IV Modeling Weldment Fatigue Behavior

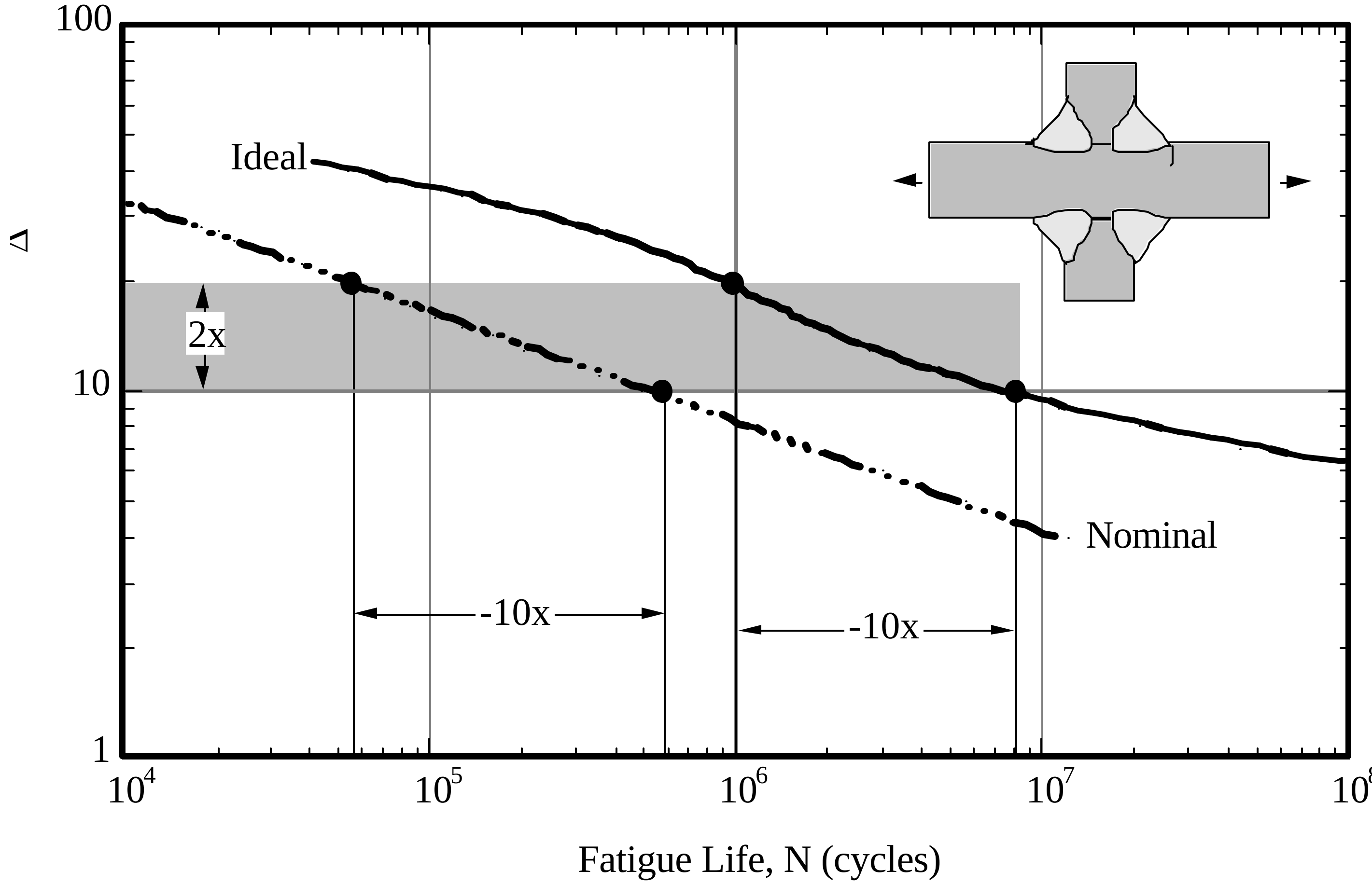
before

after

Outline

- Modeling difficulties posed
- Basic Information
- Possible models

Applied stresses are always uncertain!

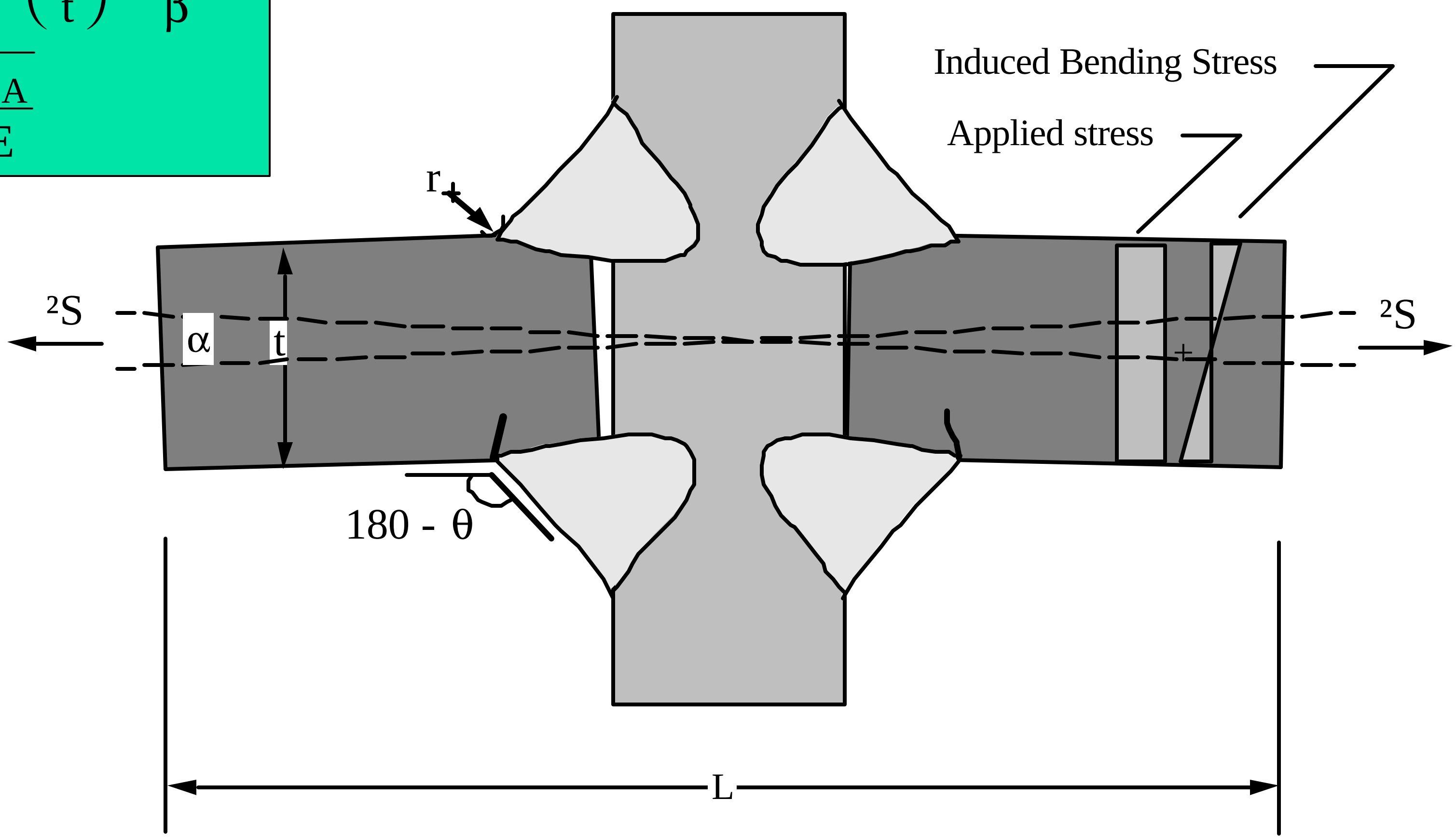


A factor of 2 uncertainty in the applied load causes the life to vary by a factor of 10!

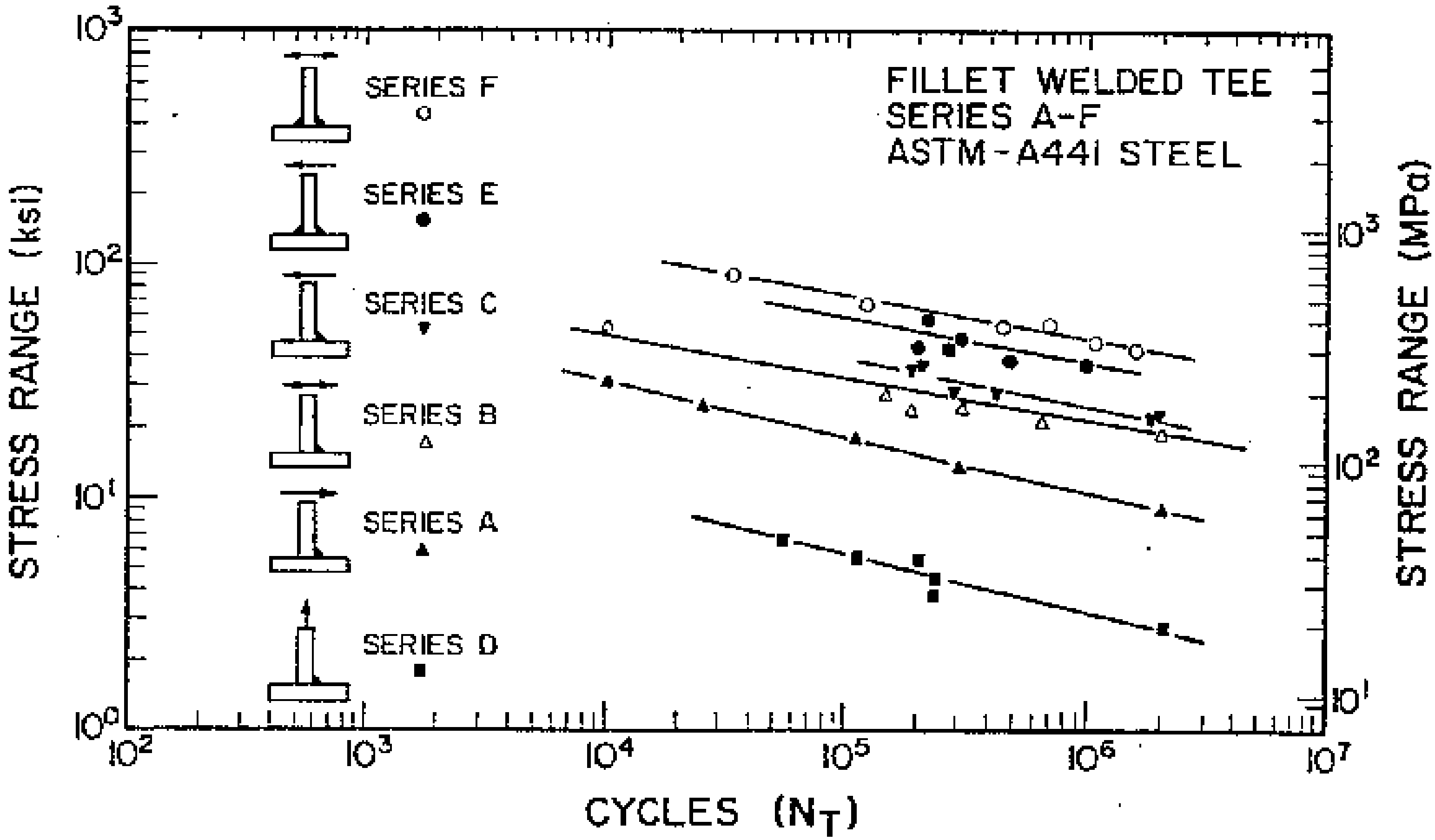
Distortions cause secondary stresses!

$$S_B = \frac{3}{2} \alpha \, S_A \left(\frac{L}{t} \right) \frac{\tanh \beta}{\beta}$$

$$\beta = \frac{L}{t} \sqrt{\frac{3 \, S_A}{4E}}$$



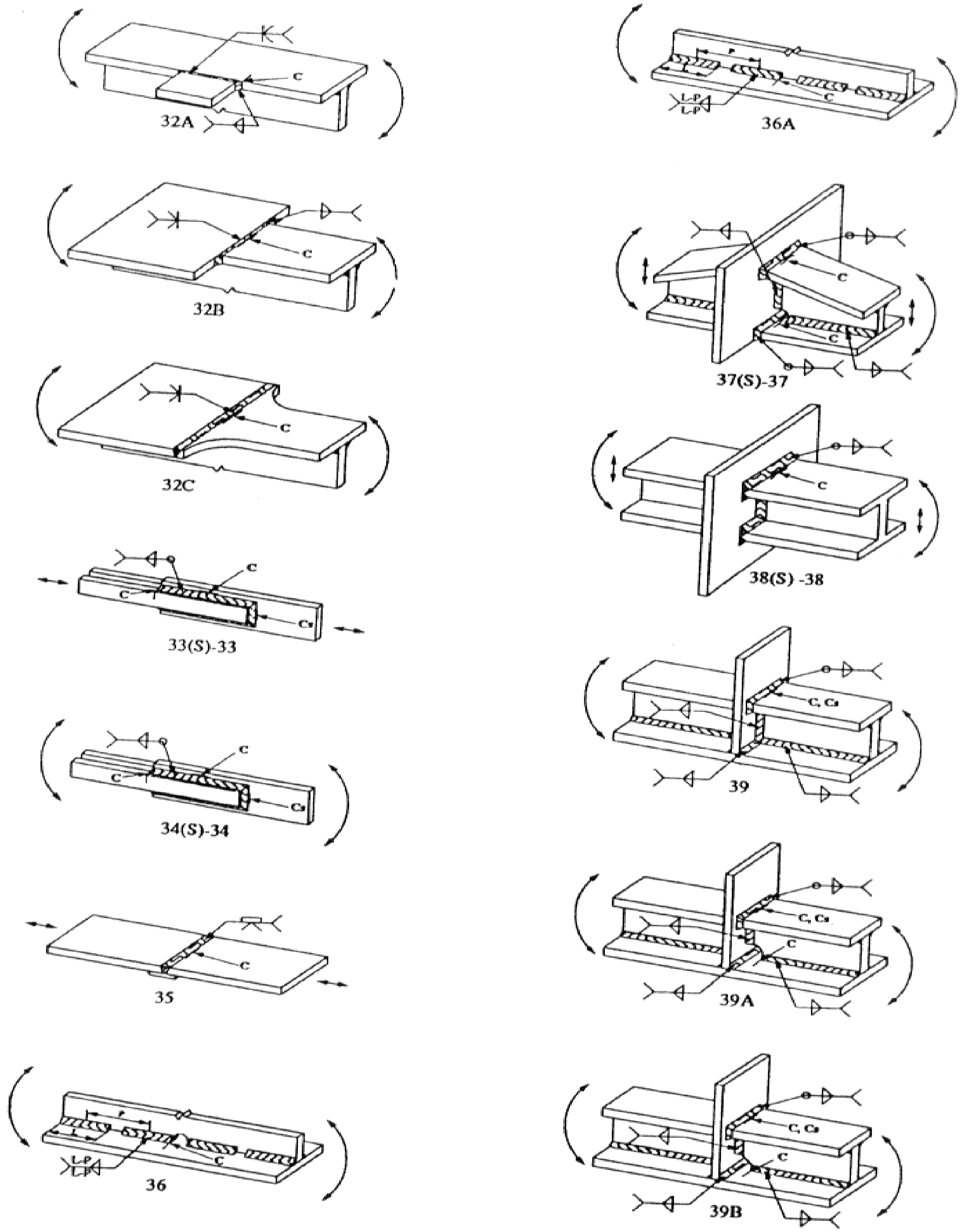
Weldment fatigue behavior is dependent on the manner of loading!



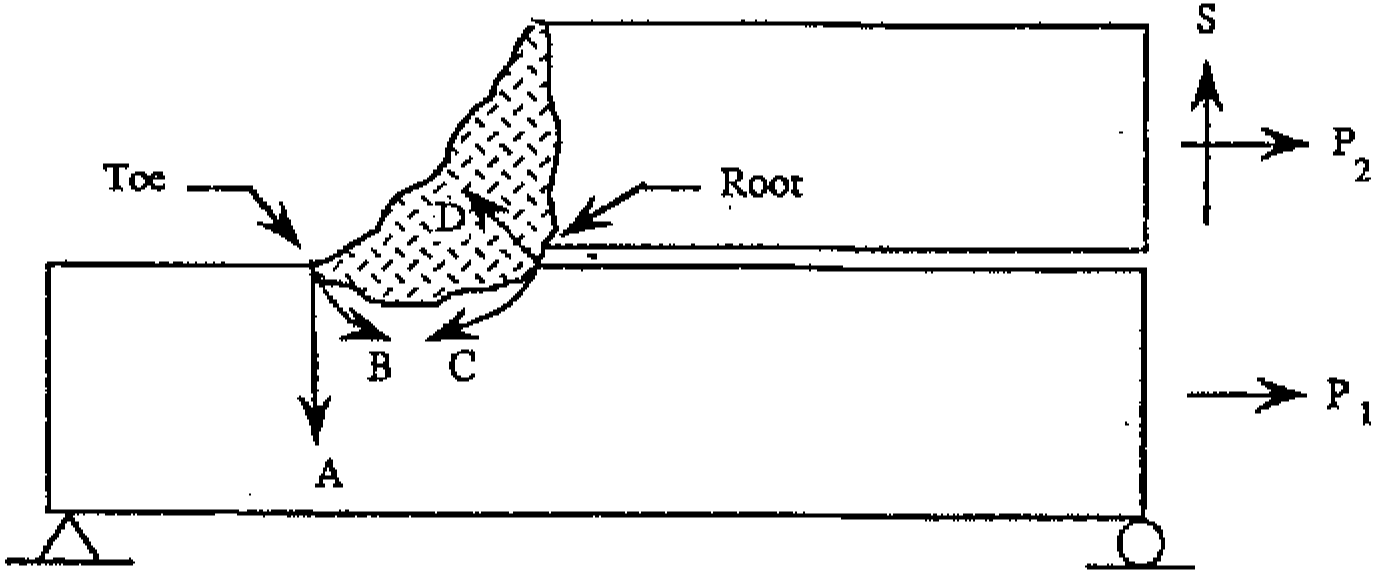
Fatigue resistance depends upon loading conditions

So many geometries!

There is an infinite number of weldment geometries.



A simple weld may have many failure modes!



While the weldment may be simple, many different failure scenarios may exist.

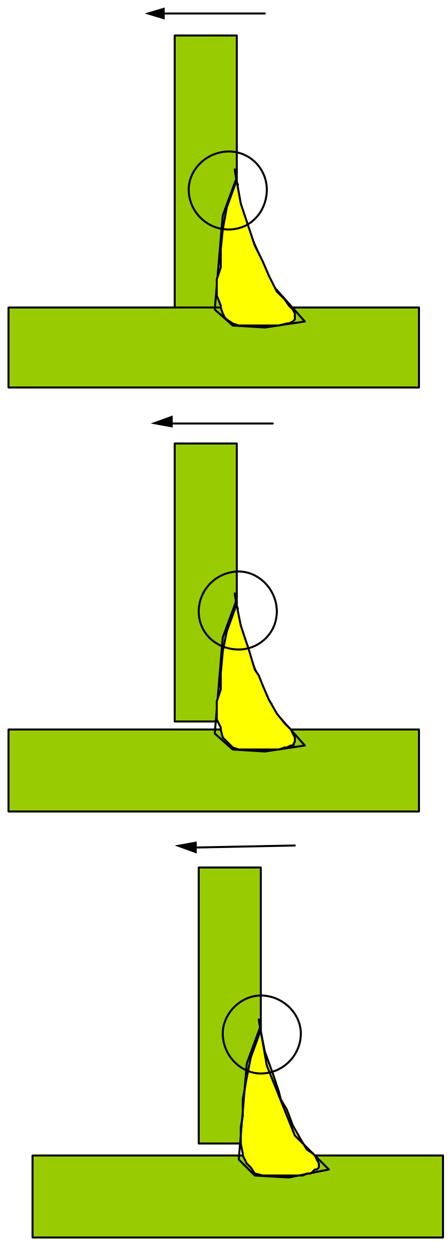
Weldment geometry may actually be undefined!

Example: T-joint with a variable fit-up

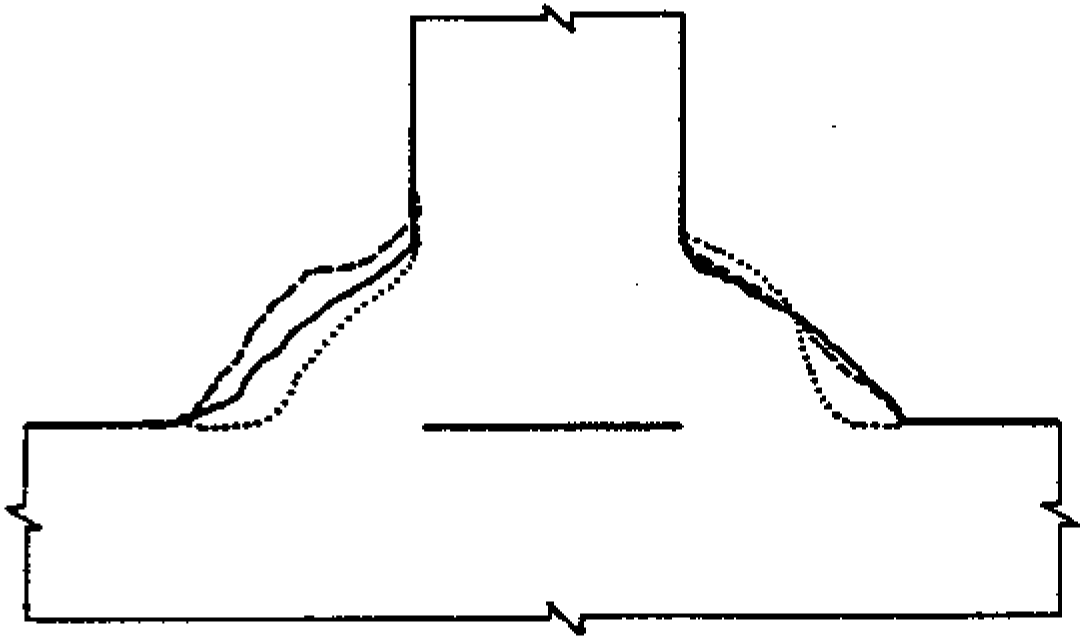
Tight fit-up: K_t- = 3.6

Normal fit-up: 3.6 < K_t < 6.4

Loose fit-up? K_t = 6.4

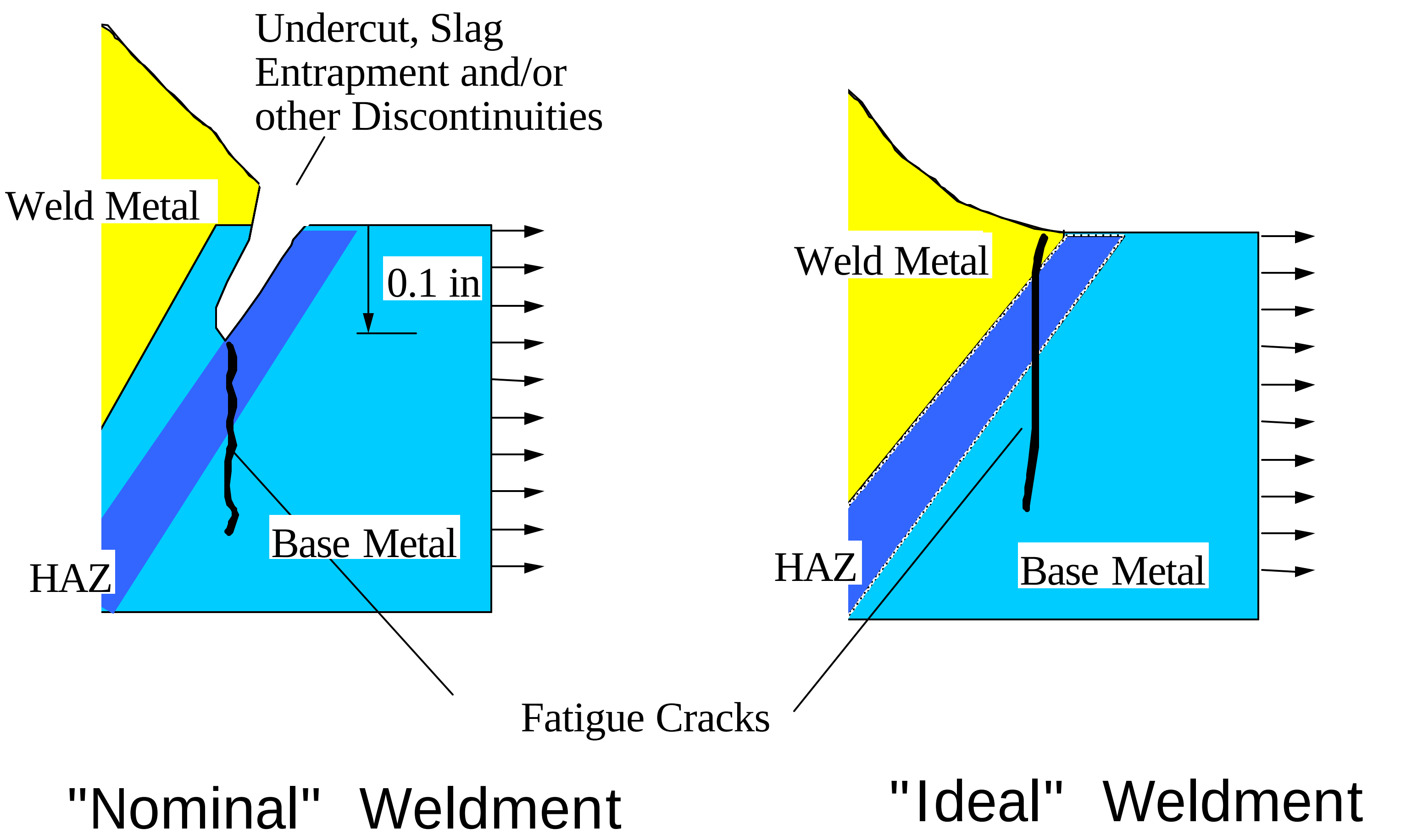


Weld shape may vary!

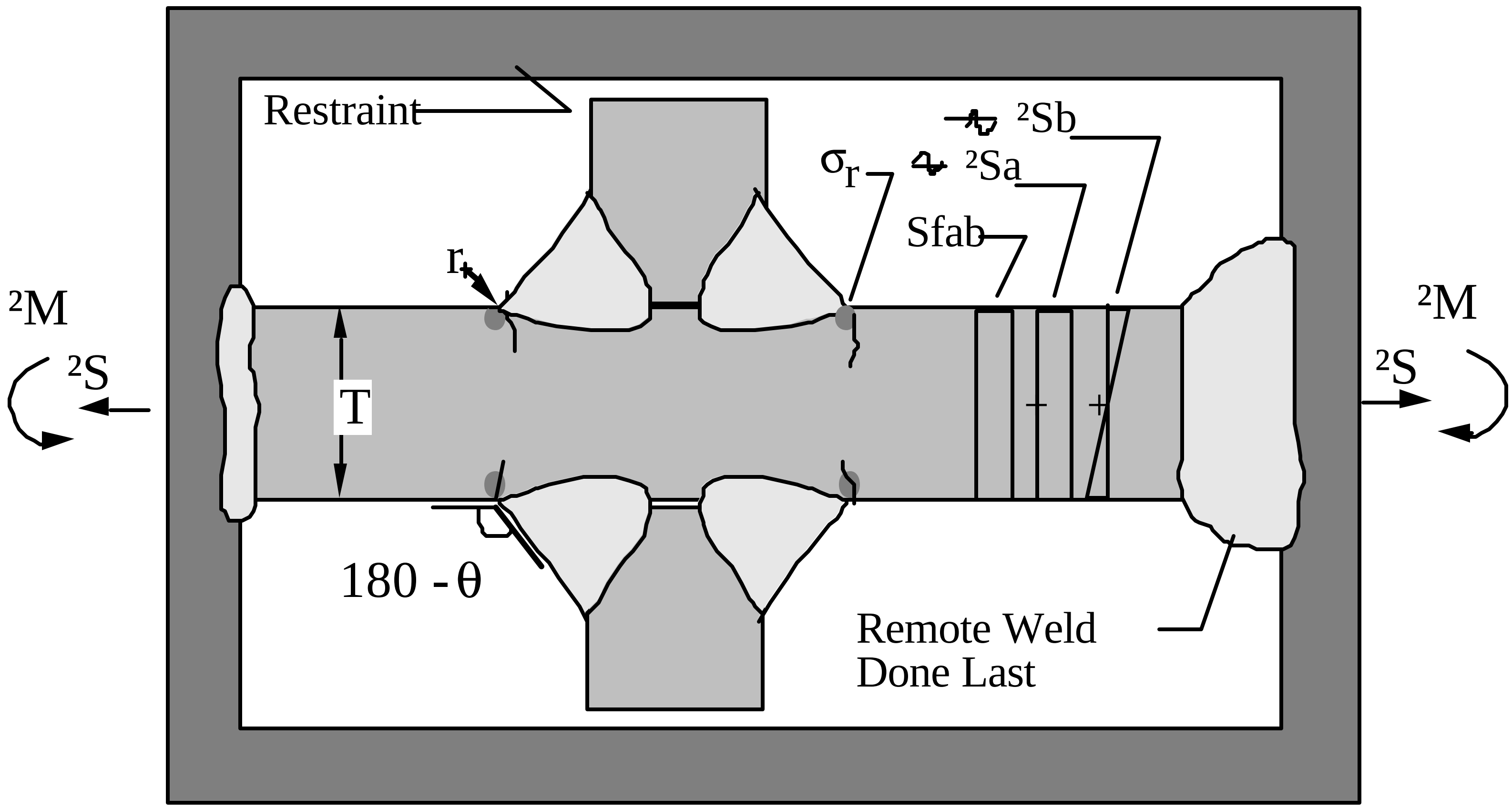


The geometry of a weldment may vary with location.

Weld quality variable!

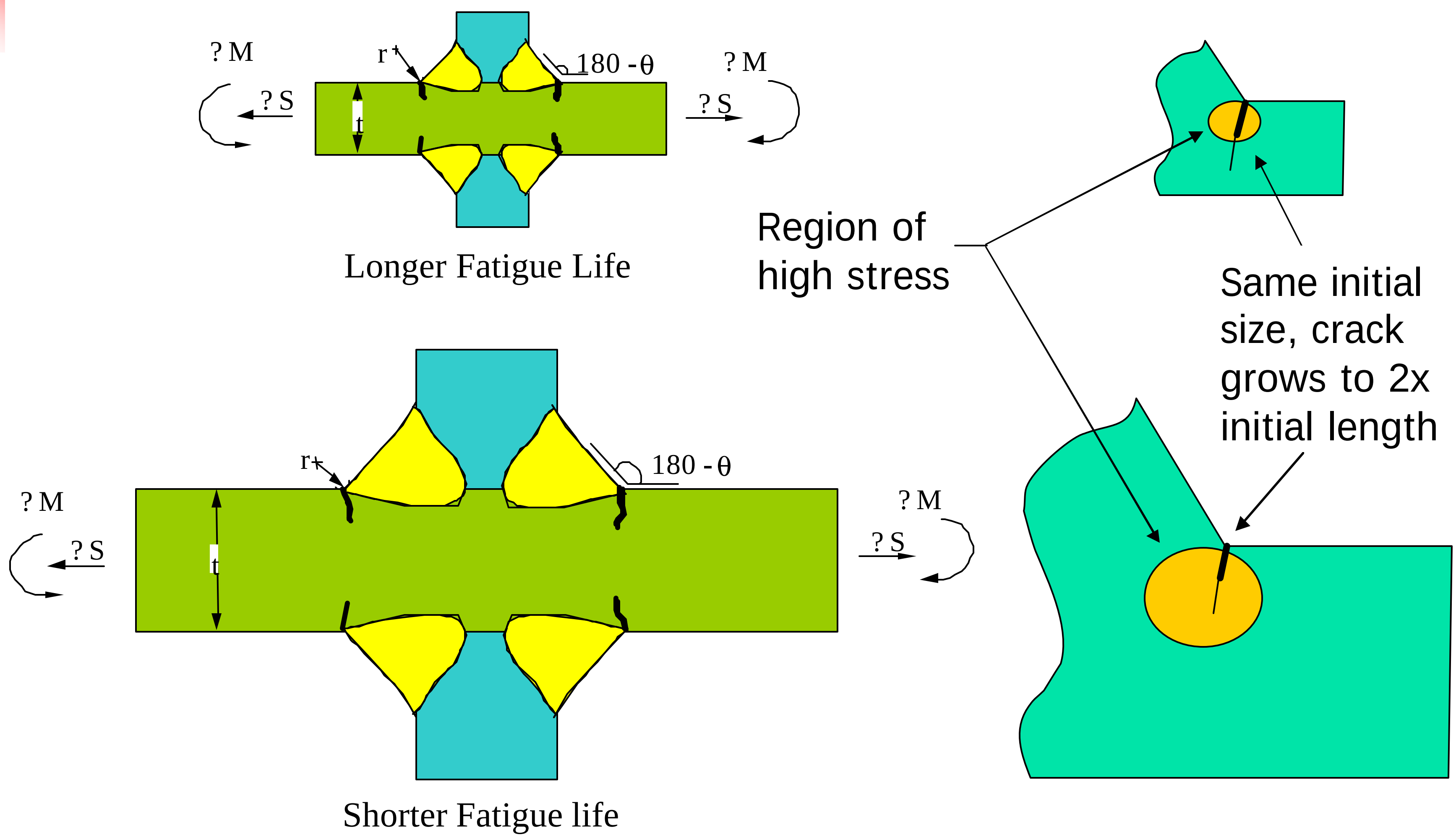


Mean stresses alter fatigue life!

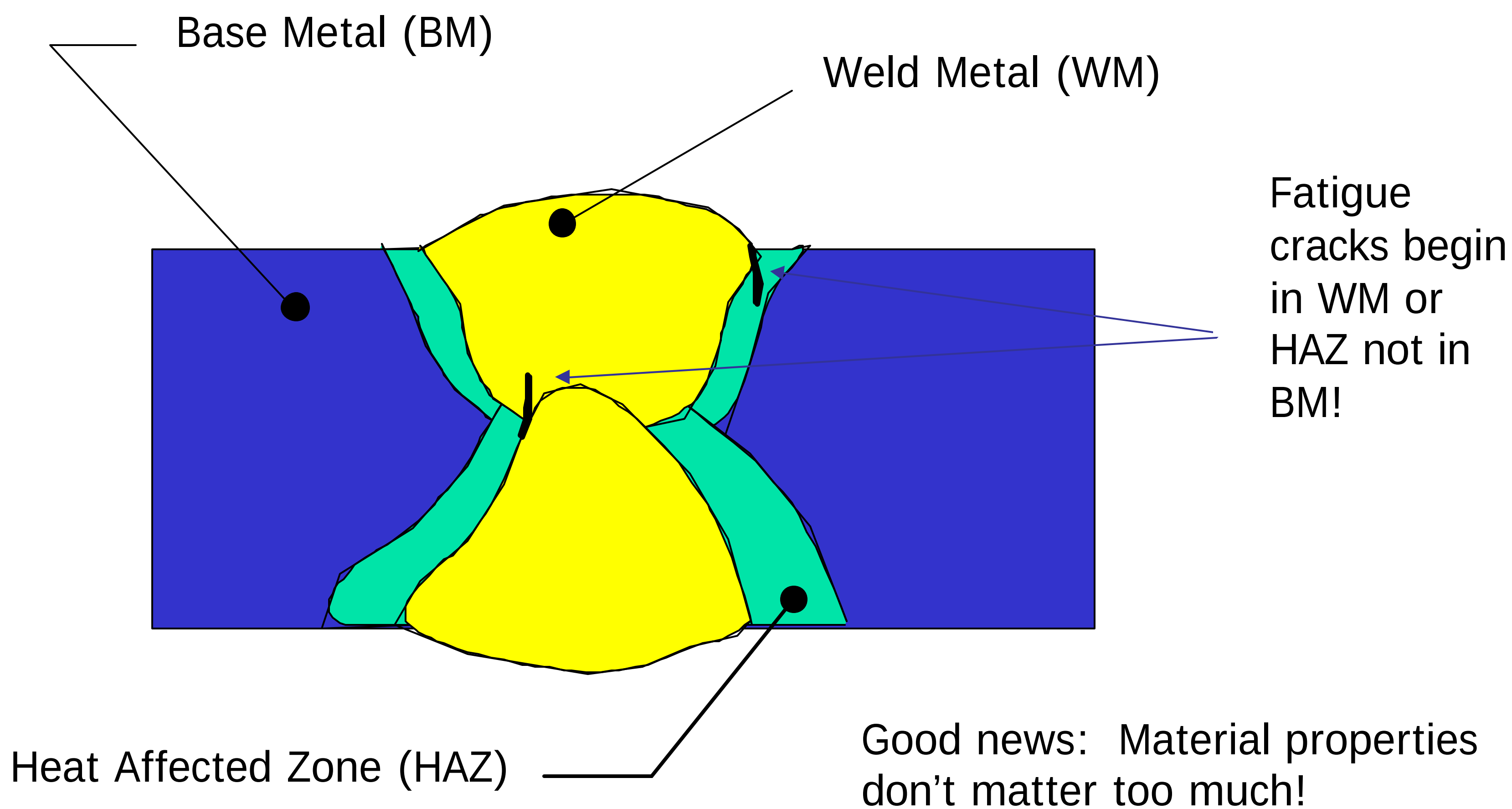


Applied mean stresses, welding residual stresses, and fabrication residual stresses

Weldment size affects fatigue life!



Material properties generally unknown!



Good news: Material properties don't matter too much!

Summary

- The variables influencing weldment fatigue life can be thought of as being only two:
  - the magnitude of the notch root stresses.
  - the properties of the notch root material.

- In this sense, the applied stresses, the degree of bending, the welding residual stresses, the fabrication residual stresses, the applied mean stresses, the weldment geometry, the notch root weld defects, and the weldment size all influence the magnitude of the notch root stresses.

Summary

- The fatigue behavior of a weldment is controlled by the local (notch root, hot-spot) stress-strain history.

- For structural steel weldments: material properties are of minor importance except (as we shall see) to the degree that they determine and limit the value of the residual stresses.

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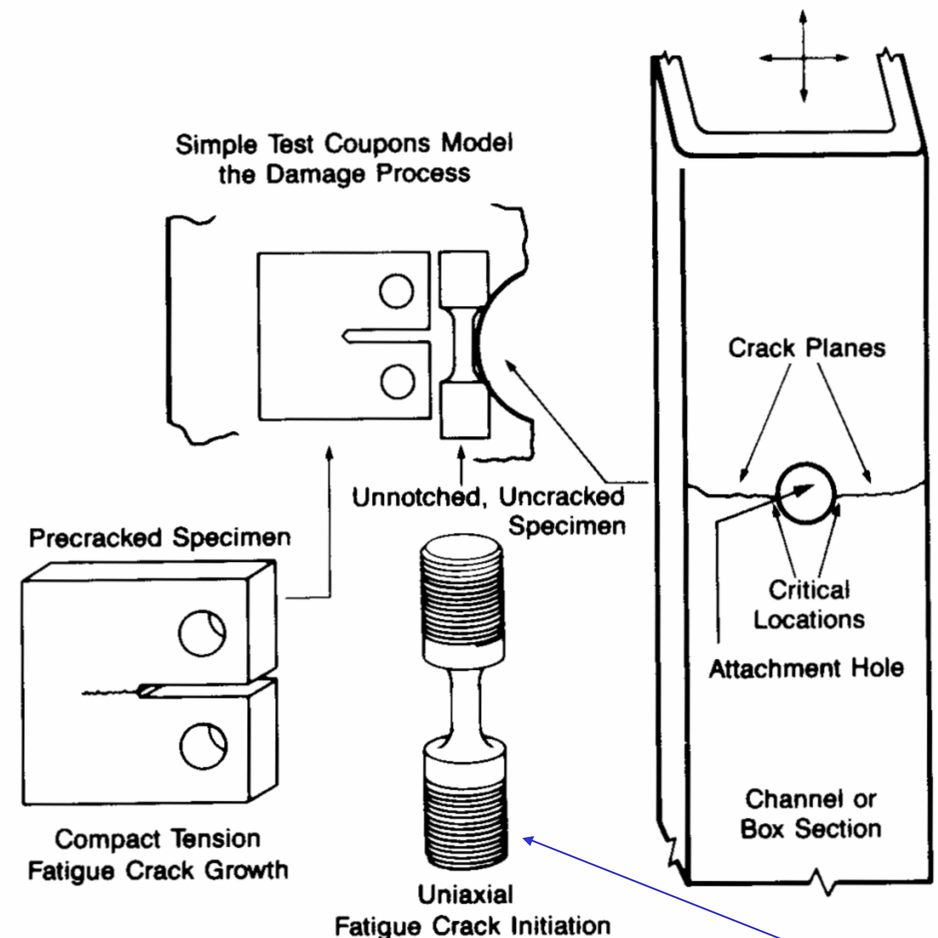
Fatigue of a component



The fatigue life of an engineering component consists of two main life periods:

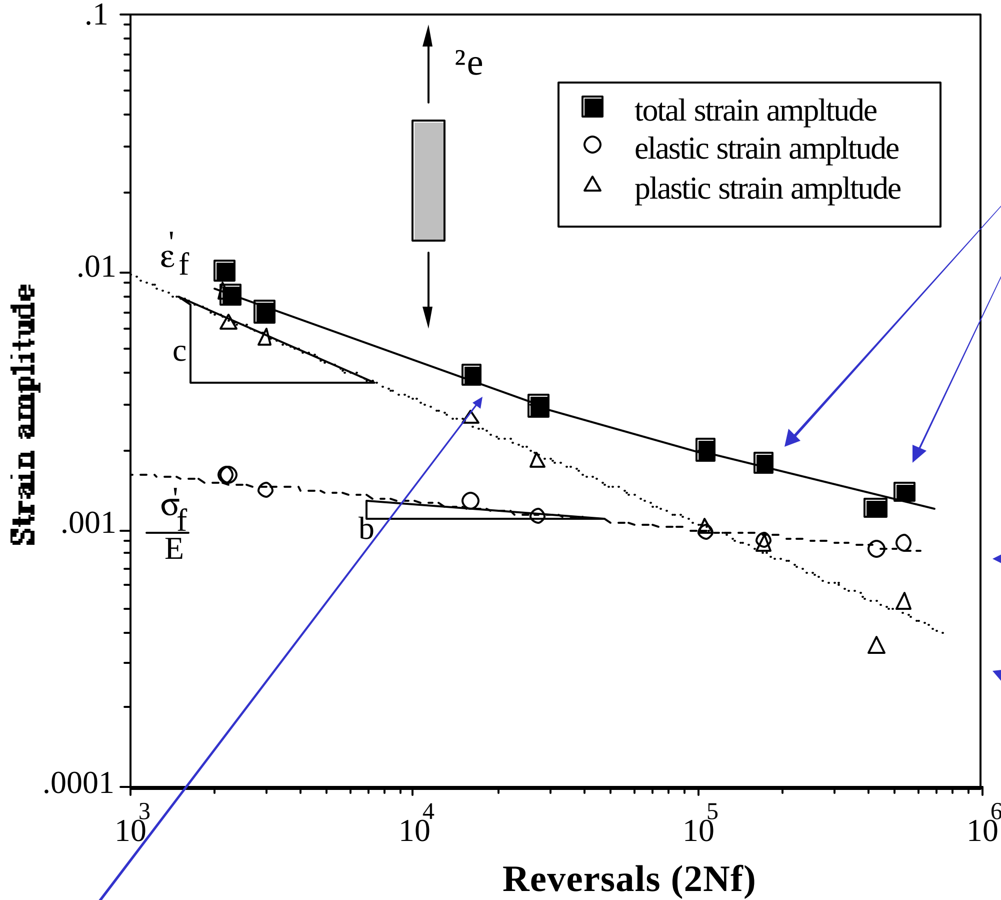
Initiation or nucleation of a fatigue crack (NI)

And

Its growth to failure (NP)

A smooth specimen

Basic Information - crack initiation



Fatigue test data from strain-controlled tests on smooth specimens.

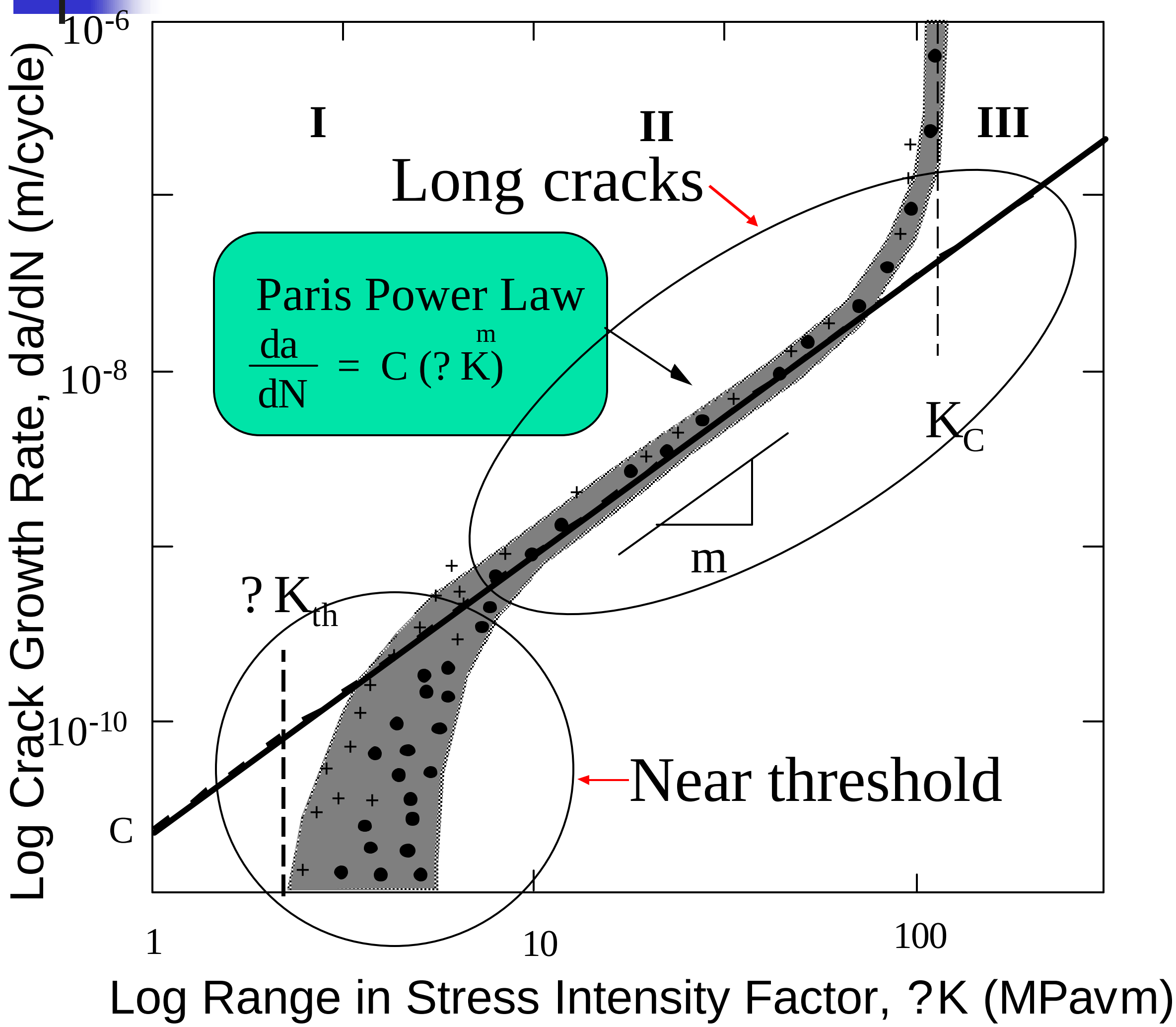
Elastic component of strain, ?e_e

Plastic component of strain, ?e_p

Smooth specimen behavior

$$\Delta\varepsilon_t = \Delta\varepsilon_e + \Delta\varepsilon_p = \frac{\sigma'_f}{E}(2N_f)^b + \varepsilon'_f(2N_f)^c$$

Basic Information - crack growth



I Sensitive to microstructure and environment. Dominated by crack closure effects.

II Paris power Law.

III Approaching fracture when Kmax ˜ K_{IC}.

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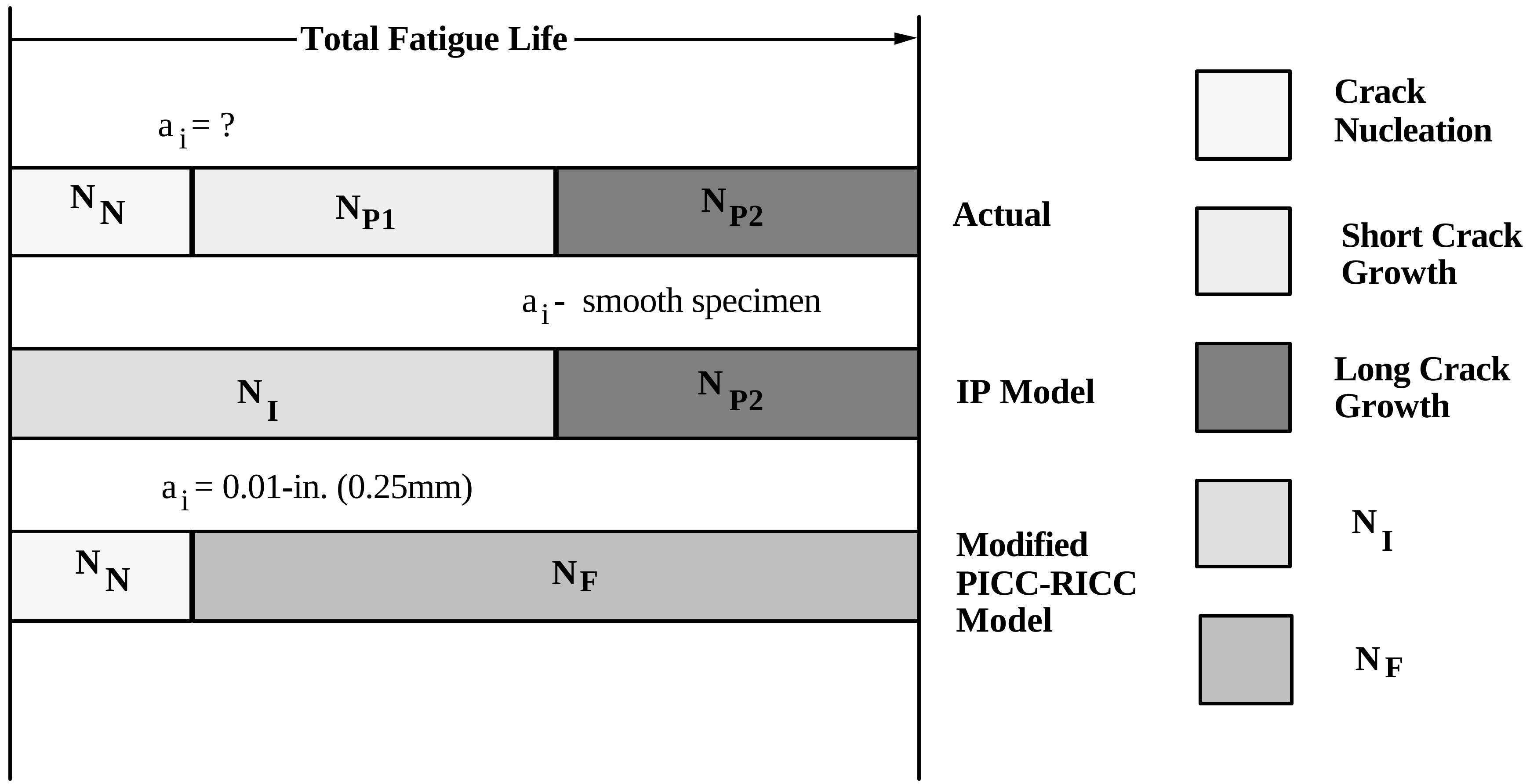
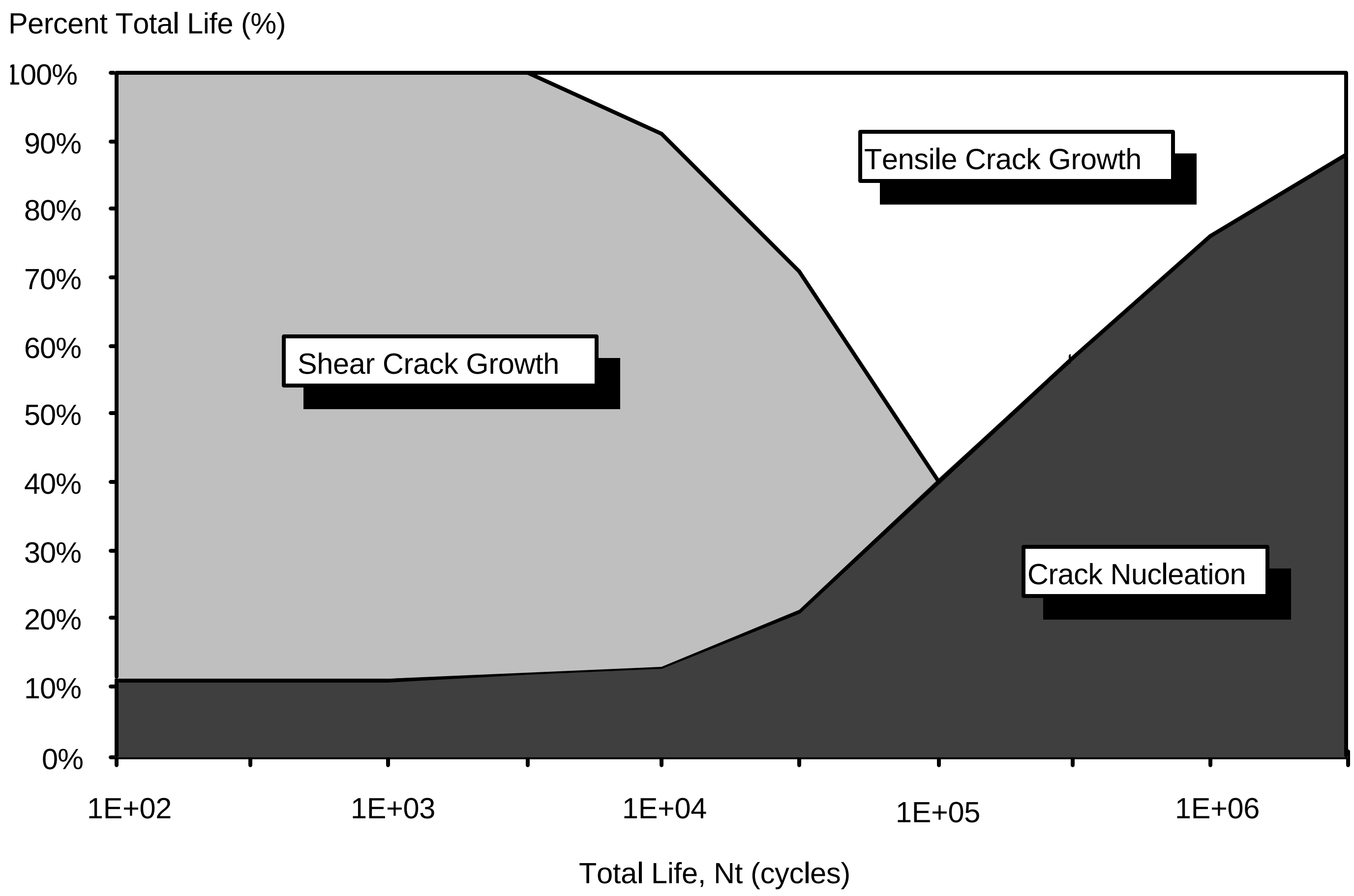
Modeling options



Models

- N_I only - Strain controlled fatigue
- N_{P2} - Current TWI models
- N_F only - Dong et al.
- $N_N + N_F$ - PICC-RICC model
- $N_I + N_{P2}$ - The I-P model

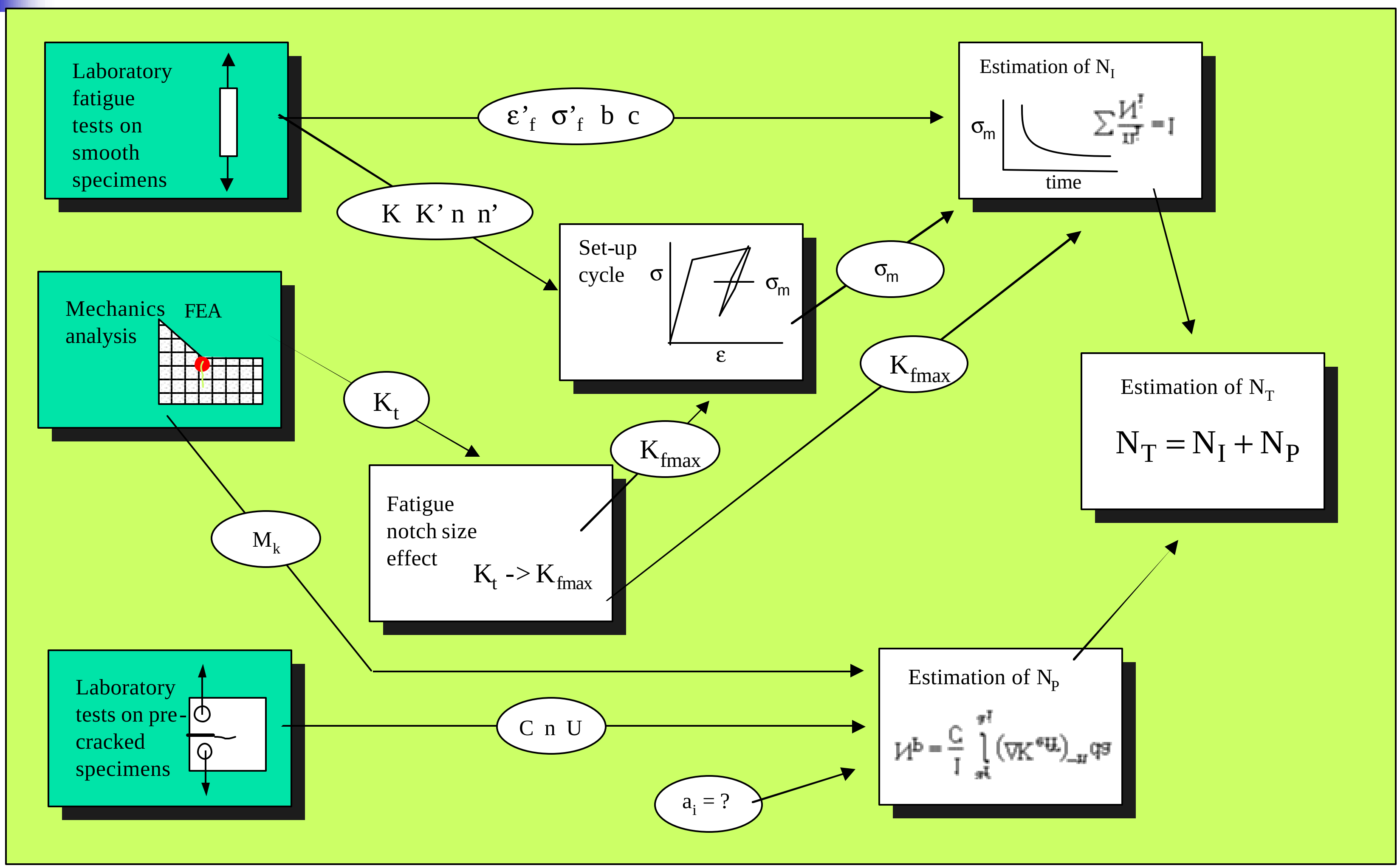
Relative importance of NI and NP



The relative importance of fatigue crack initiation and propagation in smooth specimens of SAE 1045 steel. (after Socie)

IP Model details

$$N_T = N_I + N_{P2}$$

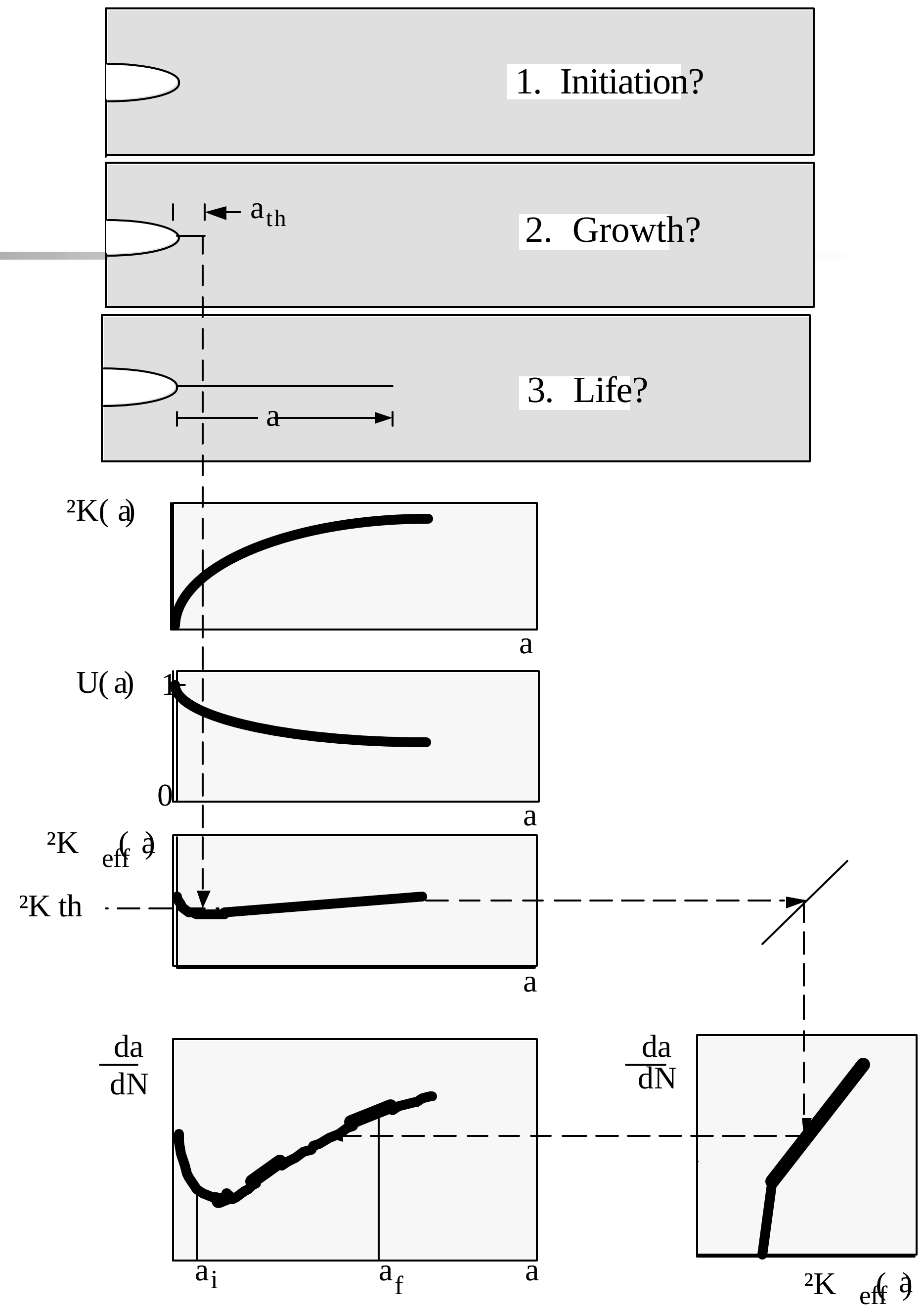


CCN model

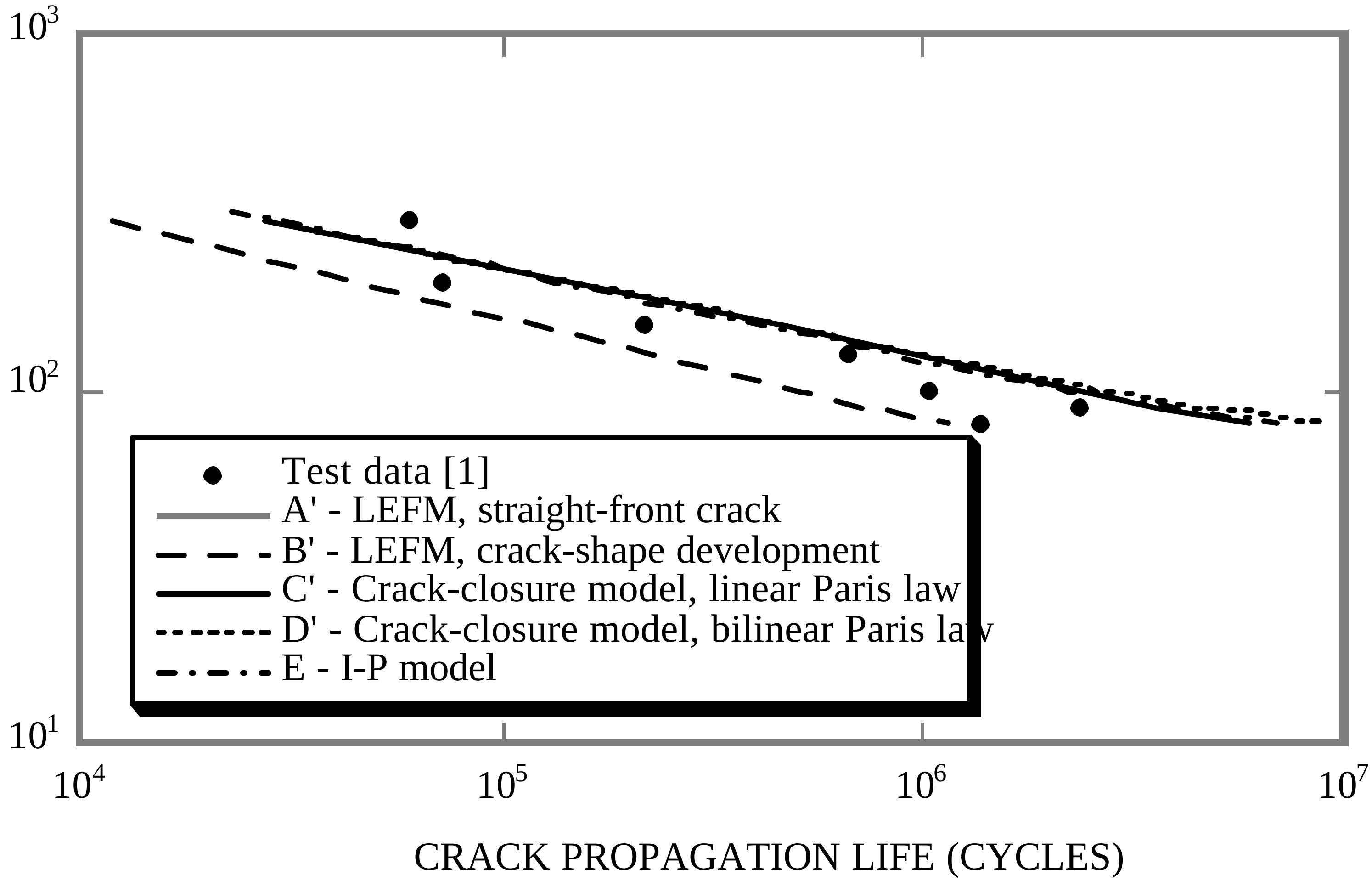
$N_T \sim N_F$

Crack closure at a notch model. Information about U(a) becomes the "sticking point."

$$N_F = \int_{a_i}^{a_f} \left(\frac{da}{dN}\right)^{-1} da$$



Model performance



Unresolved modeling difficulties

- IP - What is the size of the crack at the end of the N_I stage? 0.01-in? a_{th}?
- IP - What is the meaning of K_f?
- CCN - What is the value of U as a function of crack length? What is the value of U?
- All - What are the residual stresses, and how do they vary with location and change during the service life of the weldment?