Total Fatigue Life = Crack Initiation + Crack Propagation

Next Focused Effort?

FD&E Committee Meeting
At the University of Toledo
15 October 2008

Presented by: Tom Cordes – nCode (Currently), John Deere (JD) Retiree

Fixture and Test Specimen Design and Test/Analysis Direction:
Dan Lingenfelser - CAT, Phil Dindinger – Stork, Mark Earley – JD, Mike Langner – JD

Strain Gaging & Data Acq: Dale Schutte – Independent Consult. (Currently), JD Retiree

Funded by: Brian Dabell – nCode

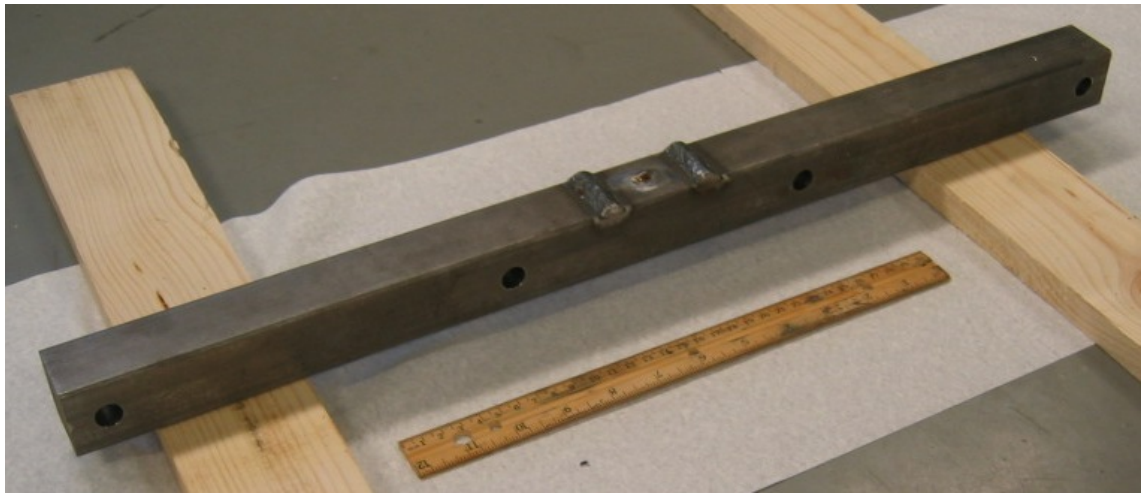
Question(s)?

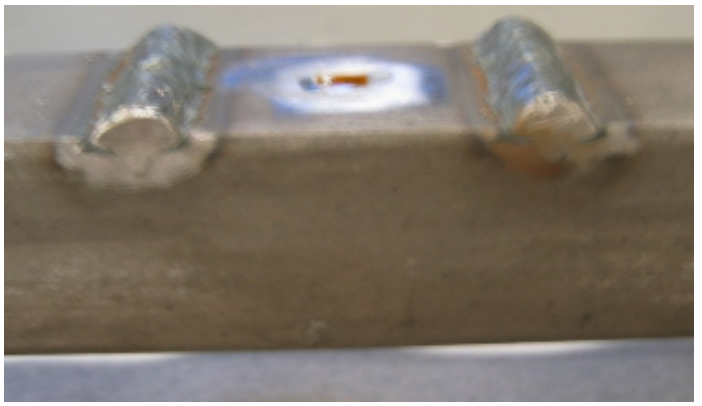
- **This committee has been validating (just) crack initiation fatigue life predictions of welds against tests of samples with increasingly more complex boundary conditions. And the tests have been to fatigue test lives that produced cracks larger then that typically associated with a (just) a crack initiation prediction.**

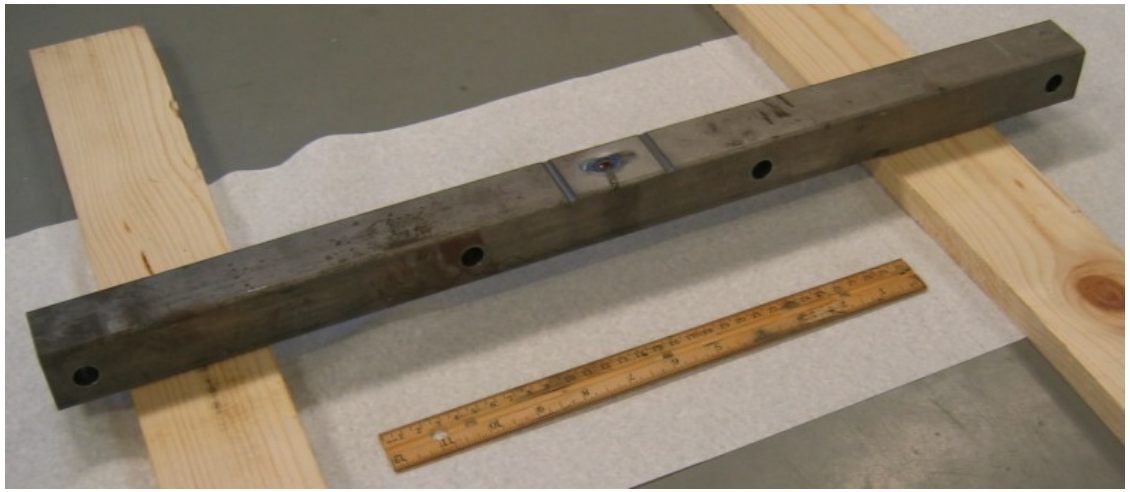
- **Have we really been evaluating our ability to accurately predict the "load carrying capable " fatigue life (to what size crack?), or our ability to more properly model the samples boundary conditions?**

- **Lets answer the above questions by addressing a "real world" sized sample and stress state where the test boundary conditions are not an issue. As a "physics" check, lets do that not only on welded samples but also relative to samples of the same design with a notch machined in place of the weld.**

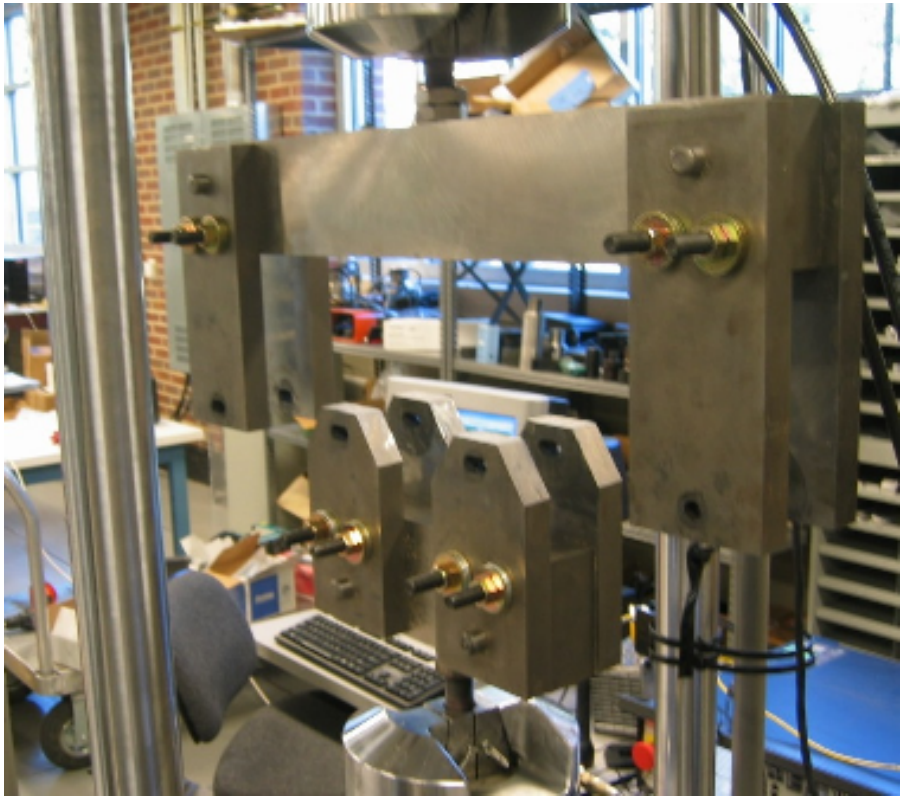
Two Four-Point Bending Test Sample Geometries

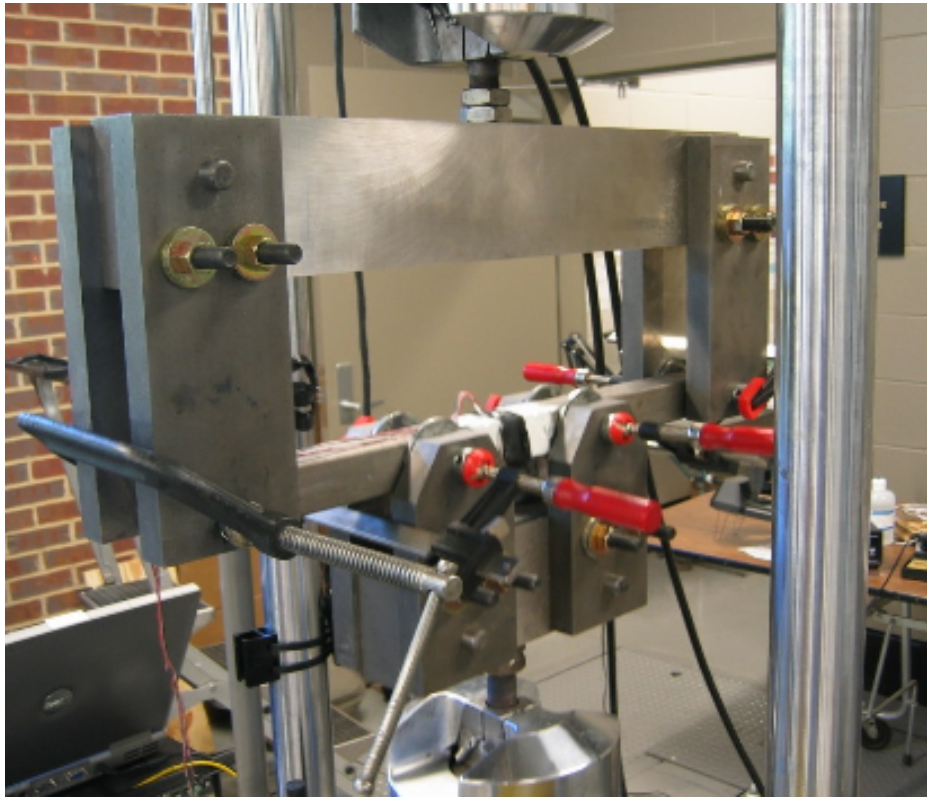


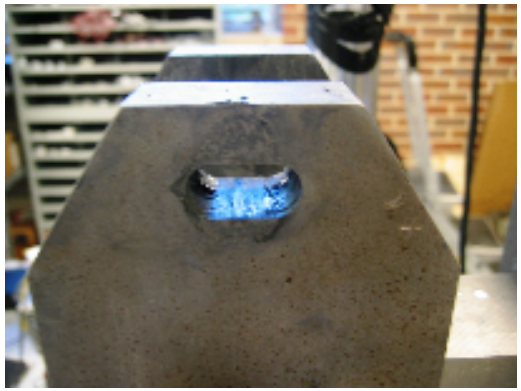




Four-Point Bending Test Fixture (MSU)

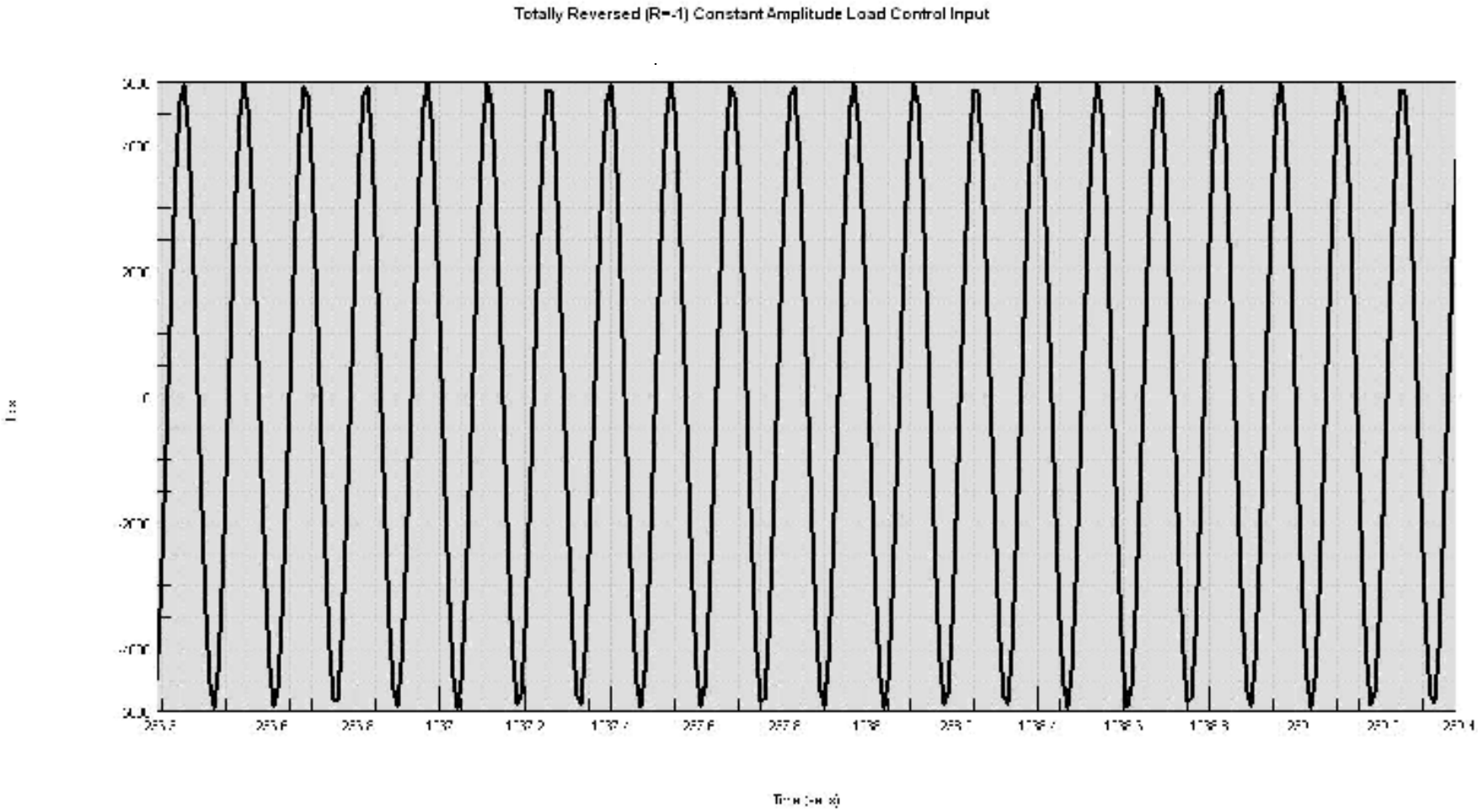




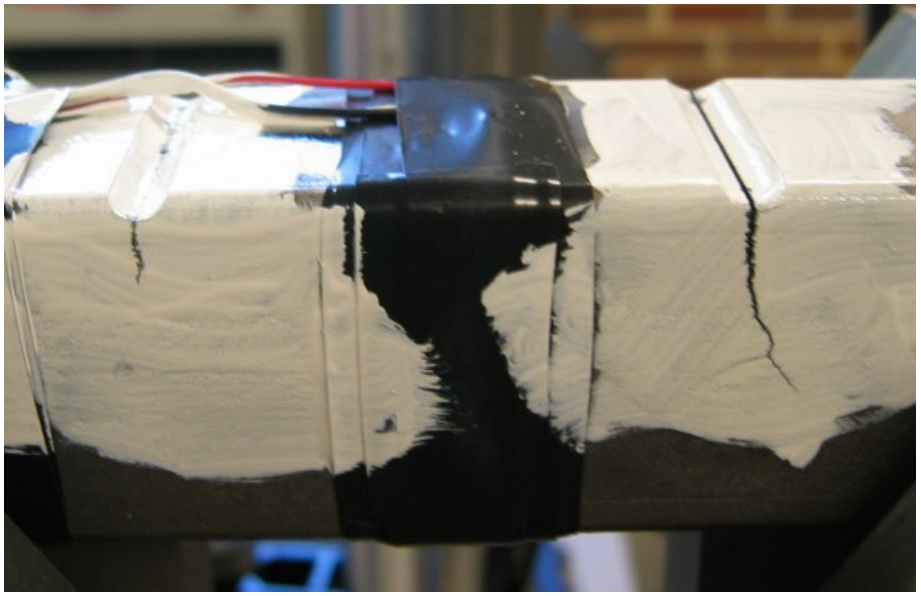


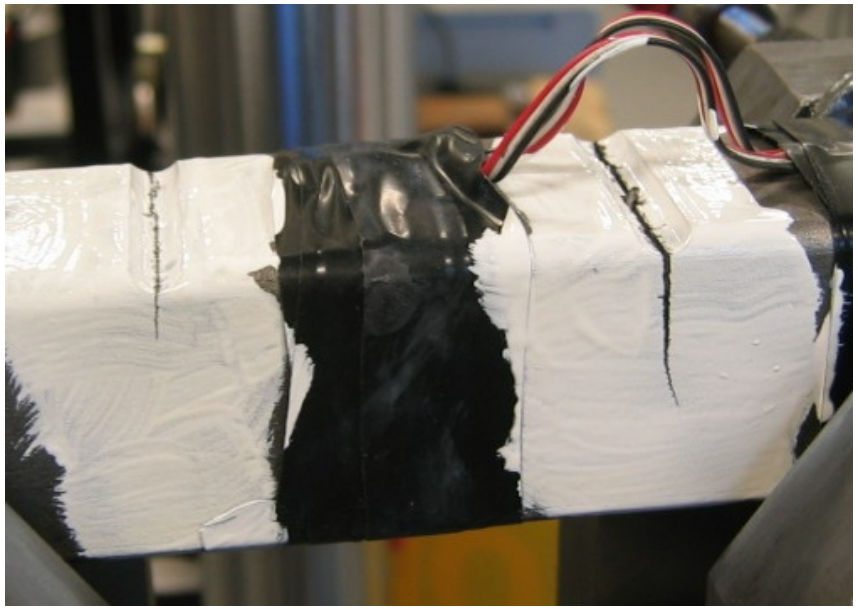
Four Samples Tested to Totally Reversed (R=-1) Constant Amplitude Load Control Input

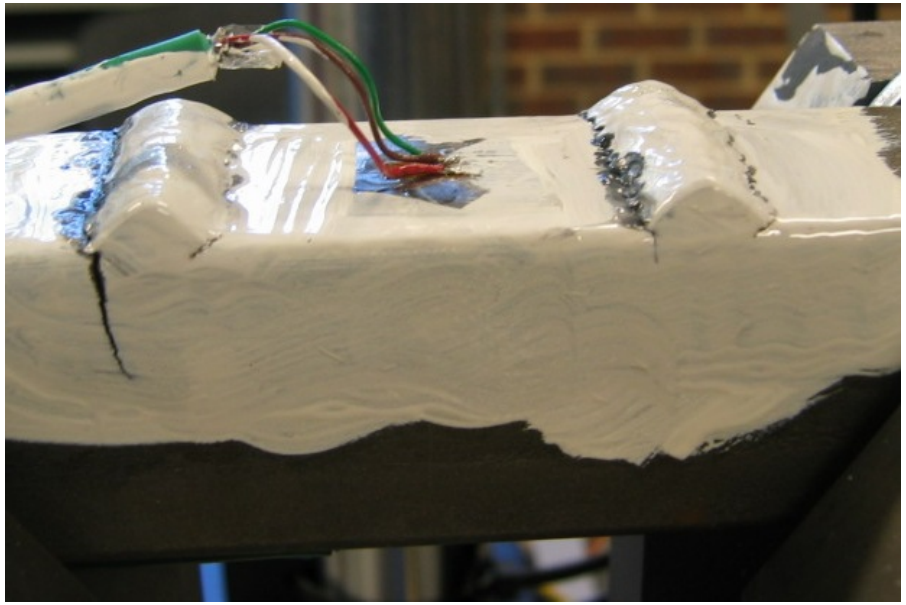
at 6000 Lbs (26.689 kN), 5000 Lbs (22.241 kN) & 3500 Lbs (15.569 kN)

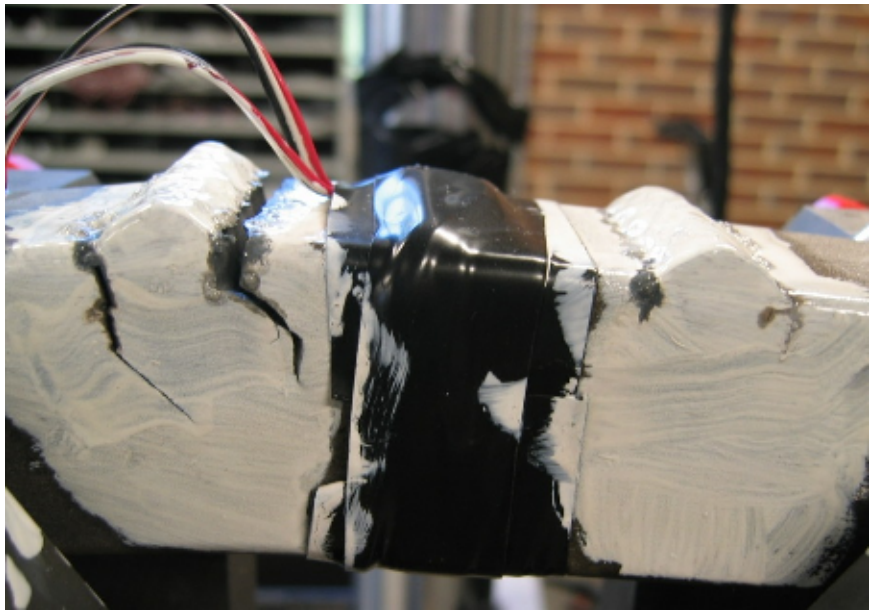


Four Samples Tested to Failure

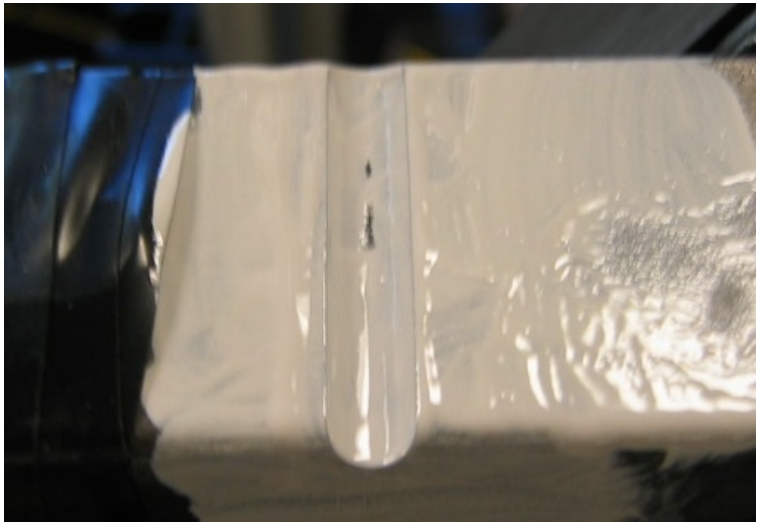




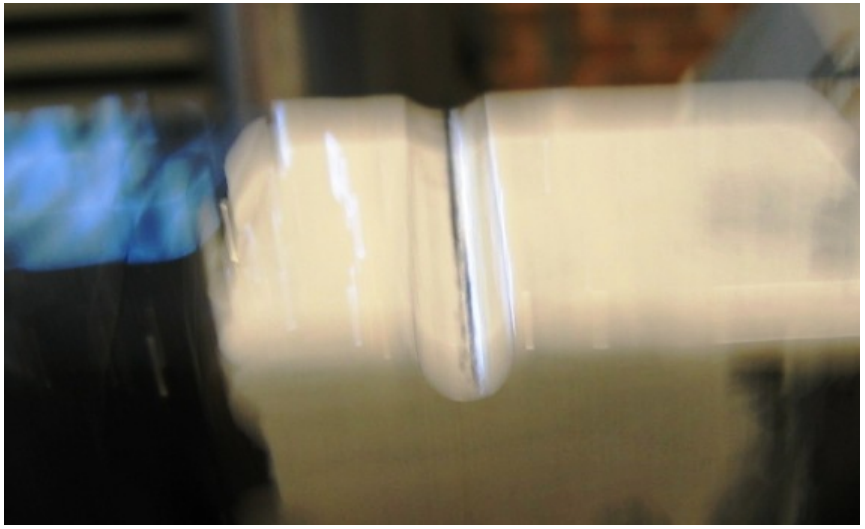




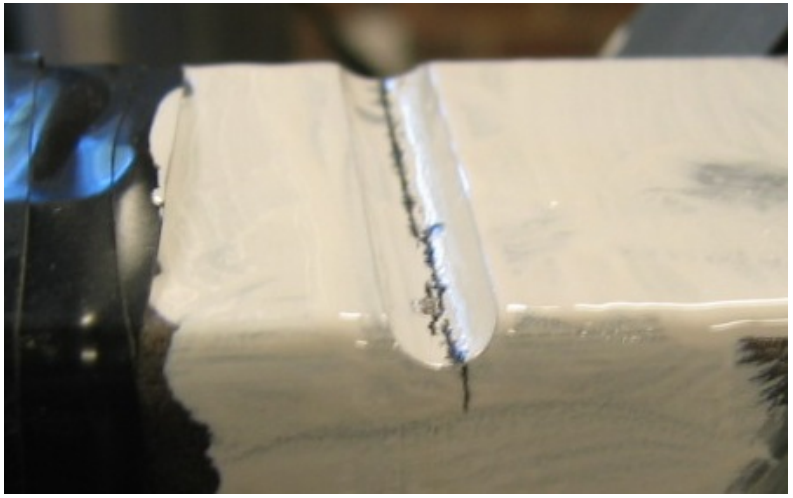
Notch “Total Fatigue Life” Stages



(1) First Crack Indication(s) Development



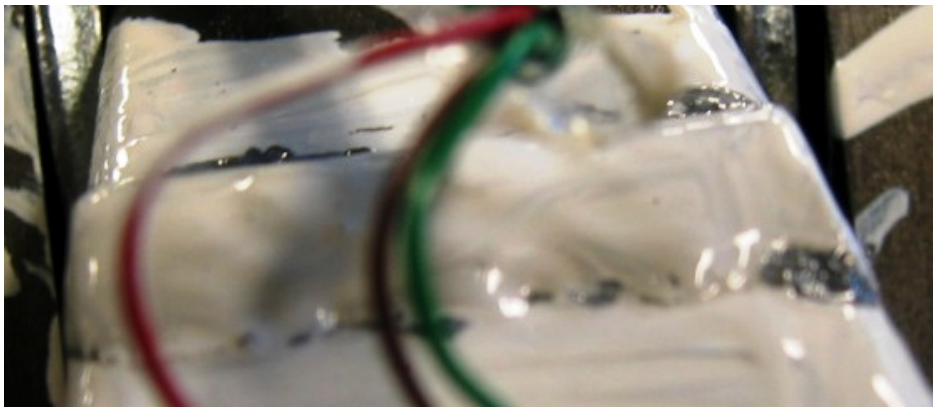
(2) Crack All the Way Across Width



(3) Obvious Edge Crack

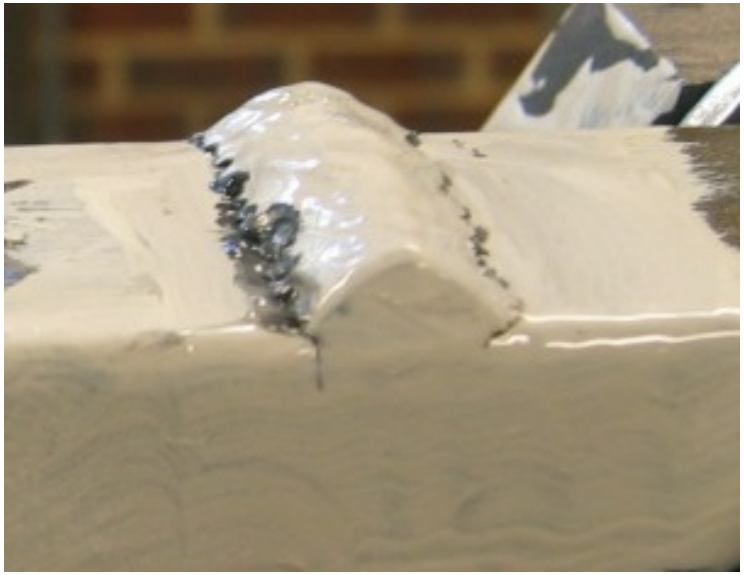
(4) Failure–Loss of Load Carrying Capability

Weld “Total Fatigue Life” Stages



(1) First Crack Indication(s) Development

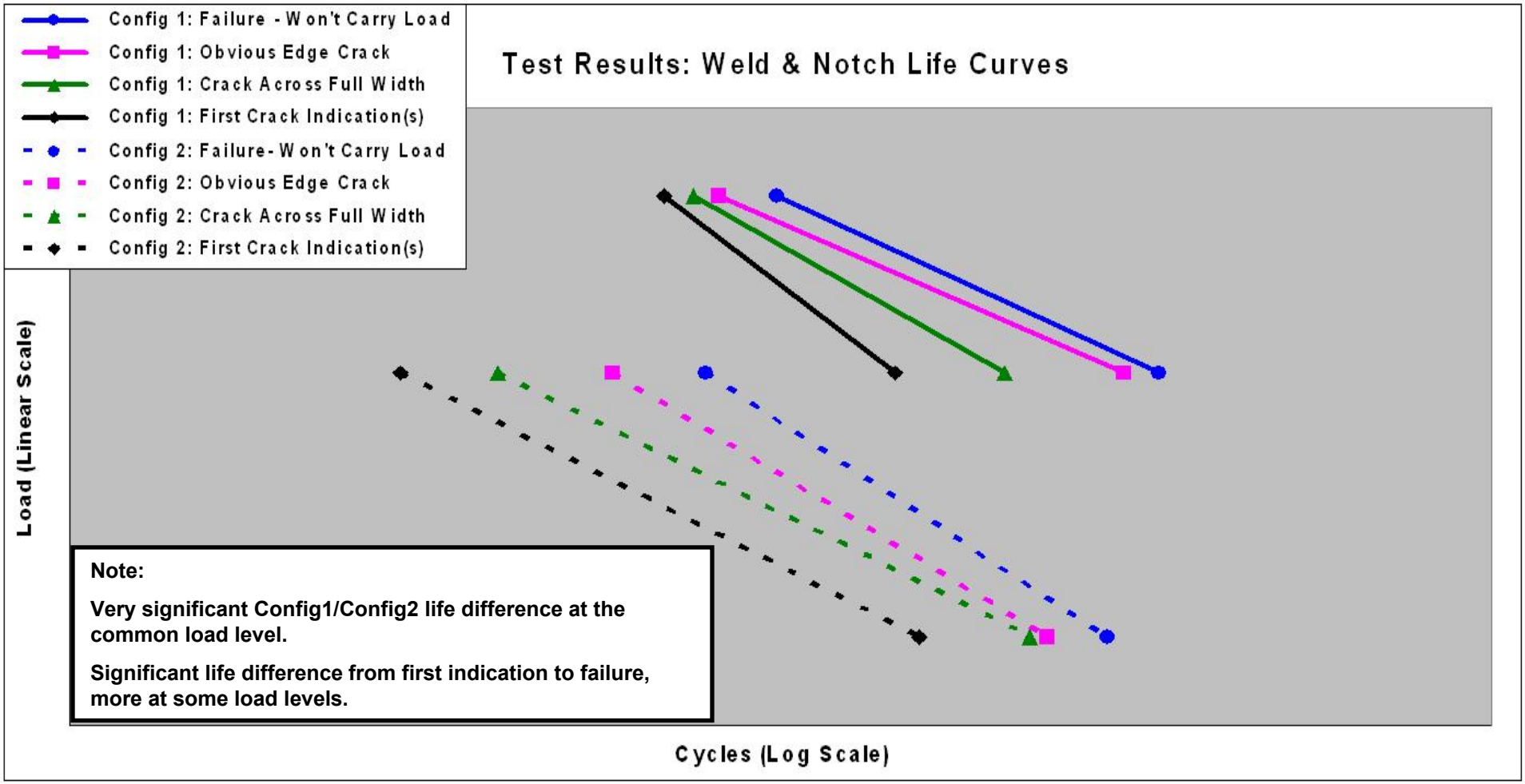
(2) Crack All the Way Across Width



(3) Obvious Edge Crack

(4) Failure–Loss of Load Carrying Capability

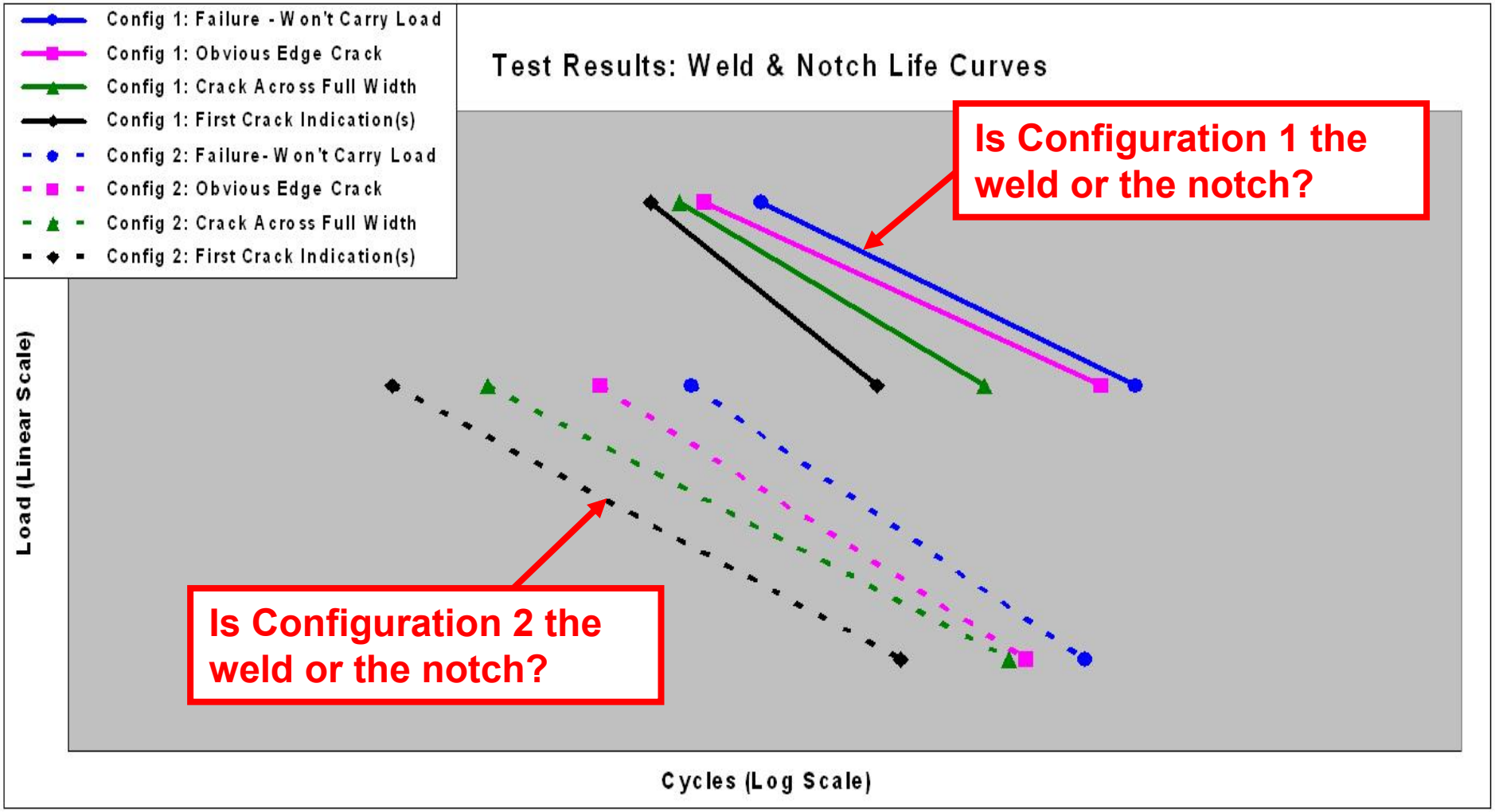
Test Results: Weld & Notch Life Curves



Our (Just) Fatigue Analysis Ability
“Round Robin”
Check

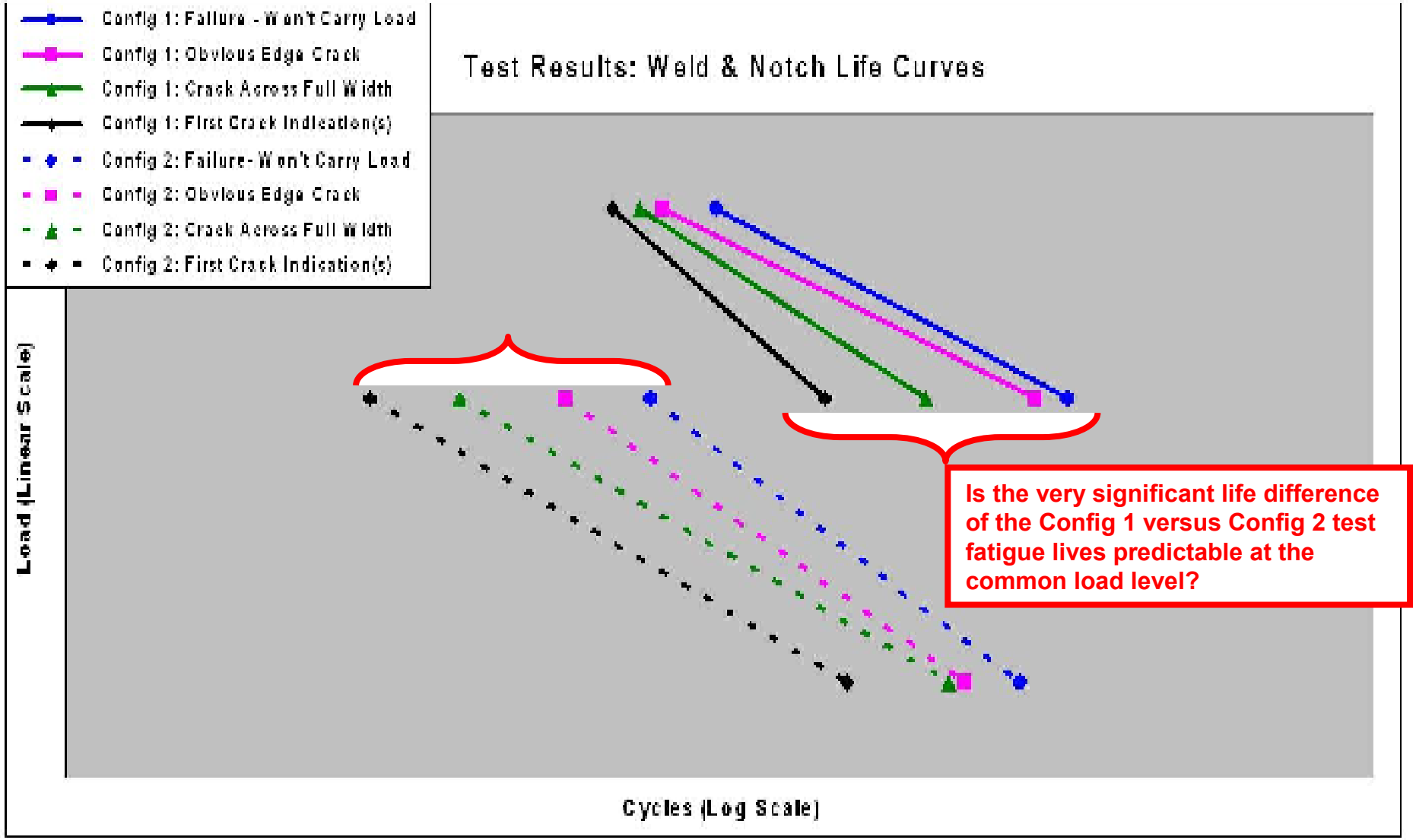
How Good Are Our Predictions?

First Question?



How Good Are Our Predictions?

Second Question?



How Consistent Are Our Predictions at Different Load Levels?

Third (and final) Question?

To What Life *and* What Size of Crack are We Predicting?

List your fatigue life predictions for the Config.1 and Config.2 Geometries
(Please fill in fatigue life predictions and corresponding crack sizes in the table below:)

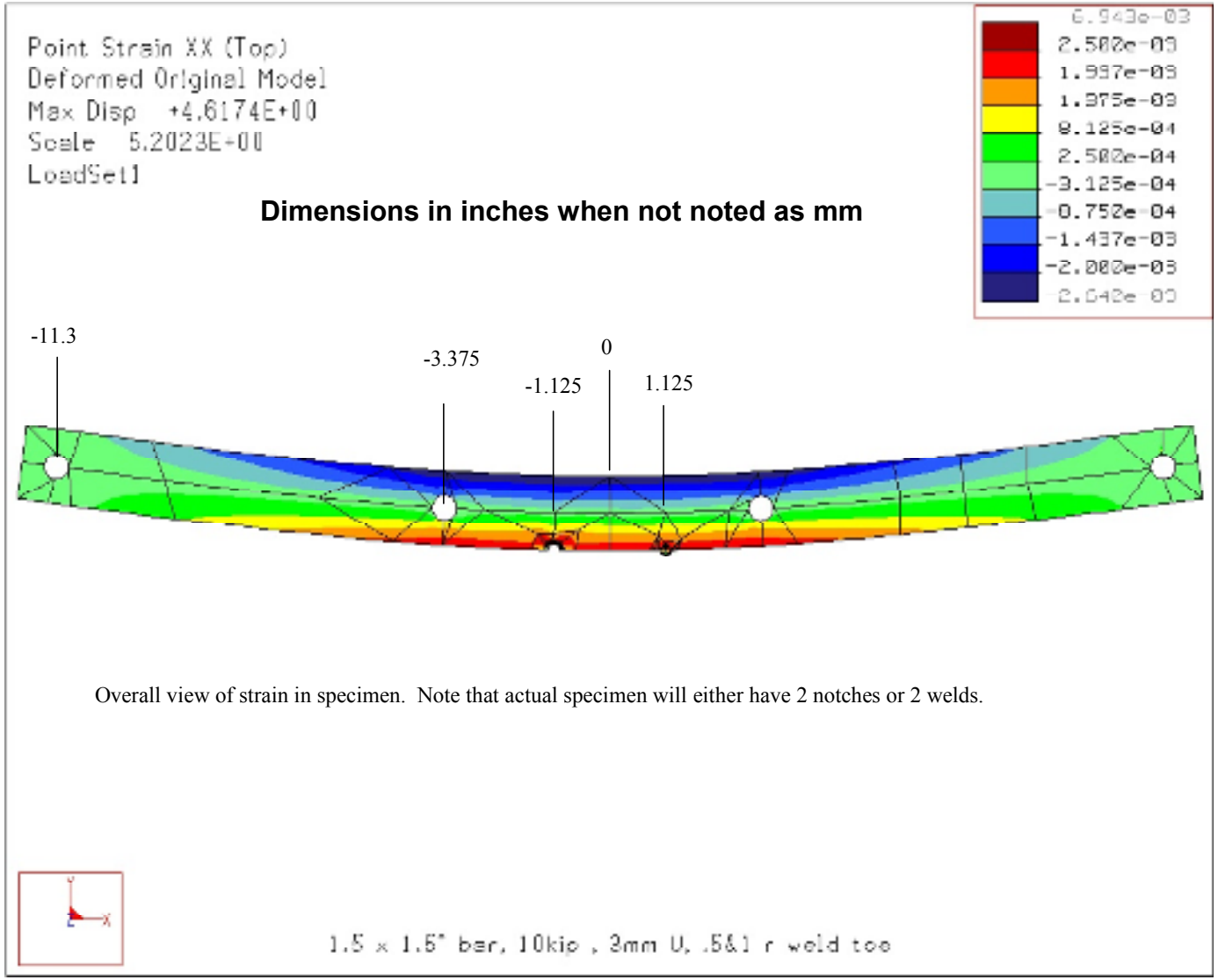
		Fatigue Life Predictions			
	Test Load Level?	Fatigue Life Predictions (to what crack growth stage - fill in at least one or more columns)			
Test	6000, 5000, 3500 Lbs?	(1) First Crack Indication(s)	(2) Crack Across Width	(3) Obvious Edge Crack	(4) Failure–No Load Carrying
Weld 1	?	?	?	?	?
Weld 2	?	?	?	?	?
Notch 1	?	?	?	?	?
Notch 2	?	?	?	?	?

Other Information Needed for Analysis

Bending test samples have been made and tested for comparing life predictions to actual results. The basic specimen is 1.5 inch square steel stock, 24 inches long, loaded in fully reversed 4 point bending. There are 2 specimen types. The first has a machined U shaped notch 0.125" radius 0.09375" deep in the test section. The other has a weld bead transverse to the length of the bar. The challenge is to predict the number of cycles at three load levels to break the bar. The specimens will be monitored to assess the portion of life before a crack is identified and a measure of crack growth versus cycles.

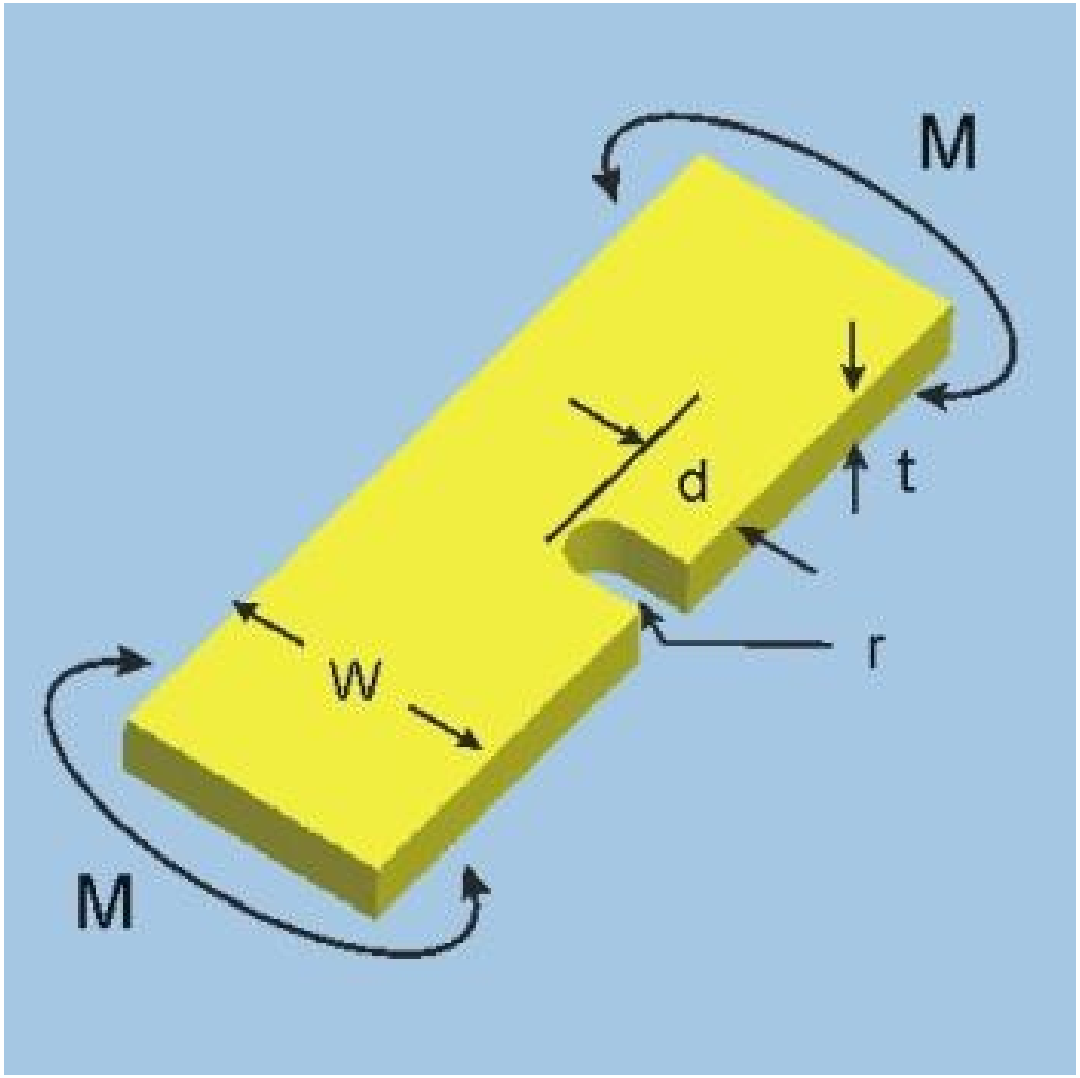
Some of the specimen details are in the figure. While the figure shows one specimen with a weld and a notch, actual specimens have either 2 welds or 2 notches at the locations shown. Material was normalized A36 (with 20 points carbon at 77- 78 HRB or 137-140 BHN). The welds were made with a Lincoln Power-wave 455, STT Mode 22 (Pulse Mode), with 90% Argon /10% CO_2 gas mixture (at 35psi) using L50 / 0.045" diameter wire. Welder settings were 80 trim / 380 in/min (wire) /10 in/min travel speed. Weld bead height was measured at 3/16". If interested in making a prediction, contact Tom Cordes at tom.cordes@ncode.com or Dan Lingenfelser at lingenfelser_dan@cat.com

Other Information Needed for Analysis



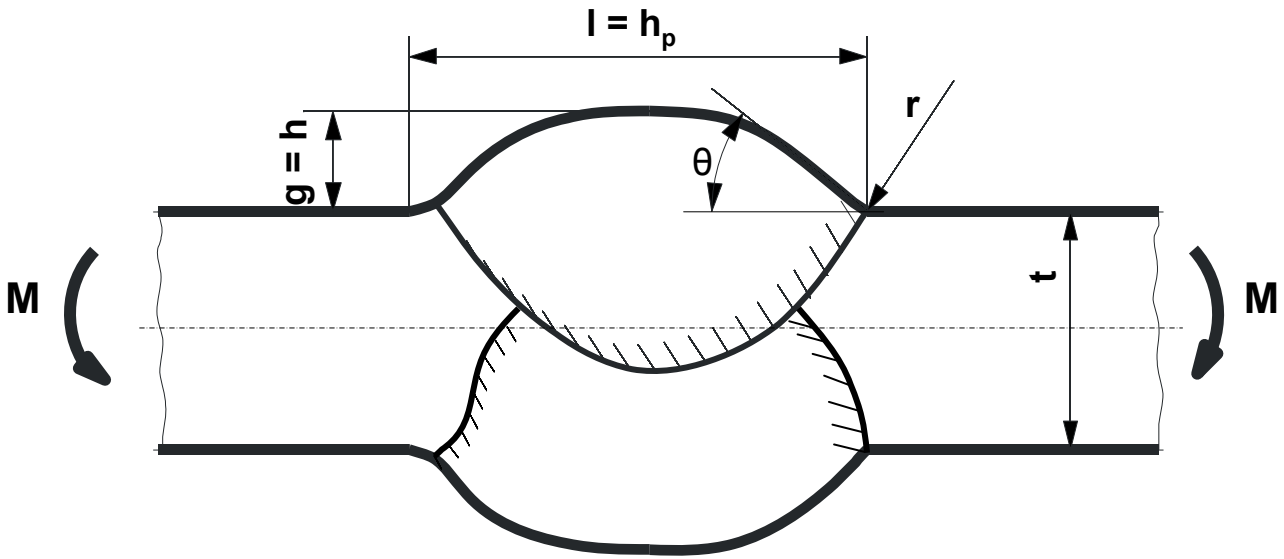
Overall view of strain in specimen. Note that actual specimen will either have 2 notches or 2 welds.

Notch Kt (and more) Available at: Darrell Socie's: eFatigue.com



Weld Kt (and more) Available from: Greg Glinka's Publications

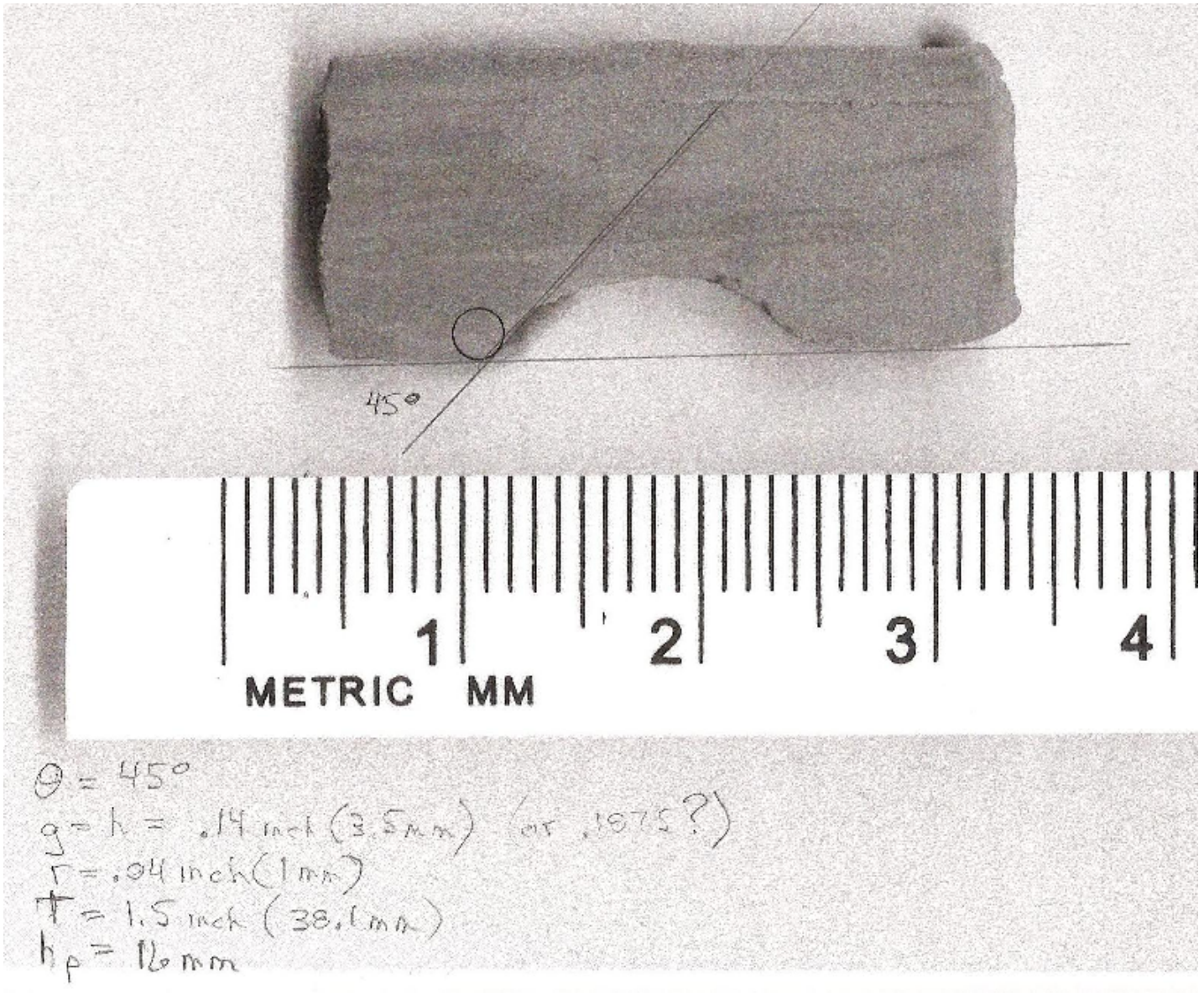
Stress concentration factor for a butt weldment under bending load



$$where: \quad W = t + 2h + 0.6h_p$$

Range of application - reasonably well designed weldments, *(K.Iida and T. Uemura, ref. 11)*

Important Weld Dimensions From Scalable Picture: For One (Typical) Weld Impression at One Location



Participation

- **Need Participants** Especially those without grey hair

- **To Do Analysis – Fatigue and Crack Growth from FEM or Mc/I** This power-point, and any missing details necessary to do the analysis, will be e-mailed to anyone who signs up to do analysis. When you return your analysis to Dan Lingenfelser or myself you will be e-mailed the load life plot with a grid, scales and your predictions marked on it. Your prediction will be assigned a number that is kept anonymous. We ask that you please keep these test results (the lives) to yourself. A summary plot showing all the analysis results (identified only with that anonymous number) will be presented at the next meeting. We would encourage anyone who would like to volunteer to share their analysis to sign up to present at the next meeting.

- **To Do Further Testing** The four-point bending fixture is available to anyone who will put it to good use. The Mississippi State University (MSU) testing facilities are available to anyone who will fund the work. Samples can be made for about $50/sample plus shipping.

- **To Make This Effort Even More Interesting** When you return your analysis, if you are so inclined, please indicate whether you are under or 50 years of age or older. If enough people participate, we will look at those two populations of analysis results relative to each other. Lets put a little competition into this for the fun of it.

Closing Thought

- **Quotation from a very successful heart specialist after fifty years of experience:**

" Beware of the Dr. who doesn't question his own diagnosis."

- **Are we so confident in our own "fatigue life" diagnosis abilities that we don't consider double checking to be worthwhile? Or don't we care?**

- **Please take the small amount of time it requires to help us do this.**