Future Recommendations on Fatigue-Crack Growth Testing and Analyses

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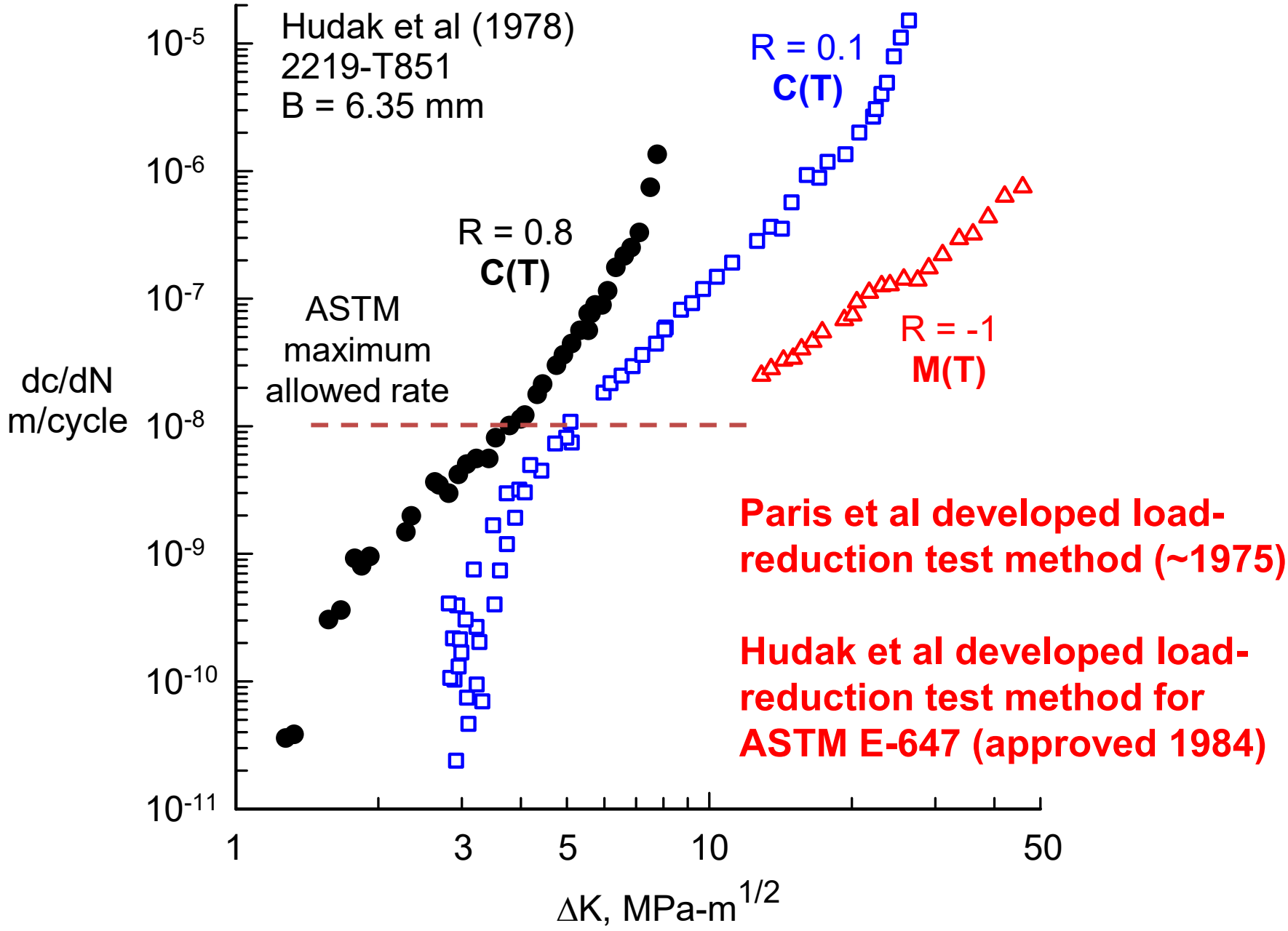
USA

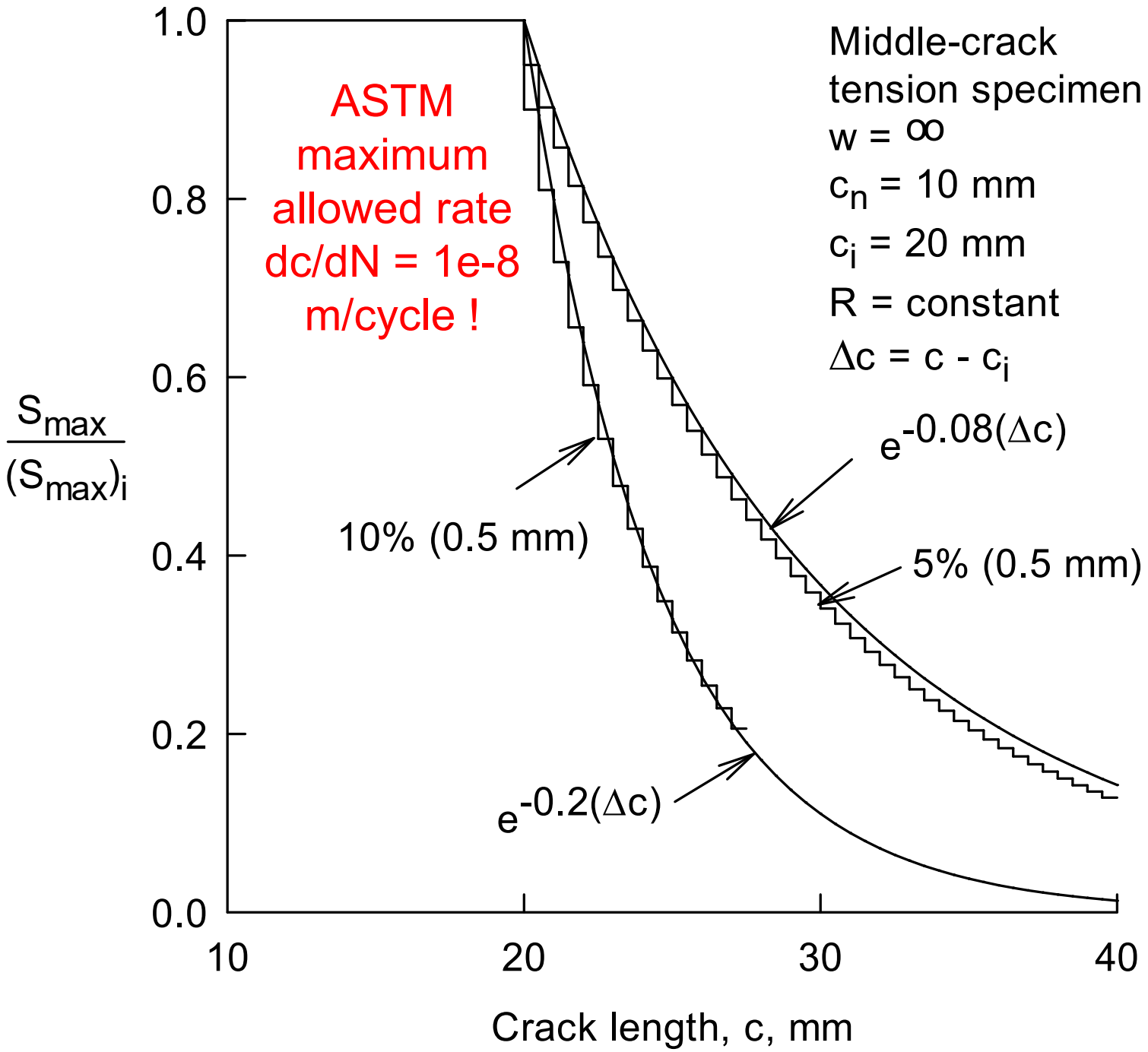
Data used in Original Development of ASTM E-647 Load-Reduction Test Procedures



Paris et al developed load-reduction test method (~1975)

Hudak et al developed load-reduction test method for ASTM E-647 (approved 1984)

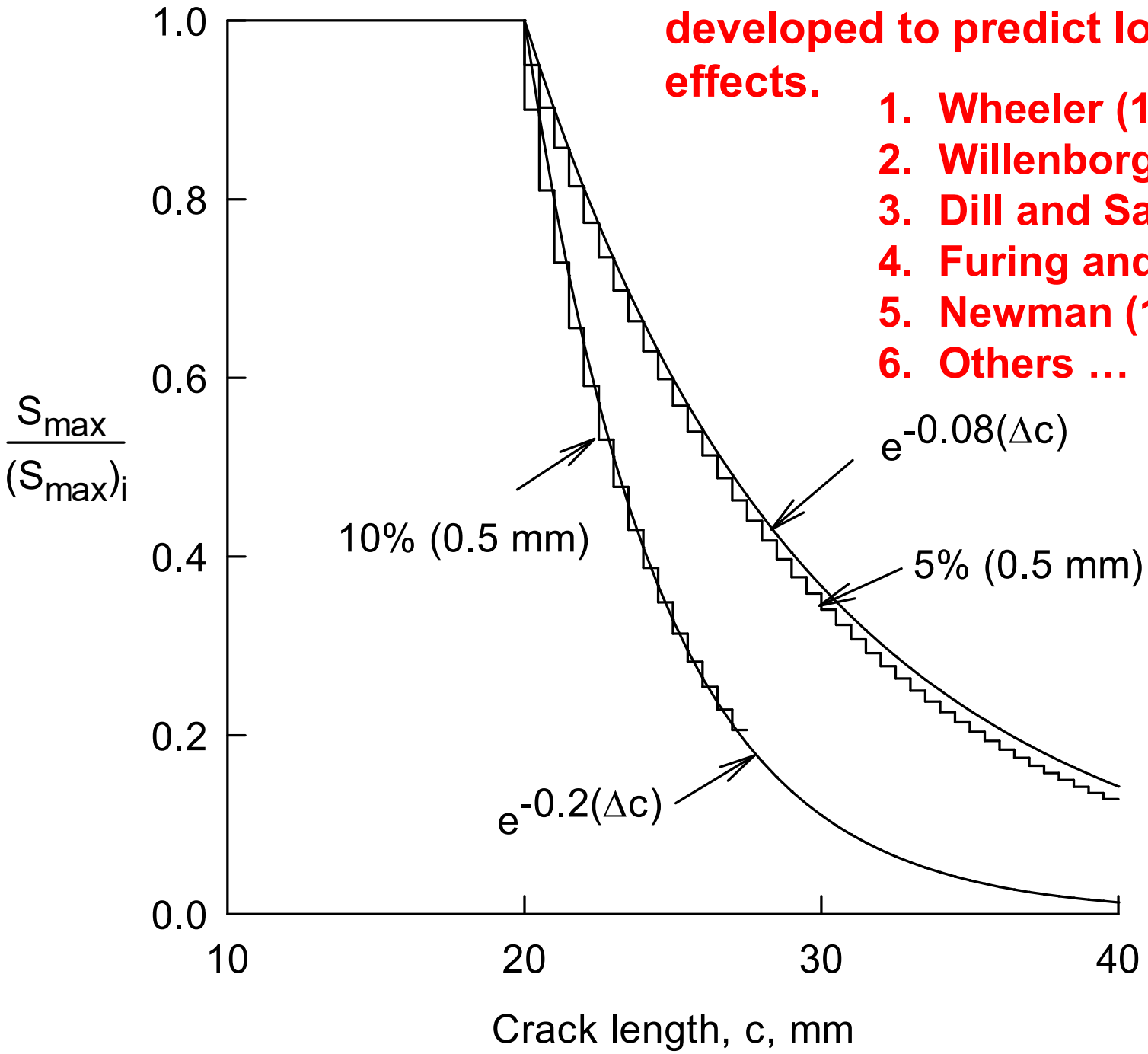
ASTM Load-Reduction Test Method (1984)



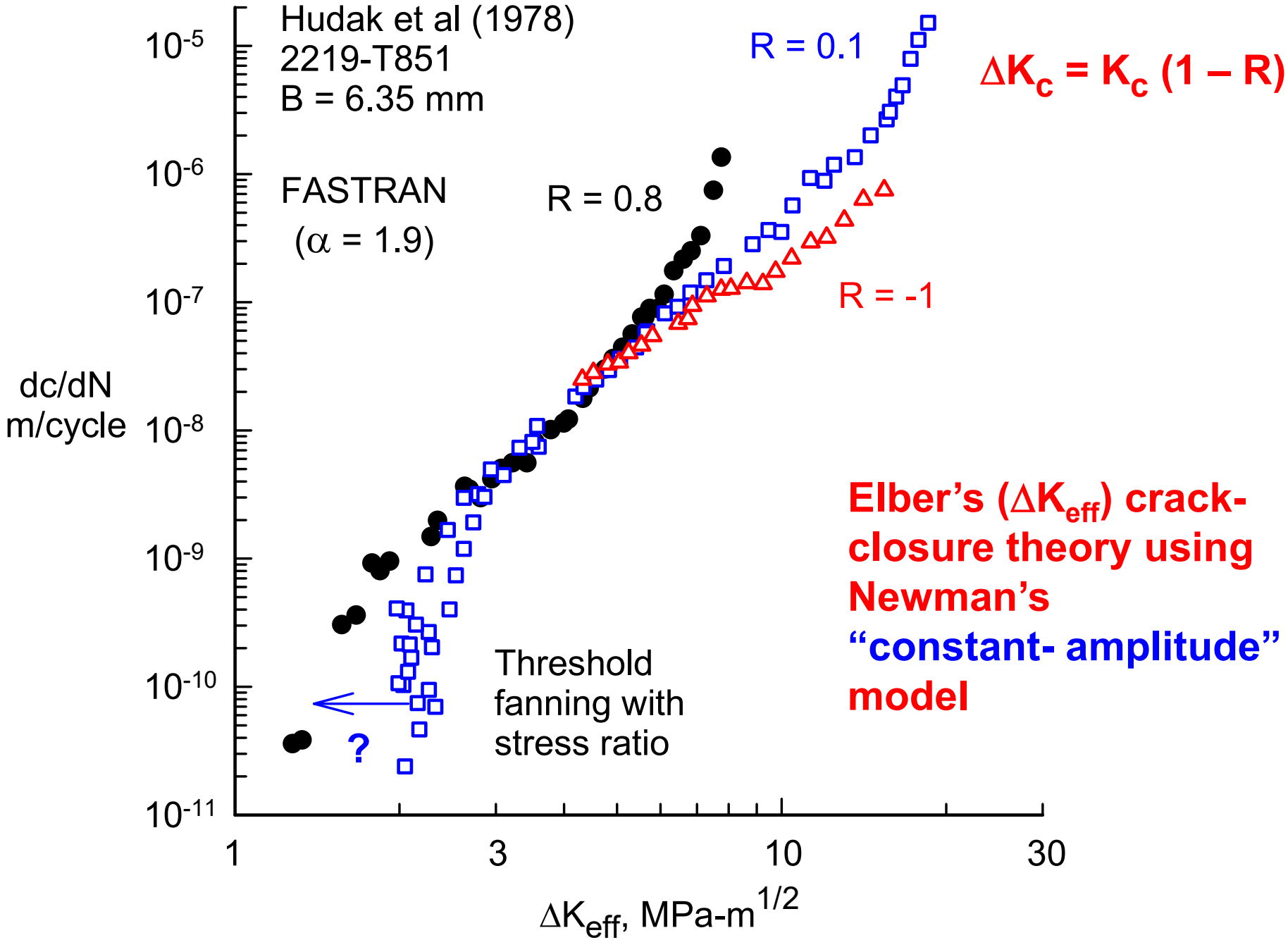
ASTM Load-Reduction Test Method (1984)

Retardation/acceleration models developed to predict load-history effects.

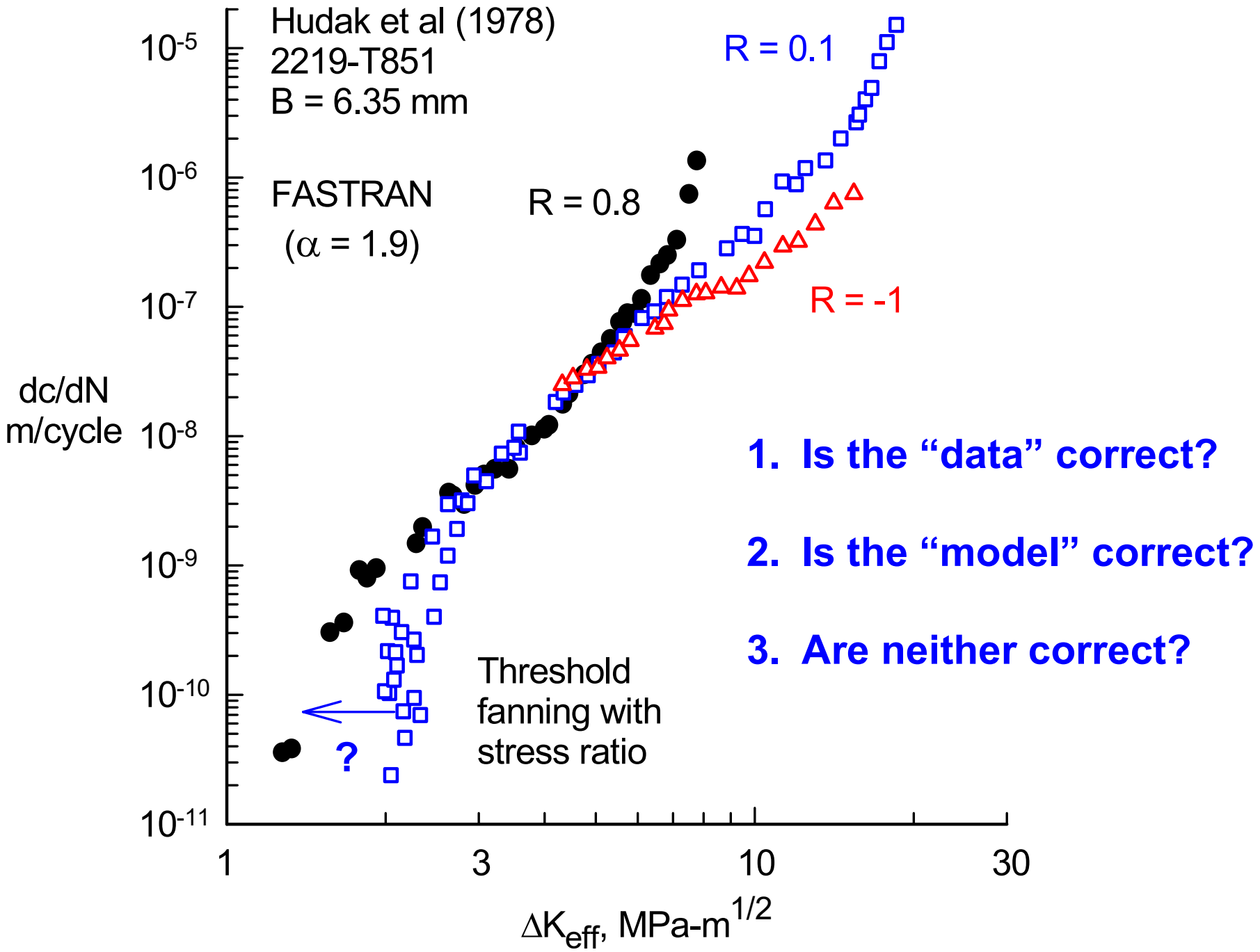
1. **Wheeler (1970)**
2. **Willenborg et al (1971)**
3. **Dill and Saff (1976)**
4. **Furing and Seeger (1979)**
5. **Newman (1977, 1981)**
6. **Others …**



Threshold Data Fanning with R Values



Threshold Data Fanning with R Values



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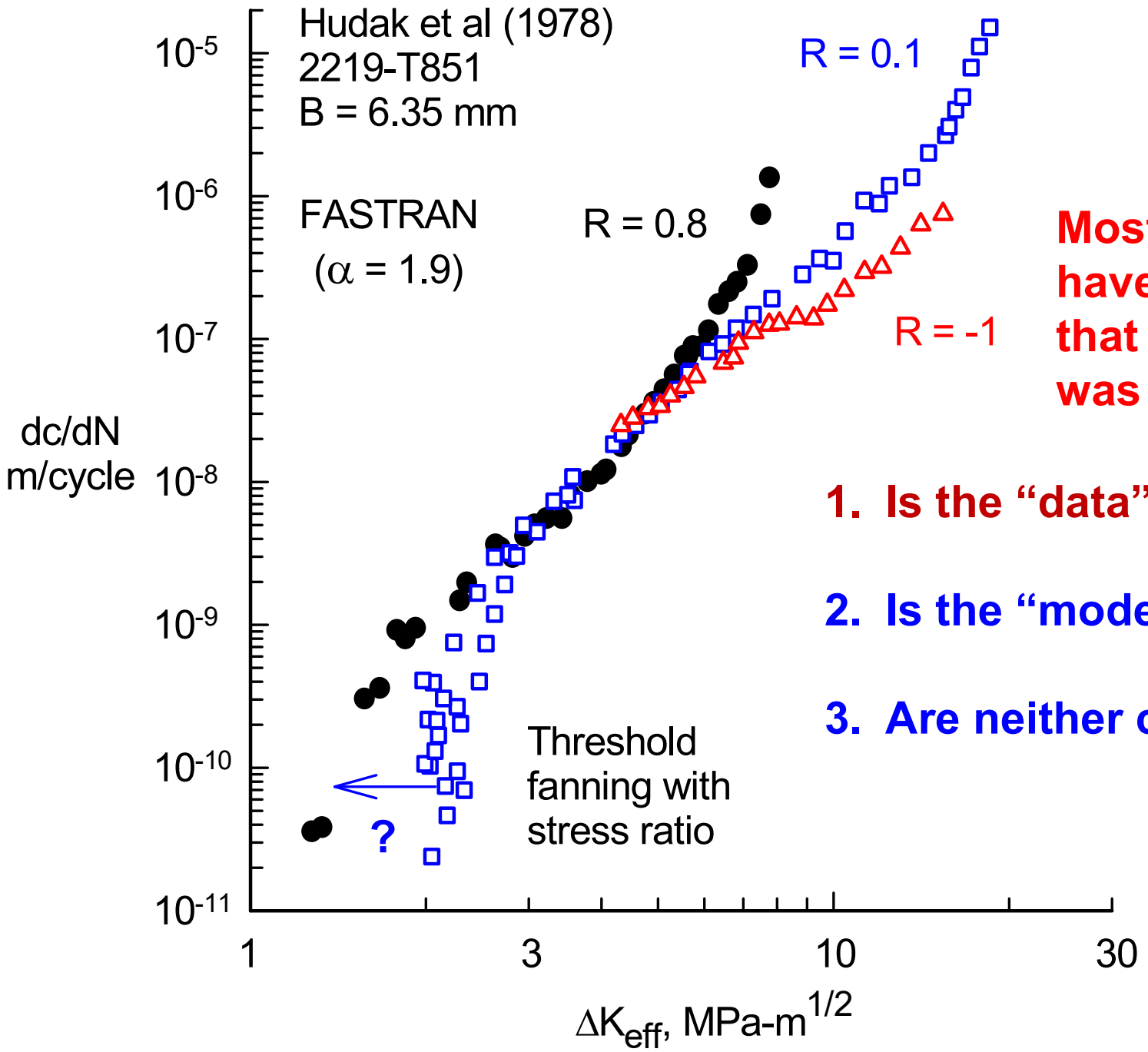


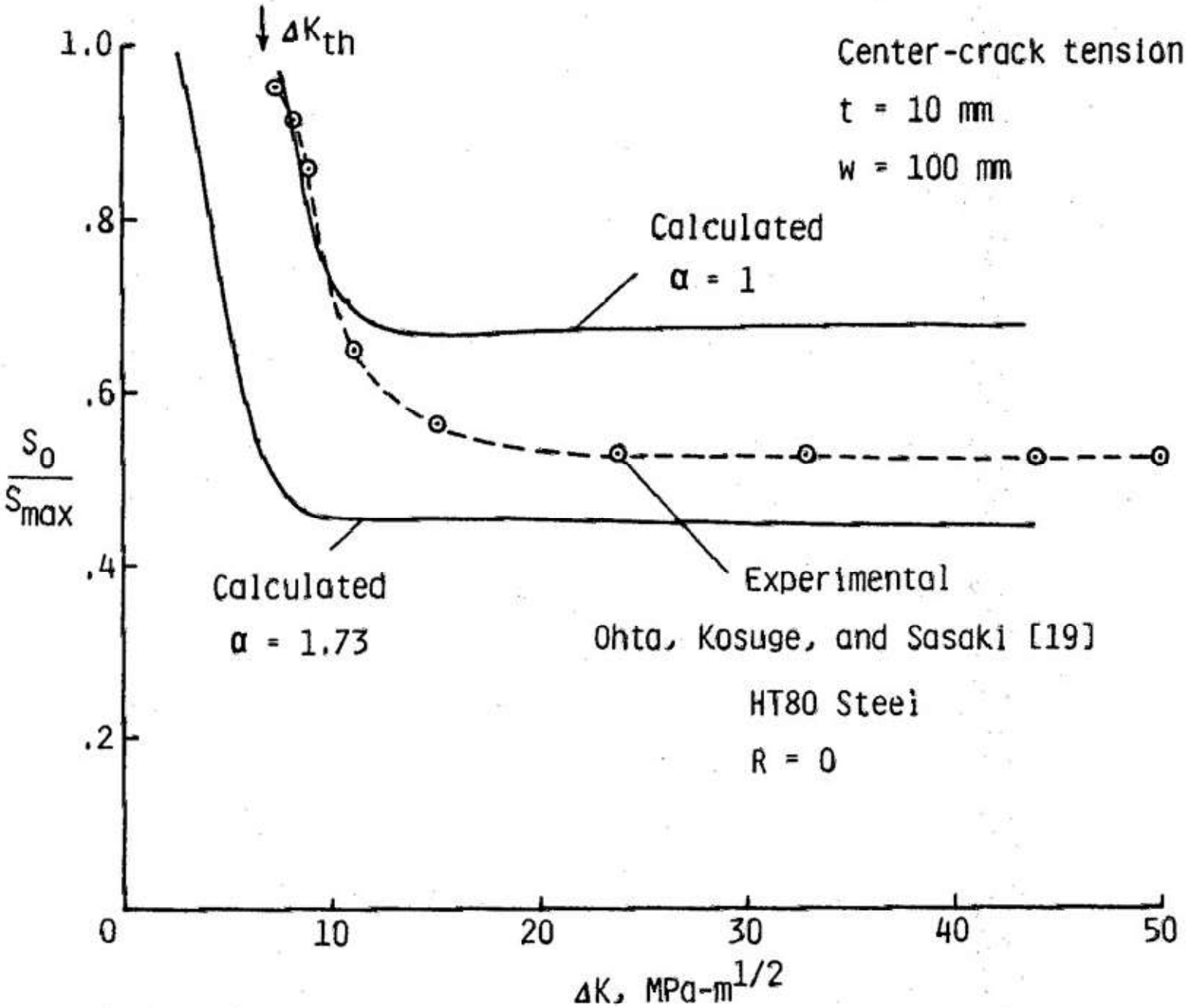
Most researchers have assumed that test "data" was correct !

1. **Is the "data" correct?**
2. **Is the "model" correct?**
3. **Are neither correct?**

Some Early History on Load-Reduction Testing

Ohta et.al. (**1978**): ***Load-reduction tests*** show ***rise*** in crack-opening loads (using ***local*** method) at various R !

Ohta et al. (1978) *Local* Crack-Opening Measurements and FASTRAN (1983) Calculations



Some Early History on Load-Reduction Testing (2)

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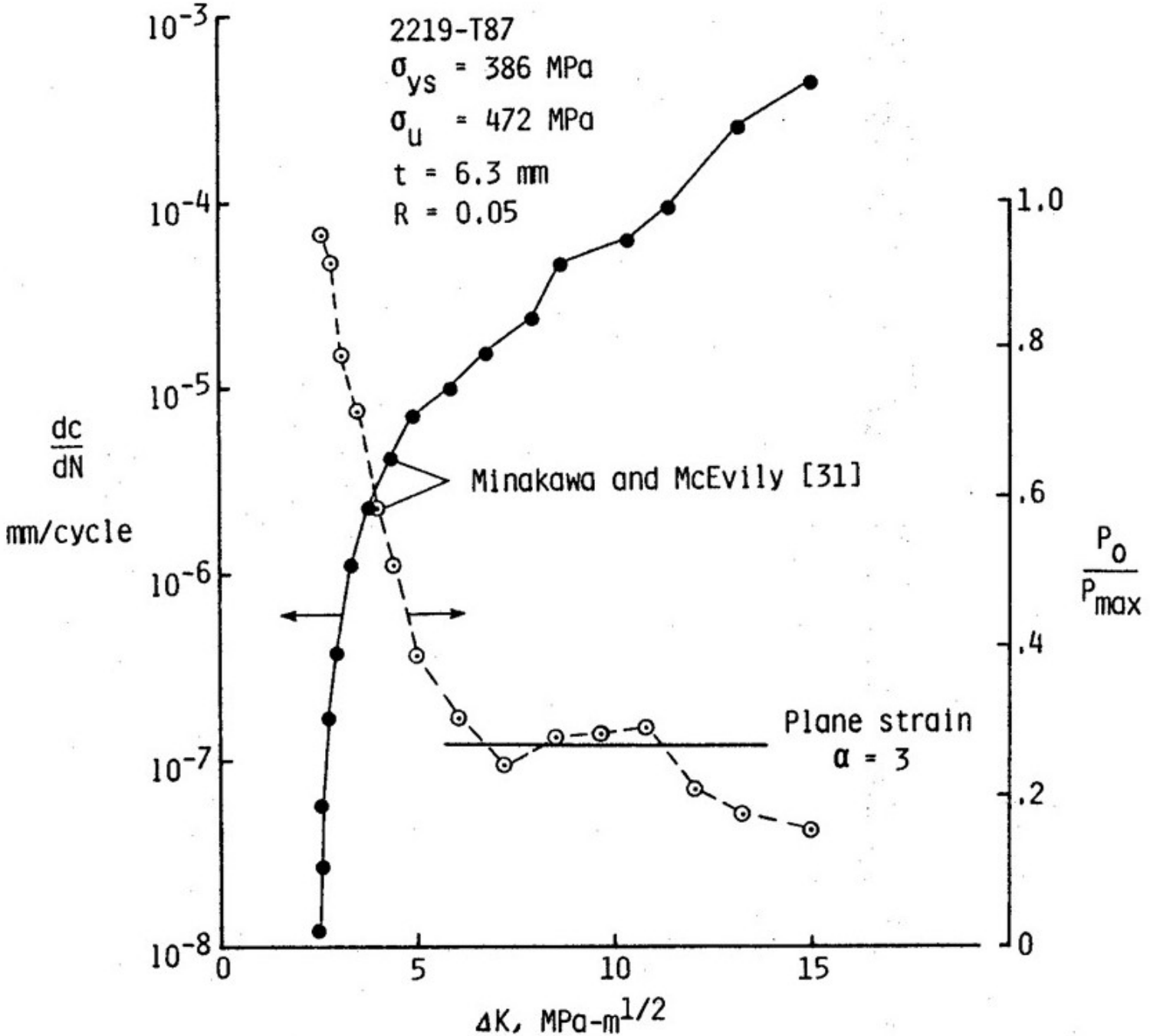
Minikawa & McEvily (**1981**): ***Load-reduction tests*** show ***rise*** in crack-opening loads (using ***remote*** method) at low R !

Minikawa & McEvily (1981) *Remote* Crack-Opening Measurements



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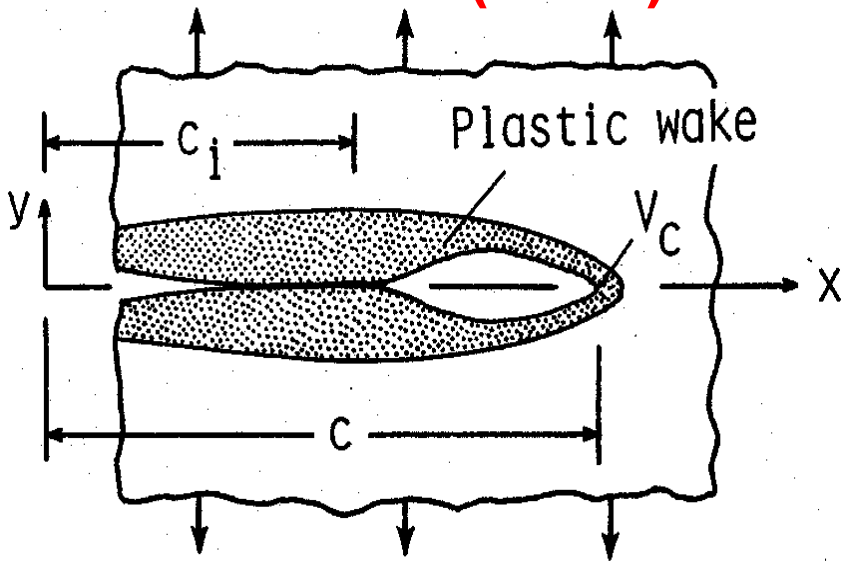
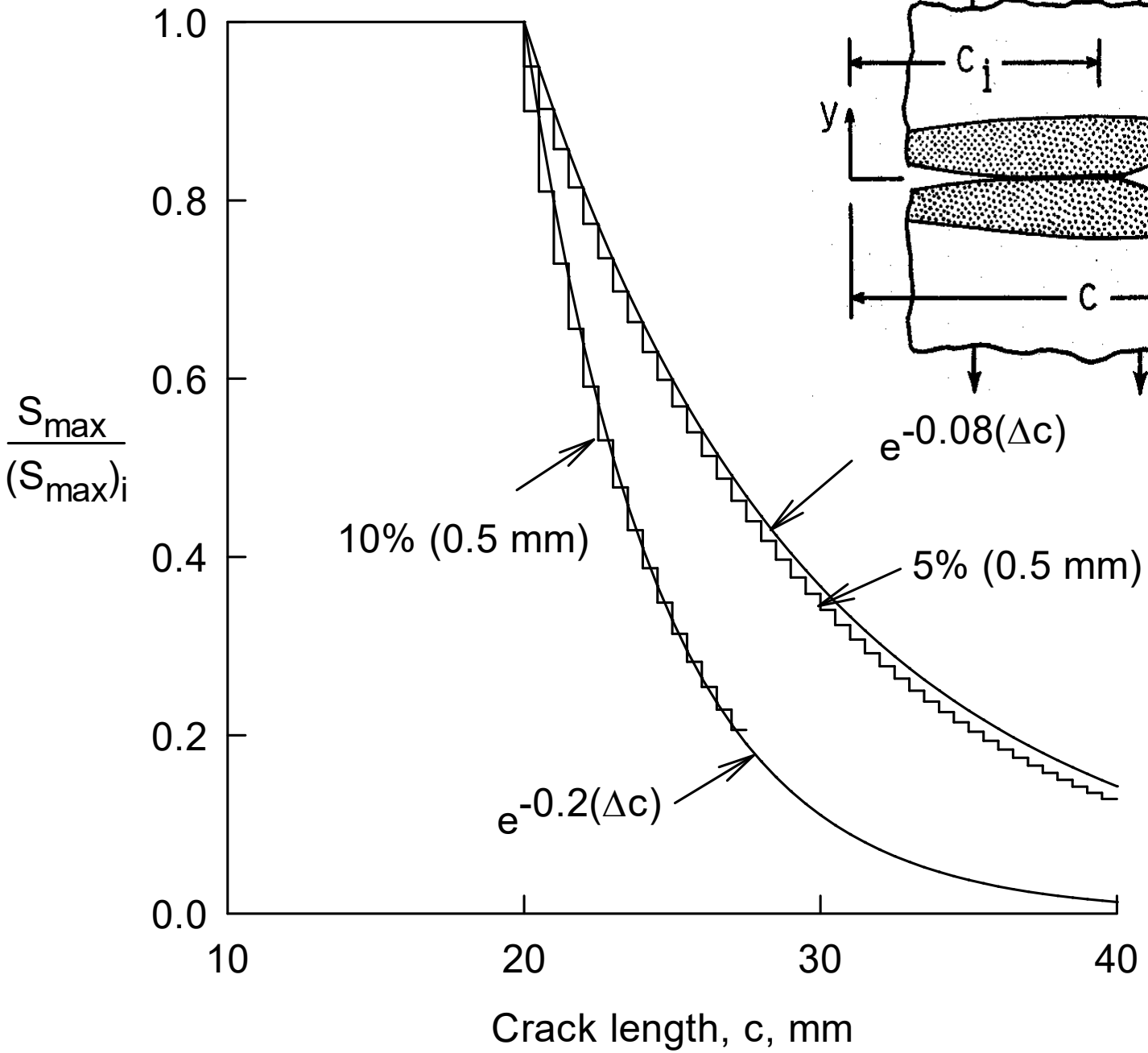
Newman (**1983**): ***Analyses*** using strip-yield model and **ASTM load-reduction** methods show ***rise*** in crack-opening loads due to ***PICC***!

ASTM Load-Reduction Method (circa 1980's)

Newman (1983)





Some Early History on Load-Reduction Testing (4)

Ohta et.al. (1978): ***Load-reduction tests*** show ***rise*** in crack-opening loads (using ***local*** method) at various R !

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Newman (1983): ***Analyses*** using strip-yield model and ASTM **load-reduction** methods show ***rise*** in crack-opening loads due to PICC !

Committee E-24 (1984) approved current load-reduction method for E-647.

ASTM Committees E-24 and E-08 members have ***NEGLECTED*** past literature that indicated load-history effects from load-reduction testing due to a rise in crack-opening load behavior!!

Some Recent History on Load-Reduction Testing

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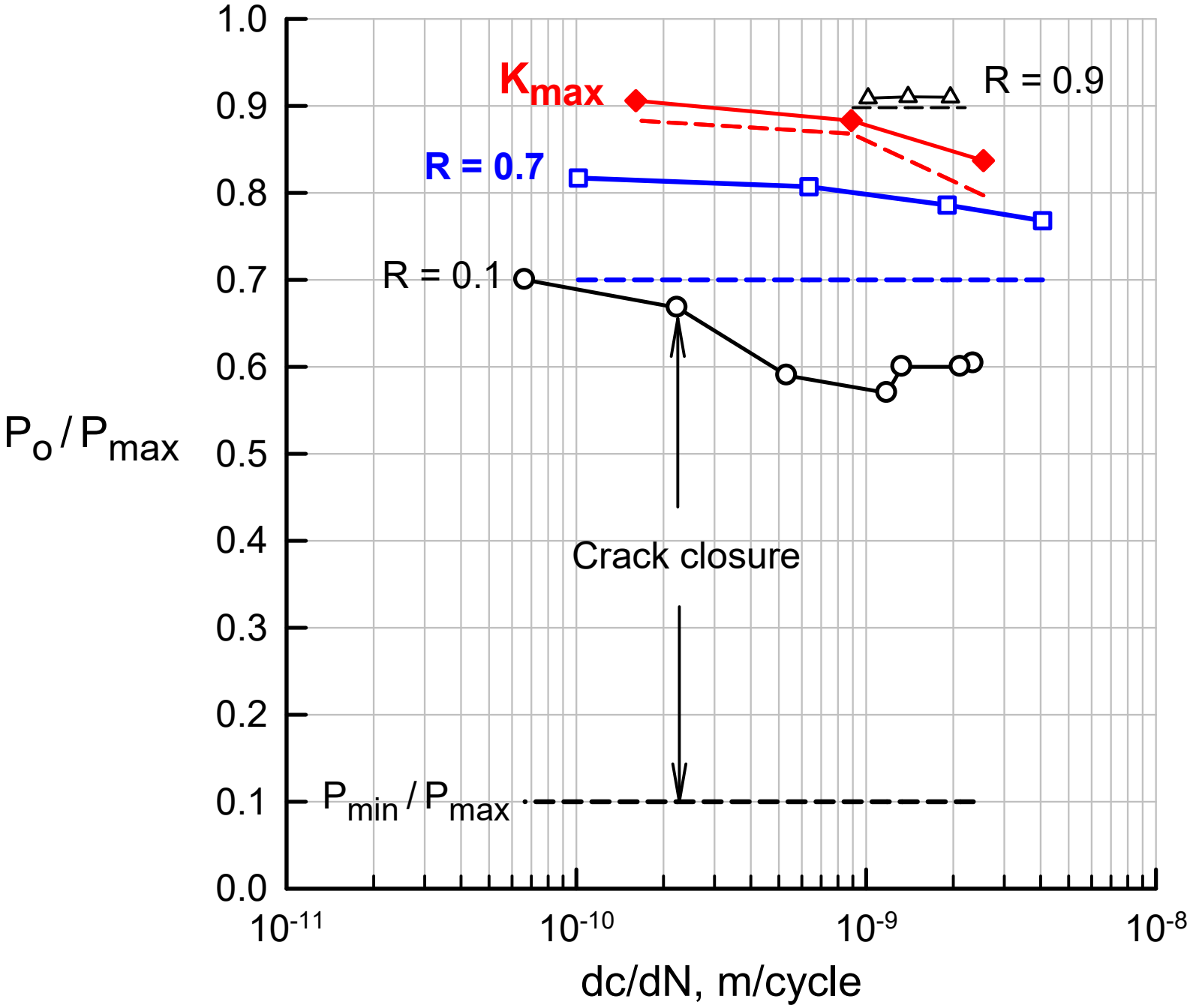
Yamada et.al. (**2008**): ***Load-reduction tests*** show ***rise*** in crack-opening loads (using ***local*** method) at low R and "***high-R***" closure!

Yamada et.al. (2008) "*Locally*" Measured Crack-Opening Loads for 2324-T39 using Load-Reduction Method



***K_{max}* test is a load-reduction test and *K* does not control "*crack-surface displacements*"**

Some Recent History on Load-Reduction Testing (2)

Ohta et.al. (1978): ***Load-reduction tests*** show ***rise*** in crack-opening loads (using ***local*** method) at various R!

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J. A. Newman et.al. (NASA TM-**2008**-215331): Conducted many ***load-reduction tests*** but ***crack-closure behavior*** was "***not***" measured.

Concluded:

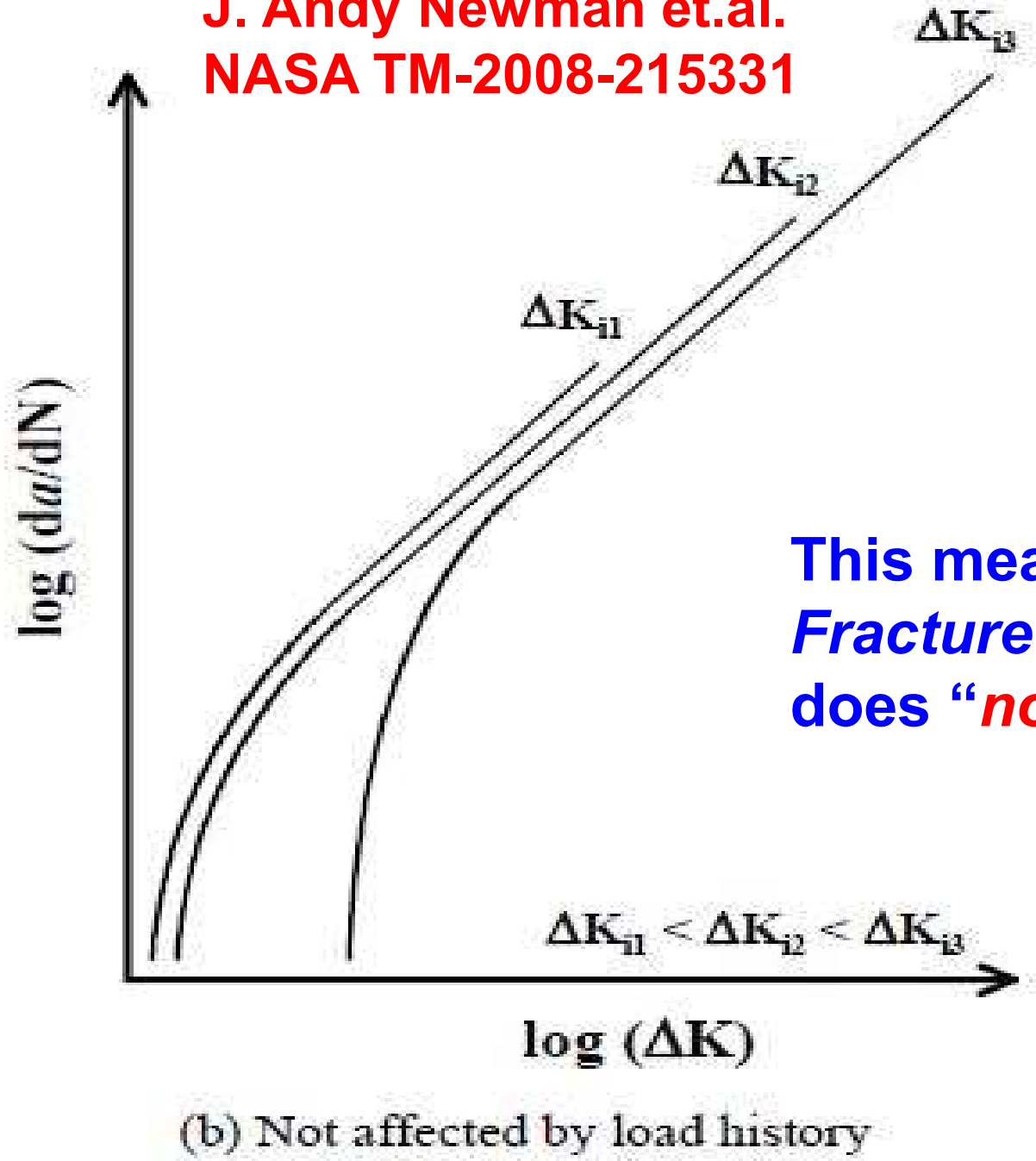
(1) "… no load history problems were found when the standard crack growth test procedure (ASTM E647) was strictly followed."

Fanning of ΔK-Rate Data "NOT Affected by Load History"?

***Figure from*:**

J. Andy Newman et.al.

NASA TM-2008-215331

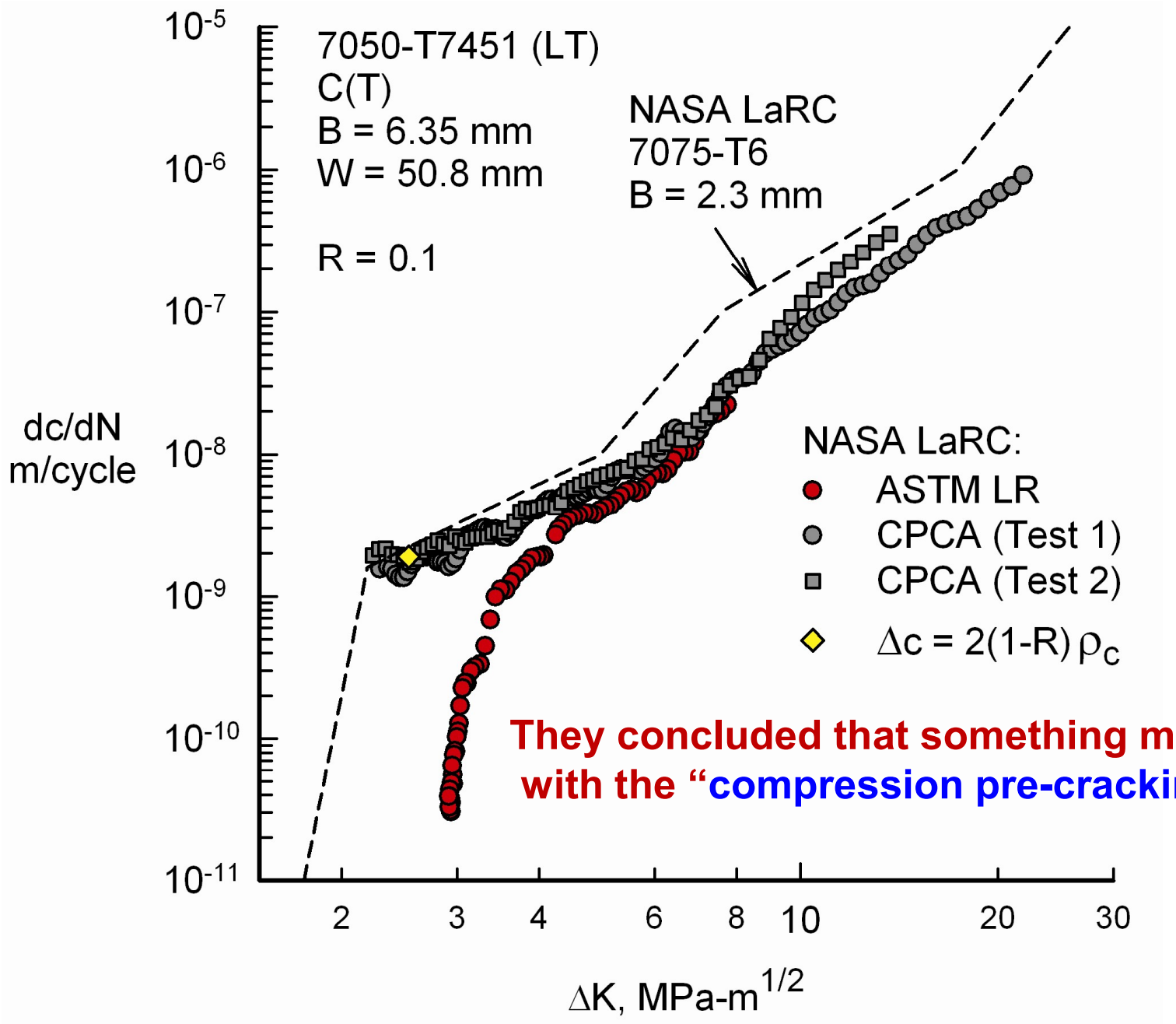


(b) Not affected by load history

This means that *Fracture Mechanics* does "*not*" work !!

Comparison of ASTM Load-Reduction and Compression Pre-cracking Constant Amplitude (CPCA) Test Data at R = 0.1

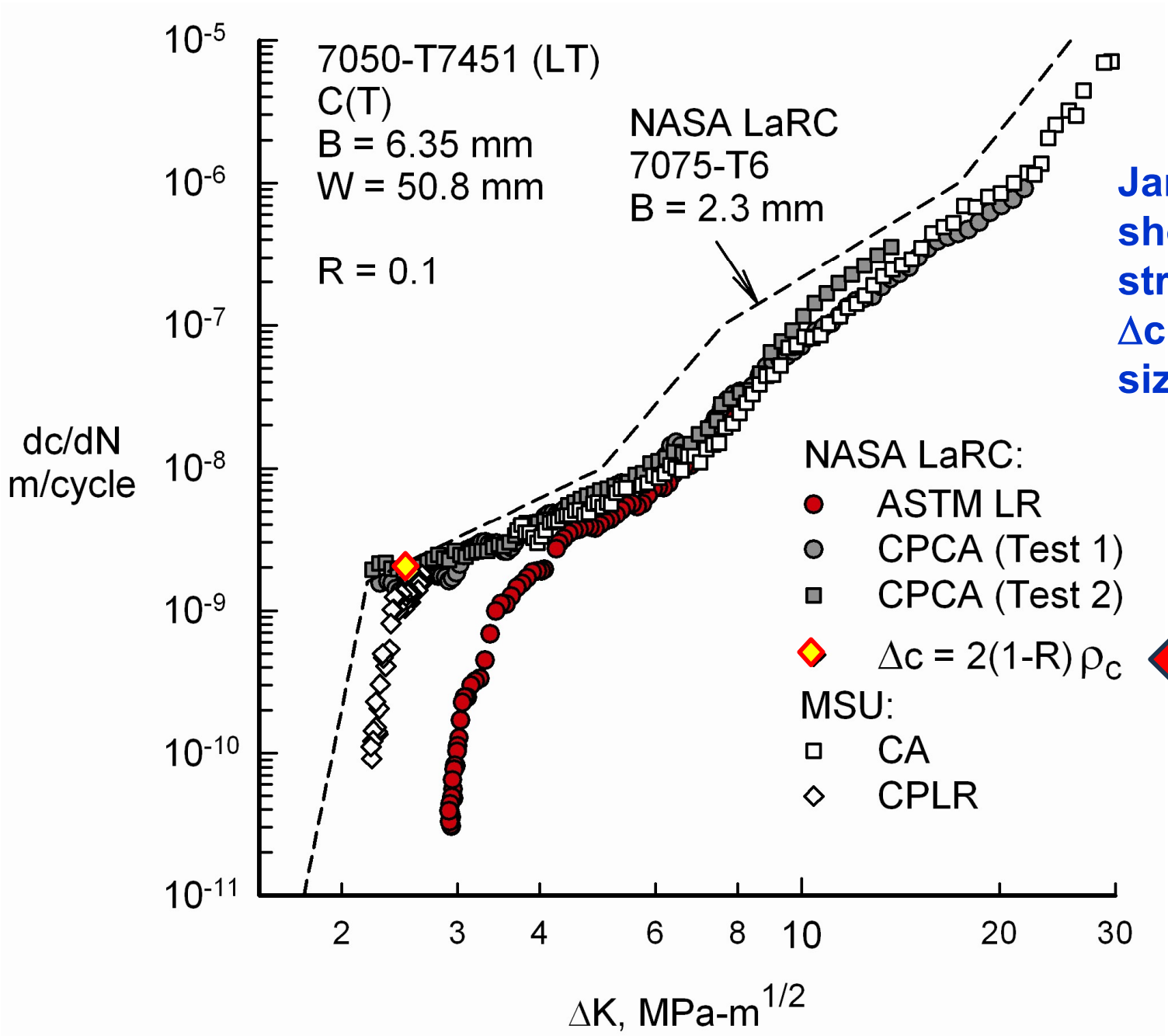
J. Andy Newman, Mark James (2007)



They concluded that something must be wrong with the "compression pre-cracking" tests!

Comparison of ASTM Load-Reduction and CPLR/CPCA Test Data at R = 0.1

J. Andy Newman, Mark James (2007) and Newman-Yamada (2009)



James et.al. (2005) showed "no" residual stress effects for $\Delta c > 2$ plastic-zone sizes using EPFEA!

Crack growth beyond the Δc criteria has no residual stress effects and is steady-state behavior!

Some Recent History on Load-Reduction Testing (3)

Ohta et.al. (1978): ***Load-shedding tests*** show ***rise*** in crack-opening loads (using ***local*** method) at various R!

Minikawa & McEvily (1981): ***Load-reduction tests*** show ***rise*** in crack-opening loads (using ***remote*** method) at low R!

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(1) "… no load history problems were found when the standard crack growth test procedure (ASTM E647) was strictly followed."

(2) "… the compression pre-cracking (CP) test method was shown to produce load history effects …"

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Concluded:

(1) "… no load history problems were found when the standard crack growth test procedure (ASTM E647) was strictly followed."

(2) "… the compression pre-cracking (CP) test method was shown to produce load history effects …"

Andy Newman had "no" experimental justification for conclusions—but only a *strong negative feeling* about CP testing!!!

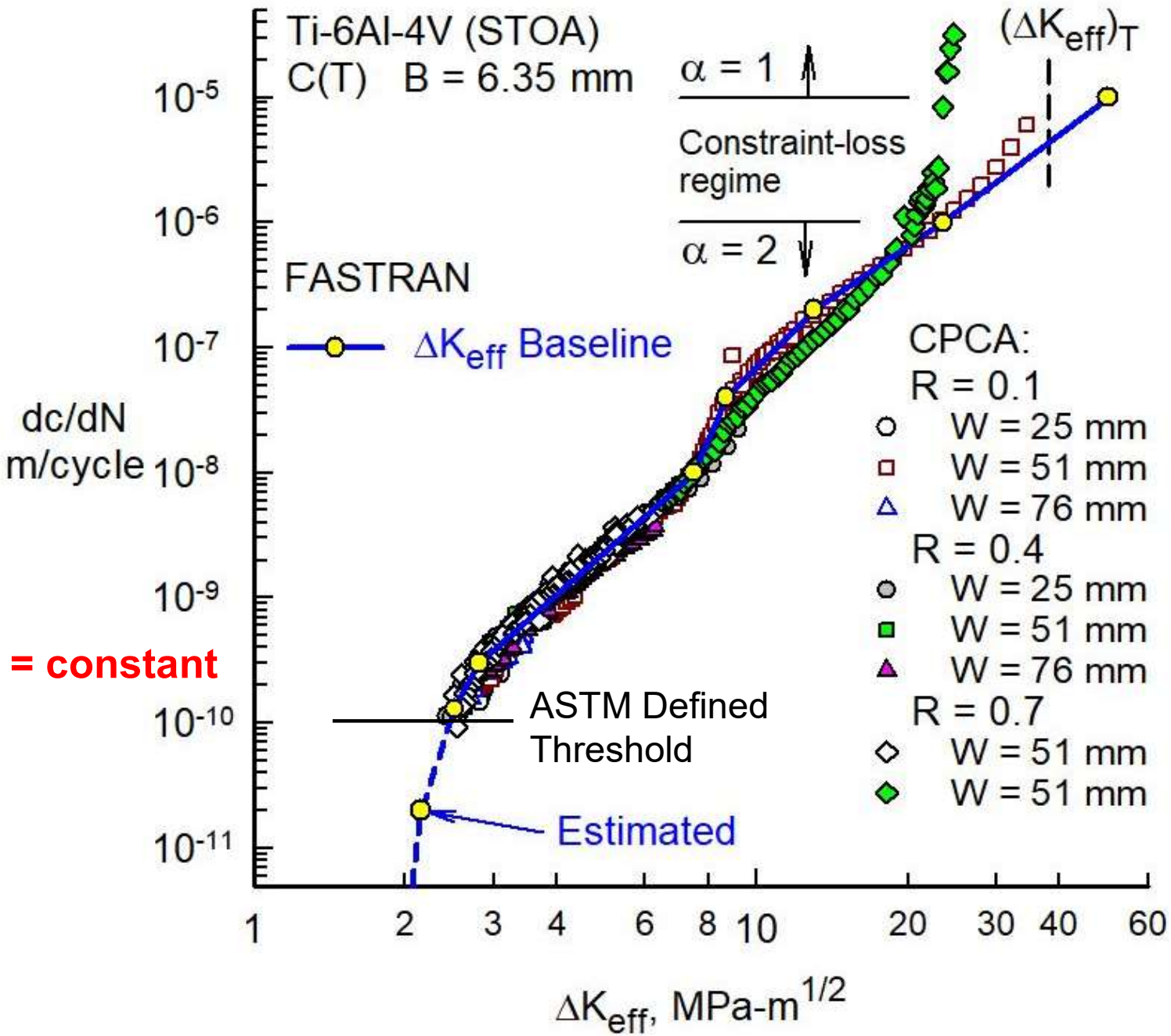
Future ASTM Recommendations

1. **Reactivate the "Crack-Closure" Task Group to study Plasticity-, Debris-, and Roughness-Induced Crack Closure (PICC, DICC and RICC) mechanisms and incorporate these concepts & equations into current standard(s)**

Elber's crack-closure concept has been able to ***correlate*** ΔK_{eff} against rate on many metallic materials over the past 40+ years (***but ignoring the flawed load-reduction test method data***)!

Example of Excellent ΔK_{eff}-Rate Correlation

Newman, Ruschau and Hill (2010)



$(\Delta K_{eff})_{th}$ = constant

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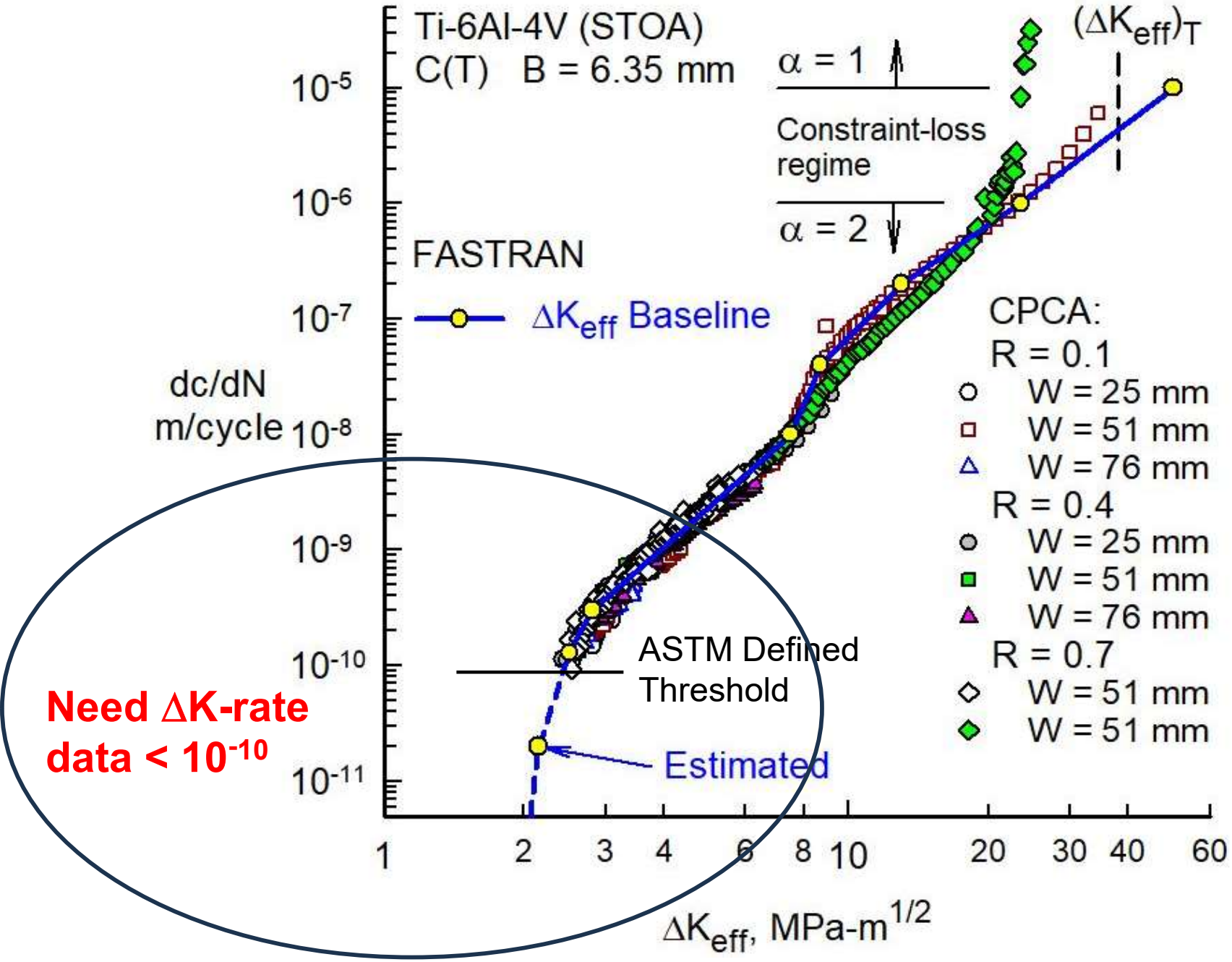
Example of Excellent ΔK_{eff}-Rate Correlation

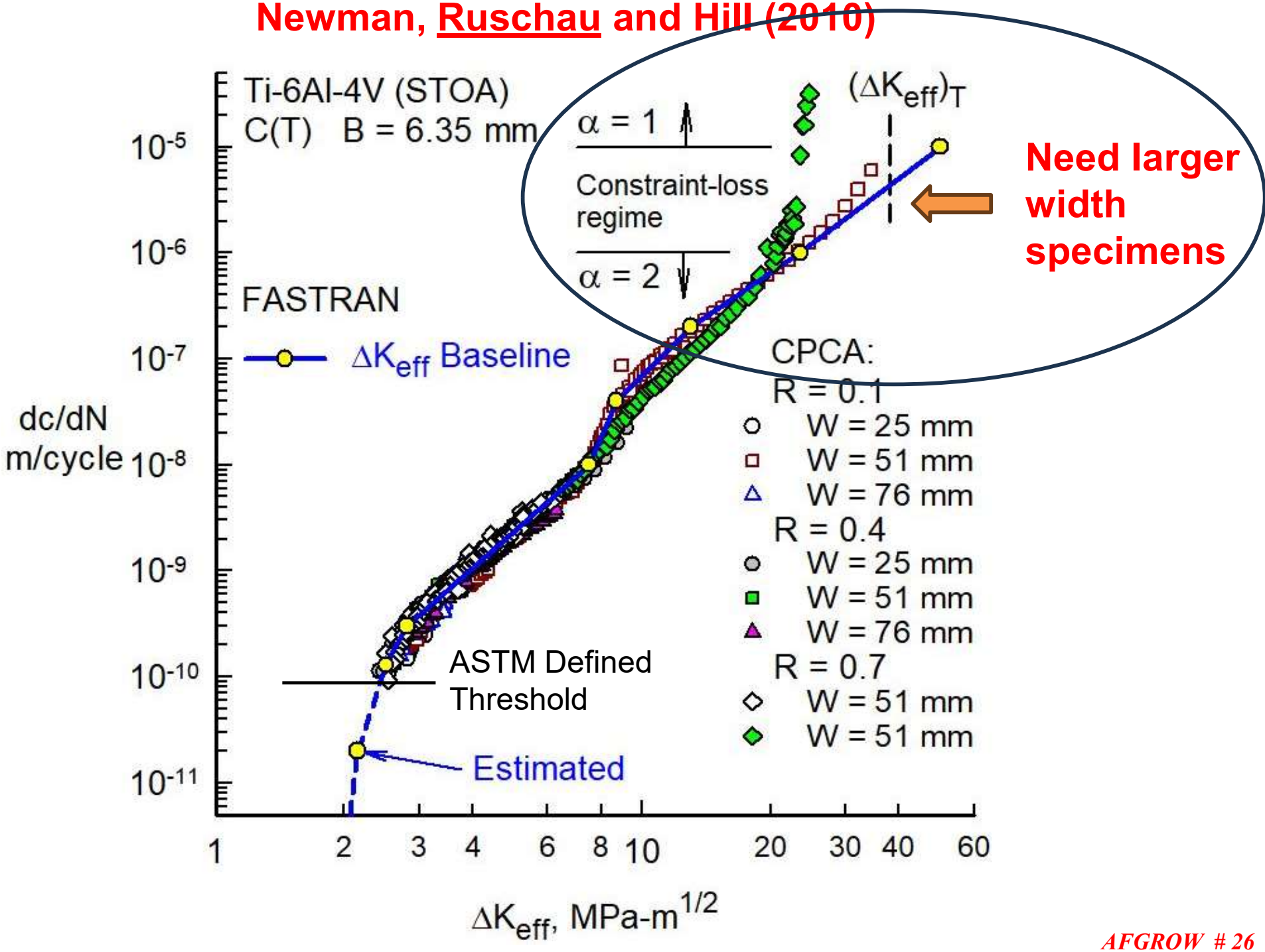
Newman, Ruschau and Hill (2010)



AFGROW # 25

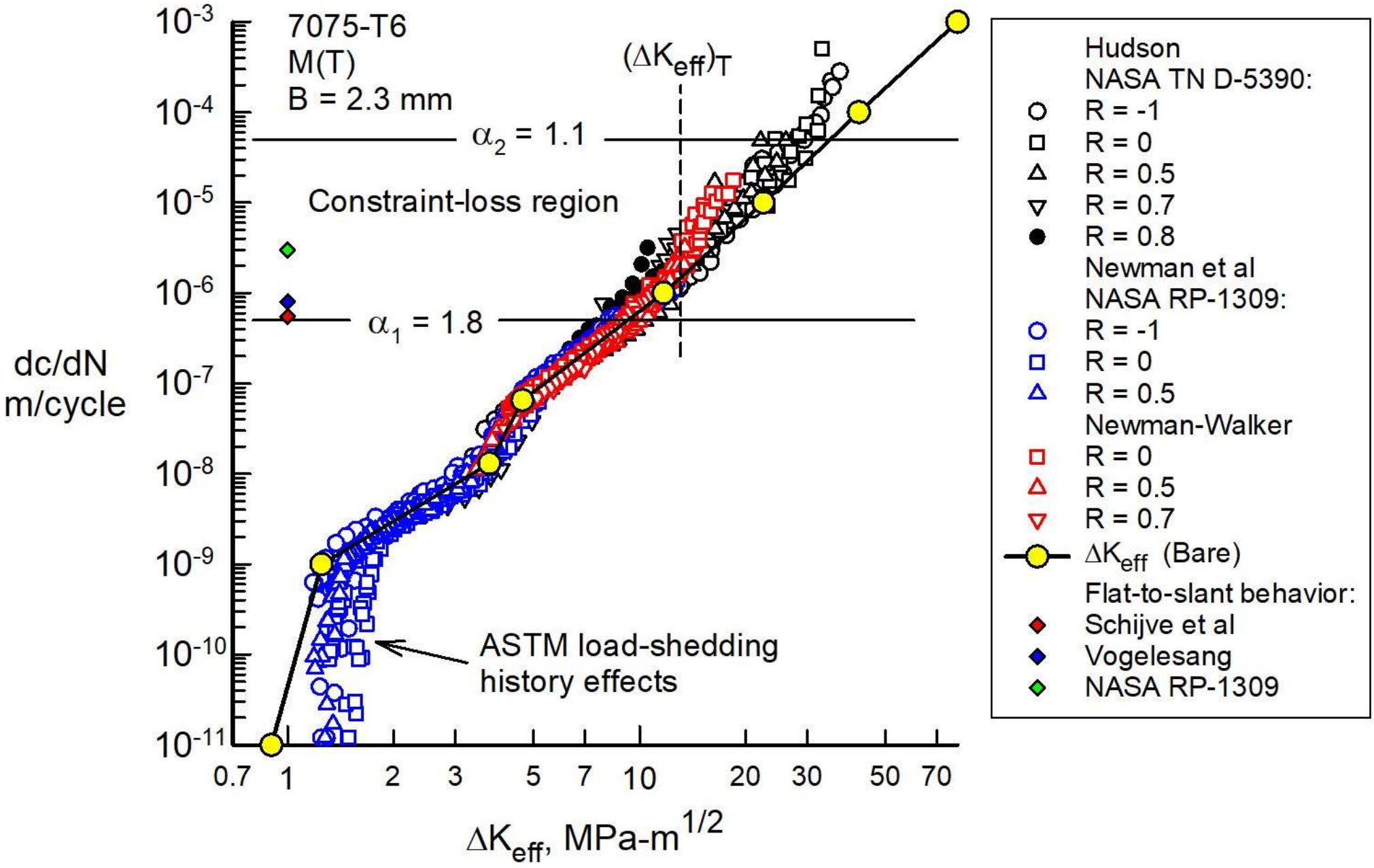
Example of Excellent ΔK_{eff}-Rate Correlation

Newman, Ruschau and Hill (2010)

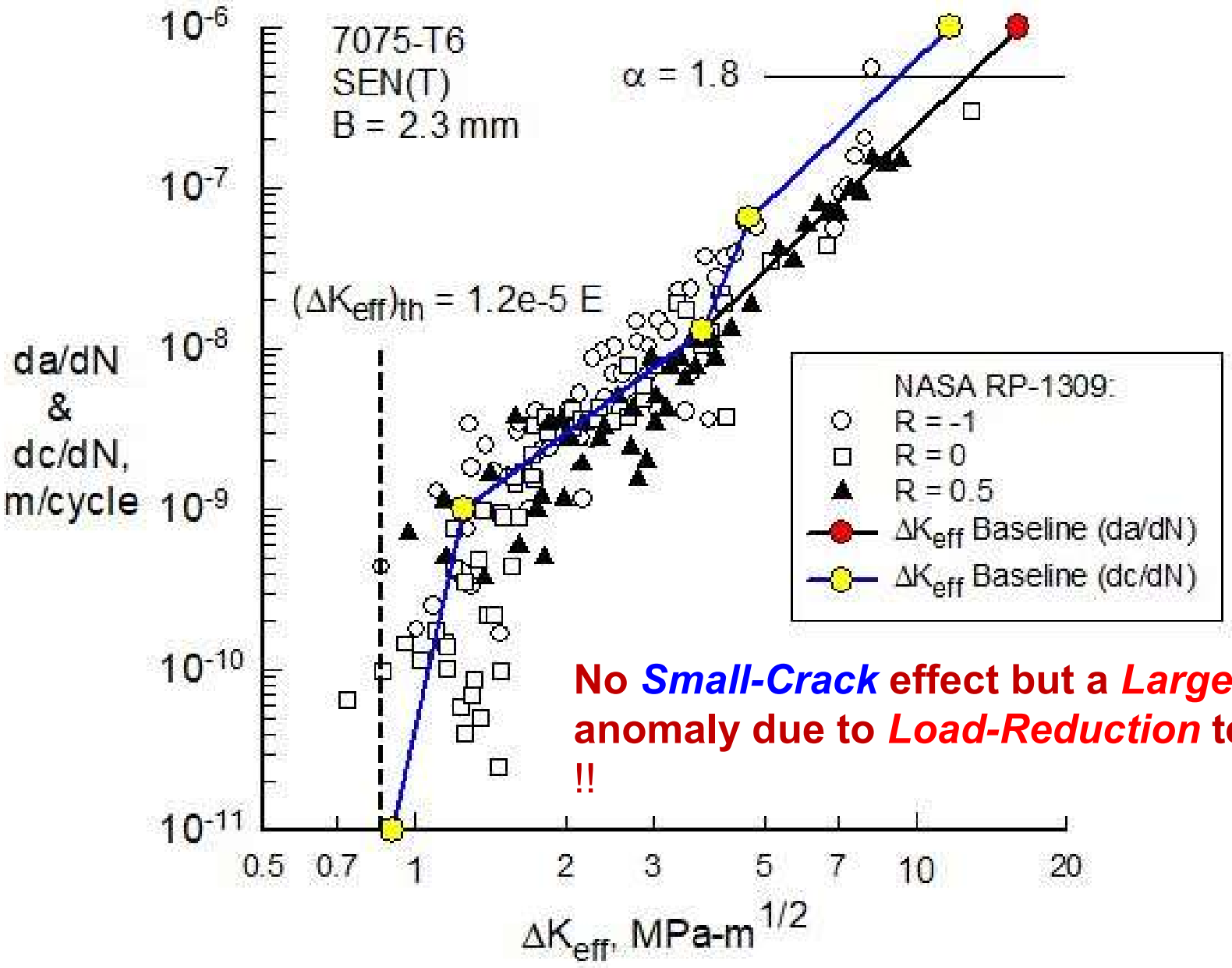


An Issue with Low-Rate ΔK_{eff}-Rate Correlation

Newman and Walker (2024)



Small Cracks Close Like Large Cracks on Same ΔK_{eff}-Rate Correlation



No *Small-Crack* effect but a *Large-Crack* anomaly due to *Load-Reduction* test method !!

Future ASTM Recommendations (2)

1. Reactivate the "Crack-Closure" Task Group to study Plasticity-, Debris-, and Roughness-Induced Crack Closure (PICC, DICC and RICC) mechanisms and incorporate these concepts & equations into current standard(s)

2. **Include proposed Appendix X6 (~2018) on Compression Pre-Cracking in ASTM E-647 or develop a new fatigue-crack-growth standard without *load-reduction test* methods (*40 years is way too long!*)**

Concluding Remarks

- **ASTM E-647 load-reduction test method has load-history effects – a rise in crack-opening loads has been *measured* and *calculated*.**
- **Committees E-24 and E-08 members have *neglected* the *past literature* and *failed* to correct the E-647 standard.**
- ***Compression pre-cracking* test methods have been developed to generate *more accurate constant-amplitude* ΔK-rate data in the low-rate regime—but has yet to be used in ASTM standards.**
- ***Crack-closure concepts* have been used to *correlate ΔK-rate data* from near threshold to fracture in terms of Elber's ΔK_{eff} for many materials.**
- ***No small-crack effect—small-crack ΔK-rate data agree with large-crack data generated without using load-reduction test data*.**
- **Flawed *ΔK-rate data* at various R values *can be corrected* !**