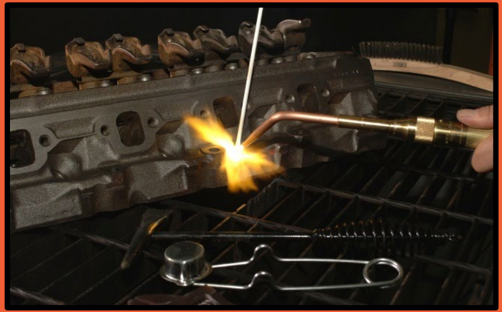
MECH3460
Weld Design



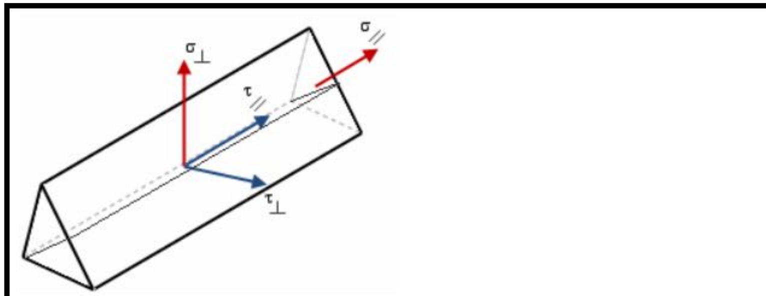
THE UNIVERSITY OF SYDNEY

A short lecture on Weld Design as Part of MECH3460: Mechanical Design 2

By Paul Briozzo and Dr. Andrei Lozzi.

Basic Weld Design Methods

1. Analyse the weld as shown using Solid Mechanics methodology. Try alternate weld outlines to arrive at a preferable weld which has some advantages e.g. length, weight, least preparation. **A programmable CAD system could be used to automate the analysis.**



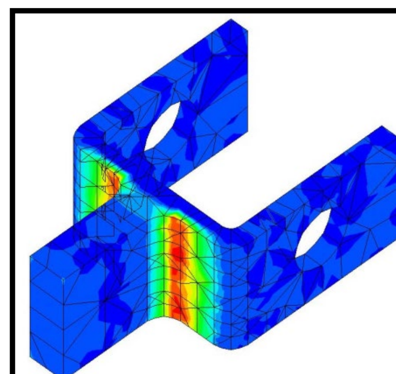
The resistance of a fillet weld is sufficient if the following formulas are both satisfied:

$$[\sigma_{\perp}^{2} + 3\,(\tau_{\perp}^{2} + \tau_{//}^{2})]^{0,5} \leq f_u / (\beta_w \gamma_{M2})$$

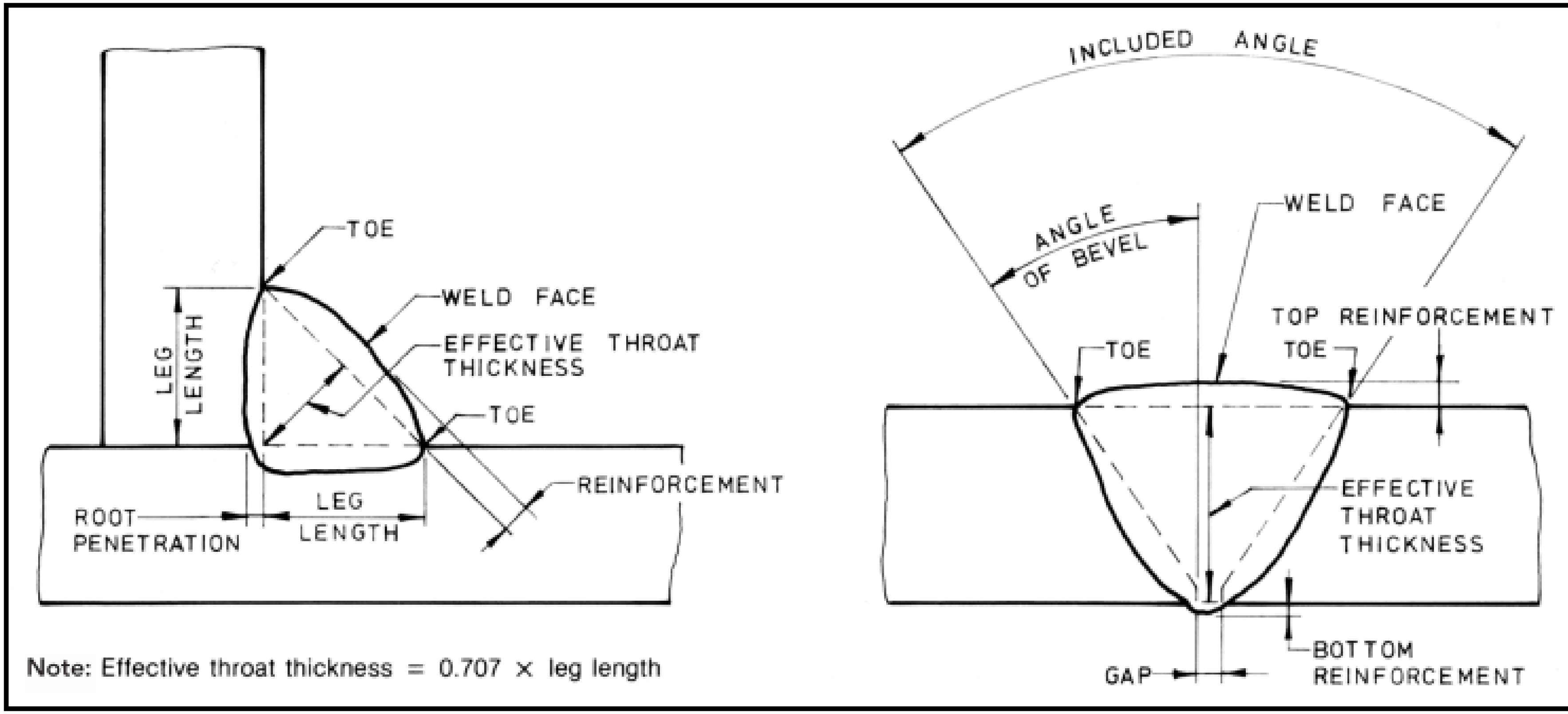
$$\sigma_{\perp} \leq f_u / \gamma_{M2}$$

2. Design a structure so that its components are able to carry their loads. **Then weld all around the joins to the depth of the wall of the components. Do not analyse the welds.** All around welds are employed in many situation to seal the joining faces from corrosion or other intrusions.

3. **Use an FEA method of analysis.** Insert welds at required to the depth and width that they lower stresses in their neighbours below safe limits.



Welding Terminology



Standard terminology for various elements of fillet and butt welds.

Basic Weld Design - Overview

A Quick Overview:

1. Select the weld outline that you would like to analyse. Figure 1.0 shows a simple “C” outline shape that lies on the outside of the “C” shaped channel.

2. Ensure that you know the value and direction of all of the forces and the boundary conditions that are acting on the design.

3. This method determines how wide the weld needs to be to be to carry the necessary loads. However, the outline of the weld needs to be decided on **<u>first.</u>**

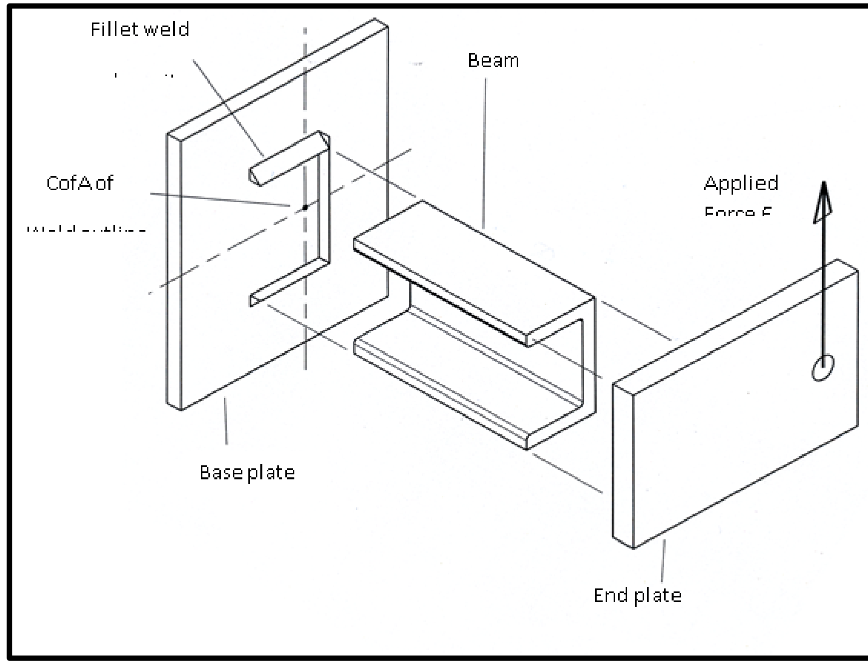


Figure 1.0

The creative part of weld design is to determining the shape and length of the weld outline.

Basic Weld Design - Overview

For Example:
For the weld shown in Figure 1.0, the “C” shaped outline that goes around the outside of the “C” channel has been chosen.

Alternatively, just 2 horizontal runs, top and bottom could be used or many other alternatives. Having chosen the outline the weld width is then calculated.

If there appears to be an issue with the chosen width, then another outline needs to be considered and calculations redone. Once this process is undertaken a number of times (optimisation), a suitable outcome could be that the weld outline requiring the least weld deposit is arrived at.

The use of a spreadsheet would greatly assist in this process.

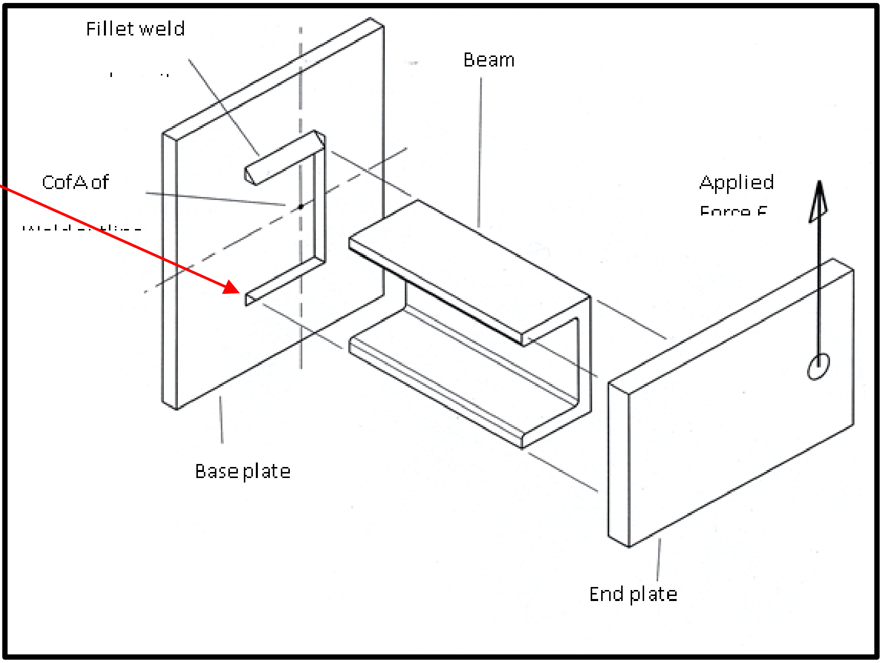


Figure 1.0

Basic Weld Design - Deposition

The weld deposit is "The Thing" that we are trying to analyse. The weld shown in Figure 1.0 joins 2 adjacent parts, the beam and the base plate but, **the weld is the only 'component' being analysed here.**

It is assumed that the base plate is flat and that the beam meets it with a flat cross section.

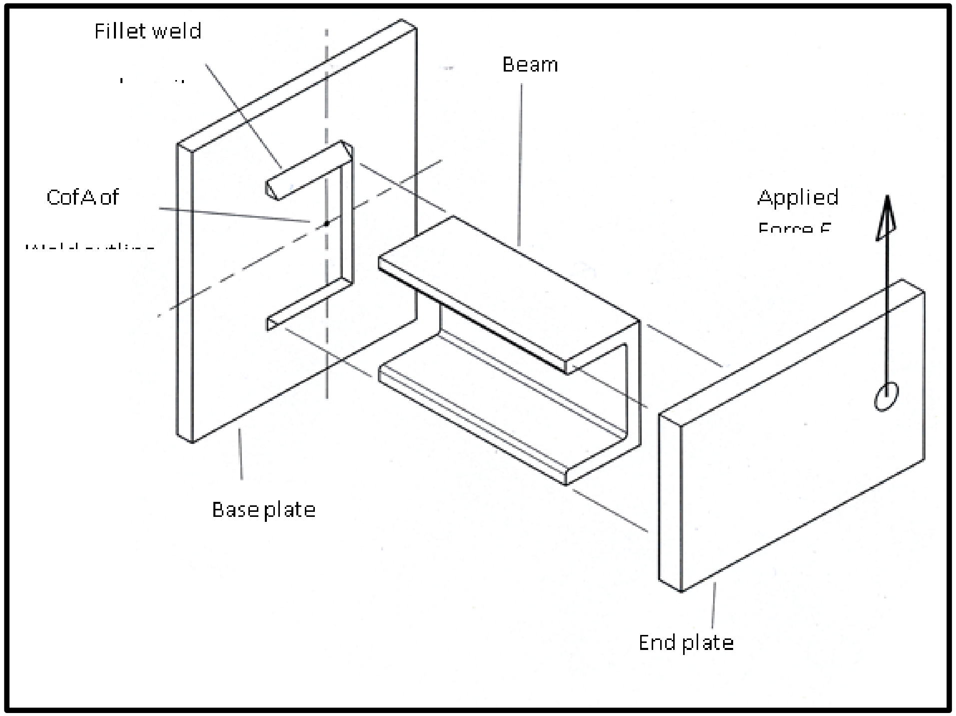


Figure 1.0

Basic Weld Design - Deposition

The beam does not have to be perpendicular to the plate, and the shape and size of the beam from the weld to the load has no effect on the weld calculation. The beam can be curved, bent and joined to other components.

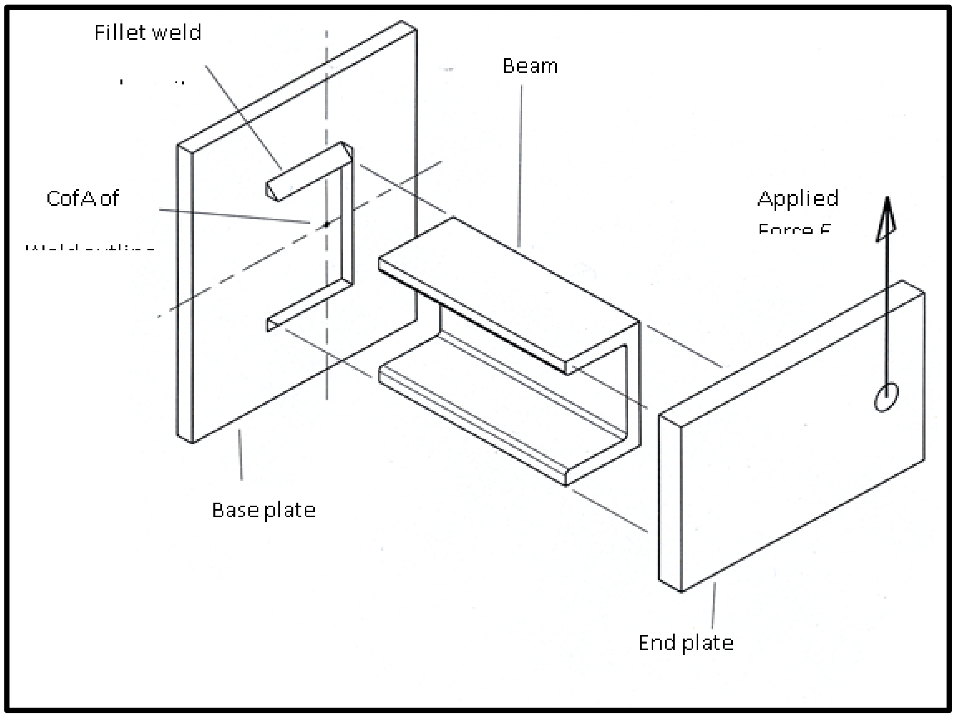


Figure 1.0

Basic Weld Design - Deposition

The main concern is the relative location in space of the load relative to the Centre of Area, (C of A) of the weld outline.

The exploded view below can be replaced with Figure 2.0 where the location of the force and the weld outline are shown schematically.

Figures 2.0 and 3.0 show how we arrive at the shear force, moment and torque that the weld has to be designed to carry.

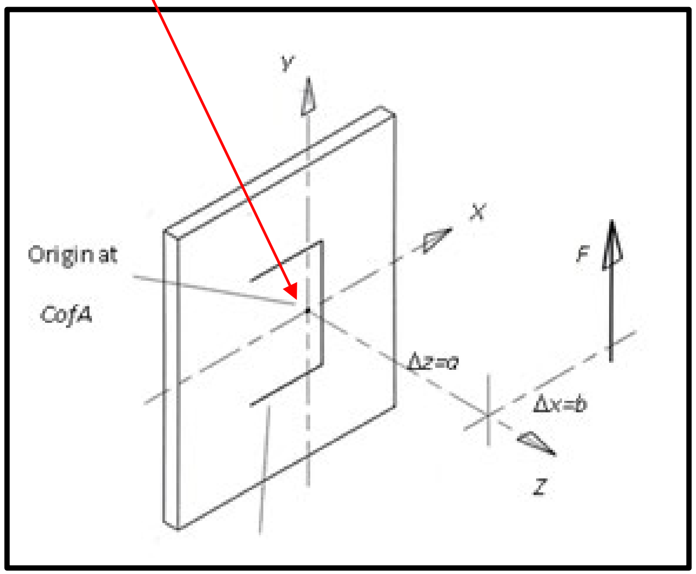


Figure 2.0

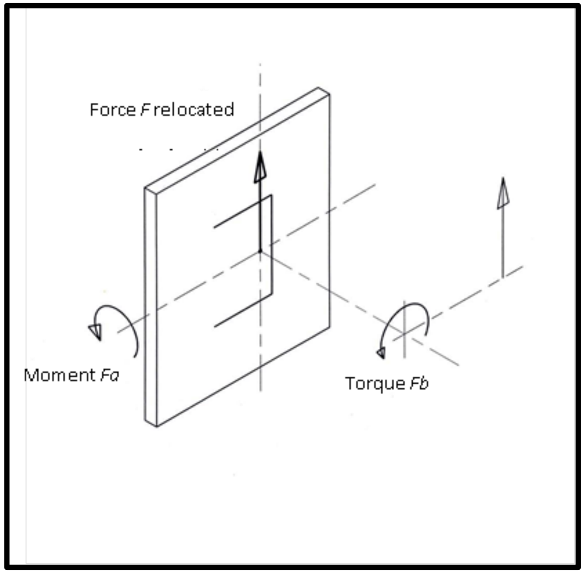


Figure 3.0

Basic Weld Design - Deposition

Figure 2.0 represents a schematic diagram reproducing Figure1.0, showing force *F* and its location in space with respect to the C *of A* of the weld outline.

Because (in this case) the weld is on the outside of the beam, the weld outline is taken to be the outer boundary of the beam.

Note that it is the *C of A* of the weld run NOT the *C of A* of the beam, that is relevant here.

Note again that it does not matter what the shape of the components are that connect force *F* to the weld. This may have to be considered separately.

Other factors that need consideration include; compatibility of weld deposit to the plate thicknesses. This requires research and consultation with the welder undertaking the weld at hand.

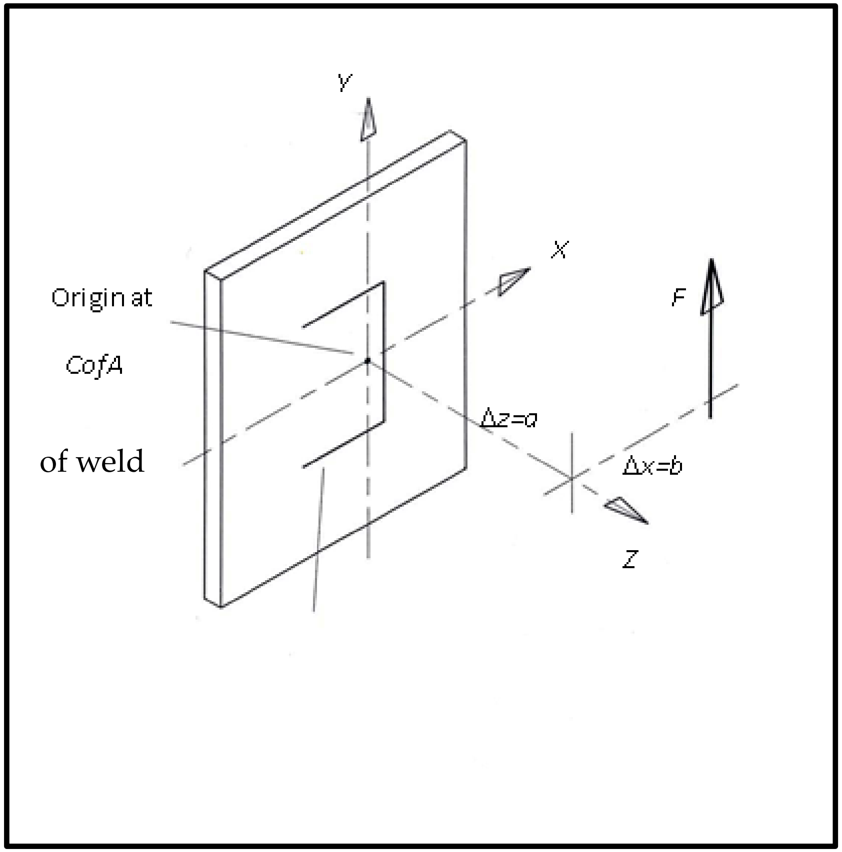


Figure 2.0

Basic Weld Design - Deposition

Figure 3.0 illustrates that the stresses in the weld are determined by firstly translating the force *F* from its point *F* of application to the C *of A* of the weld outline.

Moving the force to the *Z* axis through distance *b* generates the torque F_b, moving it down the *Z* axis to the C *of A* of the weld generates the moment F_a.

In this case, *F* is assumed parallel to the base plate and the *Y* axis, but this does not need not be the case in all weld arrangements.

We can now arrive at the weld width, *w* from the loads that it has to carry:

1. The torque F_b
2. The moment F_a and
3. The shear force ***F***.

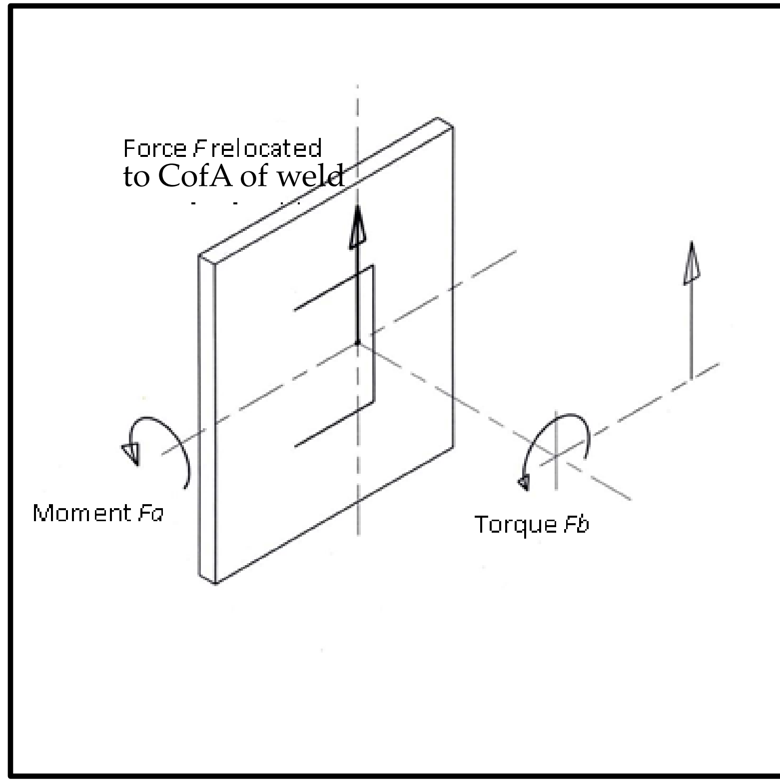


Figure 3.0

Basic Weld Design – Practical Short Cuts Taken to Simplify Weld Analysis

Practical short-cuts taken to simplify weld analysis. The analysis presented here is based on that of the American Welding Association (AWS) as written up in Hall and Blodget. The objective is to provide a simple means of calculating fillet widths ***w*** for any combination of shear force, moment and torque. It has been developed to reduce an engineer's time and ultimately, engineering costs.

1. Initially consider shear forces and shear stresses only – this simplifies calculations, it is a conservative approach. However, where the theoretical modelling is less than conservative, a correction will be made.

2. This method only considers equal legged fillet welds (45° fillets) as these are the most common. The analysis method may be extended to unequal legged welds by modification to the geometry being examined.

3. In the calculations, the **leg length *w***, NOT the minimum cross section, i.e. the throat thickness *t*, because we cannot easily measure ***t*** but measuring ***w*** is more easily done. A correction is made for this measurement.

4. It is assumed that the point where the load is being applied is sufficiently far enough away from the weld so as **not to cause any stress concentration at the weld**.

Basic Weld Design – Practical Short Cuts Taken to Simplify Weld Analysis

Figure 4.0 illustrates a short, straight fillet weld of equal leg w and length l. The 2 plates shown transmit force ***F*** through the weld. Two of the components of the force lie transverse to the weld, i.e. F_x and F_y, the third component F_z lines up parallel with the weld run.

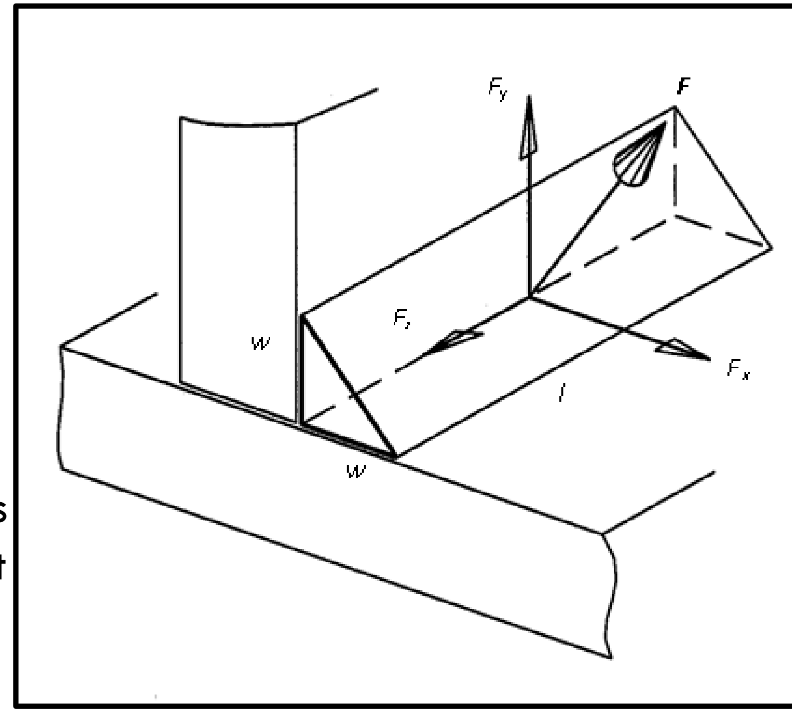


Figure 4.0

The rule is: If any component of a force at a weld is parallel to the weld then the whole force will be assumed to be parallel to the weld. Most of the time this will forgo a small advantage of transverse welds (about 15%) for the sake of reducing the cost of analysing welds. If the deposit is particularly large and expensive the advantages of transverse welds may be considered.

Also for the sake of simplification we will also use,
w . l as the nominal stress area.

The fact that the minimum stress area is less than w . l is allowed for with coefficient at a later stage in the calculations.

Basic Weld Design - Shear Force

We will now examine the effect of the shear force transmitted by the weld outline. We will characterise this by a force per mm of the weld length due to shear force - f_s.

Eq 1. Shear stress is: $\tau = \frac{shear\_force}{Area} \cdot FS$ Assuming **F** is completely in shear and

Eq 2. at nominal stress area: $\tau = \frac{F}{w \cdot l} \cdot FS$ Where, ***FS*** = Factor of Safety, which may be 1.2 to 2.

Eq 3. rearrange to give *w*: $w = \frac{Force}{\tau_{all} \cdot l} \cdot FS$ Where τ_{all} is the allowable shear stress of the weld deposit

Eq 4. we will use the form: $w = \left(\frac{FS}{\tau_{all}}\right) \cdot \left(\frac{F}{l}\right)$ This gives weld width *w* for a shear force and length *l*

Eq 5. or: $w = \left(\frac{FS}{\tau_{all}}\right) \cdot f_s$

Since the terms in the first bracket are predetermined by the choice of materials and ***FS***, the second bracket (***F / l***) or force per unit length of weld, determines the weld width *w*. The expression ***F / l*** is substituted by the term f_s, **which is called the,**

Force per unit length (mm) of weld run due to the shear force.

Basic Weld Design - Shear Force

Note that $\boldsymbol{f_s}$ is a vector, because it comes from dividing $\boldsymbol{F}$, a vector, by a scalar $\boldsymbol{l}$. Therefore $\boldsymbol{f_s}$ points parallel to $\boldsymbol{F}$, in this example in the $\boldsymbol{Y}$ direction and in the plane of the base plate, i.e. $\boldsymbol{f_s}$ has only a $\boldsymbol{y}$ component.

Also $\boldsymbol{f_s}$ exists undiminished (does not change) all around the weld outline. Left like that this analysis would not be conservative because shear stress, due to a shear force, is not equally distributed across a section, it is a maximum at the neutral axis and is 0 at the most distant fibres. This will be further discussed in this lecture.

Equation 6 and Equation 5 can be reordered to give $$w \cdot \tau_{all} = \left(\frac{F}{l}\right) = f_s$$

(temporarily omitting the FS).

This form tells us that if we can evaluate $\boldsymbol{w.\tau_{all}}$ for the moment and the torque that is transmitted through the weld, **M** and **T** on Figure 3.0, it will give us the force per mm of weld length resulting from each of those loads.

Finally, the vector sum of all the 3 forces per unit length, when divided by will give us the width of the weld.

Basic Weld Design – Bending Moment

Bending moment We will now deal with the shear stress at the weld due to the bending moment. We will characterise this by a force per mm of the weld length due to bending - $\boldsymbol{f_b}$.

Equation 7: Normal stress due to bending: $\sigma = \frac{M \cdot y}{I}$

Equation 8: Using modulus of section *Z*: $\sigma = \frac{M}{Z}$ Where $Z = I/y$ is tabled in catalogues of metal sections

Equation 9: Assuming, $\tau \leq \sigma$ we can let: $\tau = \frac{M}{Z_w \cdot w}$ where $Z = Z_w \cdot w$, that is Z_w is the modulus of section for that weld outline, for a width $w = 1$ mm. The Z for the actual section will be larger than $Z_w \cdot w$ unless the width, $w < 1$ mm. This analysis will be conservative for all but very thin welds.

Equation 10 and Equation 9 gives us, f_b $\tau \cdot w = \frac{M}{Z_w} = f_b$ **Which is the force per mm of weld length due to bending.**

Basic Weld Design – Bending Moment

Figure 5.0 illustrates that just as the normal stress σ created by the bending moment is a vector, so is the force per unit length due to bending f_b is also a vector, which was derived from it.

Note that f_b ranges between a maximum positive to max negative value, at the largest distance y from the neutral axis X.
f_b varies linearly to 0 at the neutral axis.

The weld outline is a reversed C. From Figure 1.0 we know that it attaches a "C" channel to a plate, but the analysis of this outline would be no different if it were used on 3 sides of a Rectangular Hollow Section (RHS) or any other beam that has 3 suitable sides.

Note also that $\mathbf{f_b}$ is perpendicular to the plate and that in this coordinate system it has only a $\boldsymbol{z}$ component.

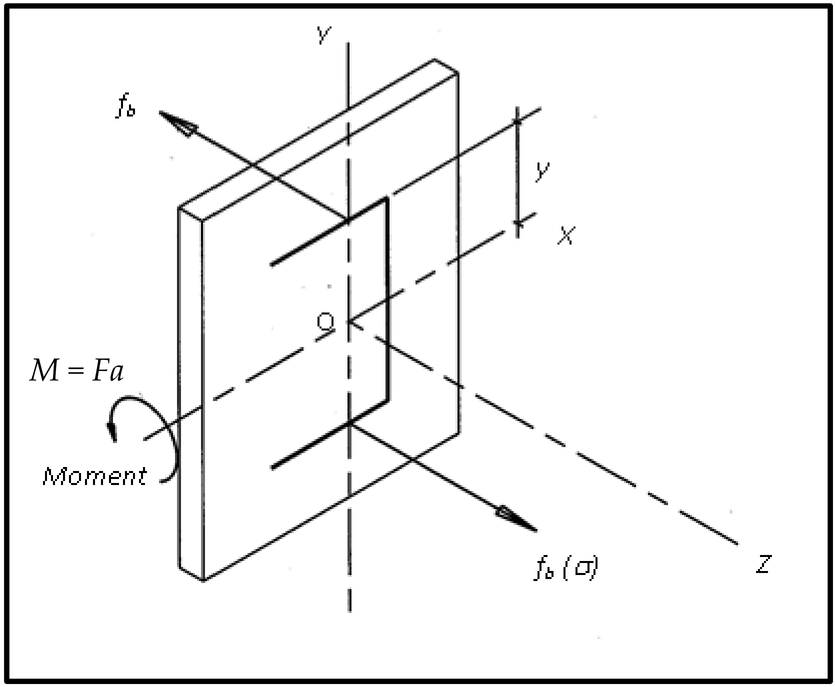


Figure 5.0

Basic Weld Design – Torque

Torque We will now deal with the force per mm of the weld length, due to torque f_j.

Equation 11 Shear stress due to torque: $\tau = \frac{T \cdot r}{J}$ normally this equation applies to circular sections only.

Equation 12 let polar moment of area *J*: $J = J_w \cdot w$

Equation 13 $\tau = \frac{T \cdot r}{J_w \cdot w}$ where J_w is the polar moment of area of the weld outline, for a width $w = 1$ mm. The J for the actual section will be larger than $J_w \cdot w$ unless as indicated above the width $w < 1$ mm. This analysis will also be conservative for all but very thin welds.

Equation 14 The above gives us f_j: $\tau \cdot w = \frac{T \cdot r}{J_w} = f_j$ **Force per mm weld length due to torsion.**

Basic Weld Design – Torque

Figure 6.0 This figure shows graphically how f_i is evaluated around a weld outline. f_i is a vector quantity and will typically have a different value for each point around the outline. The applied torque T will be a constant as will J_w and Z_w.

Figure 7.0 on the following slide gives expressions for J_w and Z_w for common outlines. The only variable in the calculation of f_i will then be r_i, the radial distance from the *CofA* of the weld to the point of interest on the weld. F_i being in the same direction as the shear stress τ, will be in the plane of the plate and perpendicular to r_i.

Here f_{ji} will only have *x* and *y* components. Equation 11 applies only to circular sections (tubes etc) cannot be applied to the beam of "C" section but may be applied to this weld because the inner portion of the square plate will behave approximately like part of a circular plate.

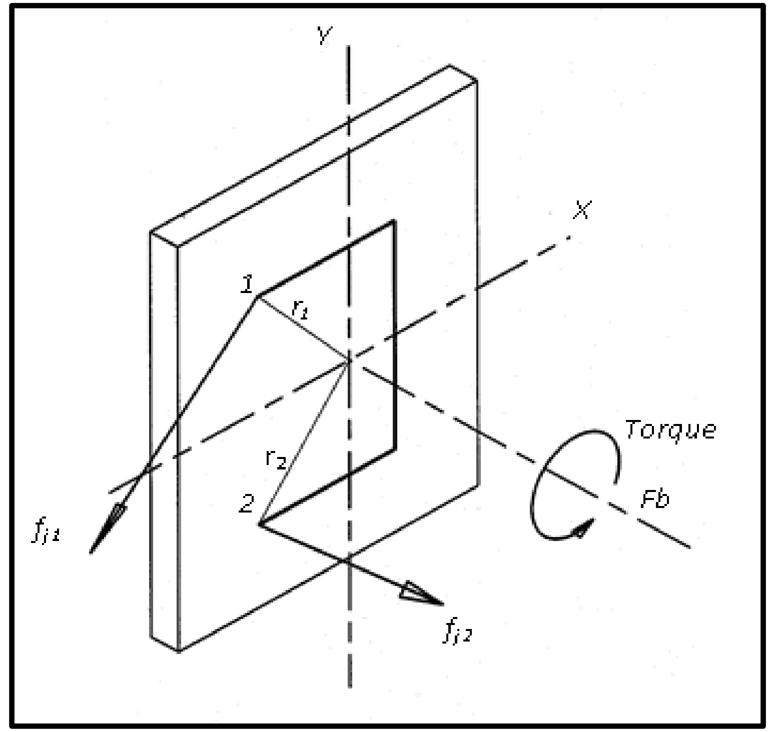


Figure 6.0

Basic Weld Design – Torque

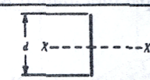
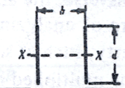
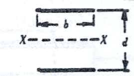
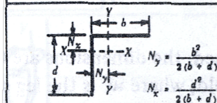
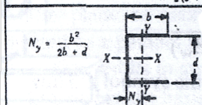
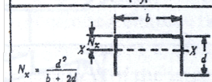
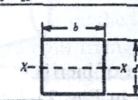
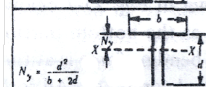
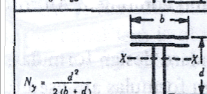
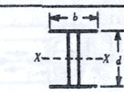
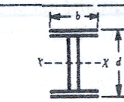
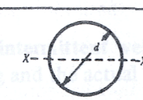
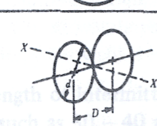
Figure 7.0 alongside provides expressions for J_w and Z_w for common outlines.

The only variable in the calculation of f_i will then be r_i, the radial distance from the C of *A* of the weld to the point of interest on the weld.

F_i being in the same direction as the shear stress τ, will be in the plane of the plate and perpendicular to r_i.

Here f_{ji} will only have *x* and *y* components. Equation 11 applies only to circular sections (tubes etc.) cannot be applied to the beam of "C" section but may be applied to this weld because the inner portion of the square plate will behave approximately like part of a circular plate.

Properties of Weld Treated as a Line

Outline of Welded Joint (b = width, d = depth)	Bending (about horizontal axis X-X)	Twisting
	$Z_w = \frac{d^2}{6}$	$J_w = \frac{d^3}{12}$
	$Z_w = \frac{d^2}{3}$	$J_w = \frac{d(3b^2+d^2)}{6}$
	$Z_w = bd$	$J_w = \frac{b^3+3bd^2}{6}$
	$Z_w = \frac{4bd+d^2}{6}$ (top) $= \frac{d^2(4bd+d)}{6(2b+d)}$ (bottom)	$J_w = \frac{(b+d)^4-6b^2d^2}{12(b+d)}$
	$Z_w = bd + \frac{d^2}{6}$	$J_w = \frac{(2b+d)^3}{12} - \frac{b^2(b+d)^2}{(2b+d)}$
	$Z_w = \frac{2bd+d^2}{3}$ (top) $= \frac{d^2(2b+d)}{3(b+d)}$ (bottom)	$J_w = \frac{(b+2d)^3}{12} - \frac{d^2(b+d)^2}{(b+2d)}$
	$Z_w = bd + \frac{d^2}{3}$	$J_w = \frac{(b+d)^3}{6}$
	$Z_w = \frac{2bd+d^2}{3}$ (top) $= \frac{d^2(2b+d)}{3(b+d)}$ (bottom)	$J_w = \frac{(b+2d)^3}{12} - \frac{d^2(b+d)^2}{(b+2d)}$
	$Z_w = \frac{4bd+d^2}{3}$ (top) $= \frac{4bd^2+d^3}{6b+3d}$ (bottom)	$J_w = \frac{d^3(4b+d)}{6(b+d)} + \frac{b^3}{6}$
	$Z_w = bd + \frac{d^2}{3}$	$J_w = \frac{b^3+3bd^2+d^3}{6}$
	$Z_w = 2bd + \frac{d^2}{3}$	$J_w = \frac{2b^3+6bd^2+d^3}{6}$
	$Z_w = \frac{\pi d^2}{4}$	$J_w = \frac{\pi d^3}{4}$
	$Z_w = \frac{\pi d^2}{2} + \pi D^2$	

Courtesy The Lincoln Electric Co.

Figure 7.0 Table of Equations to Evaluate Z_w and J_w for some common outlines, of unit width.

Basic Weld Design – Vector Sum

Vector sum of f_s, f_b and f_j. These 3 values are often mistakenly added like scalars i.e. ($f_s + f_b + f_j$). This will overstate their sum except for the situation when they are collinear to each other. In contrast adding them as if they are perpendicular to each other $(f_s^2 + f_b^2 + f_j^2)^{1/2}$ would understate their sum. The vector sum of: f_s, f_b and f_j is of course:

Eq. 15

$$f_t = ((f_{sx} + f_{bx} + f_{jx})^2 + (f_{sy} + f_{by} + f_{jy})^2 + (f_{sz} + f_{bz} + f_{jz})^2)^{1/2}$$

In most situations many of these components are equal to 0. For the weld outline shown on Figure 1.0, only 4 of the 9 components are not equal to 0.

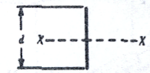
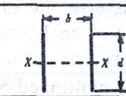
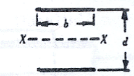
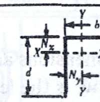
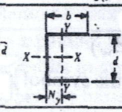
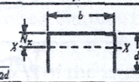
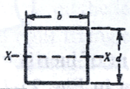
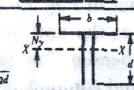
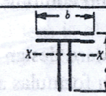
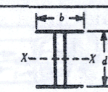
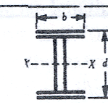
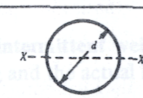
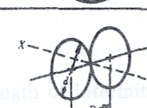
Eq. 16 **Finally the weld width** is arrived at by a version of Equation 5:

$$w = \left(\frac{FS}{\tau_{all}}\right) \cdot f_t$$

given a suitable allowable shear stress for the weld deposit and an appropriate ***FS*** to the welded joint.

Table of Equations to Evaluate Z_w and J_w for Some Common Outlines, of Unit Width.

Properties of Weld Treated as a Line

Outline of Welded Joint b = width d = depth	Bending (about horizontal axis X-X)	Twisting
	$Z_w = \frac{d^2}{6}$	$J_w = \frac{d^3}{12}$
	$Z_w = \frac{d^2}{3}$	$J_w = \frac{d(3b^2+d^2)}{6}$
	$Z_w = bd$	$J_w = \frac{b^3+3bd^2}{6}$
 $N_y = \frac{b^2}{2(b+d)}$ $N_x = \frac{d^2}{2(b+d)}$	$Z_w = \frac{4bd+d^2}{6} = \frac{d^2(4bd+d)}{6(2b+d)}$ top bottom	$J_w = \frac{(b+d)^4 - 6b^2d^2}{12(b+d)}$
$N_y = \frac{b^2}{2b+d}$ 	$Z_w = bd + \frac{d^2}{6}$	$J_w = \frac{(2b+d)^3}{12} - \frac{b^2(b+d)^2}{(2b+d)}$
$N_x = \frac{d^2}{b+2d}$ 	$Z_w = \frac{2bd+d^2}{3} = \frac{d^2(2b+d)}{3(b+d)}$ top bottom	$J_w = \frac{(b+2d)^3}{12} - \frac{d^2(b+d)^2}{(b+2d)}$
	$Z_w = bd + \frac{d^2}{3}$	$J_w = \frac{(b+d)^3}{6}$
$N_y = \frac{d^2}{b+2d}$ 	$Z_w = \frac{2bd+d^2}{3} = \frac{d^2(2b+d)}{3(b+d)}$ top bottom	$J_w = \frac{(b+2d)^3}{12} - \frac{d^2(b+d)^2}{(b+2d)}$
$N_y = \frac{d^2}{2(b+d)}$ 	$Z_w = \frac{4bd+d^2}{3} = \frac{4bd^2+d^3}{6b+3d}$ top bottom	$J_w = \frac{d^3(4b+d)}{6(b+d)} + \frac{b^3}{6}$
	$Z_w = bd + \frac{d^2}{3}$	$J_w = \frac{b^3+3bd^2+d^3}{6}$
	$Z_w = 2bd + \frac{d^2}{3}$	$J_w = \frac{2b^3+6bd^2+d^3}{6}$
	$Z_w = \frac{\pi d^2}{4}$	$J_w = \frac{\pi d^3}{4}$
	$Z_w = \frac{\pi d^2}{2} + \pi D^2$	

Courtesy The Lincoln Electric Co.

Figure 7.0

Basic Weld Design – Example

1 The selected weld outline is to be the 2 horizontal welds
at top & bottom of the RHS (rectangular hollow section).

2 Select a point on the outline that may be the most heavily loaded location on the outline.
Here we will try the bottom LH corner.

3 given b & d, we get that l = *perimeter length* and we calculate Z_x & J_x from Fig 7, 3rd row down.

4 Given perpendicular distance ln from force F to CofA of the weld, the moment about the weld is $ln \cdot F$

5 Torque about CofA of weld is $F \cdot d/2$. Note: CofA of weld and of the section of the beam coincide.

6 Force per unit length due to shear is: $f_s = \dfrac{F}{l}$, a vector made up of the components: $(0, -f_s, 0)$.

7 Force per unit length due to bending is: $f_b = \dfrac{M}{Z_w}$, it is composed of the components $(0, 0, -f_b)$

8 Force per unit length due to torsion is: $f_j = \dfrac{Tr}{J_w}$, its components are: $(-f_j \cos(\theta), f_j \sin(\theta), 0)$.

9 The vector sum of f_s, f_b & f_j is: $f_t = ((-f_j \cos\theta)^2 + (f_j \sin\theta - f_s)^2 + (-f_b)^2)^{1/2}$.

10 Finally the weld width is to be: $w = \left(\dfrac{FS}{\tau_{all}}\right) \cdot f_t$, try FS ~1.5 and τ_{all} ~100 N/mm²

11 All this work has to be repeated for a number of other likely locations around the outline.
The rule is: the weld width required at the most heavily loaded location is to be used everywhere on the outline. Only if it is particularly expensive may the width be varied around the outline.

12 The value for w needs to be compared to the wall thickness of the RHS and the thickness of the plate being welded to. The weld width w should be less than or equal to the smaller wall thickness.

13 The above calcs should be repeated for different weld outlines, to arrive at possibly the outline that requires the least weld deposit. Depending on the loads some outlines will be more effective than others.

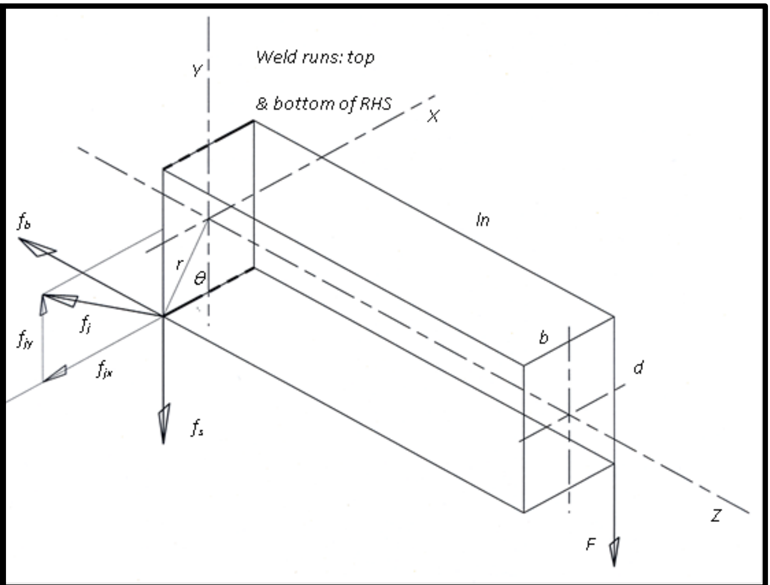


Figure 8.0

Basic Weld Design – Use of Spreadsheets

		Weld Analysis, 100X50 RHS & 2 horzontal welds				
		Input Variables				
1	ln	200	mm	Length - RHS		**Assumptions:**
2	b	50	"	Width - RHS		
3	d	100	"	Depth - RHS		Load in acting in the plane of the end of the beam
4	F	1750	N	Force Applied		Load is acting vertically at all times
5	FS	1.5	number	Safety Factor		Base Plate is fixed
6	Su	410	N/mm^2	Nominal Tensile Strength		Weight of structure neglected
	Dimensional Calculations					
3	Tal	96.6	N/mm^2	Su/(3*SQRT(2))	Allowable Shear Strength	
4	M	350000.0	Nmm	F*l	Moment	
5	T	87500.0	"	F*arc	Torque	
6	rad	55.9	mm	SQRT((b/2)^2 + (d/2)^2)	Radial Distance to corner of Max Load	
7	Theta	63.4	degrees	(ATAN(d/b)*180)/PI()	Angle of Applied Torque to Horizontal	
		Solutions				
	Properties of 2 horizontal welds					
8	lwt	100.0	mm	2*b	Total weld length	
9	Zwt	5000.0	mm^2	b*d	Modulus of section	
10	Jwt	270833.3	mm^3	((b^3)+(3*b*(d^2)))/6	Polar mom of area	
11	fst	17.5	N/mm	F/(2*b)		F/l due to shear force
12	fbt	70.0	"	M/zwt		" Bending
13	fjt	18.1	"	(T*rad)/jwt		" Torsion
14	ftt	78.1	"	SQRT((fbt^2)+((fst+(fjt*SIN((PI()*theta)/180)))^2)+ (fjt*COS((PI()*theta)/180))^2)		Total force/length
15	wt	1.2	mm	ftt*FS/Tal	weld width	fillet weld width
16	vt	73.5	mm^3	wt*wt*lwt/2	weld volume	volume of weld deposit

Shear Stress in Welds Loaded in Parallel

Shear stress in fillet welds loaded in parallel

Here we will endeavour to find a closer approximation to the shear stress in a fillet weld.

To make the situation simple we will consider mirror image welds.

This will remove an unbalanced bending moment. On Figure 9.0 the loads are parallel to the fillets, i.e. in and out of the paper, with each filet transmitting force ***F***.

We will determine the max shear stress at a throat ***t***, at angle ***θ***.

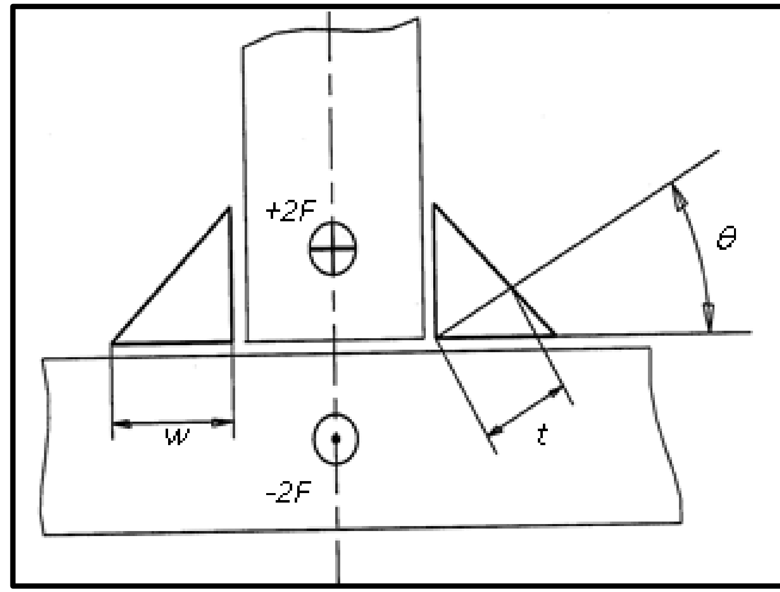


Figure 9.0

Shear Stress in Welds Loaded in Parallel

$$t = \frac{w}{(\sin\theta + \cos\theta)} \quad \text{from sine rule} \qquad \textbf{Eq 17}$$

$$\tau = \frac{F}{Area} = \frac{F}{t \cdot l}$$

$$\tau = \frac{(\sin\theta + \cos\theta)}{w} \cdot \frac{F}{l} \qquad \textbf{Eq 18}$$

Applying calculus to get the max value of τ gives the unsurprising answer that it occurs at the min throat, ie for $\theta = 45°$.

$$\therefore \tau_{all} = \frac{\sqrt{2}}{w} \cdot \frac{F}{l} \qquad \textbf{Eq 19}$$

$$w = \frac{\sqrt{2}}{\tau_{all}} \cdot \frac{F}{l} \qquad \textbf{Eq 20}$$

Thus if we use w as parameter to measure be fillet welds when loaded in parallel we can use the form:

$$w = \frac{3\sqrt{2}}{410} \cdot \frac{F}{l} = \frac{1}{96.6} \cdot \frac{F}{l} \qquad \textbf{Eq 21}$$

Effectively **for parallel welds** $\tau_{all} = 96.6\ N/mm^2$

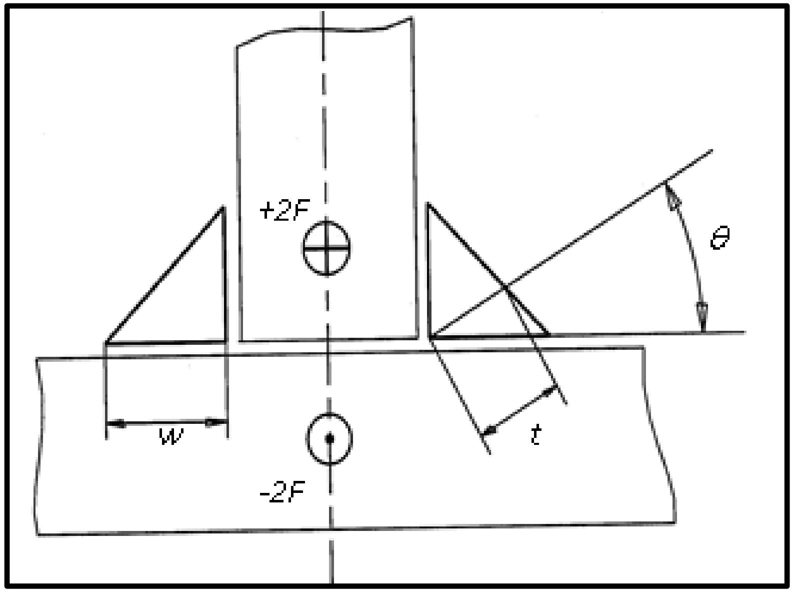


Figure 9.0

Fig 9. Fillets weld loaded in parallel
The **min tensile stress of welding rod steel** may taken to be $S_u \geq 410\ N/mm^2$

By AWS convention the max allowable shear

Eq 22 **stress is to be** $\tau_{all} \leq \frac{S_U}{3}$.

Shear Stress in Welds Loaded in Transverse

$$F_S = F\sin\theta \qquad \textbf{Eq 23}$$

Taking only the shear force into account, from Eq 18 we deduce:

$$\tau = \frac{(\sin\theta + \cos\theta)}{w}\cdot\frac{F\sin\theta}{l} \qquad \textbf{Eq 24}$$

Since the above expression for τ is different to Eq 18, τ_{max} occurs at $\theta = 67.5°$.

$$\tau_{max} = \frac{1.21}{w}\cdot\frac{F}{l} \qquad \textbf{Eq 25}$$

$$w = \frac{3\cdot 1.21}{410}\cdot\frac{F}{l} = \frac{1}{113}\cdot\frac{F}{l} \qquad \textbf{Eq 26}$$

Effectively **for transverse welds τ_{all} = 113 N/mm²** ie capable of about 15% greater loads than parallel welds.

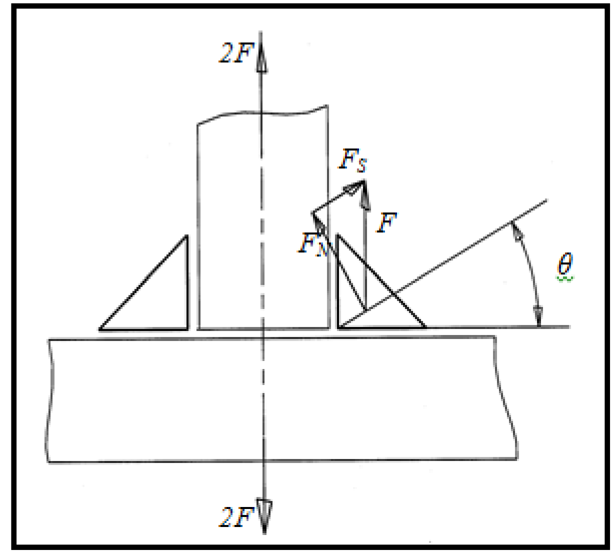


Figure 10.0
Fillet welds loaded in transverse

As illustrated in Figure 4.0, **an AWS rule** is that if any component on any part of a weld outline is loaded in parallel; then the whole weld is to be analysed as if it is all in parallel.

Obviously if it were worth the time, at the cost of an engineer's rate of pay, adjustments could be done for different part of a weld and the fillets could be tapered from point to point.

Shear Stress in Welds Loaded in Transverse

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Obviously if it were worth the time, at the cost of an engineer's rate of pay, adjustments could be done for different part of a weld and the fillets could be tapered from point to point.

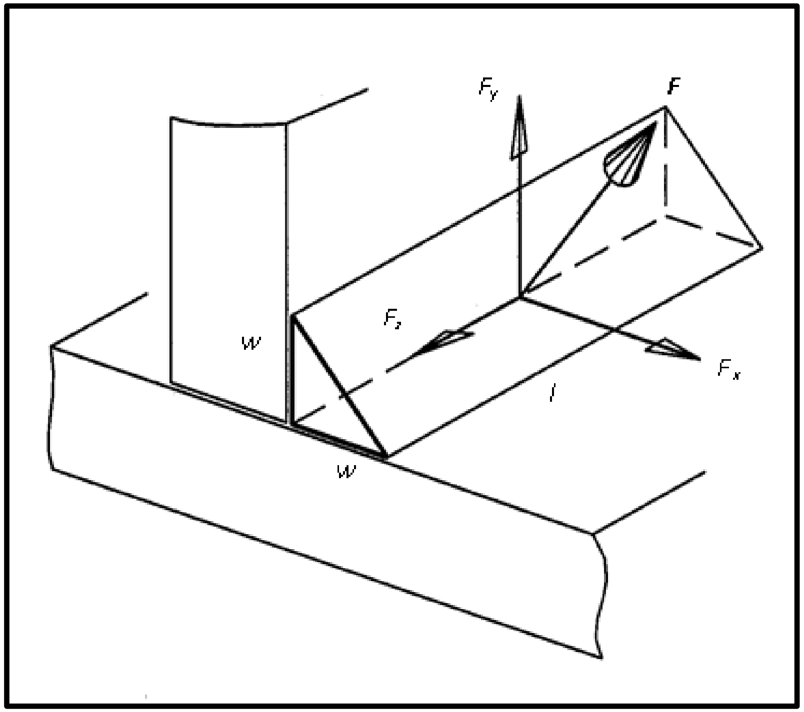


Figure 4.0

Application of Welding

There are many applications of welding such as pressure vessels, pipe work, bridges and many others which are **covered by particular codes.**

Take care to make yourself aware of them and adhere to them. The procedure examined here may be used for machine frames and similar mechanical applications.

Welding typical involves human judgement to a greater degree than most other machine operations.

As a consequence there are precautions taken in important jobs that are not often seen in other operations.

To ensure a high degree of safety it may be worth considering the use of more than one joint to carry a large load instead of applying a large Factor of Safety to a single joint.

Figure 10.1
Pipe Welded to Pressure Vessel

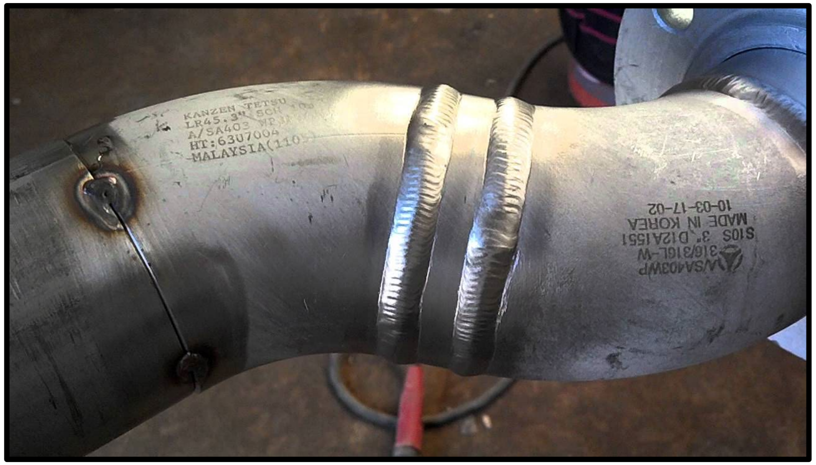


Figure 10.2
Welded Pipe Elbow - In Two Places

Application of Welding

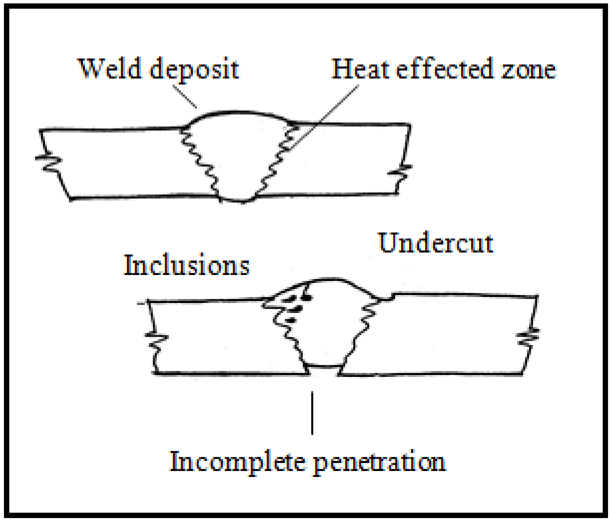


Figure 11.0

Shows some of the undesirable realities of a welded joint that may go undetected

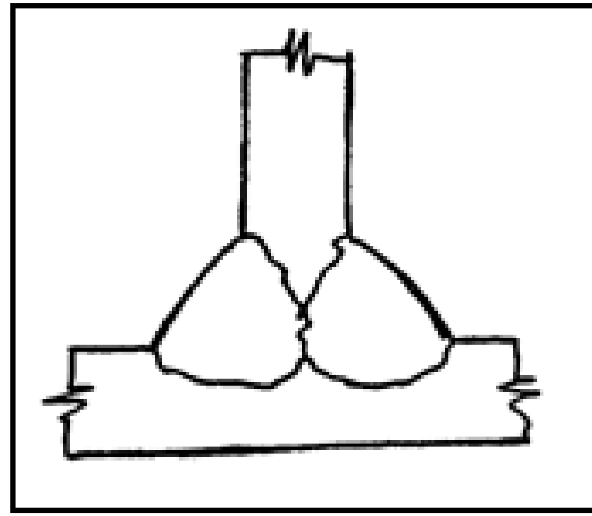


Figure. 12.0

Shows one of the reasons that when a joint fails it is usually not the weld deposit that fails. The penetration has provided a greater deposit than allowed for in the calculations.

Application of Welding

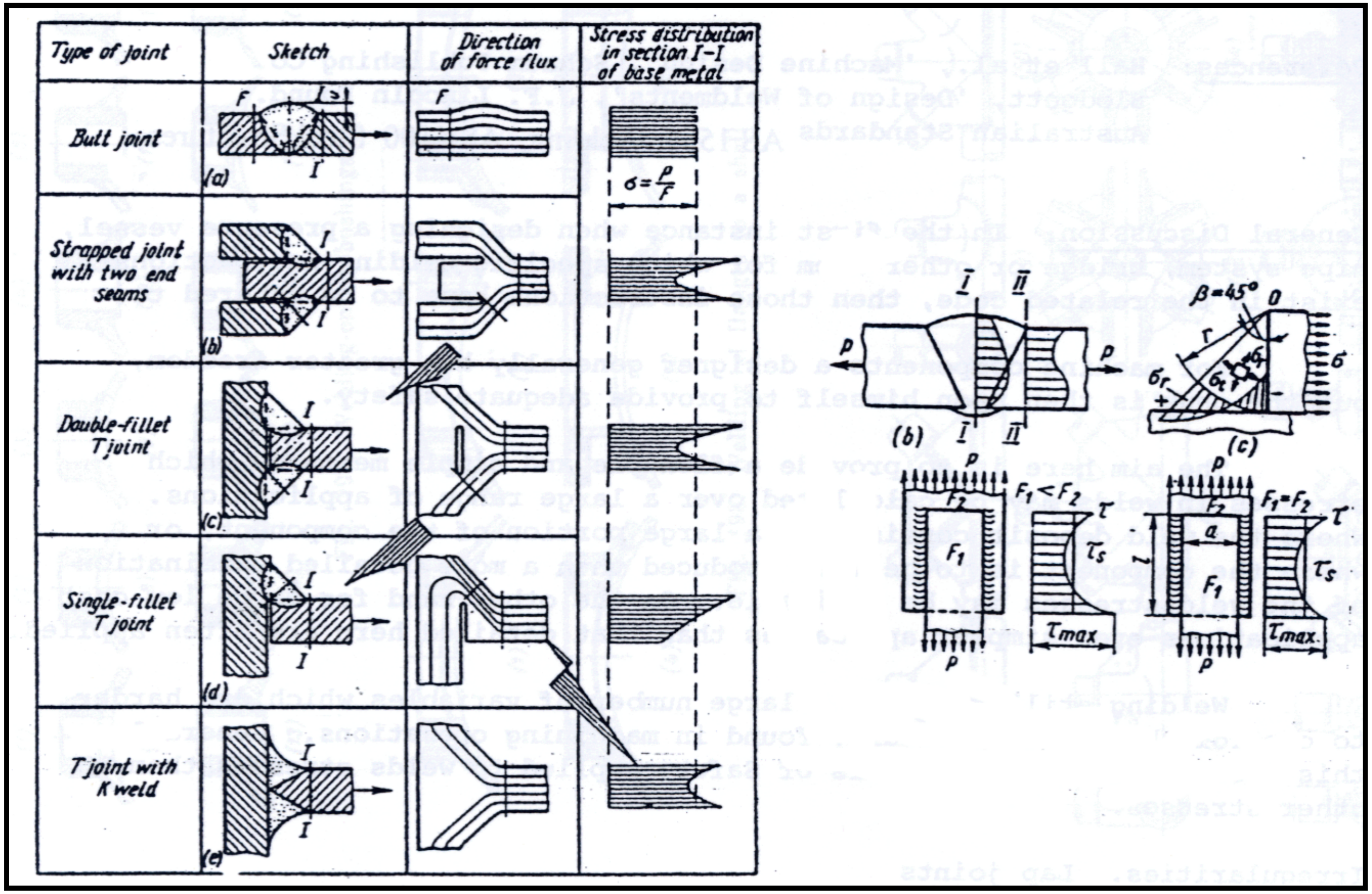


Figure 13.0

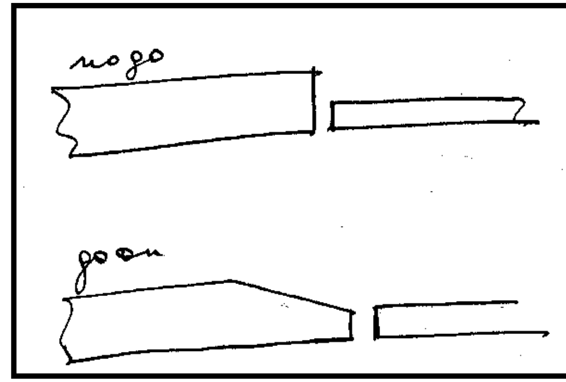
These figures from Reshtov give an <u>indication</u> of the stress concentration that takes place in wide range of welded joints. Normal and shear stresses are shown together with the effect of partial and full weld penetration.

Some Precautions

1. Every joint generates some stress concentration. A well prepared butt joint that is machined flat after welding may cause the least, but it too may raise the stresses by at least 10%.

2. Plate or sections joined together should not vary in thickness by more than about 50%.

   If the welder is suitably experienced a larger difference may be used, but it is better to have section that provides for a transition in thickness. This is indicated by Figure 14.



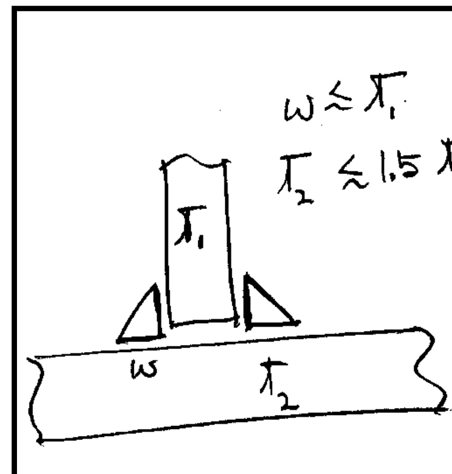
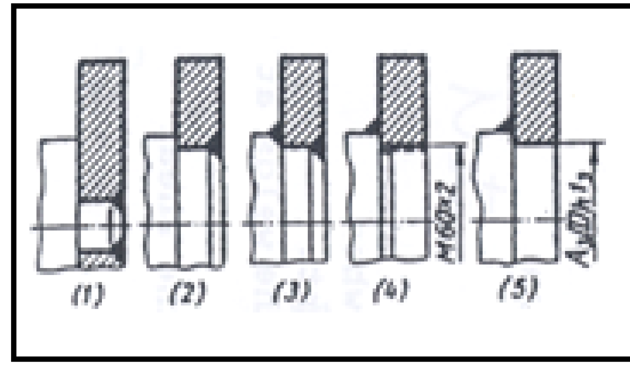


Figure 14.0
Indications of limits
in disparity in thicknesses

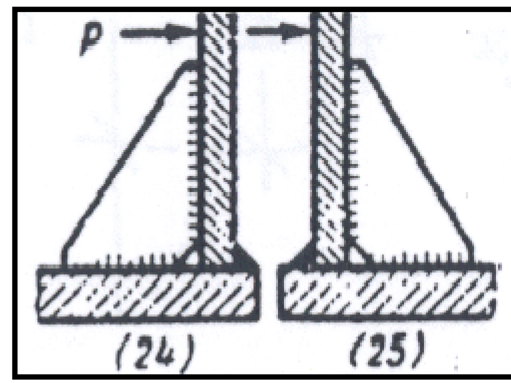
Some Precautions

3. When designing a welded joint that has to be relatively stiff under load or has to be relatively safe against failure, reinforce the joint with plates and other section to spread the load into a larger portion of the parent materials. Examples of this are shown on the next slide.

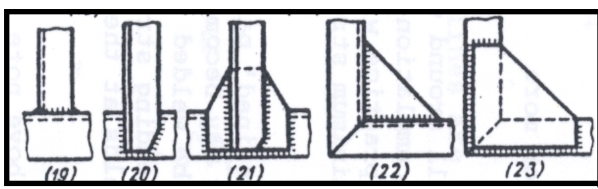
- Figures 1 to 5 (to the right) show how an end flange on a shaft is reinforced with larger and double welds Figures 2 and 3 and by a screw thread and an interference fit in Figures 4 and 5.

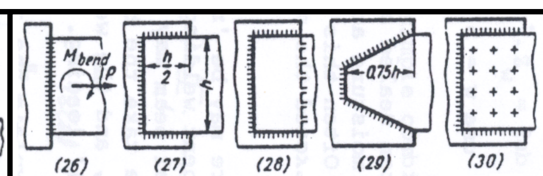


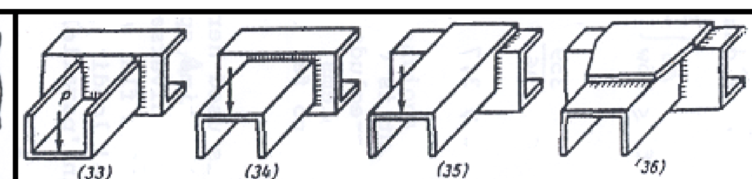
- Note the web in tension in Figure 24 and compression in Figure 25. Which is the safer design?



- The loads are spread at the joint in Figures 19 to 23 and in Figures 26 to 30, again in Figures 33 to 36.







Some Precautions

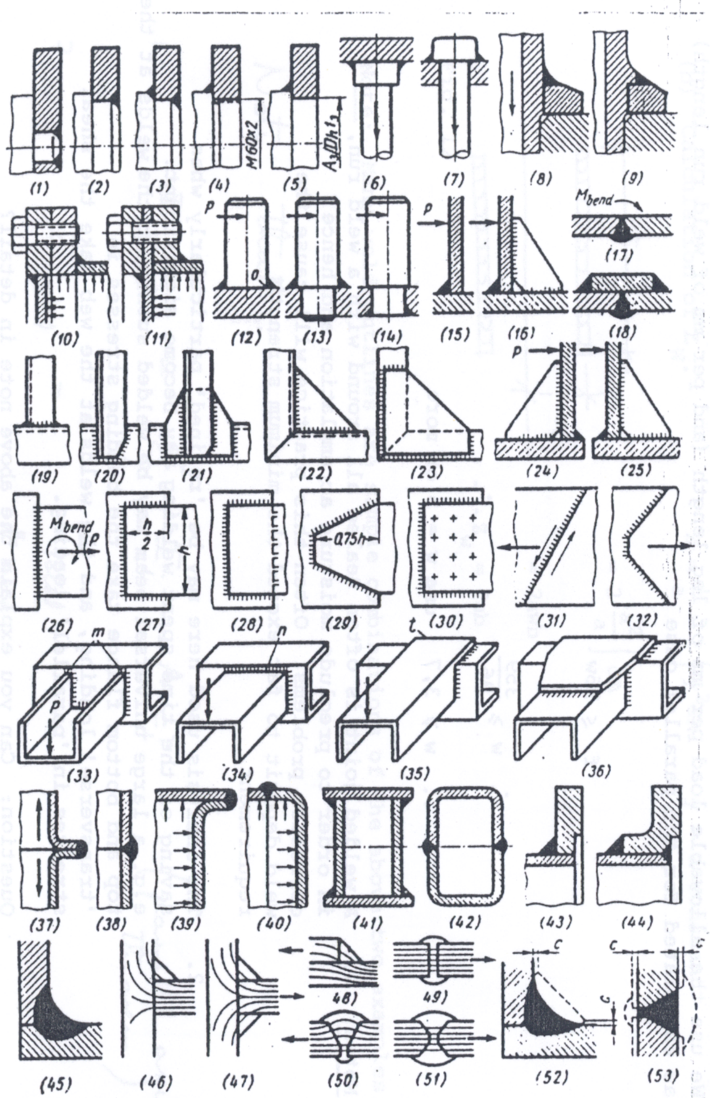


Fig. 191. Strengthening of welded joints

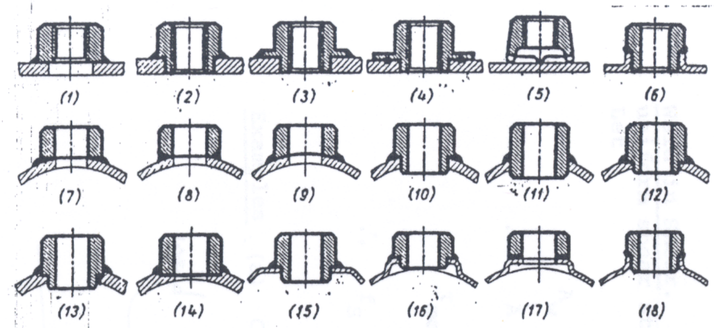


Fig. 197. Welding-on of bushings

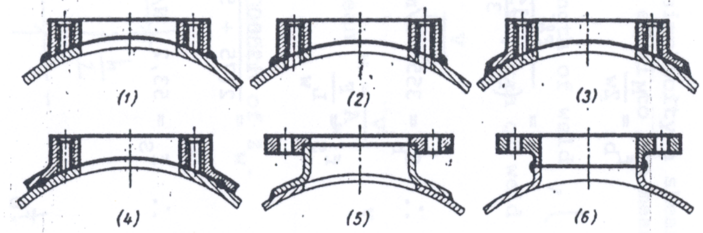


Fig. 198. Welding of flanges to a shell

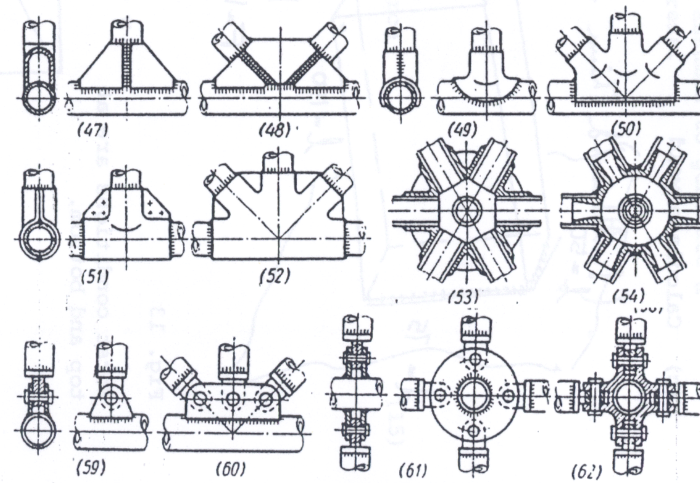
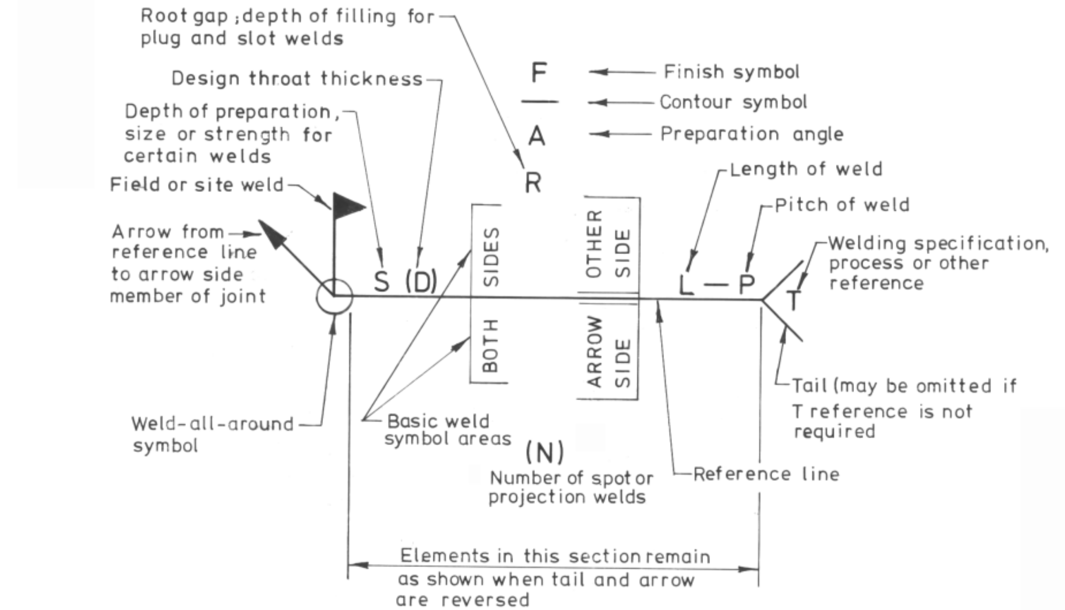


Fig. 204 (continued)

Basic Weld Design - Welding Symbol

The Welding Symbol is a complete instructional symbol indicating the particular joint, the type of weld required and all supplementary instructions necessary to complete the welded joint.



Notes:

1. The actual weld length is to include allowance for starting and stopping the weld.
2. Information relating to a particular weld, e.g. S, [D], F, A, R, L and P, must be placed on the same side of the reference line as the symbol for that weld.

Main Components

1. An arrow which points to the welded joint inclined at 30° to 90° to the reference line
2. A horizontal reference line 20 to 30mm long
3. Tail for specifications, procedures or references
4. A basic Weld Symbol (different to the Welding Symbol)
5. Supplementary Symbols

Further Reading on Weld Design

- Blodget, Design of Weldments, J F Lincoln Foundation.
- Hall et.al, Machine Design, McGraw Hill (Schaum).
- Shigley et al, Mechanical Engineering Design, Editions 4 to 7, McGraw Hill.
- Australian Standard Association AS 1554 welding & AS 3990 steel structures.
- Engineering Drawing, A.W. Boundy, 8th Edition, McGraw Hill.
  Chapter 3, 3.3 Welding Drafting.
- Applied Mechanical Design Workbook 1st Edition.
  Chapter 3, 3.3 Welding Drafting.