F.D.E. Notes April 15 2014
(Draft before Participant Comment return)

Notes on presentations during Fatigue Design and Evaluation Committee meeting at Stress Engineering Services, Mason Ohio

Disclaimer: These are not official minutes; they are just one attendee's notes and are subject to omissions and errors. If you find serious errors please notify the author or F.D.E. Chairman. These notes and the agenda will probably be posted on the website http://www.fatigue.org .

7:30 am Coffee, juice, pastries, fruit (all excellent)
Thank you Stress Engineering!

8:00 am Host Dan Morrow opened the meeting with welcome to attendees and outline of day's schedule and facilities.

F.D.E. Chairman Chad Kerestes introduced himself (area in test engineering at CAT) and the alternate Chairman Casey Gales from John Deere (area: Structural Testing)

Derrick Rogers Overview of Stress Engineering Services (SES):

Company has lots of business with Oil/Gas companies where problems are similar to those of ground vehicle: SES; Failure Analysis; Testing; Fitness for Serv.; Remaining Life; Design; Medical devices

Founded 1972, 430 employees, 235 engrs, Average 20 yrs service (less than 2% turnover. Many people come from big industries.

SES has 3 Met. labs: Cinn., Houston, N.Orleans; large SEM chamber

Follows API 579 Levels I, II, III, and IV
Test machines: 1 M lbs, 6 M lbs, 42" pipe axial+bending+pressure
Thermal cycle testing, Threaded/Welded connections.
Large pipe fatigue: weight on one end in resonance.
Coiled Tubing tests; Creep lab.
Waller Testing Lab: Sour Gas testing, Crack(longitudinal) Arrestor testing on pipeline specimens.
Data Acq.: Plastics, Steam Div., Oil Riser (accelerometer bottles), VIV
Example given of undersea jumper fluid flow vibration induced by pipe geometry. Assessed using accel. bottle.
Pipe Lines: Dent assessment and testing. Developed a SCF factor set for dents.
Materials Technology Group: API, EPRI(elec.power) sharing of knowledge found very helpful.

Break

Total Life Project: Machined T bar Specimen

Tom Cordes Project Leader

The group decided to test Welded samples for Total Life in terms of predicting both Crack Initiation and Crack Propagation life. Both a welded Tbar and a machined Tbar specimen was designed and tested.
The welded Tbar was available first and tested as described in previous presentations:

http://

Several talks today will address how we are doing on the machined Tbar samples.

Eric Norton has done the testing, the source of our data. Results are high quality and low in scatter. Matt Campbell did the FEA with high resolution elastic and plastic stress/strain analysis.

Eric Norton, John Deere:

Ryan Broderick did the weld Tbar testing. see:
http://

Present results are for Machined Tbar testing.

Test were done load control 5.1 hz

RPC software control for Variable ampl. tests.

11kip ram 10 inch stroke, USB cameras for crack init. detect.

Feedback time history stored

Video of (variable ampl. test) where crack was only seen beyond 80% life

Photos of all fracture surfaces. The Constant Ampl. (CA) test crack did not quite reach the full width of the bar before final fracture.

Block Load test shows marker bands.

Future Work: 0.60" stacked rosette gages on each side of samples.

Presentation: http://

Matt Campbell:

Study was done to eliminate variables:

Clarify stress levels for both Plane Strain / Stress vs. 3D analysis.

Mesh sensitivity

Geometric sensitivity (toe radius varied in model)

Provide necessary information for modelling.

Stress profile shown: Plane stress, Plane strain predict Kt =1.66

3D analysis Kt = ? with stress at center 7.7% higher than the stress at edge.

Linear models are well above yield.

Mesh Sensitivity: Need lots of elements. 0.10 mm smallest.

Graph of size vs result shown.

Hexahedral elements with mid-side nodes

Graph of stress vs distance from fillet shows a very steep gradient

Table of root radii vs Kt available. smallest 3mm Kt= 1.78 ?

Non-Linear Model: Ran both monotonic and cyclic.

Used Kinematic Hardening (moving yield surfaces for Masing effect)

Monotonic (higher than cyclic) max strain .0055

Cyclic max strain predicted 0.0082 for Load = ?

Both models run also during unloading from max back to zero.

Stress distributions graphed at max and back at zero.

Presentation: http://

Al Conle, Univ. of Windsor

Showed results of Open Source Crack Initiation and Crack Propagation Software.

At request of Tom Cordes reviewed the expected local stress-strain hysteresis loop shapes and behavior as predicted by Neuber plasticity correction using a Kt=1.78. Constant amplitude test loops are large and should be evaluated for cyclic mean stress relaxation. Introduced relaxation results of Ron Landgraf and another work on Mild steel
http://fde.uwaterloo.ca/Fde/Articles/Relax/conleSo.html
Initiation predictions for constant ampl. shown to expect cyclic relaxation.
Lives predicted using relaxed hysteresis loops.

Variable amplitude results shown to be affected by damage caused by cycles below the fatigue limit. Compensation curve used for A36 initiation predictions of VA tests. VA predictions close to test results.
Crack propagation simulations show less than 1 Block life for VA tests.
Presentation: http://

Tom Cordes, HBMncode

Described test program and results of predictions using traditional Crack initiation software and software developed by Glinka et al for propagation.
This project is partly to find out how good our tools are in predicting total life.

Initial crack Ao= 0.1mm (2 grains) in this material (A36 steel).
Variable amplitude tests had two cracks present (both sides). Compressive stress on hot-spot goes up as the other side crack grows.
Predictions were run for both the double crack stress increase and the normal assumed single crack. Double crack magnified history also used for traditional crack initiation prediction.
Results presented in graphs.
Presentation: http://

Lunch

Tour of Stress Engineering Services labs

1:00-2:00 pm: Session 1

Henry O. Fuchs Award Seminar

Peter Huffman Iowa Sate and John Deere

"A Quantitative ... Theory of ...
Includes Size Effect, Variable Ampl., Crack Propagation.
Relates da/dn vs deltaK curve to cyclic Stress-Strain behavior
Strain energy in front of a crack can be estimated by using Glinka method of computing local stress-strain.
da/dN = [C * DeltaK**mplas * (Kmax)** melas] -nEpsilon
C is fn(n') not of a', m = f(n') not a f(E)
Conclusion: Method seems to work well for pure Fe, Al and Ti
Secondary phases seem to mess up method, thus does not work for A36 nor Martensite.
Presentation: http://

Mark Norfolk – Fabrisonic LLC – "Material Property Characterization for 3d Printing"

Background: Weld engr., 10yr J.D., Cordes' lab
Most difficult about 3D metal printing: All Welds!
3 Types:
1. Direct energy deposition
2. Powder bed fusion (Laser) most popular
3. Sheet laminations (what we do) (Video)

Ultrasonic metal welding, 250F max, Ti+Al sheets etc
Metal matrix composites, Embedded sensors, high power RFIDs
1/3 of business is heat exchangers; Satellite components; Complex Shapes
Typically big parts 6' x 6'
How it works:
Pieziolectric horn vibrates 20Khz, use 3 axis mill
Diffusion bonding -oxide layer prevents Dif. bonds but vibration knocks off oxide layer
Other methods in industry: Inconel 625 Powder formed feed stock
Very little fatigue data available
Variability: due to size diff. in particles, melt pool size, atmosphere, Laser raster algorithms.
GE aviation has powder Inconel in production
NIST project with AmericaMakes
Ultrasonic: Project with TsingHua Univ. China.
2024 Al + post weld heat treat.
UltraS results close to base metal tensile.
Brick pattern of sheets can be a problem.
Did some fatigue R=0.1 5hz inside SEM chamber.
See Ref.: Materials Letters, 112 2013 pp 47-50
Some applications want delaminations to increase toughness.
Q: "What about coatings ?"
A: "Ultrasonics removes any coating due to man"

Link: http://www.fabrisonic.com

Break

2:40 – 4:00 pm: Session 2

Brian Jordon, Univ. Alabama "Fatigue of Friction Stir Welding in Magnesium Alloys"

Spot Joining of Mg sheets. Self Piercing Riveting in Mg does not work well (no ductility) Ford is using 20 lbs of rivets in F150 Alum structure.
Spot weld(fric. stir) cross-section shows surface profile and "hooks" where interface of faying surfaces ends in the weld zone. Ends of hooks are stress concentrators. Hooks due to trapped oxides.
Hitachi made 2 batches, 2nd better than first. Tensile test.
Failures in fatigue are Shear of "nugget" and Eyebrow failures.
At high cycles failures occur on back face sheet.
The "effective sheet thickness" (free distance between hook tip and surface) is important factor and influences crack prop. Shows da/dn vs Ni/Nf curve.

Presentation: http://

Roger Cordes, Stress Engineering Services, Houston Office

"Fatigue of Risers and Pipeline Girth Welds: Factors Driving Crack Nucleation and Small Crack Growth"

Topic is Pipeline girth welds - total life prediction or how we use fracture mechanics every week. Frac. Mech: API 579, ASME FFS-1 and BS7910.

SES also does high pressure (10ksi) vessels.

Extensive use of acoustic emmission to find crack locations: use 15 to 20 sensors and overpressure of 20% to give signal.

Girth weld project: Fatigue loads on risers (up to 6000' down) are important

Normally S/N design with Fact. Safety = 10

ECSs with F.S.=5 allowed with NDE limits of 1-2 mm.

We are trying to better understand nucleation.

A Joint Industrial Project. DNV SINTEF NTNU -->Test data available

Collect an analyze available experiments. Examine nucleation sites, I.D. features;

Also work in progress: mock up 24 pipe pieces -Run them -model –check 1099 full scale tests. 110 strip sample tests

Figure shows 3 pipe sections girth welded with strain gages, 300" long.

End weight resonance fatigue. Fractures and crack locations. Check local weld geometry.

Many plots of S/N weld results, with results split out for pipe sizes, weld quality, post weld grinding etc.

Presentation: http:// ?

4:00 – 4:30 Business

Notes as taken by A.Conle with formatting and minor corrections by H. Brown