The Purpose of Generating Fatigue Crack Growth Threshold Data

Scott Forth

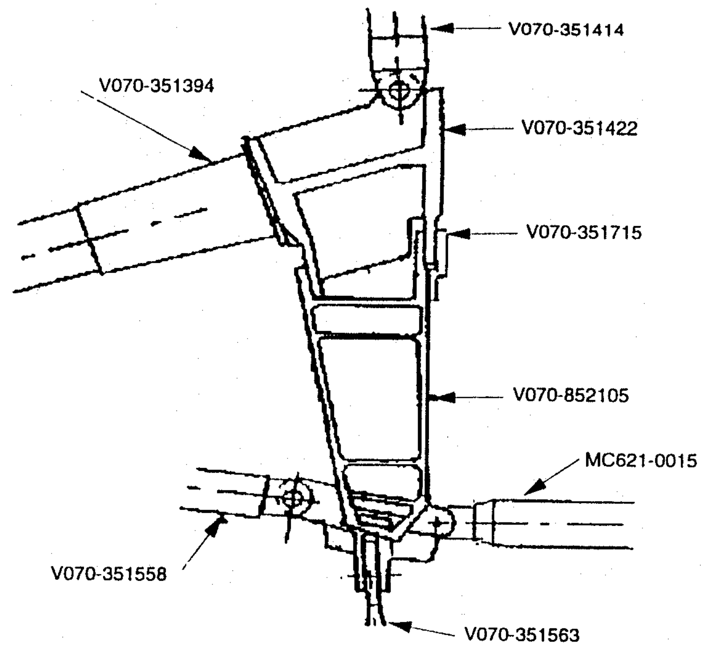
NASA Johnson Space Center

Overview

- NASA Applications
- Laboratory Data
- Summary

NASA Applications

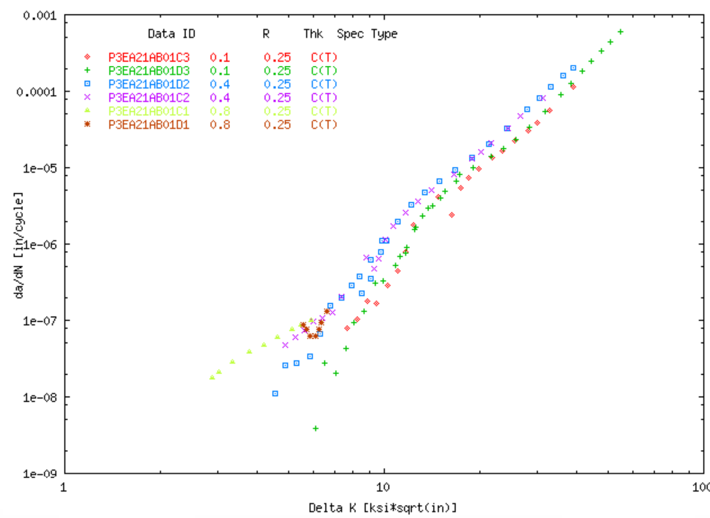
- Space Shuttle Main Engine Thrust Structure
- Ti-6Al-4V Titanium
- High Cycle Fatigue
  - Launch Vibration
- Threshold used as design allowable
  - All ΔK values below ΔK_{th}

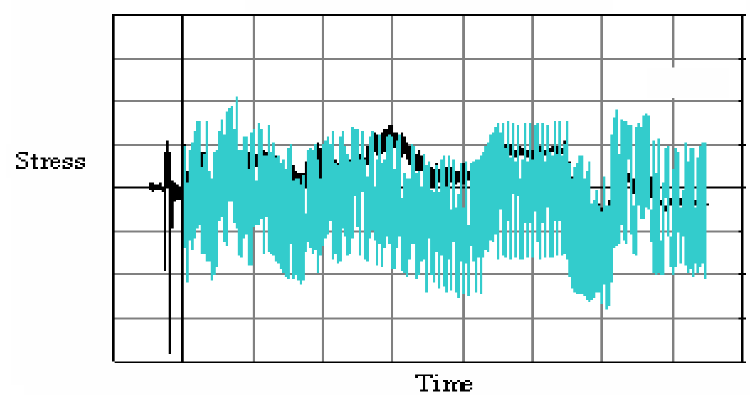


NASA Applications cont'

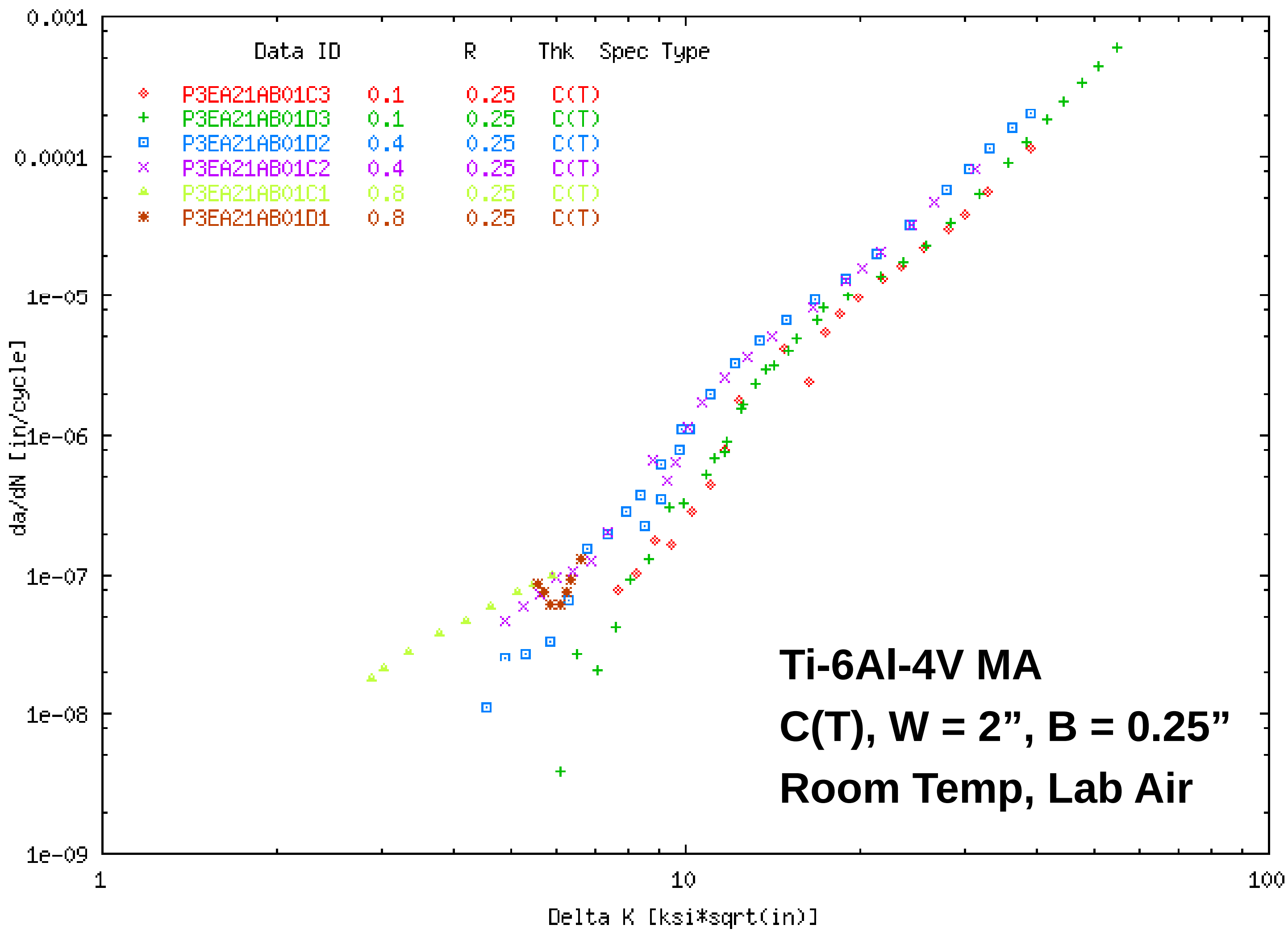
<u>High Cycle Fatigue (HCF) Components</u>. Fracture critical components operating in a potential HCF environment…

The metallic component is acceptable if the calculated HCF stress intensity is below the stress intensity factor threshold for the metallic material.





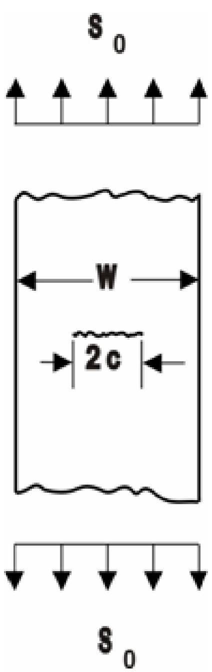
Design Threshold Data



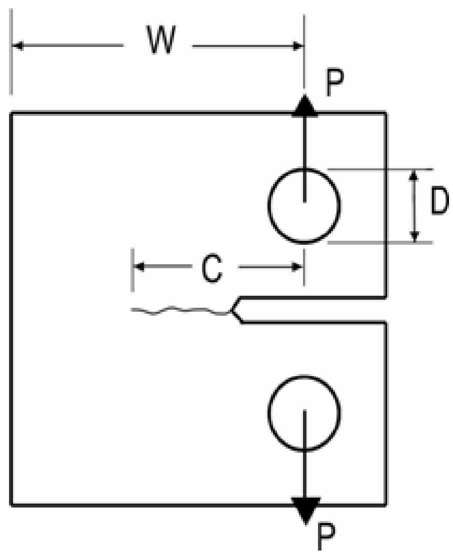
Harrington, T. R., " C-17 Material Specimen Tests for Fracture Mechanics Data. Phase II, Titanium, CRES, Inconel Lot 1

Recent Threshold Testing

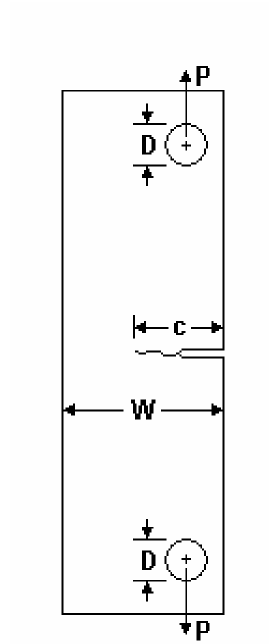
- Threshold testing completed on Ti-6-4 MA specimens to compare threshold values between C(T), ESE(T), M(T) & SM(T) designs



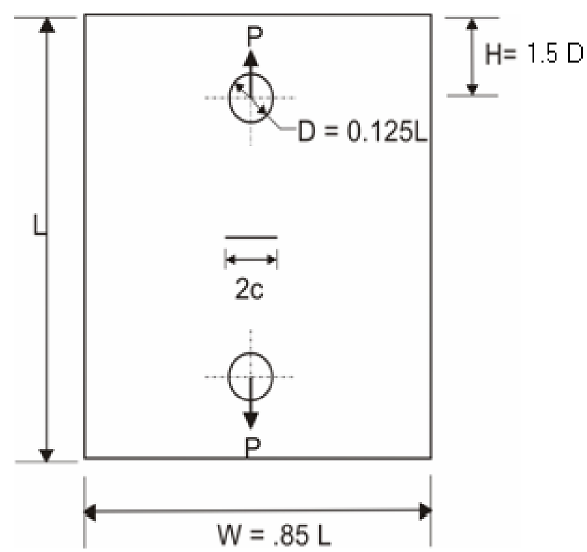
M(T)



C(T)



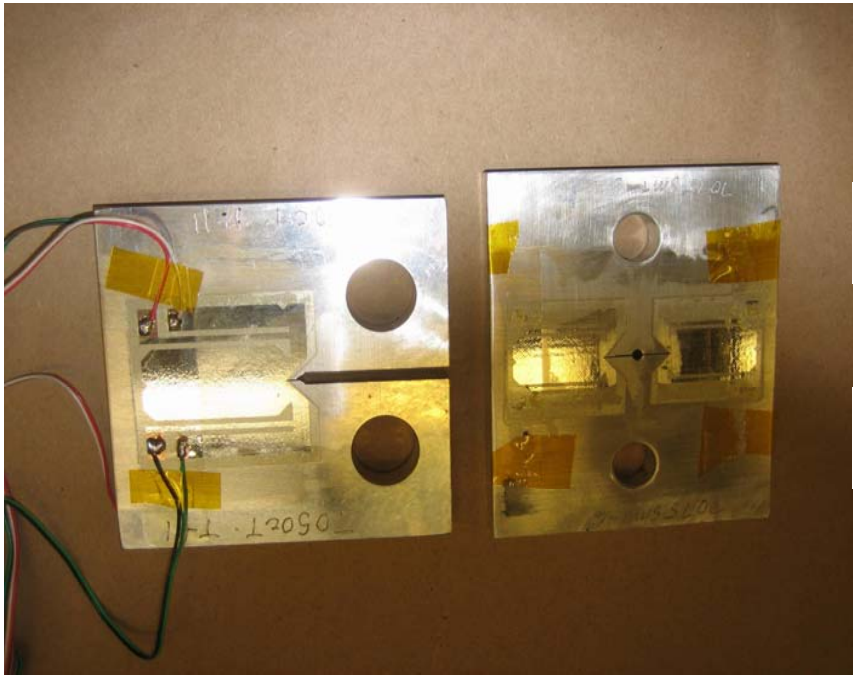
ESE(T)



SM(T)

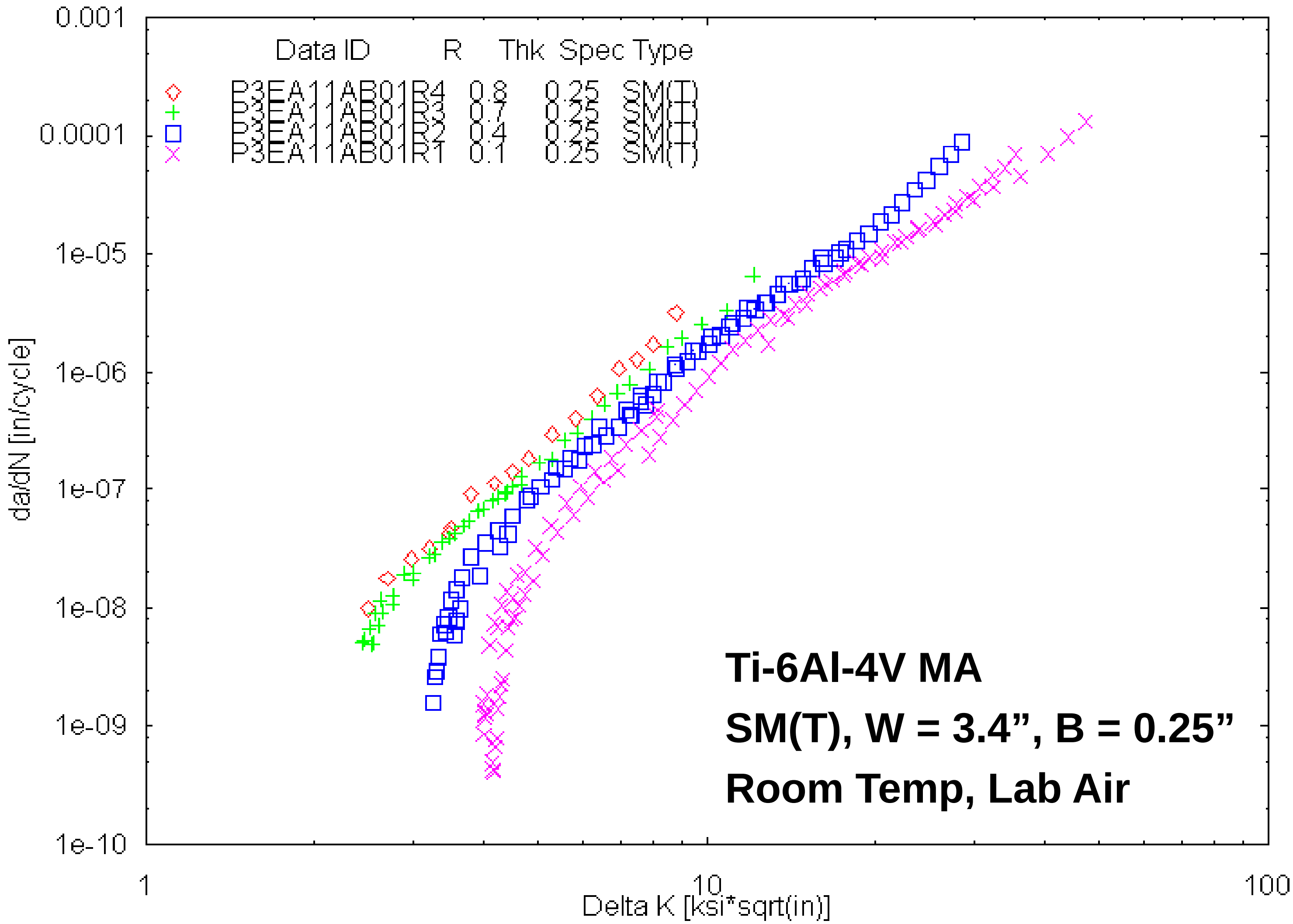
Short Middle Through Crack Specimen SM(T)

- Crack has less tendency to turn compared to the C(T) specimen
- Specimen has high stiffness - allowing high cyclic frequency
- Requires much less material than for an M(T) specimen.



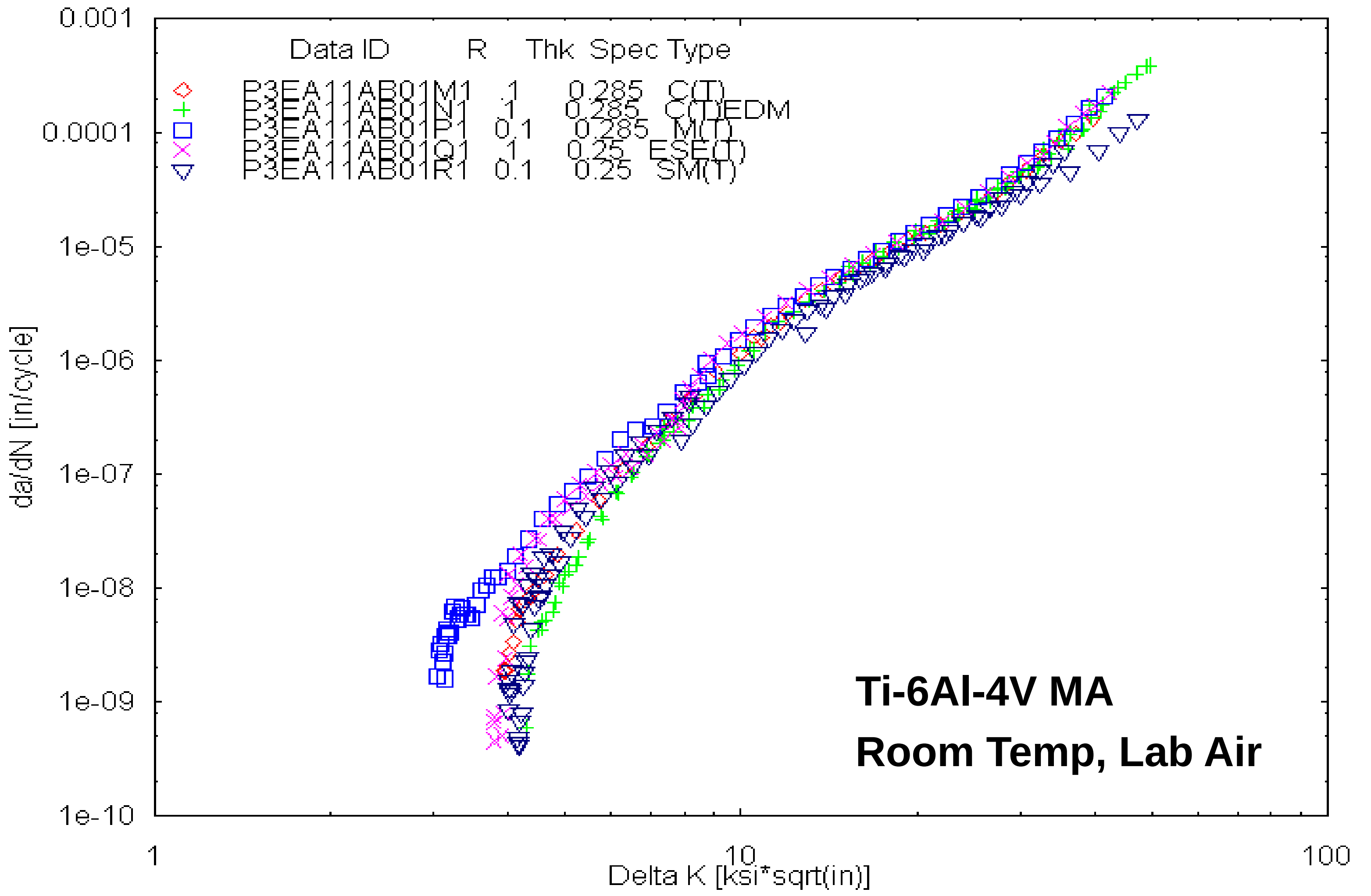
Comparison of W = 3” C(T) specimen with W = 3.4” SM(T) specimen.

SM(T) Threshold Data



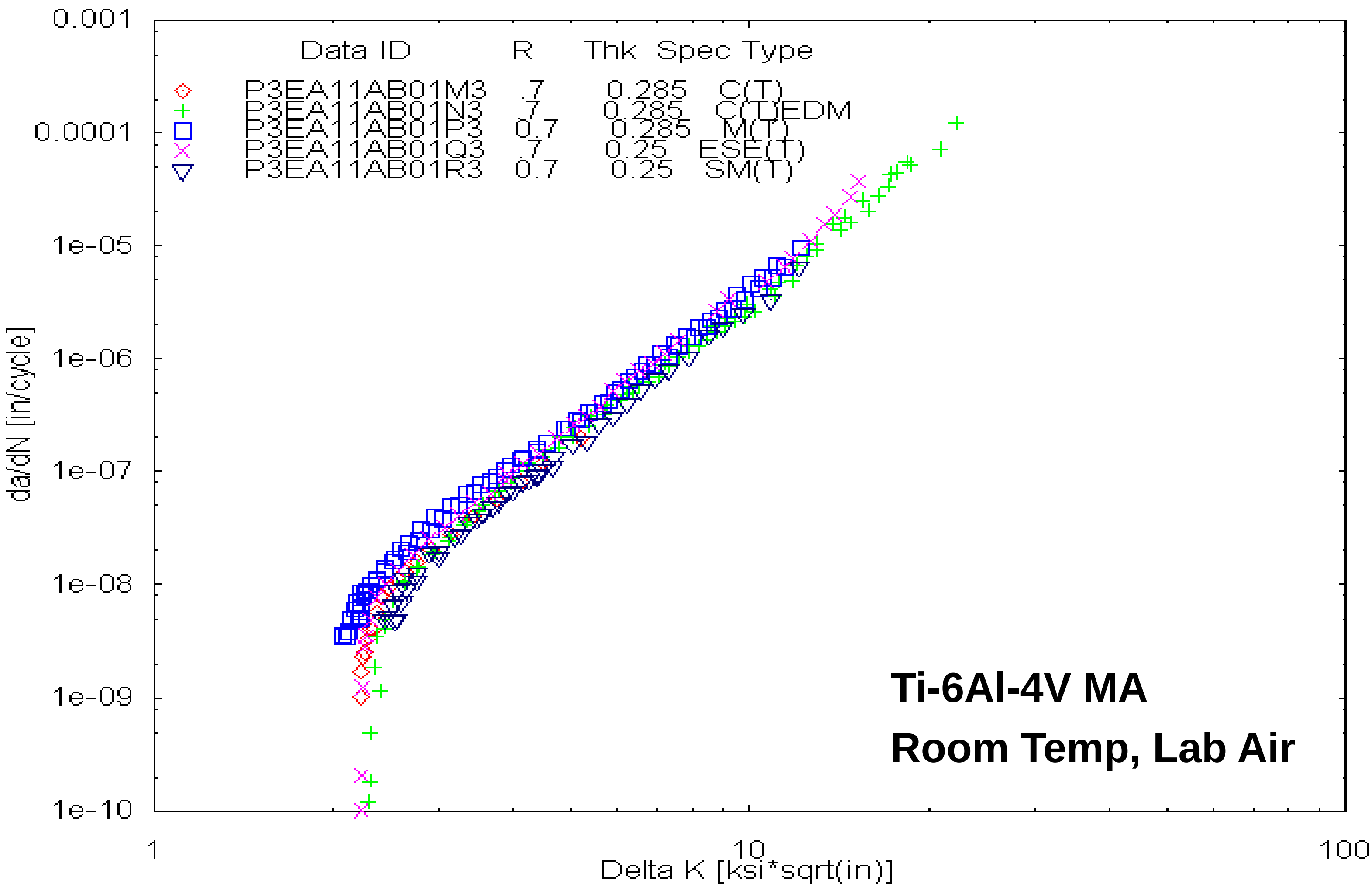
Forman, R.G., unpublished

Effect of Specimen Geometry on R = 0.1 Threshold



Forman, R.G., unpublished

Effect of Specimen Geometry on R = 0.7 Threshold

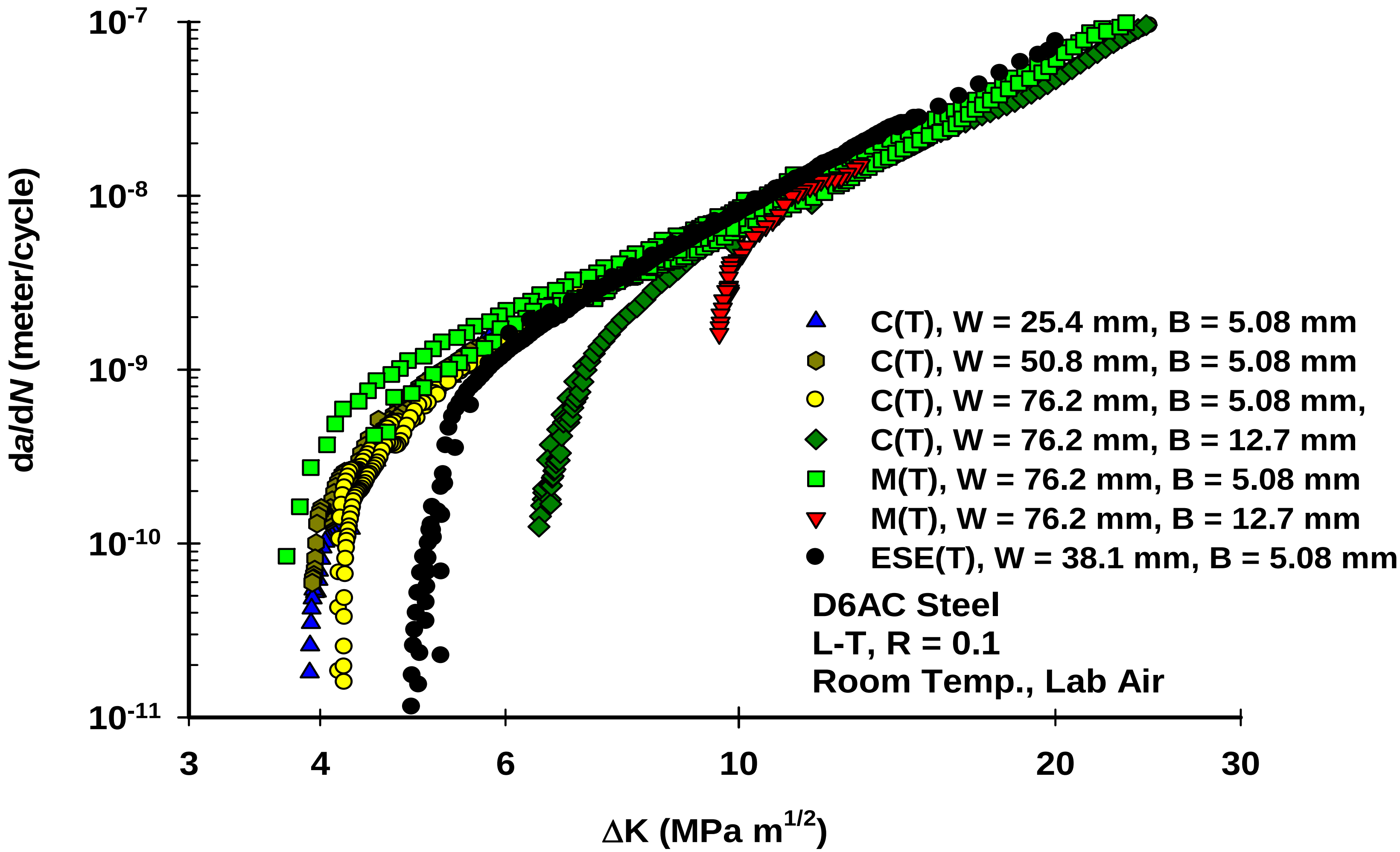


Forman, R.G., unpublished

Ti-6Al-4V MA Thresholds

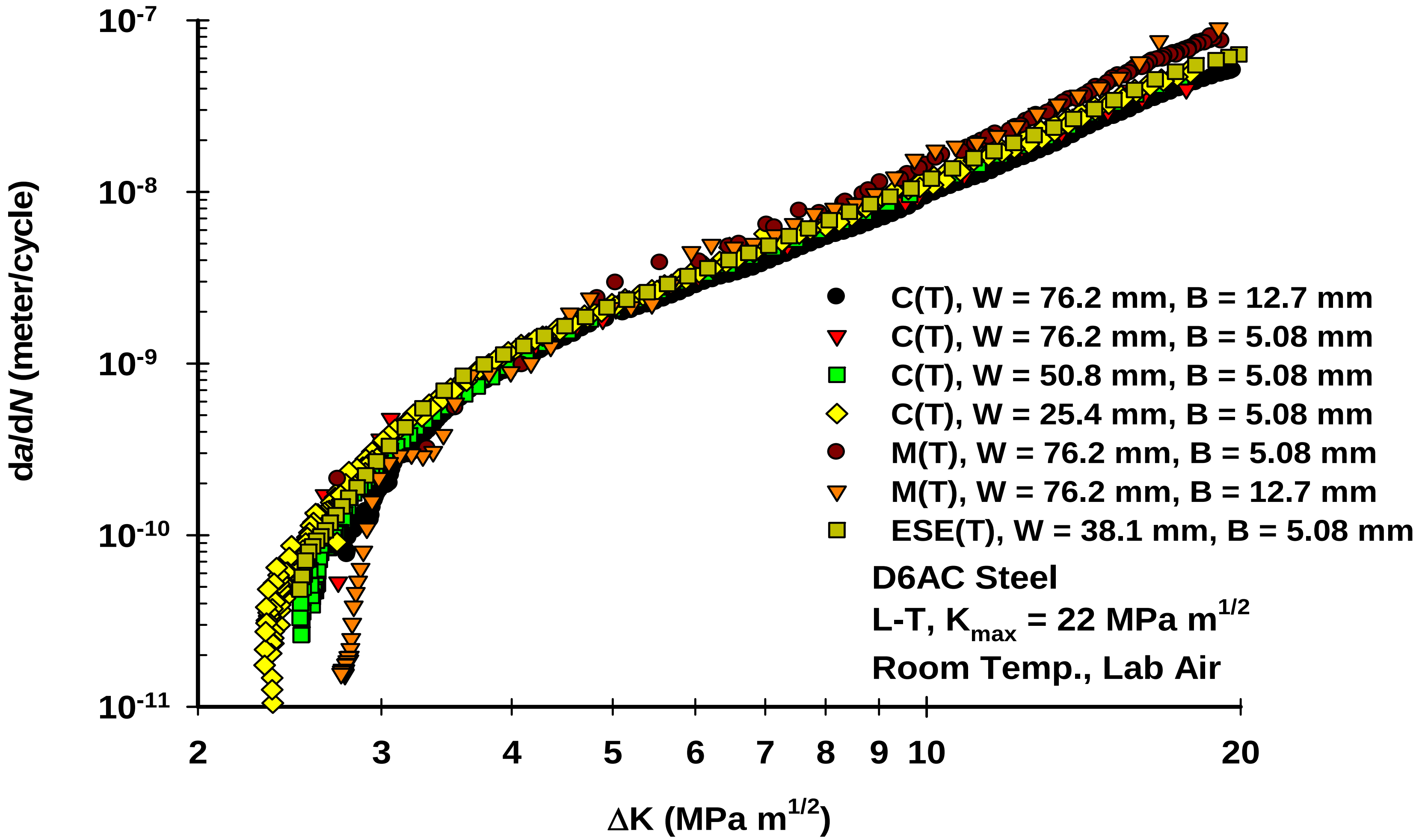
R Value	Specimen Type	ΔK_{th} (ksi $in^{1/2}$)
0.1	C(T)	6.0
	M(T)	3.1
	ESE(T)	3.9
	SM(T)	4.1
0.7	C(T)	2.4 / 2.1
	M(T)	2.0
	ESE(T)	2.1
	SM(T)	2.2

Specimen Configuration Effects



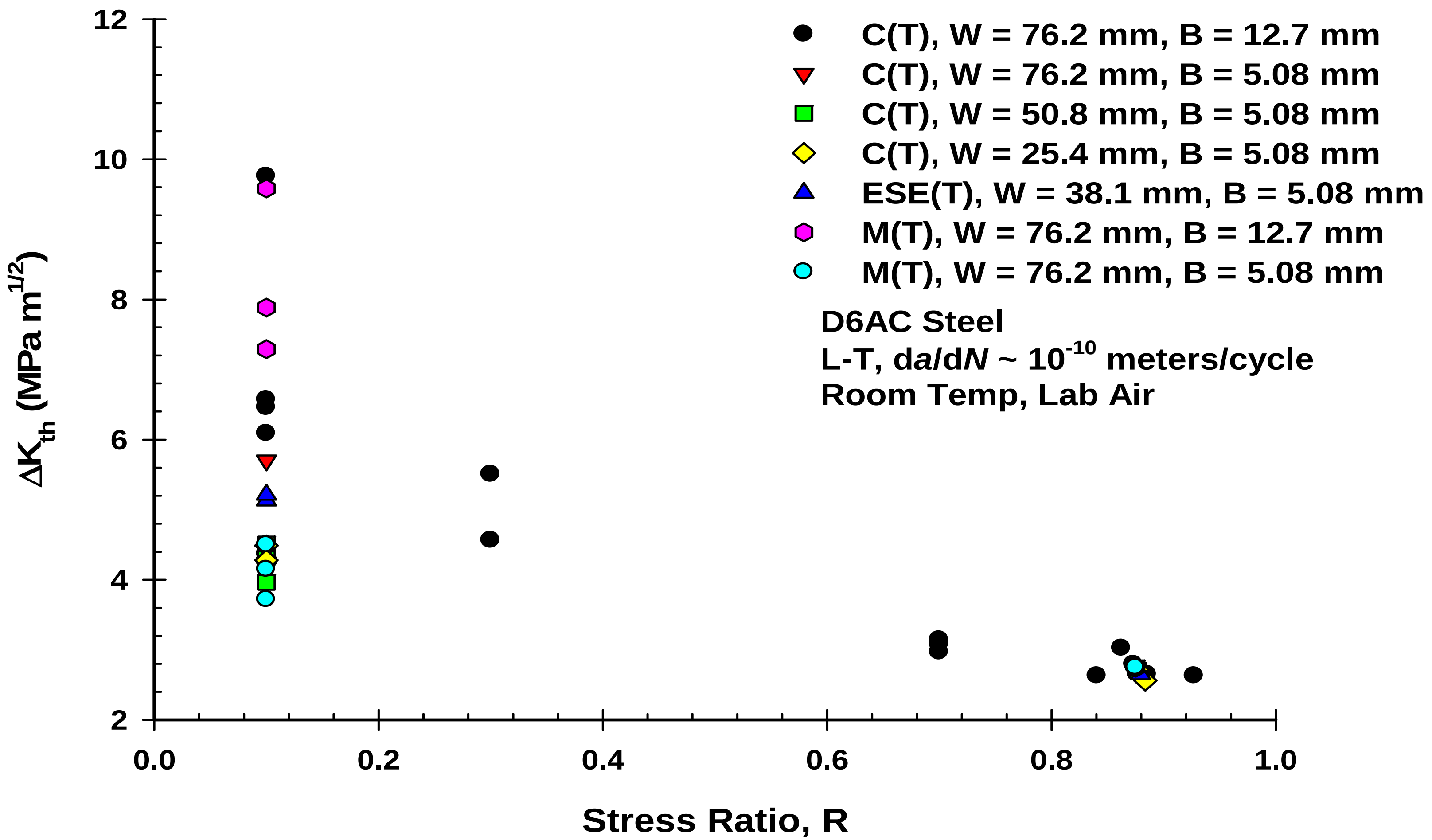
Forth, S.C., Johnston, W.M., Seshadri, B.R., *Proc. Of ECF16*, 2006

Constant K_{max} Data



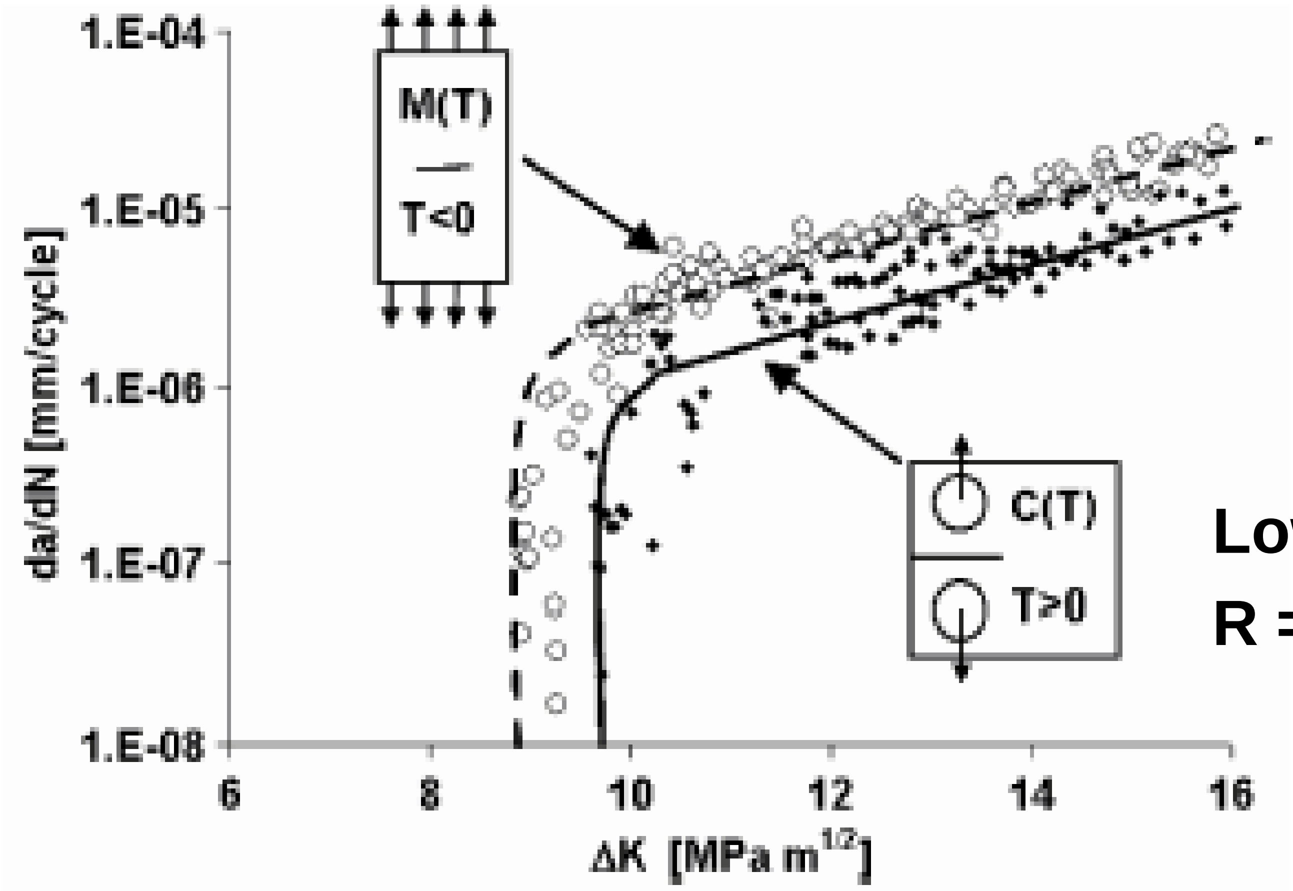
Forth, S.C., Johnston, W.M., Seshadri, B.R., *Proc. Of ECF16*, 2006

Specimen Configuration Effects at Threshold



Forth, S.C., Johnston, W.M., Seshadri, B.R., *Proc. Of ECF16*, 2006

Specimen Configuration Effects at Threshold



Low Carbon Steel

R = 0.1

Hutar, P., Seitl, S., Knesl, Z., *Comp. Mat. Sci.*, Vol 37, 2006

Summary

- Test data shows that different width and thickness C(T), M(T) and ESE(T) specimens generate different thresholds
- Structures designed for "infinite life" are being re-evaluated
  - Threshold changes from 6 to 3 ksi in$^{1/2}$
  - Computational life changes from infinite to 4 missions
- Multi-million dollar test programs required to substantiate operation
- Using ASTM E647 as standard guidance to generate threshold data is not practical

- A threshold test approach needs to be standardized that will provide positive margin for high cycle fatigue applications