Weld Design and Specification

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I can’t explain everything . . .

Inside weld entire length

4 in
6 in
1000 ft
1/4”
Factors in Weld Design

- Strength (static and/or fatigue)
- Material and the effects of heating
- Cost
- Distortion
- Residual Stresses
- Easy to Weld

Static Strength

\[ \text{Stress (}\sigma\text{)} = \frac{F}{A} \]

\[ \text{Strain (}\varepsilon\text{)} = \frac{\Delta L}{L} \]
Shear Strength

- In general, material fails in shear due to distortion (at a molecular level)
- Criteria for failure:
  - Ductile: Shear Strength ~ 0.5 Tensile Strength
  - Brittle: Shear Strength ~ 0.75 Tensile Strength
- Weld strength analysis is generally based on Shear Strength

\[ \sigma_x = \frac{M y}{I} \]

where \( I \) = moment of inertia
Static Strength of Welds

Butt

\[ F \rightarrow F \]

Normal = \( \frac{F}{w \times h} \)

Shear = \( \frac{F}{w \times h} \)

\( h = \) throat size!

Fillet

\[ 2F \rightarrow F \]

Max Normal = \( \frac{F}{0.618w \times h} \)

Max Shear = \( \frac{F}{0.707w \times h} \)

Weld Size vs. Throat Size

Butt

\[ \downarrow \]

\( h = \) plate thickness = weld size

Fillet

\[ \downarrow \]

\( h = 0.707 \times \) plate thickness

\( 0.707 \times \) weld size
Fatigue Strength

**Stress-Concentration Factor**

\[ K_T = \frac{\sigma_{\text{max}}}{\sigma_{\text{nom}}} = 1 + \frac{2a}{b} \]

For \( a \gg \rho \), \( \rho = b^2/a \)

\[ K_T = 2 \left( \frac{\rho}{a} \right) \]

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**Fatigue Strength**

- Static Tensile Strength
- Endurance Limit
- Low Cycle
- High Cycle
- Infinite Life

Cycles of Loading

1 1000 1,000,000
Endurance Limit

For Steel:

- Endurance Limit = 0.5 * Tensile Strength or 100 kpsi, whichever is lower.

For Aluminum:

- No endurance limit (cannot have an infinite life)

\[ \Delta \sigma = \sigma_{\text{max}} - \sigma_{\text{min}} \]
\[ \sigma_{\text{mean}} = \frac{\sigma_{\text{max}} + \sigma_{\text{min}}}{2} \]
\[ \sigma_{\text{amp}} = \frac{\sigma_{\text{max}} - \sigma_{\text{min}}}{2} \]
\[ R = \frac{\sigma_{\min}}{\sigma_{\max}} \]
Factors for Fatigue Stress Analysis

<table>
<thead>
<tr>
<th>Type of Weld</th>
<th>Stress Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt Weld</td>
<td>1.2</td>
</tr>
<tr>
<td>Transverse Fillet</td>
<td>1.5</td>
</tr>
<tr>
<td>Parallel Fillet</td>
<td>2.7</td>
</tr>
<tr>
<td>T-butt with corners</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Strength Considerations

- Try to minimize the stresses in welds; make the parent materials carry highest stresses.
- Butt welds are the most efficient
- Avoid stress concentrations
- Intermittent weld length should be at least 4 times the fillet size
- Minimize weld size to reduce potential for fatigue failure
Effects of Welding on Metallurgy

- Depends on the alloy and welding process
- In general, cracking is promoted by:
  - stress concentrations
  - brittle parent material after welding (low carbon steels)
  - hydrogen in the weld metal
  - impurities in the weld metal
Reducing Distortion

- Prevent overwelding
- Intermittent welding
- Minimize number of passes
- Place welds near the **neutral axis** of the part
- Balance welds around the **neutral axis**
- Anticipate shrinkage forces
- Residual stress relief

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**Thermal Strains in an Edge Welded Plate**

- Heat Input
- **ΔT**
- Unit Length
- **Z**

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**Basics of Welding Mechanics**

**Residual Stresses and Distortion**
Neutral Axis

- The line (plane) where bending stresses are zero.
Basics of Welding Mechanics  Residual Stresses and Distortion

Examples

Welding near Neutral Axis

Balancing Welds around Neutral Axis
Check List for Minimizing Distortion

6. Use backstep welding

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Direction of each bead segment

Direction of Welding