

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

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AFGROW Workshop
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Outline of Presentation

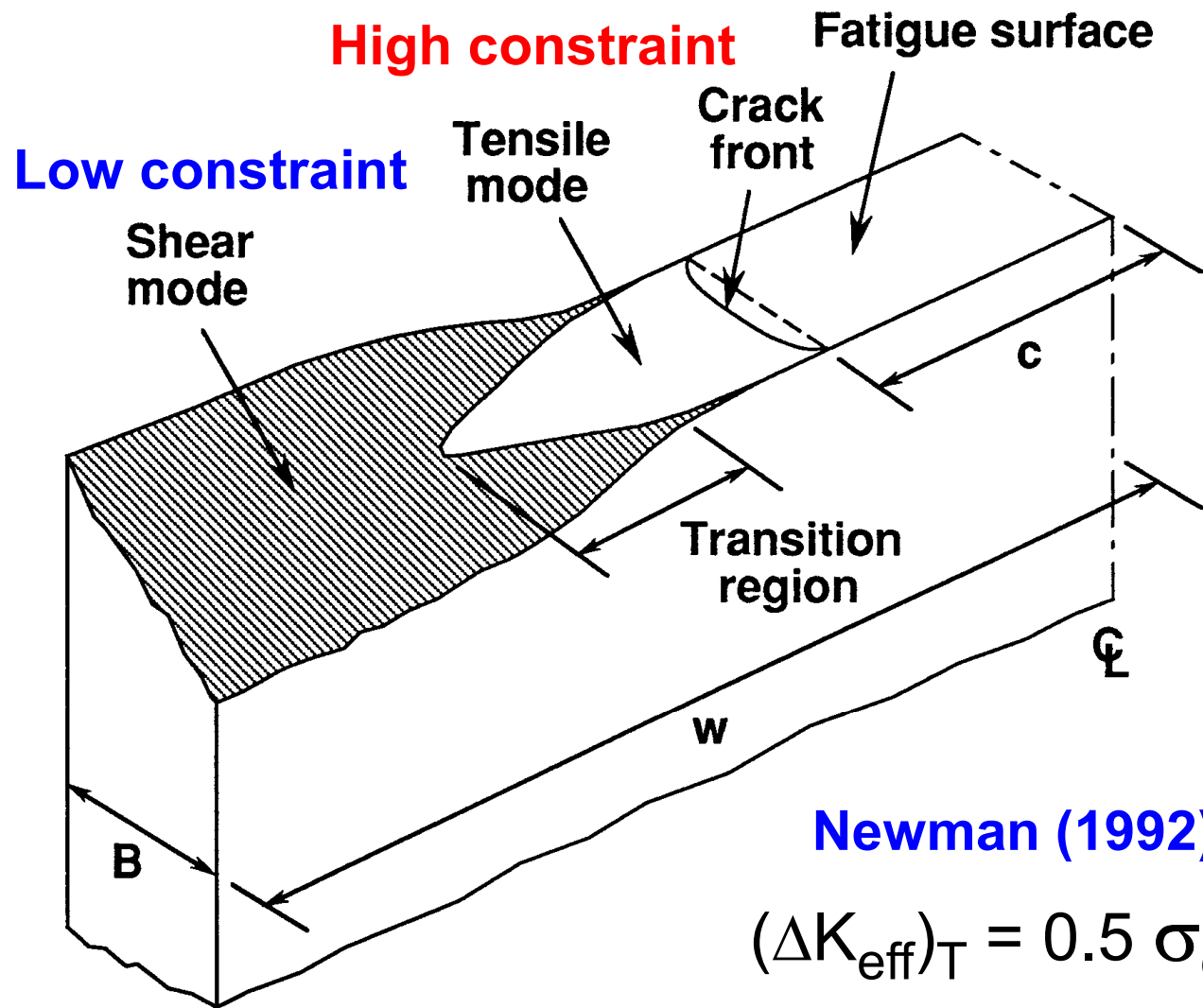
- **Plane-strain to plane-stress fatigue-crack growth behavior**
- **Fatigue-crack-growth rate against ΔK_{eff} correlations**
- **Single-spike overload/underload tests and analyses**
 - 2024-T3 Yisheng-Schijve (1995; 1997)
 - 2024-T3 Newman-Walker
 - 7075-T6 Newman-Walker
 - 9310 Steel Newman et.al. (2013)
- **TWIST spectrum crack-growth tests and analyses – Wanhill (1977)**
- **Concluding remarks**

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

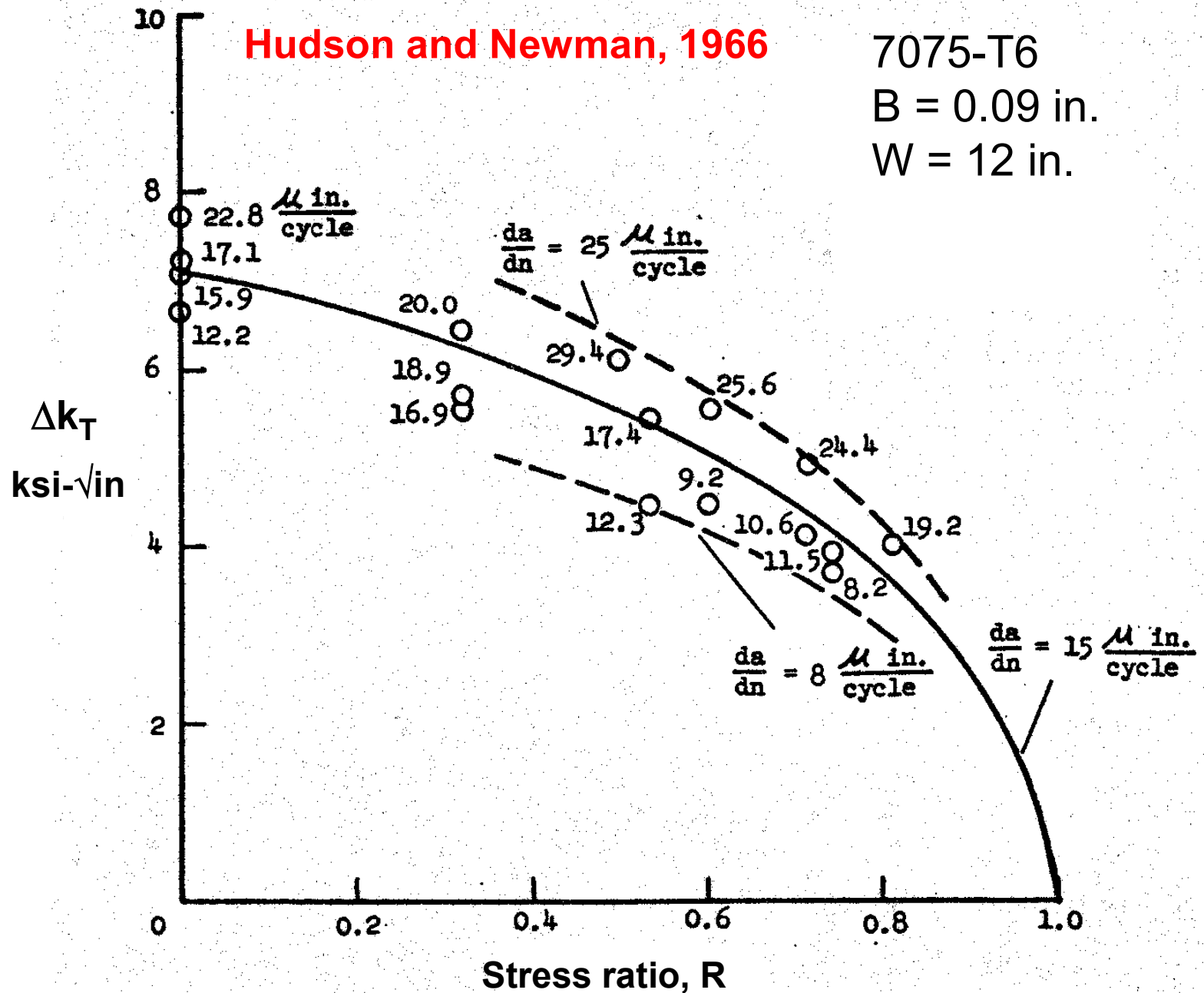
Schijve (1966)

ASTM STP-415:

Crack-growth rate was “constant” at transition on 2024-T3

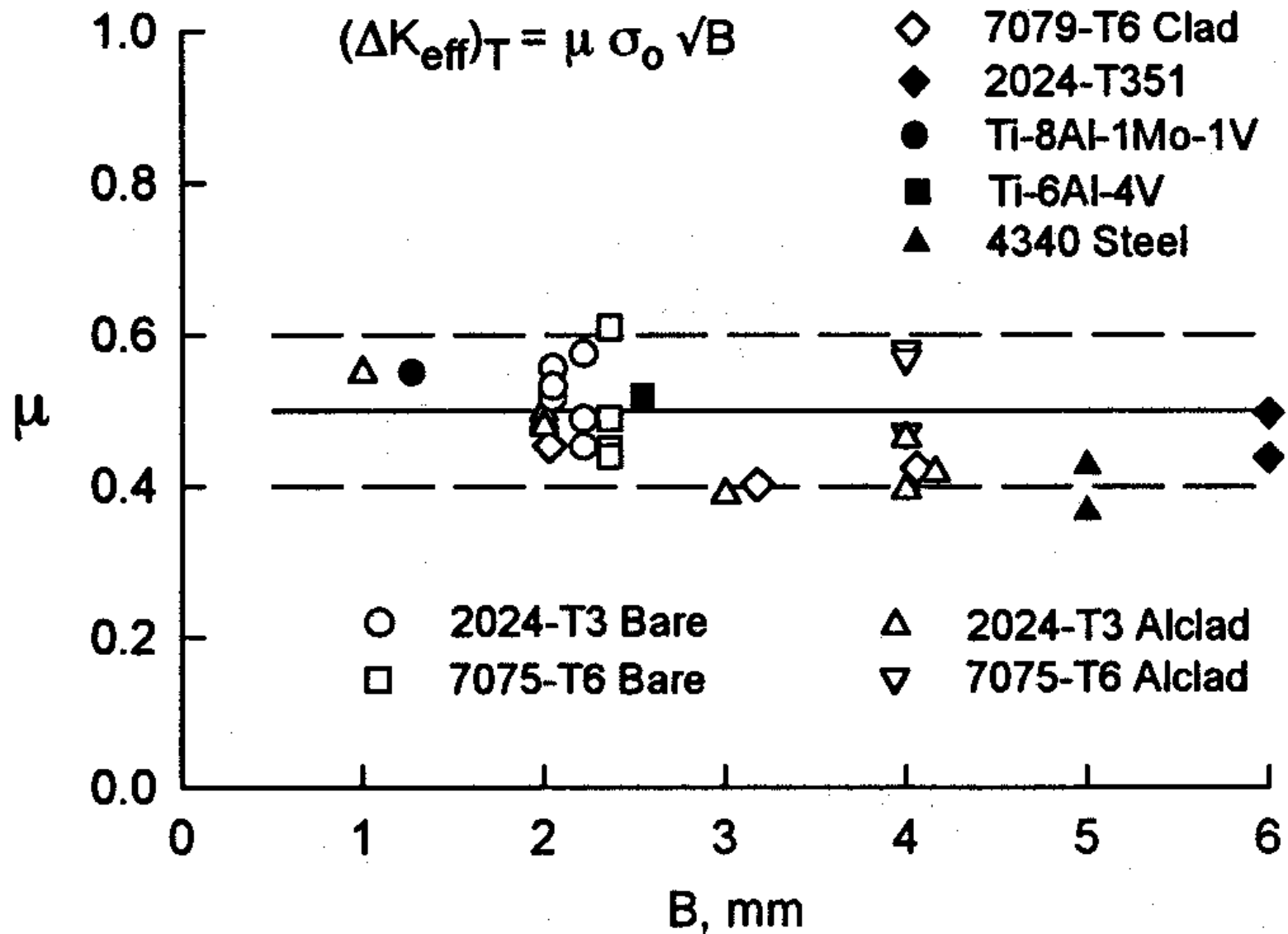


Flat-to-Slant Crack-Growth Behavior in 7075-T6



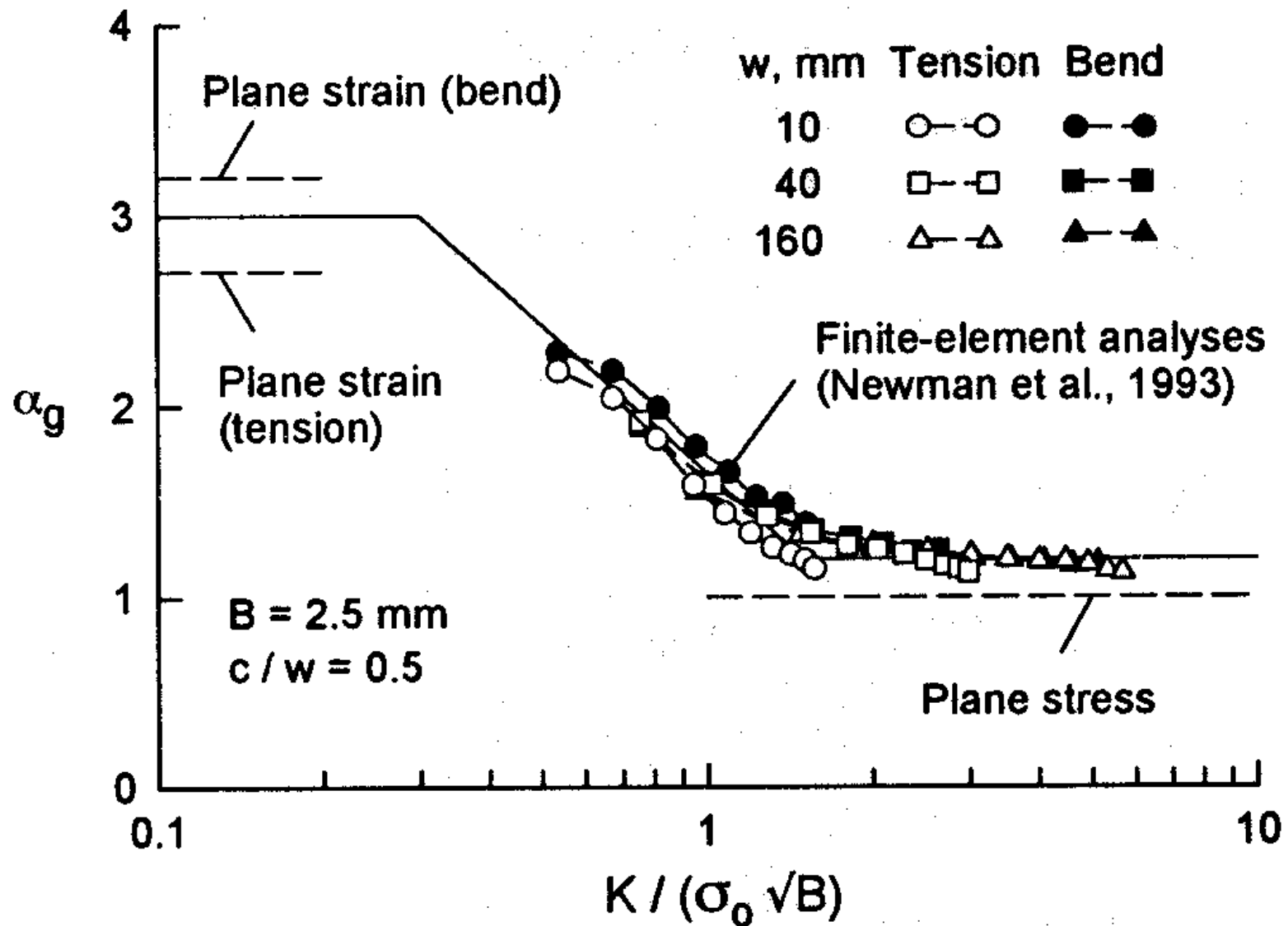
Flat-to-Slant Crack-Growth Transition in Terms of ΔK_{eff}

Newman (1992)



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

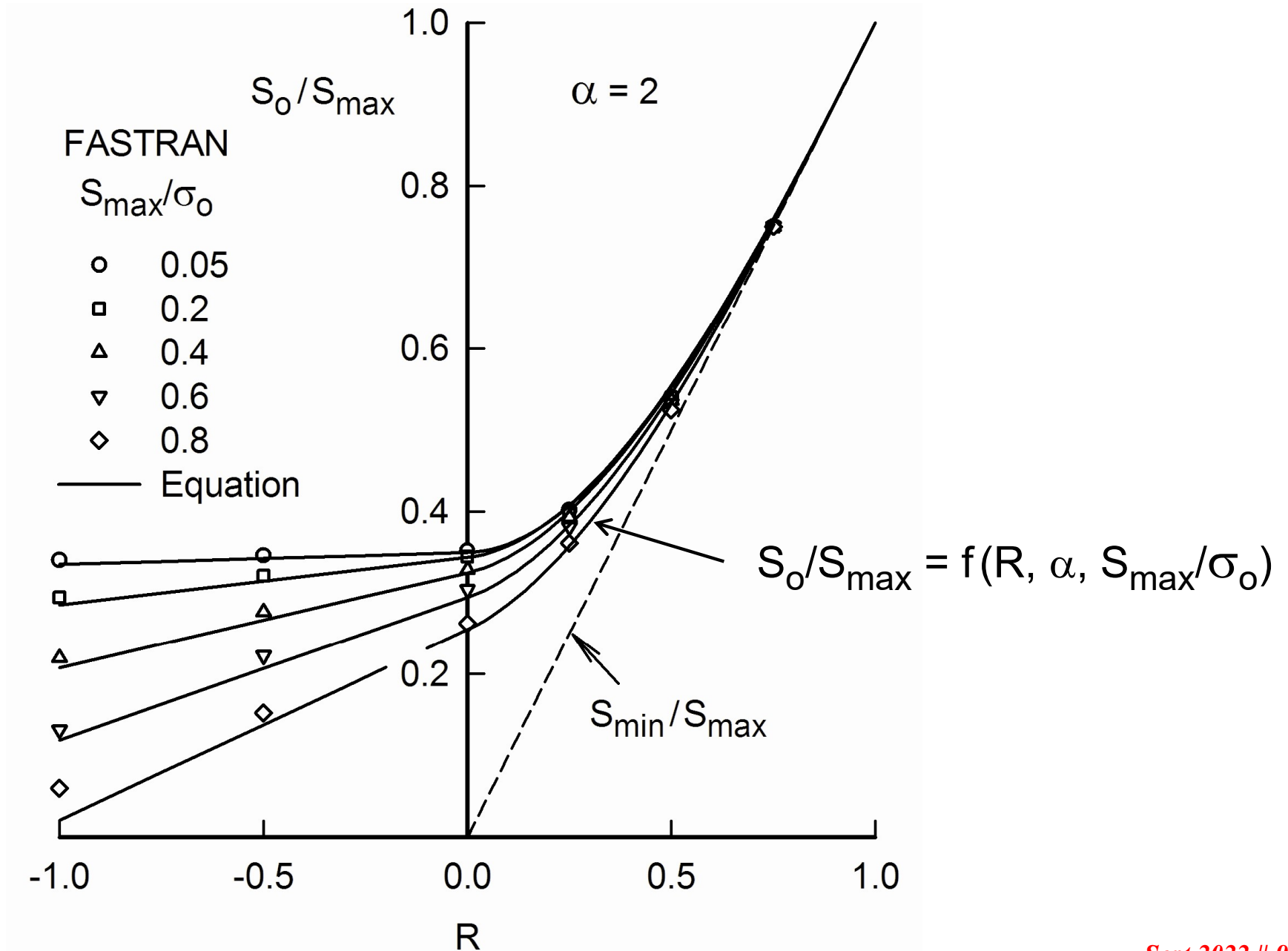
Newman, Bigelow & Shivakumar, 1993



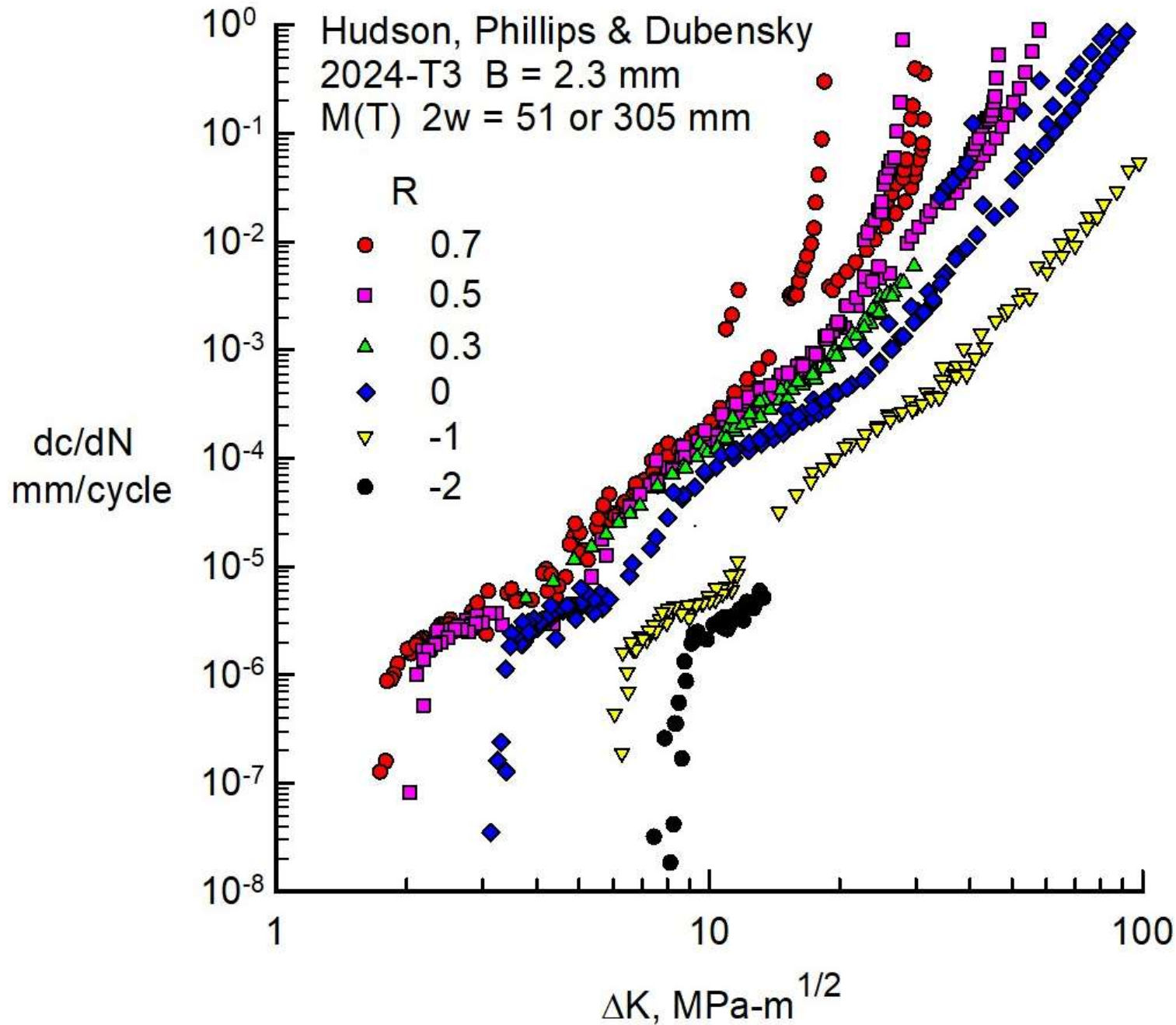
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Crack-Opening Stresses as Function of R and S_{\max}/σ_o for $\alpha = 2$

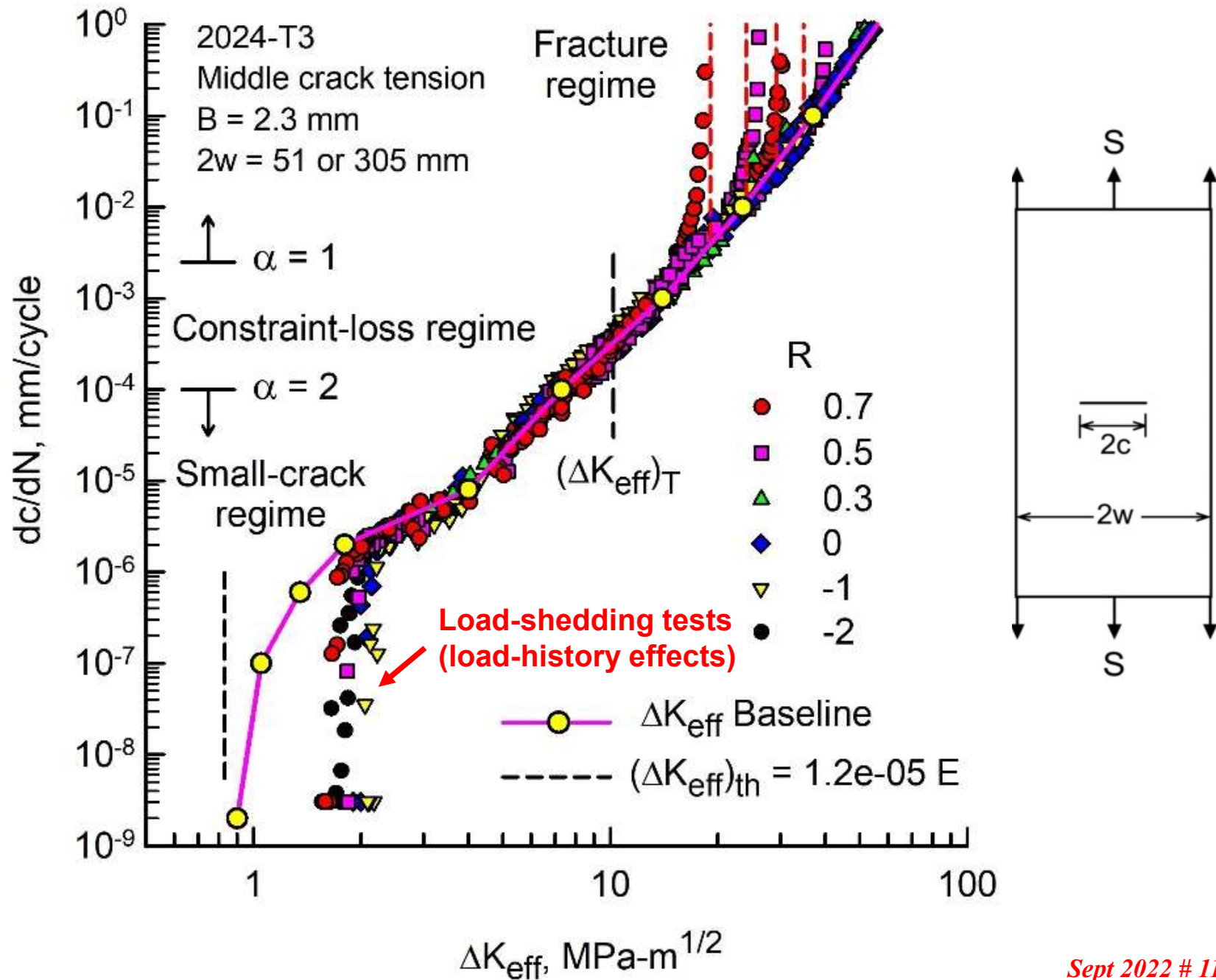


Stress-Intensity Factor (SIF) against Rate Data for 2024-T3 M(T) Specimens – Hudson, Phillips and Dubensky (NASA LaRC)



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

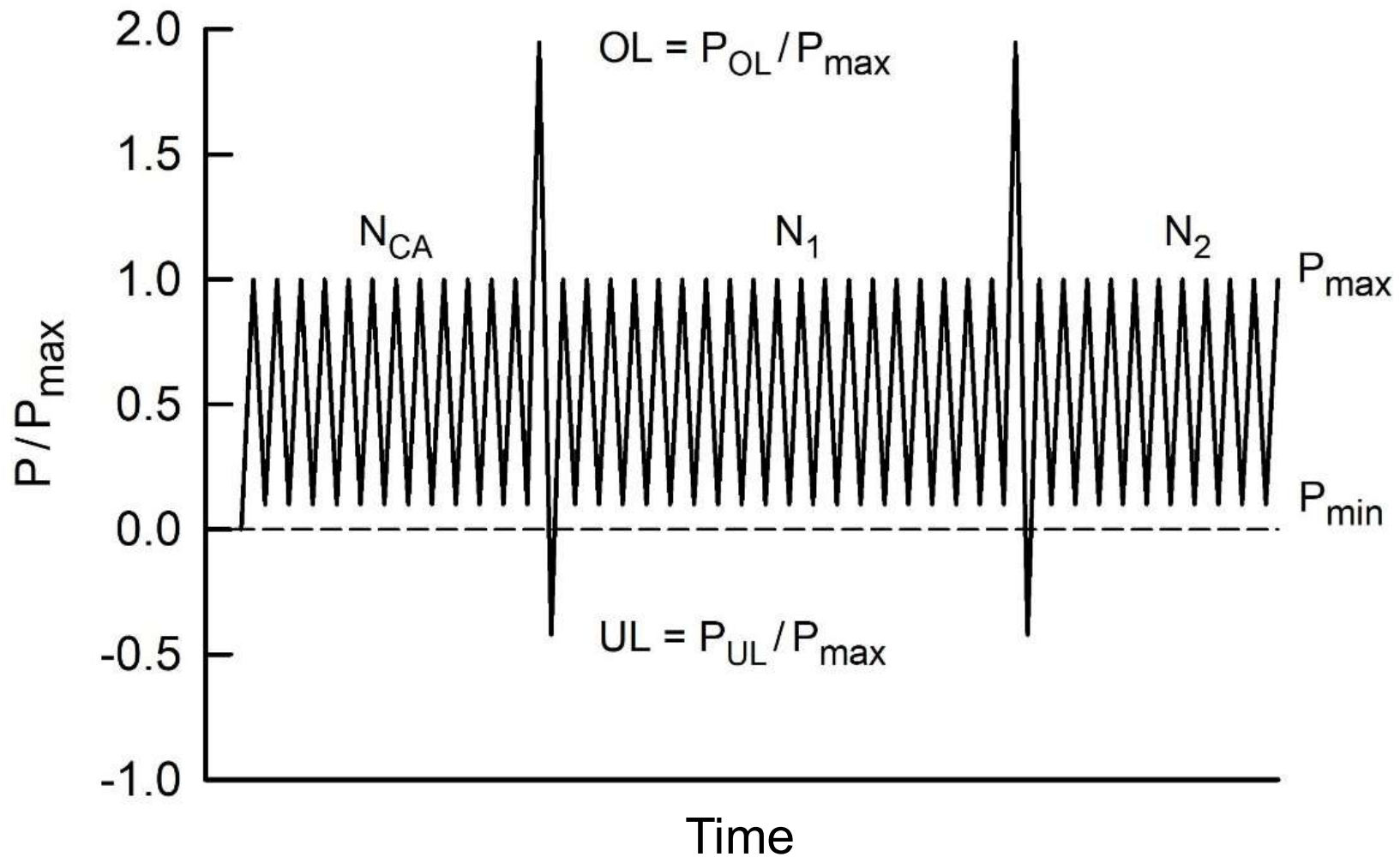
Newman, Swain and Phillips (1986)



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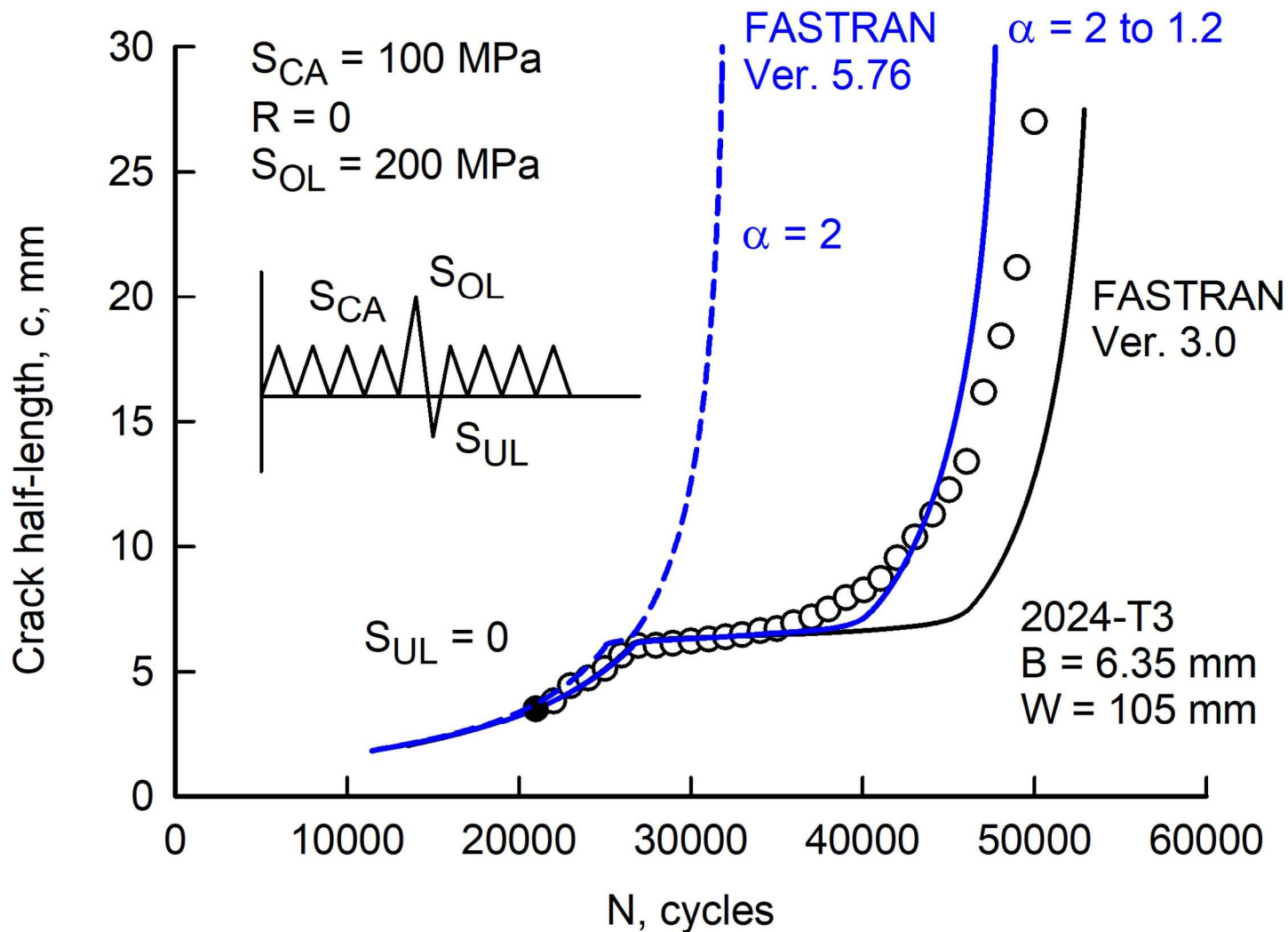
Repeated Single-Spike Overload/Underload History under Constant-Amplitude Loading



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

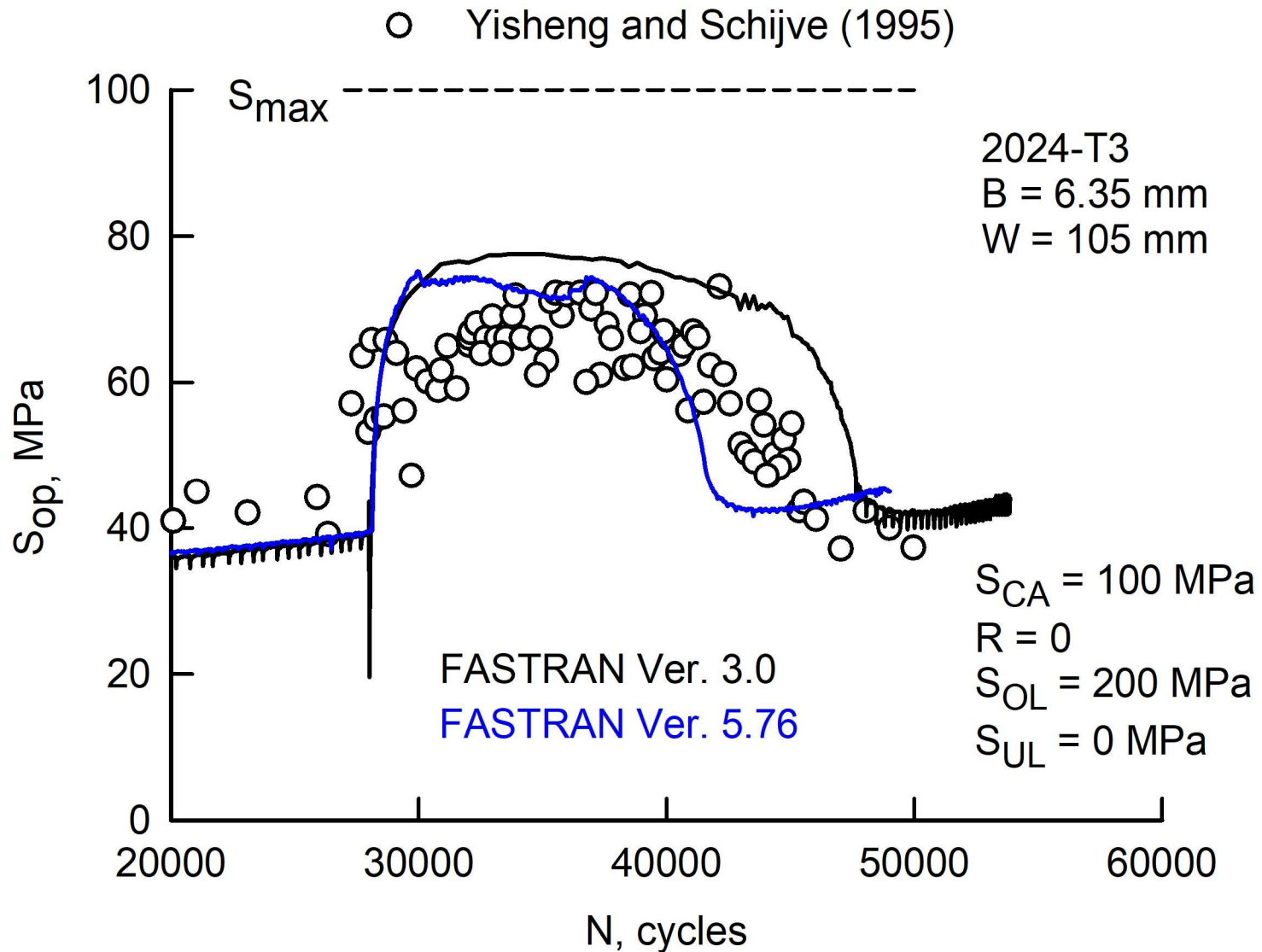
Newman (1997; 2021)

○ Yisheng and Schijve (1995)



Measured and Predicted Crack-Opening Stress for a Single-Spike Overload on 2024-T3 Plate

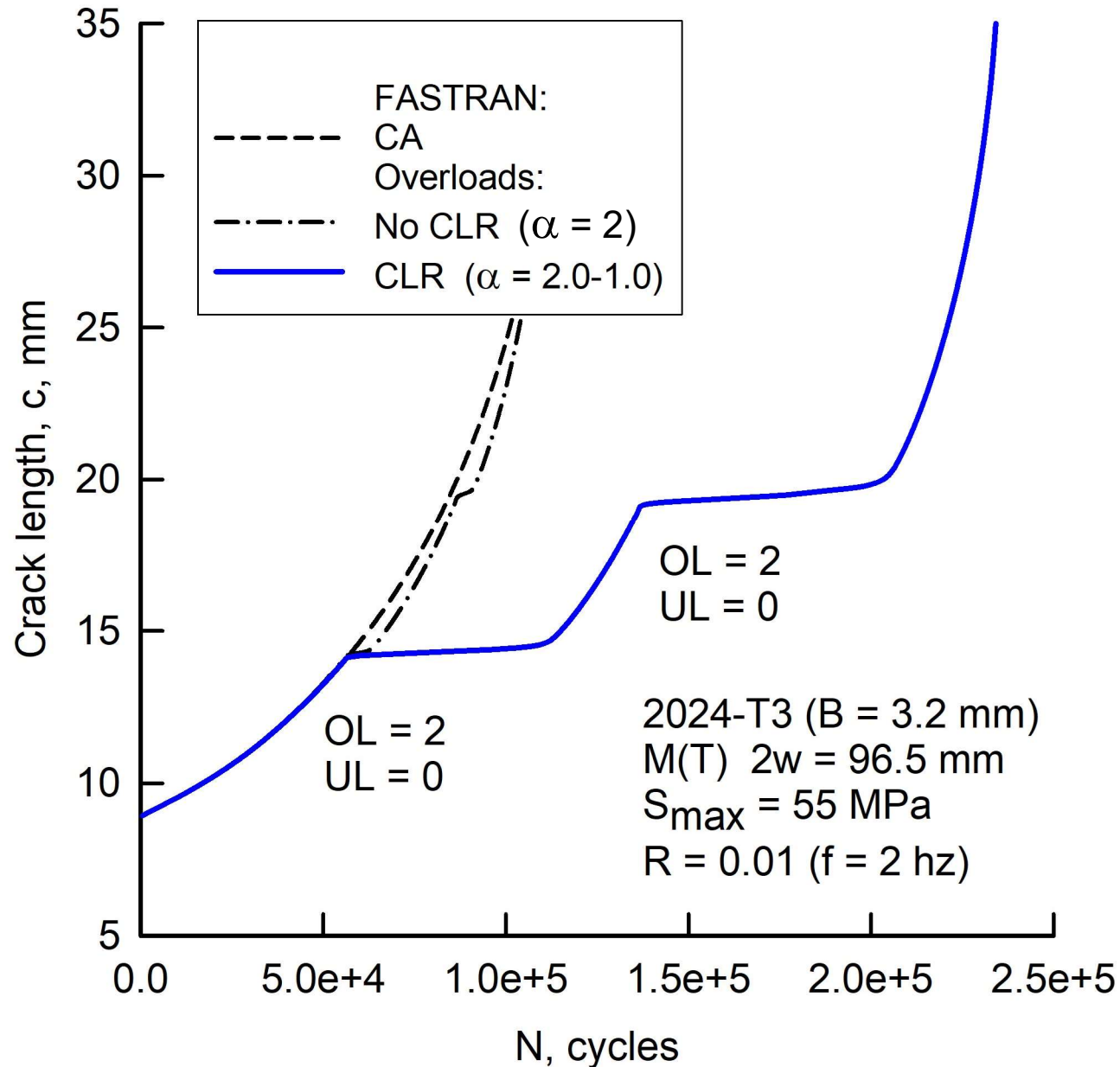
Newman (1997; 2021)



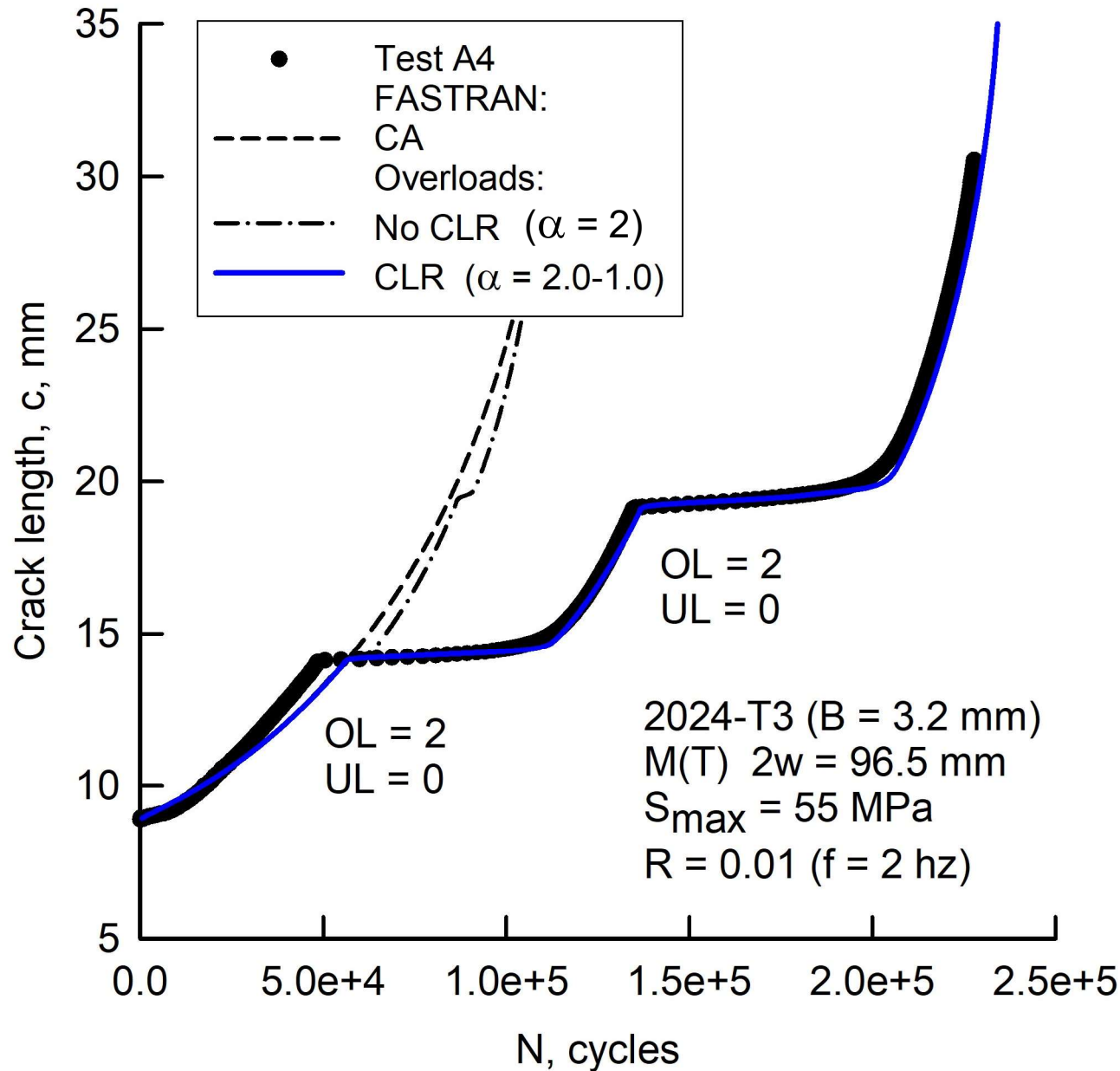
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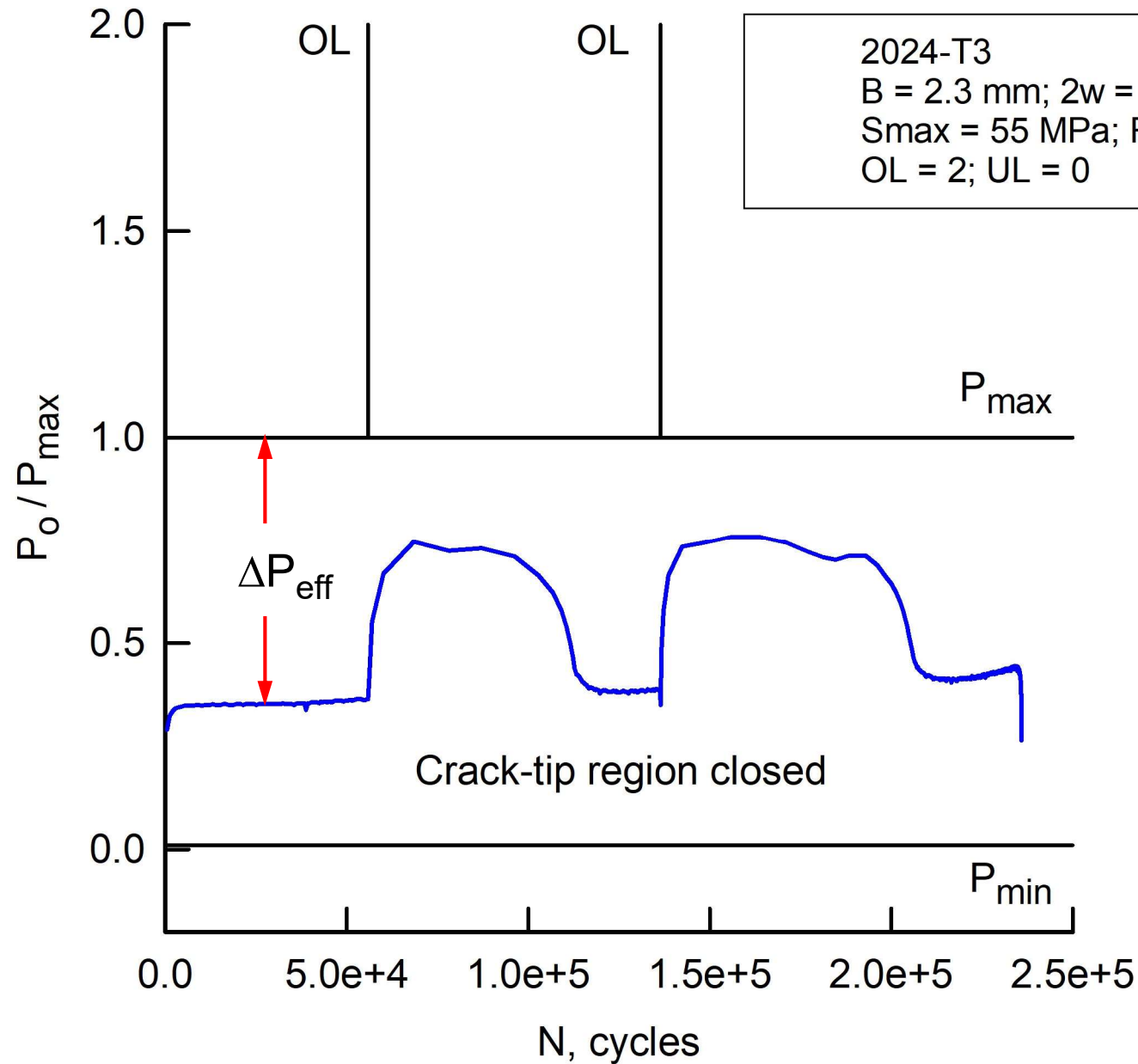
Predicted Crack-Length against Cycles under Repeated Single-Spike Overloads in 2024-T3



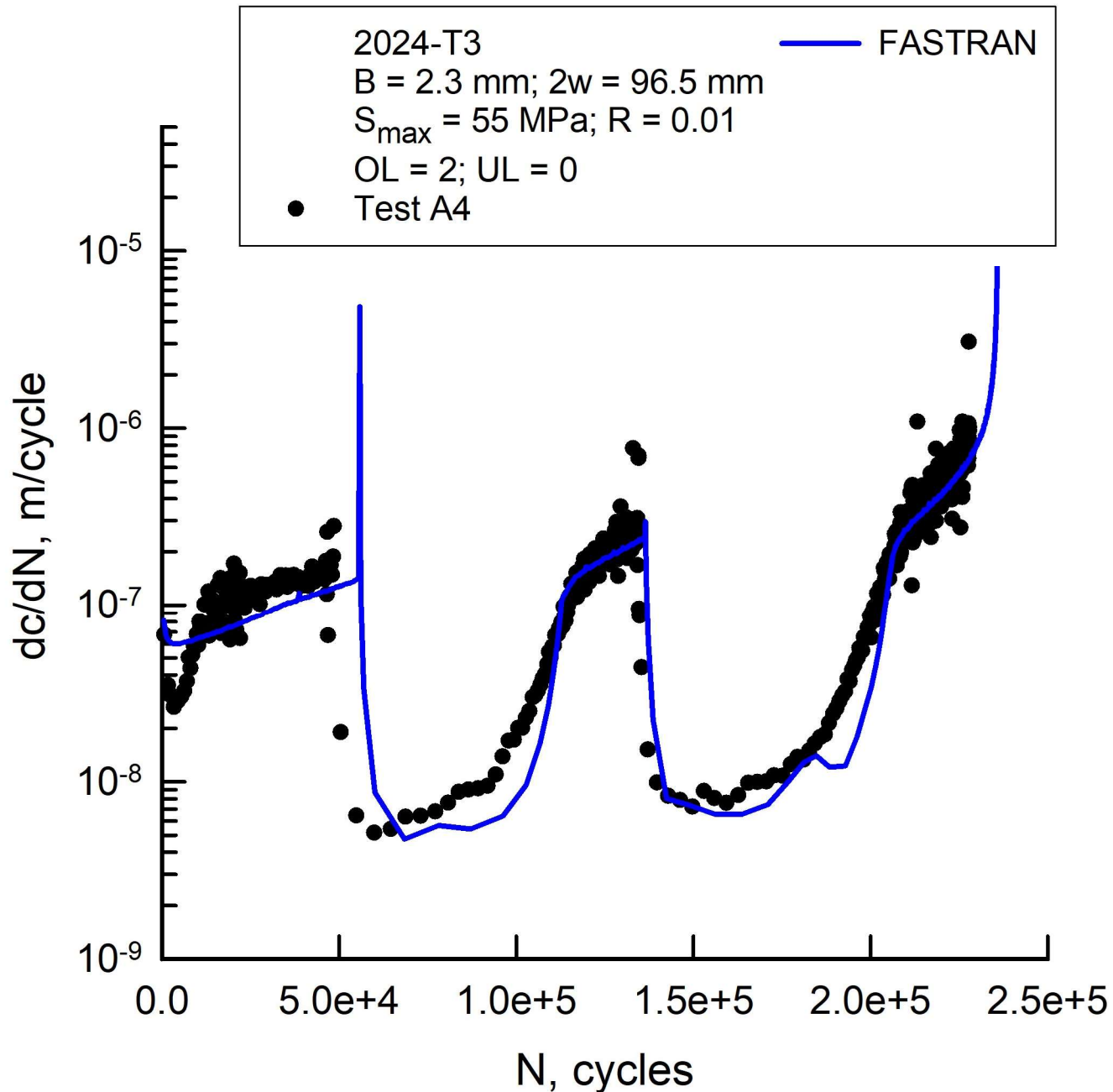
Measured and Predicted Crack-Length against Cycles under Repeated Single-Spike Overloads in 2024-T3



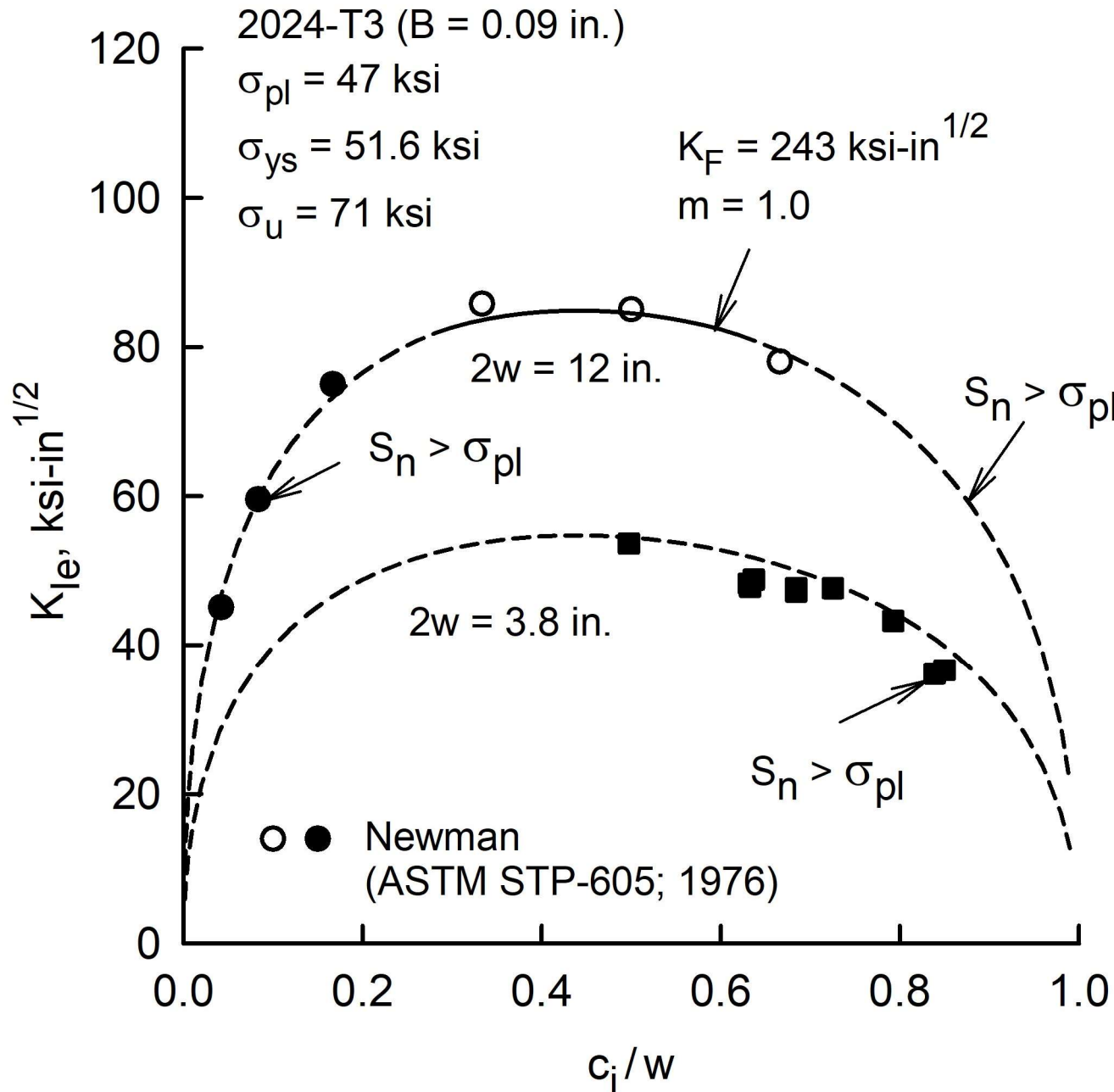
Predicted Crack-Opening-Load Ratio against Cycles under Repeated Single-Spike Overloads



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



Measured and Calculated Stress-Intensity Factors at Failure for 2024-T3 M(T) Specimens



TPFC (1973):

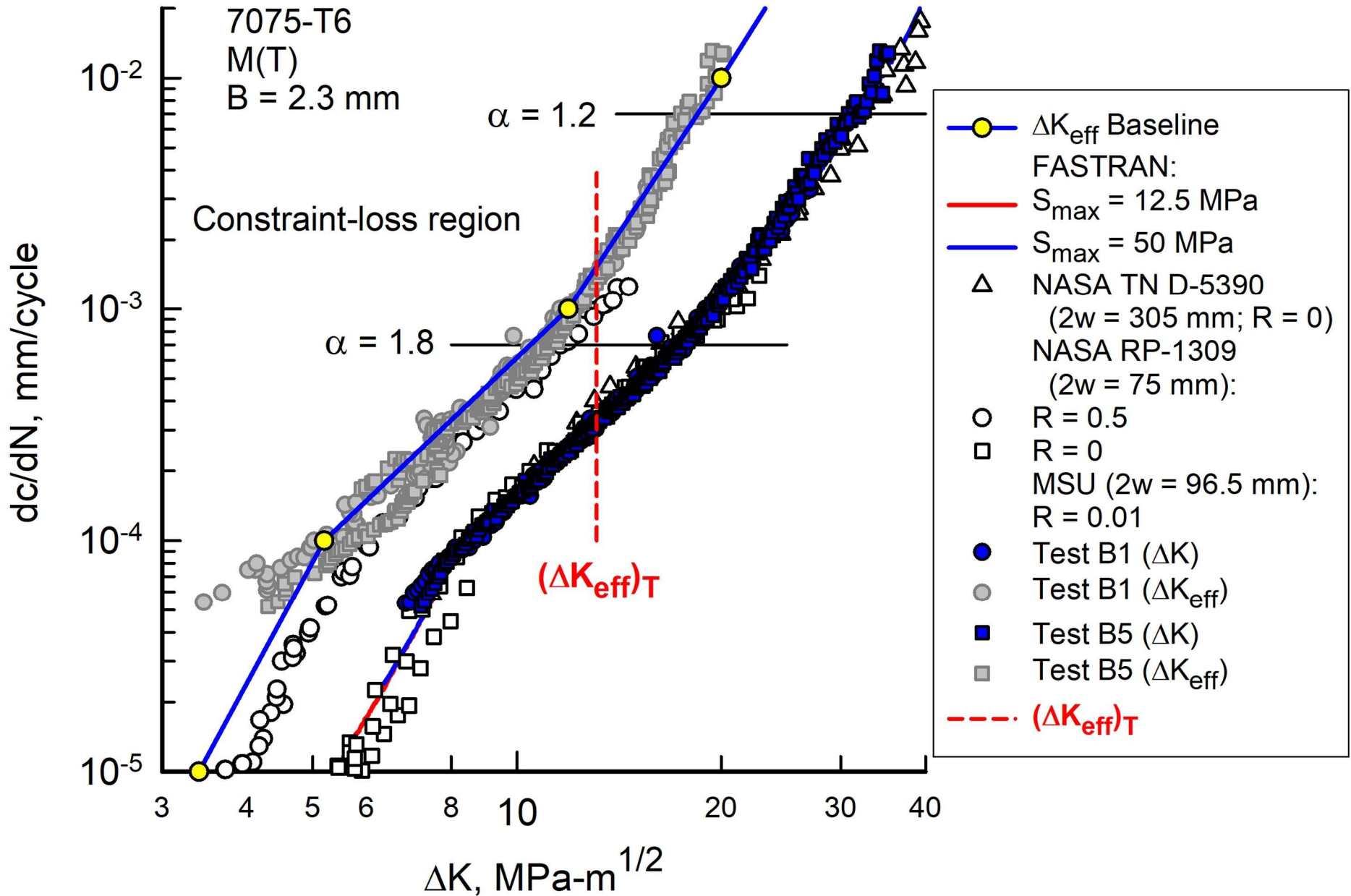
$$K_F = \frac{K_{Ie}}{1 - m (S_n / \sigma_u)}$$

$$S_n < \sigma_{pl}$$

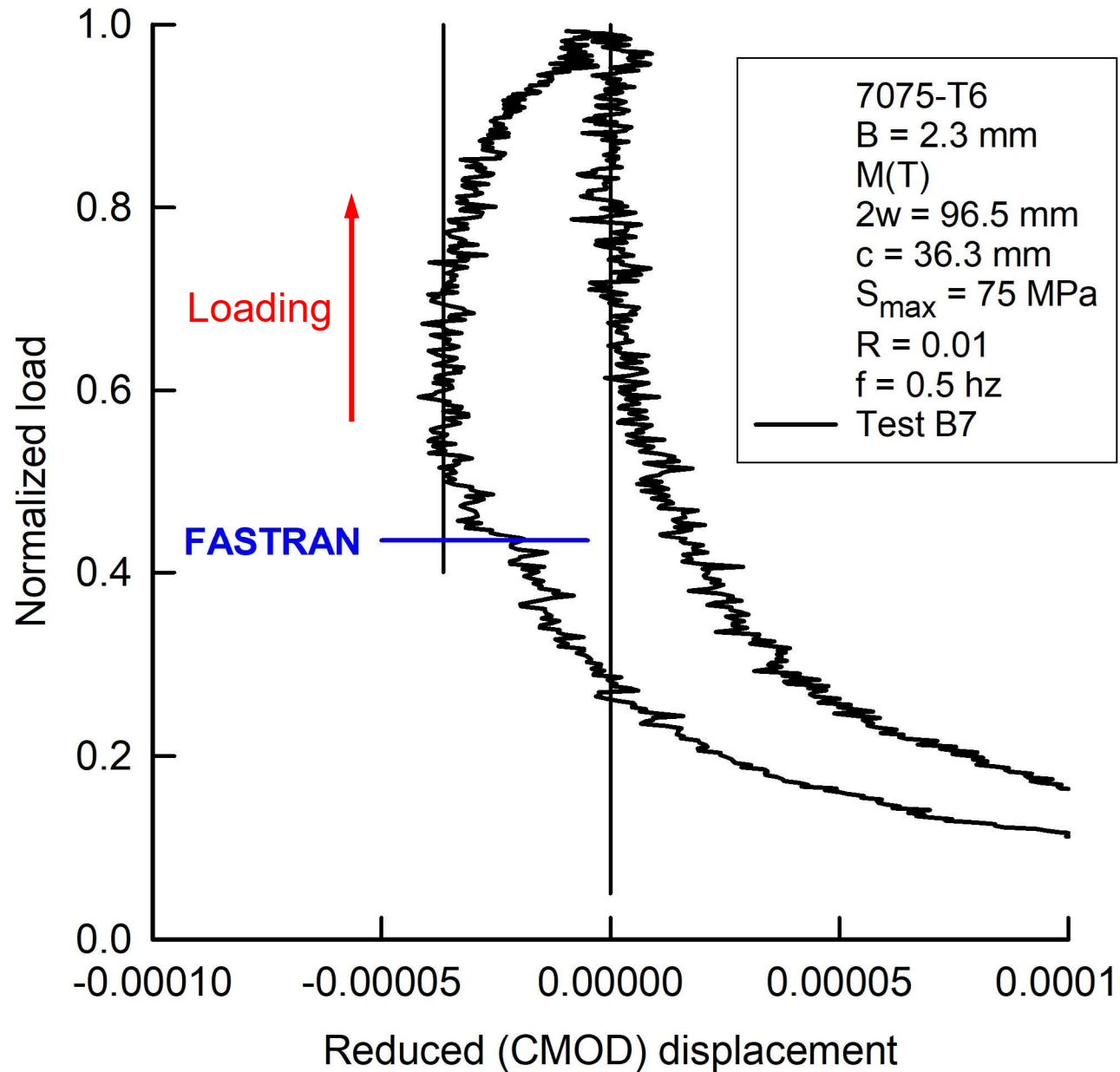
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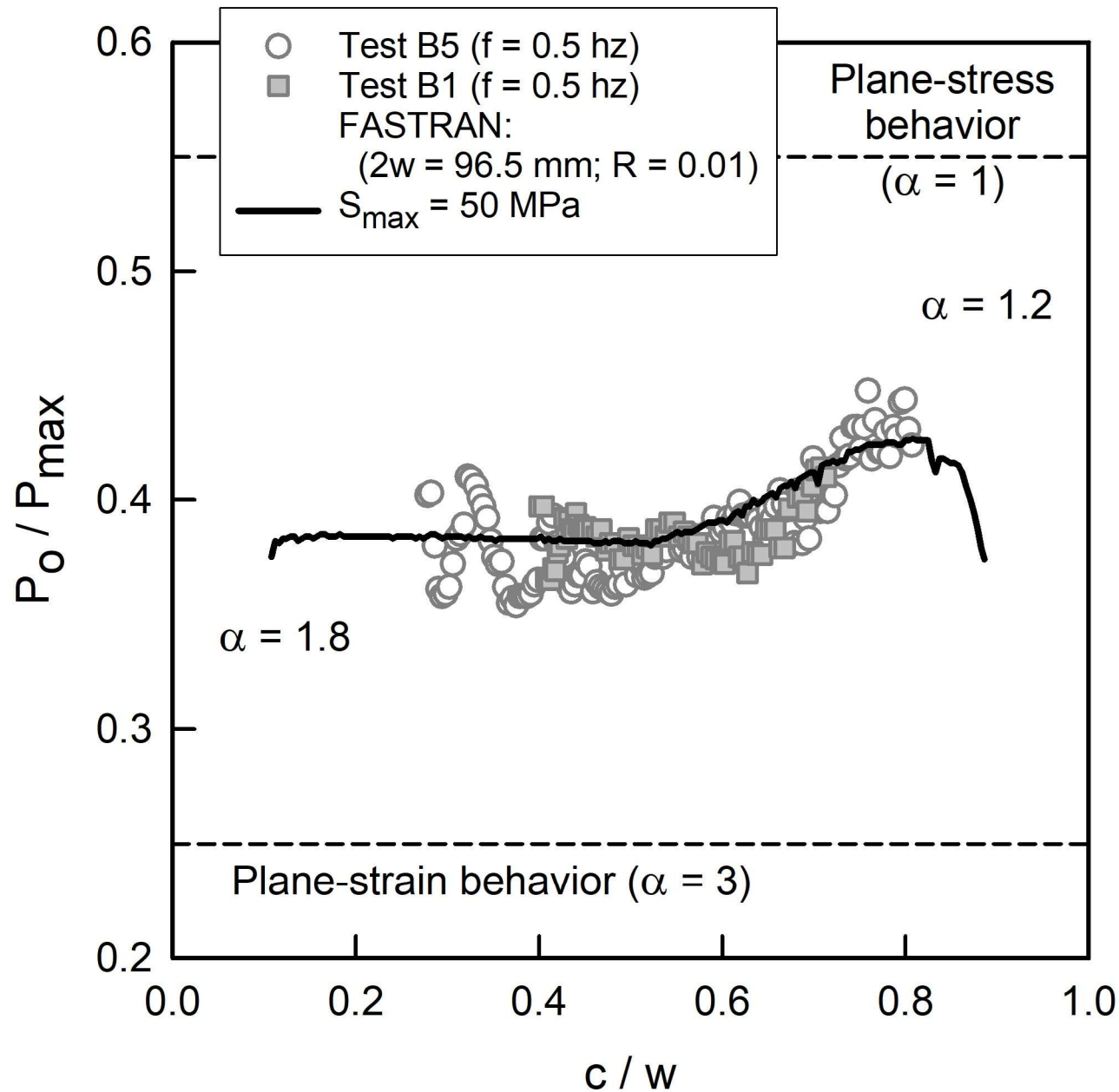
Stress-Intensity Factor (SIF) against Rate Data for 7075-T6 M(T) Specimens – Hudson, Newman et al. (NASA LaRC)



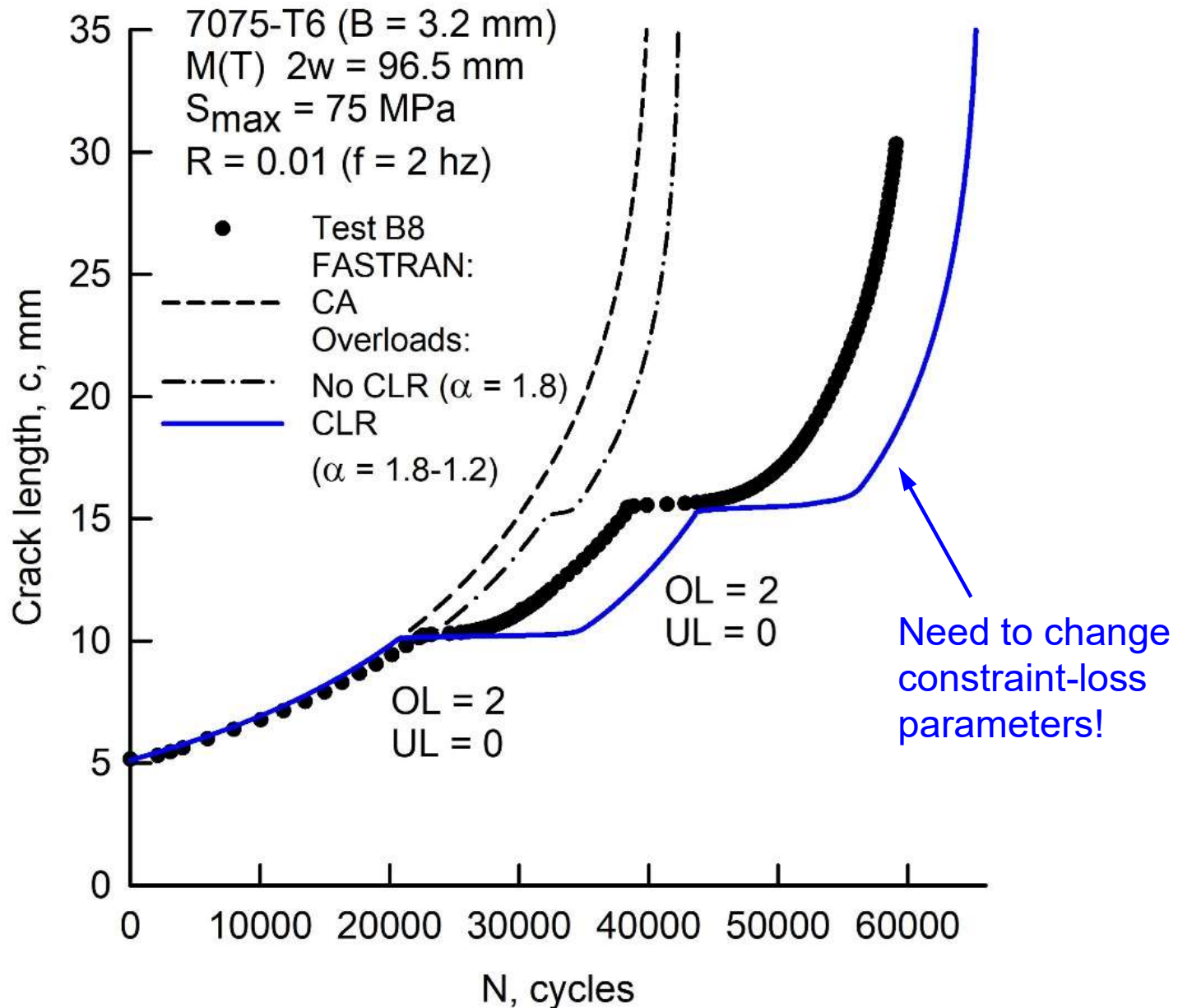
Crack-Opening-Load Determined from Load-Reduced CMOD Record and FASTRAN during Constraint-Loss Regime using Elber's Method



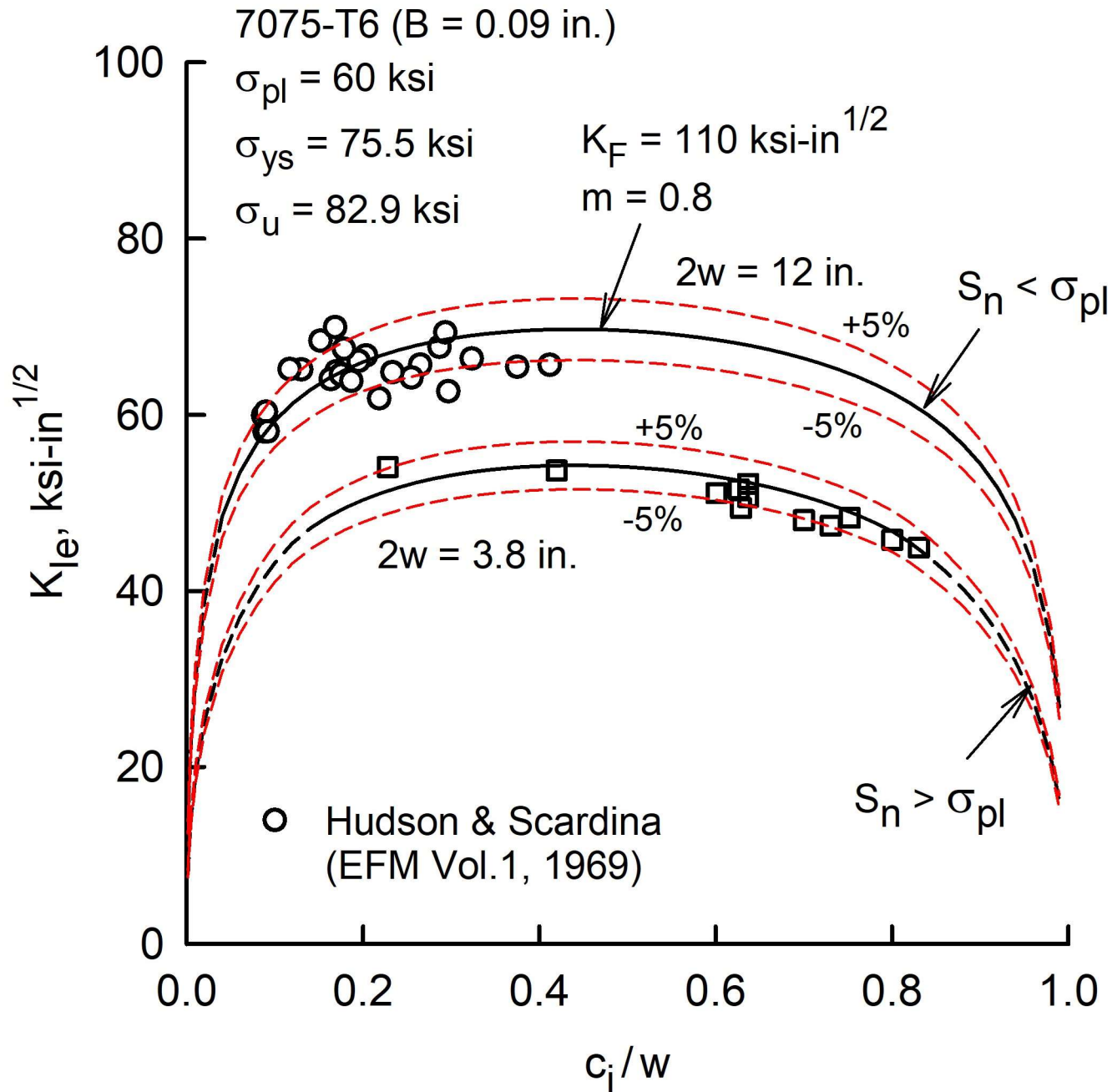
Crack-Opening-Load Ratio against Crack Length to Width Ratio during Constraint-Loss Regime



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



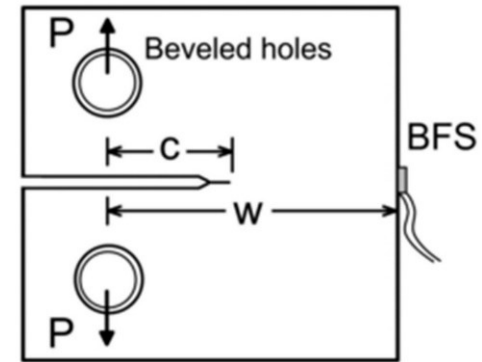
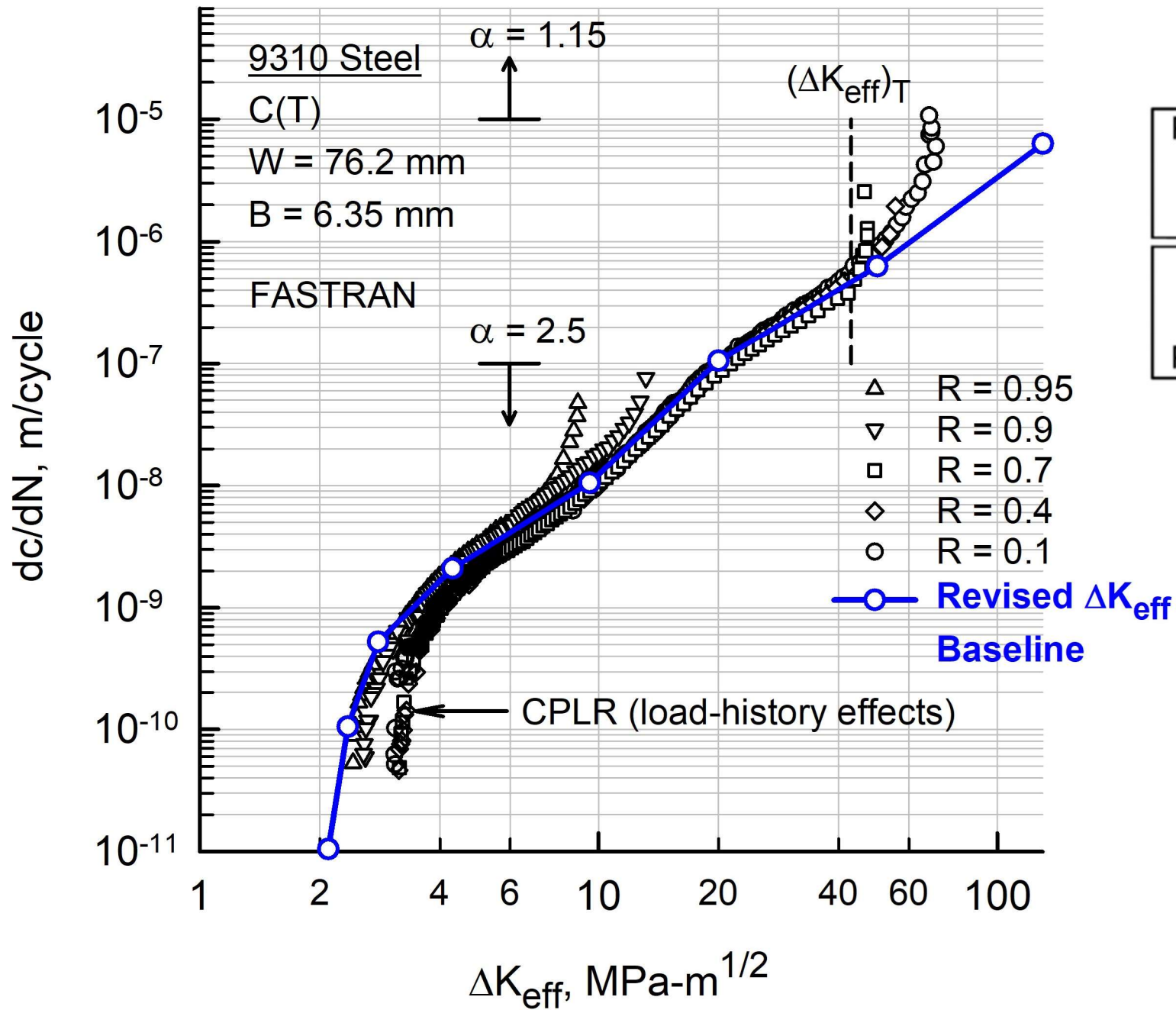
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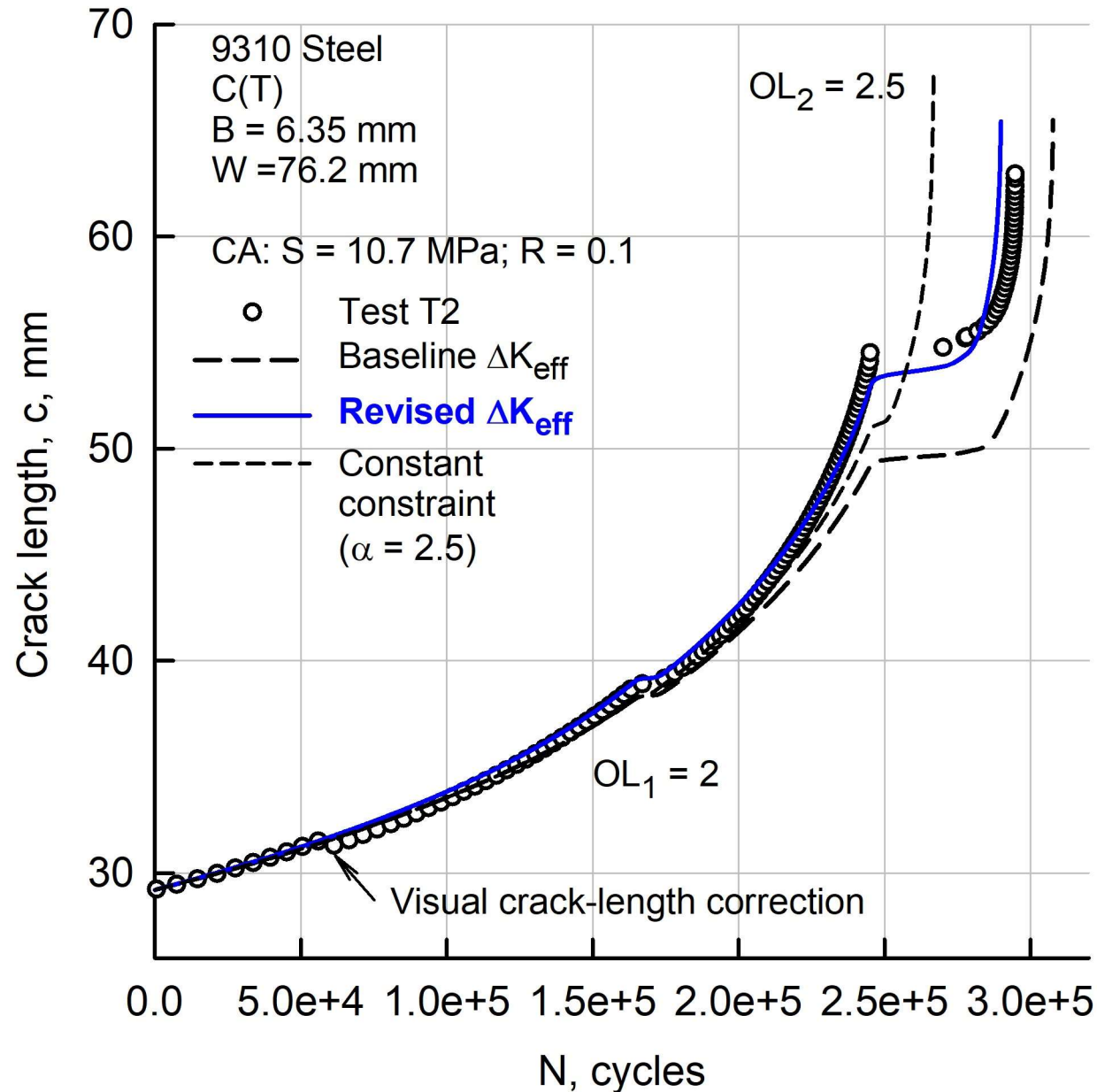
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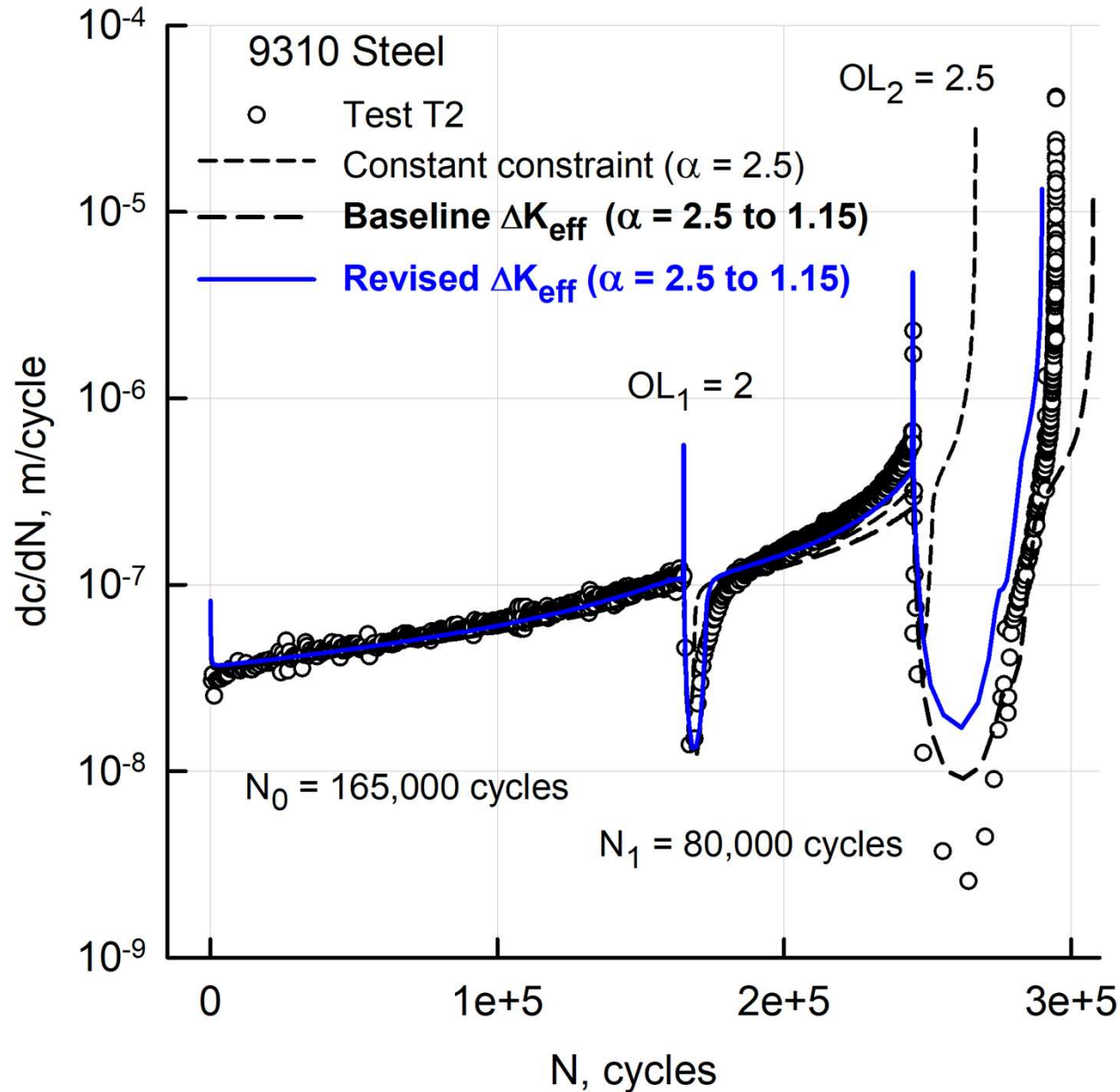
Effective SIF Relation for 9310 Steel C(T) Specimens



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



Measured and Predicted Crack-Growth Rates for C(T) Specimen made of 9310 Steel under Repeated Single-Spike Overloads

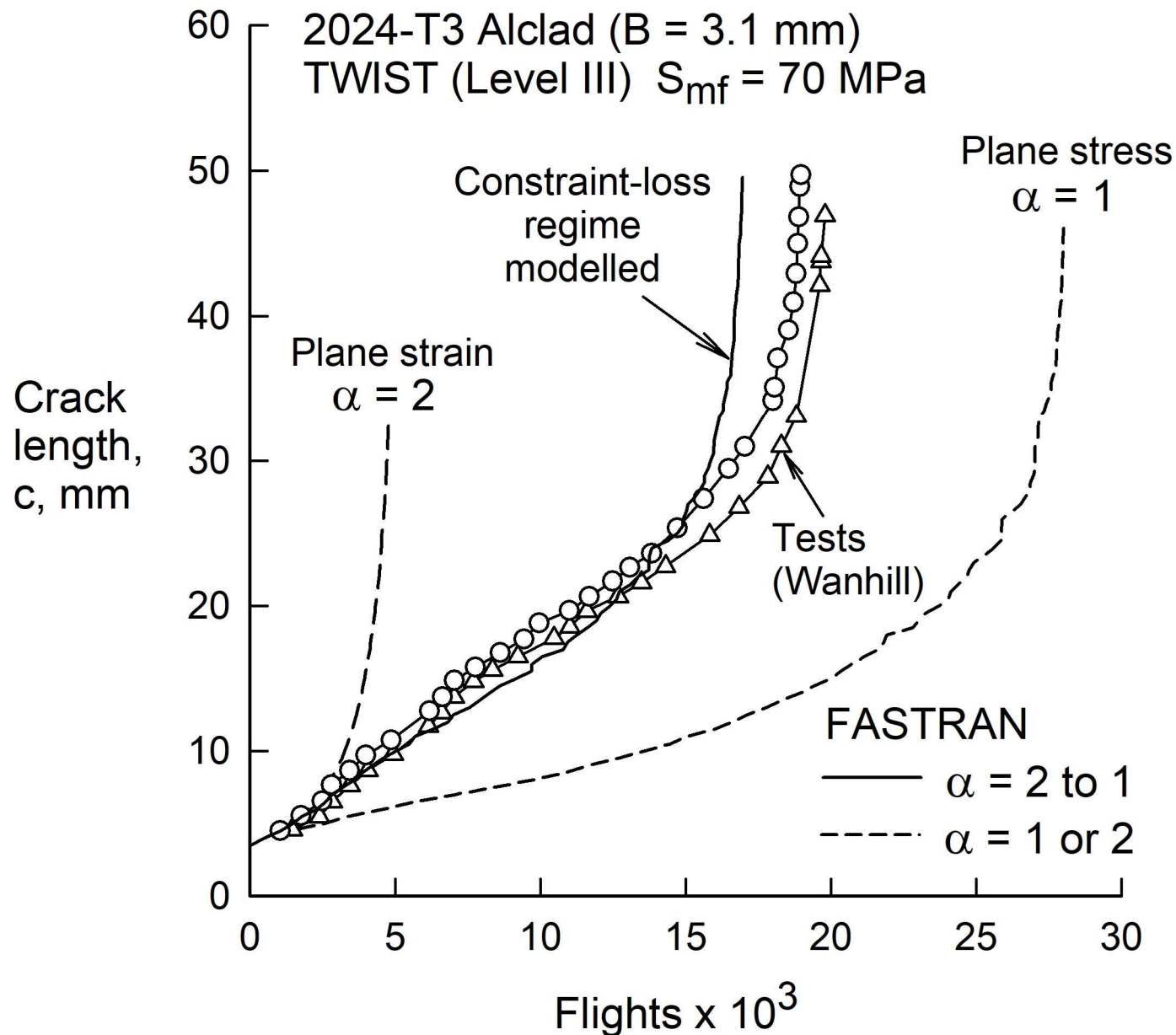


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Crack Growth under TWIST (Level III) Spectrum Loading

Wanhill (1977)



Concluding Remarks

- Transition from plane-strain to plane-stress behavior (flat-to-slant crack growth) occurs at **constant crack-growth rate** and is **controlled** by $(\Delta K_{\text{eff}})_T$.
- “Constant” constraint behavior was **unable** to predict the delays caused by single-spike overloads/underloads and crack growth under the TWIST (Level 3) spectrum loading.
- Constraint-loss behavior from plane-strain to plane-stress behavior was **able** to calculate or predict the delays caused by single-spike overloads and underloads.
- Constraint-loss behavior from plane-strain to plane-stress behavior was **needed to calculate** crack growth under the TWIST (Level 3) spectrum loading.