6.3 Improving the fatigue life of weldments
Outline

- Avoid crudities
  - Improving “good” weldments
  - Improving “bad” weldments
Crude! (bad)
Better
Bad - planar weld discontinuities
Outline

- Avoiding crudities
- Improving “good” weldments
- Improving “bad” weldments
Weldment with a transverse attachment

A “good” weld
TWI suggestions as to weld improvement procedures
Improvement strategies

Fatigue Strength (ksi) at $10^6$ cycles

Base metal UTS (ksi)

- Shot Peen
- Residual stress
- Plain plate
- Geometry
- Base metal strength

Over Stressed
Stress Relieved
As Welded
Example

Model predictions and experimental data.
Trends in “Ideal” 1.0-in plate thickness, non-load carrying cruciform weldments fatigue strength.

- $R = 0$
- Welding residual stresses $= 50\%$ of $S_{YBM}$
- $S_{fab} \sim S_{YBM}$

Predicted effect of $S_{uBM}$

![Fatigue Strength vs Base Metal Ultimate Strength Graph]

- Hot Rolled Steel
- Q & T Steel
- Stress Relieved
- As Welded, $S_{fab} = 0$
- As Welded, $S_{fab} = S_{YBM}$

Fatigue Strength at $1 \times 10^7$ cycles, $S_a$ (ksi)
Base Metal Ultimate Strength, $S_{BM}$ (ksi)
Good - grind off reinforcement
Good - burr grind weld toe
Very good - full face grinding
Shot peened weld toe
Remelted weld toe (laser)
ASTM A 36 butt weldment

![Graph showing stress range versus reversals to failure for A36/E60S-3 bead on plate weldments.](image)

**Graph Details:**
- **Legend:**
  - SS (Pred)
  - AW (Pred)
  - SP
  - TD
  - LD
- **Symbols:**
  - ○ AW
  - △ SP
  - □ TD
  - △ LD
- **Plate Failure:**
  - Symbol: ΔΔ
- **Axes:**
  - Stress Range ΔS, ksi
  - Reversals To Failure, 2N
  - MJ

**Graph Description:**
- The graph compares the stress range (ΔS) to the number of reversals to failure (2N) for different weldment conditions.
- The stress range is measured in ksi (kilopounds per square inch).
- The reversals to failure are plotted on a logarithmic scale.
- Different symbols represent different conditions (e.g., SS, AW, SP) and are used to compare the experimental data with predicted values.
- The graph includes a line for predicted behavior (SS (Pred)) and actual test data points for AW, TD, and LD conditions.
- Plate failure (ΔΔ) is indicated by a specific symbol on the graph.
ASTM A 514 butt weldment
Light, heavy industry weldments

- Light industry weldments are presumed to be fabricated from 1/2” or smaller plate and not to have large fabrication stresses.

- Heavy industry weldments are presumed to be fabricated from larger than 1” thick plates and to possess large fabrication stresses.
Light industry weldments

- Remote Stress Range, $\Delta S$ (ksi)

- Fatigue Life, $N_T$ (cycles)

Graph shows:
- Ideal
- Nominal
- Toe Ground (radius = 0.1 in.)
- Over Stressed
- Stress Relieved
- Weld Profile (flank angle 20°)
- As Welded

$t = 0.5$-in. (12mm); $R = 0$
Without Fabrication Stresses

Light industry weldments
Heavy industry weldments

Remote Stress Range, $\Delta S$ (ksi) vs. Fatigue Life, $N_T$ (cycles)

- Toe Ground (radius = 0.1 in.)
- Over Stressed
- Stress Relieved
- Weld Profile (flank angle 20°)
- As Welded

$t = 2.0$-in. (50 mm); $R = 0$
With Fabrication Stresses

Nominal
Ideal
Outline

- Avoid crudities
- Improving “good” weldments
- Improving “bad” weldments
Weldments with longitudinal attachments have a low fatigue resistance because of the presence of weld terminations. Starts and stops introduce weld discontinuities. Residual stresses very high. 3-D stress concentrations effects
Cold lap defects at weld toe

Series 1 and 2

Series 3
Examples of terminations
Placement of stress diffuser

Longitudinal attachment with stress diffusers
3-D FEM modeling
Effectiveness of a stress diffuser

Longitudinal attachment

Longitudinal attachment with stress diffuser
Effect on $M_K$ and $N_P$

![Graph showing the effect of crack length on the weld geometry correction factor and fatigue crack propagation life.](image)

- **Weld geometry correction factor, $M_K$**
  - L.A.
  - L.A. with stress diffusers
  - Transverse attachment

- **Fatigue Crack Propagation Life, $N_P$ (cycles)**
  - Initial crack length / main plate thickness, $(a/T)$
    - L.A.
    - L.A. with stress diffusers
    - Transverse attachment

![Bar chart showing the relationship between initial crack length and fatigue crack propagation life.](image)
Fatigue test results
Fatigue test results

- Transverse attachments, database
- Longitudinal attachments, database
- LA specimens, Procedures 1 and 2
- LA specimens, Procedure 3
- SD specimens, Procedure 1
- SD specimens, Procedure 3
Summary

• The fatigue strength of “Ideal” weldments can be much improved; whereas, the fatigue strength of “Nominal” weldments cannot.

• Weld toe grinding or weld profile control works best for “Ideal” weldments at short lives. Beware of corrosion pitting.

• Smaller “Ideal” weldments are more susceptible to improvement than larger weldments.

• Fabrication stresses are critically important.
Summary

• The behaviors of light and heavy industry weldments are dissimilar.

• Stress relief annealing and over-stressing works best for “Ideal” weldment at long lives. Beware of compressive overloads.

• Fatigue behavior of weldments and effective life improvement methods depends upon weldment size and weld quality

• Stress-diffuser can substantially improve the fatigue life of terminations without post-weld processing.