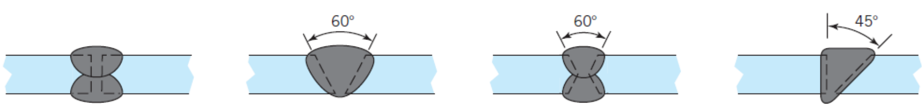
Welded joints

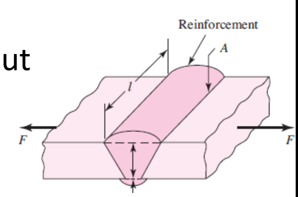
- Welding process involving fusion of the work pieces together
- Extensively used in steel structures
- Compared to bolted or riveted joints welding
  - does not require geometry changes in members (holes)
  - is leak proof
  - quicker and less in weight
- Members are taken to higher temperature
  - can lead to metallurgical changes that can affect their properties locally: **Heat Affected Zone**
  - can induce local residual stresses and distortion
- Is permanent connection
- Properties of welding rod (filler material) should be matched properly with those of parent material

Butt welds



Open square | Single V groove | Double V groove | Single bevel

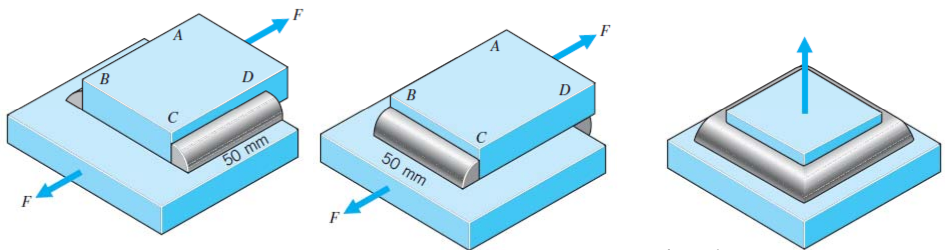
- If the strength of the electrode is matched with that of the parent material, then no analysis is needed for static loads
- If filler penetrates fully through the thickness and welding is properly done, then joint is as strong as the parent material
- In fatigue loading, voids and inclusions can cause stress concentration
- The "reinforcement" i.e weld protruding out beyond plate thickness can cause stress concentration (point A in figure)



- See table 9-5 in data book

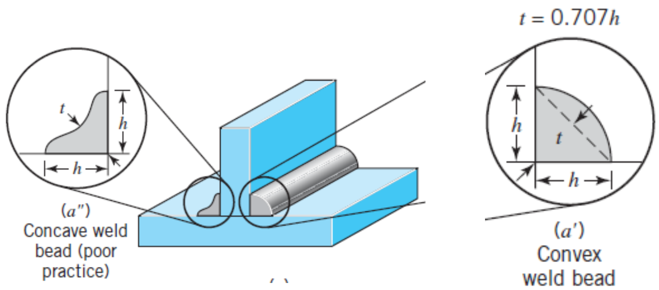
Fillet welds

- Classified according to direction of loading



Parallel loading

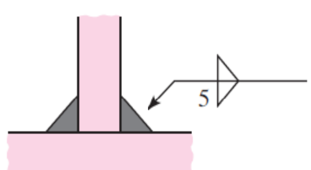
Transverse loading



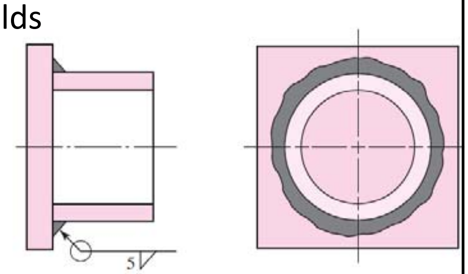
t- throat
h- leg size

Welding symbols

Fillet welds

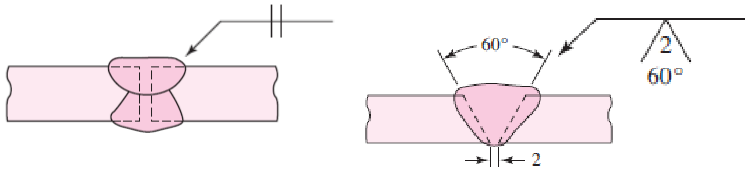


- Number indicates leg size in mm
- Two triangles indicate same size weld on both sides



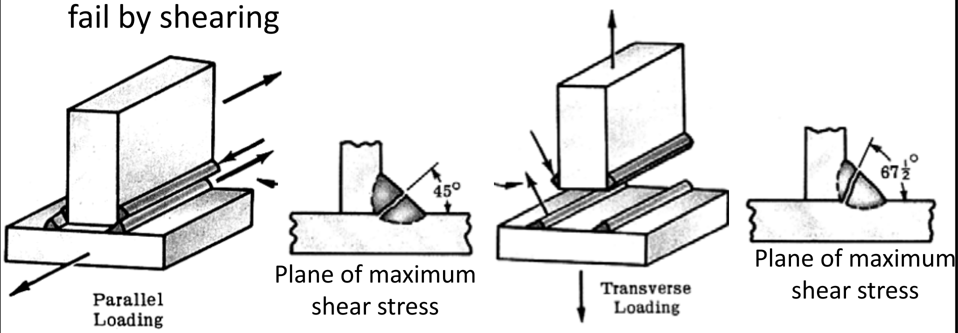
Circle indicates same size weld all around

Butt welds

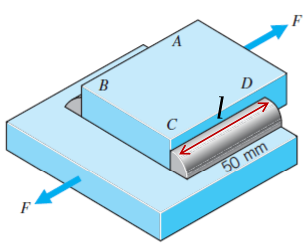


Design of fillet welds

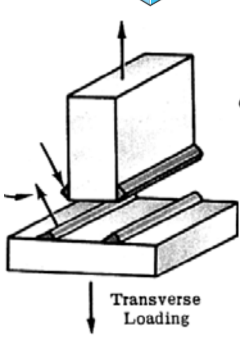
- Irrespective of type of loading, fillet welds are observed to fail by shearing

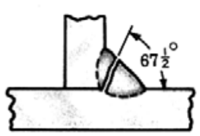


- For same length and leg size, strength will be more in transverse loading as area along plane of maximum shear stress (67.5°) is higher
- Design is carried out using the area along the throat (is 45° plane)
  - Takes care of uncertainty of loading direction
  - Conservative



$$\tau = \frac{F}{A_{throat}} = \frac{F}{2(0.707hl)} = \frac{0.707F}{hl}$$



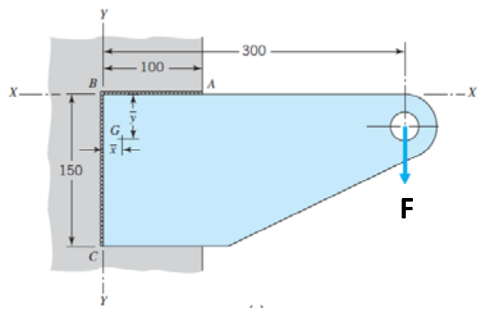


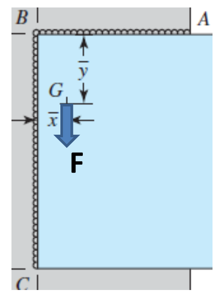
$$\tau = \cancel{\frac{0.605F}{hl}}$$

$$\tau = \frac{0.707F}{hl}$$

Use this expression

Weld under torsion

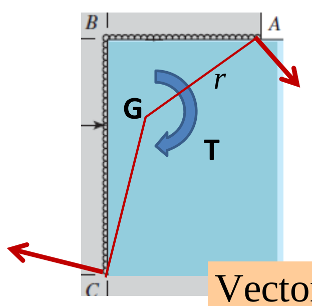




- Determine the cetroid

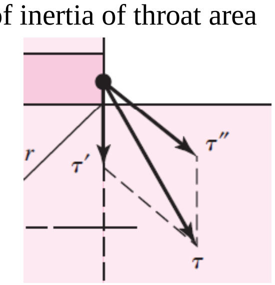
Primary shear; $\tau' = \dfrac{F}{A_{throat}}$

- Assumed to be uniformly distributed over the entire length of the weld

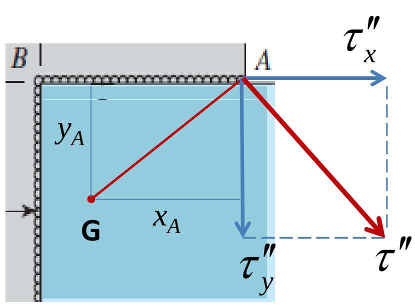


Secondary shear; $\tau'' = \dfrac{Tr}{J}$

J is the polar moment of inertia of throat area



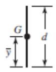
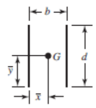
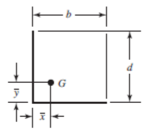
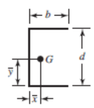
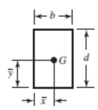
Vectorially add τ' and τ''



$$\tau''_x = \frac{Ty_A}{J}; \quad \tau''_y = \frac{Tx_A}{J}$$

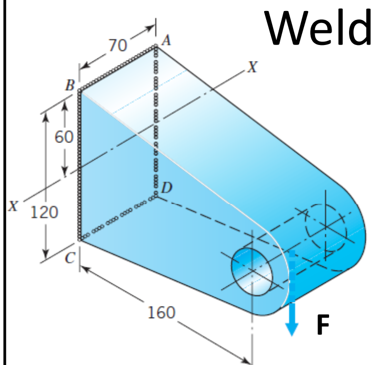
$$\tau'_x = 0; \quad \tau'_y = \frac{F}{A_{throat}}$$

$$\tau = \left\{(\tau'_x + \tau''_x)^2 + (\tau'_y + \tau''_y)^2\right\}^{1/2}$$

Weld	Throat Area	Location of G	Unit Second Polar Moment of Area
	$A = 0.70\,hd$	$\bar{x} = 0$ $\bar{y} = d/2$	$J_u = d^3/12$
	$A = 1.41\,hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$J_u = \frac{d(3b^2 + d^2)}{6}$
	$A = 0.707h(2b + d)$	$\bar{x} = \frac{b^2}{2(b+d)}$ $\bar{y} = \frac{d^2}{2(b+d)}$	$J_u = \frac{(b+d)^4 - 6b^2d^2}{12(b+d)}$
	$A = 0.707h(2b + d)$	$\bar{x} = \frac{b^2}{2b+d}$ $\bar{y} = d/2$	$J_u = \frac{8b^3 + 6bd^2 + d^3}{12} - \frac{b^4}{2b+d}$
	$A = 1.414h(b + d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$J_u = \frac{(b+d)^3}{6}$
	$A = 1.414\,\pi hr$		$J_u = 2\pi r^3$

$$J = 0.707hJ_u$$

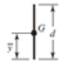
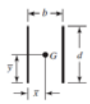
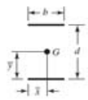
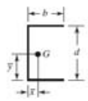
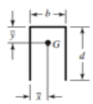
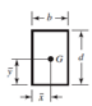
Weld under bending



$$\text{Primary shear;}\ \tau' = \frac{F}{A_{throat}}$$

$$\text{Secondary shear;}\ \tau'' = \frac{My}{I}$$

$$\tau = \sqrt{(\tau')^2 + (\tau'')^2}$$

Weld	Throat Area	Location of G	Unit Second Moment of Area
	$A = 0.707hd$	$\bar{x} = 0$ $\bar{y} = d/2$	$I_u = \frac{d^3}{12}$
	$A = 1.414hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \frac{d^3}{6}$
	$A = 1.414hd$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \frac{bd^2}{2}$
	$A = 0.707h(2b + d)$	$\bar{x} = \frac{b^2}{2b+d}$ $\bar{y} = d/2$	$I_u = \frac{d^2}{12}(6b+d)$
	$A = 0.707h(b + 2d)$	$\bar{x} = b/2$ $\bar{y} = \frac{d^2}{b+2d}$	$I_u = \frac{2d^3}{3} - 2d^2\bar{y} + (b+2d)\bar{y}^2$
	$A = 1.414h(b + d)$	$\bar{x} = b/2$ $\bar{y} = d/2$	$I_u = \frac{d^2}{6}(3b+d)$

$$I = 0.707hI_u$$

I is about horizontal axis

Strength of weld electorde

AWS Electrode Number*	Tensile Strength kpsi (MPa)	Yield Strength, kpsi (MPa)	Percent Elongation
E60xx	62 (427)	50 (345)	17–25
E70xx	70 (482)	57 (393)	22
E80xx	80 (551)	67 (462)	19
E90xx	90 (620)	77 (531)	14–17
E100xx	100 (689)	87 (600)	13–16
E120xx	120 (827)	107 (737)	14

- Yield strength in shear $S_{sy} = 0.577\ S_y$
- Check the design for failure in the weld
- Also check the members based on their material strength (weld attachment)

Fatigue loading

- SN diagram

$$S_e = k_a k_b k_c k_d k_e k_f S'_e; \quad S'_e = 0.5 S_{ut}$$

  - For surface factor , use “as forged” surface finish
  - Size factor is 1 as stress is assumed to be uniform
  - Load factor is 0.59 since design is based on shear stress
  - Stress concentration factor is given in table 9-5
  - Apply this on the stress
- Use Goodman line