--To: All members and mailing listees of SAE FD&E Committee:

UNCONFIRMED MINUTES OF SAE Fatigue Design and Evaluation Committee

Component Test Division:

Fall 2001 Meeting, Toledo, OH

Tuesday 16 October : Division Progress Meeting

The minutes of the division's progress meeting and planning session held 3-4 April 2001 were approved. As was noted for all divisions, anyone who did not receive the minutes via E-mail (Al Conle's distribution list) or did not look at the minutes at the "fatigue.org" site did not see the minutes, as they were not posted at SAE's web site.

ATV Status : Ric Mousseau

Ric noted that a few of the presentations in Wednesday's technical session would provide information about the ATV project during the last six months.

Presentation: "Vibration Theory and Practice of Failure Mode Verification Testing" : Alex Porter

FMVT is based on testing for any condition that can break the design. All load sources are input as random profiles, not profiles based on road load data or nominal operating conditions. Nominal loading tends to be a narrow representation of the potential failure sources, leading to tests that generate only the expected (biased) failure types. FMVT uses six-axis random vibration. Multiple failure modes can be found when inputting all identified stress sources such as vibration, temperature, and humidity. The presentation showed an example of testing on an instrument panel/cockpit system, using 6 axes of loading plus temperature, humidity, simulated sunlight, and actuation of duty cycle features like pedals and switches. 14 hours of testing on this system found 62 potential failure modes, of which 8 have known warranty history, and 41 probably would not have been found through conventional methods. FMVT needs a large spectrum; this need required an evaluation of different
types of equipment for the loading. Capabilities in frequency and displacement had to be considered. FMVT uses chaos theory-based recursive
control to achieve response spectra in frequencies far above those of the relative low "operating" control frequencies. The chaos equations of the control achieve very drastic changes in behavior from relatively small changes in coefficients, and the equations have symmetry of scale. The behavior can eventually bifurcate into non-repeating randomness.
 The presentation demonstrated this rapidly changing behavior via application of the equations to the creation of music. The FMVT system controls the base frequency, the rate of iteration, and the energy level.

Presentation: "Accelerating a Durability Test with Fatigue Editing" : Kurt Munson

The goals of the test-building project were to create a test schedule capable that reproduces a heavy truck's service life in a short time, and to run a multi-axis test based on that schedule. Data collection covered 15 events and over 12 hours of customer use, utilizing 16 strain channels for durability analysis and 32 acceleration channels for test control and modeling. The actual time for the vehicle's service life is about 12,000 hours, but the target time for the lab test was <400 hours. The data channels included vehicle accelerations for test control and strain gages for correlation. The test was to use several hydraulic actuators attached to the vehicle frame, and was to be time-based to reproduce variable amplitudes and vibration modes. The long, unedited strain histories were from 15 field events. These were the histories subjected to fatigue-based editing. The fatigue calculation parameters for editing included strain-life data provided by the steel supplier, as well as a Kf determined by back-calculation from component test data. Damage histories were determined at each critical location. The time histories were divided into frames of a size equal to the inverse of the lowest frequency of interest. The determination of frames to retain was via a Boolean OR function, i.e. if notable damage occurred at one or more locations during a given time slice or frame, the frame was retained for all channels. The retention of all channels is necessary to maintain phasing. In order to meet the test length target of 400 hours or less, a damage retention target of 40% was used, and the retained test content was repeated 2.5 times in order to return to 100% of field damage. An exceedence plot for one of the critical strain channels showed the cycles distribution of the edited data converging with that of the unedited data for strain ranges of ~700 me and higher. The frequency content before and after editing was compared to verify that proper structural excitation was maintained. The resulting lab test was successful at reproducing several field incidents.

Wednesday 17 October : Division Planning Session

Ideas and proposed studies were discussed for assessing variability in the loads of the ATV dynamic model as a function of the following variables: payload, springs, shocks, steering, speed, and the test track. What creates the worst case?

Attendees of the session re-stated the availability of Caterpillar Component Technology's facility and equipment for bolt fatigue testing. This availability had been noted previously in a Tuesday presentation about bolt fatigue results.
Please contact Dan Lingenfelser or Jeff Nash if interested in more information.

Time limitations in the session prevented discussion of additional possible project initiatives in the division. However, ideas for such initiatives, which were listed on overhead sheets during the session, are listed here:

Variability and uncertainty studies

Accelerated testing (new methods, how much acceleration is too much)

Thermal fatigue testing (and acceleration thereof)

Projects of potential cooperation with the Structural Analysis division.

THE DIVISION IS STILL SEEKING A VOLUNTEER FOR VICE-CHAIRPERSON!

Respectfully submitted,
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UNCONFIRMED MINUTES OF SAE Fatigue Design and Evaluation Committee

Structural Analysis Division
Fall 2001 Meeting, Toledo, OH

Tuesday 16 October : Division Progress Meeting

Mary announced the new Structural Analysis Division vice-chairman of is Jin Qian.

Greg Glinka presented "Stress Concentration and Stress Distribution In Weldments," based on discussions with John Deere and Ralph Stephens. The approach to structural analysis of complex cross sections to find local point stresses at weld toe and apply standards with nominal stress is OK for test specimens, but difficult to apply to real components. Therefore, he uses hotspot stresses or average stresses. In offshore applications for tubular structures definition of nominal stress is not unique. Finding nominal stresses is not easy; and some other method is needed. He can use detailed numerical analysis and get nominal stress from sections of interest equal to hotspot stresses. He uses a method proposed by a Japanese analyst, where mean stresses are calculated away from the weld toe, with two stress concentration factors and linear extrapolation to the section of interest all along the surface. He could also linearize the stress distribution through the thickness. Greg's method uses membrane stress and bending stress obtained from a shell element analysis of the structure, as a direct output of hot spot stress. He can then find stress concentration factors from membrane and bending stresses. For example, fatigue problems in a crane arm were caused by local stresses not by a nominal bending stresses. A shell finite element model of the entire box gave stresses in each cross section. He calculated peaks stresses for stress concentration factors from pure bending and stress concentration factors for tension. Peak stresses with were obtained with Neuber analysis, and then applied to damage calculations. Another example was a T-joint loaded in bending and tension. The stress concentration

factor for fillet depends on weld height and toe radius. Greg applied his method to a T-joint modeled by Jin Qian with finite element shell elements and found results compared closely to FEA results. The key point is to split the stress into membrane and bending stresses from a shell finite element analysis and apply to crack growth. Finite element stresses are for uncracked sections. Greg also integrated weight functions
and compared to results from the Paris equations. He assumed 0.3 to 0.5 mm internal cracks in the weight functions.

Jim McConville, from Mechanical Dynamics Inc., presented " A Survey of FEA Based Stress Recovery Methods in ADAMS." The primary purpose of engineering analysis is to "prevent nasty surprises." Structural models are only as good as the loading. A "good analysis" rule is that it needs all three of these qualities "good, fast, and cheap." But you usually only get two at a time. As an example Jim described a flexible airframe landing simulation that was modeled with a Nastran finite element model. The model was a condensed structure with 60 retained modes, out of 2400 degrees of freedom 2.1 Hz through 1572 Hz. It used Greg Brampton's hard points, static superelement condensation, eigenvalue extraction with a Lagrangian approach to show the effect of landing stresses. Jim showed a comparison of landing gear loads for the rigid model and flexible aircraft models for a force-based model and a displacement based model. Force based linear elastic structural analysis methods depend on loads the interface points. The accuracy of force based linear elastic structural analysis methods depend on loads at the interface points and are incomplete because it cannot account for accelerations. The FEA solution is valid if reactions at the supports are equal to zero or small or compared to the applied loads. The displacement based model method is linear elastic. Flexible coupling uses a reduced degree of freedom set. A MSC Nastran example problem showed supports are arbitrary if support reactions are small. Automotive customers typically inertia relief methods. Jim concluded that
flexibility is important. The free-free modal behavior of a condensed model agreed closely with the behavior of a full model. Retained modes of interest work the notches. Highly condensed models can yield very accurate results. One simulation predicted fatigue life at 7.1 hours compared to test life of 12 hours. These analysis results were good for low frequency damped structural simulations. Jim described an "Autoflex" process that automates the modeling process that makes early predictions of fatigue life feasible and practical.

Planning Session Results. The activity plan, generated during the meeting, is included below.

SAE FD&E -- Structural Analysis Division Planning Session -- Fall 2001

Item Activity

1 Mesh refinement criteria -- How to evaluate adequacy of

mesh Michele Wegscheid Ric Mousseau Gary Mauritzon (test)

2 Implement G.Glinka's weight function and evaluate potential applications Jerry Green

3. Define overall sequence of actions for ATV project and where Structural Analysis Division can participate Alice Popescu Mary Wickham

4 Collect prior presentations, index and put on web. Include contact of Dr. Socie, Kurt Munson Ric Mousseau

5 Create design/ analysis goals. What are we trying to accomplish with ATV project? Review old goals Alice Popescu Mary Wickham

6 Check to see if MTS can run test data through MTS code for verification of data integrity Mary Wickham

7 Committee to use test data with dynamic model Ric Mousseau

8 Fatigue evaluation of aluminum sheet metal connections Hari Agrawal

9 Fatigue of sheet metal for automotive structures Hari Agrawal Barry Lin

10 U of Toledo model to be put on web site Ric Mousseau

Respectfully submitted,

Mary Wickham
Chairperson, Structural Analysis Division

UNCONFIRMED MINUTES OF SAE Fatigue Design and Evaluation Committee

Road Load Data Division

Fall 2001 Meeting, Toledo, OH

Tuesday 16 October : Division Progress Meeting

Christoph Leser moderated the meeting.

Minutes from the previous meeting were not available and therefore not approved.

Robert Geisler of GM gave a presentation entitled: "Using Analytical Loads
Prediction to Using Analytical Loads Prediction to Assist in Generating

Laboratory Assist in Generating Laboratory Dynamic Loads for Durability Testing Dynamic Loads for Durability Testing"

Darragh Murphy of MTS Systems Corporation gave a presentation entitled: "Automated Road Load Data Analysis for Verification of Data Integrity"

Christoph Leser of MTS Systems Corporation gave an update on "ATV Shock Absorber Load Modeling"

Wednesday, October 17 - Divisional Planning Meeting

Christoph Leser chaired the meeting

As per the last meeting the RLDA group will support the ATV group when requested.

New activities - no proposals for new activities were made.

The RLDA group will evaluate "automated data analysis tools". To this end MTS and nCode will be contacted to use their automated tools on existing SAE ground vehicle load records. To verify that the original histories are
valid Tom Cordes of John Deere and Brian Dabell (formerly GKN) of nCode and Mark Early on the recently acquired ATV records could be contacted.

Efstatios Nikoladis suggested reviving statistical road load analysis. There is an SAE committee on probabilistic Design that he will contact to give us input on how statistical variations in loads need to be considered for to account for probabilistic aspects in design.

The meeting was adjourned.

Respectfully submitted,

Christoph Leser
Chairperson, Road Load Data Division

UNCONFIRMED MINUTES OF SAE Fatigue Design and Evaluation Committee

Fatigue Life Prediction Division

Fall 2001 Meeting, Toledo, OH

Tuesday 16 October : Division Progress Meeting

1. Minutes from the previous (Spring 2001) session were unavailable and could not be approved.

2. Russ Chernenkoff reported on "High Mean Stress Level Tests".

The material for this test was a normalized 1045 steel (Phase II material from FD&E biaxial project). Testing was on axial samples using stress-control with strain monitored at room temperature. Three sets of tests were conducted:

Set 1 at constant max. stress = 381Mpa,

Set 2 at constant min. stress = -381Mpa,

Set 3 at constant min. stress = 0.0

The data is on the website:
http://fde.uwaterloo.ca/Fde/Highs0/racccc.html

3. Chin Chan Chu discussed " Life Prediction for Specimens Subjected to High Mean Stress Levels." The purpose of the analysis of this test data was to help correlate methods from Tim Topper, University of Waterloo. The portion of cycle that does the fatigue damage is the opening part of a given stress cycle. An intrinsic material fatigue property is:

$S_{op} = ?\ S_{max} [1-(S_{max}/S_y)2] + S_{min}$

4. The results of items 2 and 3 above have been accepted for publication in Int. J. Fatigue paper by C.-C. Chu and R.A. Chernenkoff "Crack Closure-based analysis of fatigue tests with mean stress."

5. Jeff Nash discussed "Bolt Fatigue."

- Mean stress affects were best predicted by Morrow equations.

- High preloads can drastically reduce fatigue life.

- For grade 9 bolts, half of failures were at the head.

The threads were ground and rolled after heat treatment. The primary failure was the first engaged thread. Question: Have you calculated the local stresses? Answer: No, looking for volunteers.

6. Al Conle discussed information on the website at Waterloo, and demonstrated how someone can pick a standard data set for processing and come back with curves and plots. Contributors were Ron Landgraf, NASA, Endo/Morrow, Brian Leis, Peter Kurath, and John Bonnen. Ohter FD&E members are encouraged to contribute more data. He also presented a report on "Using the Hot-Spot Stress Method for Predicting the Life of Fusion Welds."

Respectfully submitted,

Al Conle
Chairperson, Life Prediction Division

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UNCONFIRMED MINUTES OF MEETINGS OF SAE Fatigue Design and Evaluation Committee

Material Properties Division

Fall 2001 Meeting, Toledo, OH

Tuesday 16 October : Division Progress Meeting

Minutes of the April 3/4 2001 approved as written.

1) The 2nd annual database awards were presented, and this year the awards went to

I) Peter Kurath for Ti6Al4V Beta-annealed

II) NASA for 1100 aluminum, 304, 310 and AM350 stainless steels, Ti6Al4V, Ti_5Al_2.5Sn, and 4340 steel.

III) K. Endo and J. Morrow (U. Illinois) for 7075-T6, 2024-T4, and SAE4340.

IV) Brian Leis (U. Waterloo) for 2024-T351

V) Ron Landgraf (U. Illinois) SAE1045, SAE4142, and Maraging steel (several different data sets of each).

2) A Revised version of SAE J2409 (standard file format for exchanging strain-life data) and the new proposed format for overload data was briefly presented.

3) Russ Chernenkoff (Ford) gave a brief synopsis of the digitization of the upper and lower

ATV control arms. The "step" files are available at the fde website. Check the

link ftp://ftp.fatigue.org/data/ATV/Control_Arm

4) Russ Chernenkoff then gave a presentation entitled "Mechanical Properties of Aluminum Composites for Forged Powder Metal Connecting Rods." This work was performed under the auspices of the USAMP program.

Pucks forged out of an aluminum metal matrix composite (2XXX class Al alloy combined with 20% SiC) were solutionized, heat treated to T6 condition and then machined into fatigue specimens. The fatigue specimens
were separated into two groups: one polished, the other shot peened.

The room temperature fatigue strength of the shot peened specimens (180MPa) was better than that of the polished specimens (150MPa). Fractography showed that the initiation sites were primarily either SiC clusters (distribution) and regions of poor interparticle bonding in the Al alloy. No effect of inclusion content was found.

5) Al Conle gave a talk for Kin Yeung (Ford) entitled "Shaft Straightneing Fracture Estimation".

They modeled the development of the residual stress distribution from the thermal processing of an induction hardened shaft using ABAQUS. After developing a satisfactory result they simulated a shaft straightening operation (wherein a shaft which has warped due to heat treatment is straightened mechanically) in order to predict the point at which the shaft would fracture.

By modeling the case, core and two layers of intermediate hardness, they found that they could predict both the forces used in straightening the shaft and those necessary to fracture it, given reliable values of true fracture strain. Further, they were able to predict the redistribution of residual stresses as a result of the straightening operation.

6) Ralph Stephens (U. Iowa) gave a talk entitled "The Influence of High R Ratio on Unnotched Fatigue Behavior of 1045 Steel with Three Different heat Treatments."

High tensile mean stress tests for R ratios of 0.8 and 0.9 were conducted on smooth uniaxial fatigue specimens made from SAE 1045 steel with hardness levels of Rc 10, 37 and 50.

S-N curves for all three hardness levels for both R=0.8 and 0.9 were very flat except Rc=50 specimens with R=0.8. The experimental results showed that at high R ratios, the fatigue strength based on Smax was higher than that for low R ratios but were lower when based on Sa. Acquired e-N applied curves showed that cyclic creep was present for all three hardness
levels. At Rc=10 and 37 had more cyclic creep/ratcheting resulted than at Rc 50. Scanning Electron Microscopy (SEM) analyses showed that Rc 10 and 37 specimens fractured in a ductile manner with cup-cone shaped final fracture, where ductile dimples were dominant with small amount of micro cleavage. Rc 50 specimens fractured in a brittle manner involving less cyclic creep. Tensile and cyclic (fatigue) final fracture surfaces were very similar for Rc 10, 37 and short life (Nf <3000) specimens of Rc 50. The failures of these specimens were caused by cyclic creep/ratcheting
rather than fatigue cracking. Rc 50 specimens with Nf>3000 were the only specimen group that failed due to thumbnail surface fatigue cracking. S-N and e-N life prediction models were compared. S-N models predicted actual specimen lives better than e-N models, although none of the models was successful in calculating the fatigue lives for high R ratios.

Divisional Planning Session, Oct. 16

1) The revised version J2409 (strain-life data file format) was

discussed. Many new tags were added (both optional and mandatory) for monotonic properties, specimen design, and material form. A methodology was adopted for denoting "runout" tests. This new standard has now been submitted to SAE for balloting.

2) The proposed new standard for data exchange of overload fatigue datasets also was discussed. This file format shares the same tag definitions as the revised J2409, but the actual data format is quite different. This standard was also submitted to SAE for balloting.

3) A proposal was forwarded for drawing up a standard for overload testing.

4) A call was made for more dataset donations to the free database project.

Strain-Life Fatigue Data Exchange File Format (Revised)

The file can be viewed at
http://fde.uwaterloo.ca/Fde/sae_strain_life_J2409rev.txt

Note: These files should not be edited with MSWord which often "wraps" lines unexpectedly. One should use an editor that does not wrap, such as MS Notepad or vi in Linux.

Periodic Overload Fatigue Data Exchange File Format

The file can be viewed at
http://fde.uwaterloo.ca/Fde/sae_ol_strain_life_Jxxxx.txt

Note: These files should not be edited with MSWord which often "wraps" lines unexpectedly. One should use an editor that does not wrap, such as MS Notepad or vi in Linux.

Respectfully submitted,

John Bonnen
Chairperson, Life Prediction Division