SAE Fatigue Design and Evaluation Committee Meeting Micro Minutes
October 16 and 17, 2001
University of Toledo, Toledo, Ohio

Disclaimer: These are not the official minutes. They are just one individual's notes.
Tuesday morning October 16, 2001:
Phil Dindinger announced that SAE is deciding where we best fit in their organization. We were in the SAE technical standards division and we don't
write many standards? The F D & E executive committee is not happy with a "Toptec " meeting fee of seven hundred dollars per person, or with a "mini-conference" arrangement at $100-$200 per person. We will refine our case and review with SAE management. Possibly breaking off from SAE? We will try and fix the situation. There is no SAE representative here at this meeting, we've had no support for this meeting, and our minutes from the spring meeting were not posted on the SAE website. This is Phil's last meeting as chairman. Effective next meeting John Hakala is our new chairman, and Russ Chernenkoff is the new Vice Chairman.

Host Dr. Ali Fatemi announced that this building is on campus of The University of Toledo, College of Engineering. The Surface Enhancement Division is meeting in the fourth floor conference room. There is a lab tour this afternoon. There will be a social hour at the hotel following the meetings sponsored by Dynamic Test Equipment Company. Tomorrow, the meetings will be held in the hotel ballroom, with six technical presentations by Un. of Toledo faculty and students.

Education report Ralph Stephens:
Approximately 3000 people have attended the short course in Fatigue Design since 1970. This year's short course was planned for November in Chicago, but was moved to the MSU Management Center in Troy, Michigan because of a high nonrefundable deposit required. 35 people had signed up, and we needed 60 to break even. After the 911 incident six people canceled. We have used up the seed money, so the course was canceled for this year. Three of the faculty (Drew Nelson, Steve Haeg. and Harold Reemsnyder) want to continue the course next year. It takes about six weeks to coordinate and Ralph does not wish to continue the coordination effort. Continuing education has changed drastically due to the Internet. Any thoughts?

The ASTM meeting on Fatigue is in three weeks in Dallas, TX. Included are a Thermo-mechanical Fatigue Behavior Symposium, a Predictive Material Modeling Symposium, and the normal division meetings.

Next meeting:
The next meeting will be held in the Detroit area hosted by Russ Chernenkoff and Ford Motor Co. Tentative dates are April 16 and 17, 2002.

Henry Fuchs Award: "Prediction and Correlation of the Average Crack Opening Stress Level with Frequency of Occurrence of the Cycles of Three SAE Service Spectra Using Three Different Materials," by Mohammed Khalil from the University of Waterloo. Mohammed studied the variability in crack closure affects as a function of service load histories. He examined the accuracy of Del Quesnay crack opening models.

Sop = ? ?max [1-(??max/??y)2] + ???min

Crack closure depends on the effect of tensile overloads relative to one half of the yield stress. Compressive overloads drop crack opening stress levels. He studied effects on three materials: 2024 Al, 1045 as received, and 1045 Q& T. He used a threaded specimen with a 12.7 mm flat and with a notch, and a 900 x microscope for specimen examinations. He took readings 0.1mmm from the crack tips for three load spectrums, and compared Sop calc and Sop exp. Experimental and calculated fatigue lives were in good agreement. Average crack opening stress occurred at 100 reversals for soft materials and around 1000 reversals for hardened materials. Recovery rate studies indicated hardened materials recovered quicker than softer materials. Crack opening stress can be modeled using a simple exponential build up formula.

If you don't consider closure, predictions were 30% unconservative.

Structural Analysis Division - Mary Wickham
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 hot spot 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 0.5mm 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.

John Bonnen: Material Properties Division

John recently sent out an e-mail copy of a revised data file format that will be discussed during the planning session. They will try to ballot in the next few months. They have recently developed a new standard for periodic overload files. John gave the second annual database awards for strain life data sets to Brian Lies Ron Landgraf and Peter Kurath

Russ Chernenkoff. reported that since the last meeting the metrology lab at Ford digitized the lower control arm of the ATV and give it to a Ge Wang. This is the other control arm from the ATV. The data is available on the www.fatigue.org/ website under ATV control arm. Russ also reported on "Powder- Forged Aluminum Composite for Powertrain Applications. " This material is an aluminum metal matrix composite that is forged into connecting rods. They are looking for lower cost processes and materials. Powdered aluminum material is mixed with silicon carbide, compacted, forged some into a near net shape and machined. Reduced machining improves material yields on complex geometric parts. Tailored alloys provide a net cost savings. The aluminum metal matrix contains 1.8 % magnesium, 3.7 % copper, 20 % silicon carbide and 0.15% binder. They looked at a course particle size for cost reasons. The material was forged into pucks for test samples. They cut tensile, compression, and fatigue samples from the pucks. The test samples were solution treated at 493 degrees Celsius for two hours, quenched in room temperature water and age hardened at 175 degrees Celsius for 24 hours. The samples were then shot-peened and polished. Ultimate tensile strength as forged was 300 Mpa with elongation of 0.7 to 2.1%, and 432 MPa in the T6 condition with elongation of 0.6 to 1.2%. Their goal for fatigue strength is 220 Mpa @ 107 cycles. Currently they are at 120 to 170 MPa at 107 cycles. Their shot peening process is not optimized yet. One problem is segregation of silicon carbide particles from the aluminum powder. One solution is possibly to coat the materials with a polymer base to blend more uniformly. To arrive at a more cost-effective solution they need to get the polymer out during the sintering operation. One sample indicated a "ferrous flake", but was not located at an initiation site. In summary, the fatigue strength of the polished specimens was 150 MPa compared to the shot-peened samples at 170 Mpa. Some issues were the silicon carbide distribution and particle bonding. Potential applications include connecting rods, camshafts, bearing caps, valves, and pistons. Some challenges include: high strength, fatigue strength, elevated temperature response, wear resistance, corrosion resistance, and low-costs. With a fatigue strength target of 220 Mpa, they're looking for a low stressed engine application.

K. Yeung, and Al Conle from Ford discussed " Shaft Straightening Fracture Estimation." Production shafts sometimes get out of straight during induction hardening process. The process to cure this is to spin and measure this out-of-straightness and then repair the shafts with a set of three hammers. A potential problem is if someone forgets to tie down the anvils. The problem is surface cracks are suspected. They didn't want to test actual shafts and decided to use a finite element analysis. The question was: "will a case crack during the repair procedure." They measured the hardness profiles and found a quick transition at 4mm depth. They used an Abaqus finite element solution to simulate the three point bending process. The Abacus model included a hardened material, soft material, and two transition material properties. They looked at data for True Fracture Strain vs. Hardness from the literature. They applied a thermal load of 700-800o C. Plotted surface longitudinal stress, and hoop stress, and real residual stresses. They found high compression stresses from -1000 Mpa to 2400 MPa in tension, and the back calculated the loads on the shafts. Conclusion was that the shaft would break between 2-5% surface strain with corresponding bending load computed.

Ralph Stephens from the University of Iowa reported on "The Influence of High R-Ratio on Unnotched Fatigue Behavior of 1045 Steel with Three Different Heat Treatments." This work was based on student master's thesis work by Tom Tiger, Murat Karadof and Trent Pals (?). They examined strain life behavior of 1045 steel, with a notched axial specimen. KT ranged from 1.65 to 3.65. Material hardnesses were Rockwell C10, Rockwell C37, and Rockwell C50. They correlated experimental fatigue life with common life estimate models including modified Goodman, Gerber, and Morrow. High R-ratio tests gave some strange results (before looking in the literature), with flat lines and low slopes. They found small changes in stress significantly affected the life and found a significant influence of ultimate strength. Microscopic examinations showed very little difference between tensile and cyclic and test results. Creep rates were found at shorter lives. They looked at calculated life versus experimental life, which showed a great inability to calculate life, with five or six orders of magnitude difference using nominal stress approach. A local strain approach from Morrow, and Smith, Watson and Topper, showed the effects of a mild notch on Rc 10, Rc 37 and are Rc 50 materials. The notch was detrimental to the R50 specimens. In summary, most SN curves were very flat with substantial data scatter. Cyclic creep or ratcheting was present. Hysteresis was shown for all three materials. Creep caused failure, not by fatigue. Stress life and strain life models were not successful in most cases. Notched section SN curves had better fatigue properties than smooth specimen data. Rc10 material was as rolled and stress relieved. The Rc37 material was tempered back from the quenched condition.

Fatigue Life Prediction Division. Al Conle reported there were no minutes to approve since SAE did not distribute them. Russ Chernenkoff reported on "High Mean Stress Level Tests. Note that connecting rod loads are not compression / compression as previously stated. The testing is done in a fully reversed condition. The material for this test was a normalized 1045 steel. They ran stress-controlled tests with strain monitored at room temperature. Yield =476 -397 Mpa.
They ran three sets of tests: Set 1 at constant max. stress = 381Mpa , Set 2 at constant minimum stress = -381Mpa, smax = +105 to +333 MPa, and Set 3 with min stress = 0.0 and max stress = 90% to 135% of the monotonic loads. The data is on the website.

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. An intrinsic material fatigue property is:

?op = ? ?max [1-(??max/??y)2] + ???min

Is there an easier way to determine these properties? We do constant amplitude tests, but we run overload tests to determine effective strain life curves.

Jeff Nash discussed "Bolt Fatigue." This summer he had a real good intern who ran axial bolt fatigue tests. Mean stress affects were best predicted by Morrow equations. Why? Local mean stress was nonlinear, with but notch plasticity/thread yielding. 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.

Al Conle discussed information on the website at Waterloo, and demonstrated how we can pick a standard data set for processing and come back with curves and plots. Contributors were Ron Landgraf, Phil Dindinger, and John Bonnen. The life prediction calculator is missing a materials list. Al needs more data! He's thinking of adding a "fusion weld tool " to the calculator!

Road Load Data Acquisition Division, Christoph Leser

Robert Geisler from GM discussed "Using Analytical Loads Prediction to Assist in Generating Laboratory Dynamic Loads for Durability Testing," co-authored by Jim Birchmeier, and Nikolai Moschuk. GM has adopted RPC durability testing based on full vehicle loads acquisition. In a recent front shock tower test R PC files were developed for road load data acquisition off an older test. Later prototypes had stiffer jounce bumper than earlier versions. They used ADAMS full vehicle simulations to modify the older drive files to match the new suspension of tuning. They constructed a full vehicle ADAMS model. Ran the vehicle model over proving ground road surfaces, and obtained nominal response for each event. Recovered ADAMS model from earlier project and converted analytical results to a spline. Constructed ADAMS mechanism to simulate an RPC test fixture, analyzed all the road surfaces of interest and compared to nominal response. Then they adjusted input files from the previous step to match nominal responses. Results: They reduced inputs to 90 percent of original to match pothole number 2. Rough road Event: They examined level crossings with two jounce bumpers. Conclusions: Changes in jounce bumpers had large effect on high amplitude events. Note that shock tower plasticity was not included in the Adams models. Hardware tests on RPC fixture yielded similar results. The Nastran model was based on inertia relief. This creates logistic problems because of huge memory requirements and the need to get answers quick to effect suspensions design changes. They scaled only the vertical displacements.

Darragh Murph from MTS, discussed "Automated Road Load Data Analysis for Verification of Data Integrity. " Road load data acquisition is one of the most critical steps in product design and evaluation. To begin product evaluation professional services evaluate accurate loads. We need good data to evaluate durability, noise and vibration, performance and handling, and fatigue life. Bad data is typically not caught until late in the testing and evaluation process. Therefore, in order to minimize wasted time, we want to automatically process large amounts of data. We need a concise presentation of issues list, accurate interpretations and detection of data anomalies. This work is based on a Ph.D. thesis by Tom Hunt, entitled: "The Classification and Detection of Anomalies in Digitally Sampled Dynamic Data." Bad data can come from human error, wrong calculations, or incorrect selection of transducers. Measured environment errors can include temperature drift, shock, noise, and backlash. Data anomalies can be general. simple to correct, which include zero drift, zero offsets, and zero shift, polarity, amplitude errors, and data impulses. of include probably 80 percent of the anomalies. Then there are specific anomalies that are complex and difficult to detect. These include missing data intermittent data, and ringing. An example is mounting accelerometers on inappropriate specimens, which could lead to incorrect statistical summaries and incorrect rain flow data. Anomaly detection can detect under-resolved data, under-sampled data, missing data and signal to noise issues. Saturated channels: look for clipping. Spiked high frequency impulses occur randomly in the data, which the physical system is not capable of producing. A two step procedure to determine spikes: first enhance the spikes with a high pass filter with a "crest factor." Then use the second order "Butterworth" filter set at 80 % of the Nyquist value. The crest factor detector uses a 1000 point window, calculates the RMS value of the window. Then:

Crest Factor=Max/RMS

A five-point spline was used to smooth out the spike. (This is not a used for groups of spikes.) Enhanced version uses cluster analysis to pinpoint a spiked location. The local mean method calculates an absolute value and the local standard deviations, then applies a spike detection threshold. Any point outside of seven standard deviations is considered a spike. The automatic data checking process quickly lists the anomalies, is linked with a graphic browser in the time domain, and verifies corrected data. Getting good data early is the key to the development process but data validation must be automatic. Question: Would there be any benefit to run the SAE road histories through this technique?

Component Test Division, Paul Lubinski.
Ric Mousseau Discussed the ATV Progress. Ric helped Darrel Socie obtain 20 ATV frames for testing. First quote was $450 each for 20 frames. Then the price went to a thousand dollars per frame. Ric's contacts helped to get the price down to $750 per frame. Someday we'll have good answers! Question: Are we handling the ATV project properly? Productivity seems to have dropped off. Do we need a different format? Certain people are still interested. Ric will continue. Anyone is free to work with the models. What would motivate more people's interest? Russ did some work on control arms, Xian Zheng Bai at GM did some FEA models, and Ge Wang did some work on the frame.

Alex Porter discussed "Vibration Theory and Practice of F MVT (Failure Mode Verification Testing." FMVT was discussed here three years ago. This technique test is based on what can break the system. Mechanical, vibration, and electrical loads are input to the system over a long period. A broad range of loads gets randomly distributed through six degrees of freedom. Cracked parts are based on what can damage the product, not nominal operating conditions. A failure is when the product is longer serviceable. One example was a cockpit system FMVT with six actuators that identified 62 failure modes. Some problems with this method are: Servo valves are limited to 200 Hz. Air hammer machines built for electronics tests are not very repeatable and don't have significant displacement. Electrodynamic machines are usually single axis machines.

They wanted low frequency displacement up to a maximum frequency. The solution was to use iterative equations and channels. Behavior of

equations was radically changed with a small change in coefficients. They hooked three pairs of cylinders 90 degrees to each other. Small changes to cylinders caused huge changes to systems behavior. One window regulator
system with +/- 4 inches displacements produced equivalent fatigue damage in metal and wear correlated in an eight hour FMVT test which compared to a 400-hour traditional test. A second test article was a military power supply that weighed approximately 100 lbs. One cannot use FMVT to accelerate corrosion or creep, or other time dependent failure modes.

Kurt Munson from nCode International reported on " Creating a Durability Test Schedule with Fatigue Editing Techniques. " This project was developed with a class A truck manufacturer. The goal was to create a durability test schedule capable of reproducing heavy truck service life in a short time, and run a multi axis, time based durability test based on that schedule. Field service use identified the test environment. Data was collected for 15 events over 600 miles in 12 hours. Forty-eight channels of data were recorded for durability analysis and test rig control. This included 16 channels of strain gauges, and 32 channels of accelerometers. The drive file to produce cab accelerations contained 2+ gigabytes of data represented 600,000 miles of use for 12,000 hours equivalent to one year's worth of testing. The durability test goal was to complete the tests in less than 400 hours in the lab, with a time based approach to reproduce amplitudes and variable vibration modes with multiple hydraulic actuators directly coupled to vehicle frames. Fatigue editing resulted in shorter time histories with equivalent fatigue damage. Time domain was used to retain frequency content. Multi channels were used to maintain phasing relationships. Strain life analysis of strain data was used for fatigue assessment. Fifteen events were concatenated to produce one long file history for each of 16 gages. Material properties were provided by steel suppliers. Kf was determined by back calculation from lab test data. Damage time histories were plotted to track damage accumulation. They plotted a road map that showed when damage occurred. If no damage occurred, they got rid of that frame. The created RPC drive files ran successful rig tests that reproduced several major test incidents. Comment: I don't understand "Nondamaging cycles.

Technical Session, Wednesday Morning, October 17,2001
Introduction to the UT College of Engineering, Dr. Nagi Naganathan, Interim Dean
Dean Naganathan welcomed us to the University of Toledo. U of T has approximately 20,000 students with 3500 grad students, faculty of 1200 and staff of 1200 in eight colleges. U of T is one of 13 state-sponsored universities. They consolidated an engineering technology department into
their college of engineering. Students need a 3.0 grade point average and ACT average of 25.8. They have a mandatory co-op program that started in the fall of 1997. The co-op program works with 482 companies in 33 states and 10 foreign countries. The engineering school is at or near capacity. They retain approximately 70 percent of freshmen. They hold two career fairs a year. They are concentrating on "Infotech, Bio Tech, and Nano Tech.". An example of Info tech in transportation is to find better ways of routing traffic. U of T has a Micromachining Center, a

Center for Manufacturing Value Chain Science, Fatigue and Fracture Lab, Center for Gear Research, Tribology Consortium, Computational Vehicle Systems Lab, Dynamics of Smart System Lab, a Bolting Management System Lab, and a new transportation initiative.

"Multiaxial Fatigue Behavior of Rubber: Experimental" by Dr. Will Mars from Cooper Tire.
Last year Dr. Mars discussed cracking energy density, a parameter to calculate at a point and use for complex strain histories. We need to understand the physics of the process. Today he will discuss the experimental aspects, including experimental results, the failure process, short and long term stress strain, cracks and failure criteria, correlation of fatigue life with several parameters, and the effect of Crack closure and R-ratios. Will used a hollow cylindrical test specimen so he was able to control axial and torsional strains similar to the strains in the belt edge region of tires. Some characteristics of rubber containing fillers are: softening, mostly elastic behavior after the first few cycles, inelastic effects depend on maximum strain, known as the "Mullins Effect". There's an effect of strain path for combined axial and torsional loading. and there is cyclic softening during the fatigue tests. He took a sequence of photographs during the fatigue tests to show progress of crack growth. Star cracks developed during fully reversed torsion. He plotted crack length vs. number of cycles, and found by comparison of two-failure criterion, that they were equivalent. He developed a model to relate Z criteria showing crack energy density was traction vector dot product with the incremental strain vector. Which is the definition of work that was equal to the portion of energy available to be released on a particular plane. The need to account for crack closure came out of plots for proportional axial torsional loading. On the compression side of a cycle, cracks can not pass through each other. In conclusion, the stress strain behavior of rubber is quite complex. There are reversible short-term effects and long term softening effects. CED is effective, maximum principal strain gives good correlation, but SED is not effective. It is important to consider crack closure and the R-ratio in fatigue life tests. The mechanism in high R-ratio tests it is recrystallization. At high levels of strain, long chains become crystalline this is a well-known effect.

"Fatigue Reliability of Cars Under Road -Induced Cyclostationary Excitation" by Dr. Efstratios Nikolaidis from the U of T. were stationery loads are very severe and include loads caused by rail tracks, pavement with warning stripes, and concrete slabs. Approximating loads using stationary process models with the same RMS values significantly underestimates the severity of loads and probabilities of failure. This work is related to work published by Darrel Socie in 1999. An example was a front suspension load on ten laps developed a cyclostationary model. This is a well-known effect on electrical systems. Periodically stationary random processes include vibrations of a vehicle driven on s road made up of concrete slabs of constant length. An example is turbine blades that can vibrate in a random flow with a periodic excitement. The period is dependent on the distance between the blades. Turbine blades, propellers and internal combustion engines exhibit cycle static intensity that changes periodically with time. He showed plots of an autocorrelation process. Conclusions: Cyclostationary processes are frequently encountered in engineering problems. Cyclostationary models are more accurate than equivalent stationery models for the prediction of vibration response, durability assessments, and stationary models are nonconservative.

"ATV Dynamics Model for Handling and Loads Analysis" by Nikhil Kulkarni, and Girish Markdale Graduate Assistants, University of Toledo. The model is a sprung mass dynamics model of the Honda 4 by 4. It assumes interconnected rigid bodies, springs are forces or moments, and bushings are modeled as springs. Inputs include vehicle geometry, physical properties, tire data (from Cooper Tire), speed, steering angle, and terrain geometry. The model has four subsystems: tire, steering, speed control, and a shock model. The model is automatically trimmed at the start of the simulation. The tire model is a handling tire, where inputs are the vertical tire force, slip angle and tire properties. The tire model is a dynamic enveloping tire model for obstacle impact over an area, rather than a single point. Tire forces are not instantaneous. They develop as a function of time depending on length of obstacle. The tire model works well at low speed. Input is the terrain geometry. The steering system input is a lookup table. Controls are needed to provide vehicle speed. Proportional integration control is used to maintain constant speed. Automatic trim balances vehicle weight through suspension properties. Static loads on tires are calculated for static equilibrium of front suspension.

The shock mount compliance models are inverse table lookup of shock forces. Force developed by the shock lags velocity. There' is a user defined subroutine for a force calculations at the UBJ, LBJ, TR, UCSA, and the LCA. For equilibrium moments are taken about the kingpin axis, written in a "C" program. Calculated suspension toe and yaw rate for four-degree steer at handlebars, and vertical tire force for 4-degree steering input at handlebars. Then, response for a single bump input over a 0.04 m height with a length of 1 mm at a speed of 30 kph. The dynamic and enveloping tire model showed vibration modes. Shock forces were read at the UBJ and tie rod.

In summary the basic an ATV model was completed for handling on a flat surface, with obstacle inputs, and is computationally efficient. Future work includes comparing the ATV calculations to test data, with additional tests on ATV. Investigation of the impact of the driver motion to the dynamics of the ATV, variation and sensitivity studies, and investigate the impact of driver inputs using optimal preview control. How do you know the model is correct? Planning to compare to test data, and certain "sanity" checks. They plan to look at a single simple event. What was the software? Autosim Multibody. It will be posted on the website. Are there jounce and rebound bumpers in the model? Not yet.

"Torsional Behavior of a Spring Steel, Including Mean Stress Effects " Dane McClaflin, Graduate Assistant, the University of Toledo, and Dr. Ali Fatemi. University of Toledo.
Most strain life information is for tensile loading. Many components are under torsional loads. The objective was to obtain strain life fatigue properties for one hardened spring steel, 9254 fine grained Q&T. They compared a 1.25 mm wall thickness tubular specimen to a solid steel specimen of the same diameter. The tubular specimen was machined from

bar stock on a CNC machine, the hole rough drilled, honed, heat treated, subjected to a final honing, and polished with an aluminum oxide lapping film. That test procedure was on an axial-torsional load frame, under strain control and torque control for the rotating motion. The biaxial extensiometer was used until mid life. For monotonic torsion the loads were run in pure torsion with R ratio =-1, biaxial torsion with R = 0 and axial tension with R= -1. Results showed that the torsional yield strength was 0.46 of the axial yield strength. He showed comparisons with Ransberg Osgood equation, the Coffin Manson equation, and the Tresca criteria. Results indicated there was not much difference between the solid and tubular specimen results. The Tress criteria correlated very well with the standard stress strain data. Maximum principal strain was nonconservative. Failure modes were cracks in the longitudinal or transverse directions. It was difficult to stop the test at the first sign of cracks in some cases cracks occurred on the 45 o plane. Mean stress had a great effect on long life tests. Additional work is intended in crack development replication, S/N predictions and approximations, further investigations of mean stress effects, and prediction of torsional behavior from hardness. Question: Planes on which fatigue cracks form? Shear planes? How? And why? Reply: Saw some small thumbnail cracks. Will look closer at the specimens. Didn't see any max principal plane cracks. Very brittle material.

"An Efficient 3D Tire Model" by Dr. Ric Mousseau, University of Toledo. This model was from another tire model for predicting dynamic response and
spindle forces during obstacle impacts. The model includes the forces and moments a free rolling condition. It is a three dimensional analysis, and does not calculate internal stress of the tires. Three basic approaches to tire models are semi-empirical models, enveloping tire models for obstacle impact, and detailed finite element models. Specific purpose F/E models build assumptions into model and don't model the internal stress field. All require tire data. Tire models all have three components: side wall, tread, and tread block. This model has a two step process: First a 2-D model of the side wall constrained to the anticipated tread position, apply pressure, solve for forces at the tread shoulder and bead,
and calculate forces at the interface points. The sidewall assumptions include constitutive relations for the tread and sidewall. There is no coupling between adjacent elements of the sidewall. A sidewall slice is similar to a radial tire cord, perpendicular to longitudinal and vertical planes. The sidewall F/E model is a 3 D.O.F. lookup table. The sidewall has 3 nodes, the tread 2 nodes and the hub one node. The rim is rigid and produces reaction forces with the spindle. The tread uses standard Abacus shell elements loaded with the tire pressure. We need to know bending stiffness, hoop stiffness, and calculate and effective modulus. The model uses a simple Coulomb Friction yield surface, and a linear elastic tread block model. An "Arbitrary Lagrange Euler " approach
(ALE) minimizes noise and affords large time steps. A "Single Node ALE" mechanism (SNALE) defines nonsteady state rotations with a single D.O.F. for nonsteady state rotations. Tread blocks isolate tread from the ground. Tread block shear strain depends on adjacent tread blocks, and is recursively solved. Convection depends on tire rotation and moves

along streamlines. Showed slow speed results for a quasi-static simulation with the tire rolling over an obstacle for one to two inch deformations, with results close to experimental. The model reproduced relaxation effects fairly well. The self-aligning moment involves a pressure distribution. For durability at higher speeds we need to test on a "big drum" with an instrumented spindle. Nonlinear dynamic simulations need to be verified with tests on Firestone's drum machine. Results at 48 kph showed first vertical mode as expected. Conclusions: Showed very efficient computationally. ALE approach converges to steady state values. A new approach for calculating spindle forces accommodates 3-D deformations. Acknowledgments: Smither Scientific Services, and Firestone.

"Fatigue Behavior of Gears" by Dr. Ahmet Kahraman, University of Toledo. The interest in power transmission and gearing involves kinematics, dynamics, vibrations, material fatigue and wear. Indicated benefits are: increased power density, improved QR&D related to increased product life and minimized warranty costs, reduced noise, reduced costs and quieter gears. A roller contact fatigue test machine was used to simulate contact point on helical gears. A gear dynamics test machine determined vibration of parallel axis gearing. A gear coordinate measuring machine provided three-dimensional surface profiles to characterize the contact surfaces. A wear prediction project is of importance because wear is a major failure mode in transmission gears applications