SAE Fatigue Design and Evaluation Committee
Micro Minutes
April 4 & 5, 2000, Cedar Falls (Waterloo), IA
Host: Ray Thompson - John Deere Product Engineering Center

Tuesday 8:00am Main Committee Meeting
Announcements:
Phil Dindinger opened the meeting and announced that SAE has initiated a new "SAE Strategic Alliance." Committee participants from non -SSA companies will no longer be assessed a participation fee. However, there is a mailing list fee if you are not from an "SSA" company. Retired participants are staff exempted. Note that SAE is switching to entirely electronic distribution of minutes and meeting notices. You will need to pull the minutes and meeting notices off the SAE website. Please include your latest e-mail address on the registration form.

Local Arrangements:
Ray Thompson introduced Don Funsteen, Manager of Product Verification at John Deere Product Engineering Center. Don said the SAE FD&E Committee work is well recognized at John Deere Product Engineering Center. Their work in product verification and validation utilize the tools of this committee. They are focused on doing a better job by using the analytical side of fatigue analysis to build their products right the first time, use full tractor evaluations at test sites across the country, and look forward to the progress of work by this committee.

Ray announced a social hour starts at 6:00 p.m. today and a tour of the John Deere tractor works is scheduled for 9:30 am on Wednesday. We will return at noon for lunch with planning sessions starting at 1:00 p.m. The instrumented ATV, just returned from a load measurement exercise at Sundown Ski Resort, was on display in the lobby. Report on Meeting with JSAE Fatigue and Reliability Committee: Phil reported that the division chairmen met with representatives of the Japan SAE to discuss mutual activities and interests at the recent SAE Congress in Detroit, and are considering ways to work together. Their group meets six times per year and consists of 26 members (17 from their auto companies, four and from material suppliers, four university professors and one from a national lab.) They have concentrated on evaluating fatigue of both mig and spot welds, and are very interested in digital prototype optimizations. The JSAE group presented two papers on fatigue of welds at the SAE Congress. Andrew Whalen has discussed our ATV test project with them. If you are interested in participating with this group contact, Russ Chernenkoff or Chris Leser.

Education:
Ralph Stephens announced the SAE FD&E/U of Iowa Fatigue Concepts in Design Short Course will again be held at the MSU Management Education Center in Troy, Michigan, August 1-4, 2000. Steve Haeg has replaced Gail Leese on the faculty this year. Ralph will send out course notices. Please make the course information available to your colleagues.

H.O. Fuchs Student Travel Award:

Gavin Horn, from the University of Illinois, presented his work on "Nondestructive Residual Life Estimation for Damaged Fiber Reinforced Polyurethane and SRIM Epoxy." Gavin has worked with Peter Kurath, and acknowledged previous work by Ed Stanley and Ali Fatemi at the U. of Toledo, and support fom the National Science Foundation and Tri State Machining Company.

Thermoelastic stress analysis is based on an effect discovered by Lord Kelvin that the temperature of a material changes in cyclic loading in proportion to the change in stress. These small changes in temperature are detected with infrared cameras. The sample is painted flat black to eliminate reflected hot spots. A cyclically varying load is applied to the specimen, and a thermal image of the component is obtained. He defined a Modified Stress Concentration Factor as:

MSCF = (Tlocal /(T far field
and Modified Stress as
(mod = MSCF x (applied

The test materials were polyurethane /fiberglass composite with about 9%(?) glass fiber, and an SRIM epoxy/fiberglass composite with 40% glass fiber. The samples were impacted on a Dynatup impact tower. Grayfield scanned images of the test specimens were obtained after impacts of 6 joules up to 27 joules and thermoelastic stress analysis showed progression of cracks. The SRIM samples were tested at two levels , 17 Joules and 25.8 joules. The lower impact level resulted in cracks just starting and at the higher level, the impactor passed through the specimen.

Fatigue tests were run in a tension/tension mode at 2hz (with R=0.1). John Deere, U. of Illinois, U. of Iowa, and U. of North Dakota fatigue data on polyurethane composites showed wide scatter, but when the data was plotted against Modified Stress Concentration Factor the data aligned nicely in a curve similar to the baseline material, with some divergence at lower cycle levels due to heating effects. Fatigue results for the epoxy composite showed large scatter with applied stress, but damage lines up with modified stress concentration factor. However, the fatigue results did not show as good correlation as the polyurethane composite. Thermoelastic stress analysis can show inherent cracking and delamination. Machining can cause delaminating, matrix fiber to chip out, fiber breakage, and matrix overheating.

Measured machining damage to SRIM epoxy composites for a 6.3 mm diameter hole made from a standard point drill (cost = $1) after 1000 holes were drilled were: heavy chip out, spalling, and a rough surface inside the hole. The carbide brad point drill (cost =$33) produced very clean holes with slight chip out, and the abrasive water jet with 80mesh garnet produced heavy delamination and rounded edges. Results from Thermal stress analysis and fatigue test results were :

	Med. SCF	50% Prob. of Failure	SEM Image
Standard Point Drill	3.19	288,000	fibers at edge
Brad Point Carbide	3.23	271,000	clean cuts

Abr. Water Jet	3.89	187,000	small cracks within 2mm of edge of hole

Component Testing Division:
Paul Lubinski opened the meeting and the October 1999 minutes were approved.

ATV Structural Analysis:

Dan Klann reported on the progress of structural analysis on the ATV project. Dan needs loads information before attempting serious stress analysis. U. of Illinois students built the original model in Hypermesh 2.0. Dan is concerned about the mesh density and faceting, and wants to remesh. He converted the model to Patran, but lost the connectivity information. Dan is concerned that the model needs refinement, and the mesh is no longer associated with the geometry information. These problems should take one to two days to clean up. Dan proposes to analyze just the frame first and needs the loads from a test measurement or simulation. Mary Wickham has talked to Darrel Socie about tests at the U. of Illinois.

ATV Multi Body Dynamics Simulation:
Ric Mouseau has been developing a simple, easy to use, dynamics model to predict durability loads information and support Adams and DADS simulation efforts. This model uses the codes "Autosim" which creates source code and very efficient simulations, and "CarSimEd" which interfaces the dynamics model to the plotter and animation and executes in Windows. The model is a 24 d.o.f. rigid body model with revolute joints and force elements and no suspension bushings. The initial tire model consists of vertical inputs. Inputs are vehicle speed and left and right road profiles. Ric showed the results of a single impact event. He wants to clean up the model and ATV parameter sets, implement a tire model lookup table, enveloping tire model, bushings and ball joints, add additional acceleration outputs, post on the website for people to evaluate, and eventually develop loads for structural analysis. This might be an ideal model to investigate driver characteristics.

ATV Data Acquisition:
Gary Mauritzon showed video tape of some data acquisition that took place recently at Sundown Ski area. They recorded 56 channels of information including four wheel forces, steering wheel position, suspension position, straingages, spindle F/A accelerations, and lateral accelerations. Note that the electrician usually carries a toolbox with him that is heavier than this instrumentation. Most runs were made on dry land, but the ski area still had some patches of snow. Four drivers, Al @ 185 lb, G.S. @ 245 lb, G.M. and D.H. were used. Runs were made on and off the seat, one aggressive run up and down the hill and one run on the snow patchs. The ATV was also run over a flat bumpy area at the technical center. Bill Nybeck has offered to analyze the data tape. A question was asked: "What's next?" Despike, dedrift, annotate, store on website, fatigue analysis of strain gage data, analyze effect of different driver weights, store

video, and determine FEA loads are some of the tasks. The vehicle goes back to

Technical Presentation:
Mark Prezlawski discussed "Load History Editing for Analytical and Experimental Durability Assessments." (Mark announced that Kurt Munson who has also contributed to this project could not be present because of the birth of daughter, Lauren.)

Currently load histories are measured from and to everywhere, for example from field to rig tests, or for use as input data for finite element models. We often need to simplify and establish continuity, and control over raw and user data. Raw data analysis manipulates data with filters, mean removal, and re-scaling, establishes baseline fatigue damage for raw data, and selects raw events to simulate. For example one test evaluated eighteen strain gages over eight events for fatigue damage. They removed lower damage events through peak /valley extraction (no frequency content) peak/valley slicing maintaining synchronization across channels (still no frequency content) and then rainflow cycle counting (which reduces high count low damage cycles.)

Frequency correlated damage calculates damage as a function of frequency. This highlights frequency regions of high damage content, and has an impact on test development by comparing rig responses and influencing fixture designs. If you remove a portion of the frequency band does the fatigue life change? Band pass filter, calculate damage and compare life. If rig only goes up to 30 Hz you may miss 50 Hz. components.

Manual deletion of "smooth sections" is time consuming and not very scientific. Damage editing can be accomplished by Rainflow cycle counting the entire file. Determine load at one second time slices and evaluate damage. Use damage from critical locations. Evaluate % damage retained or % time reduction. For example, one original test required 225 day versus 96% damage retained in a 12-day durability test. For parts with multiple input loads establish damage from multiple combinations of input loads. Look at all possible combinations, assess for every few degrees of rotation. Refer to Vladimir Ogarovic's work. The question for a multiaxial part is can we load uniaxially and obtain reasonable results? One final technique is based on finite element analysis where you take customer accelerated tests and eliminate lower stressed nodes and with correlation find an equivalent accelerated test.

R. S. questioned the consideration of corrosion effects? G.Glinka. stated that in the offshore industry editing out small cycles is dangerous. R.L.said that work on corrosion effects on fatigue has increased particularly on aging aircraft. Also, editing out frequency content can cause problems. Minor changes to design can cause major changes to response frequencies. Standardized procedures still need to apply some degree of engineering judgement.

Fatigue Life Prediction Division:
Chin-Chan Chu opened the meeting and the October 1999 minutes were approved. Al Conle has agreed to serve as vice chairman of the Fatigue Life Prediction Division.

Charles Sieck discussed "Differences of Variability and Uncertainty." Variability does not drive uncertainty. Deterministic analysis takes discrete values and calculates discrete answers, where probabilistic analysis uses probability distributions to calculate probability of failures. Considering fixed costs and variable costs there is some optimum number of loads to measure. If we just looked at number of loads measured versus cost, it would indicate we should measure no loads. If we consider sources of uncertainty like variations of inputs, customer applications, material strengths, and manufacturing in our calculations and put these variations into a Monte Carlo simulation, we might determine that four or five load measurements would be optimum. It is very rare that we get data based on 100 test samples. If we required 90% confidence the optimum sample size might require measuring loads on ten samples. In order to characterize uncertainty we could say that we have a mean of 300 and a standard deviatio

Russ Chernenkoff discussed updates on "Effects of High Mean Stress Study."
Last meeting Chin-Chan Chu proposed a project to determine the effects of high mean stress on fatigue. They did a literature search and started tests at Ford on gray iron. Some earlier work on investment cast A356 T6 samples from Mike Mitchell includes some constant amplitude tests results. They conducted some variable amplitude tests with high mean stress and periodic compressive overloads, as developed by Dave DuQuesnay for his MS thesis. They looked at strain amplitude at 10000 cycles and Miners rule where:

D total = D small cycle + D overload

then looked at equivalent cycles to failure.
There is not much data available on the effects of high mean stress. Chin-Chan Chu would like to see more comparison tests run with strain histories and material properties available on the website.

Al Conle gave a brief update on "Standard file formats for Load Histories and Material Properties." Try the routine to create a digital curve for use in simple analysis tools that is on the website at www.fde.uwaterloo.ca.

Road Load Data Acquisition Division:
Christoph Leser opened the meeting and the October 1999 minutes were approved. For comments on proposed Rainflow Counting standard contact Mark Pompetski. The time history format issue is closed. Contact Andrew Whalen or Al Conle for comments on ASCII data for the web page.

Chris Leser reported on "Modeling of Non-stationary Variance in Vehicle Loading Histories for Fatigue Loading." His objective is to find a concise fatigue load distribution. His motivation includes storage reduction, improved FEA capability, for test machines, monitoring, and

to concentrate work on major events. For stationary load histories, the data reduction scheme includes a full time history recording in the time domain, a stochastic stationary generally linear model. A scheme for the non-stationary load history the scheme would include counting methods such as Markov, or rainflow methods, deterministic nonlinear models and autoregressive random characterizations. Comments: Lee Tucker stated it would be valuable to be able to simplify and condense real road load data and determine what are the characteristics of a load history? How do we model a bump as a discrete event, and then what do we do with it? Run an instrumented vehicle over a measured surface? We don't know the road profile of the "Sundown

R. L.: We have a similar problem except load measurements are expensive and time consuming. One company monitored aircraft loads extensively for various events and calculated exceedance curves, and monitered these curves over a long period of time. L. T.: There are two types of loads: deterministic and vibration or resonance. The question is are we making the right decisions? The customer controls changes to the operating environments, and make the machines work harder, or as hard as possible and still comfortable. T.C.:Is it a function of this group to figure out how to compress the data used in the future?

A.P.: Why not use Kurt Munson's RPC test data for initial correlation? What happens in the first stages of data acquisition? Why do we measure and what happens? D.K: Can we run the vehicle over "steps" test track? What is the size of the steps? This vehicle may not follow standard procedures. Discrete events should be easier, and offer an incremental advance over D. Socies initial work. There may be a suitable track available in Moline.

Material Properties Division:
Ed Lu opened the meeting and the October 1999 minutes were approved. John Bonnen has agreed to take the position of Chairman of the Material Properties Division.

ATV Project Support:
Phil Dindinger reported on "Chemistry of the ATV Frame": The material was characterized as SAE 1015 with very clean and very fine grain microstructure. The tubing contained .08% carbon, .67% manganese, .03% copper, and .03% chromium.

Technical Session:
Peter Kurath presented " Nuances of Approximate Notch Methods ." Plastic zone stress calculations from FEA models are usually handled with Neuber or Glinka relations for small scale yielding or with Hoffman-Seeger for net section yielding. For a plate with a center hole and w/t = 50 look at plane strain and plane stress. For a notched shaft with tension past yielding and bulk yielding, the basic conclusion is that you can sometimes extrapolate a little farther. The methods usually stop at bulk yielding. Nonproportional loading is very path dependent. There are significant differences between Seeger and FEA results for a "bowtie path."

Greg Glinka reported on "Fatigue Crack Growth Through Residual Stress

Fields (Shot Peening)" In order to calculate Stress Intensity Function for an application we need to calculate "Weight Functions" and "Green's Functions." Find stress distribution without the cracks and superimpose for Mode I loading. Calculate stress distribution and apply that stress distribution to the crack surface. Gregg discussed an example of a crack in a thick walled cylinder (a cannon.) FEA results compared very well with his methods.

Structural Analysis Division:
Zheng Xian Bai opened the meeting and the October 1999 minutes were approved.

Technical Session:
Pingsha Dong, from Battelle, discussed " Mig-welded Structural System Fatigue Simulations." Pingsha works on weld performance and processing in a "Virtual Welding Lab" on property heat flow, weldability, fatigue and fracture. He said there are many fatigue related design issues with today's light weight tubular construction including mig-welds on thin gage automotive structures, and hydro-forming induced prior stress and strain conditions. He showed a modified fatigue design rule approach that considered nominal stress and defined a "structural stress" and extraction method that reduces 16 design curves to two. . He also discussed a fatigue resistant joint design and welding procedure optimization.

Technology Session (Wednesday Morning, April 5,2000)
Alice Popescu-Gatlan and Merlin Green discussed "Alternative Load Measurement Methods" The problem is to move fatigue analysis into the product development process. Fatigue life prediction requires loads information. ADV/RPC requires dynamic loads. Complicated machines like a crawler mainframe have seven inputs per side. Some, like lift cylinders and pivot pins are easy to strain gage. Cross-arms and final drive housings are more complicated and require more structural analysis to turn into transducers. Refer to M. Wickham's PhD thesis. This includes running an FEA model to determine gage locations, writing out strain tensors for each element. Ideally, choose one gage location for each load-case. They use an optimization procedure to calculate gage locations and angles to locate strain gages. Accurate location of gages is very important, gage angle should be within 15 sec. of arc. Calibration is done with unit loads applied one at a time in same direction as FEA. After a final matrix is created a calibration check measures cross-talk. If cross-talk is unacceptable the system is redone. Som

C.S. Do you need to know the magnitude of loads? We apply unit loads. Vertical loads are relative to jacking up tractor, F/A are relative to a tractor pull.

Pete Kosmicki (and D. Klann) discussed " FEA Analysis of a Rig Test. " They are trying to do more rig type test simulations with multiple load channels FEA, with the objective of predicting when their structure will fail. They have repeated tests experimentally with brittle lacquer and strain gages and compared to FEA based results for verification. The procedure includes: determine the component and

principal stresses for each of the three directions under unit loads. Modify sensitivities to convert to strain histories, and adjust for "big loop" loading factor. Calculate damage including "big loop" damage and a "net " damage. They concluded that accounting for "big loop" cycles helps to more accurately position smaller hysteresis loops and provide better damage estimates.

Ray Thompson , "Understanding Product Use in a World Wide Market." Ray discussed his involvement in product use validation process that includes an overview of one tractor program with a 10 bottom plow in the United Kingdom, and another tractor program in Turkmenistan with a 6 bottom plow. Load histories were collected from customer with known heavy usage. These histories produced high loads on chassis, axles, and hitches. These loads are then used in analytical assessments for new designs before hardware is built. Loads are used in durability tests for multiaxial variable amplitude test to verify product durability. Product usage factors: It is very important to know how customer actually uses the products, effects of changes in farming practices, and usage in new markets. The example from the U.K. had received complaints about the hitch, which was used with an implement that was unique to the U.K. Test planning included making sure of access to the implement, tractors and the regular operators. They built the transducers and shipped to the site. The U.K. plow is on

Turkmenistan is part of the former Soviet Union, independent since 1991,and is located north of Iran. The Turkmenistan project was a new market for John Deere with unknown operator conditions, and various complaints causing a need to understand customer usage. Travel accommodations required an invitation from Turkmenistan government, a visa was obtained upon arrival at airport, U.S. dollars only in new bills, visitors were not allowed to drive, few hotels available, they were cautions about the food and water, and two interpreters were required. Ray video taped inspections and operation of the tractors. Strain gage chemicals were not allowed because of hazardous material requirements, so substitute chemicals were improvised, vodka and superglue. In summary understanding product usage is very important to structural durability. They need to stay in touch with new applications and conditions, when load measurements are required, and they need a database to share information with design and test engineers.

Divisional Planning Sessions were held concurrently in two meeting rooms. The chairman and the task will coordinate the future work efforts of these five Divisions group leaders of the respective divisions. Please contact the chairman with any questions or needs. Documentation of future work planned will be included in the full minutes to be distributed before the nest meeting.

Future Meeting Schedule:

Fall 2000: (October 9-11)	University of Illinois, Host Darrel Socie
Spring 2001:	Detroit MI, Host Zheng Xain Bai GM
Fall 2001:	University of Toledo, Host Ali Fatemi
Spring 2002:	Detroit, MI - Host Russ Chernenkoff

Respectfully submittted by: John Hakala - SAE FD&E Vice Chairperson