Text: Read 9.1, 9.2

Welding processes.

fusion welding: melting at the common interface.

heat by I^2R or a gas flame.

Electric Arc welding

1. SMAW (Shielded metal arc welding)

   a flux on the welding rod (electrode) vaporizes and forms a protective shield on the weld pool. Common, non-automated process.

2. MIG (metal-inert gas welding)

   - automated. Consumable electrode
   - electrode not coated, but a nozzle provides a shielding gas - Argon / CO_2.

     (Argon ↑ Al; CO_2 ↑ Steels)

3. TIG (tungsten-inert gas welding)

   - non-consumable tungsten electrode.
   - a nozzle provides a shielding gas - Ar, He.
   - filler wire fed separately.
     - Ferrous or non Ferrous welds.

resistance welding I^2R (no filler material) + pressure

laser, electron beam : Specialized applications.

Welded Joints Subject to Static Axial and direct Shear Loading:

<u>CODE</u> AWS Structural welding code.

aim is to 'fuse' two materials into a single, homogeneous member.

AWS & ASTM Standardize welding electrode Specs (Strength, ductility, etc.)

e.g. E 60 XX $\quad 60 \Rightarrow S_{ut}$ at least 60 ksi.

E 70 XX $\quad 70 \Rightarrow S_{ut}$ " " 70 ksi

S_y is about 12 ksi below tensile str.

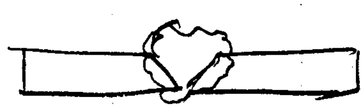
min. elongation bet. 17-25 %.

These properties apply to <u>as-welded</u> material.

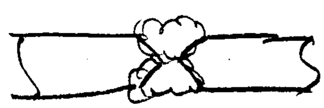
Types of weld:

Butt Weld

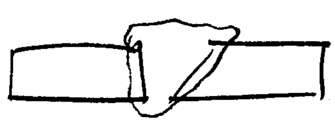
open square



Single V groove

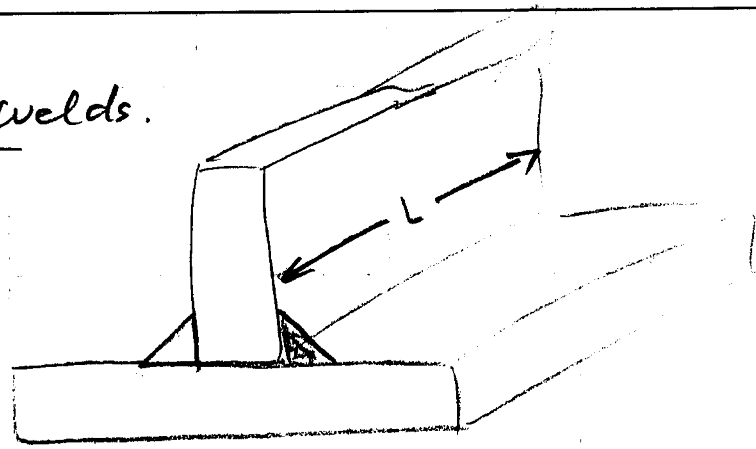


double V groove

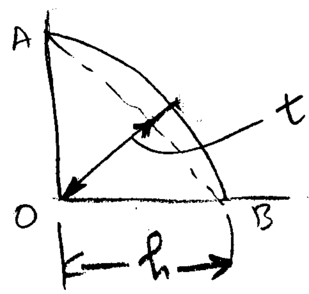


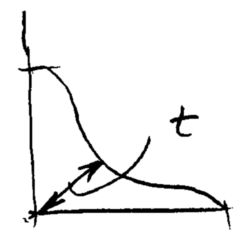
Single bevel

Fillet welds.



Convex bead.





(poor weld)
Concave bead

"h" ⇒ size of the weld.

Significant stress: Shear stress at the throat section.

| Conventional Engg Practice |

$t =$ Shortest distance from O to AB

$t = \frac{1}{\sqrt{2}} h$

$t = .707\ h$

$(2t)^2 = 2h^2$

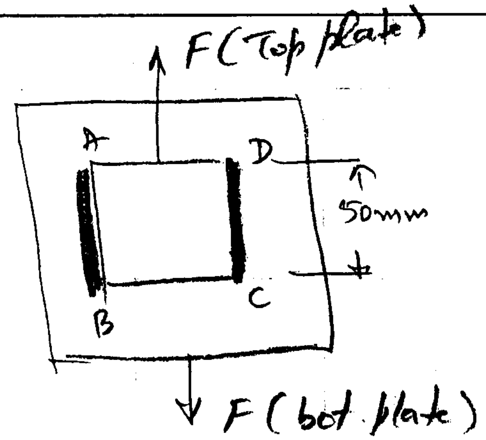
$4t^2 = 2h^2$

$t^2 = \frac{1}{2} h^2$

$t = \frac{1}{\sqrt{2}} h$

throat area $= t L$

weld size: h at least 3 mm for plate < 6 mm thick and at least 15 mm for plates > 150 mm thick.



EXAMPLE #1

Parallel-loaded Fillet weld.

Plates 12 mm thick of Steel $S_y = 350$ MPa
welded along AB, CD, each 50 mm long.

$S_{y,weld} = 350$ MPa.

with a fos of 3 (based on yield str.)
what static load F can be carried using a 6 mm weld leg?

Assumption: weld fails in shear at throat.

1) total weld throat area = $A = tL$
$= (.707)(6)(100)$
$= 424\ mm^2$

2) distortion energy theory: $S_{sy} = .577\ S_y = 203$ MPa

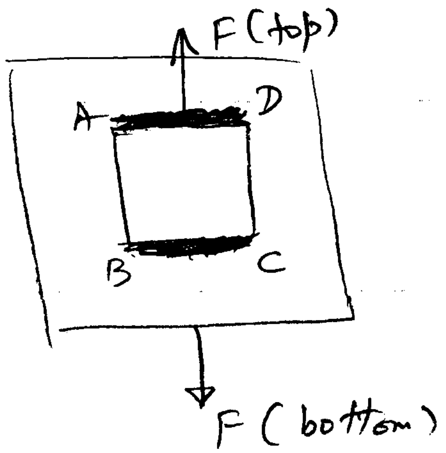
3) $n\left(\frac{F}{A}\right) = S_{sy}$ $\quad F = \frac{S_{sy} \cdot A}{n}$

$= \frac{(203)(424)}{3} = 28,700$ N

$= 28.7$ kN.

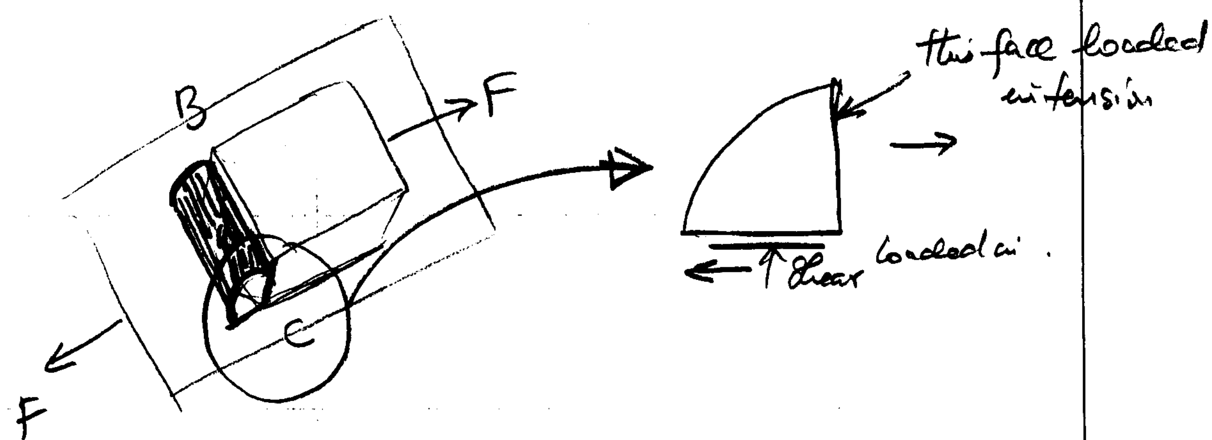
EXAMPLE #2.

Transversely loaded fillet weld



Suppose now sides AD and BC are welded.
the weld is transversely loaded.

Again we assume that the weld fails at the throat, which carries the entire load in shear.



Assumption. As the load F 'flow' thru the weld metal the loading has varying proportions of tension & shear. the critical section is assumed to be the minimum throat section, with area tL, which carries entire ~~the~~ load in shear ~~alone~~.

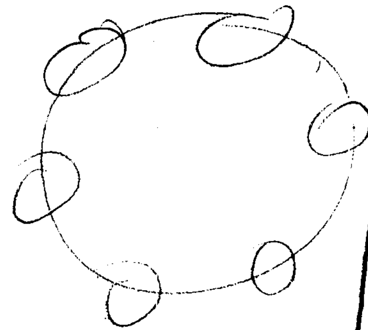
$$\frac{F}{A} = \frac{S_{sy}}{n} \qquad F = 28.7 \text{ kN}$$
as before.

(this solution is less rigorous than Ex 1. due to assumption made)

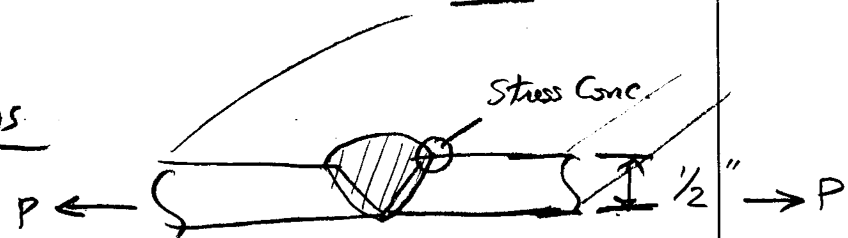
Note on bolt spacing FOR PROJECTS

$$3 < \frac{\pi d_b}{N} < 6$$

- 3 ← wrench clearance
- $\frac{\pi d_b}{N}$
- 6 ← effective seal.



Fatigue Considerations



(K_f Tabulated).

butt weld.

for fatigue, better to grind the weld flat to eliminate stress raiser.

Example # 3

P fluctuates between 5000 and 15000 lb.
Plates are 1/2 in. thick.
weld is not ground off. ; $K_f = 1.2$
E 60 welding rod is used with $S_u = 62$ ksi
$S_y = 50$ ksi
n, fos, $= 2.5$
what length of weld L is required?

Assumptions:

- infinite life is required
- $k_{c,ax} = 0.85$
- ~~kf~~ assume surface condition comparable to ~~ksurf~~ as-forged surface (Table ~~4~~ 7-5, p 375)

$$K_{surf} = 39.8\ (62)^{-.995}$$

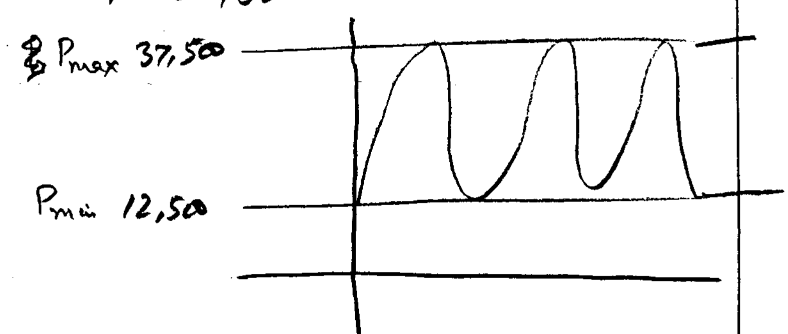
$$= 0.655$$

$$S_e' = .506\ (62) = 31.4\ ksi$$

$$S_e = (31.4)(.85)(.655) = 17.5\ ksi$$

with a fatigue fos of 2.5, the tensile load varies from 12,500 to 37,500 lb.

weld area = .5 L



$$\sigma_m = K_f \frac{P_m}{A}$$

$$\sigma_a = K_f \frac{P_a}{A}$$

$$P_m = \frac{1}{2}(P_{max} + P_{min}) = 25,000$$

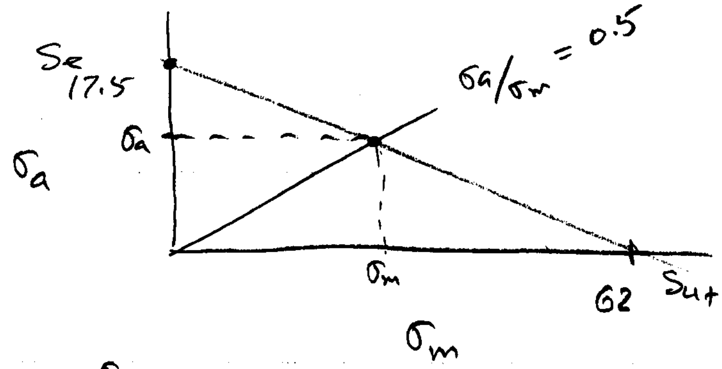
$$P_a = \frac{1}{2}(P_{max} - P_{min}) = 12,500$$

$$\sigma_m = \frac{60,000}{L}$$

$$\sigma_a = \frac{30,000}{L}$$

$$\sigma_a / \sigma_m = .5$$

Goodman :



$$\frac{\sigma_a}{Se} + \frac{\sigma_m}{Su} = 1.0$$

$$\frac{\sigma_a}{\sigma_m} = \frac{1}{2} \qquad \sigma_m = 2\,\sigma_a$$

~~$\frac{1}{Se} + \frac{(\sigma_m)(\sigma_a)}{Su}$~~

$$\frac{\sigma_a}{Se} + \frac{2\,\sigma_a}{Su_t} = 1.0$$

$$\sigma_a Su + 2\,\sigma_a Se = Se\,Su_t$$

$$\sigma_a\,(Su + 2\,Se) = Se\,Su_t$$

$$\sigma_a = \frac{(17.5)(62)}{62 + (2 \times 17.5)}$$

$$= 11.18 \text{ ksi}$$

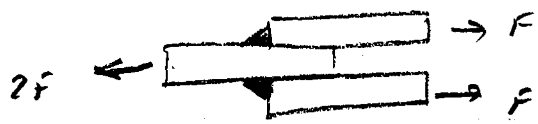
$$\sigma_a = \frac{30{,}000}{L} = 11.18 \text{ ksi.} = 11{,}180 \frac{lb}{in^2}$$

$$L = \frac{30{,}000}{11{,}180} = \underline{2.68 \text{ in}}$$

L could be rounded off to 3.0 in.

— Ans.

Read 9.1, 9.2 (Butt & Fillet Welds)



t  h

$t = .707\,h$

Shear stress at throat $\tau = \frac{F}{tL} = \frac{S_{sy}}{n\,(fos)}$

Example #4

The 1018 steel strap has a 1000 lb, completely reversed load. Evaluate the fatigue strength of the weld for infinite life for $n_d = 3.0$ (n_d = design fos)

(a) use the conventional ~~sa~~ factor-of-Safety approach.

~~(b) use AISC code fatigue allowable stress method.~~

1018 Steel

Table E20

$S_{ut} = 58$ ksi

$S_y = 32$ ksi.

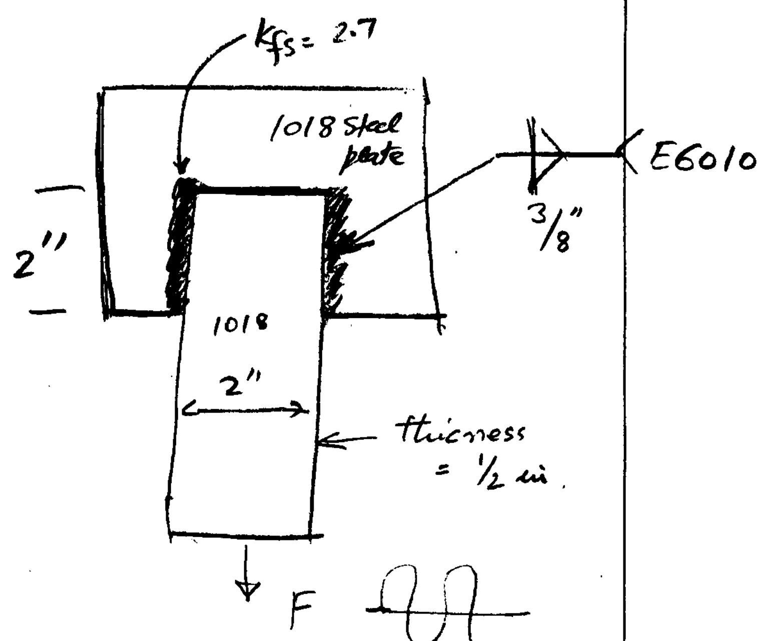
E60 Electrode

(Text Table 9-4)

$S_{ut} = 62$ ksi.

$S_y = 50$ ksi

$K_{fs} = 2.7$



1000 lb fully reversed.

Throat Area:

$A = (.707)(.375)(2\times 2) = 1.061\ in^2$

Analysis is based on weaker of the two materials.

surface factor (assume as-forged surface)

$$k_a = 39.8\,(58)^{-.995} = 0.7$$

Size factor:
for uniform shear stress on the throat, use $k_b = 1$

Load factor: (~~to~~ uniform shear, use k_c for torsion)

$$k_c = 0.59 \quad \text{(average)}$$

OR $$k_c = 0.328\,(58)^{.125} = .545 \quad \text{(Table 7-7)}$$

Let us use $k_c = .545$ in this example.

k_d (Temp), k_e (Misc) $= 1.0$

Now

$$S_{se} = (.7)(1)(.545)(1)(1)(.506)(58) = 11.2 \text{ ksi}$$

$F_a = 1000$ lb $\qquad F_m = 0$

$K_{fs} = 2.7$

$$\tau_a = K_{fs}\frac{F_a}{A} = \frac{2.7\,(1000)}{1.061} = 2545 \text{ psi.}$$

$$n_f = \frac{S_{se}}{\tau_a} = \frac{11{,}200}{2545} = 4.4$$

Since $n_f > n_{design}\,(3.0)$, the weld is satisfactory for fatigue.

Adequacy assessment of a weld

~~first decide:~~ variables are:

decide first → weld pattern, Electrode, type of weld (eg fillet)

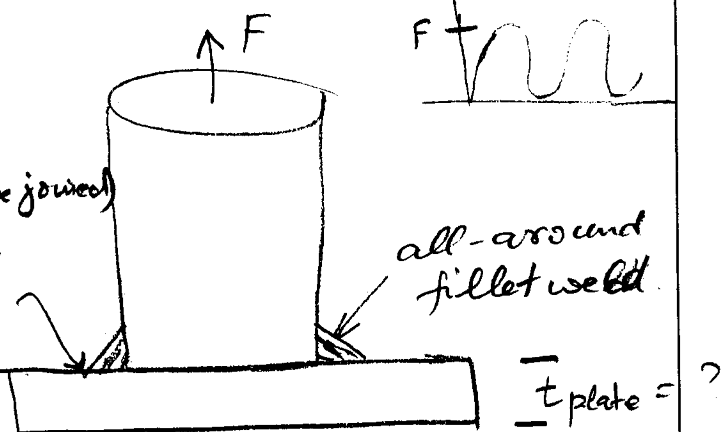
l = Length of weld	one of these may be
Leg size, h	design variable.

or, specify both l and h, and check to see if weld strength (static & fatigue are OK).

Now for Project:

1) Pick electrode (stronger than ~~conduct~~ materials to be joined) use. $K_{fs} = 1.5$

60/70/80/
90/100/120
Table 9-4



Minimum fillet Weld Size, h (Table 9-7)

Thickness of the thicker part	Min. weld size
up to 1/4", incl.	1/8
over 1/4" to 1/2"	3/16
1/2 to 3/4"	1/4
3/4 to 1 1/2"	5/16
1 1/2 to 2 1/4"	~~1/2~~ 3/8
2 1/4 to 6"	1/2

F varies from 0 to F.

$F_a = \frac{F}{2}$, $F_m = \frac{F}{2}$

Estimate S_{se} (for, weaker of the weld, steel or plate)

$\tau_a = K_{fs} \frac{F_a}{A}$

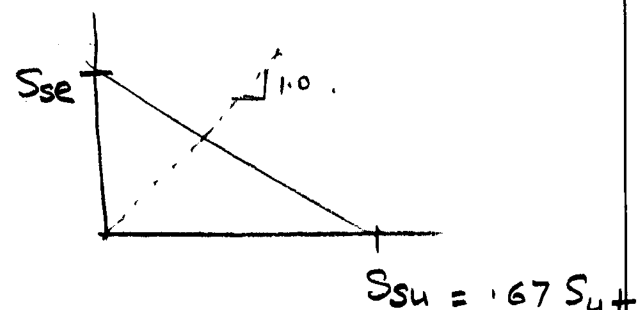
$\tau_m = K_{fs} \frac{F_m}{A}$

$A = (\pi D_{shell})(.707)(h)$

h = weld leg.

Goodman:

$$\frac{\tau_a}{S_{se}} + \frac{\tau_m}{S_{su}} = \frac{1}{n_f}$$



find n_f and see how it compares to the design fos of 3.5