# Lecture 13

Analyzing Nonlinear Fracture Mechanics Test Results

- Given the following set of data from a multiple specimen JIc test
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- i) Calculate the J vs Δa points
- ii) Find JQ using the E 813-87 method
- iii) Determine whether these meet the JIc validity criteria
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- Data: Compact specimen, W = 2 in., B = 1.0 in.
-  Material, steel
-  E = 30,000 ksi
-  sys = 70 ksi
-  sUTS = 90 ksi
-  n = 0.3
-
- Individual specimen results:
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| Test | Initial Crack Length | Final Crack Length | Final Load | Final Plastic Area |
|---|---|---|---|---|
| 1 | 1.185 in | 1.268 in | 9.50 kips | 1020 in-lb |
| 2 | 1.228 | 1.236 | 9.40 | 310 |
| 3 | 1.210 | 1.252 | 9.75 | 750 |
| 4 | 1.195 | 1.252 | 9.95 | 970 |
| 5 | 1.220 | 1.240 | 9.50 | 440 |
| 6 | 1.280 | 1.311 | 9.75 | 530 |
| 7 | 1.205 | 1.260 | 9.85 | 850 |

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# $J_{Ic}$ Test Data

| Test No | Initial Length | Final Plastic Length |
|---|---|---|
| 1 | 1.185 in | 1.268 in |
| 2 | 1.228 | 1.236 |
| 3 | 1.210 | 1.252 |
| 4 | 1.195 | 1.252 |
| 5 | 1.220 | 1.240 |
| 6 | 1.280 | 1.311 |
| 7 | 1.205 | 1.260 |

# More Data

- Test No Final load Plastic Area

- 1 9.50 kips 1020 in-lb

- 29.40 310
- 3 9.75 750
- 49.95 970
- 59.50 440
- 6 9.75 530
- 79.85 850
-

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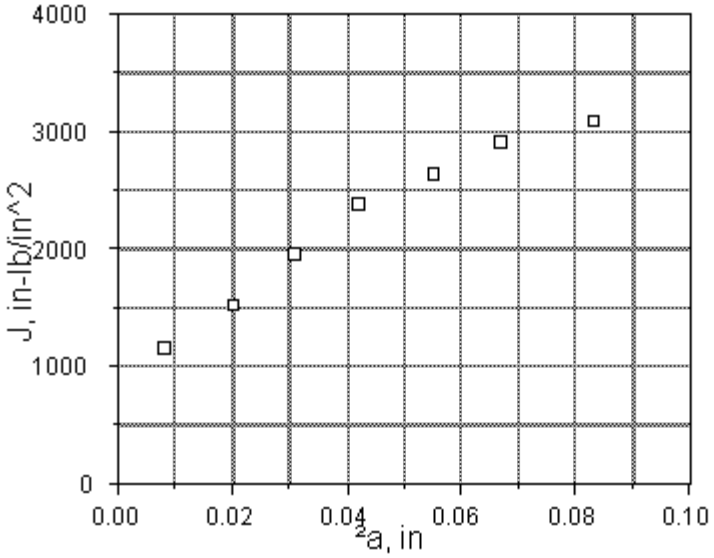
# Example Calculation, Test 1

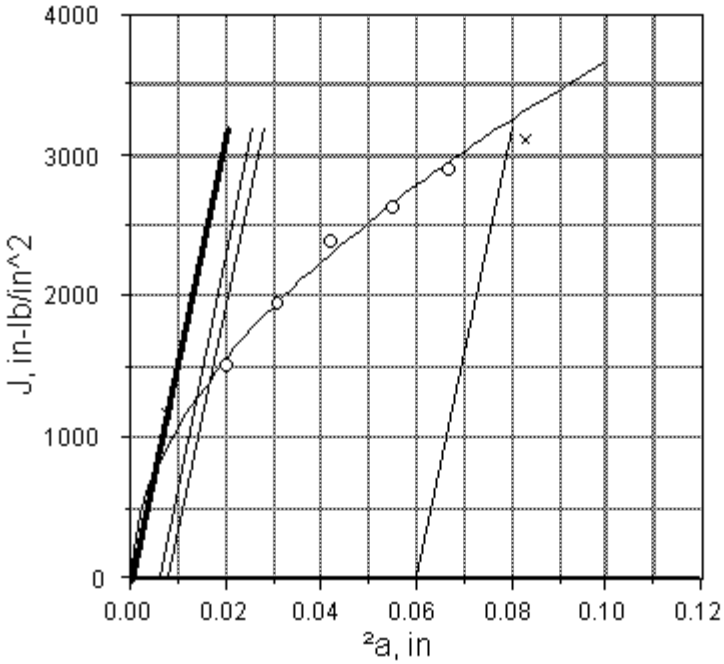
- $J_{el} = K^2(1 - n^2)/E = (89.1)^2(0.91)/(30, 000) = 0.24$ kip-in/in$^2$
-
- $J_{pl} = \eta(\text{area})/Bb = (2.213)(1020)/(1.0\text{x}0.815) = 2770$ in-lb/in$^2$ = 2.77 kip-in/in$^2$
-
- b =W - a = 2.0 – 1.185 = 0.815,
- $\eta = 2 + 0.522(b/W) = 2 + 0.522(0.815/2) = 2.213$
-
- $J_{tot} = J_{el} + J_{pl} = 0.240 + 2.77 = 3.01$
- (All J values in.-lb/in$^2$)

# Table of J versus Δa

| J, in-lb/in2 | Δa, in |
|---|---|
| 3010 | .083 |
| 1160 | .008 |
| 2380 | .042 |
| 2900 | .057 |
| 1520 | .020 |
| 1960 | .031 |
| 2640 | .055 |




**Workshop 6 - J versus ²a**




**Workshop 6 - J versus ²a with Construction**

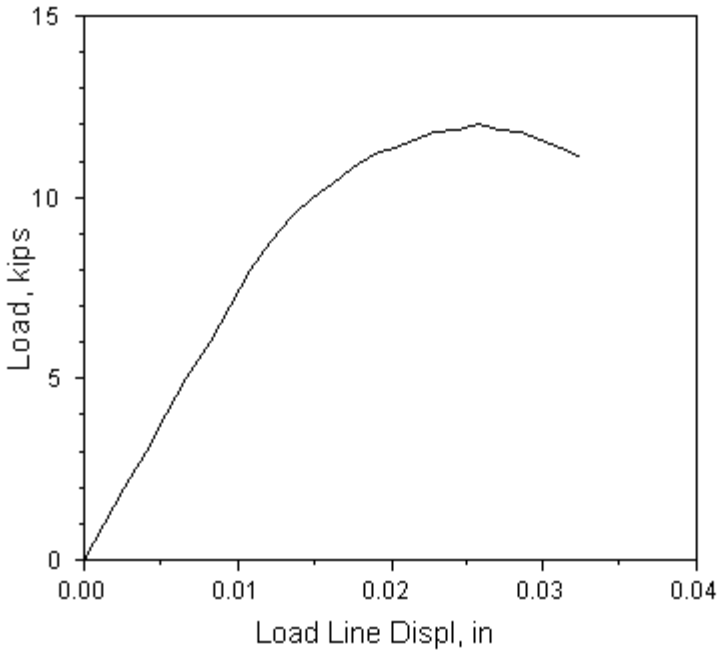
- 
- fit points 3 to 7 with $\ln(J) = \ln(C_1) + C_2 \ln(\Delta a)$
- 
- result $J = 12{,}597(\Delta a)^{0.537}$
- 
- solve with $J = 2x80{,}000(\Delta a - 0.008)$ ($J_Q$ calculation line)

# Table to iterate

| $\Delta a$ | $J_{fit}$ | $J_{line}$ | comment |
|---|---|---|---|
| .016 | 1367 | 1280 | Too low |
| .017 | 1413 | 1440 | Too high |
| .0168 | 1403 | 1408 | close |
| .01675 | 1401 | 1400 | correct |

- $J_Q$ = 1400 in-lb/in$^2$
- 
- Validity
- 
- $J_{max} = b_{min}\ \sigma_Y/15 = (0.720)(80{,}000)/15 = 3840$; all points okay
- 
- $25(J_Q)/\sigma_Y = 25(1400)/(80{,}000) = 0.44$ in < all B, b
- 
- So $J_Q = J_{Ic}$ = 1400 in-lb/in$^2$

# P-v for CTOD Test




**P-v Curve for CTOD Measurement**

# CTOD Problem

- Use the above P-v curve to get a critical value of CTOD as a
- $\delta_m$ value. Assume a CT specimen with W = 2.0 in, B = 1.0 in,
- $a_o$ = 1.0 in and material properties:

- $\sigma_{ys}$ = 60 ksi
- E = 30,000 ksi, $\nu$ = 0.3
- (load-line displacement)
-
-
-

-

# CTOD Solution

- . $P_{max}$ = 12.0, from construction, $v_{pl}$ = 0.0085 in, f = 9.66
- 
- K = (12)(9.66)/(1√2) = 82.0
- 
- $\delta_{el} = K^2(1 - n^2)/(2s_{ys}E) = (82)^2(.91)/[(2)(30{,}000)(60)] = 0.0017$in
- 
- $\delta_{pl} = r_p (W - a_o)v_{pl}/[Z + a_o + r_p (W - a_o)]$
- 
- load line v, Z = 0; CT, $r_p$ = 0.46, $a_o$ = 1.0
- 
- $\delta_{pl} = (0.0085)(0.46)(1.0)/[1 + 0.46(1.0)] = 0.00268$
- 
- $\delta_{tot} = \delta_{el} + \delta_{pl} = 0.0017 + 0.00268 = 0.00438$ in