**Chapter 9**

**Figure for Probs.**

**9-1to 9-4**

**9-1** Given, *b* = 50 mm, *d* = 50 mm, *h* = 5 mm, *τ*allow = 140 MPa.

*F* = 0.707 *hlτ*allow = 0.707(5)[2(50)](140)(10−3) = 49.5 kN *Ans*.

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**9-2** Given, *b* = 50.8 mm, *d* = 50.8 mm, *h* = 7.93 mm, *τ*allow = 172.37 mm.

*F* = 0.707 *hlτ*allow = 0.707(7.93)[2(50.8)](172.37)(10-3) = 98.30 kN *Ans*.

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**9-3** Given, *b* = 50 mm, *d* = 30 mm, *h* = 5 mm, *τ*allow = 140 MPa.

*F* = 0.707 *hlτ*allow = 0.707(5)[2(50)](140)(10−3) = 49.5 kN*Ans*.

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**9-4** Given, *b* = 101.6 mm, *d* = 50.8 mm, *h* = 7.93 mm, *τ*allow = 172.37 MPa.

*F* = 0.707 *hlτ*allow = 0.707(7.93)[2(101.6)](172.37)(10-3) = 196.6 kN *Ans*.

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**9-5** Prob. 9-1 with E7010 Electrode.

Table 9-6: *f* = 102.52(5) = 0.512 kN/mm

*F* = *f l* = 0.512[2(50.8)] = 51.2 kN *Ans*.

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**9-6** Prob. 9-2 with E6010 Electrode.

Table 9-6: *f* = 102.52(7.93) = 0.815 kN/mm

*F = f l* = 815[2(50.8)] = 82.6 kN *Ans*.

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**9-7** Prob. 9-3 with E7010 Electrode.

Table 9-6: *f* = 102.52(5) = 0.512 kN/mm

*F* = *f l* = 0.512[2(50.8)] = 51.2 kN *Ans*.

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**9-8** Prob. 9-4 with E6010 Electrode.

Table 9-6: *f* = 102.52(7.93) = 0.815 kN/mm

*F = f l* = 815[2(101.6)] = 165.2 kN *Ans*.

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**9-9** Table A-20:

1018 CD: *Sut*= 440 MPa,*Sy*= 370 MPa

1018 HR: *Sut*= 400 MPa,*Sy*= 220 MPa

Cold-rolled properties degrade to hot-rolled properties in the neighborhood of the weld.

Table 9-4:



for both materials.

Eq. (9-3): *F* = 0*.*707*hlτ*all= 0*.*707(5)[2(50)](88)(10−3) = 31.1 kN *Ans.*

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**9-10** Table A-20:

1020 CD: *Sut*= 470 MPa,*Sy*= 390 MPa

1020 HR: *Sut*= 380 MPa,*Sy*= 210 MPa

Cold-rolled properties degrade to hot-rolled properties in the neighborhood of the weld.

Table 9-4:



for both materials.

Eq. (9-3): *F* = 0*.*707*hlτ*all= 0*.*707(7.93)[2(50.8)](82.74)(10-3) = 47.15 kN *Ans.*

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**9-11** Table A-20:

1035 HR: *Sut*= 500 MPa,*Sy*= 270 MPa

1035 CD: *Sut*= 550 MPa,*Sy*= 460 MPa

Cold-rolled properties degrade to hot-rolled properties in the neighborhood of the weld.

Table 9-4:



for both materials.

Eq. (9-3): *F* = 0*.*707*hlτ*all= 0*.*707(5)[2(50)](108)(10−3) = 38.2 kN*Ans.*

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**9-12** Table A-20:

1035 HR: *Sut*=500 MPa,*Sy*= 270 MPa

1020 CD: *Sut*= 470 MPa,*Sy*= 390 Mpa,

1020 HR: *Sut*= 380 MPa,*Sy*= 210 Mpa

Cold-rolled properties degrade to hot-rolled properties in the neighborhood of the weld.

Table 9-4:



for both materials.

Eq. (9-3): *F* = 0*.*707*hlτ*all= 0*.*707(0.00793)[0.0508(0.1016)](83)(106) = 94.3 kN *Ans.*

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

**9-13**

Eq. (9-3): 

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**9-14**

Eq. (9-3): 

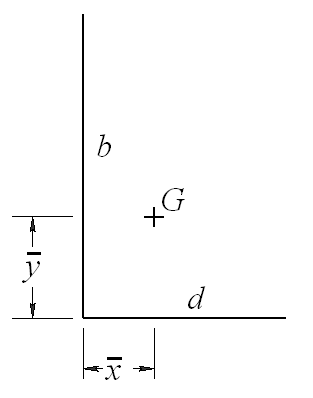
**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**9-15** Eq. (9-3): 

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

**9-16** Eq. (9-3): 

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

**9-17** *A* = (throat area)(length) = 0.707*h* (*b* + *d*) *Ans*.





For line *b*:



Similarly,





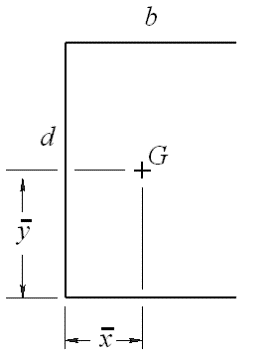
This reduces to



Add and subtract 6*b*2*d* 2 to Eq. (1) giving



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**9-18** *A* = (throat area)(length) = 0.707*h* (2*b* + *d*) *Ans*.





For lines *b*:



Line *d*:



*Ju* = (*Ju*)*b* + (*Ju*)*d*



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

**9-19** *b = d =*50 mm, *c* = 150 mm, *h* = 5mm, and *τ*allow = 140 MPa.

**(a**) *Primary shear*, Table 9-1, Case 2 (Note: *b* and *d* are interchanged between problem figure and table figure. Note, also, *F* in kN and *τ* in MPa):



*Secondary shear*, Table 9-1:



*J* = 0.707 *h Ju* = 0.707(5)(83.33)(103) = 294.6(103) mm4



 (1)



(**b**) For E7010 from Table 9-6, *τ*allow = 21 kpsi = 21(6.89) = 145 MPa

1020 HR bar: *Sut* = 380 MPa, *Sy* = 210 MPa

1015 HR support: *Sut* = 340 MPa, *Sy* = 190 MPa

Table 9-3, E7010 Electrode: *Sut* = 482 MPa, *Sy* = 393 MPa

The support controls the design.

Table 9-4: *τ*allow = min(0.30*Sut*, 0.40*Sy* ) =min[0.30(340), 0.40(190) = min(102, 76)

= 76MPa

The allowable load, from Eq. (1) is



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**9-20** *b = d =*50.8 mm, *c* = 152.4 mm, *h* = 7.95 mm, and *τ*allow = 172.4 MPa.

**(a**) *Primary shear*, Table 9-1(Note: *b* and *d* are interchanged between problem figure and table figure. Note, also, *F* in kN and *τ* in MPa):



*Secondary shear*, Table 9-1:



*J* = 0.707 *h Ju* = 0.707(7.95)(87392) = 490.32(103) mm4



 (1)



(**b**) For E7010 from Table 9-6, *τ*allow = 145 MPa

1020 HR bar: *Sut* = 380 MPa, *Sy* = 210 MPa

1015 HR support: *Sut* = 340 Mpa, *Sy* = 190 MPa

Table 9-3, E7010 Electrode: *Sut* = 482 MPa, *Sy* = 393 MPa

The support controls the design.

Table 9-4: *τ*allow = min(0.30*Sut*, 0.40*Sy* ) =min[0.30(340), 0.40(190) = min(103.42, 75.84)

= 75.84 MPa

The allowable load, from Eq. (1) is



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**9-21** *b =*50 mm, *c* = 150 mm, *d =* 30 mm, *h* = 5 mm, and *τ*allow = 140 MPa.

**(a**) *Primary shear*, Table 9-1, Case 2 (Note: *b* and *d* are interchanged between problem figure and table figure. Note, also, *F* in kN and *τ* in MPa):



*Secondary shear*, Table 9-1:



*J* = 0.707 *h Ju* = 0.707(5)(43.33)(103) = 153.2(103) mm4





 (1)



(**b**) For E7010 from Table 9-6, *τ*allow = 21 kpsi = 21(6.89) = 145 MPa

1020 HR bar: *Sut* = 380 MPa, *Sy* = 210 MPa

1015 HR support: *Sut* = 340 MPa, *Sy* = 190 MPa

Table 9-3, E7010 Electrode: *Sut* = 482 MPa, *Sy* = 393 MPa

The support controls the design.

Table 9-4: *τ*allow = min(0.30*Sut*, 0.40*Sy* ) =min[0.30(340), 0.40(190) = min(102, 76)

= 76 MPa

The allowable load, from Eq. (1) is



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**9-22** *b =* 101.6 mm, *c* = 152.4, *d =* 50.8 mm, *h* = 7.95 mm, and *τ*allow = 172.4 MPa.

**(a**) *Primary shear*, Table 9-1(Note: *b* and *d* are interchanged between problem figure and table figure. Note, also, *F* in kN and *τ* in MPa):



*Secondary shear*, Table 9-1:



*J* = 0.707 *h Ju* = 0.707(7.94)(305.9)(103) = 1717(103) mm4





 (1)



(**b**) For E7010 from Table 9-6, *τ*allow = 145 MPa

1020 HR bar: *Sut* = 380 MPa, *Sy* = 210 MPa

1015 HR support: *Sut* = 340 MPa, *Sy* = 190 MPa

Table 9-3, E7010 Electrode: *Sut* = 482 MPa, *Sy* = 393 Mpa

The support controls the design.

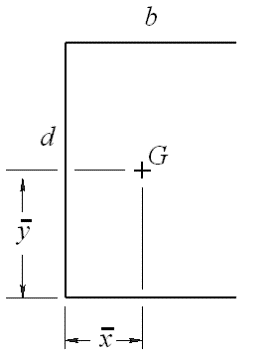
Table 9-4: *τ*allow = min(0.30*Sut*, 0.40*Sy* ) =min[0.30(340), 0.40(190) = min(103.42, 75.84)

= 75.84 Mpa

The allowable load, from Eq. (1) is



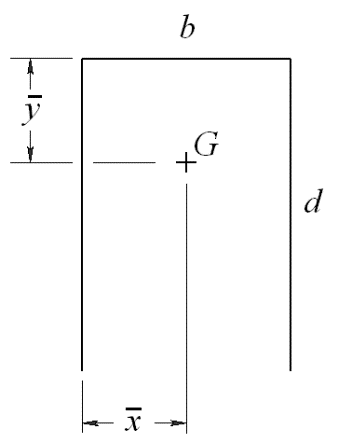
\_\_\_\_\_\_**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**9-23** *A* = (throat area)(length) = 0.707*h* (2*b* + *d*) *Ans*.







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**9-25** Given, *b* = 50 mm, *c* = 150 mm,*d* = 50 mm, *h* = 5 mm, *τ*allow = 140 MPa.

*Primary shear* (*F* in kN, *τ* in MPa, *A* in mm2):



*Secondary shear*:

Table 9-1: 

*J* = 0.707 *hJu* = 0.707(5)166.7(103) = 589.2(103) mm4



Maximum shear:

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

**9-26** Given, *b* = 50.8 mm, *c* = 152.4 mm, *d* = 50.8 mm, *h* = 7.95 mm, *τ*allow = 172.4 MPa.

*Primary shear*:



*Secondary shear*:

Table 9-1: 

*J* = 0.707 *hJu* = 0.707(7.95)174.85(103) = 981(103) mm4



Maximum shear:

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

**9-27** Given, *b* = 50 mm, *c* = 150 mm,*d* = 30 mm, *h* = 5 mm, *τ*allow = 140 MPa.

*Primary shear* (*F* in kN, *τ* in MPa, *A* in mm2):



*Secondary shear*:

Table 9-1: 

*J* = 0.707 *hJu* = 0.707(5)85.33(103) = 301.6(103) mm4





Maximum shear:

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

**9-28** Given, *b* = 101.6 mm, *c* = 152.4 mm, *d* = 50.8 mm, *h* = 7.95 mm, *τ*allow = 172.4 MPa.

*Primary shear*:



*Secondary shear*:

Table 9-1: 

*J* = 0.707 *hJu* = 0.707(7.95)589.9(103) = 3310.7(103) mm4





Maximum shear:

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**9-29** Given: *b* = 50 mm, *c* = 150 mm,*d* = 50 mm,*h* = 5 mm, *τ*allow = 140 MPa.

Primary shear (*F* in kN): 

Secondary shear: *M* = 0.707 *F* (103)(175 − 25) = 106.05(103) *F*

Table 9-1: 





Upper right end of weld:





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**9-30** Given: *b* = 50.8 mm, *c* = 152.4 mm, *d* = 50.8 mm,*h* =7.95 mm, *τ*allow = 172.4 MPa.

Primary shear (*F* in kip) :

Secondary shear: *M* = 0.707 *F*(103 )(177.8 − 25.4) = 107.7(103) *F*

Table 9-1: 





Upper right end of weld:





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**9-31** Given: *b* = 50 mm, *c* = 150 mm,*d* = 30 mm,*h* = 5 mm, *τ*allow = 140 MPa.

Primary shear (*F* in kN): 

Secondary shear: *M* = 0.707 *F* (103)(175 − 15) = 113.12 (103) *F*

Table 9-1: 





Upper right end of weld:





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

**9-32** Given: *b* = 101.6 mm, *c* = 152.4 mm, *d* = 50.8 mm,*h* =7.95 mm, *τ*allow = 172.4 mm.

Primary shear (*F* in kN) :

Secondary shear: *M* = 0.707 *F* (103)(203.2 − 25.4) = 125.7(103) *F*

Table 9-1: 





Upper right end of weld:





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

**9-33** Given, *b* = 50 mm,*d* = 50 mm, *h* = 5 mm, E6010 electrode.

*A* = 0.707(5)(50 +50 + 50) = 530.3 mm2

Member endurance limit: From Table A-20 for AISI 1010 HR, *Sut* = 320 MPa.

Eq. (6-18) and Table 6-2: *ka* = 54.9(320)−0.758 = 0.693

*kb*= 1 (uniform shear), *kc*= 0.59 (torsion, shear), *kd*= 1

Eqs. (6-10) and (6-17): *Se* = 0.693(1)(0.59)(1)(0.5)(320) = 65.4 MPa

Electrode endurance: E6010, Table 9-3, *Sut* = 427 MPa

Eq. (6-18) and Table 6-2: *ka* = 54.9(427)−0.758 = 0.557

As before, *kb*= 1 (direct shear), *kc*= 0.59 (torsion, shear), *kd*= 1

*Se* = 0.557(1)(0.59)(1)(0.5)(427) = 70.2 MPa

The members and electrode are basically of equal strength. We will use *Se* =65.4 MPa. For a factor of safety of 1, and with *Kfs* = 2.7 (Table 9-5)



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**9-34** Given, *b* = 50.8 mm, *d* =50.8 mm, *h* = 7.95 mm, E6010 electrode.

*A* = 0.707(7.95)(50.8 +50.8 + 50.8) = 855.5 mm2

Member endurance limit: From Table A-20 for AISI 1010 HR, *Sut* = 320 MPa.

Eq. (6-18) and Table 6-2: *ka* = 54.9(320)−0.758 = 0.686

*kb*= 1 (uniform shear), *kc*= 0.59 (torsion, shear), *kd*= 1

Eqs. (6-10) and (6-17): *Se* = 0.686(1)(0.59)(1)(0.5)(320) = 65.57 MPa

Electrode endurance: E6010, Table 9-3, *Sut* = 427 Mpa

Eq. (6-18) and Table 6-2: *ka* = 54.9(427)−0.758 = 0.556

As before, *kb*= 1 (uniform shear), *kc*= 0.59 (torsion, shear), *kd*= 1

*Se* = 0.556(1)(0.59)(1)(0.5)(427) = 70.33 MPa

For a factor of safety of 1, with *Kfs* = 2.7 (Table 9-5), using *Se* = 70.33 MPa



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**9-35** Given, *b* = 50 mm,*d* = 30 mm, *h* = 5 mm, E7010 electrode.

*A* = 0.707(5)(50 +50 + 30) = 459.6 mm2

Member endurance limit: From Table A-20 for AISI 1010 HR, *Sut* = 320 MPa.

Eq. (6-18) and Table 6-2: *ka* = 54.9(320)−0.758 = 0.693

*kb*= 1 (direct shear), *kc*= 0.59 (torsion, shear), *kd*= 1

Eqs. (6-10) and (6-17): *Se* = 0.693(1)(0.59)(1)(0.5)(320) = 65.4 MPa

Electrode endurance: E6010, Table 9-3, *Sut* = 482 MPa

Eq. (6-18) and Table 6-2: *ka* = 54.9(482)−0.758 = 0.508

As before, *kb*= 1 (direct shear), *kc*= 0.59 (torsion, shear), *kd*= 1

*Se* = 0.508(1)(0.59)(1)(0.5)(482) = 72.2 MPa

For a factor of safety of 1,with*Kfs* = 2.7 (Table 9-5), and using *Se* =65.4 MPa



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**9-36** Given, *b* = 101.6 mm, *d* = 50.8 mm, *h* = 7.95 mm, E7010 electrode.

*A* = 0.707(7.95)(101.6 +101.6 + 50.8) = 1425 mm2

Member endurance limit: From Table A-20 for AISI 1010 HR, *Sut* = 320 Mpa.

Eq. (6-18) and Table 6-2: *ka* = 54.9(320)−0.758 = 0.686

*kb*= 1 (direct shear), *kc*= 0.59 (torsion, shear), *kd*= 1

Eqs. (6-10) and (6-17): *Se* = 0.686(1)(0.59)(1)(0.5)(320) = 65.57 Mpa

Electrode endurance: E7010, Table 9-3, *Sut* = 482 Mpa

Eq. (6-18) and Table 6-2: *ka* = 54.9(482)−0.758 = 0.507

As before, *kb*= 1 (direct shear), *kc*= 0.59 (torsion, shear), *kd*= 1

*Se* = 0.507(1)(0.59)(1)(0.5)(482) = 72.39 Mpa

For a factor of safety of 1, with *Kfs* = 2.7 (Table 9-5), and using *Se* = 65.57 MPa



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**9-37** *Primary shear*: *τ′* = 0 (why?)

*Secondary shear*:

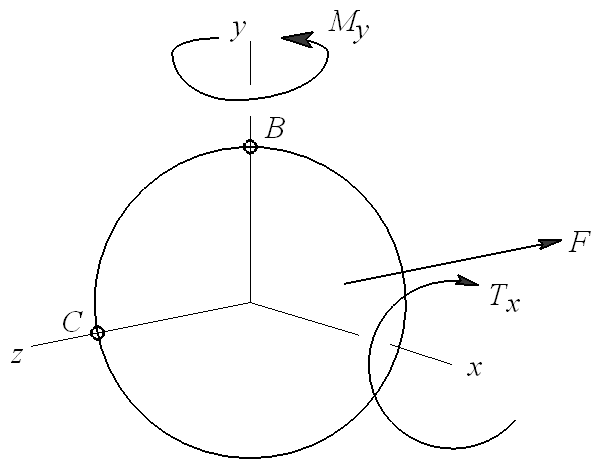
Table 9-1: *Ju* = 2*πr*3= 2*π* (38.1)3 = 347.6(103 ) mm3

*J* = 0.707 *h Ju* = 0.707(7.95)(347.6)(103) = 1560.5(103) mm4

2 welds: 



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

**9-38** Direct shear *Vz* = *F*, Torsion *Tx* = 8*F*, Bending *My* = 6*F*

*B*: Direct shear:



Torsion, Table 9-1:

*Ju* = 2π*r*3 = 2π (38.1)3 =347.6(103) mm3

*J* = 0.707*hJu* = 0.707 (6.35) 347.6(103) = 1560.4(103) mm4







*C*: Direct shear, torsion, and bending.

Bending, Table 9-2:

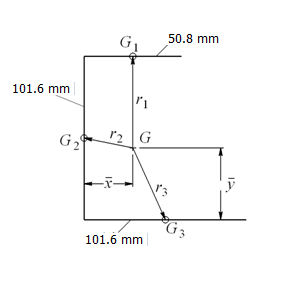
*Iu* = π*r*3 = π (38.1)3 = 173.7(103) mm3, *I* = 0.707*hIu* = 0.707(6.35) 173.7(103) =780(103) mm4.







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

**9-39** *l* = 50.8 + 101.6 + 101.6 = 254 mm



*M* = *FR* = *F*(254 −25.4) = 228.6*F*



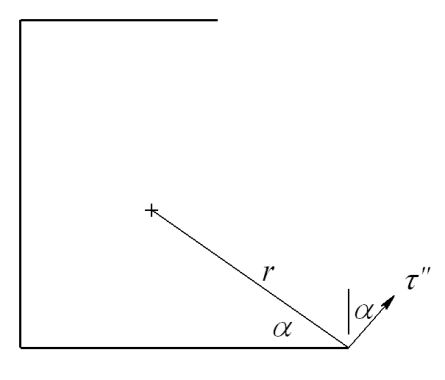
















*Primary shear* (*τ* in kN, *F* in kN) :



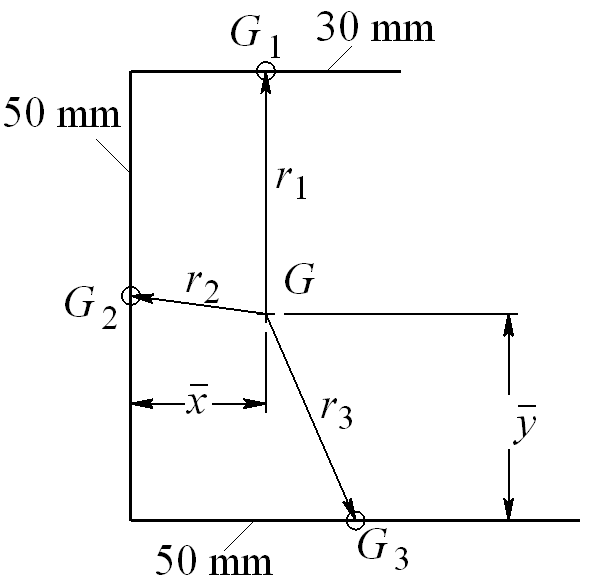
*Secondary shear*:





*τ*max = *τ*allow⇒5.76*F* = 172.4⇒*F* = 29.8 kN *Ans*.

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

**9-40** *l* = 30 + 50 + 50 = 130 mm



*M* = *FR* = *F*(200 − 13.08)

= 186.92 *F* (*M* in N⋅m, *F* in kN)



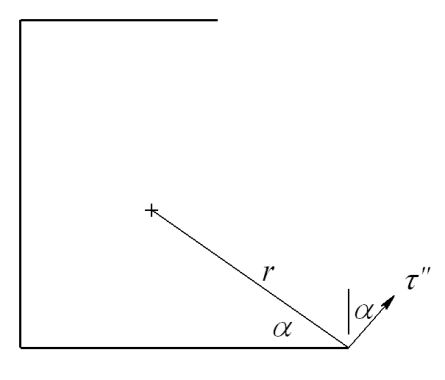
















*Primary shear* (*τ* in MPa, *F* in kN) :



*Secondary shear*:





*τ*max = *τ*allow⇒ 13.48 *F* = 965 ⇒*F* = 5.04 kN*Ans*.

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

**9-41**

Weld

Pattern Figure of merit Rank\_\_\_\_\_\_

1.  **5**

2.  **1**

3.  **4**

4.  **2**

5.  **1**

6.  **3**

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

**9-42**

Weld

Pattern Figure of merit Rank\_\_\_\_\_\_

1.  **6**

2.  **6**

3.  **1**

4.\*  **2**

5. & 7. 



 **5**

6. & 8.  **3**

9.  **4**

\*Note. Because this section is not symmetric with the vertical axis, out-of-plane deflection may occur unless special precautions are taken. See the topic of “shear center” in books with more advanced treatments of mechanics of materials.

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

**9-43** Attachment and member (1018 HR), *Sy* = 220 MPa and *Sut* = 400 MPa.

The member and attachment are weak compared to the properties of the lowest electrode.

*Decision* Specify the E6010 electrode

Controlling property, Table 9-4: *τ*all = min[0.3(400), 0.4(220)] = min(120, 88) = 88 MPa

For a static load, the parallel and transverse fillets are the same. Let the length of a bead be *l* = 75 mm, and *n* be the number of beads.





where*h* is in millimeters. Make a table

Number of beads, *n* Leg size, *h* (mm)

1 21.43

2 10.71

3 7.14

4 5.36 → 6 mm

*Decision* Specify *h* = 6 mm on all four sides.

Weldment specification:

Pattern: All-around square, four beads each side, 75 mm long

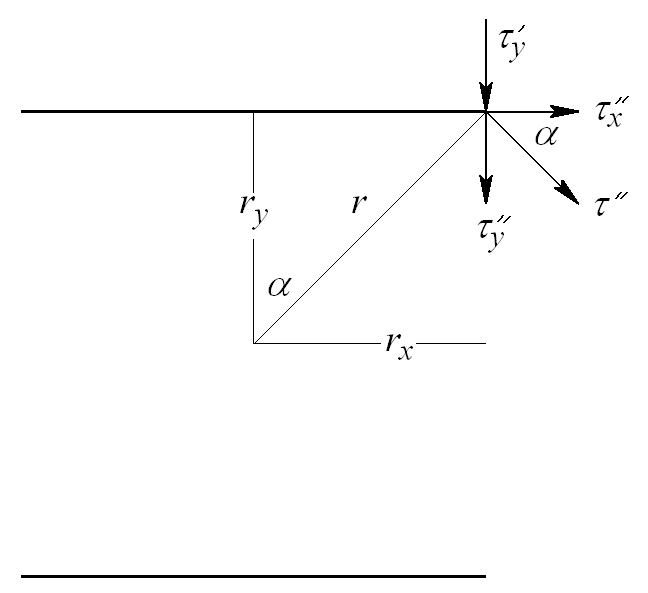
Electrode: E6010

Leg size: *h* = 6 mm

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**9-44** *Decision*: Choose a parallel filletweldment pattern. By so-doing, we’ve chosen an optimal pattern (see Prob. 9-41) and have thus reduced a synthesis problem to an analysis problem:

Table 9-1, case 2, rotated 90°: *A* = 1*.*414*hd* = 1*.*414(*h*)(75)= 106.05*h* mm2

* Primary shear*



*Secondary shear*:



With *α* = 45°,



Attachment and member (1018 HR): *Sy*= 220 MPa, *Sut*= 400 MPa

*Decision:* Use E60XX electrode which is stronger



*Decision:* Specify 8 mm leg size

Weldment Specifications:

Pattern: Parallel horizontal fillet welds

Electrode: E6010

Type: Fillet

Length of each bead: 75 mm

Leg size: 8 mm

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

**9-45** Problem 9-44 solves the problem using parallel horizontal fillet welds, each 75 mm long obtaining a leg size rounded up to 8 mm.

For this problem, since the width of the plate is fixed and the length has not been determined, we will explore reducing the leg size by using two vertical beads 75 mm long and two horizontal beads such that the beads have a leg size of 6 mm.

*Decision:* Use a rectangular weld bead pattern with a leg size of 6 mm (case 5 of Table

9-1 with *b* unknown and *d* = 75 mm).

*Materials:*

Attachment and member (1018 HR): *Sy*= 220 MPa, *Sut*= 400 MPa

From Table 9-4, AISC welding code,

*τ*all = min[0*.*3(400), 0*.*4(220)] = min(120, 88) = 88 MPa

Select a stronger electrode material from Table 9-3.

*Decision:* Specify E6010

*Solving for b*: In Prob. 9-44,every termwas linear in the unknown *h*. This made solving for *h* relatively easy. In this problem, the terms will not be linear in *b*, and so we will use an iterative solution with a spreadsheet.

Throat area and other properties from Table 9-1:

*A* = 1.414(6)(*b* + 75) = 8.484(*b* + 75) (1)

, *J* = 0.707 (6) *Ju* = 0.707(*b* +75)3 (2)

*Primary shear* (*τ* in MPa, *h* in mm):



*Secondary shear* (See Prob. 9-44 solution for the definition of *α*) :



Enter Eqs. (1) to (6) into a spreadsheet and iterate for various values of *b*. A portion of the spreadsheet is shown below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *b* (mm) | *A* (mm2*)* | *J* (mm4) | *'y* (Mpa) | *"y* (Mpa) | *"x* (Mpa) | **max (Mpa) |  |
| 41 | 984.144 | 1103553.5 | 12.19334 | 69.5254 | 38.00722 | 90.12492 |  |
| 42 | 992.628 | 1132340.4 | 12.08912 | 67.9566 | 38.05569 | 88.63156 |  |
| 43 | 1001.112 | 1161623.6 | 11.98667 | 66.43718 | 38.09065 | 87.18485 | < 88 Mpa |
| 44 | 1009.596 | 1191407.4 | 11.88594 | 64.96518 | 38.11291 | 85.7828 |  |

We see that *b*≥ 43 mm meets the strength goal.

*Weldment Specifications:*

Pattern: Horizontal parallel weld tracks 43 mm long, verticalparallel weld tracks 75 mm long

Electrode: E6010

Leg size: 6 mm

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

**9-46** *Materials:*

Member and attachment (1018 HR): 

Table 9-4: 

*Decision:* Use E6010 electrode. From Table 9-3: 



*Decision:* Since 1018 HR is weaker than the E6010 electrode, use 

*Decision*: Use an all-around square weld bead track.

*l*1 = 152.4 + *a* = 152.4 + 158.75 = 311.15 mm

Throat area and other properties from Table 9-1:



*Primary shear*



*Secondary shear*









Relate stress to strength



*Decision:*

Specify 9.5 mm leg size

*Specifications:*

Pattern: All-around square weld bead track

Electrode: E6010

Type of weld: Fillet

Weld bead length: 610 mm

Leg size: 9.5 mm

Attachment length: 312 mm

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

**9-47** This is a good analysis task to test a student’s understanding.

(1) Solicit information related to a priori decisions.

(2) Solicit design variables *b* and *d*.

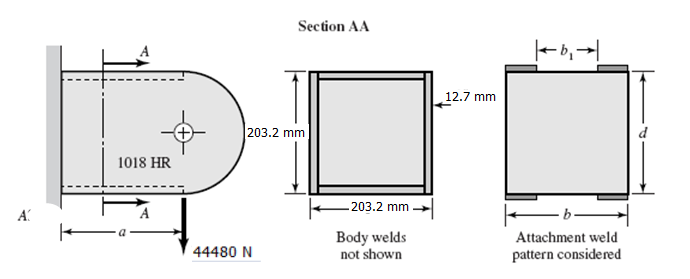
(3) Find *h* and round and output all parameters on a single screen. Allow return to Step 1 or Step 2.

(4) When the iteration is complete, the final display can be the bulk of your adequacy assessment.

Such a program can teach too.

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**9-48** The objective of this design task is to have the students teach themselves that the weld patterns of Table 9-2 can be added or subtracted to obtain the properties of a contemplated weld pattern. The instructor can control the level of complication. We have left the presentation of the drawing to you. Here is *one* possibility. Study the problem’s opportunities, and then present this (or your sketch) with the problem assignment.



Useas the design variable. Express properties as a function of From Table 9-3,

case 3: Use F=44480 N











*Parametric study*

Let 













from which Do not round off the leg size – something to learn.

















Now consider the case of uninterrupted welds,

















Do not round off *h*.







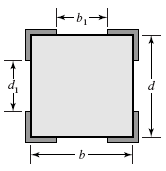






*Conclusions:* To meet allowable stress limitations, *I* and *A* do not change, nor do *τ* and *σ*. To meet the shortened bead length, *h* is increased proportionately. However, volume of bead laid down increases as *h*2. The uninterrupted bead is superior. In this example, we did not round *h* and as a result we learned something. Our measures of merit are also sensitive to rounding. When the design decision is made, rounding to the next larger standard weld fillet size will decrease the merit.

Had the weld bead gone around the corners, the situation would change. Here is a followup task analyzing an alternative weld pattern.



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**9-49** From Table 9-2

For the box 

Subtracting





Length of bead 

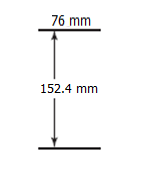


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**9-50** Computer programs will vary.

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

**9-51** *τ*all = 82.74 MPa. Use Fig. 9-17(*a*) for general geometry, but employ beads and then beads.



*Horizontal parallel weld bead pattern*

*b* = 76.2 mm, *d* = 152.4 mm

Table 9-2: 











Equate the maximum and allowable shear stresses.



from whichIt follows that



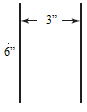
The volume of the weld metal is



The effectiveness, (eff)H, is

*Ans.*

*Vertical parallel weld beads*





From Table 9-2, case 2





 mm4







Equating  to  gives It follows that





*Ans.*

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

**9-52** *F* = 0, *T* = 1.69(106) N⋅mm.

Table 9-1: *Ju* = 2*π r* 3 = 2*π* (25.4)3 = 102.9(103) mm3, *J* = 0.707(6.35)102.9(103) = 462.4(103) mm4



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**9-53** *F* = 8.896 N, *T* = 0.

Table 9-2: *A* = 1.414 *π h r* = 1.414 *π* (6.35)(25.4) = 717 mm2

*Iu* = *π r* 3 = *π* (25.4)3 = 51.5(103) mm3, *I* = 0.707(6.35)51.5(103) = 231.1(103) mm4





*τ*max = (*τ′* 2 + *τ′′* 2)1/2 = (12.412 + 1492)1/2 = 150 MPa *Ans*.

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

**9-54** *F* = 8.896 kN, *T* = 1.69(106) N⋅mm.

*Bending*:

Table 9-2: *A* = 1.414 *π h r* = 1.414 *π* (6.35)(25.4) = 716.3 mm2

*Iu* = *π r* 3 = *π* (25.4)3 = 5.15(103) mm3, *I* = 0.707(6.35)5.15(103) = 2.31(105) mm4





*Torsion*:

Table 9-1: *Ju* = 2*π r* 3 = 2*π* (25.4)3 = 1.03(105) mm3,

*J* = 0.707(6.35)1.03(105) = 4.62(105) mm4





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

**9-55** *F* = 8896 N, *T* = 1.69(106) N⋅mm.

*Bending*:

Table 9-2: *A* = 1.414 *π h r* = 1.414 *πh* (25.4) = 112.8*h* mm2

*Iu* = *π r* 3 = *π* (25.4)3 = 5.15(103) mm3, *I* = 0.707 *h* (5.15)(103) = 36.4(103)*h* mm4





*Torsion*:

Table 9-1: *Ju* = 2*π r* 3 = 2*π* (25.4)3 =1.029(105) mm3, *J* = 0.707 *h*(1.029)(105) = 72.8(103)h mm4







Should specify a9.525 mm (in) weld. *Ans*.

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

**9-56** 

From Table 9-2, case 2:

*A* = 1.414(9)(200) = 2.545(103) mm2



*I* = 0.707*h Iu* = 0.707(9)(1.333)(106) = 8.484(106) mm4



*M* = 25(150) = 3750 N⋅m





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**9-57** *h* = 6.35 mm, *b* = 63.5 mm, *d* = 127 mm.

Table 9-2, case 5: *A* = 0.707*h* (*b +*2*d*) = 0.707(6.35)[63.5 + 2(127)] = 1425.4 mm2





*I* = 0.707 *h Iu* = 0.707(6.35)(5.46)(105) = 2.45(106) mm4

*Primary shear*:



*Secondary shear* (the critical location is at the bottom of the bracket):

*y* = 127-50.8 = 76.2 mm

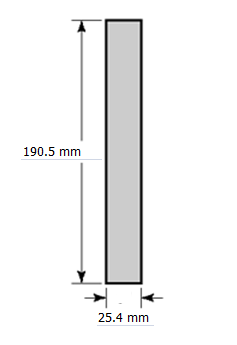






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**9-58** The largest possible weld size is 1.587 mm. This is a small weld and thus difficult to accomplish.The bracket’s load-carrying capability is not known. There are geometry problemsassociated with sheet metal folding, load-placement and location of the center of twist.This is not available to us. We will identify the strongest possible weldment.

 Use a rectangular, weld-all-around pattern – Table 9-2, case 6:

**

*Material properties:* The allowable stress given is low. Let’s demonstrate that.

For the 1020 CD bracket, use HR properties of *Sy*= 210 MPa and *Sut*= 380 MPa. The 1030 HR support, *Sy*= 260 MPaand *Sut*= 470 MPa. The E6010 electrode hasstrengths of *Sy*= 345 MPa and *Sut*= 427 MPa.

Allowable stresses:

1020 HR: *τ*all = min[0*.*3(380), 0*.*4(210)]= min(113.76, 82.74) = 82.74 MPa

1020 HR: *τ*all = min[0*.*3(470), 0*.*4(260)]= min(140.65, 103.42) = 103.42 MPa

E6010: *τ*all = min[0*.*3(427), 0*.*4(345)]= min(128.24, 137.90) = 128.24 MPa

Since Table 9-6 gives 18.0 kpsi (124.11 Mpa) as the allowable shear stress, use this lower value.

Therefore, the allowable shear stress is

*τ*all = min(99.28, 82.74, 124.11) = 82.74 MPa

However, the allowable stress in the problem statement is 10.34 MPa which is low from theweldment perspective. The load associated with this strength is



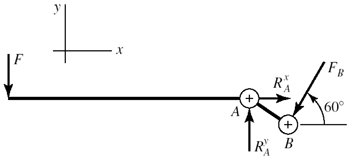
If the welding can be accomplished (1.58mm leg size is a small weld), the weld strength is 82.74 MPa and the load associated with this strength is *W*= 82.74/0.006 = 13.68 kN*.* Can the bracket carry such a load?

There are geometry problems associated with sheet metal folding. Load placement isimportant and the center of twist has not been identified. Also, the load-carrying capabilityof the top bend is unknown.

These uncertainties may require the use of a different weld pattern. Our solution providesthe best weldment and thus insight for comparing a welded joint to one which employsscrew fasteners.

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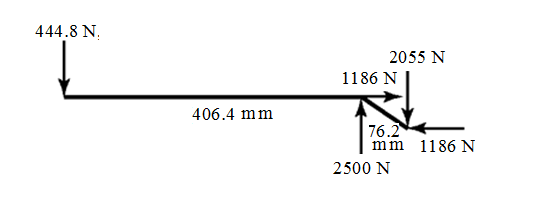
**9-59**





It follows that and *RA*=2767 N

*M* = 444.8(0.4064) = 180.8 N · m



The OD of the tubes is 25.4 mm. From Table 9-1, case 6:

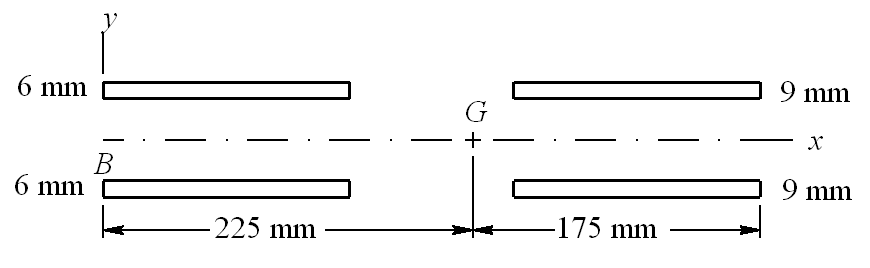


The weld only carries the torsional load between the handle and tube *A*. Consequently, the primary shear in the weld is zero, and the maximum shear stress is comprised entirely of the secondary shear.



*Decision:* Use 6.35 mm fillet welds *Ans.*

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

**9-60**

For the pattern in bending shown, find the centroid *G* of the weld group.







*I* =*I* 6 mm + *I* 9 mm = (31.02 + 22.67)(106) = 53.69(106) mm4

The critical location is at *B*. With *τ* in MPa, and *F* in kN







*Materials*:

1015 HR (Table A-20): *Sy* = 190 MPa, E6010 Electrode(Table 9-3): *Sy* = 345 MPa

Eq. (5-21): *τ*all = 0.577(190) = 109.6 MPa



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**9-61** In the textbook, Fig. Problem 9-61*b* is a free-body diagram of the bracket. Forces and moments that act on the welds are equal, but of opposite sense.

**(a)** *M* = 5337.8(9.3) = 49.6 kN· mm *Ans.*

**(b)** *Fy*= 5337.8 sin 30° = 2.67 kN *Ans.*

**(c)** *Fx*= 5337.8 cos 30° = 4.62 kN *Ans.*

**(d)** From Table 9-2, case 6:



The second area moment about an axis through *G* and parallel to *z* is



**(e)** Refer to Fig. Problem 9-61*b*. The shear stress due to *Fy*is



The shear stress along the throat due to *Fx*is



The resultant of *τ*1 and *τ*2 is in the throat plane



The bending of the throat gives



The maximum shear stress is

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**(f)** *Materials:*

1018 HR Member: *Sy*= 220 MPa, *Sut*= 400 MPa (Table A-20)

E6010 Electrode: *Sy*= 345 MPa (Table 9-3)



**(g)** Bending in the attachment near the base. The cross-sectional area is approximately equal to *bh.*



At location *A*,



The von Mises stress  is



Thus, the factor of safety is,



The clip on the mooring line bears against the side of the 12.7-mm hole. If the clip fills the hole



Further investigation of this situation requires more detail than is included in the task statement.

**(h)** In shear fatigue, the weakest constituent of the weld melt is 1018 HR with *Sut*= 400 MPa, Eq. (6-10), gives



Eq. (6-18): *ka*= 54.9(400)-0*.*758 = 0*.*585

For uniform shear stress on the throat, assume *kb*= 1.

Eq.(6-25): *kc*= 0*.*59

From Eq. (6-17), the endurance strength in shear is

*Sse*= 0*.*585(1)(0*.*59)(200) = 68.95 Mpa

From Table 9-5, the shear stress-concentration factor is *Kf s*= 2*.*7*.* The loading is repeatedly-applied



Eq. (6-48): Gerber factor of safety *nf*, adjusted for shear, with *Ssu*= 0*.*67*Sut*



Attachment metal should be checked for bending fatigue.

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**9-62** (**a**) Use *b* = *d* = 101.6 mm. Since *h* = 15.87 mm, the primary shear is



The secondary shear calculations, for a moment arm of 355.6 mm give



Thus, the maximum shear and allowable load are:



The load for part (a) has increased by a factor of 48.15/12.07 = 3.99 *Ans*.

(**b**) From Prob. 9-20*b*, *τ*all = 75.84 MPa



The allowable load in part (b)has increased by a factor of 21.17/5.3 = 4 *Ans.*

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**9-63** Purchase the hook having the design shown in Fig. Problem 9-63*b*. Referring to text Fig. 9-29*a*, this design reduces peel stresses.

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**9-64** **(a)**



**(b) **

**(c)** 

For computer programming, it can be useful to express the hyperbolic tangent in termsof exponentials:



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**9-65** This is a computer programming exercise. All programs will vary.