

Fatigue Analysis Techniques

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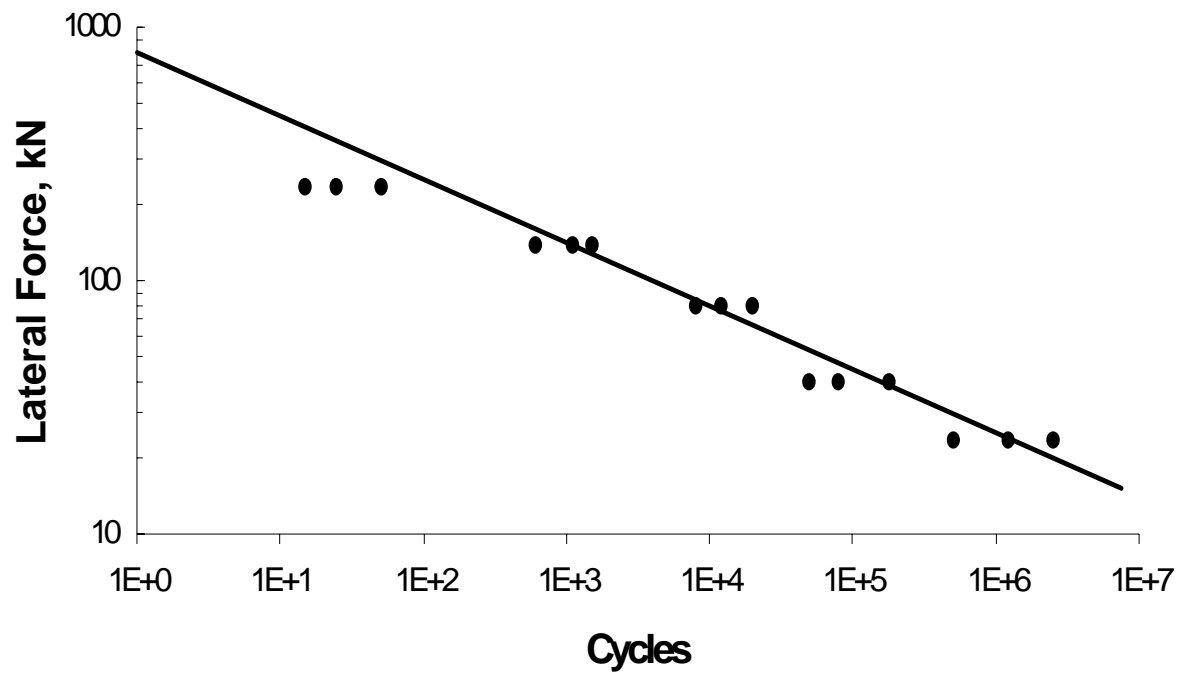
Fatigue Analysis Techniques

- Load-Life
- Stress-Life
- BS 5400 (Eurocode 3)
- Strain-Life
- Crack Growth

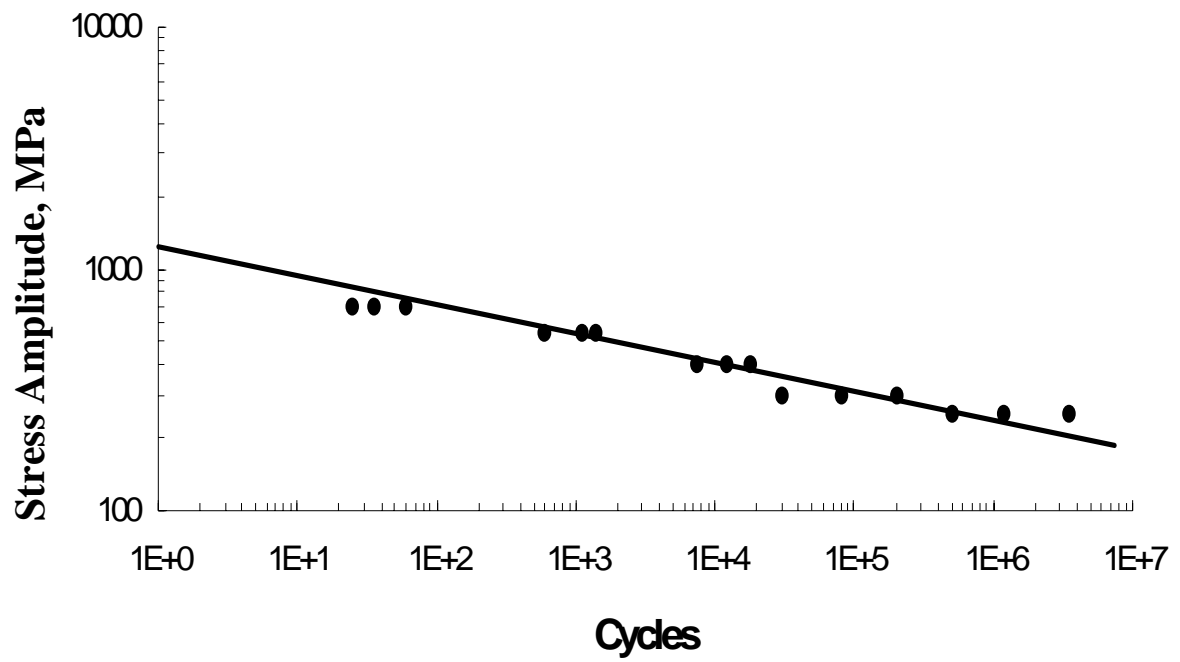
Common Features

- Constant amplitude test data
- Rainflow
- Linear damage

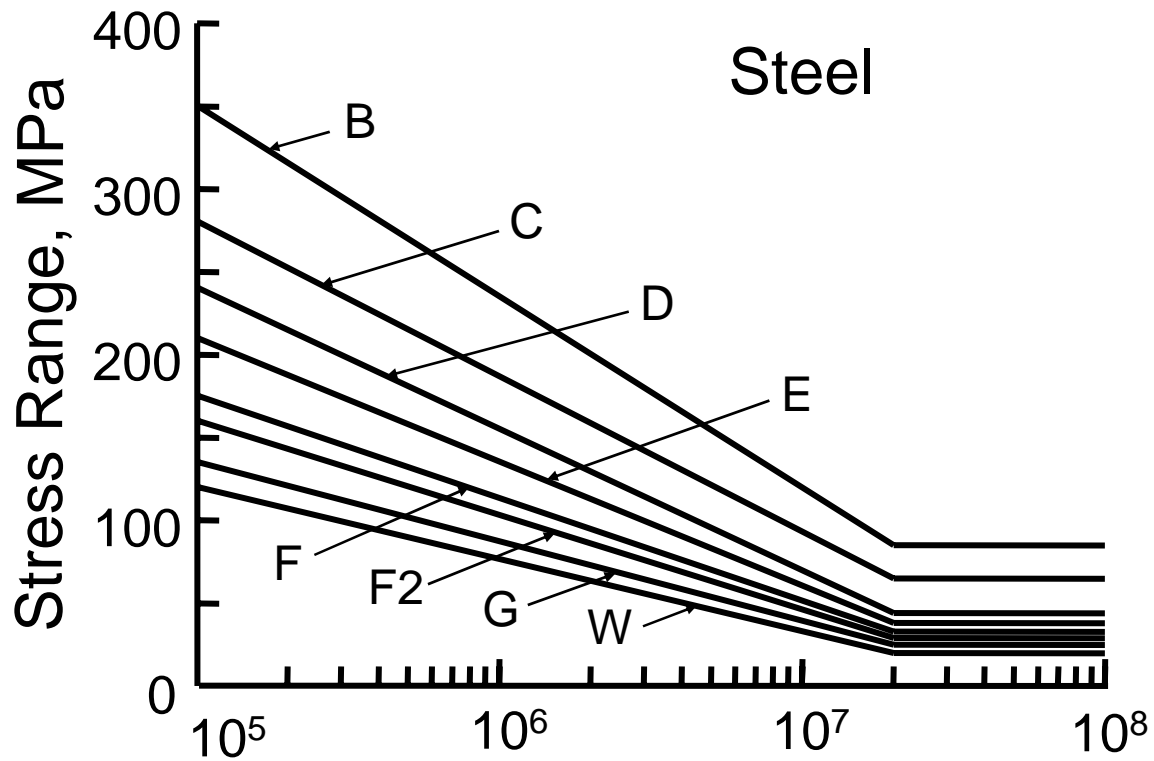
Load-Life Data



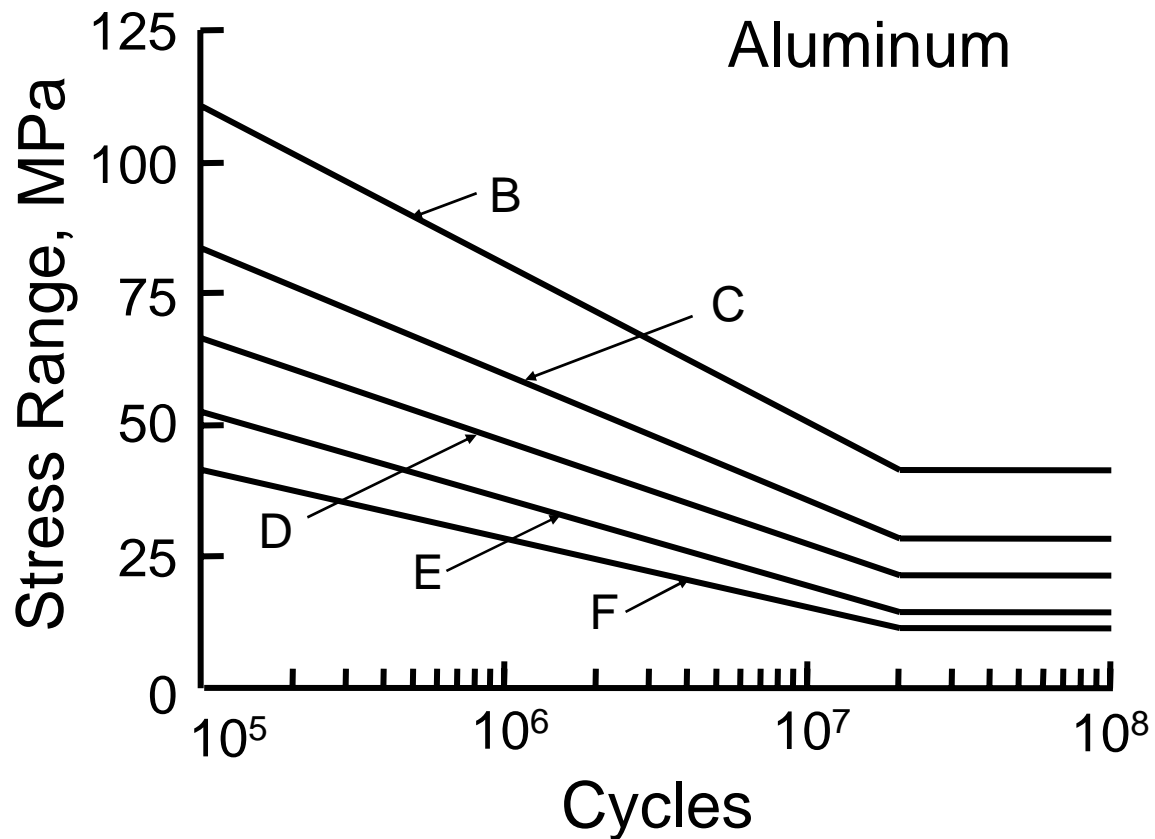
Stress-Life Data



BS 5400 (Eurocode 3) Data

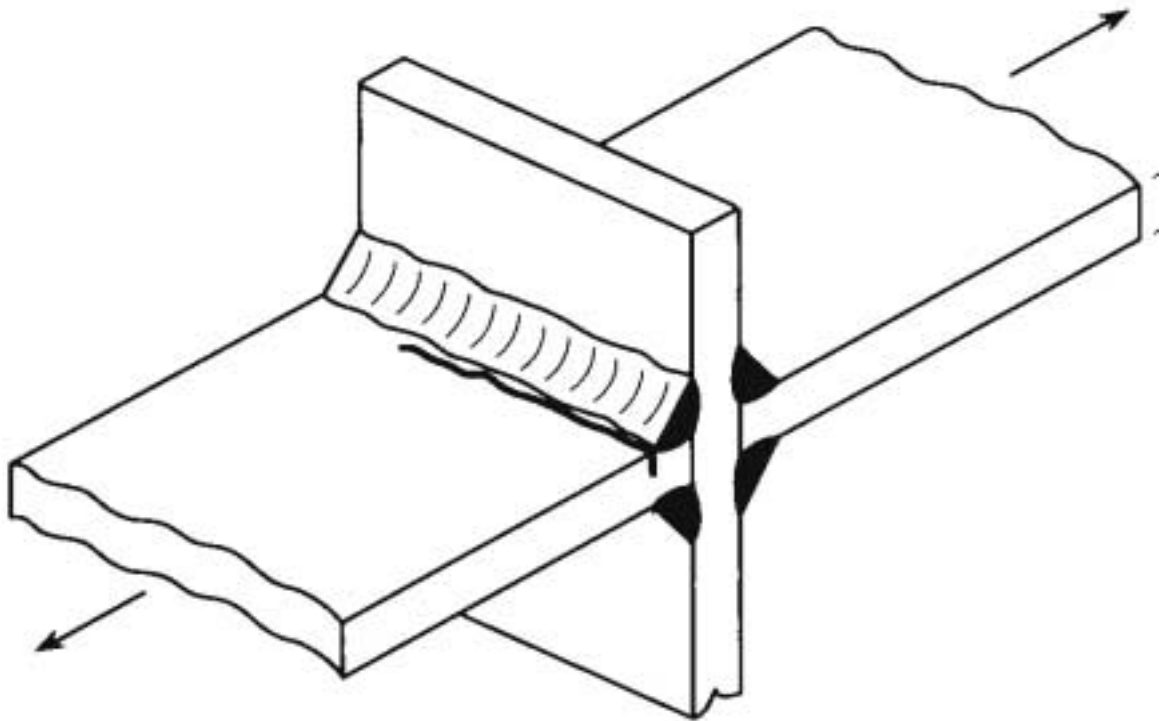


BS 5400 (Eurocode 3) Data



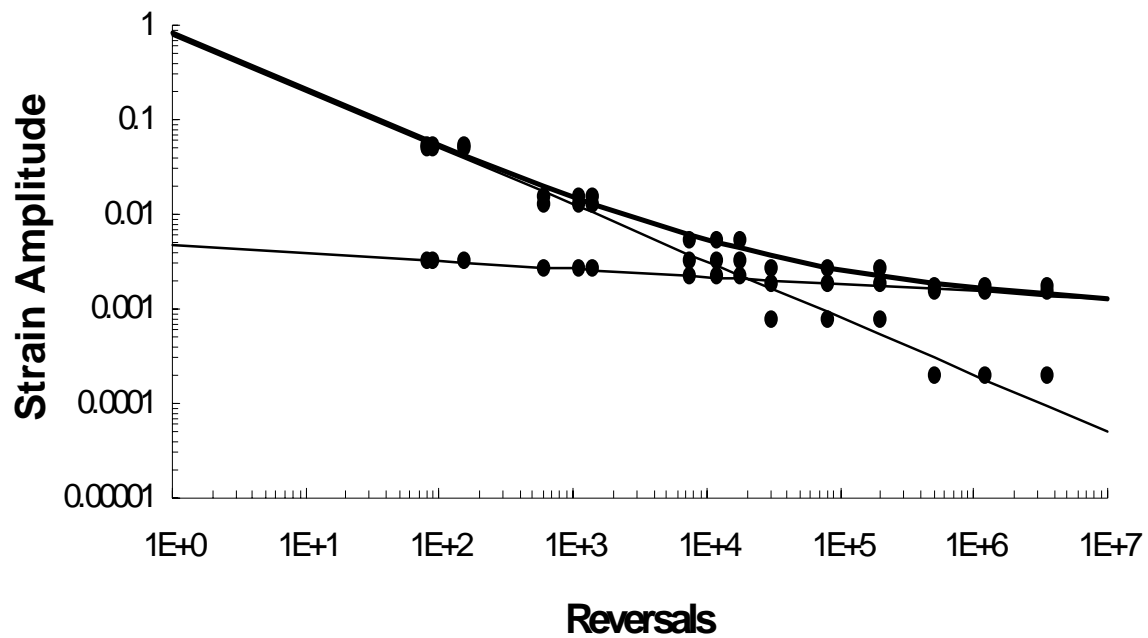
BS 5400 (Eurocode 3)

Weld Class F

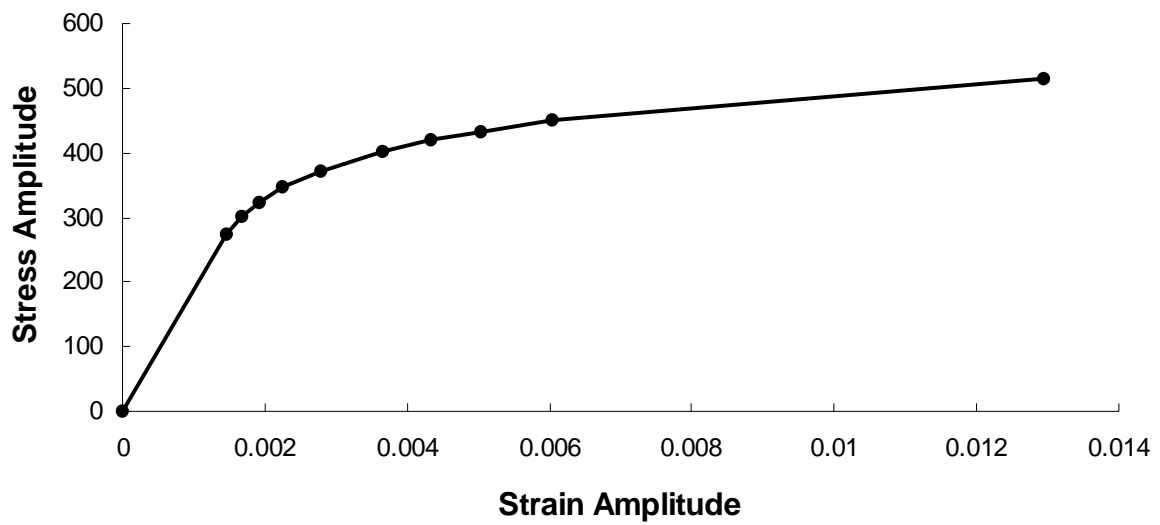


Strain-Life Data

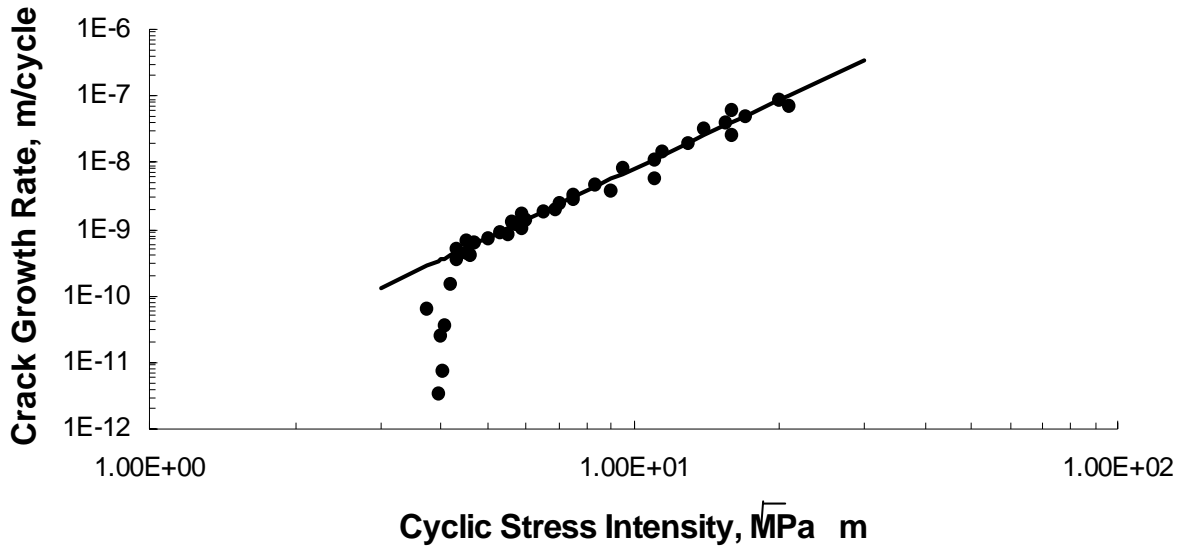
$$\Delta\varepsilon - 2N_f$$



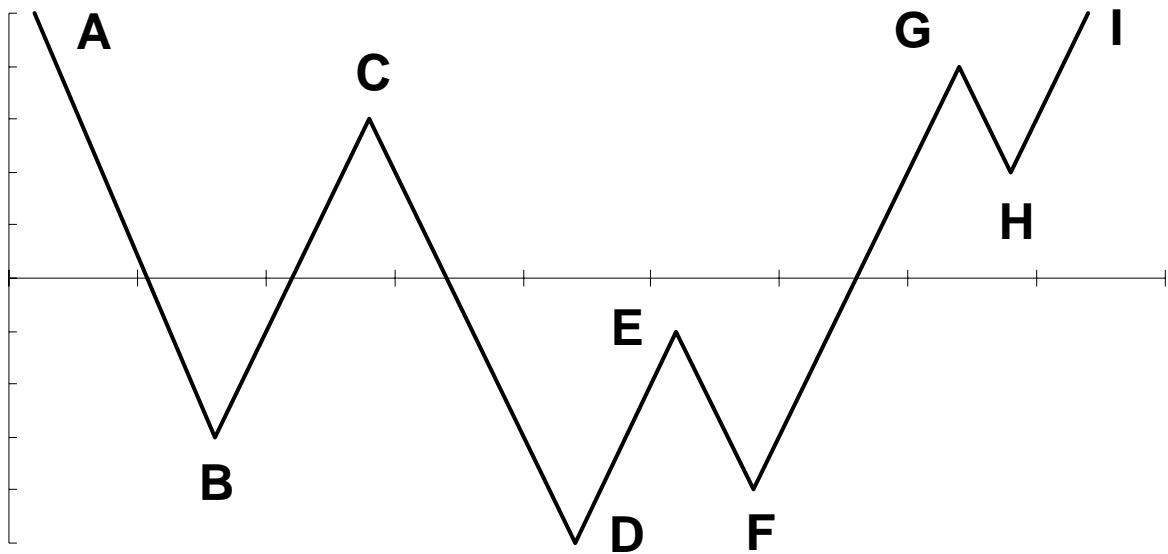
Strain-Life Data $\sigma - \epsilon$



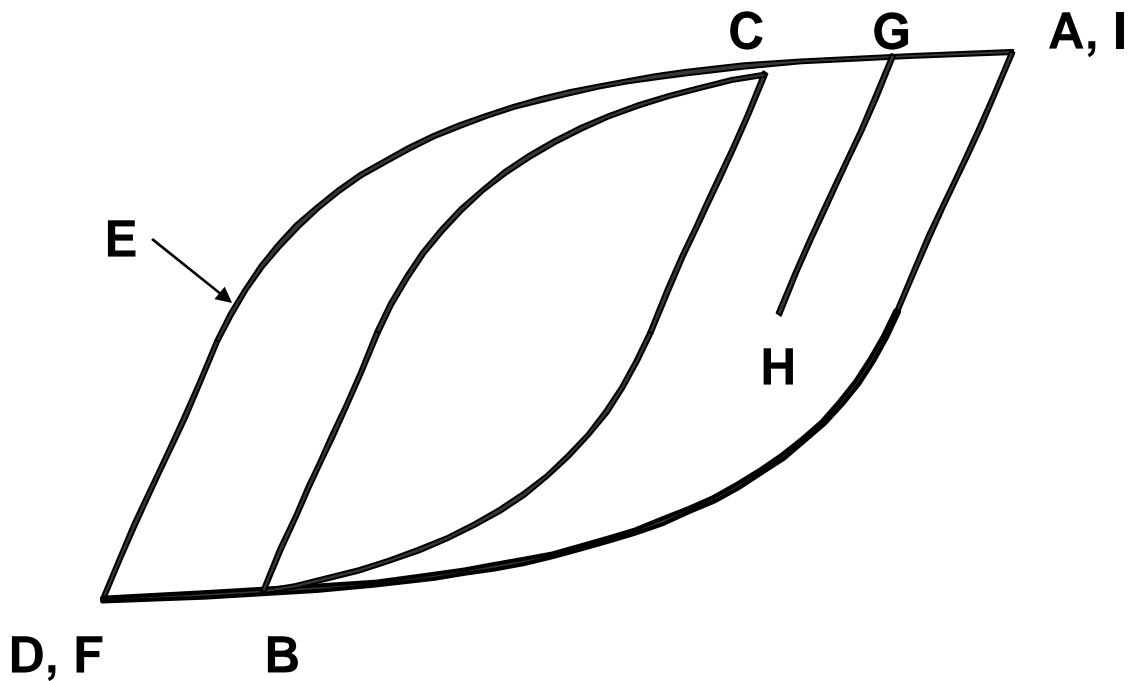
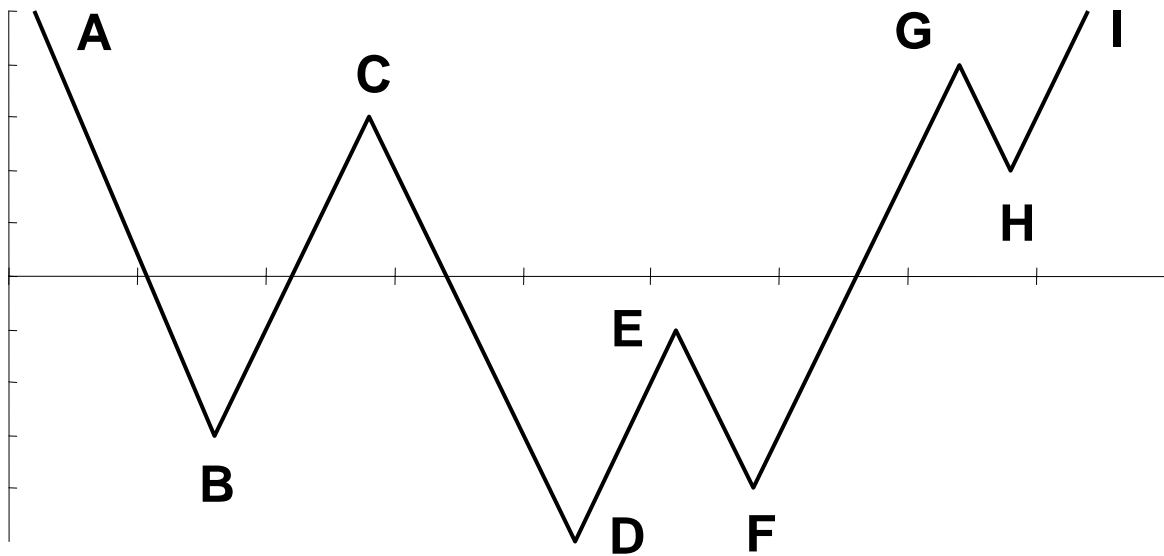
Crack Growth Data



Rainflow Counting



Hysteresis Loops



Damage Accumulation

- Miner's Linear Damage Rule
 - $\sum N_i / N_f = 1$

Load-Life

- Major Assumption
 - Loads used to generate baseline data are the same as service loading

Load-Life

- Advantages
 - Actual test of structure
 - Manufacturing and local stress concentration effects automatically included
 - Stress analysis is not needed

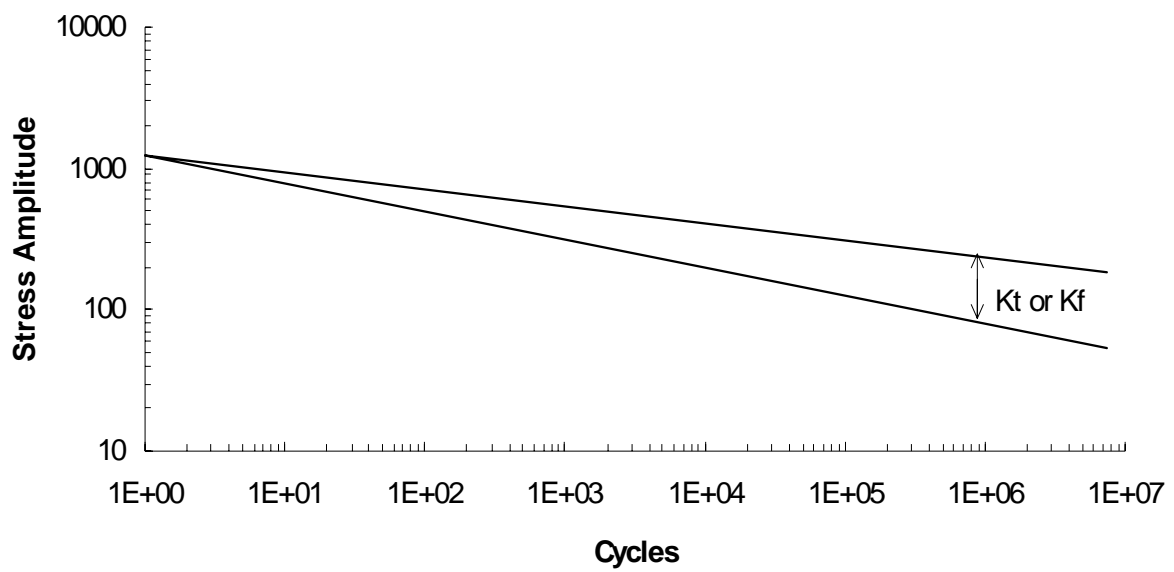
Load-Life

- Limitations
 - Actual test of structure
 - New tests required for each change in material, loading or geometry
 - Mean stress effects can not be included

Stress-Life

- Major Assumptions
 - Nominal stresses and material strength control fatigue life
 - Accurate determination of K_f for each geometry and material

Notched S-N Curve



Stress-Life

- Advantages
 - Changes in material and geometry can easily be evaluated
 - Large empirical database for steel with standard notch shapes

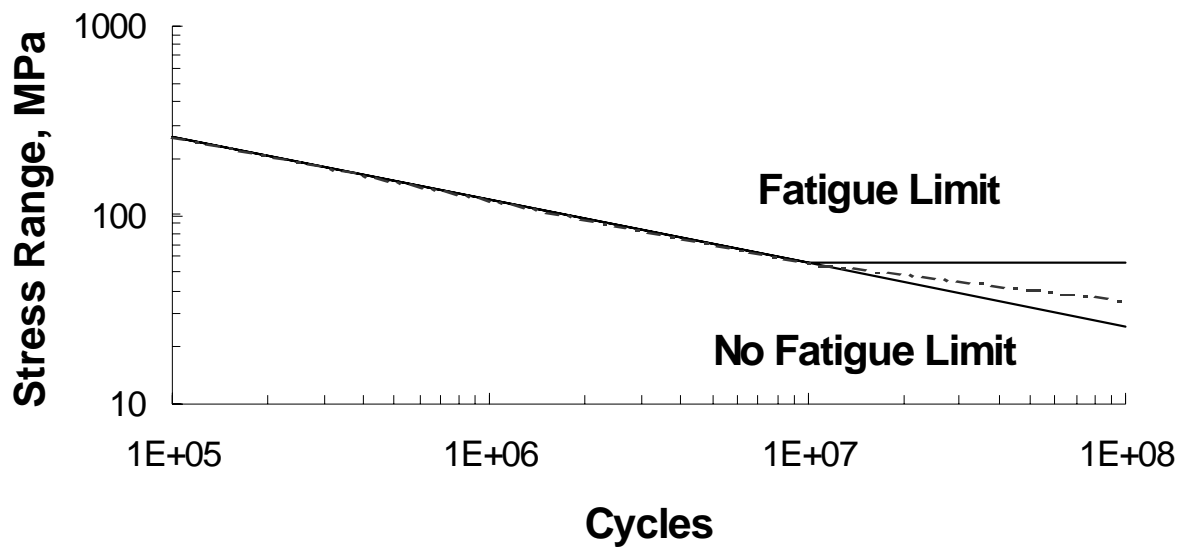
Stress-Life

- Limitations
 - Does not account for notch root plasticity
 - Mean stress effects are often in error
 - Requires empirical K_f for good results

BS 5400 (Eurocode 3)

- Major Assumptions
 - Complex weld geometries can be described by a standard classification
 - Crack growth dominates fatigue life
 - Results independant of material and mean stress for structural steels

BS 5400 (Eurocode 3)



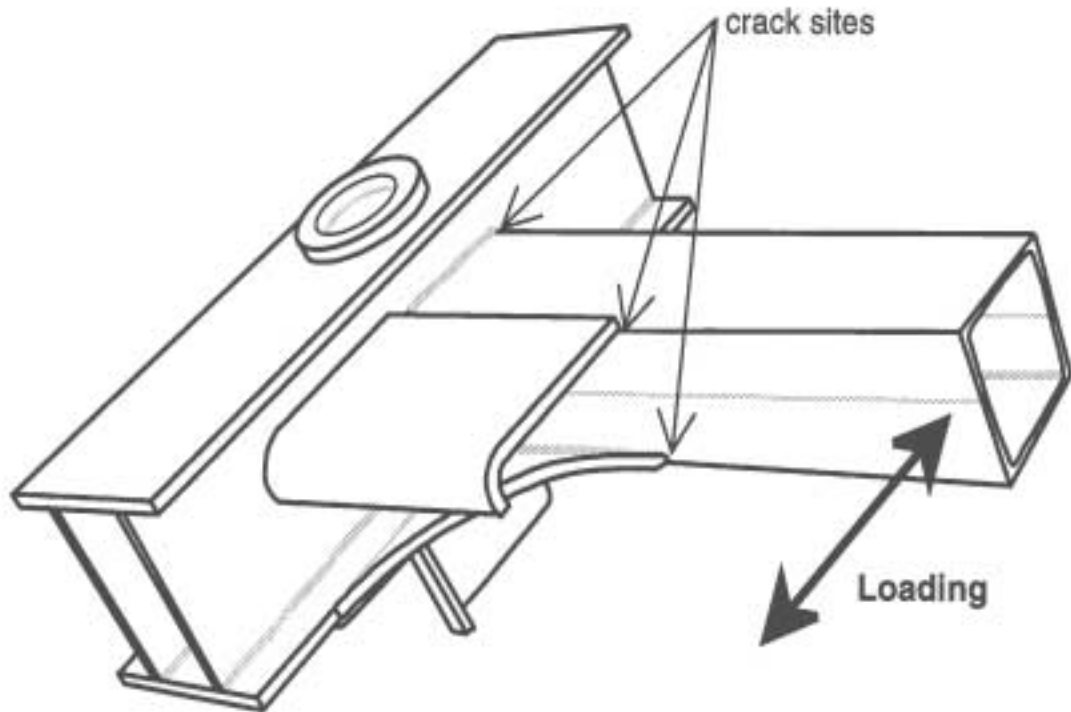
BS 5400 (Eurocode 3)

- Advantages
 - Manufacturing effects are directly included
 - Large empirical database exists

BS 5400 (Eurocode 3)

- Limitations
 - Difficult to determine weld class for complex shapes
 - No benefit for improving manufacturing process

Welded Structure



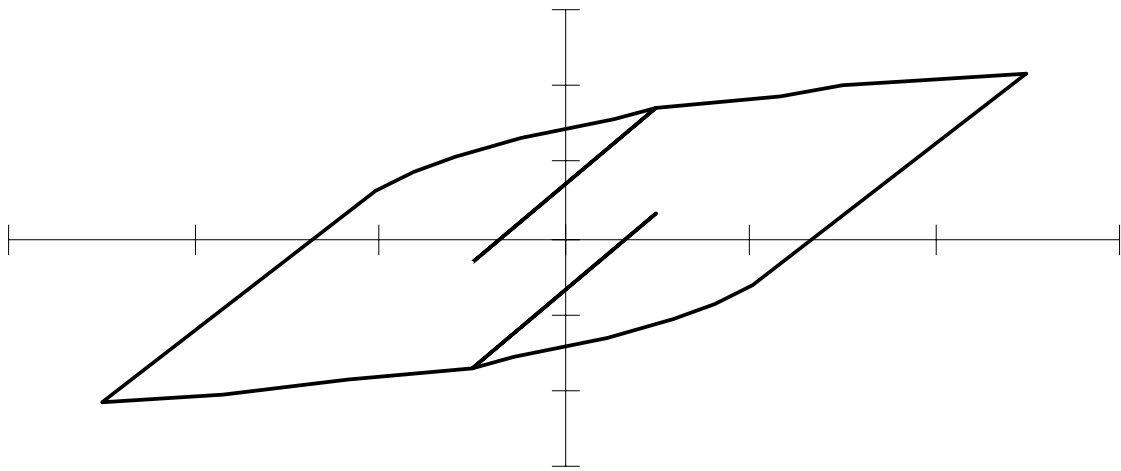
Strain-Life

- Major Assumptions
 - Local stresses and strains control fatigue behavior
 - Accurate determination of K_f

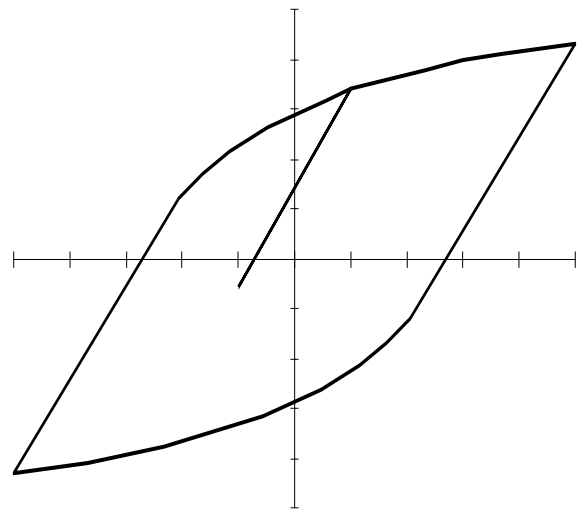
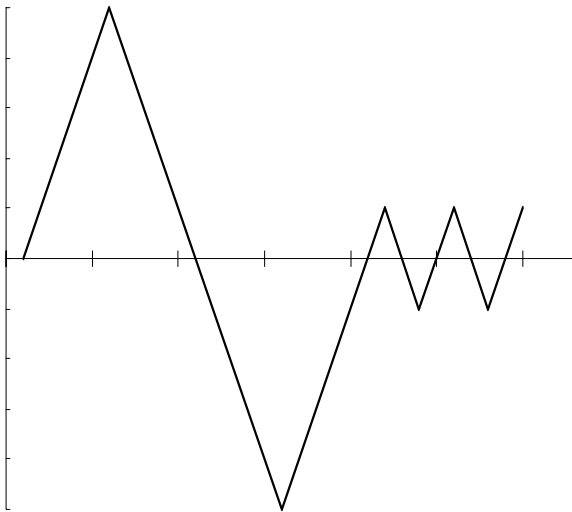
Strain-Life

- Advantages
 - Plasticity effects
 - Mean stress effects

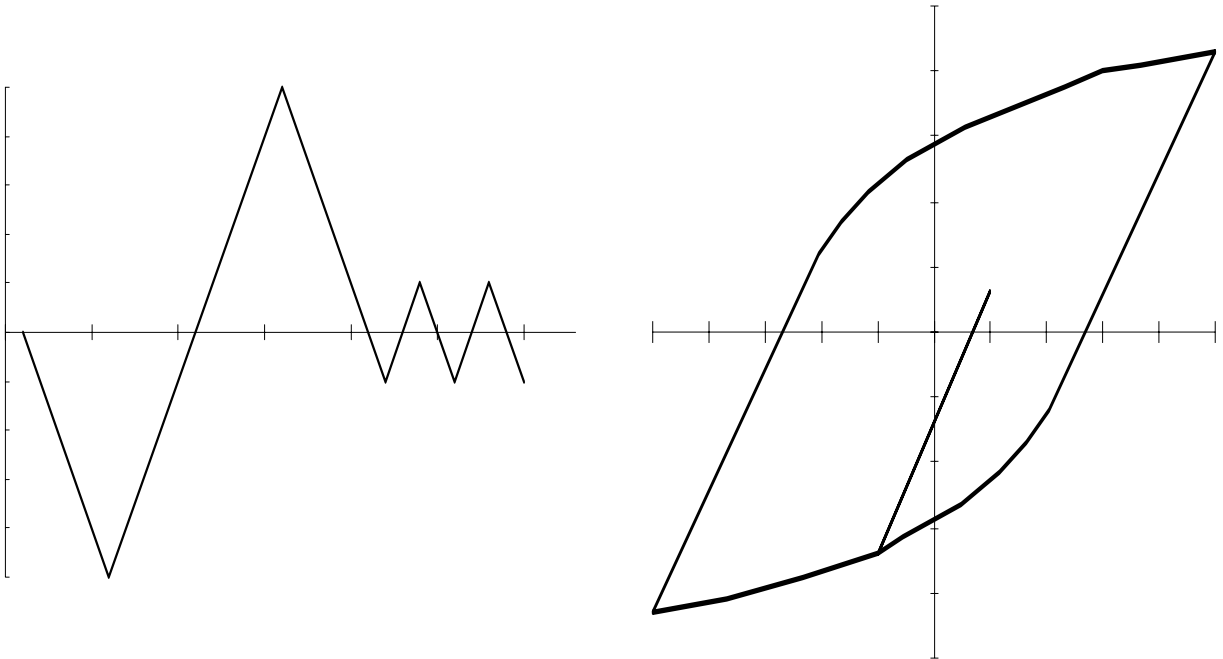
Mean Strain Example



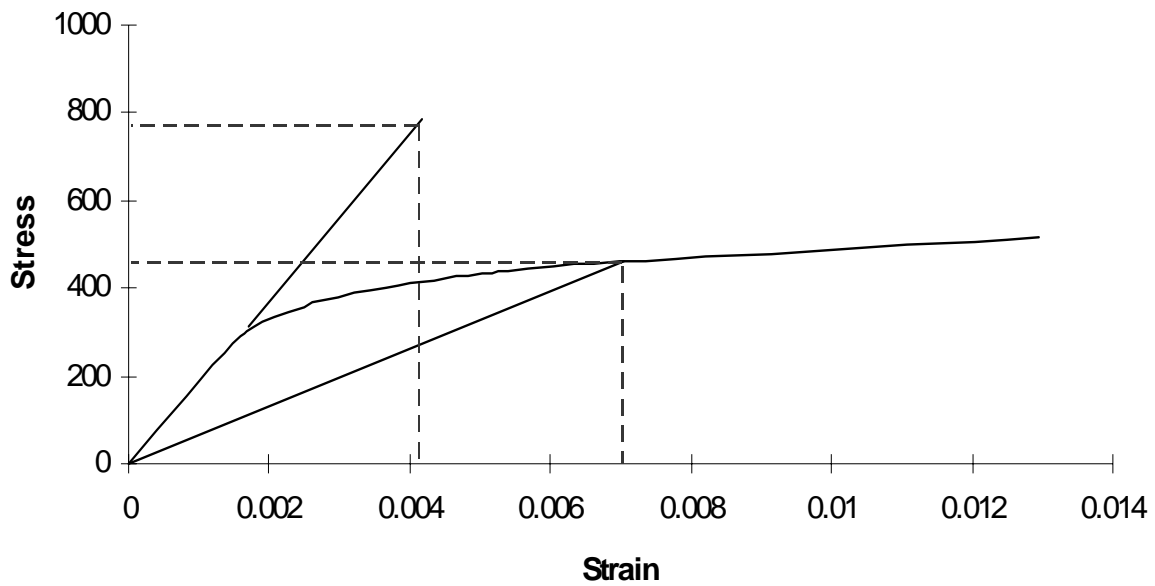
Tensile Mean Stress



Compressive Mean Stress



Neuber's Rule



$$K_f^2 \Delta S \Delta e = \Delta \sigma \Delta \epsilon$$

Strain-Life

- Limitations
 - Requires empirical K_f
 - Long life situations where surface finish and processing variables are important

Crack Growth

- Major Assumptions
 - Nominal stress and crack size control fatigue life
 - Accurate determination of initial crack size

Crack Growth

- Advantage
 - Only method to directly deal with cracks

Crack Growth

- Limitations

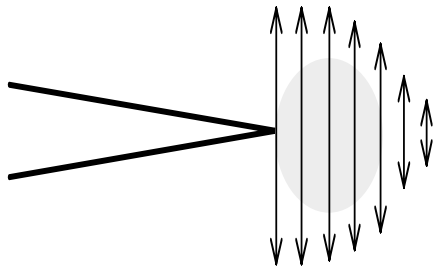
- Sequence effects

- $\Delta K_{\text{eff}} = f (\Delta K)$

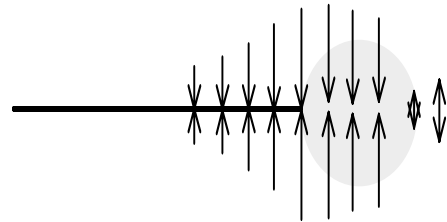
- $\Delta K = E \Delta e Y(a) \sqrt{a}$

- Accurate determination of a_i

Crack Closure

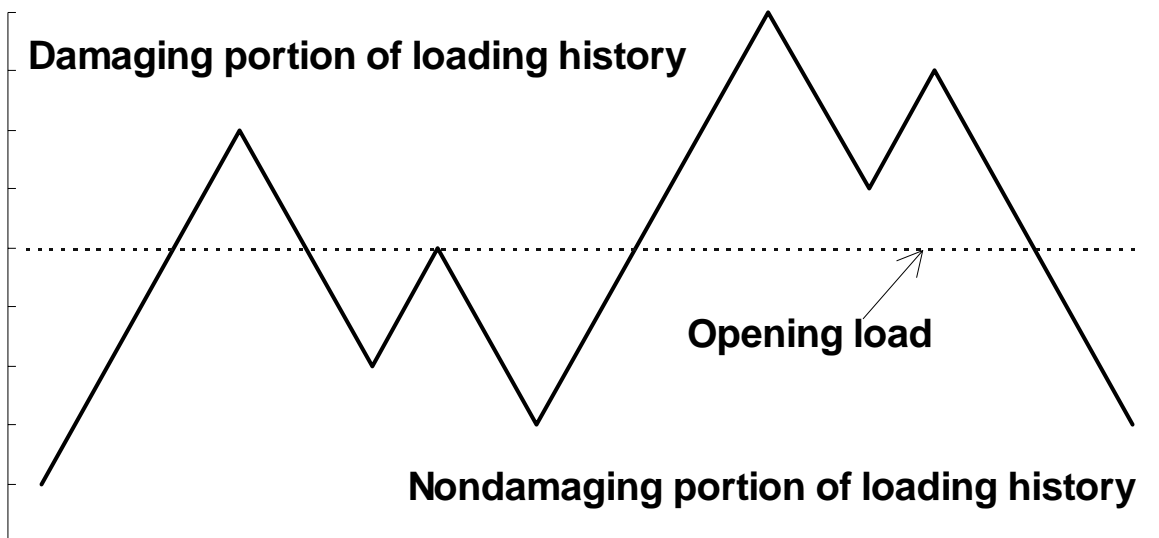


Crack Opened



Crack Closed

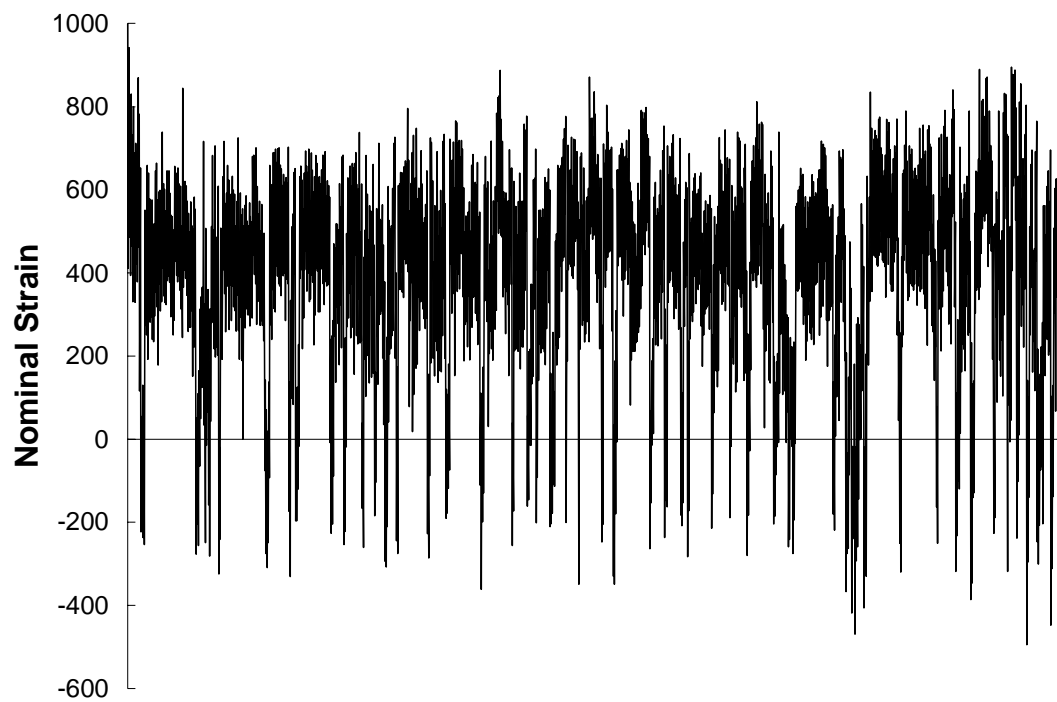
Crack Opening Load



Applications

- Material Selection / Improvement
- Fillet Weld
- Scaling / Editing Load Histories
- Crack Size / Shape

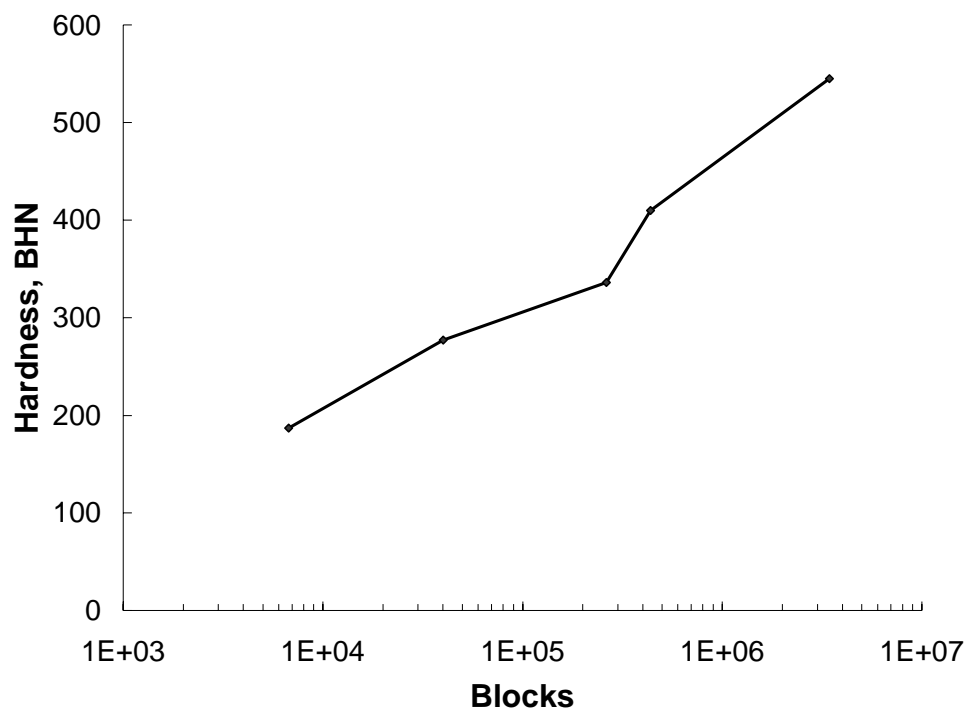
Transmission History



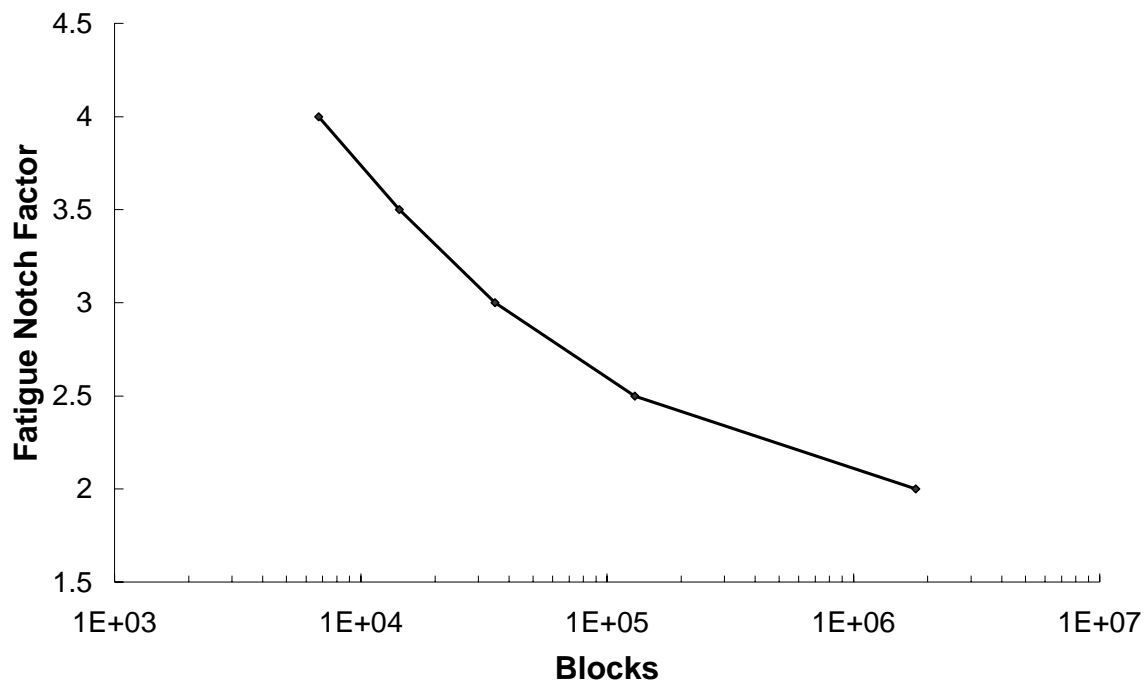
Material Properties

BHN	187	277	336	410	545
σ'_f , MPa	1668	2978	3902	4593	5666
b	-0.149	-0.158	-0.159	-0.167	-0.170
ϵ'_f	0.556	0.700	0.563	0.381	0.068
c	-0.522	-0.578	-0.595	-0.589	-0.603
K', MPa	1460	1743	2051	2381	4438
n'	0.234	0.189	0.163	0.172	0.169
E, GPa	206	206	208	206	205

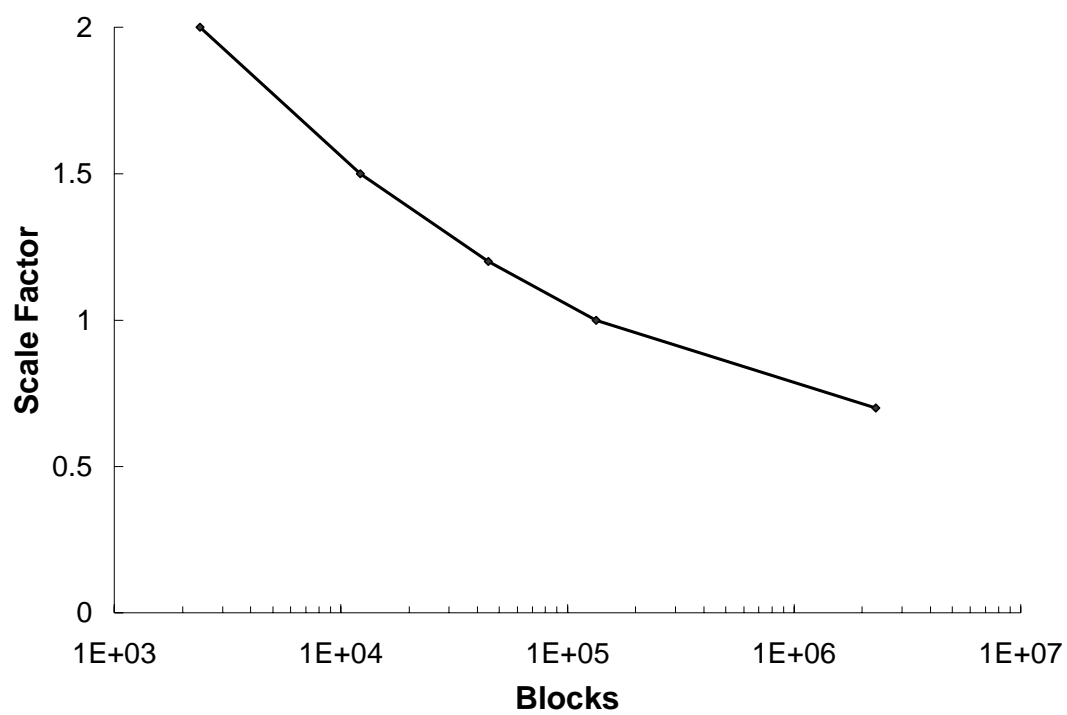
Strength Variation



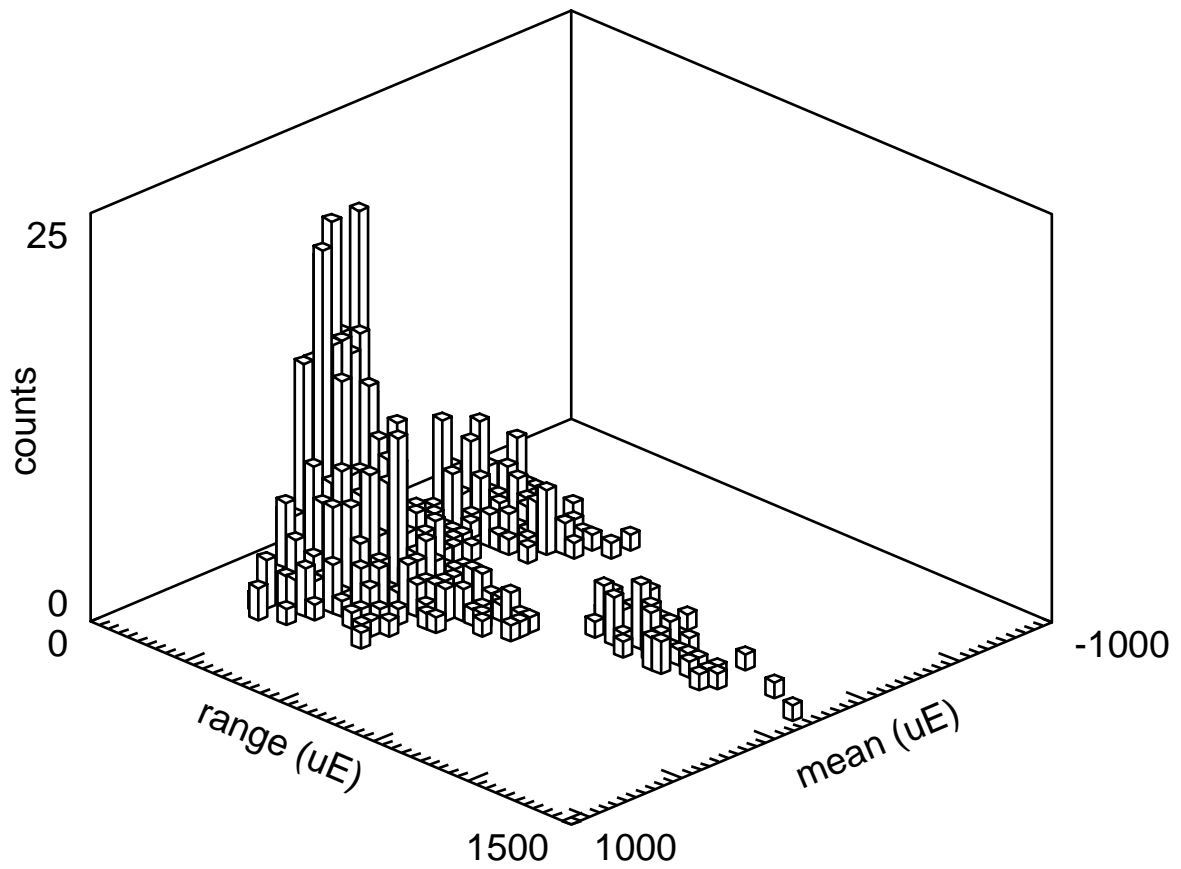
K_f Variation



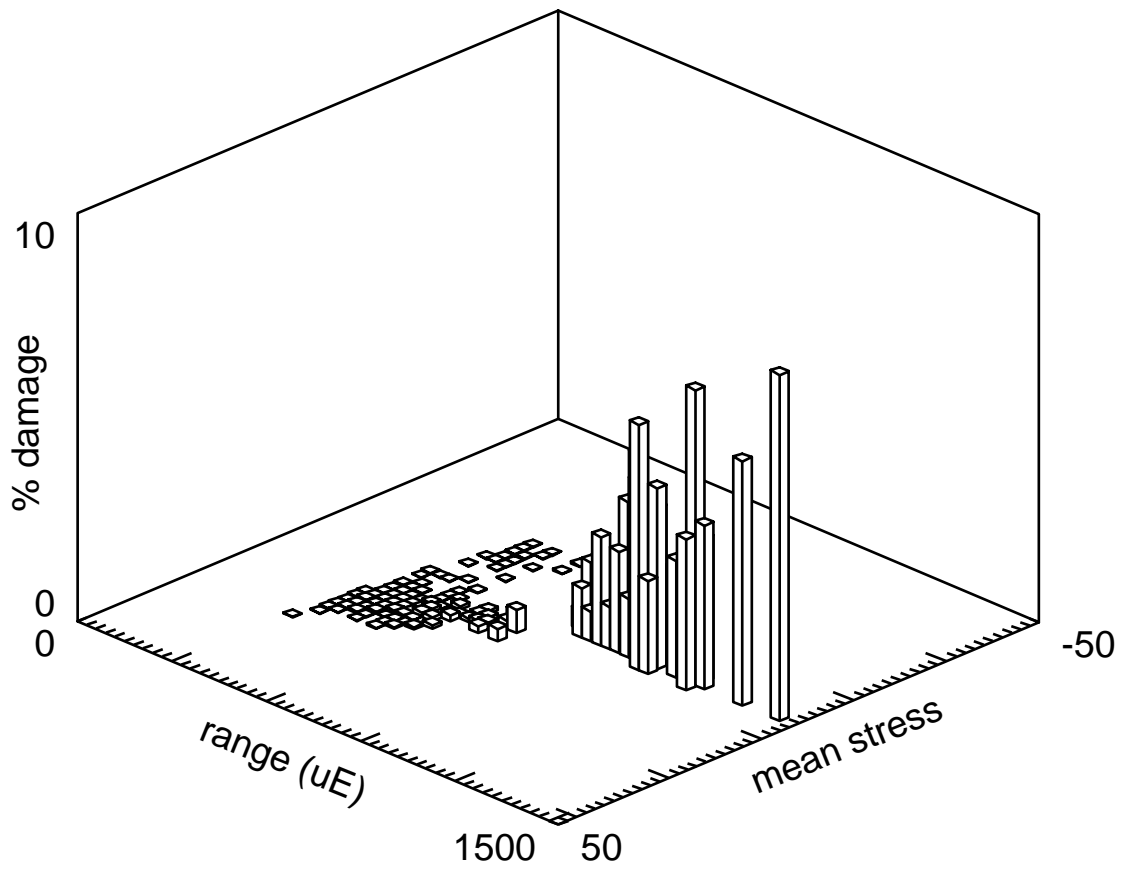
Scale Factor Variation



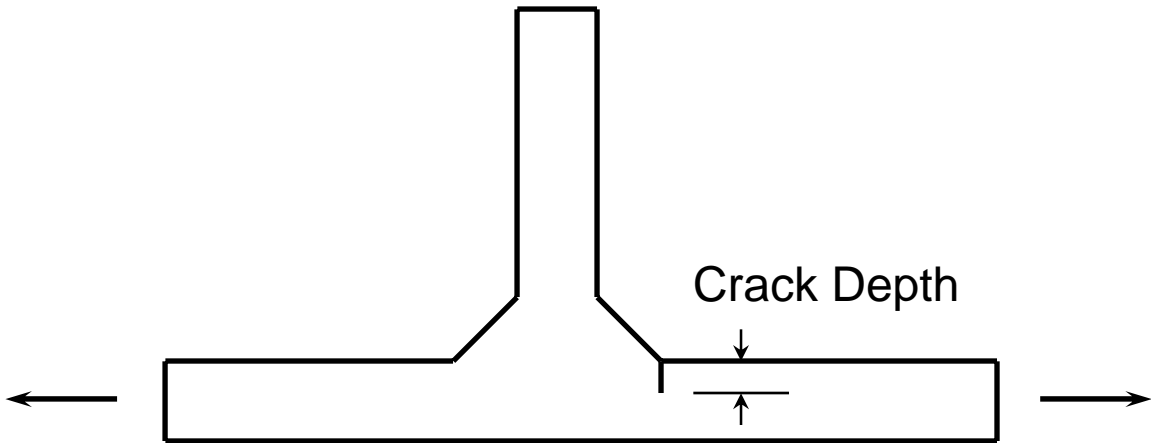
Cycle Histogram



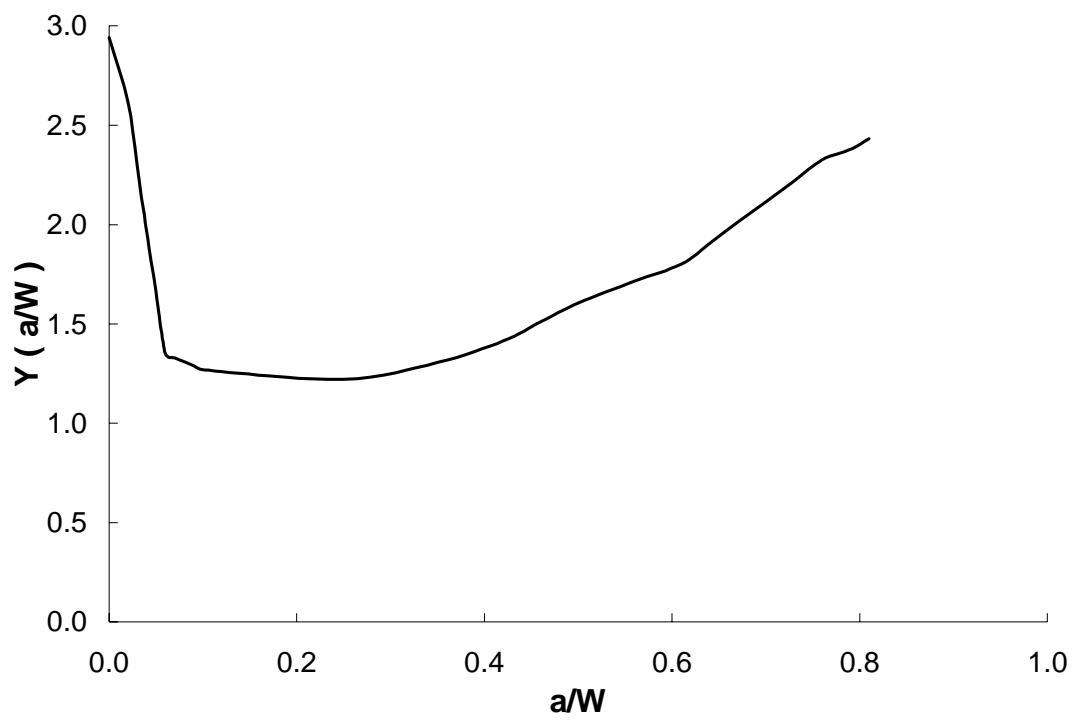
ϵ -N Damage



Weld Geometry



Geometry Factor



Crack Length

