Fatigue-Crack-Growth under Single-Spike Overloads/Underloads and Aircraft Spectra during Constraint-Loss Behavior

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QinetiQ Australia

Outline of Presentation

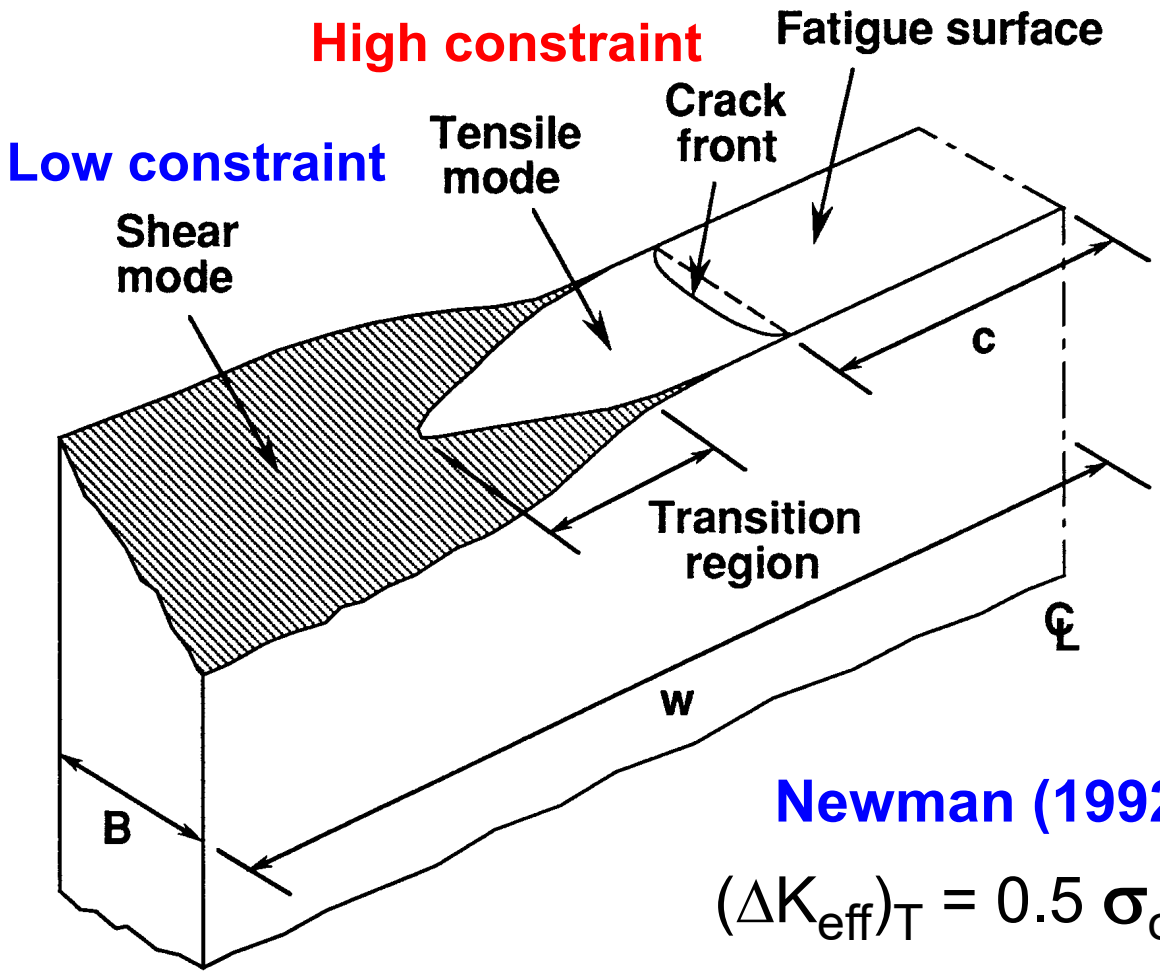
- **Plane-strain to plane-stress fatigue-crack growth behavior**
- **Fatigue-crack-growth rate against ΔK_{eff} correlations**
- **Single-spike overload/underload tests and analyses**
  - 2024-T351 M(T) Yisheng-Schijve (1995; 1997)
  - 2024-T3 M(T) Newman-Walker
  - 7075-T6 M(T) Newman-Walker
  - 9310 Steel C(T) Newman et.al. (2013)
- **TWIST spectrum crack-growth tests and analyses**
- **Concluding remarks**
- **Future recommendation**

Flat-to-Slant Crack Growth and the Associated Constraint-Loss Behavior

Schijve (1966)

ASTM STP-415:

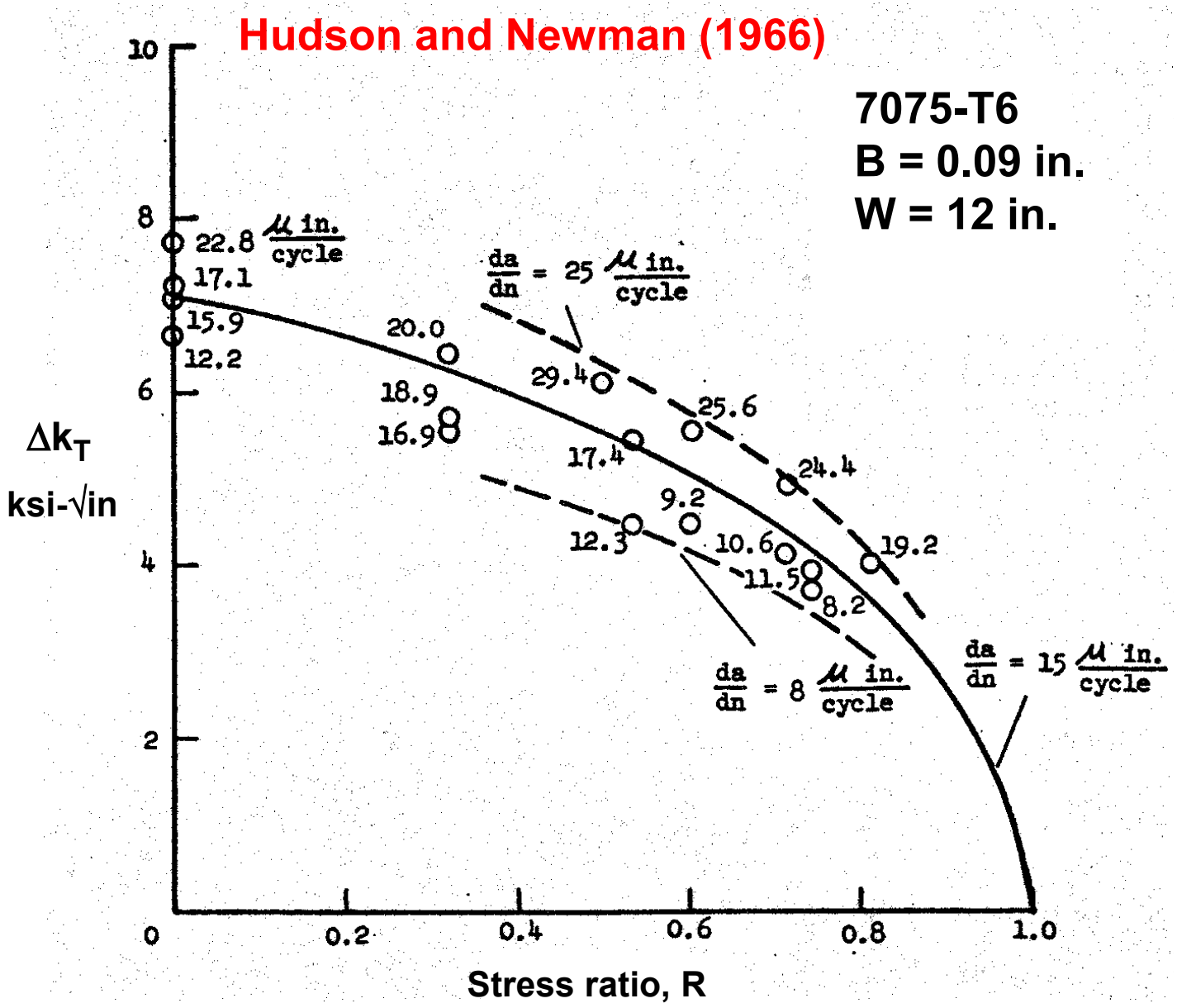
Crack-growth rate was "constant" at transition on 2024-T3



Newman (1992)

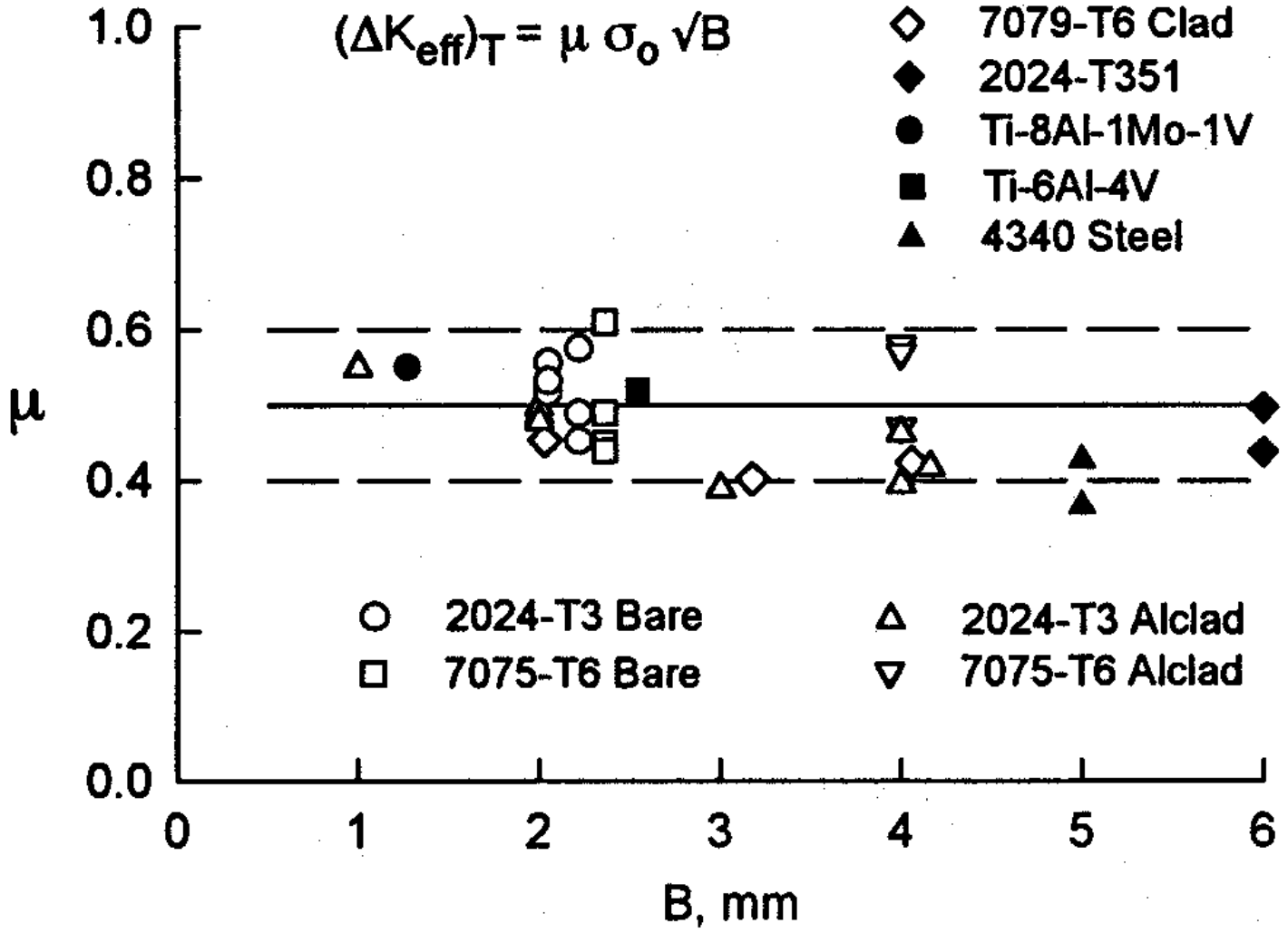
$$(\Delta K_{eff})_T = 0.5\ \sigma_o\ B^{1/2}$$

Flat-to-Slant Crack-Growth Behavior in 7075-T6 Sheet



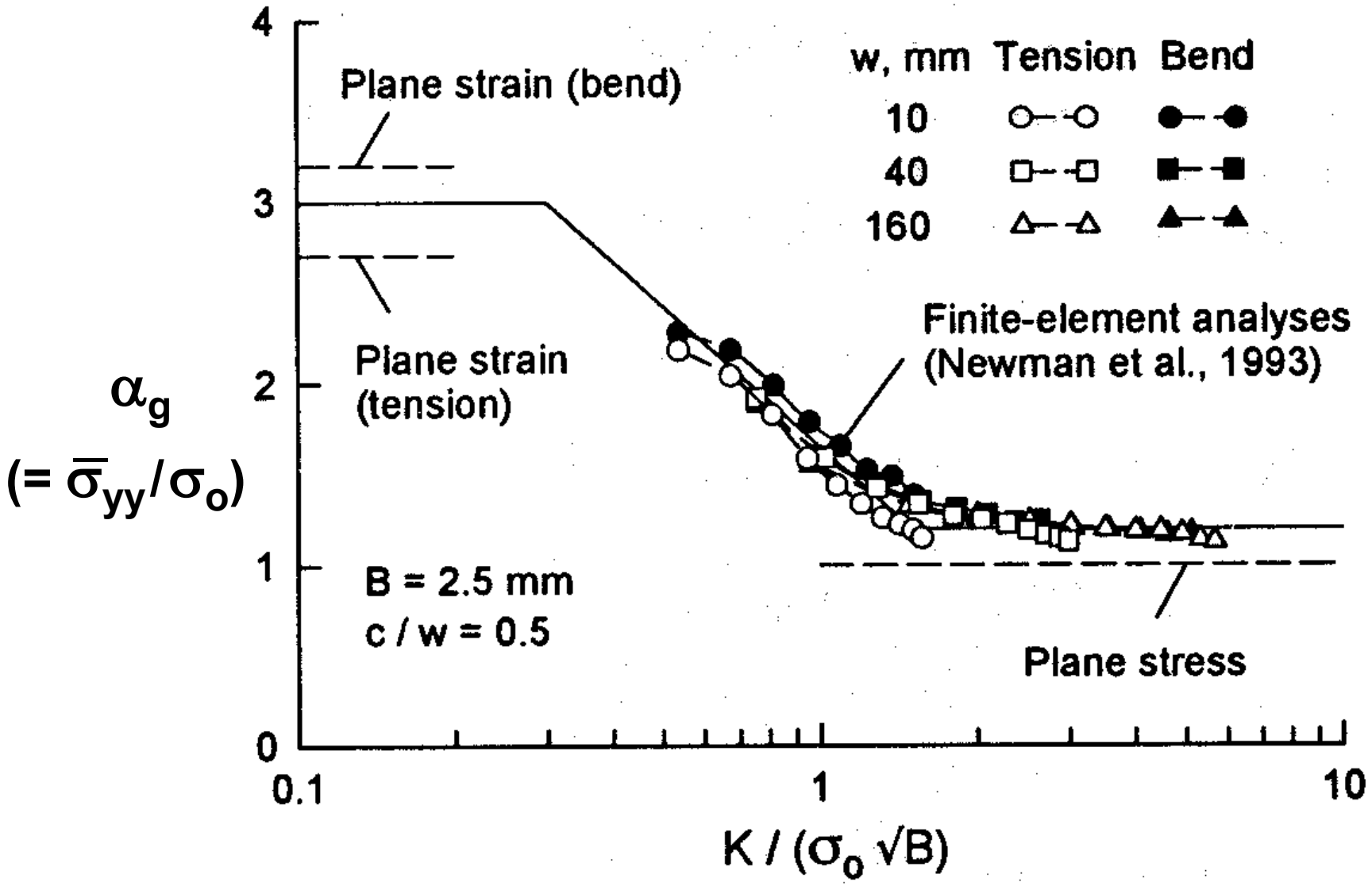
Flat-to-Slant Crack-Growth Transition in Terms of ΔK_{eff}

Newman (1992)



Constraint Effects in Cracked Bodies from 3D Elastic-Plastic Finite-Element Analyses – ZIP3D & ZIP2D

Newman, Bigelow & Shivakumar (1993)



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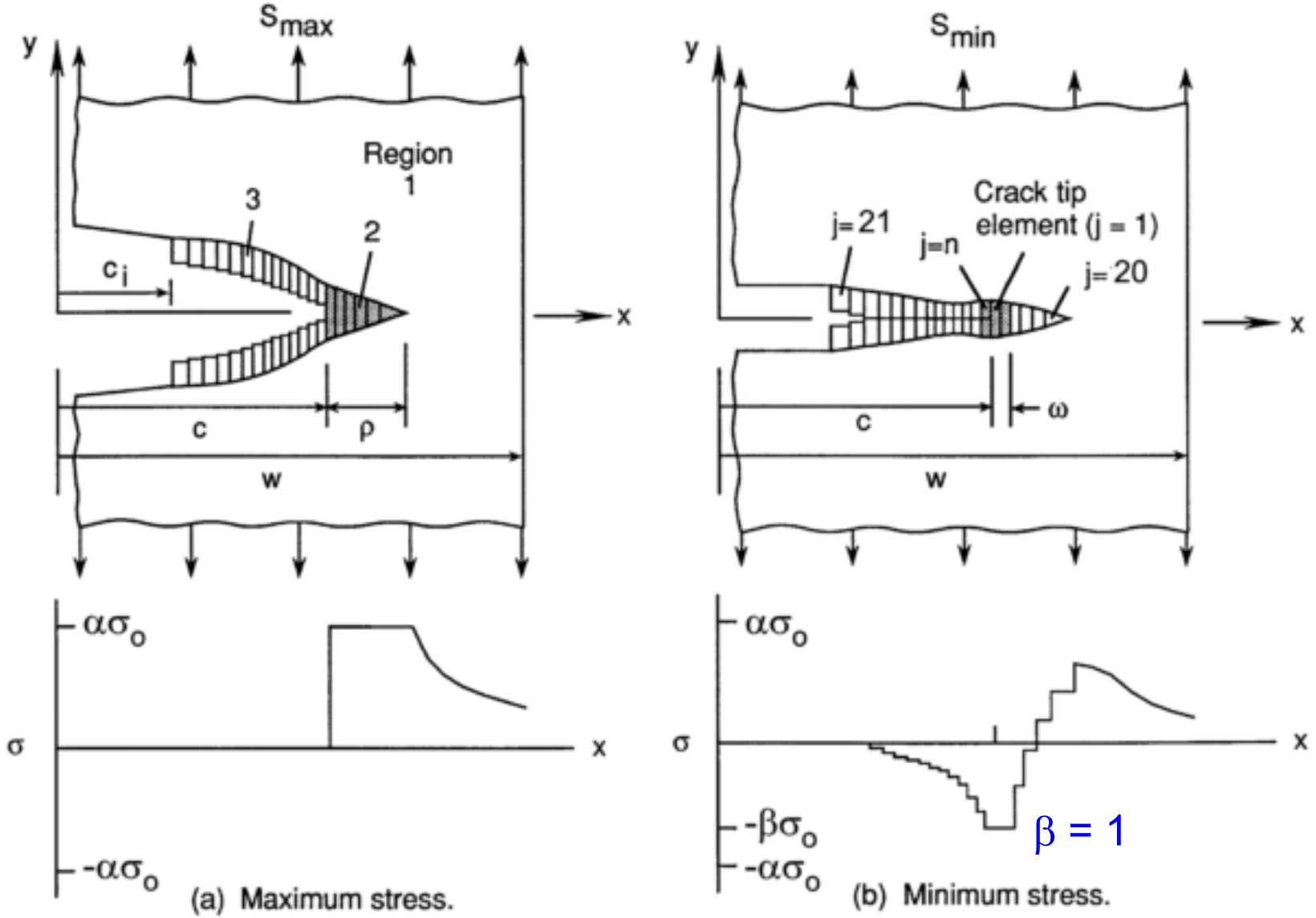
FASTRAN – Fatigue-Crack-Closure based Life-Prediction Code



Some Important Features of *FASTRAN*

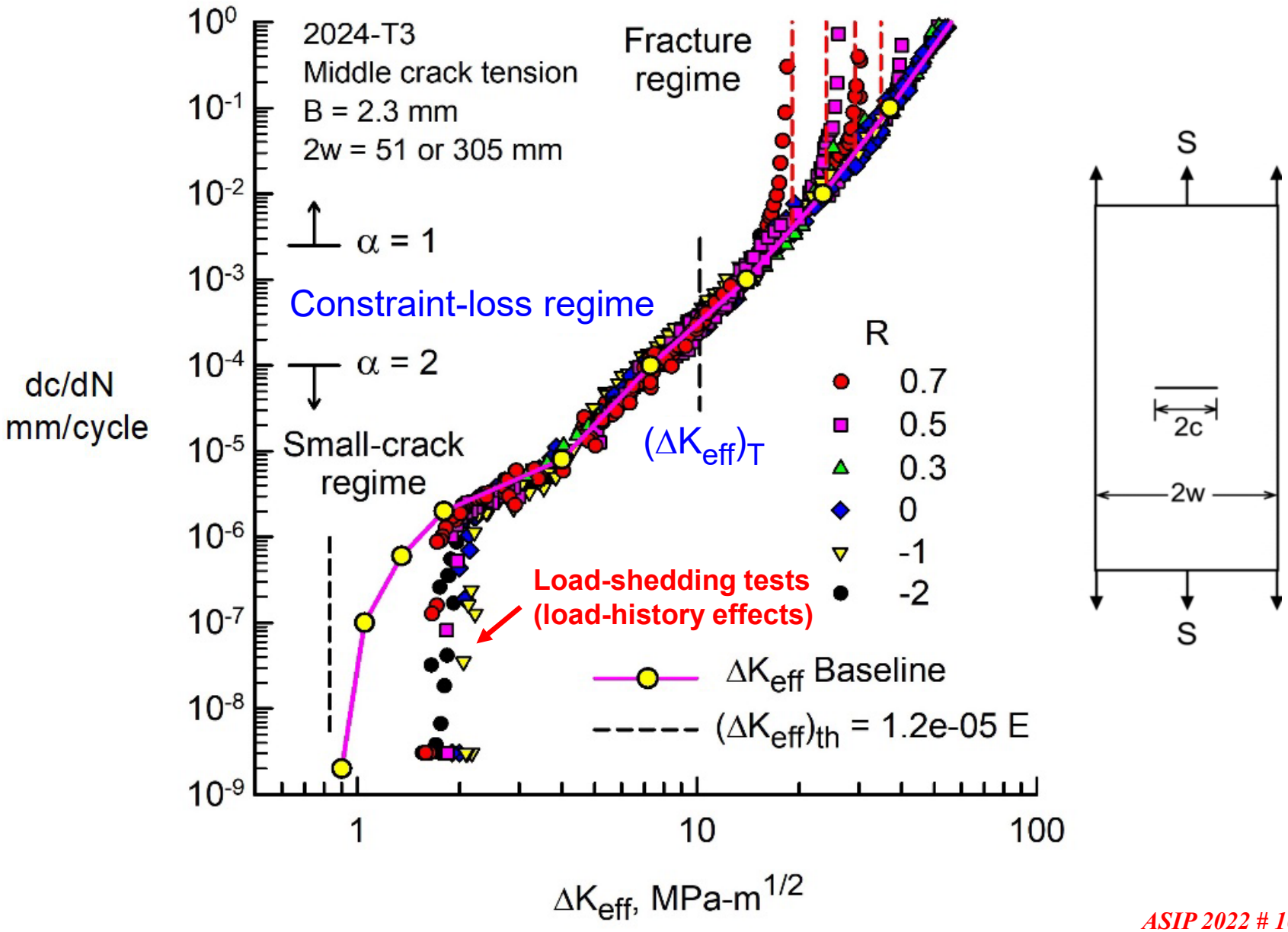
- Plane-strain to plane-stress constraint-loss behavior (needed for spectrum loading)

- Cycle-by-cycle life calculations (NMAX = 1)
  (1976: 1 cycle, 7 sec; 2015: ~1,000 cycles/sec)

- Rainflow or other cycle counting methods are not needed for aircraft spectrum loading — Rainflow-on-the-Fly methodology is used

Effective SIF Relation for 2024-T3 Sheet M(T) Specimens

Newman, Swain and Phillips (1986)



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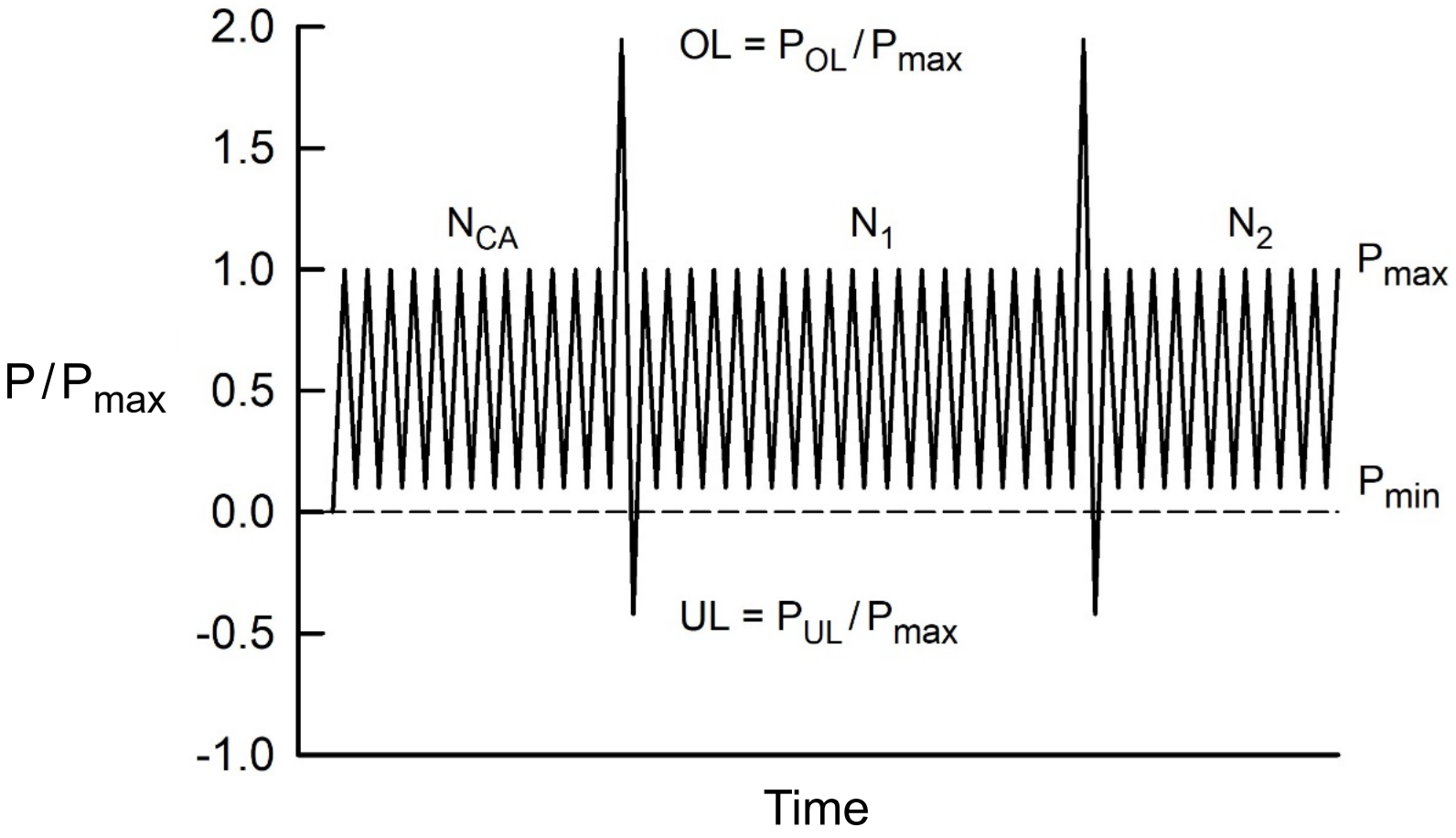
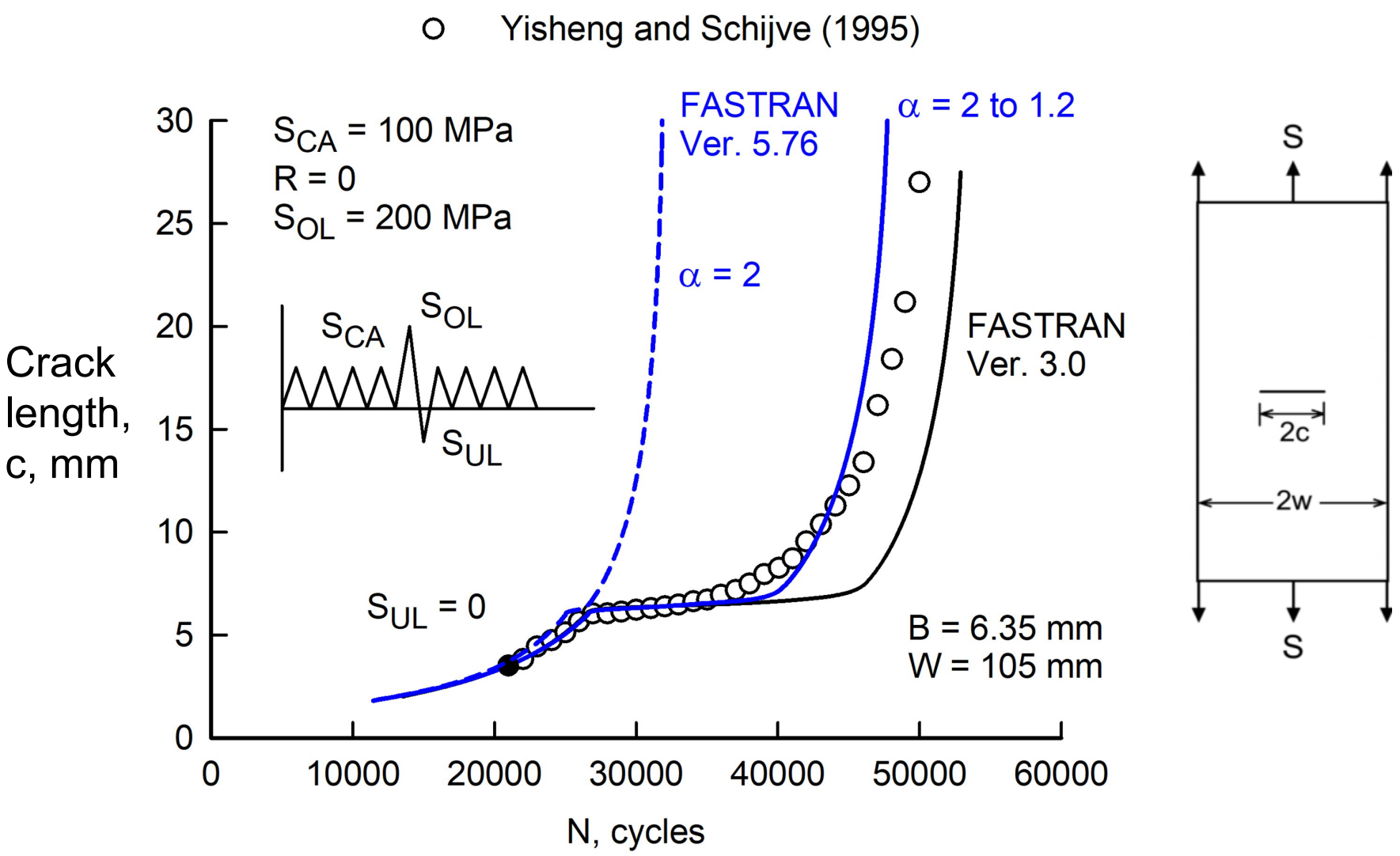
Repeated Single-Spike Overload/Underload History under Constant-Amplitude Loading



Test and Analyses of a Single-Spike Overload on 2024-T351 Plate

Newman (1997; 2021)



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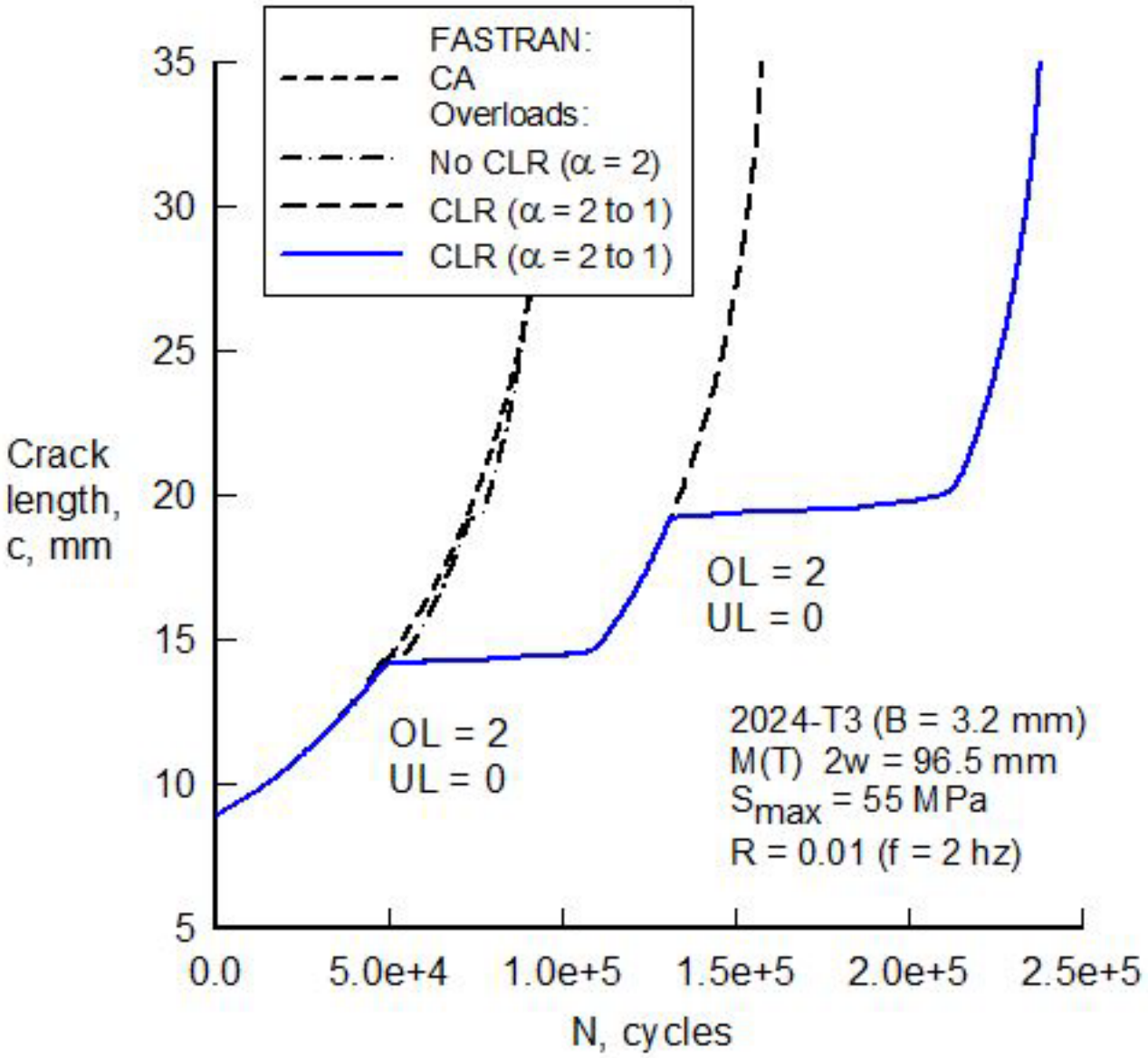
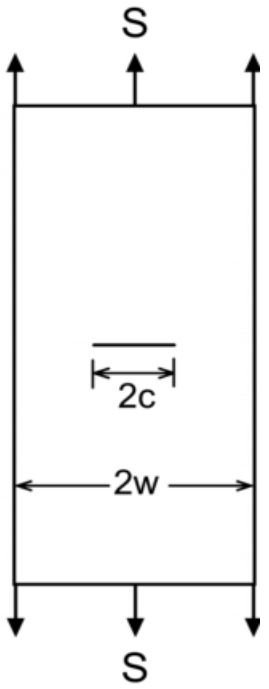
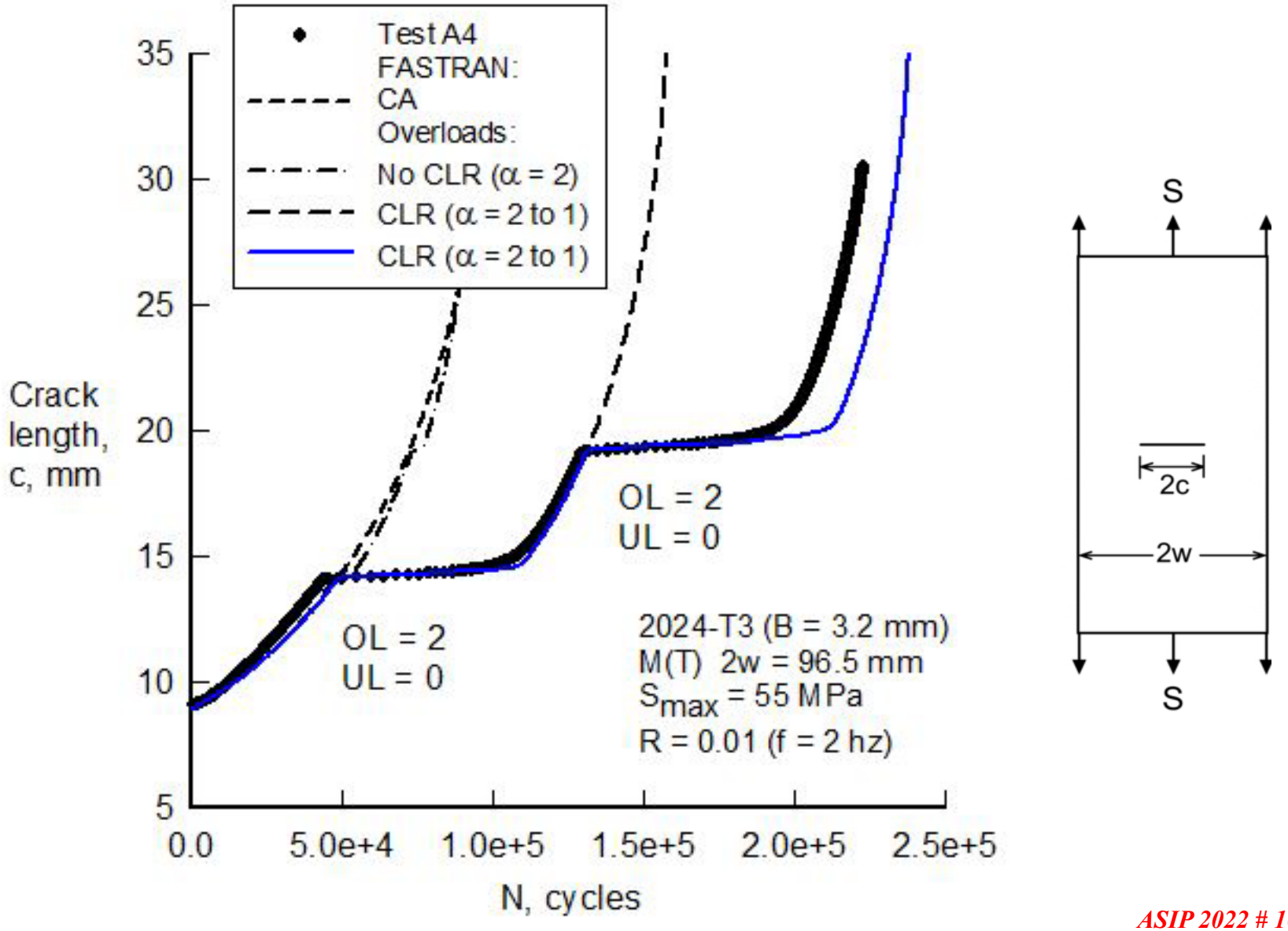
Predicted Crack-Length against Cycles under Repeated Single-Spike Overloads in 2024-T3 Sheet

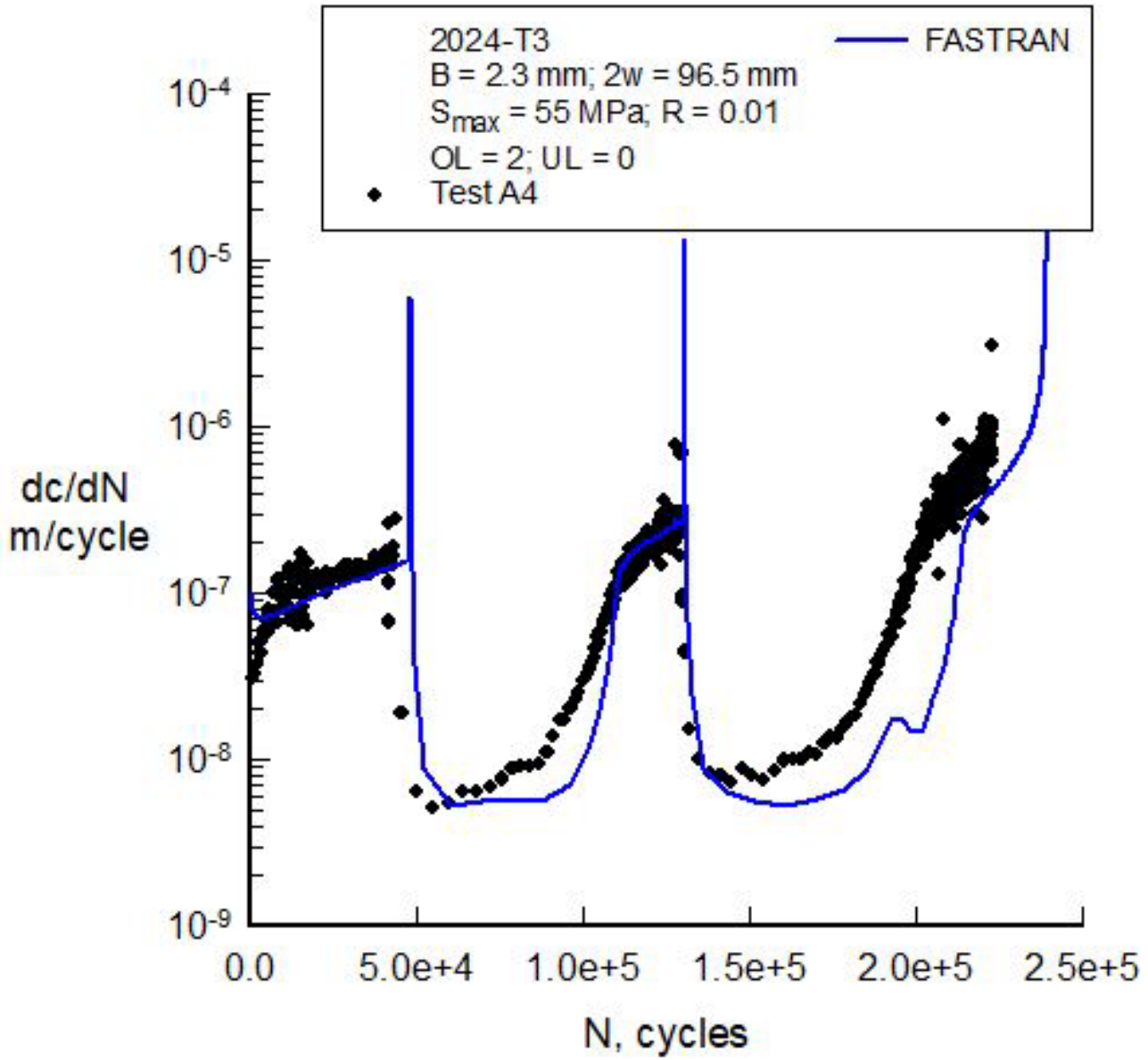




Measured and Predicted Crack-Length against Cycles under Repeated Single-Spike Overloads in 2024-T3 Sheet



Measured and Predicted Crack-Growth-Rate against Cycles under Repeated Single-Spike Overloads in 2024-T3 Sheet



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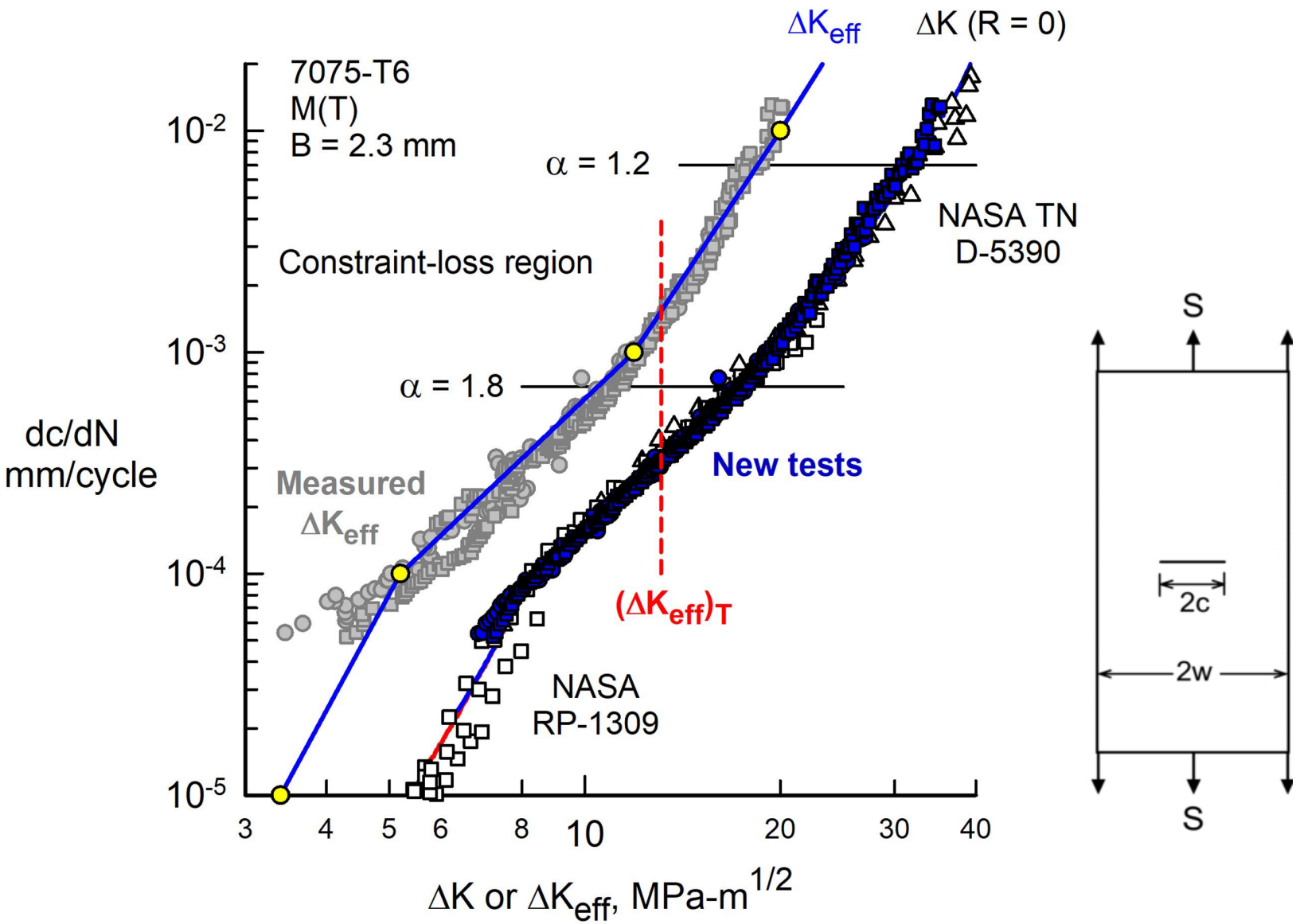
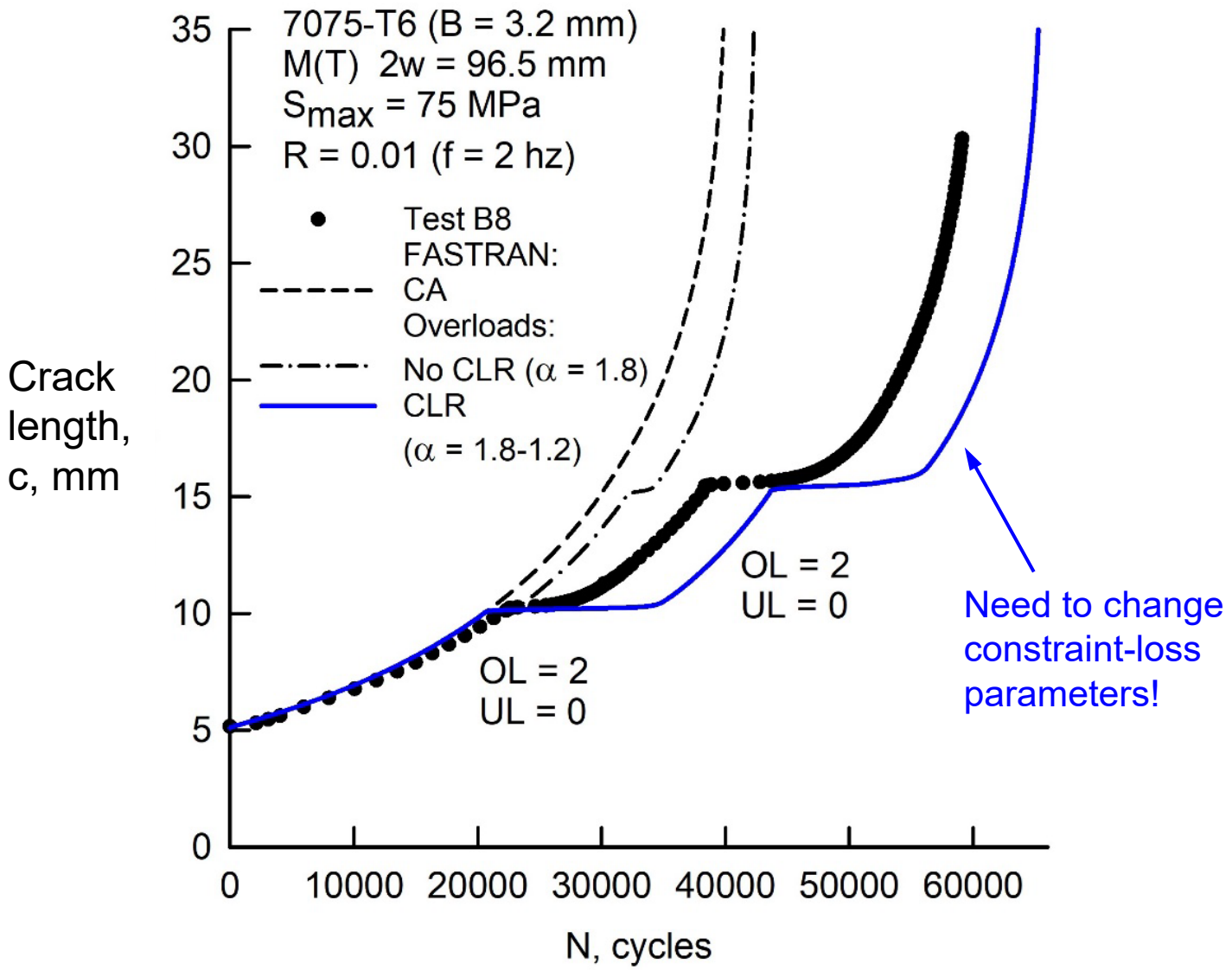
Stress-Intensity Factor (SIF) against Rate Data for 7075-T6 Sheet M(T) Specimens – Hudson, Newman et al. (NASA LaRC)



Measured and Predicted Crack-Length against Cycles under Repeated Single-Spike Overloads in 7075-T6 Sheet



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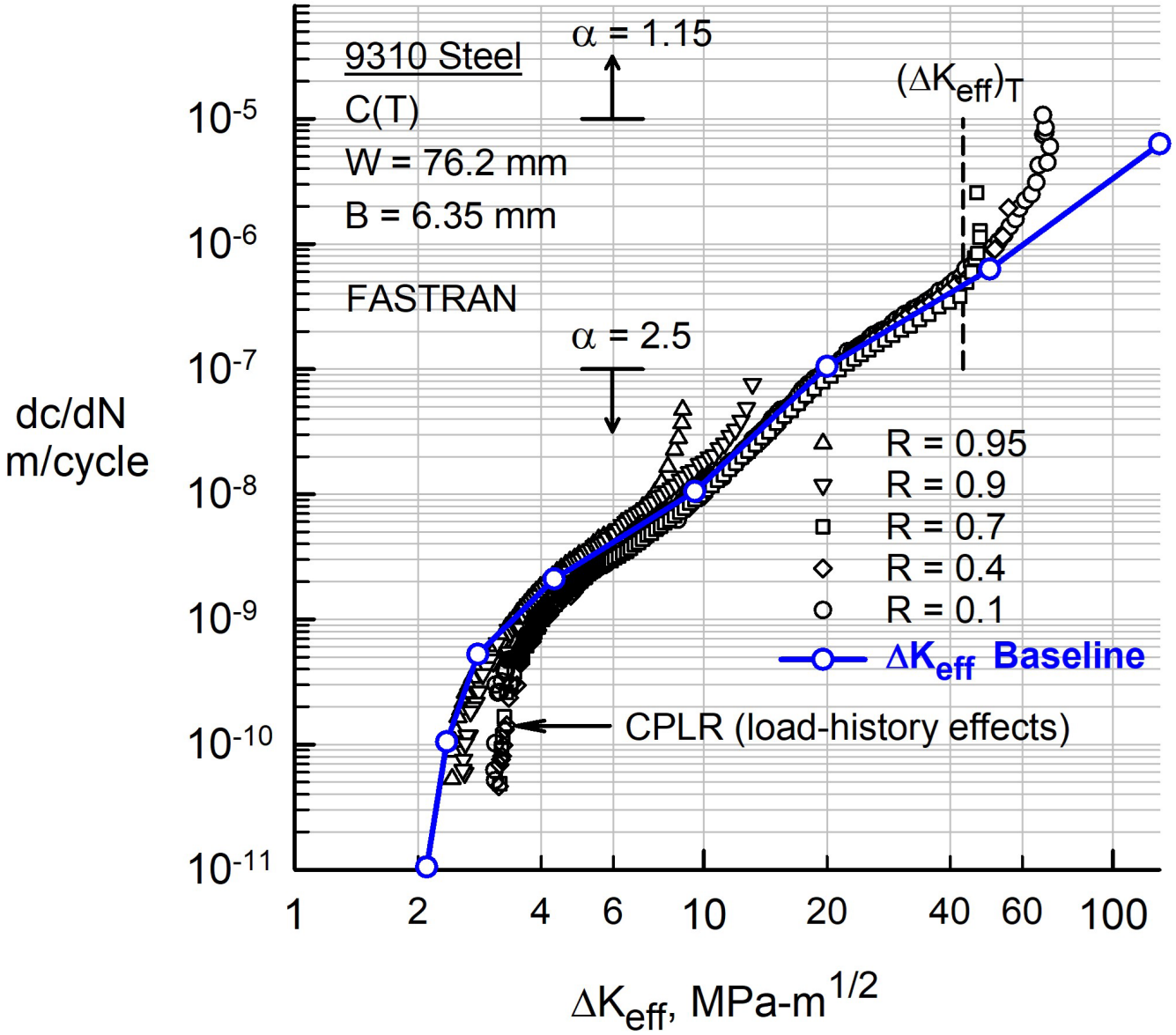
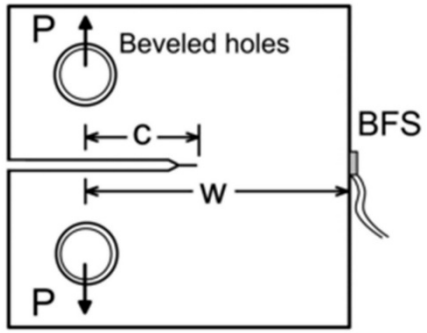
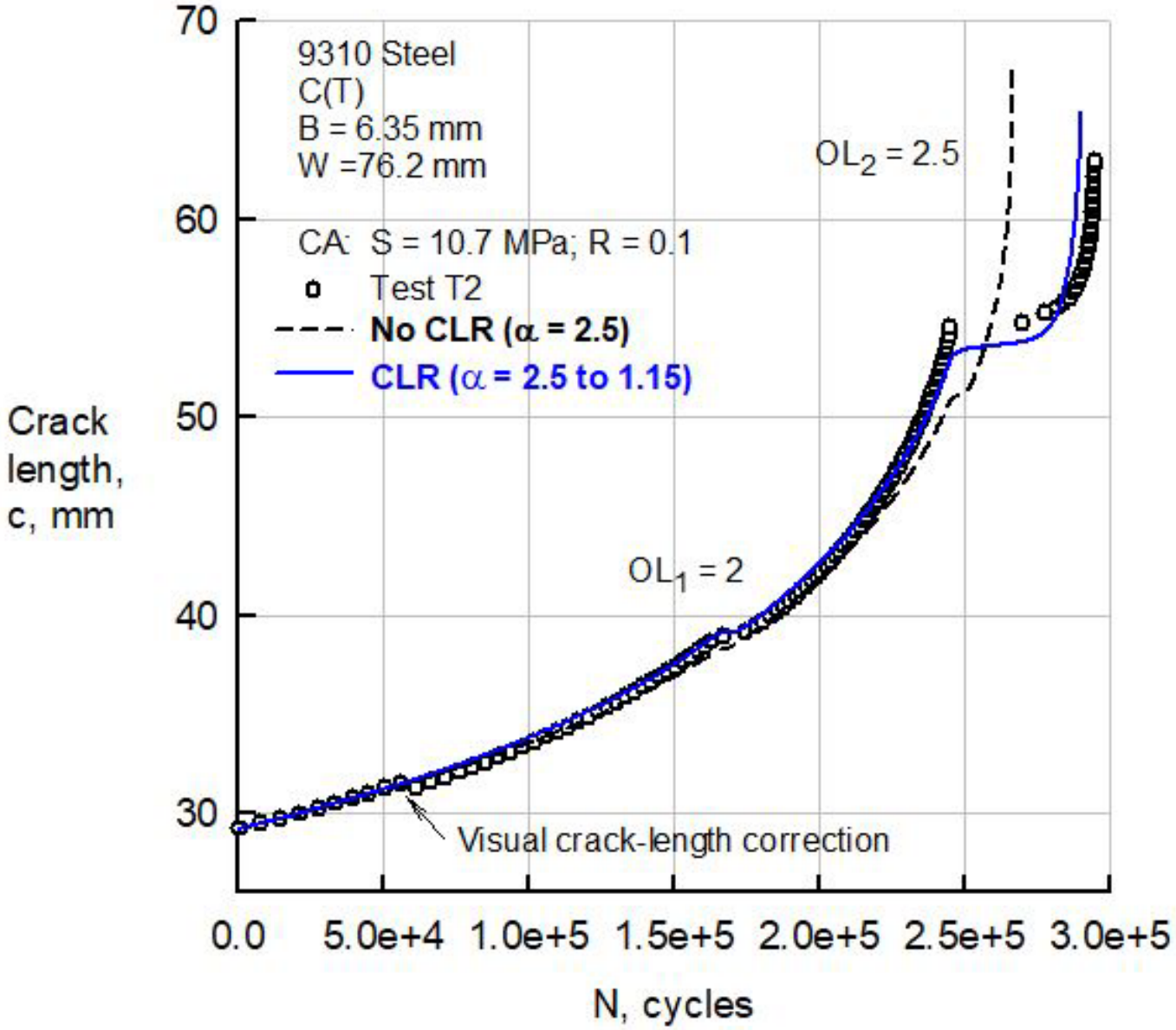
Effective SIF Relation for 9310 Steel Plate C(T) Specimens





Measured and Predicted Crack-Length-against-Cycles for C(T) Specimen made of 9310 Steel Plate under Repeated Single-Spike Overloads



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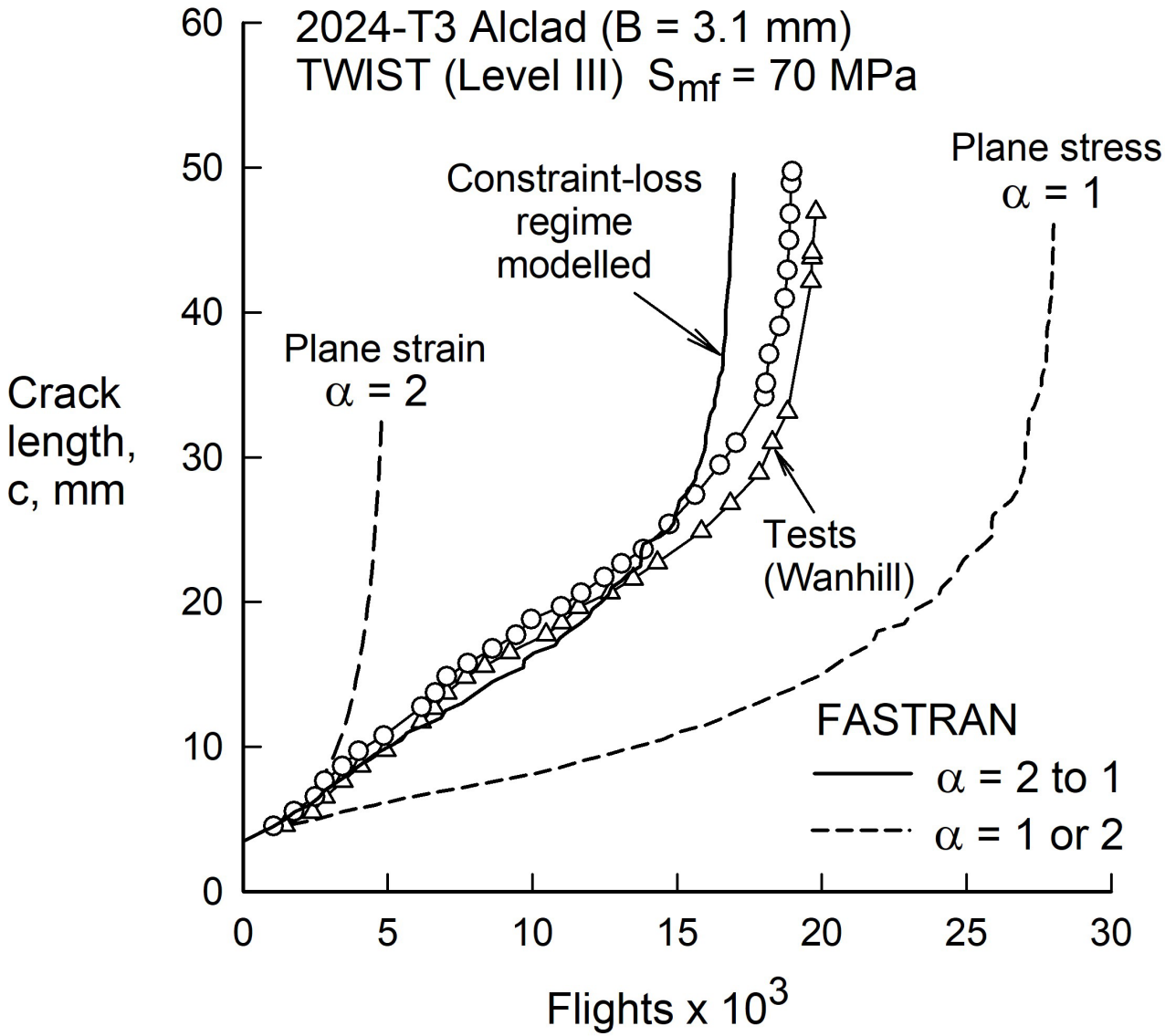
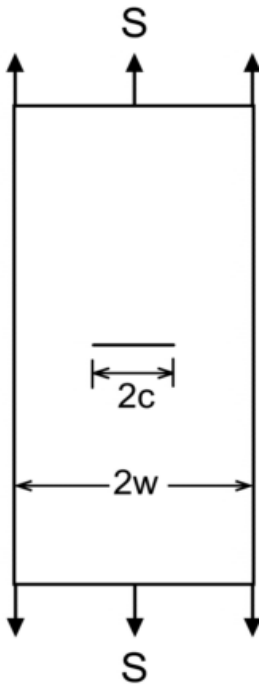
Crack Growth under TWIST (Level III) Spectrum Loading

Wanhill (1977), Newman (1992)





Concluding Remarks

- Transition from plane-strain to plane-stress behavior (flat-to-slant crack growth) occurs at a **constant crack-growth rate** and is controlled by $(\Delta K_{eff})_T$.

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- ***Constant*** constraint behavior was **unable** to predict delays caused by single-spike overloads/underloads and crack growth under the TWIST spectrum loading.

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- ***Constant*** constraint behavior was **unable** to predict delays caused by single-spike overloads/underloads and crack growth under the TWIST spectrum loading.
- **Constraint-loss behavior** from plane-strain to plane-stress behavior was **able** to calculate or predict delays caused by single-spike overloads and underloads.

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- ***Constant*** constraint behavior was **unable** to predict delays caused by single-spike overloads/underloads and crack growth under the TWIST spectrum loading.
- Constraint-loss behavior from plane-strain to plane-stress behavior was **able** to calculate or predict delays caused by single-spike overloads and underloads.
- **Constraint-loss behavior** from plane-strain to plane-stress behavior was **able** to predict crack growth under the **TWIST** spectrum loading.

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Future Recommendation

U.S. Air Force should fund LexTech, Inc. to incorporate FASTRAN Version 5+ into the AFGROW software.

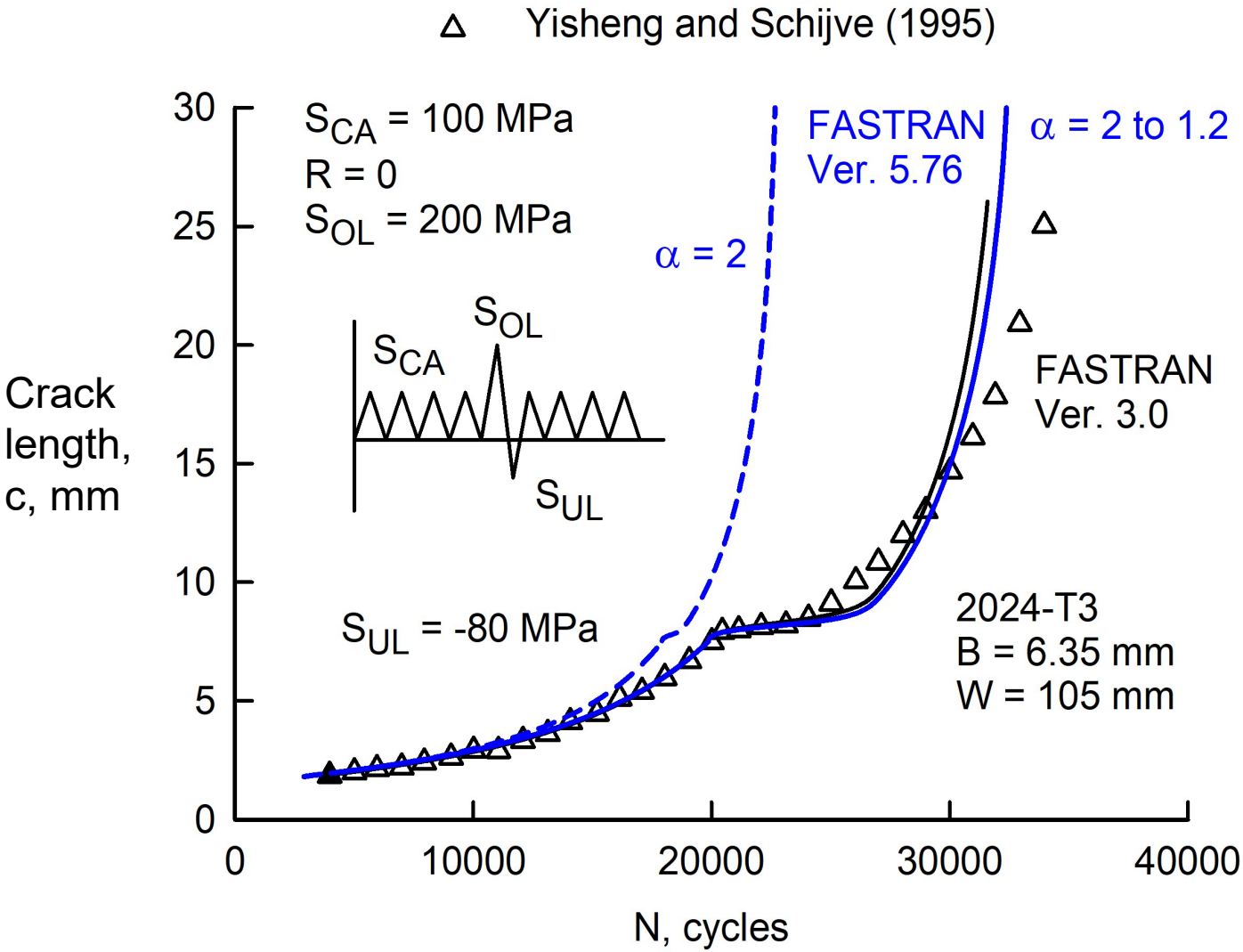
Thank You, Very Much !

Questions ?

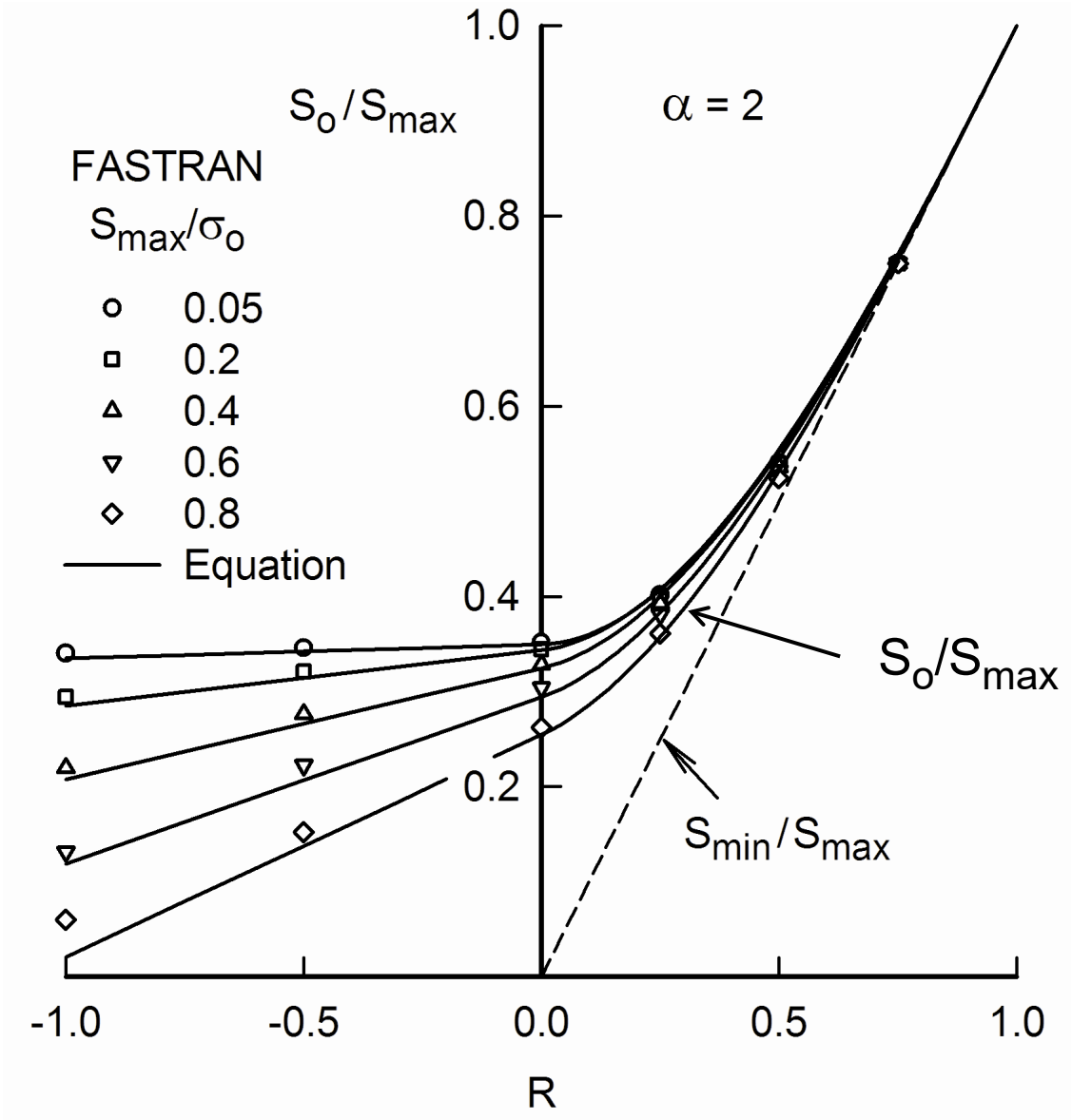
Backup Slides

Test and Analyses of a Single-Spike Overload/Underload on 2024-T3 Plate

Newman (1997; 2021)



Crack-Opening Stresses as Function of R and S_{max}/σ_o for $\alpha = 2$



$S_o/S_{max} = f(R, \alpha, S_{max}/\sigma_o)$

$R = S_{min}/S_{max}$

$\sigma_o = (\sigma_{ys} + \sigma_u)/2$

Stress-Intensity Factor (SIF) against Rate Data for 2024-T3 M(T) Specimens – Hudson, Phillips and Dubensky (NASA LaRC)