of safety, Eq. (8-29)



Separation factor of safety, Eq. (8-30)



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**8-39**

From Table 8-7, *h = t*1= 20 mm

For *t*2>*d*, *l = h + d* /2 = 20 + 10/2 = 25 mm

*L* ≥ *h* + 1.5 *d* = 20 + 1.5(10) = 35 mm. Let *L* = 35 mm

*LT* = 2*d* + 6 = 2(10) + 6 = 26 mm

*ld* = *L*−*LT* = 35− 26 = 9 mm

*lt*= *l* −*ld* = 25 − 9 = 16 mm

From Table 8-1, *At*= 58.0 mm2.*Ad*= *π* (102)/4 = 78.5 mm2

Eq. (8-17),



Similar to Fig. 8-23, we have three frusta.

Top frusta, steel: *t*= *l* / 2 = 12.5 mm, *d* = 10 mm, *D*= 15 mm, *E*= 207 GPa. Eq. (8-20)



Middle frusta, steel: *t*= 20 − 12.5 = 7.5 mm, *d*= 10 mm, *D*= 15 + 2(12.5− 7.5) tan 30° = 20.77 mm, *E* = 207 GPa. Eq. (8-20) ⇒*k*2 = 10 975 MN/m

Lower frusta, cast iron: *t*= 25− 20 = 5 mm, *d*= 10 mm, *D*= 15 mm, *E*= 100GPa (see Table 8-8). Eq. (8-20)⇒*k*3 = 3239 MN/m

Eq. (8-18), *km*= (1/4 163 + 1/10975 + 1/3 239)−1= 1562 MN/m

*C = kb /* (*kb + km*) = 530.1/(530.1 + 1562) = 0.253

Table 8-11: *Sp*= 830 MPa. For a non-permanent connection, using Eqs. (8-31) and (8-32)

*Fi*= 0.75 *AtSp*= 0.75(58.0)(830)10−3 = 36.1kN

The total external load is *P*total= *pg Ag*, where *Ag* is the effective area of the cylinder, based on the effective sealing diameter of 0.8 m. The external load per bolt is *P = P*total /*N*. Thus

*P*= [550*π*(0.82)/4]/36 = 7.679 kN/bolt

Yielding factor of safety, Eq. (8-28)



Overload factor of safety, Eq. (8-29)



Separation factor of safety, Eq. (8-30)



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**8-40**

From Table 8-7, *h = t*1= 9.53 mm

For *t*2>*d*, *l = h + d* /2 = 9.53 + 11.11/2 = 15.08 mm

*L* ≥ *h* + 1.5 *d* = 9.53 + 1.5(11.11) = 26.09 mm. Round up to *L* = 31.75 mm

*LT* = 2*d* + 6.35 = 2(11.11) + 6.35 = 28.58 mm

*ld* = *L*−*LT* = 31.75 − 28.59 = 3.18 mm

*lt* = *l* −*ld* = 15.08 − 3.18 = 11.91 mm

*Ad*=*π* (11.11)2/4 = 96.96 mm2, Table 8-2: *At*= 68.58 mm2

Eq. (8-17),



Similar to Fig. 8-23, we have three frusta.

Top frusta, steel: *t*= *l* / 2 = 7.54 mm, *d*= 11.11 mm, *D*= 16.67 mm, *E*= 207 GPa



Middle frusta, steel: *t*= 9.53−7.54 = 1.98 mm, *d*= 11.11 mm,

*D* =16.67+ 2(15.08−9.53) tan 30° = 23.08 mm, *E* = 207 GPa.

Eq. (8-20) ⇒*k*2 = 37885 MN/m

Lower frusta, cast iron: *t*= 15.08−9.53 = 5.56 mm, *d*= 11.11 mm, *D*= 16.67 mm,

*E*= 100 GPa. Eq. (8-20)⇒*k*3 = 3599 MN/m

Eq. (8-18), *km* = (1/6227 + 1/37885 + 1/3599)−1= 2151 MN/m

*C = kb /* (*kb + km*) = 1002/(1002 + 2151) = 0.318

Table 8-9,*Sp* = 827(106). For a non-permanent connection, using Eqs. (8-31) and (8-32)

*Fi*= 0.75 *AtSp*= 0.75(6.85(10-5))(827)(106) = 42.5 kN

The total external load is *P*total= *pg Ag*, where *Ag* is the effective area of the cylinder, based on the effective sealing diameter of 82.55 mm. The external load per bolt is *P = P*total /*N*. Thus

*P*= [8274(103)*π*(0.082552)/4]/8 = 5.5 kN/bolt

Yielding factor of safety, Eq. (8-28)



Overload factor of safety, Eq. (8-29)



Separation factor of safety, Eq. (8-30)



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**8-41**

This is a design problem and there is no closed-form solution path or a unique solution. What is presented here is one possible iterative approach. We will demonstrate this with an example.

1. Select the diameter, *d*. For this example, let *d* = 10 mm. Using Eq. (8-20) on members, and combining using Eq. (8-18), yields *km* = 1 141 MN/m (see Prob. 8-33 for method of calculation.

2. Look up the nut height in Table A-31. For the example, *H* = 8.4 mm. From this, *L* is rounded up from the calculation of *l* + *H* = 40 + 8.4 = 48.4 mm to 50 mm. Next, calculations are made for *LT*= 2(10) + 6 = 26 mm, *ld* = 50 − 26 = 24 mm, *lt* = 40 − 24 = 16 mm. From step 1, *Ad=π* (102)/4 = 78.54 mm2. Next, from Table 8-1, *At*= 78.54 mm2. From Eq. (8-17), *kb*= 356 MN/m. Finally, from Eq. (*f*), Sec. 8-7, *C*= 0.238.

3. From Prob. 8-33, the bolt circle diameter is *E*= 200 mm. Substituting this for *Db*in Eq. (8-34), the number of bolts are



Rounding this up gives *N* = 16.

4. Next, select a grade bolt. Based on the solution to Prob. 8-33, the strength of ISO 9.8 was so high to give very large factors of safety for overload and separation. Try ISO 4.6 with *Sp*= 225 MPa. From Eqs. (8-31) and (8-32) for a non-permanent connection, *Fi*= 9.79 kN.

5. The external load requirement per bolt is *P*= 1.15 *pgAg/N*, where from Prob 8-33,*pg*= 6 MPa, and *Ag* = *π* (1002)/4. This gives *P*= 3.39 kN/bolt.

6. Using Eqs. (8-28) to (8-30) yield *np*= 1.23, *nL*= 4.05, and *n*0= 3.79.

Steps 1 - 6 can be easily implemented on a spreadsheet with lookup tables for the tables used from the text. The results for four bolt sizes are shown below. The dimension of each term is consistent with the example given above.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *d* | *km* | *H* | *L* | *LT* | *ld* | *lt* | *Ad* | *At* | *kb* |
| 8 | 854 | 6.8 | 50 | 22 | 28 | 12 | 50.26 | 36.6 | 233.9 |
| 10 | 1141 | 8.4 | 50 | 26 | 24 | 16 | 78.54 | 58 | 356 |
| 12 | 1456 | 10.8 | 55 | 30 | 25 | 15 | 113.1 | 84.3 | 518.8 |
| 14 | 1950 | 12.8 | 55 | 34 | 21 | 19 | 153.9 | 115 | 686.3 |
|  |  |  |  |  |  |  |  |  |  |
| *d* | *C* | *N* | *Sp* | *Fi* | *P* | *np* | *nL* | *n*0 |  |
| 8 | 0.215 | 20 | 225 | 6.18 | 2.71 | 1.22 | 3.53 | 2.90 |  |
| 10 | 0.238 | 16 | 225 | 9.79 | 3.39 | 1.23 | 4.05 | 3.79 |  |
| 12 | 0.263 | 13\* | 225 | 14.23 | 4.17 | 1.24 | 4.33 | 4.63 |  |
| 14 | 0.276 | 12 | 225 | 19.41 | 4.52 | 1.25 | 5.19 | 5.94 |  |

\*Rounded down from13.08997, so spacing is slightly greater than four diameters.

Any one of the solutions is acceptable. A decision-maker might be cost such as

*N*× cost/bolt, and/or *N*× cost per hole, etc.

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**8-42** This is a design problem and there is no closed-form solution path or a unique solution. What is presented here is one possible iterative approach. We will demonstrate this with an example.

1. Select the diameter, *d*. For this example, let *d* = 12.7 mm. Using Eq. (8-20) on three frusta (see Prob. 8-34 solution), and combining using Eq. (8-19), yields *km* = 1769 MN/m.

2. Look up the nut height in Table A-31. For the example, *H* = 11.11 mm. From this, *L* is rounded up from the calculation of *l* + *H* = 28.58 + 11.11 = 39.69 mm to 44.45 mm. Next, calculations are made for *LT*= 2(12.7) + 6.25 = 31.75 mm, *ld* = 44.45− 31.75= 12.7 mm, *lt* = 31.75−12.7= 15.88 mm. From step 1, *Ad=π* (12.72)/4 = 126.65 mm2. Next, from Table 8-1, *At*= 91.5 mm2. From Eq. (8-17), *kb*= 755.8 MN/m. Finally, from Eq. (*f*), Sec. 8-7, *C* = 0.299.

3. From Prob. 8-34, the bolt circle diameter is *E*= 152.4 mm. Substituting this for *Db*in Eq. (8-34), for the number of bolts



Rounding this up gives *N*= 10.

4. Next, select a grade bolt. Based on the solution to Prob. 8-34, the strength of SAE grade 5 was adequate. Use this with *Sp*= 586 MPa. From Eqs. (8-31) and (8-32) for a non-permanent connection, *Fi*= 40.2 kN.

5. The external load requirement per bolt is *P*= 1.15 *pg Ag/N*, where from Prob 8-34,

*pg* =10.34 Mpa, and *Ag* = *π* (88.92)/4 . This gives *P*= 7383 kN/bolt.

6. Using Eqs. (8-28) to (8-30) yield *np*= 1.26, *nL* =6.07, and *n*0 = 7.78.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *d* | *km* | *H* | *L* | *LT* | *ld* | *lt* | *Ad* | *At* | *kb* |
| 9.53 | 1182 | 8.33 | 38.10 | 25.40 | 12.70 | 15.88 | 71.23 | 50.00 | 417.3 |
| 11.11 | 1606 | 9.53 | 38.10 | 28.58 | 9.53 | 19.05 | 96.97 | 68.58 | 550.1 |
| 12.70 | 1769 | 11.11 | 44.45 | 31.75 | 12.70 | 15.88 | 126.64 | 91.55 | 755.8 |
| 14.29 | 2098 | 12.30 | 44.45 | 34.93 | 9.53 | 19.05 | 160.32 | 117.42 | 933.3 |
|  |  |  |  |  |  |  |  |  |  |
| *d* | *C* | *N* | *Sp* | *Fi* | *P* | *np* | *nL* | *n*0 |  |
| 9.53 | 0.261 | 13 | 586 | 21.98 | 5.68 | 1.25 | 4.95 | 5.24 |  |
| 11.11 | 0.273 | 11 | 586 | 30.14 | 6.71 | 1.26 | 5.48 | 6.18 |  |
| 12.70 | 0.299 | 10 | 586 | 40.24 | 7.38 | 1.26 | 6.07 | 7.78 |  |
| 14.29 | 0.308 | 9 | 586 | 51.60 | 8.20 | 1.27 | 6.81 | 9.09 |  |

Any one of the solutions is acceptable. A decision-maker might be cost such as

*N*× cost/bolt, and/or *N*× cost per hole, etc.

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**8-43** This is a design problem and there is no closed-form solution path or a unique solution. What is presented here is one possible iterative approach. We will demonstrate this with an example.

1. Select the diameter, *d*. For this example, let *d* = 10 mm.Using Eq. (8-20) on three frusta (see Prob. 8-35 solution), and combining using Eq. (8-19), yields *km* = 1 087 MN/m.

2. Look up the nut height in Table A-31. For the example, *H* = 8.4 mm. From this, *L* is rounded up from the calculation of *l* + *H* = 45 + 8.4 = 53.4 mm to 55 mm. Next, calculations are made for *LT*= 2(10) + 6 = 26 mm, *ld* = 55− 26 = 29 mm, *lt* = 45− 29= 16 mm. From step 1, *Ad=π* (102)/4 = 78.54 mm2. Next, from Table 8-1, *At*= 58.0 mm2. From Eq. (8-17), *kb*= 320.9 MN/m. Finally, from Eq. (*f*), Sec. 8-7, *C* = 0.228.

3. From Prob. 8-35, the bolt circle diameter is *E*= 1000 mm. Substituting this for *Db*in Eq. (8-34), for the number of bolts



Rounding this up gives *N*= 79. A rather large number,sincethe bolt circle diameter,*E* is so large. Try larger bolts.

4. Next, select a grade bolt. Based on the solution to Prob. 8-35, the strength of ISO 9.8 was so high to give very large factors of safety for overload and separation. Try ISO 5.8 with *Sp*= 380 MPa. From Eqs. (8-31) and (8-32) for a non-permanent connection, *Fi*= 16.53kN.

5. The external load requirement per bolt is *P*= 1.15 *pg Ag/N*, where from Prob 8-35,*pg* =0.550 MPa, and *Ag* = *π* (8002)/4 . This gives *P*= 4.024kN/bolt.

6. Using Eqs. (8-28) to (8-30) yield *np*= 1.26, *nL* =6.01, and *n*0 = 5.32.

Steps 1 - 6 can be easily implemented on a spreadsheet with lookup tables for the tables used from the text. The results for three bolt sizes are shown below. The dimension of each term is consistent with the example given above.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *d* | *km* | *H* | *L* | *LT* | *ld* | *lt* | *Ad* | *At* | *kb* |
| 10 | 1087 | 8.4 | 55 | 26 | 29 | 16 | 78.54 | 58 | 320.9 |
| 20 | 3055 | 18 | 65 | 46 | 19 | 26 | 314.2 | 245 | 1242 |
| 36 | 6725 | 31 | 80 | 78 | 2 | 43 | 1018 | 817 | 3791 |
|  |  |  |  |  |  |  |  |  |  |
| *d* | *C* | *N* | *Sp* | *Fi* | *P* | *np* | *nL* | *n*0 |  |
| 10 | 0.228 | 79 | 380 | 16.53 | 4.024 | 1.26 | 6.01 | 5.32 |  |
| 20 | 0.308 | 40 | 380 | 69.83 | 7.948 | 1.29 | 9.5 | 12.7 |  |
| 36 | 0.361 | 22 | 380 | 232.8 | 14.45 | 1.3 | 14.9 | 25.2 |  |

A large range is presented here.Any one of the solutions is acceptable. A decision-maker might be cost such as*N*× cost/bolt, and/or *N*× cost per hole, etc.

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**8-44** This is a design problem and there is no closed-form solution path or a unique solution. What is presented here is one possible iterative approach. We will demonstrate this with an example.

1. Select the diameter, *d*. For this example, let *d* = 9.53 mm. Using Eq. (8-20) on three frusta (see Prob. 8-36 solution), and combining using Eq. (8-19), yields *km* = 1300 MN/m.

2. Look up the nut height in Table A-31. For the example, *H* = 8.33 mm. From this,

*L*≥*l* + *H* = 22.23 + 8.33 = 30.56 mm. Rounding up, *L* =31.75 mm. Next, calculations are made for *LT*= 2(9.53) + 6.25= 25.4 mm, *ld* = 31.75− 25.4= 6.35 mm, *lt* = 22.23− 6.35 = 15.88 mm. From step 1, *Ad=π* (9.532)/4 = 71.23 mm2. Next, from Table 8-1, *At*= 50 mm2. From Eq. (8-17), *kb*= 508.7 MN/m. Finally, from Eq. (*f*), Sec. 8-7, *C* = 0.263.

3. From Prob. 8-36, the bolt circle diameter is *E*= 152.4 mm. Substituting this for *Db*in Eq. (8-34), for the number of bolts



Rounding this up gives *N* = 13.

4. Next, select a grade bolt. Based on the solution to Prob. 8-36, the strength of SAE grade 8 seemed high for overload and separation.Try SAE grade 5 with *Sp*=586 MPa. From Eqs. (8-31) and (8-32) for a non-permanent connection, *Fi*= 22 kN.

5. The external load requirement per bolt is *P*= 1.15 *pg Ag/N*, where from Prob 8-36,

*pg*= 8.27 MPa, and *Ag* = *π* (82.552)/4. This gives *P*= 39.2 kN/bolt.

6. Using Eqs. (8-28) to (8-30) yield *np*= 1.27, *nL*= 6.65, and *n*0 =7.81.

Steps 1 - 6 can be easily implemented on a spreadsheet with lookup tables for the tables used from the text. For this solution we only looked at one bolt size,, but evaluated changing the bolt grade. The results for four bolt grades are shown below. The dimension of each term is consistent with the example given above.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *d* | *km* | *H* | *L* | *LT* | *ld* | *lt* | *Ad* | *At* | *kb* |
| 9.53 | 1300 | 8.33 | 31.75 | 25.4 | 6.35 | 15.88 | 71.23 | 50 | 508.7 |
|  |  |  |  |  |  |  |  |  |  |
| *d* | *C* | *N* | SAE grade | *Sp* | *Fi* | *P* | *np* | *nL* | *n*0 |
| 9.53 | 0.281 | 13 | 1 | 227.53 | 8.53 | 3.92 | 1.18 | 2.58 | 3.03 |
| 9.53 | 0.281 | 13 | 2 | 379.21 | 14.22 | 3.92 | 1.24 | 4.30 | 5.05 |
| 9.53 | 0.281 | 13 | 4 | 448.16 | 16.80 | 3.92 | 1.25 | 5.08 | 5.97 |
| 9.53 | 0.281 | 13 | 5 | 586.05 | 21.98 | 3.92 | 1.27 | 6.65 | 7.81 |

Note that changing the bolt grade only affects *Sp, Fi , np, nL,* and*n*0. Any one of the solutions is acceptable, especially the lowest grade bolt.

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**8-45** (**a**) ****

Half of the external moment is contributed by the line load in the interval 0 ≤ *θ*≤ *π*



from which 



Noting *φ*1 = 75°, *φ*2 = 105°,

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**(b) **



**(c)** *F* = *F*max sin *θ*

*M* = 2*F*max*R*[(1) sin2 90° + 2 sin2 60° + 2 sin2 30° + (1) sin2(0)] = 6*F*max*R*

from which,



The simple general equation resulted from part (*b*)



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**8-46**

(**a**) From Table 8-11, *Sp* = 600 MPa. From Table 8-1, *At* = 353 mm2.

Eq. (8-31): 

Table 8-15: *K* = 0.18

Eq. (8-27): *T*= *K Fi d* = 0.18(190.6)(24) = 823 N⋅m *Ans.*

(**b**) Washers: *t* = 4.6 mm, *d* = 24 mm, *D* = 1.5(24) = 36 mm, *E* = 207 GPa.

Eq. (8-20),



Cast iron: *t* =20 mm, *d* = 24 mm, *D* = 36 + 2(4.6) tan 30° = 41.31 mm, *E* = 135GPa. Eq. (8-20) ⇒*k*2 = 10 785 MN/m

Steel joist: *t* = 20 mm, *d*= 24 mm, *D* = 41.31 mm, *E*= 207 GPa. Eq. (8-20) ⇒*k*3 = 16 537 MN/m

Eq. (8-18): *km* = (2 / 31 990 + 1 / 10 785 +1 / 16 537)−1 = 4 636 MN/m

Bolt: *l* = 2(4.6) + 2(20) = 49.2 mm. Nut, Table A-31, *H*= 21.5 mm. *L*> 49.2 + 21.5 = 70.7 mm. From Table A-17, use *L* = 80 mm. From Eq. (8-14)

*LT* = 2(24) + 6 = 54 mm, *ld* = 80 − 54 = 26 mm, *lt* = 49.2 − 26 = 23.2 mm

From Table (8-1), *At* = 353 mm2, *Ad*= *π*(242) / 4 = 452.4 mm2

Eq. (8-17):



*C*= *kb* / (*kb* + *km*) = 1680 / (1680 + 4636) = 0.266, *Sp* = 600 MPa, *Fi*= 190.6 kN,

*P*= *P*total / N = 18/4 = 4.5kN

Yield: From Eq. (8-28)



Load factor: From Eq. (8-29)



Separation: From Eq. (8-30)



As was stated in the text, bolts are typically preloaded such that the yielding factor of safety is not much greater than unity which is the case for this problem. However, the other load factors indicate that the bolts are oversized for the external load.

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**8-47** (**a**)ISO M 20 × 2*.*5 grade 8.8 coarse pitch bolts, lubricated.

Table 8-2, *At*= 245 mm2

Table 8-11, *Sp*= 600 MPa

*Fi* = 0.90*AtSp*= 0.90(245)600(10−3) = 132.3 kN

Table 8-15, *K* = 0.18

Eq. (8-27), *T = KFid* = 0.18(132.3)20 = 476 N ⋅ m *Ans.*

(**b**)Table A-31, *H* = 18 mm,*L* ≥ *LG*+ *H* = 48 + 18 = 66 mm. Round up to*L* = 80 mm per Table A-17.



*Ad* = *π* (202) /4 = 314.2 mm2,



Members: Since all members are steel use Eq. (8-22) with *E* = 207 MPa, *l* = 48 mm, *d* = 20mm





*P* = *P*total/*N* = 40/2 = 20 kN,

Yield: From Eq. (8-28)



Load factor: From Eq. (8-29)



Separation: From Eq. (8-30)



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**8-48** From Prob. 8-29 solution, *P*max =59.3 kN, *C* = 0.2, *Fi* = 56.8 kN, *At* = 9.15(10-5) m2



Eq. (8-39), 

Eq. (8-41), 

(**a**) Goodman Eq. (8-45) for grade 8 bolts, *Se* = 160 MPa (Table 8-17), *Sut* = 1034 MPa (Table 8-9)



(**b**) Gerber Eq. (8-46)



(**c**) ASME-elliptic Eq. (8-47) with *Sp* = 827 MPa (Table 8-9)



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**8-49** **Attention to the Instructor**. Part (**d**) requires the determination of the endurance strength, *Se*, of a class 5.8 bolt. Table 8-17 does not provide this and the student will be required to estimate it by other means [seethe solution of part (**d**)].

Per bolt, *Pb*max = 60/8 = 7.5 kN, *Pb*min = 20/8 = 2.5 kN



(**a**) Table 8-1, *At* = 20.1 mm2; Table 8-11, *Sp* = 380 MPa

Eqs. (8-31) and (8-32), *Fi* = 0.75 *AtSp* = 0.75(20.1)380(10−3) = 5.73 kN

Yield, Eq. (8-28), 

(**b**) Overload, Eq. (8-29), 

(**c**) Separation, Eq. (8-30), 

(**d**) Goodman, Eq. (8-35), 

Eq. (8-36), 

Table 8-11, *Sut* = 520 MPa, *σi = Fi /At* = 5.73(103)/20.1 = 285 MPa

We have a problem for *Se*. Table 8-17 does not list *Se* for class 5.8 bolts. Here, we will estimate *Se* using the methods of Chapter 6. Estimate  from the,

Eq. (6-10): .

Table 6-2: *a* = 3.04, *b* = − 0.217

Eq. (6-18): 

Eq. (6-19): *kb* = 1

Eq. (6-25): *kc* = 0.85

The fatigue stress-concentration factor, from Table 8-16, is *Kf* = 2.2. For simple axial loading and infinite-life it is acceptable to reduce the endurance limit by *Kf* and use the nominal stresses in the stress/strength/design factor equations. Thus, from

Eq. (6-17), *Se = ka kb kc / Kf*=0.783(1)0.85(260) / 2.2 = 78.7 MPa

Eq. (8-38),



It is obvious from the various answers obtained, the bolted assembly is undersized. This can be rectified by a one or more of the following: more bolts, larger bolts, higher class bolts.

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**8-50** Per bolt, *Pb*max = *P*max /*N* = 355.8/10 = 35.58 kN, *Pb*min = *P*min /*N* = 88.96/10 = 8.89 kN

*C = kb* / (*kb* + *km*) = 700/(700 + 2101) = 0.25

(**a**) Table 8-2, *At* = 9.15(10-5) m2, Table 8-9, *Sp* = 827 MPa and *Sut* = 1034 MPa

Table 8-17, *Se* = 160 MPa

Eqs. (8-31) and (8-32), *Fi* = 0.75 *At Sp*⇒*σi*= *Fi* /*At* = 0.75 *Sp* = 0.75(827) =620.53 MPa

Eq. (8-35), 

Eq. (8-36), 

Eq. (8-38),



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**8-51** Given: (8) M8 × 1.5 class 9.8 bolts, *kb* = 1.5 MN/mm, *km* = 3.9 MN/mm, reversing load with *P*max = 50 kN.

Per bolt, *P* = *P*max/*N* = 50/8 = 6.25 kN

Table 8-1, *At* = 36.6 mm2, Table 8-11, *Sut* = 900 MPa, *Sp* = 650 MPa,

Table 8-17, *Se* = 140 MPa

Eq. (*f*), Sec. 8-7: *C* = *kb* / (*kb*+ *km*) = 1.5/(1.5 + 3.9) = 0.278

Eqs. (8-31) and (8-32): *Fi* = 0.75 *At Sp* = 0.75(36.6)650(10−3) = 17.84 kN

*σi* = *Fi* / *At* = 17.84(103)/36.6 = 487.5 MPa

Eq. (8-39): *σa* = *CP* / (2*At*) = 0.278(6.25)103/[2(36.6)] = 23.74 MPa

(**a**) Goodman: Eq. (8-45):

*Ans.*

(**b**) Gerber: Eq. (8-46):



(**c**) Morrow: Use Goodman Eq. (8-45) replacing *Sut* with. Equation (6-44) gives

= *Sut* + 345 = 900 + 345 = 1 245MPa



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**8-52** From Prob. 8-33, *C* = 0.263,*P*max=4.712kN / bolt*, Fi*= 41.1 kN,*Sp* = 650 MPa, and

*At* = 84.3 mm2

*σi* = 0.75 *Sp* = 0.75(650) = 487.5 MPa

Eq. (8-39): 

Eq. (8-40) 

(**a**) Goodman: From Table 8-11, *Sut*= 900 MPa, and from Table 8-17, *Se* = 140 MPa

Eq. (8-45): 

(**b**) Gerber:

Eq. (8-46):



(**c**) ASME-elliptic:

Eq. (8-47):



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**8-53** From Prob. 8-34, *C* = 0.299*,P*max= 6.4 kN/bolt,*Fi*= 40.25 kN,*Sp* = 586 MPa, and

*At*= 9.15(10-5) m2



Eq. (8-37): 

Eq. (8-38) 

(**a**) Goodman: From Table 8-9, *Sut*= 827 MPa, and from Table 8-17, *Se*= 129.6 MPa

Eq. (8-45): 

(**b**) Gerber:

Eq. (8-46):



(**c**) ASME-elliptic:

Eq. (8-47):



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**8-54** From Prob. 8-35, *C* = 0.228*, P*max = 7.679 kN/bolt,*Fi*=36.1 kN, *Sp*= 830 MPa, and

*At* =58.0 mm2

*σi* = 0.75 *Sp*= 0.75(830) = 622.5 MPa

Eq. (8-37): 

Eq. (8-38) 

(**a**) Goodman: From Table 8-11, *Sut*= 1040 MPa, and from Table 8-17, *Se* = 162 MPa

Eq. (8-45): 

(**b**) Gerber:

Eq. (8-46):



(**c**) ASME-elliptic:

Eq. (8-47):



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**8-55** From Prob. 8-36, *C* = 0.291*,P*max=5.53 kN/bolt,*Fi*= 42.56 kN,*Sp* = 827 MPa, and

*At* =6.86(10-5) m2



Eq. (8-37): 

Eq. (8-38) 

(**a**) Goodman: From Table 8-9, *Sut*= 1034 MPa, and from Table 8-17, *Se* =160 MPa

Eq. (8-45): 

(**b**) Gerber:

Eq. (8-46):



(**c**) ASME-elliptic:

Eq. (8-47):



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**8-56** From Prob. 8-52, *C* = 0.263, *Se* = 140 MPa, *Sut* = 900 MPa,*At* = 84.4 mm2, *σi* = 487.5 MPa, and *P*max = 4.712 kN.

*P*min =*P*max / 2 = 4.712/2 = 2.356 kN

Eq. (8-35): 

Eq. (8-36):



Eq. (8-38):



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**8-57** From Prob. 8-53, *C* = 0.299, *Se* = 130 MPa, *Sut* = 827 MPa,*At* = 9.15(10-5) mm2, *σi* = 440 MPa, and *P*max = 6.4 kN

*P*min =*P*max / 2 = 6.4/2 = 3.2 kN

Eq. (8-35): 

Eq. (8-36):



Eq. (8-38):



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**8-58** From Prob. 8-54, *C* = 0.228, *Se* = 162 MPa, *Sut* = 1040 MPa,*At* = 58.0 mm2, *σi* = 622.5 MPa, and *P*max = 7.679kN.

*P*min =*P*max / 2 = 7.679/2 = 3.840kN

Eq. (8-35): 

Eq. (8-36):



Eq. (8-38):



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**8-59** From Prob. 8-55, *C* = 0.291, *Se* = 160 MPa, *Sut* = 1034 MPa, *At* = 6.86 (10-5) m2, *σi* = 620 MPa, and *P*max = 5.53 kN

*P*min =*P*max / 2 = 5.53/2 = 2.76 kN

Eq. (8-35): 

Eq. (8-36):



Eq. (8-38):



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**8-60** Let the repeatedly-applied load be designated as *P*. From Table A-22, *Sut*= 646 MPa*.* Referring to the Figure of Prob. 3-136, the following notation will be used for theradii of Section AA.

*ri*= 38.1 mm, *ro*= 63.5 mm, *rc*= 50.8 mm

From Table 3-4, with *R* = 12.7 mm,



If *P* is the maximum load



(**a**)*Eye:* Section AA,

Table 6-2: *a* = 75.84 MPa, *b* = − 0.650

Eq. (6-18): 

Eq. (6-23): *de* = 0.370 *d*

Eq. (6-19): 

Eq. (6-25): *kc* = 0.85

Eq. (6-10): 

Eq. (6-18): *Se* = 0.575(0.978)0.85(323) = 154.44 MPa

From Eq. 6-48, forGerber,



With *σm* = *σa*,



where *P* is in kN.

*Thread:* Die cut. Table 8-17 gives*Se* = 128.24 MPa for rolled threads. Use Table 8-16 to find*Se*for die cut threads

*Se*= 128.24(3*.*0*/*3*.*8) = 101.35 MPa

Table 8-2, *At* = 427.7 mm2, *σ = P/At* = *P* /4.27(10-4) = 2338 *P*, *σa = σm =σ* /2 = 1169 *P*

From Eq. 6-48, Gerber



Comparing 0.085*/P* with 0.0071*/P*, we conclude that the *eye* is weaker in fatigue. *Ans.*

(**b**)Strengthening steps can include heat treatment, cold forming, cross section change (around section is a poor cross section for a curved bar in bending because the bulk of the materialis located where the stress is small). *Ans.*

(**c**)For *nf*= 2



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**8-61** Member, Eq. (8-22) with *E* =110 GPa, *d* = 19.05 mm, and *l* = 38.1 mm



Bolt, Eq. (8-13),

*LT* = 2*d* + 6.35 = 2(19.05) + 6.35 = 44.45 mm

*l* = 38.10 mm

*ld*=*L −LT* =63.50 − 44.45 = 19.05 mm

*lt*=*l*−*ld* =38.10 −19.05 = 19.05 mm

Table 8-2,

*At* = 240.6 mm2

*Ad* = π(19.052)/4 = 285.16 mm2

Eq. (8-17),





Eq. (8-35),



Eq.(8-36),



(**a**) From Table 8-9, *Sp* = 586 MPa, and Eq. (8-51), the yielding factor of safety is



(**b**) From Eq. (8-29), the overload factor of safety is



(**c**) From Eq. (8-30), the factor of safety based on joint separation is



(**d**) From Table 8-17, *Se* = 128.24 MPa; Table 8-9, *Sut* = 827 MPa; the preload stress is

*σi* = *Fi* / *At* = 112(103)/2.4(10-4) = 462 MPa; and from Eq. (8-38)



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**8-62** (**a**)Table 8-2, *At*= 91.54 mm2

Table 8-9, *Sp*= 827 MPa, *Sut*= 1034 Mpa

Table 8-17, *Se*= 160 Mpa

Eqs. (8-31) and (8-32), *σi* = 0.75 *Sp* = 0.75(827) = 620 Mpa



Eq. (8-45) for the Goodman criterion,



(**b**)*Fi*= 0.75*AtSp* = 0.75(9.15)(10-5)827(106) = 56.8 kN

Yield, Eq. (8-28),



Load factor, Eq. (8-29),



Separation load factor, Eq. (8-30)



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**8-63** Table 8-2, *At*= 625 mm2 (coarse), *At*= 692 mm2 (fine)

Table 8-9, *Sp*= 510 MPa, *Sut*= 724 MPa

Table 8-17, *Se*= 112 Mpa

Coarse thread,

*Fi* = 0.75 *AtSp*= 0.75(6.25)(10-4)510(106) = 23.9 kN

*σi*= 0.75 *Sp* = 0.75(510)(106) = 383 MPa



Gerber, Eq. (8-46),



With *nf*=2,



Fine thread,

*Fi*= 0.75 *AtSp*= 0.75(6.9)(10-4)510(106) = 26.5 kN

*σi*= 0.75 *Sp* = 0.75(510)(106) = 383 MPa



The only thing that changes in Eq. (8-46) is *σa*. Thus,



Percent improvement,



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**8-64** For an M 30 × 3.5 ISO 8.8 bolt with *P*= 65 kN/bolt and *C* = 0.28

Table 8-1, *At* = 561 mm2

Table 8-11, *Sp* = 600 MPa, *Sut*= 830 MPa

Table 8-17, *Se* = 129 MPa

Eq. (8-31), *Fi* = 0.75*Fp* = 0.75 *AtSp*

= 0.75(5610600(10−3) = 252.45 kN

*σi*= 0.75 *Sp*= 0.75(600) = 450 MPa

Eq. (8-39), 

Gerber, Eq. (8-46),



The yielding factor of safety, from Eq. (8-28) is



From Eq.(8-29), the load factor is



The separation factor, from Eq. (8-30)is



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**8-65** (**a**)Table 8-2, *At*= 5(10-5) m2

Table 8-9, *Sp*= 586 MPa, *Sut*= 827 MPa

Table 8-17, *Se*= 128 MPa

Unthreaded grip,



(**b**)*Fi*= 0.75 *AtSp*= 0*.*75(5)(10-5) (586) = 21.9 kN



From Eq. (8-46) for Gerber fatigue criterion,



(**c**)Pressure causing joint separation from Eq. (8-30)



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**8-66** From the solution of Prob. 8-64, *At*= 5.0(10-5) m2, *Sut*= 827 MPa, *Se*= 128 Mpa,*C* = 0.102, *σi*= 440 MPa

*P*max = *p*max*A* =13.79(106) *π* (0.10162)/4 = 111.8 kN, *P*min = *p*min*A* = 8.27(106) *π* (0.10162)/4 = 67 kN,

Eq. (8-35),

Eq. (8-36), 

Eq. (8-38), 

This predicts a fatigue failure.

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**8-67** Members: *Sy*= 393 MPa,*Ssy*= 0*.*577(393) = 227 MPa.

Bolts: SAE grade 5, *Sy*= 634 MPa, *Ssy*= 0*.*577(634) = 366 MPa

Shear in bolts,





Bearing on bolts,

*Ab* = 2(0.0064)0.0064 = 80.6(10-5) m2



Bearing on member,



Tension of members,

*At*= (0.0318 − 0.0064)(0.0064) = 1.6(10-4) m2



The shear in the bolts controls the design.

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**8-68** Members, Table A-20,*Sy* = 290 MPa

Bolts, Table 8-9,*Sy* = 896 Mpa, *Ssy*= 0.577(896) = 517 Mpa

Shear of bolts,







Bearing on bolts,

*Ab* = 2(0.0064)(0.0079) = 1(10-4) m2





Bearing on members,



Tension of members,

*At* = [0.0603 − 2(0.0079)] (0.0064) = 2.8(10-4) m2





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**8-69** Members: Table A-20, *Sy*= 490 MPa,*Ssy*= 0*.*577(490) = 282.7 MPa

Bolts: Table 8-11, ISO class 5.8, *Sy*= 420 MPa,*Ssy*= 0*.*577(420) = 242.3 MPa

Shear in bolts,





Bearing on bolts,

*Ab* = 2(20)20 = 800mm2



Bearing on member,



Tension of members,

*At*= (80− 20)(20) = 1 200mm2 

The shear in the bolts controls the design.

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**8-70** Members: Table A-20, *Sy*= 320 MPa

Bolts: Table 8-11, ISO class 5.8,*Sy*= 420 MPa, *Ssy*= 0*.*577(420) = 242.3 MPa

Shear of bolts,

*As* = *π* (202)/4 = 314.2 mm2





Bearing on bolt,

*Ab* = 3(20)15 = 900 mm2





Bearing on members,



Tension on members,

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**8-71** Members: *Sy* = 398 MPa

Bolts: *Sy* = 690 MPa, *Ssy* = 0.577(690) = 398 Mpa

Shear of bolts,







Bearing on bolts,

*Ab* = 3(0.0064)(0.0079) = 1.5(10-4) m2





Bearing on members,

*Ab* = 1.5(10-4) m2 (From bearing on bolts calculation)

*σb* = − 146.8 MPa (From bearing on bolts calculation)



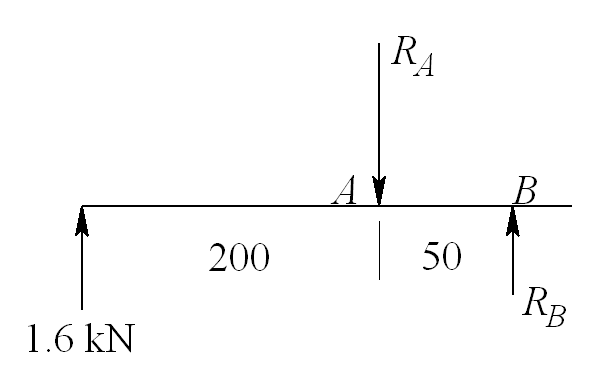
Tension in members, failure across two bolts,







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**8-72** By symmetry, the reactions at each support is 1.6 kN. The free-body diagram for the left member is



Members: Table A-20,*Sy*= 370 MPa

Bolts: Table 8-11,*Sy*= 420 MPa, *Ssy*= 0*.*577(420) = 242*.*3 MPa

Bolt shear, 



Bearing on member,  *Ab*= *td* = 10(12) = 120 mm2



Strength of member. The bending moments at the hole locations are:

In the left member at *A*, *MA*= 1*.*6(200) = 320 N · m. In the right member at *B*, *MB*= 8(50) = 400 N · m. The bending moment is greater at *B*



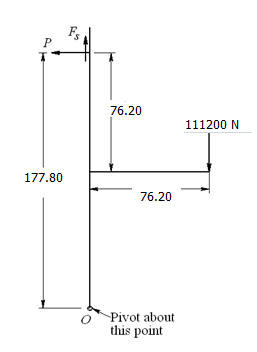
At the center, call it point*C*,

*MC*= 1*.*6(350) = 560 N · m



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**8-73** The free-body diagram of the bracket, assuming the upper bolt takes all the shear and tensile load is



*Fs* = 111.2 kN



Table A-31, *H* = 11.11 mm. Grip, *l* = 2(12.7) = 25.4 mm. *L* ≥ *l* + *H* = 36.51 mm. Use 38.10 mm bolts.

Eq. (8-13), *LT* = 2*d* + 6.35= 2(12.7) + 6.35 = 31.75 mm

Table 8-7, *ld*= *L − LT*= 38.1 − 31.75 = 6.35 mm

*lt*= *l −ld* = 25.4 − 6.35 = 19.05 mm

Table 8-2, *At* = 91.5 mm2

*Ad* = *π* (12.72) /4 = 126.6 mm2

Eq. (8-17), 

Eq. (8-22), 



Table 8-9, *Sp* = 448 MPa

Eqs. (8-31) and (8-32), *Fi* = 0.75 *AtSp* = 0.75(9.15)(10-5)448(106) = 30.7 kN

*σi* = 0.75 *Sp* = 0.75(65) = 216.8 kN

Eq. (*a*): 

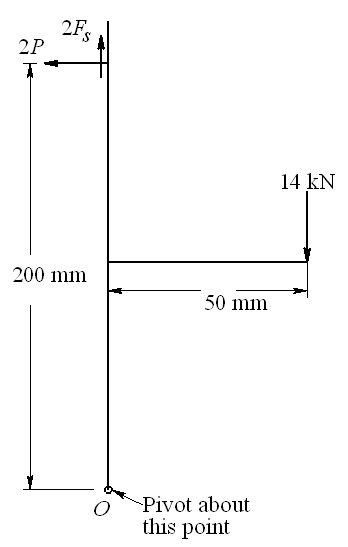
Direct shear, 

von Mises stress, Eq. (5-15),



 *Ans.*

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**8-74**

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*Ans.*

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**8-75** Using the result of Prob. 5-80 for lubricated assembly (replace 0.2 with 0.18 per Table

8-15)



With a design factor of *nd*gives



or *T/d* = 3210. Also,



Form a table 8-2

|  |  |  |  |
| --- | --- | --- | --- |
| Size | *At* | *T/d* = 79.12(106)*At* | *n* |
|  | 0.0364(23.48) | 1858 | 1.75 |
|  | 0.058(37.42) | 2961 | 2.8 |
|  | 0.0878(56.64) | 4482 | 4.23 |

where the factor of safety in the last column of the table comes from



Select a  UNF capscrew. The setting is given by

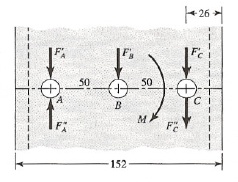
*T* = (79.12(106)*At*)*d*= 4482(9.53) = 42.71 N· m

Given the coarse scale on a torque wrench, specify a torque wrench setting of 45.2 N· m.

Check the factor of safety



**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**8-76**

Bolts, from Table 8-11, *Sy* = 420 MPa

Channel, From Table A-20, *Sy* = 170 MPa. From Table A-7, *t* = 6.4 mm

Cantilever, from Table A-20, *Sy* = 190 MPa

*F′A* = *F′B* =*F′C* = *F* / 3

*M* = (50 + 26 + 125) *F* = 201 *F*



Max. force,  (1)

Shear on Bolts: The shoulder bolt shear area, *As* = *π*(102) / 4 = 78.54 mm2

*Ssy* = 0.577(420) = 242.3 KPa



From Eq. (1), *FC* = 2.343 *F*. Thus



Bearing on bolt: The bearing area is *Ab* = *td* = 6.4(10) = 64 mm2. Similar to shear



Bearing on channel:*Ab* = 64 mm2, *Sy* = 170 MPa.



Bearing on cantilever: *Ab* = 12(10) = 120 mm2, *Sy* = 190 MPa.



Bending of cantilever: At *C*

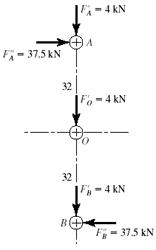






So*F* = 2.32 kN based on bearing on channel. *Ans.*

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**8-77** Bolts, from Table 8-11, *Sy* = 420 MPa

Bracket, from Table A-20, *Sy* = 210 MPa



Bolt shear:

The shoulder bolt shear area, *As* = *π*(122) / 4 = 113.1 mm2

*Ssy* = 0.577(420) = 242.3 KPa



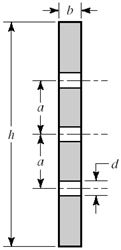
Bearing on bolts:



Bearing on member:



Bending stress in plate:

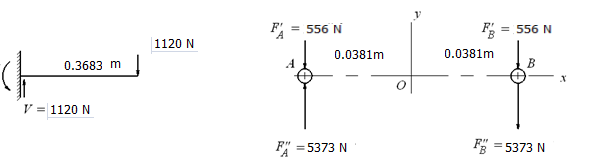




Failure is predicted for bolt shear and bearing on member.

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**8-78**





Bolt shear:

*As* = (*π* / 4)(0.00952) = 7.12(10-5) m2



From Table 8-10, *Sy* = 690 Mpa, *Ssy* = 0.577(690) = 397.8 Mpa



Bearing on bolt: Bearing area is *Ab* =*td* = 0.0095 (0.0095) = 9.07(10-5) m2.





Bearing on member: From Table A-20, *Sy* = 370 MPa. Bearing stress same as bolt



Bending of member: At *B*, *M* = 1120(0.3302) = 367.2 N⋅m







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**8-79** The direct shear load per bolt is*F′* = 8960/6 = 1493 N. The moment is taken only by thefour outside bolts. This moment is *M* = 8960(0.127) = 1130 N· m.

Thus  and the resultant bolt load is



Bolt strength, Table 8-9,*Sy*= 690 MPa; Channel and Plate strength, *Sy*= 290 MPa

Shear of bolt: *As*= *π*(0.0508)2*/*4 = 1.26(10-4) m2  
 

Bearing on bolt:Channel thickness is *t* = 4.76 mm, *Ab* = 0.127(0.00476) = 6.05(10-5) m2



Bearing on channel*:* 

Bearing on plate: *Ab* = 0.0127(0.0064) = 8.06(10-5) m2

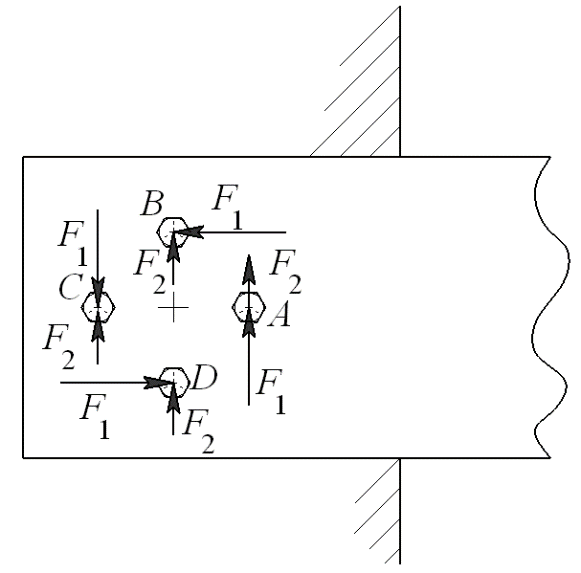


Strength of plate:





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**8-80** *A* = 58 mm2. From Table A-9, beam 14,

*R*1 = *R*2 = *F*/2 = 10/2 = 5 kN,

*M*1 = *M*2 = *Fl*/8 = 10(0.4)103/8 = 500 N۰m.





Bolt *A* has the maximum force of

*FA* = *F*1 + *F*2 = 5000 + 1250 = 6250 N



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**8-81** Given: 186.42 kW at 600 rev/min, *r*1 = 0.0635 m , *r*2 = 0.127 m.

Eq. (3-42): 

**(a)**



Yields *F*1 = 2337 N and *F*2 = 4672 N



From Table A-17 select *d* =  in(7.94mm) *Ans*.

**(b)**

*nFr*2 = *T* ⇒ *n* (6823) 0.127 = 2967 ⇒ *n* = 3.4 bolts

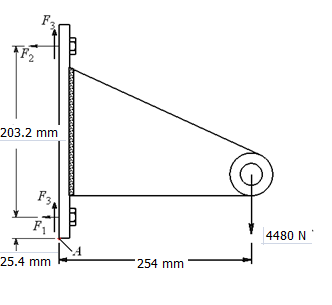
Use four bolts without need of the inner bolts *Ans*.

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**8-82 to 8-84** Specifying bolts, screws, dowels and rivets is the way a student learns about such components. However, choosing an array a priori is based on experience. Here is a chance for students to build some experience.

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**8-85** Assume tensile forces to be proportional to deflections. Thus,



Σ*MA* = 0 = 2 *F*1 (0.0254) + 2*F*2 (0.2286)− 4480 (0.254)

Substitute Eq. (1) in,

Yields *F*1 = 271 N, *F*2 = 2442 N.

Combining the preload,



The shear forces are *F*3 =4480/4 = 1120 N.

The shear stress is,



The maximum tensile stress is,



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