--To: All SAE FD&E members

SAE Fatigue Design and Evaluation Committee Meeting
Micro Minutes
April 3 and 4, 2001
Doubletree-Airport Hotel
Romulus, Michigan
Host: Zheng Xian Bai, General Motors Corp.

Disclaimer: These are not the official minutes. They are just one individual's notes.

Date and the location of the next meeting:
October 16 and 17, 2001
University of Toledo, Toledo, Ohio

TUESDAY MORNING, (APRIL 3, 2001)
Phil Dindinger announced that SAE is considering changing the SAE FD&E administrative support from the technical standards group (MPPD) to a group more suitable as an industry information center.
Local Arrangements - Zheng Xian Bai announced there would be a social hour sponsored by nCode. Zheng Xian introduced Ed Vaughn from General Motors. Ed welcomed everyone to Detroit on behalf of General Motors and said he appreciates what this committee does to get everyone on the same wavelength. Ralph Stephens Announced the ASTM E08 Committee will meet in Phoenix, Arizona, May 6. The 33rd Natinal Symposium on Fatigue and Fracture Mechanics will be held in Jackson Hole, Wyoming, (date?) with papers by Russ Chernenkoff, Al Conle , Chin Chan Chu, and John Bonnen, members of this committee. The Fatigue Concepts in Design short course date has been changed to November 6 through 9 at the MSU Management Center in Troy, Michigan. The faculty is the same as last year.
Handouts include a copy of all the slides and a copy of the new second edition of Ralph's book on fatigue design. Since four of the faculty are in their sixties, they may need some young "tigers" to take over. There have been more than 3000 people attend this short course over the years.

Henry O. Fuchs Student Travel Award & Presentation "Direct Measurements of Dynamic Shear Transfer Lengths in a Model Laminated System" Mark Brandi from the University of Illinois Department of Mechanical Engineering discussed his work with thermoelastic stress analysis, infrared imaging equipment and setup, model fretting geometry, imaging results, future considerations and conclusions. His motivation was to study and determine causes of fretting fatigue and contact failures at low amplitude and high frequencies. Wear and surface damage in between stick/ slip and that caused by surface contact temperature fields.
The thermoplastic effect (Lord Kelvin) indicates a small temperature rise proportional to the change in stress under adiabatic conditions and cyclic loading. The small temperature chance is detectable with infrared detection devices where a -.003 degrees K temperature resolution is equivalent to -25 micron spatial resolution. The imaging is out of phase with the load signal. Frictional heating is of twice the load frequency and lags by 90 degrees. His test specimen was a laminated plastic material (?) 80 mm long by 2 mm wide and 2 mm and 2 mm thick,

with shear pads 20 mm long supported in steel clamps. He used a Stress Photonics infrared imaging camera and studied interfacial sliding that occurs at the front of a slip zone due to Poisson effects. He determined shear transfer length by making a line scan along a length and plotting shear transfer length versus applied displacement. He looked at STL for various clamping forces. He also took STL measurements near the pads and subtracted from the centerline measurements. He compared his measurements to Shear Lag Theory from Greszcuk (sp?) from 1969. He is looking at an FEA model to determine stresses present in the pad. For the 90 degrees out of phase shear transfer looked at slip zone length vs. applied displacement. Showed larger displacements in slip zone. Future work needs to study metals including aluminum and large scale geometry such as turbine blade dove tail roots. Conclusions: Developed a new experimental method to measure slip zone lengths and extract interfacial fretting constitutive laws. Measurements can help predict wear and fatigue lifetimes. Acknowledgments: Air Force Office of Scientific Research.

Questions: Did you consider the sliding friction constitutive laws proposed in Abaqus? For plane stress conditions simple Coulomb friction doesn't explain the slip zone effects. What was the surface condition? Polished with a 10 micron paste. Has not verified surface roughness on these samples. Will determine surface roughness on metal samples.

Phil Dindinger presented Mark a certificate of appreciation and a check.

Surface Enhancement Division Meeting ran concurrent to the other meetings in Salon 3.

Structural Analysis Division - Zhengxian Bai

Minutes from last meeting were approved -Technical Presentations. Zheng Xian announced that Mary Wickham will be the chairperson of the Structural
Analysis Division starting next meeting and she will need a volunteer for vice chair. Please contact Zheng Xian or Mary.

ATV project: Dan Klann stated that Zheng Xian Bai has reworked a new Hypermesh model of the ATV that is available on the website.
Mark Pompetzki discussed an "Integrated Durability System for CAE based Vehicle Development" by Mark Pompetzki, Vivek Sandell, and Zhengxian Bai. This project combines the following CAE technologies: finite element analysis (FEA), multibody dynamics(MBD), and fatigue analysis to facilitate common methods and automate the process in order to arrive at estimates of fatigue life. They generate component loads from MBD and input load locations and orientations into finite element models, then transfer stress states into the fatigue model. The process is repeated for a second load history, and then the results are combined for a link between system loads, component loads, finite element stresses and durability schedules. The process integrates the work flow, mapping, project management, and different analysis methods. The system keeps track of the mapping required between the suspension dynamics model and the FEA model geometry. System integration manages lots of files in the process for multiple events, components, fatigue parameters, and design iterations. The analysis method uses linear static superposition, modal superposition, transient analysis, determines dynamic modal behavior

of flexible components, and static load case behavior. Choice of mesh density depends on accuracy required and time available for analysis.

Question: Progress on road load inputs? Answer Tire models are still being developed, typically use wheel force transducers, run model over virtual proving grounds. Still question accuracy of high impact events.

Question: Do you have an easy way to optimize fatigue life results? Answer: Nothing built in yet.

Question: Public domain? Answer: Trying to use standard commercial codes.

Question: Internal MBD codes or stand alone package? Answer: Commercial codes. They facilitate transfer of information. Let the models exist for their own uses rather than separate fatigue based models.

David Zhang from General Motors VSAS discussed "Fatigue Based Channel Sensitivity Study for SUV Frames." The objective was to determine individual channel sensitivity of typical truck frames subjected to analytical loads generated from four poster tests. The proving grounds measures rough road events with wheel spindle transducers that can be duplicated in the lab with correlation between Adams and physical models. 138 channels of output went into Nastran and then into F/E Fatigue. The Nastran solution used inertia relief Solution 101. Fatigue results range from two cycles up through millions of cycles. Focused on low life elements. Looked at relative difference for low life elements, medium life elements and high life elements to determine what is the minimum number of channels required. Compared results at front and rear locations with baseline the full 132 channel results. Results based on three studies indicate 70 channels should be a good representation for stress range approach on analytical frame. Concluded that vertical forces
dominate front suspension rough road durability events, moments in front suspension attachments can be eliminated, proposed minimum channels of input that can be used on (?) DOF (?) SUV with similar accuracy, CPU time shortened by 40% (33 hours vs. 19 hours for 70 channel for fatigue calculations based on HP machine and 720000 DOF.)

Question: how were brackets attached in model? Answer: RBE2's.

Surface Enhancement Division Meeting ran concurrent to the other meetings in Salon 3.
Component Testing Division - Paul Lubinski

Meeting minutes for October 2000 were approved. We need a volunteer for vice chairman of the Surface Enhancement Division. Please notify Paul of your interests.

Progress Report of ATV - Ric Mousseau. Ric recently volunteered to be "czar" of the ATV project following the recent retirement of Raj Thakkar. Work is in progress on a rigid body dynamics model to supplement DADS and Adams, available over the web for use on Windows personal computer. The model has revolute joints for bushings that will be upgraded to force elements, and linear force tire models that will be upgraded to an enveloping tire model. The model basically behaves like a four-poster machine. He recently obtained funding for student projects to develop a human body response driver model. Intends to add steering forces and improve the tire model and add additional force and acceleration outputs, a shock table and rebound stops. Ric will discuss what's going on and information available in the planning session of the combined component and road load measurements divisions.

Question: What are the plans to make an ATV publication? Answer: Probably a special publication in about another year.

Question: Would it be appropriate to devote a separate day to the ATV project? Answer: Lots of work is done on personal agendas. Don't want to create another obstacle.

Question: There is work published on driver models. What is your approach?
Answer: Work off a "path following" approach from UMTRI.

Question: Would the U.of Iowa multi-body driving simulator be of any use?

Dan Lingenfelser discussed "Considerations of Variability and Uncertainty in Component Life." A single answer to a set of inputs is of limited value without an idea of the variation" Dan's test machine tests about 600 parts per year, usually two test s result in two different answers. Usually he runs constant amplitude tests because they cost less than variable amplitude tests. He must consider statistical aspects, such as group to group variations from a single source and source to source variations. Looking at bushing cycle tests to a detectable crack initiation, he needs to keep variability and uncertainty effects separate. We do tests to make good decisions, like can we make a part change to save $XX per year. We need to have confidence in the data. Who ran the test? Calibration? They also looked at total life tests or life to crack through the parts. Here an uncertainty is: Do I have the right model? How can this data help manage risk versus cost? Should we use load versus life or stress versus life? Part use helps determine life prediction model. Some variability sources are loads and sequence effects, material properties (hardness, fatigue and toughness) and residual stress. We can buy integrated probabilistic life prediction models that generate cumulative distribution functions, but what is the uncertainty? Then we can generate confidence bands and look at sensitivities to determine where to spend our time and money. But, then business decisions will be made on the basis of risk analysis without knowledge of the internal uncertainties. Dan's corollary: Any analysis is of limited value without an understanding of the certainty/uncertainty. A single life prediction without estimates of uncertainties is of lower value than an accurate prediction with known uncertainty. We must quantify uncertainty from each step in the process. Question: What is the environmental influence? It's another uncertainty. We sometimes our track bushings run under water, in sand, mud or sea water versus a more consistent environment for connecting rods. This can be indicated with different uncertainty bands.

Question: How do you account for corrosion? We try to eliminate corrosion, not calculate the effects. Comment: Maybe you should add process control plan to your chart. Sometimes we didn't even do back of the envelop calculations. Comment: Probabilistic analysis depends on variability. Some variabilities you can control better than others. We specify what we can to result in the desired fatigue properties, but we haven't been able to specify fatigue properties directly.

Ge Wang (University of Illinois) discussed his work on the "ATV Project." This work was similar to the nCode work on digital simulation discussed earlier. His project plan was to set up test fixture, run dynamic Adams models, static Ansys analysis, fatigue analysis with nCode, and run physical tests after analysis is completed. The ATV frame is a welded tubular structure so he concentrated on the welded joints. The test fixture was fixed at the rear, and right side, while the left side was exercised in two directions. The first study was on the shock absorber assembly. There is a ball joint at the upper support. Initial studies indicate nonlinear reactions. A mode shape and frequency analysis
from Ansys indicated higher than actual frequencies (83.17 and 112 Hz.) Performed a suspension system analysis. Wanted to use left side data as input to static analysis. Frequency effects on joint reactions as load spectrum and amplitude varies. Need to transfer model from Adams to Ansys to translate 15 force components from Adams. Looked at hot spot stress with Class F2 from British Standards (1993). Searched for maximum stress in a range and ended up with a fatigue map of the ATV frame. Plotted points on a vertical force versus horizontal force plot that showed hot spot I.D.s. Conclusion: Let the tests begin. Comments : A solid model of the lower left control arm is available on the web site.

Fatigue Life Prediction Division - Chin-Chan Chu
-October 2000 meeting minutes were approved.
Ric Leist reported on the progress of a new "Damage Tolerance Task Group." This group met informally last night and came up with a list of possible tasks:

Press fit bushing lugs
Cold worked holes long life
Corrosion effects on fatigue life
Residual strength of large scale components
Verification of the most promising first efforts
Bolted joints
Crack growth on lugs
Crack growth rate modeling
Short crack growth
Negative R effects for R.0.8
Load interactions

Their approach would be to:
Identify geometry for instance cracks in holes
Collect and produce B-factors (SIF solutions)
Evaluate factors and solutions
Apply solutions to case histories
Try to work with linear elastic fracture mechanics

Ric will e-mail this list to interested parties.

Question: Why "damage tolerance " versus "fatigue crack growth?
Answer: A presentation tomorrow on Damage tolerant design may answer this question. It's not just a crack growth issue. The issue came about after some aircraft crashes caused by key small fatigue cracks. More discussion at the planning session.

"Influence of High R-Ratio on Fatigue of 1045 Steels with Three Hardness Ranges," by R. Stephens, U. of Iowa Tom VanTiger and Marat Kasadaz University of Iowa

Ralph Stephens discussed this the results of this project. Tom VanTiger worked on the notched specimens and Marat Kasadaz worked with the smooth specimens. The objective was to determine S/N behavior of 1045 steel with smooth axial and notched specimens with:

Ki =1.65
Rc =10, 37, and 50
R=Smin/Smax=0.8 and 0.9
A=Sa/Sm= 0.1 and 0.05

They compared their experimental fatigue results with common life estimation models: modified Goodman, Gerber, Morrow and Manson.-McLord(?).
The notched specimen was a dogbone shape 127mm long by 12.6mm wide and 5 mm thick with a 20 mm radius notch on both sides. Minimum thickness at the root of the notch was 6mm. Ralph showed stress versus ram displacement
for notched and smooth specimens. The following were average monotonic properties:

	Rc 10	Rc 37	Rc 50
Su	760	1220	2370
Sy	490	1130	1460
Sf	1190	1620	2610
%RA	46	47	17
E	208	207	205

Ralph displayed plots comparing Smax versus Nf for the three hardness materials and compared fractography for monotonic versus fatigue fractures.

Summary: Most S/N curves were very flat, Rc 10 samples showed interfacial fractures, Rc 37 had internal fractures for smooth specimens Rc 50 specimens had very small surface cracking and showed cyclic creep. Common S/N models did not work well for the notched specimens if Su was used. Ok if Sun was used. Strain life methods are yet to be evaluated. Fatigue results of the notched specimen was better than smooth for Rc10 and Rc 37 due to high NSR, and about the same for Rc50. Discuss what to do next at the planning session.
Comment : Look at Bridgeman's solutions (1940) for that geometry.

"Computer Simulation of Stiffness and Fatigue Behavior of Spot Welds in Automotive Structures," by H. Dannbauer, J. Gumpinger, and D. Peiskammer, Magna Steyr.

Some special characteristics of spot welds are the heat affected zone, contact friction, deformed zones, and sharp notched areas. Finite element models have been made with various methods to simulate spot welds including coincident nodes, coincident one dim. Elements, shell elements for nuggets, complex 3D elements, and submodels with solid elements. There are advantages and disadvantages for each method. Including singularities, and model size. Beam models that are not located precisely cause force errors, Their method involved remeshing the weld areas with multiple shell elements with the use of a preprocessor. They then identify the way a nugget is loaded by the distribution of stresses in the elements and calculate an equivalent stress. They have shown riveted structures have higher fatigue lives than spot welded structures. Their test models involved a small car with 2075 spot welds, 200,000 elements and required about 4 hours to run, a floor pan model involving a pulsating torsional loading, a gearbox bench test, and a rear door slam test. The small car test showed quite good correlation between simulation and test results. Fatigue life predictions of shock tower showed spot weld damage was dominant. Future development include fatigue life predictions of mechanical joining techniques, developing new preprocessor features from CAD data conversions, and developing an interface to deep drawing simulations to predict the influence of total plastic deformation, wall thickness reductions, and imperfections. Conclusions: The method indicate good predictions of fatigue life at reasonable cpu time, problems still exist that may be related to nonlinear surface contacts, verification of fatigue life for BIW structures is often difficult , mechanical joining will become more important for aluminum and HSS vehicles. Audi A2 has no spotwelds, just mechanical joined rivets, laser welds and mig welds.

Road Load Data Acquisition Division - Christoph Leser
The October 2000 meeting minutes were approved.

ATV Related Activities There are video description and a bit of time history and some ASCII format data stored on the website. The SAE Japanese fatigue activity meets six times a year and is working on a full body assessment of a neutral midsize vehicle. Christoph is a liaison with that group and has made a presentation on our ATV project.

Jodi Sommerfeld MTS Systems discussed "Effects of Varying End Constraints Observed in Finite Element Analysis and Empirical Analysis of a Transducer."
Jodi is a transducer product engineer and this transducer is a strain gaged wheel force transducer. The strain gaged wheel force transducer is a common testing instrument with outputs calibrated in a lab for measurements in a specific controlled environment. It measures dynamic multiaxis forces and uses basic transducer principles including good beam design to isolate or reduce off axis strain fields, and sufficient stiffness to avoid fretting effects. Tradeoffs are made to reduce application-induced errors, and to predict magnitude of resolution errors. They compared a finite element analysis to empirical strain gage results to determine performance characteristics. Their Spinning Wheel Integrated Force Transducer (SWIFT) is a six axis force transducer

used to measure road loads on vehicles that can also be mounted on road simulators. It uses radially oriented shear beams for flexure isolation because shear beams are much more stiff than cantilever beams in bending. They tested the transducer on a flat rack test system and found typical errors in the range of 2 to 3 %. These transducer are very light weight and sometimes made from aluminum or magnesium. They wanted to verify maximum stress before sending to fatigue tests, and develop confidence in analytical model solutions. They small strain gages on several different areas at high stress locations and applied loads with a load stand. The finite element model of the part was made with nodes at the strain gage locations and the local coordinate systems lined up with the strain gage axis. Initial model of the SWIFT was mounted to a 2 in. thick steel plate. Certain areas did not have good correlation. The central beams were within 4% but the flex fillets FEA results varied from 22% low to 32% low. They then modeled the actual components and the results went from 32% low to 11.5% low. but the 22% low value remained at 22% low. Remeshing with finer mesh, modified constraints, and steel fasteners did not significantly change results. However they verified fatigue performance on actual parts per SAE J32d Rim Test. In summary finite element methods can help design good transducer, but require careful application. The designs still require empirical verifications and cross checks of data in order to understand the risks of component failure.

"Update on Empirical Dynamics Modeling Activities of the ATV Shock Absorber" by Christoph Leser, MTS Systems. This project used a black box
neural network model of a shock absorber bushing. They play a random input
file to develop a spline model of the FRF. Component "EDM" captures the test data. The shock absorber is a component structure because the bushing
data is not captures because of the test machine grips. They used an MTS shock absorber test machine. They repeatedly "trained" the N/N model, and validated by comparing measured to predicted results. Predicted error was less than 2.3 % RMS. They will next look at the data from the ski resort measurements and compare to polynomials.

Question: Did you use a lookup table? Answer: Not yet. Is there a commercial market for a universal shock ?

Materials Properties Division - John Bonnen
October 2000 meeting minutes were approved.
"LCF properties of ATV frame Material" - Phil Dindinger
This material was identified as a 1015 steel with fine grain ferrite with:
Rb hardness of 68 to 72
UTS = 64 ksi
YS = 50.2 ksi
The sample was flame cut from a tubular section and band sawed into dog bone shape with .25 in. gage lengths and was 0.80 in thick. The section was nearly square and was not flattened. The curvature was built into the grips and clamped with two set collars. The samples had a little higher stability (required a higher load to buckle) than similar flat

sections. ASTM guidelines don't cover tubular specimens. Test resulted in apparent cyclic softening. Stress at 1/2 life was pretty stable. Data will be included in the minutes. Sample size was seven pieces.

Question: Did you run curves for similar hardness materials? Answer: Not yet.

Question: What was your criteria for failure? Answer: 30% load drop Failed at faces and corners of samples.

" Discussion: Fatigue Properties Database, A Proposal." Hosted by Ron Landgraf.
Discussion concerning open fatigue data, common data formats, and data sharing. Where do we get material fatigue properties? Ron showed a "time line " of fatigue data. SAE J1099 (1975), ASTM 606E, etc. Integrated design analysis packages are data "Hungry". We need material properties and load histories. Issues: most properties are key inputs. There is a large amount of data available. We would like to have strain based fatigue properties. E, K', sf,'ef', n', b and c. FORMAT? What kind of data would be useful? "Shigley" has some approximations, but we can do better! Curves would be nice. We could use Neuber parameters to screen materials. Its often nice to see the raw data points plotted on the curves. Obstacles" It was always difficult to get people to contribute data.
Proposal: We need to:
1. Assess the needs of ground vehicle manufacturers and their suppliers
2. Identify major sources of data
3. Develop standard formats and procedures
4. Develop a master plan for database development
Concerns: Copyright ownership, liability issues, misuse, proprietary and competitive advantages. Compelling issues: Manufacturers are farming out more and more systems and components. They need to handle this in a competent manner. Still many unsolved issues: Loop width or strain controlled tests, Nf = f(strain") or Strain = f(Nf) for regressions? E606 fitted equations or digitized curves (doesn't work for some materials.) Overstrain vs. non overstrain or initial overstrains? How
to handle new theories?. Comments: AISI has collected steel bar and sheet properties for 43 different materials for fasteners, shafts, connecting rods, control arms and springs from bar stock people. Participating steel companies have contributed money for this program. Al Conle still has format problems. The Aluminum Association has published minimum and typical data in their handbooks. It is very much in the aluminum producer's interest to have the fatigue data available. If the material fatigue properties allow better designs it may be a small price to pay. They have been doing stress life tests for a long time. Strain life histories on A5754 by British Rail and U. of Illinois show lots of scatter because of design of coupons and details(?) Is there really that much variation in the material? No there's not, but it's difficult to generate 3s confidence limits. Workers of fatigue information are willing to share and are looking for help with standards and formats. But test on their own materials may not be representative of the other manufacturers.

Question: What is the method to get J1099 modified? Answer: a brutal bout with the lawyers. Comment: There has been recent interest in cast material data. Some software have features for cast materials, yet we can't talk about cast A356 as a "single material." It is very process dependent. All these databases are incomplete and redundant. AISI has a cast material database. Round robin test programs? The value of a "forum" is to make your wishes known.

E-mail comments from Phil Breshat(?)(1) Test specimen quality is vital. (2) Microstructure issues available and included with the database,
and (3) An "outlier data points stategy" is needed.

5:00 PM Social Hour Sponsored by nCode The evening went well and the members want to thank nCode.

WEDNESDAY MORNING, (APRIL 4, 2001) "Application of Damage Tolerance Principles in the Aviation Industry" - Terry Ercolani – Cessna Aircraft. Several tragic incidents led to damage tolerant design for aircraft. The British "Comet" crashed into the Mediterranean on Jan 10, 1954 after 3680 flight hours and the F111 that crashed in December 1969 after left swing wing pivots failure were caused by cracks initiating at forging defects. A Boeing 707 crashed in Zambia when the horizontal tail surface separated on approach at 47000 hours. In 1985 a Boeing 747 aft pressure bulkhead with improper repairs installed in 1978 failed. In 1988 An Aloha Airlines 737 with 35000 hours and 89000 landings incurred multiple site damage that led to crack joining to form a large crack that failed well below the requirements. Contributing factors were: Lack of inspections, obvious partial cracks and a lack of fatigue testing. Since these incidents aircraft regulations including CFR's, JAA Regulations, and Military Standards require damage tolerant designs. Crack growth analysis requires four components: Load/stress history, material characterizations, Stress field, and a basic crack growth algorithm. The approach is to make sure any new crack length is less than
the critical crack length. They assume the initial crack size is 0.05 inch. Crack growth rate is calculated as a function of stress ratio and stress intensity for specific material temperatures and environments. Does the empirical data fit the measured data? They use ASTM E647 to determine coupon size etc. Sources for stress intensity factor include SIF Handbooks, crack growth calculations, numerical methods including finite element methods, weight function methods, and theory of elasticity for simple geometries. Some crack growth codes include UDRI Cracks 95 and Cracks 98 and AFGROW. Load spectrums: DADT uses a spectrum of typical loads and stress. Military aircraft designs use measured data and compare to assumed loading. Loads considered include maneuvering, gusts, pressurization, thrusts, and ground loads. Random load effects include retardation due to sequence effects, (overloads can make cracks grow slower.) They look at residual stresses and strength diagrams, net section yield or fracture failures, and derive a basic inspection plan that determines inspection threshold limits, and recurring inspection that
depends on detectable crack lengths based on inspection methods. Cyclic testing demonstrates durability by surviving multiple lifetimes without detectable damage. Damage tolerance is demonstrated by cycling with

inflicted damage (saw cuts) and continuous airworthiness is demonstrated with multiple lifetime tests followed by limit load applications and tear down inspections. They typically run a developed 1000 hour block of cyclic loads with a random load sequence. Typical life is from 12000 to 15000 hours of operation. Loads are iterated on limit loads defined as the highest an aircraft will ever see equal to 2/3 of ultimate. Boeing designed the 777 based on stress /life of components, not smooth specimen data . FAA regulations do not allow flights with "known " cracks. The plane is grounded. Eddy current inspection methods can detect flaws from a threshold of 0.08 inch long up to .25 inch long.

"Damage Tolerance Analysis of a Business Jet" by Claire Stroede Durability and Damage Tolerance Group Raytheon Aircraft, Wichita, Kansas.
This paper describes the process to perform damage tolerance analysis on specific geometry and Beta/stress intensity factor solutions developed for specific control points on a Hawker 4000, a new 10 to 13 passenger plus two crew aircraft. Some unique features are the composite fuselage construction with forward, mid, and aft sections spliced together. The wings are all metal construction. The discussion is about the metallic components. Three steps include preliminary FAA certification analysis, full scale fatigue tests, and revised analysis based on the full-scale fatigue test results. The first step involves identifying control point locations in the metal parts, defining mission profiles and segments, and defining the type of fatigue loads and total loads. Then establishing occurrence spectrum, determining local stresses, and developing and performing fatigue crack growth models. One severe test load is a "bird strike" test where they shoot fresh chickens out of cannons at the test articles. Mission profiles are divided into segments and they may consider 100 different load segments. Fatigue loads include vertical maneuvers, vertical PSD gusts, Lateral PSD Gusts, taxi loads, landings, and pressurization. Their occurrence spectrum is from NASA SP 270 SP14 CFR part 25g25.1 . Stress spectra and occurrences determine 1g, per g landing and pressurization stresses due to segment loads using FEA results and local section properties. Crack growth codes include AFGROW, Cracks95 and NASGRO are used to obtain crack length versus time. Then they develop inspection intervals based on detectable crack size and damage tolerance factors. Second and third examples were an aft fuselage joining ring frame, and a forward bulkhead. Where they take a shortest distance, assume a corner crack, and show the crack will not grow with the highest load situation to satisfy damage tolerant requirements.
In conclusion the process to perform damage tolerance certification for the H4000 aircraft, discussed geometry, and beta/stress intensity factor solutions and developments for three control points. Demonstrated there are opportunities for advancement in these areas.

Question: What are the PSD values? Answer: Related to RMS values.

Question: Do you consider Poisson effect at bolt joints? Answer: No, they deal with fastener loads but with detail stresses. They want to be conservative .in analysis.

Question: Is composite material in common use? Answer: Now on one new aircraft.

Question: How do you determine ten locations? Answer: Look at high stress areas, and geometry, and fastener locations, locations of critical structures and materials. They might do four or five analysis per area.

"Failure of Bimetallic Taper Joints," Darrel Taylor, Research Assistant Department of Mechanical Engineering, University of Michigan. Background: Taper joints are found in automotive suspensions and in artificial hip joints. They have usually are made from steel in automotive applications, (typically SAE 5140) and forced into a steel or cast iron female tapered boss with a nut. The application of torque to the nut provides a very stiff joint. Aluminum is increasingly being used as a choice for steering knuckles for weight reduction reasons. The test samples were mounted in a flat steel circular plate with six bolt holes near the perimeter, and one tapered test mounting hole in the center. Key taper joint parameters are torque, bolt load draw distance and applied service loads (horizontal and vertical.) Some other parameters are surface finish,, contact area, taper angle, depth and radii. Interest has increased recently because experimental data and SAE standards are for steel taper joints in steel bosses. There is not much data for aluminum bosses. Failure modes to be aware of include bottoming of the stud down to the bottom of the knuckle. Additional torque increases the stress on the threaded stud and leads to early fractures. The preferred fracture location is near to the top surface of the boss. Permanent deformation of the boss causes the stud to loosen and rock in the hole, and accelerate failure. Tapered stud thread failure involves permanent plastic deformation and loss of torque and preload. An analysis program at U of M resulted in publication of two papers, one in 1999 and one in Aug. 2001. The FEA model was an axisymetric model of the test plate based on the interface problem. Compressive radial and tensile hoop stresses agree. 3D taper draw distance versus preload relation varies with friction. Normally torque is applied in the factory installation, but torque is a poor control parameter. Ideally they would prefer to look at bolt tension. The type of failure is likely permanent plastic deformation. Decided to look at yield surface representation and examine hoop stress versus radial stress with a preload. An experimental program included draw load versus distance, experimental verification of FEA, stress in taper joint as a function of draw load and applied load, and loss of preload as a function of applied service loads. Their test machine was a 5500 lb. Instron machine, and their test sample was 6061T6 extruded aluminum with typical Al properties, run in displacement control with mean stress controlled by draw load and with stresses measured with strain gages. Measured draw distance with LVDT and Draw load with washer type load cells, and torque with a load cell. Their range of rotation was limited to 90 degrees. In conclusion, they have described taper joints, important parameters, failure modes and work done to date.

Question: Is fretting involved? Answer: Don't know, investigating.

Question: Aren't ball joints designed for plastic deformation? Answer: Yes, but not this much.

Question: Are there reinstall procedures? Limited number of reinstalls? Answer: You should definitely avoid lube.

Question: How much stretch in the stud? Answer: Can't easily measure. Comment: Any yield in the aluminum causes a loss of clamp load.

"Durability Test Boogey Development for Automotive Driveline Systems and Components " Salman Haq Daimler Chrysler

They want to determine a cycle and quintile equivalents for labs tests extrapolated from road load measurements. Typically they will measure prop shaft RPM torque, and gear RPM and determine 5%, 50% and 95% drivers. Determine the number of revolutions spent at various torque levels to develop rotating moment histograms. First gear torque range is wider with less RPM range. For higher gears, torque is lower with higher RPM's. To develop the relations vehicles were measured with five drivers at the proving grounds. Needed to extrapolate tails of distributions. From known material properties and stress strain curves they calculated damage from each driver condition. The 95 % driver used up 2.3X the "life" of the mean driver. They then developed schedules for a dynamometer test that included 1.9 hours of the 50% driver schedule and 5.2 hours of the 95% driver. This was repeated for a component life test bogey development.

Question: Did you play with sequence effects? Answer: They always start with high torque events.

Question: How much time do you save? Answer: Replicate P.G. damage in lab in ¾ week without a vehicle versus 6 weeks on a vehicle proving ground test. Can save 75 to 85% of development time.

Question: Validity of extrapolating from three drivers information? Answer: Previous studies indicate mean P.G. driver was similar to 95% real life driver.

"Small Fatigue Crack Detection and Propagation in Cast Iron Crankshafts" Young Seo and Jwo Pan , University of Michigan and Darrel Close, Daimler-Chrysler. This discussion included characteristics of cast ductile iron, finite element analysis, micrographs of fatigue cracks and fatigue crack propagation. The material was SAE J434 C D5506 spheroidal or ductile cast iron for crankshafts. It contains nodule beads in the matrix.
Nodular density was 11.7% The crankshaft fillet rolling process creates areas of high compressive stress. Showed a micrograph of spheroids in a ductile iron. The nodular size was 10 to 60 mm. Microcracks apparently start at stress concentrations at the nodules. An analysis was made on one section with the geometry of the fillet radius. A constant moment was applied to open and close the test samples. Previous analysis work was without the fillet geometry. They analyzed two separate fillet geometries, and found improvements to stress distribution for roll formed fillets, with variations in shear stress from horizontal to 30 degrees is larger. Tested 40 samples at between 4000 and 4500 lb-in. Used "four bubbles" failure criterion. Applied oil around the fillets. If inspection

indicates four bubbles occur by opening and closing a crack, they stop the test. Graphite node sites near the surface were locations of crack initiation. Graphite size was 20 to 120 mm. Small cracks grow and join to form larger cracks. Conclusions: An accurate stress distribution of fillet angle versus angle of maximum opening stress is located at nodule fall off on surface. Initiation of small fatigue cracks allows crack propagation pattern.

Question: What is the cause of graphite fall-off? Answer: Opening and closing causes graphite to fall off.

Question: Do you have baseline data? Answer: Smooth specimen data was not available. Same mechanism occurs with smooth specimens.

Question: Did you look at torsion and shear loadings? Answer: No only bending loads.

Divisional Planning Sessions were held concurrently in two meeting rooms. The future work efforts of these five Divisions will be coordinated by the chairmen and the task 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:

October 16 and 17, 2001: Toledo Ohio,
Host Ali Fatemi, University of Toledo

Respectfully Submitted by: John Hakala SAE FD&E Vice Chairperson