Weld Joint Design Equations and Calculations

- Butt Weld Joint - Normal Load
- Butt Weld Joint - Shear Load
- Butt Weld Joint - Weld at Angle to Normal
- Butt Weld Load - Shear and Normal Load
- Butt Weld Joint - Torque Load
- Butt Weld Joint - Bending Perpendicular Load
- Butt Weld Joint - Bending Load
- Perpendicular Plug Weld Joint
- Perpendicular Bevel Plug Weld
- Perpendicular Groove Plug Weld
- Bevel Groove Plug Weld
- Tube / Pipe Circumference Weld Joint
- Tube / Pipe Circumference Butt Weld With Torque
- Circumference Butt Weld Stress with Combined Shear and Axial Loading
- Butt Weld Throat Area Equation and Calculation
- Butt Weld Section Modulus Equation and Calculation
- Fillet Weld Polar Moment of Inertia Equations and Calculation
- Fillet Weld Moment of Inertia Equations and Calculation
- Fillet Weld Throat Area Equations and Calculation
- Active Fillet Weld Height Specification
- Weld Joint Coefficient Conversion Constants

Spot Weld Design Equations and Calculations

- Spot Weld Single-Shear Load Stress Equation and Calculation
- Spot Weld Double-Shear Load Stress Equation and Calculation
- Spot Weld Perpendicular Loading of Weld Area Stress Equation and Calculation

Welding Types and Processes

- Gas Welding acetylene or hydrogen - General
- Shielded Metal Arc Welding SMAW, "Stick Welding"
- Gas Tungston Arc Welding, GTAW, TIG
- Electric Resistance Welding - Spot Weld and Seam Welding
- Brazing
- Laser Welding

Weld Design Menu
Normal Stress

\[
\sigma_1 = \frac{F_n}{A} \quad [\text{MPa, psi}]
\]

Where:
- \(\sigma_1\) = Normal stress [MPa, psi]
- \(F_n\) = Normal force [N, lb]
- \(A\) = Throat area of weld [mm\(^2\), in\(^2\)]

Reference Stress

\[
\sigma_5 = \frac{\sigma_1}{\alpha_1} \quad [\text{MPa, psi}]
\]

Where:
- \(\sigma_5\) = Reference stress [MPa, psi]
- \(\sigma_1\) = Normal stress [MPa, psi]
- \(\alpha_1\) = Coefficient of weld joint

Weld Design Menu

Shear Stress

\[
\tau = \frac{F_t}{A} \quad [\text{MPa, psi}]
\]
Where:

\[ \tau = \text{Shear stress [MPa, psi]} \]
\[ F_t = \text{shear force [N, lb]} \]
\[ A = \text{Throat area of the weld [mm}^2, \text{ in}^2\text{]} \]

Reference Stress

\[ \sigma_5 = \frac{\tau}{\alpha_2} \quad \text{[MPa, psi]} \]

Where:

\[ \sigma_5 = \text{Reference stress [MPa, psi]} \]
\[ \tau = \text{Shear stress [MPa, psi]} \]
\[ \alpha_2 = \text{Coefficient of weld joint} \]

Weld Design Menu

![Diagram](http://www.mohandes-iran.com)

Normal Stress

\[ \sigma = \frac{F \cdot \cos \delta}{A} \quad \text{[MPa, psi]} \]

Where:

\[ \sigma = \text{Normal Stress [MPa, psi]} \]
\[ F = \text{Acting force [N, lb]} \]
\[ \delta = \text{Weld angle [\degree]} \]
\[ A = \text{Throat area of the weld [mm}^2, \text{ in}^2\text{]} \]

Shear Stress
\[ \tau = \frac{F \cdot \sin \delta}{A} \quad [\text{MPa, psi}] \]

**Where:**
- \( \tau \) = Shear Stress [MPa, psi]
- \( F \) = Acting force [N, lb]
- \( \delta \) = Weld direction angle [\( \phi \)]
- \( A \) = Throat area of the weld [mm\(^2\), in\(^2\)]

---

**Resultant reduced stress**

\[ \sigma_R = \sqrt{\sigma^2 + 3 \cdot \tau^2} \quad [\text{MPa, psi}] \]

**Where:**
- \( \sigma_R \) = Resultant Reduced Stress [MPa, psi]
- \( \sigma \) = Normal stress [MPa, psi]
- \( \tau \) = Shear stress [MPa, psi]

---

**Reference Stress**

\[ \sigma_5 = \sqrt{\left( \frac{\sigma}{\alpha_1} \right)^2 + 3 \cdot \left( \frac{\tau}{\alpha_2} \right)^2} \quad [\text{MPa, psi}] \]

**Where:**
- \( \sigma_5 \) = Reference Stress [MPa, psi]
- \( \sigma \) = Normal stress [MPa, psi]
- \( \tau \) = Shear stress [MPa, psi]
- \( \alpha_1, \alpha_2 \) = Coefficients of the weld joint

---

**Weld Design Menu**

**Resultant Reduced Stress**

\[ \sigma_R = \sqrt{(\sigma_1 + \sigma_2 + \sigma_3)^2 + 3 \cdot \tau^2} \quad [\text{MPa, psi}] \]

**Where:**
- \( \sigma_R \) = Resultant Reduced Stress [MPa, psi]
- \( \sigma_1, \sigma_2, \sigma_3 \) = Normal stress [MPa, psi]
\[ \tau = \text{Shear stress [MPa, psi]} \]

**Reference Stress**

\[
\sigma_5 = \sqrt{\left( \frac{\sigma_1 + \sigma_2 + \sigma_3}{\alpha_1} \right)^2 + 3 \cdot \left( \frac{\tau}{\alpha_2} \right)^2} \quad [\text{MPa, psi}]
\]

**Where:**

- \( \sigma_5 \) = Reference Stress [MPa, psi]
- \( \sigma_1, \sigma_2, \sigma_3 \) = Normal Stress [MPa, psi]
- \( \tau \) = Shear stress [MPa, psi]
- \( \alpha_1, \alpha_2 \) = Coefficient of weld joint

**Weld Design Menu**

**Shear Stress**

\[ \tau_{\text{max}} = \frac{u \cdot T}{W} \quad [\text{MPa, psi}] \]

**Where:**

- \( \tau_{\text{max}} \) = Shear Stress [MPA, psi]
- \( u \) = constant
  - for calculation in metric units \( u = 1000 \)
  - for calculation in imperial units \( u = 12 \)
- \( T \) = torque [Nm, lb-ft]
- \( W \) = section modulus of throat area of the weld [mm\(^3\), in\(^3\)]
Reference Stress

\[ \sigma_5 = \frac{\tau_{\text{max}}}{\alpha_2} \]  

Where:
\( \sigma_5 \) = Reference Stress [MPa, psi]
\( \alpha_2 \) = Shear Stress [MPa, psi]
\( \tau_{\text{max}} \) = coefficient of the weld joint

Normal Stress

\[ \sigma_3 = \frac{u \cdot M_2}{W} \]  

Where:
\( \sigma_3 \) = Normal stress [MPa, psi]
\( u \) = Constant
- for calculation in metric units \( u = 1000 \)
- for calculation in imperial units \( u = 12 \)
\( M_2 \) = Bending moment [Nm, lb-ft]
\( W \) = Section modulus of throat area of weld [mm³, in³]
\( \alpha_1 \) = Coefficient of weld joint

**Weld Design Menu**

Normal Stress

\[
\sigma_2 = \frac{u \cdot M_1}{W} \quad [\text{MPa, psi}]
\]

Where:
- \( \sigma_2 \) = Normal stress [MPa, psi]
- \( u \) = Constant
  - for calculation in metric units \( u = 1000 \)
  - for calculation in imperial units \( u = 12 \)
- \( M_1 \) = Bending moment [Nm, lb ft]
- \( W \) = Section modulus of throat area of the weld [mm\(^3\), in\(^3\)]

Reference Stress

\[
\sigma_5 = \frac{\sigma_2}{\alpha_1} \quad [\text{MPa, psi}]
\]

Where:
- \( \sigma_5 \) = Reference stress [MPa, psi]
- \( \sigma_2 \) = Normal stress [MPa, psi]
- \( \alpha_1 \) = Coefficient of weld joint
Shear Stress in Weld Base Area

\[ \tau_Z = \frac{F}{0.5 \cdot d^2} \quad [\text{MPa, psi}] \]

Where:
- \( \tau_Z \) = Shear stress in weld base area [MPa, psi]
- \( F \) = Shear force [N, lb]
- \( d \) = Diameter of plug weld [mm, in]
- \( i \) = Number of welds

Shear Stress in Weld Peripheral Area

\[ \tau_O = \frac{F}{2.2 \cdot d \cdot s \cdot i} \quad [\text{MPa, psi}] \]

Where:
- \( \tau_O \) = Shear stress in weld peripheral area [MPa, psi]
- \( F \) = Shear force [N, lb]
- \( d \) = Diameter of plug weld [mm, in]
- \( s \) = Plate thickness [mm, in]
- \( i \) = Number of welds

Weld Design Menu
Shear Stress in Weld Base Area

\[ \tau_Z = \frac{F}{0.7 \cdot b \cdot L \cdot i} \quad [\text{MPa, psi}] \]

Where:
- \( \tau_Z \) = Shear stress in weld base area [MPa, psi]
- \( F \) = Shear force [N, lb]
- \( b \) = Width of weld [mm, in]
- \( L \) = Length of weld [mm, in]
- \( i \) = Number of welds

Shear Stress in Weld Peripheral Area

\[ \tau_O = \frac{F}{1.4 \cdot s \cdot L \cdot i} \quad [\text{MPa, psi}] \]

Where:
- \( \tau_O \) = Shear stress in weld peripheral area [MPa, psi]
- \( F \) = Shear force [N, lb]
- \( s \) = Plate thickness [mm, in]
- \( L \) = Length of weld [mm, in]
- \( i \) = Number of welds

Weld Design Menu

Shear Stress in Weld Base Area

\[ \tau_Z = \frac{F}{b \cdot L \cdot i} \quad [\text{MPa, psi}] \]

Where:
- \( \tau_Z \) = Shear stress in weld base area [MPa, psi]
- \( F \) = Shear force [N, lb]
- \( b \) = Width of weld [mm, in]
L = Length of weld [mm,in]
i = Number of welds

Shear Stress in Weld Peripheral Area

$$\tau_0 = \frac{F}{2\cdot s \cdot L \cdot i} \quad [\text{MPa,psi}]$$

Where:

$\tau_0$ = Shear stress in weld peripheral area [MPa,psi]
F = Shear force [N, lb]
s = Plate thickness [mm, in]
L = Length of weld [mm, in]
i = Number of welds

Weld Design Menu

Normal Stress in Weld Base Area

$$\sigma = \frac{F_Z}{A} \quad [\text{MPa,psi}]$$

Where:

$\sigma$ = Normal stress [MPa,psi]
F_Z = Applied axial force [N, lb]
A = Throat area of weld [mm$^2$, in$^2$]

Comparative Stress

$$\sigma_5 = \frac{\sigma}{\alpha_1} \quad [\text{MPa,psi}]$$

Where:

$\sigma_5$ = Comparative stress [MPa,psi]
\[ \sigma = \text{Normal stress [MPa, psi]} \]
\[ \alpha_1 = \text{Conversion coefficient of weld joint} \]

\[ \text{Weld Design Menu} \]

\[ \tau = \frac{u \cdot T}{W} \quad \text{[MPa, psi]} \]

Where:
\[ \tau = \text{Shear stress [MPa, psi]} \]
\[ u = \text{Constant} \]
\[ \text{Metric units } u=1000 \]
\[ \text{Imperial units } u=12 \]
\[ W = \text{Section modulus throat area [mm}^3, \text{in}^3] \]
\[ T = \text{Torque applied [Nm, lb-ft]} \]

\[ \text{Comparative Stress} \]
\[ \sigma_S = \frac{\tau}{\alpha_2} \]

Where:
\[ \sigma_S = \text{Comparative stress [MPa, psi]} \]
\[ \tau = \text{Shear stress [MPa, psi]} \]
\[ \alpha_2 = \text{Conversion coefficient of weld joint} \]

\[ \text{Weld Design Menu} \]

\[ \text{Circumference Butt Weld Stress with Combined Shear and Axial Loading} \]

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Resultant Reduced Stress

$$\sigma_R = \sqrt{\sigma^2 + 3 \tau^2} \text{ [MPa,psi]}$$

Where:
- $\sigma_R$ = Resultant seduced stress [MPa,psi]
- $\sigma$ = Normal Stress [MPa,psi]
- $\tau$ = Shear Stress [MPa,psi]

Comparative Stress

$$\sigma_5 = \sqrt{\left(\frac{\sigma}{\alpha_1}\right)^2 + 3 \left(\frac{\tau}{\alpha_2}\right)^2} \text{ [MPa,psi]}$$

Where:
- $\sigma_5$ = Comparative stress [MPa,psi]
- $\sigma$ = Normal stress [MPa,psi]
- $\tau$ = Shear stress [MPa,psi]
- $\alpha_1, \alpha_2$ = Conversion coefficient of weld joint

**Weld Design Menu**

<table>
<thead>
<tr>
<th>Butt Weld Orientation</th>
<th>Weld Illustration</th>
<th>Throat Area of Butt Weld [mm², in²]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Full Weld Length</td>
</tr>
<tr>
<td>Butt End Tube Weld</td>
<td>![Weld Illustration]</td>
<td>$A = s L$</td>
</tr>
<tr>
<td>Circumferential Tube Weld</td>
<td>![Weld Illustration]</td>
<td>$A = \pi s (d - s)$</td>
</tr>
</tbody>
</table>
### Weld Design Menu

<table>
<thead>
<tr>
<th>Weld Illustration</th>
<th>Section Modulus of Throat Area of Butt Weld [mm³, in³]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Full Weld Length</strong></td>
</tr>
<tr>
<td><img src="#" alt="Circular Weld" /></td>
<td>$W = \frac{\pi \cdot s \cdot (D - s)^2}{2}$</td>
</tr>
<tr>
<td><img src="#" alt="Butt Weld" /></td>
<td>$W = \frac{s^2 \cdot L^2}{3 \cdot L + 1.8 \cdot s}$</td>
</tr>
<tr>
<td><img src="#" alt="Edge Weld" /></td>
<td>$W = \frac{s^2 \cdot L}{6}$</td>
</tr>
</tbody>
</table>

Where:
- $A$ = Area in²
- $\delta$ = Weld angle [deg]
- $s$ = Plate or tube thickness [mm, in]
- $L$ = Length of weld [mm, in]
- $\pi$ = pi (3.14157)
Where:

- \( W \) = Section modulus [mm³, in³]
- \( s \) = Plate or tube thickness [mm, in]
- \( L \) = Length of weld [mm, in]
- \( \pi \) = pi (3.14157)

### Weld Design Menu

#### Polar Moment of Inertia

<table>
<thead>
<tr>
<th>Weld</th>
<th>Fillet &quot;J&quot; Weld ( [\text{mm}^4, \text{in}^4] )</th>
<th>Location Center ( \bar{x}, \bar{y} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>( J = a \cdot \frac{L^3}{12} )</td>
<td>( \bar{x} = \frac{L}{2} ) ( \bar{y} )</td>
</tr>
<tr>
<td>—</td>
<td>( J = a \cdot \frac{(H+B)^4 - 6 \cdot H^2 \cdot B^2}{12 \cdot (H+B)} )</td>
<td>( \bar{x} = \frac{B^2}{2 \cdot (H+B)} ) ( \bar{y} )</td>
</tr>
<tr>
<td>—</td>
<td>( J = a \cdot \frac{H \cdot (3 \cdot B^2 + H^2)}{6} )</td>
<td>( \bar{x} = \frac{B^2}{2 \cdot (H+B)} ) ( \bar{y} )</td>
</tr>
<tr>
<td>—</td>
<td>( J = a \cdot \frac{H \cdot (3 \cdot B^2 + H^2)}{6} )</td>
<td>( \bar{x} = \frac{B^2}{2 \cdot (H+B)} ) ( \bar{y} )</td>
</tr>
<tr>
<td>—</td>
<td>( J = a \cdot \left( \frac{8 \cdot B^3 + 6 \cdot B \cdot H^2 + H^4}{12} - \frac{B^4}{2 \cdot B + H} \right) )</td>
<td>( \bar{x} = \frac{B^2}{2 \cdot B + H} )</td>
</tr>
<tr>
<td>—</td>
<td>( J = a \cdot \left( \frac{8 \cdot H^3 + 6 \cdot H \cdot B^2 + B^3}{12} - \frac{H^4}{2 \cdot H + B} \right) )</td>
<td>( \bar{x} = \frac{B}{2} ) ( \bar{y} = \frac{H}{2} )</td>
</tr>
<tr>
<td></td>
<td>[ J = a \cdot \frac{(H+B)^3}{16} ]</td>
<td>[ \bar{X} = \frac{B}{2} ]</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>[ J = 2\pi a \left( r + \frac{a}{2} \right)^3 ]</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>[ \begin{align*} J &amp;= a \cdot \left( \frac{H^3 + B^3}{6} + \frac{B \cdot H^2}{2} \right) \ J &amp;= a \cdot \left( \frac{(H-2 \cdot t)^3 + 3 \cdot (H-2 \cdot t) \cdot s^2 + B^3 + 3 \cdot B \cdot H^2}{6} \right) \end{align*} ]</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>[ \begin{align*} J &amp;= a \cdot \left( \frac{B^3 + 2 \cdot H^3}{6} + H \cdot B^2 \right) \ J &amp;= a \cdot \left( \frac{B^3 + 2 \cdot H^3 - s^3}{6} + H \cdot B^2 + \frac{B \cdot s^2 - s \cdot B^2}{2} - 2 \cdot (H-s) \cdot (B \cdot t - t^2) \right) \end{align*} ]</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>[ \begin{align*} J &amp;= a \cdot \left( \frac{H^3 + B^3}{6} + \frac{H \cdot B^2}{2} \right) \ J &amp;= a \cdot \left( \frac{(B-2 \cdot t)^3 + 3 \cdot (B-2 \cdot t) \cdot s^2 + H^3 + 3 \cdot H \cdot B^2}{6} \right) \end{align*} ]</td>
<td>-</td>
</tr>
</tbody>
</table>

Where:
- \( J \) = Polar Moment of inertia [mm\(^4\), in\(^4\)]
- \( \bar{X} \) = Center of Gravity Location [mm, in]
- \( \bar{Y} \) = Center of Gravity Location [mm, in]
- \( A \) = Height fillet weld [mm, in]
- \( B \) = Width of weld [mm, in]
- \( s \) = Web thickness [mm, in]
- \( L \) = Length of weld [mm, in]
- \( r \) = Weld radius [mm, in]
- \( t \) = Flange thickness [mm, in]
- \( H \) = Height of fillet weld group [mm, in]

**Weld Design Menu**
<table>
<thead>
<tr>
<th>Weld</th>
<th>Moment of Inertia</th>
<th>Location Center of Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( I = a \cdot \frac{H^3}{12} )</td>
<td>( \bar{Y} = \frac{L}{2} )</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \frac{H^3}{6} )</td>
<td>( \bar{Y} = \frac{H}{2} )</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \frac{B \cdot H^2}{2} )</td>
<td>( \bar{Y} = \frac{H}{2} )</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \left( \frac{2 \cdot H^3}{3} - 2 \cdot \bar{Y} \cdot H^2 + (B + 2 \cdot H) \cdot \bar{Y}^2 \right) )</td>
<td>( \bar{Y} = \frac{H^2}{2 \cdot H + B} )</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \left( \frac{3 \cdot B \cdot H + H}{6} \right) )</td>
<td>( \bar{Y} = \frac{H}{2} )</td>
</tr>
<tr>
<td></td>
<td>( I = \pi a \left( r + a/2 \right)^3 )</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \left( \frac{3 \cdot B \cdot H + H}{6} \right) )</td>
<td>( \bar{Y} = \frac{H}{2} )</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \left( \frac{H - 2 \cdot t}{6} + \frac{B + H}{2} \right) )</td>
<td>( \bar{Y} = \frac{H^2}{2 \cdot H + B} )</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \left( \frac{(H - t)^3}{6} + 2 \cdot H \cdot \left( \frac{H + t}{2} - \bar{Y} \right)^2 + B \cdot \bar{Y}^2 \right) )</td>
<td>( \bar{Y} = \frac{H^2 - t^2}{2 \cdot H + B - 2 \cdot t} )</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \left( \frac{2 \cdot H^3}{3} - 2 \cdot \bar{Y} \cdot H^2 + 2 \cdot (B + H) \cdot \bar{Y}^2 \right) )</td>
<td>( \bar{Y} = \frac{H^2}{2 \cdot (H + B)} )</td>
</tr>
<tr>
<td></td>
<td>( I = a \cdot \left( \frac{2 \cdot H^3}{3} - 2 \cdot \bar{Y} \cdot H^2 + 2 \cdot (B + H) \cdot \bar{Y}^2 - B \cdot t \cdot (2 \cdot \bar{Y} - t) \right) )</td>
<td>( \bar{Y} = \frac{H^2 + B \cdot t}{2 \cdot (H + B)} )</td>
</tr>
</tbody>
</table>

Where:
- \( I \) = Moment of inertia [mm\(^4\), in\(^4\)]
- \( \bar{Y} \) = Center of Gravity Location [mm, in]
a = Height fillet weld [mm, in]
B = Width of weld [mm, in]
s = Web thickness [mm, in]
L = Length of weld [mm, in]
r = Weld radius [mm, in]
t = Flange thickness [mm, in]
H = Height of fillet weld group [mm, in]

**Weld Design Menu**

<table>
<thead>
<tr>
<th>Weld</th>
<th>Throat Area of Fillet Weld A ( \text{[mm}^2, \text{in}^2 ]</th>
<th>Full Weld Length</th>
<th>Active Load-bearing Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( A = a L )</td>
<td>( A = s (L - 2a) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a (H + B))</td>
<td>( A = a (H + B - 2a) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a 2H )</td>
<td>( A = a 2 (H - 2a) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a 2B )</td>
<td>( A = a 2 (B - 2a) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a (H + 2B) )</td>
<td>( A = a (H + 2B - 2a) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a (2H + B) )</td>
<td>( A = a (2H + B - 2a) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a 2 (H + B) )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = 2\pi a (r + a/2) )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a 2 (H + B) )</td>
<td>( A = a 2 (H + B - 4a) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a 2 (H + 2B) )</td>
<td>( A = a 2 (H + 2B - 2t - 4a) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( A = a 2 (H + 2B) )</td>
<td>( A = a 2 (H + 2B - s) )</td>
</tr>
</tbody>
</table>
Where:
A = Throat area of fillet weld [mm², in²]
B = Width of weld [mm, in]
s = Web thickness [mm, in]
L = Length of weld [mm, in]
r = Weld radius [mm, in]
t = Flange thickness [mm, in]
H = Height of fillet weld [mm, in]

Weld Design Menu

The active fillet weld height specification is the largest isosceles triangle which may be inscribed with the theoretical weld cross-section.

The theoretical fillet weld size height approximately specifies $a = .7$ as given by trigonometry, where $z$ is the fillet weld width. The minimum fillet weld height should be selected based on the actual thickness of the thickest weld part and the strength of the material.

<table>
<thead>
<tr>
<th>Recommended Minimum Fillet Height Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thickest Welded Part</strong></td>
</tr>
<tr>
<td>Over To 370 - 420</td>
</tr>
</tbody>
</table>
Weld Design Menu

The following are recommended values for weld joint coefficient conversion.

<table>
<thead>
<tr>
<th>Type of Weld</th>
<th>Loading</th>
<th>Coefficient of Weld joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>butt¹</td>
<td>Compression</td>
<td>α₁</td>
</tr>
<tr>
<td></td>
<td>Tension</td>
<td>.85</td>
</tr>
<tr>
<td></td>
<td>Shear</td>
<td>.70</td>
</tr>
<tr>
<td>Fillet</td>
<td>End Load</td>
<td>α₃</td>
</tr>
<tr>
<td></td>
<td>Side</td>
<td>.65^4</td>
</tr>
<tr>
<td>Groove and Plug</td>
<td>Shear</td>
<td>α₄</td>
</tr>
<tr>
<td>Spot</td>
<td>Shear</td>
<td>α₅</td>
</tr>
<tr>
<td></td>
<td>Tear-out</td>
<td>α₆</td>
</tr>
</tbody>
</table>

1. Coefficient of weld joint for loading along the axis of weld joint α = 1
2. Contact resistance welding
3. Butt welds manually welded and supported by the weld from the root side after grooving butt welds bilaterally penetrated, automatic welding under flux or in CO2 made at least from one side electro-slag welds
4. Manual arc welding while the strength of used electrode corresponds to the strength of basic material.
5. Applies to:
   - Manual arc welding of basic materials whose minimum tensile strength is 20% lower than minimum strength of weld metal of used electrode
   - Semi-automatic submerged welding, semi-automatic and automatic welding shielded by CO2 atmosphere and even for automatic submerged welding of single-pass or multi-pass welds for the weld height a 8 mm
6. Automatic submerged welding of single-pass welds for the weld height \( a < 8 \text{ mm} \)

7. **Weld Design Menu**

8. **Shear of Point**

\[
\tau_1 = \frac{4 \cdot F}{i \cdot \pi \cdot d^2} \quad \text{[MPa, psi]}
\]

9. **Tear Loading of Point along Cylindrical Surface**

\[
\tau_2 = \frac{F}{i \cdot \pi d s} \quad \text{[MPa, psi]}
\]

10. **Comparative Stress**

\[
\sigma_S = \max \left( \frac{\tau_1}{\alpha}, \frac{\tau_2}{\alpha} \right) \quad \text{[MPa, psi]}
\]

Where:

- \( \tau_1 \) = Shear stress [MPa, psi]
- \( \tau_2 \) = Tear stress [MPa, psi]
- \( \sigma_S \) = Comparative stress [MPa, psi]
- \( F \) = Applied force [N, lb]
- \( s \) = Thickness, plate [mm, in]
- \( d \) = Spot weld diameter [mm, in]
- \( i \) = Number of welds
- \( \alpha \) = Coefficient of weld joint

**Weld Design Menu**

Shear of Point

\[
\tau_1 = \frac{2 \cdot F}{i \cdot \pi \cdot d^2} \quad \text{[MPa, psi]}
\]

Tear Loading of Point along Cylindrical Surface
Comparative Stress

\[ \sigma_s = \max \left( \frac{\tau_1}{\alpha}, \frac{\tau_2}{\alpha} \right) \quad [\text{MPa, psi}] \]

Where:
- \( \tau_1 \): Shear stress [MPa, psi]
- \( \tau_2 \): Tear stress [MPa, psi]
- \( \sigma_s \): Comparative stress [MPa, psi]
- \( F \): Applied force [N, lb]
- \( s \): Thickness, plate [mm, in]
- \( d \): Spot weld diameter [mm, in]
- \( i \): Number of welds
- \( \alpha \): Coefficient of weld joint

Weld Design Menu

Tear-off Loading of Weld Area

\[ \tau = \frac{4 \cdot F}{i \cdot \pi \cdot d^2} \quad [\text{MPa, psi}] \]

Comparative Stress

\[ \sigma_s = \frac{\tau}{\alpha} \quad [\text{MPa, psi}] \]

Where:
- \( \tau \): Shear stress [MPa, psi]
- \( \sigma_s \): Comparative stress [MPa, psi]
F = Applied force [N, lb]
d = Spot weld diameter [mm, in]
i = Number of welds
\( \alpha \) = Coefficient of weld joint

---

Introduction

The following notes are general guidance notes showing methods of calculation of the strength and size of welds. Welded joints are often crucially important affecting the safety of the design systems. It is important that the notes and data below are only used for preliminary design evaluations. Final detail design should be completed in a formal way using appropriate codes and standards and quality reference documents.

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Relevant Standards

BS 5950-1:2000 - Structural use of steelwork in building. Code of practice for design. Rolled and welded sections
BS EN 10025-1:2004 - Hot rolled products of structural steels. General technical delivery conditions

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Variables related to welded joints

1. Strength of deposited weld material
2. Type of joint and weld..important
3. Size of weld ..important
4. Location of weld in relation to parts joined..important
5. Types of stress to which the weld is subjected
6. Conditions under which weld is carried out
7. Type of equipment used for welding
8. Skill of welder

---

Guidance Principles
A generous factor of safety should be used (3-5) and if fluctuating loads are present then additional design margins should be included to allow for fatigue.

Use the minimum amount of filler material consistent with the job requirement.

Try to design joint such that load path is not through the weld.

The table below provides approximate stresses in, hopefully, a convenient way.

For the direct loading case the butt weld stresses are tensile/compressive $\sigma_t$ for the fillet welds the stresses are assumed to be shear $\tau_s$ applied to the weld throat.

For butt welded joints subject to bending the butt weld stresses result from a tensile/compressive stress $\sigma_b$ and a direct shear stress $\tau_s$.

In these cases the design basis stress should be $\sigma_r = \sqrt{\sigma_b^2 + 4\tau_s^2}$

For fillet welded joints subject to bending the stresses in the fillet welds are all shear stresses. From bending $\tau_b$ and from shear $\tau_s$.

In these cases the design basis stress is generally $\tau_r = \sqrt{\tau_b^2 + \tau_s^2}$

The stresses from joints subject to torsion loading include shear stress from the applied load and shear stresses from the torque loading. The resulting stresses should be added vectorially taking care to choose the location of the highest stresses.

---

**Table of bracket weld subject to direct and bending stresses**

<table>
<thead>
<tr>
<th>Method of Loading</th>
<th>Weldment</th>
<th>Stress in Weld</th>
<th>Stress in Weld</th>
<th>Stress in Weld</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\sigma_b$</td>
<td>$\tau_s$</td>
<td>$\tau_b$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\tau_s$</td>
<td>$\sigma_b$</td>
<td>$\tau_s$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weld size (h)</td>
<td>Weld size (h)</td>
<td>Weld size (h)</td>
</tr>
</tbody>
</table>
Assessment of Fillet Weld Groups

Important note: The methods described below is based on the simple method of calculation of weld stress as identified in BS 5950- clause 6.7.8.2. The other method identified in BS 5950 - 1 clause 6.7.8.3 as the direction method uses the method of resolving the forces transmitted by unit
thickness welds per unit length into traverse forces ($F_T$) and longitudinal forces ($F_L$). I have, to some extent, illustrated this method in my examples below.

The method of assessing fillet welds groups treating welds as lines is reasonably safe and conservative and is very convenient to use.

a) **Weld subject to bending**...See table below for typical unit areas and unit Moments of Inertia

A fillet weld subject to bending is easily assessed as follows.

1) The area of the fillet weld $A_u$ (unit thickness) is calculated assuming the weld is one unit thick.
2) The (unit) Moment of Inertia $I_u$ is calculated assuming the weld is one unit thick.
3) The maximum shear stress due to bending is determined...$	au_b = M.y/I_u$
4) The maximum shear stress due to direct shear is determined...$	au_s = P/A$
5) The resultant stress $\tau_r = \sqrt{\tau_b^2 + \tau_s^2}$
6) By comparing the design strength $p_w$ with the resultant stress $\tau_r$, the value of the weld throat thickness is calculated and then the weld size. i.e. if the $\tau_r/p_w = 5$ then the throat thickness $t = 5$ units and the weld leg size $h = 1,414t$

a) **Weld subject to torsion**...See table below for typical unit areas and unit Polar moments of Inertia

A fillet weld subject to torsion is easily assessed as follows.

1) The area of the fillet weld $A_u$ (unit thickness) is calculated assuming the weld is one unit thick
2) The (unit) Polar Moment of Inertia $J_u$ is calculated assuming the weld is one unit thick. The polar moment of inertia $J = I_{xx} + I_{yy}$
3) The maximum shear stress due to torsion is determined...$\tau_t = T.r/J_u$
4) The maximum shear stress due to direct shear is determined...$\tau_s = P/A_u$
5) The resultant stress $\tau_r$ is the vector sum of $\tau_t$ and $\tau_s$. $r$ is chosen to give the highest value of $\tau_r$
6) By comparing the design strength $p_w$ with the resultant stress $\tau_r$, the value of the weld throat thickness is calculated and then the weld size. i.e. if the $\tau_r/p_w = 5$ then the throat thickness $t = 5$ units and the weld leg size $h = 1,414.t$

---

**Examples of Fillet Weld Calculations**

**Example of Weld in Torsion..**

---
**Simple Method as BS 5950 clause 6.8.7.2**

The vector sum of the stresses due to forces and moments should not exceed the design strength $P_w$.

- $A_u = \text{Unit Throat Area}$
  - $A_u = (\text{From table below}) \ b + d = (120 + 150) = 270mm^2$
  - To obtain radius of Force from weld centre of gravity
    - $A = 250-27 = 223mm$
    - Moment $M = P.r = 10000.223 = 2.23 \times 10^6 N.mm$
    - $J_u = [(b+d)^4 - 6b^2d^2] / 12 (b+d) = 1.04 \times 10^6 mm^4$

It is necessary to locate the point subject to the highest shear stress. For a weld subject to only torsion this would be simply at the point furthest from the COG. However, because the weld is subject to torsion and direct shear, the problem is more complicated. A normal method of determining the stresses in these cases is to use

---

**Direction Method as BS 5950 clause 6.8.7.3**

- $L = \text{Length of weld 1 unit thick}$
  - (From table below) $b + d = (120 + 150) = 270mm$
  - To obtain radius of Force from weld Centre of Gravity (Cog).
    - $A = 250-27 = 223mm$
    - Moment $M = P.r = 10000.223 = 2.23 \times 10^6 N.mm$
    - $J_u = \text{Polar Moment of inertia for weld 1 unit(mm) thick.}$
      - $J_u = [(b+d)^4 - 6b^2d^2] / 12 (b+d) = 1.04 \times 10^6 mm^4$/mm (From Table)

It is necessary to locate the point subject to the highest shear stress. For a weld subject to only torsion, this would be simply at the point furthest from the COG. However, because the weld is subject to torsion and direct shear, the problem is more complicated. A normal method of determining the stresses in these cases is to use...
more complicated. A normal method of determining the stresses in these cases is to use vector addition.

It is generally prudent to calculate the total shear stress at both positions, using the method below, and select the highest. For this example the method used is to resolve the stresses in the x and y directions.

First considering point Z

Horizontal distance from centroid $r_{zh} = 120-27 = 93$mm
Vertical distance from centroid $r_{zv} = 42$mm

The vertical force per mm run $F_v = F_{sv} + F_{tv}$
$F_{sv} = \frac{P}{A_u} = \frac{10000}{270} = 37 \text{ N/mm}^2$
$F_{tv} = \frac{M \cdot r_{zh}}{J_u} = \frac{2,23 \cdot 10^6 \cdot 93}{1,04 \cdot 10^6} = 199 \text{ N/mm}^2$
$F_v = 236,45 \text{ N/mm}^2$

The horizontal force per mm run for unit(mm) weld width $F_h = F_{sh} + F_{th}$
$F_{sh} = 0$
$F_{th} = \frac{M \cdot r_{zv}}{J_u} = \frac{2,23 \cdot 10^6 \cdot 42}{1,04 \cdot 10^6} = 90 \text{ N/mm}^2$
$F_h = 90 \text{ N/mm}^2$

The resultant force on the weld/mm run at $z$
$F_r = \sqrt{(F_h^2 + F_v^2)} = 253 \text{ N/mm}^2$

Now considering point w

Horizontal distance from centroid $r_{wh} = 27$mm
Vertical distance from centroid $r_{wv} = 150-42 = 108$mm

The vertical force per mm run $F_v = F_{sw} - F_{tv}$
$F_{sw} = \frac{P}{A_u} = \frac{10000}{270} = 37 \text{ N/mm}^2$
$F_v = F_{sw} - F_{tv}$
$F_{sw} = \frac{P}{L} = \frac{10000}{270} = 37 \text{ N/mm run}$
The horizontal stress $\tau_h = \tau_{sh} + \tau_{th}$

$\tau_{sh} = 0$

$\tau_{th} = \frac{M_r \, w}{J_u} = \frac{2,23 \times 10^6 \times 108}{1,04 \times 10^6} = 231,6 \text{ N/mm}^2$

$\tau_h = 231,6 \text{ N/mm}^2$

The resultant stress on the weld at $w$

$\tau_r = \sqrt{\tau_h^2 + \tau_v^2} = 232,5 \text{ N/mm}^2$

The maximum stress is similar but greatest at $z$.

The design strength $p_w$ for the weld material is $220 \text{ N/mm}^2$.

The weld throat thickness should be $253 / 220 = 1,15 \text{ mm}$.

The weld size is therefore $1,414 \times 1,15 = 1,62 \text{ mm}$ use $3 \text{ mm fillet weld}$.

The horizontal force /mm run $= F_h = F_{sh} + F_{th}$

$F_{sh} = 0$

$F_{th} = \frac{M_r \, w}{J_u} = \frac{2,23 \times 10^6 \times 108}{1,04 \times 10^6} = 231,6 \text{ N/mm run}$

$F_h = 231,6 \text{ N/mm run}$

The specific force on the weld at $w$

$F_r = \sqrt{F_h^2 + F_v^2} = 232,5 \text{ N/mm run}$

The maximum specific is greatest at $z = 253 \text{ N/mm run}$.

Referring to weld capacities for longitudinal stresses $P_l$ for fillet welds Capabilities of Fillet Welds the weld capacity for a $3 \text{ mm weld with and E35 Electrode S275 Steel is 462N /mm run. This weld would be more than sufficient.}$

Example of Weld in Bending.
P = 30000 Newtons  
d = 100mm  
b = 75mm  
y = 50mm  

Design Stress $p_w = 220 \text{ N/mm}^2$ (Electrode E35 steel S275)  

**Design Strength**  

Moment = $M = 30000 \times 60 = 18.10^5$ Nmm

### Simple Method as BS 5950 clause 6.8.7.2

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Weld Area</strong></td>
<td>$A_u = 2(d+b) = 2(100+75) = 350\text{mm}^2$</td>
</tr>
<tr>
<td><strong>Unit Moment of Inertia</strong></td>
<td>$I_u = d^2(3b+d)/6 = 100^2 (3.75 +100)/6 = 5.42.10^5$ mm$^4$</td>
</tr>
</tbody>
</table>

$\tau_r = \sqrt{\tau_s^2 + \tau_b^2}$  
$\tau_s = \frac{P}{A_u} = 30000/350 = 85.71 \text{ N/mm}^2$  
$\tau_b = \frac{M \cdot y}{I_u} = 18.10^5 \times 50 / 5.42.10^5 = 166.05 \text{ N/mm}^2$  
$\tau_r / p_w = 186.86 / 220 = 0.85$ = Throat Thickness.....  

(L Throat thickness for $\tau = 220 \text{ N/mm}^2$)

Leg Length = Throat thickness $\times 1.414 = 1.2$mm use  
3mm weld thickness  

Note: If a leg length $h = 1.2$mm is used in the equations in relevant part of the "Table of bracket weld subject to direct and bending stresses" above a value of $\tau_b = 198 \text{ N/mm}$ and a value of $\tau_s = 100 \text{ N/mm}^2$ results with a resultant stress of $\sqrt{\tau_b^2 + \tau_s^2} = 222 \text{N/mm}^2$. Which is in general agreement with the above result

### Direction Method as BS 5950 clause 6.8.7.3

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length of Weld of unit thickness</strong></td>
<td>$L = 2(d+b) = 2(100+75) = 350\text{mm}$</td>
</tr>
<tr>
<td><strong>Moment of Inertia / mm throat thickness</strong></td>
<td>$I_u / \text{mm} = d^2(3b+d)/6 = 100^2 (3.75 +100)/6 = 5.42.10^5$ mm$^4 / \text{mm}$</td>
</tr>
</tbody>
</table>

$F_r = \text{Resultant force per unit length of weld.}$  
$F_s = \text{Shear force per unit length of weld.}$  
$F_b = \text{Bending force per unit length of weld.}$

$F_r = \sqrt{F_s^2 + F_b^2}$  
$F_s = \frac{P}{L} = 30000/350 = 85.71 \text{ N per mm length of weld}$  
$F_b = \frac{M \cdot y}{I_u} = 18.10^5 \times 50 / 5.42.10^5 = 166.05 \text{ N per mm length of weld}$  

For this case for the welds under greatest loading the type of loading is traverse loading. The bending stress is in line with horizontal element and the shear stress is in line with vertical member.

The angle of the resulting specific load to the horizontal element  
$= \arctan(85.71/166.5) = 27.5^\circ$.  

http://www.mohandes-iran.com
This is an angle with the weld throat $\theta = 45^o + 27,5^o = 72,5^o$ Referring to weld capacities table below. Weld Capacities K is calculated at 1,36 for this resultant direction of forces.

$P_T = a.K.p_w$ for a E35 Weld electrode used with S275 steel

$p_w = 220$ N/mm$^2$ and therefore $P_T = a*300$N/mm$^2$.

A 3mm weld (a = 2,1mm) therefore will therefore have a design capacity of 630 N/mm run and will easily be able to support the load of 186,86 N per mm run

Properties of weld groups with welds treated as lines -

It is accepted that it is reasonably accurate to use properties based on unit weld thickness in calculation to determine the strength of welds as shown in the examples on this page. The weld properties $I_{xx}$ $I_{yy}$ and $J$ are assumed to be proportional to the weld thickness. The typical accuracy of this method of calculation is shown below...
This is illustrated in the tabled values below

<table>
<thead>
<tr>
<th></th>
<th>d</th>
<th>b</th>
<th>h</th>
<th>Ixx</th>
<th>Iyy</th>
<th>J = Ixx + Iyy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate</td>
<td>3</td>
<td>60</td>
<td>50</td>
<td>955080</td>
<td>108000</td>
<td>1063080</td>
</tr>
<tr>
<td>Simple</td>
<td>3</td>
<td>60</td>
<td>50</td>
<td>900000</td>
<td>108000</td>
<td>1008000</td>
</tr>
<tr>
<td>Error</td>
<td></td>
<td></td>
<td></td>
<td>6%</td>
<td>0</td>
<td>5%</td>
</tr>
</tbody>
</table>

Note: The error identified with this method is lower as h increases relative to d. This error is such that the resulting designs are conservative.

Example illustrating use of stress vectors
### Calculation based on real weld sizes

1) The area of the welds  
(based on throat weld thickness at 0.707.5 = 3.5mm)

\[
\text{Area} = (57.3.5 + 2.55.3.5) = 584.5 \text{mm}^2
\]

2) The moment of area about x-x =

\[
M \text{ of Area} = (57.3.5.3.5/2 + 2.55.3.5.(27.5 + 3.5)) = 12 \text{ 284mm}^3
\]

3) The centroid \( v \) = Moment of Area/Area

\[
M \text{ of Area} / \text{Area} = 21 \text{ mm}
\]

4) The radii \( r_A, r_B, r_C \) & \( r_D \) are calculated ..

\[
r_A = r_B = \sqrt{(58,5-21)^2 + 28,5^2} = 47,1
\]

\[
r_C = r_D = \sqrt{(21)^2 + 28,5^2} = 35,40...
\]

5) The angles \( \theta_A, \theta_B, \theta_C \) & \( \theta_D \) are calculated ..

\[
\theta_A = \theta_B = \tan^{-1} \left( \frac{58,5-21}{25} \right) = 52,7^\circ
\]

\[
\theta_C = \theta_D = \tan^{-1} \left( \frac{21}{25} \right) = 36,4^\circ...
\]

6) The direct shear stress on the area = Force/Area

\[
\tau_s = \frac{5000}{584} = 8,56 \text{ N/mm}^2
\]

7) The Moment on the weld group = Force.Distance to centroid

\[
M = 5000.(100+21) = 6,05.10^5 \text{Nmm}
\]

8) The polar moment of inertia of the weld group = \( J = I_{xx} + I_{yy} \)

\[
I_{yy} = 2.[55.3.5^3/12 + 3.5.55.(50/2 + 3.5/2)^2] + 57^3.3.5/12 = 3.3.10^5 \text{mm}^4
\]

\[
I_{xx} = 2.[55.3.5^3/12 + 3.5.55.(55/2 + 3.5 - 21)^2] + 3.5^3/12 = 3.5.57.(21-3.5/2)^2 = 2.097 .10^5 \text{mm}^4
\]

### Calculations based on unit values

This calculation uses equations from table below for Area, centroid, and \( J_u \)

1) Area of weld = 0.707.5.(2b+d)

\[
\text{Area} = 0.707.5 \times (2.55 + 50) = 565.6 \text{mm}^2
\]

2) There is no need to calculate the Moment of Area with this method

3) The centroid \( v \) = \( b^2/(2b+d) \)

\[
v = \frac{55^2}{2.55+50} = 18.9 \text{mm}
\]

4) The radii \( r_A, r_B, r_C \) & \( r_D \) are calculated ..

\[
r_A = r_B = \sqrt{(55-18,9)^2 + 25^2} = 43.9
\]

\[
r_C = r_D = \sqrt{18,9^2 + 25^2} = 31,34
\]

5) The angles \( \theta_A, \theta_B, \theta_C \) & \( \theta_D \) are calculated ..

\[
\theta_A = \theta_B = \tan^{-1} \left( \frac{55-18,9}{25} \right) = 55,29^\circ
\]

\[
\theta_C = \theta_D = \tan^{-1} \left( \frac{18.9}{25} \right) = 37^\circ...
\]

6) The direct shear stress on the area = Force/Area

\[
\tau_s = \frac{5000/565,5}{584} = 8,84 \text{ N/mm}^2
\]

7) The Moment on the weld group = Force.distance to centroid

\[
M = 5000.(100+18,9) = 5.94.10^5 \text{Nmm}
\]

8) The Unit Polar moment of inertia of the weld group = \( J_u = 0.707.5.(8.b^3 + 6bd^2 + d^3)/12 + b^4/(2b+d) \)

\[
J_u = 0.707.5 \times (8.55^3 + 6.55.50^2 + 50^3)/12 - 55^3/(2.55+50) = 4,69.10^5
\]

9) The stress due to torsion
J = I_{xx} + I_{yy} = 5.4 \times 10^5 \text{mm}^4

9) The stress due to torsion
\[ \tau_{TA} = \tau_{TB} = M \cdot r_A / J \] and \[ \tau_{TC} = \tau_{TD} = M \cdot r_C / J \]

\[ \tau_{TA} = 6.05 \times 10^5 \text{Nmm} / 47.1 \text{mm} / 5.4 \times 10^5 \text{mm}^4 = 52.8 \text{N/mm}^2 \]

\[ \tau_{TC} = \tau_{TD} = 6.05 \times 10^5 \text{Nmm} / 35.4 \text{mm} / 5.4 \times 10^5 \text{mm}^4 = 39.7 \text{N/mm}^2 \]

10) The resultant stresses \( \tau_{RA} = \tau_{RB} \) and \( \tau_{RA} = \tau_{RB} \)
are obtained by adding the stress vectors graphically as shown below

\[ \tau_{RA} = \tau_{RB} = 46.29 \text{N/mm}^2 \]
\[ \tau_{RC} = \tau_{RD} = 45.31 \text{N/mm}^2 \]

Note: The example above simply illustrates the vector method adding direct and torsional shear stresses and compares the difference in using the unit weld width method and using real weld sizes. The example calculates the stress levels in an existing weld group it is clear that the weld is oversized for the loading scenario. The difference in the resulting values are in less than 4%. If the welds were smaller i.e 3mm then the differences would be even smaller.

| Table properties of a range of fillet weld groups with welds treated as lines - |
|---------------------------------|------------------|----------------|-----------------|------------------|
| Weld                            | Throat Area      | Location of COG | I_{xx}-(unit)  | J-(Unit)         |
|                                 | Unit Area        | x               |                 |                  |
|                                 |                  | y               |                 |                  |

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<table>
<thead>
<tr>
<th>Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin bar</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Thick bar</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Rectangular section</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Rectangular section</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Thin Bar**

- $x = 0$
- $y = d/2$
- $I = \frac{d^3}{12}$
- $J = \frac{d^3}{12}$

**Thick Bar**

- $x = b/2$
- $y = d/2$
- $I = \frac{d^3}{6}$
- $J = \frac{d\left(3b^2 + d^2\right)}{6}$

**Rectangular Section**

- $x = b/2$
- $y = d/2$
- $I = \frac{bd^2}{2}$
- $J = \frac{b\left(3d^2 + b^2\right)}{6}$

**Rectangular Section**

- $x = \frac{b^2}{2(b+d)}$
- $y = \frac{d^2}{2(b+d)}$
- $I = \frac{(b+d)^4 - 6b^2d^2}{12(b+d)}$
- $J = \frac{(b+d)^3}{12} - \frac{b^4}{2b+d}$

**Rectangular Section**

- $x = b^2/(2b+d)$
- $y = d/2$
- $I = \frac{d(6b+d)}{12}$
- $J = \frac{z}{12} - \frac{b^4}{2b+d}$

**Rectangular Section**

- $x = b/2$
- $y = d/2$
- $I = \frac{d(3b+d)}{6}$
- $J = \frac{(b+d)^3}{6}$
The fillet weld capacity tables related to the type of loading on the weld. Two types of loading are identified traverse loading and longitudinal loading as show below

The weld loading should be such that

\[
\left\{ \frac{F_T}{P_L} \right\}^2 + \left\{ \frac{F_T}{P_T} \right\}^2 \leq 1
\]

The following table is in accord with data in BS 5950 part 1. Based on design strengths as shown in table below ...

- **Design Strength**

\[ P_L = a.p_w \]
\[ P_T = a.K.p_w \]

\( a = \) weld throat size.

\[ K = 1.25 \sqrt{1.5 / (1 + \cos^2 \theta)} \]

\( P_T \) based on elements transmitting forces at 90° i.e \( \theta = 45° \) and \( K = 1.25 \)

<table>
<thead>
<tr>
<th>Weld Capacity E35 Electrode S275 Steel</th>
<th>Weld Capacity E42 Electrode S355 Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg</td>
<td>Throat</td>
</tr>
<tr>
<td>-----</td>
<td>--------</td>
</tr>
</tbody>
</table>

![Diagram of Weld Tranverse Loading](http://www.mohandes-iran.com) ![Diagram of Weld Longitudinal Loading](http://www.mohandes-iran.com)
<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>Thickness (mm)</th>
<th>$P_L$ (kN/mm)</th>
<th>$P_T$ (kN/mm)</th>
<th>Length (mm)</th>
<th>Thickness (mm)</th>
<th>$P_L$ (kN/mm)</th>
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<tbody>
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<td>0.577</td>
<td>3</td>
<td>2.1</td>
<td>0.525</td>
<td>0.656</td>
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<td>4.375</td>
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</tbody>
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**Design Strength $p_w$ of fillet welds**

| Electrode classification |

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<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>35 N/mm²</th>
<th>43 N/mm²</th>
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