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Global News & Industry Information

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In This Issue:

Welcome Participant: AMD www.amd.com

AMD Processors meet the performance demands of today's time-critical environment

Post Processing – A tool to solving problems through visualization.
FEA Information Inc.

Contributors

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For this article we asked engineers for their opinions. Among the questions that were asked and answered are the following:

What is the definition of post processing?

Post processing is the process of analyzing the output databases from a calculation. Early in the development stage of post processing, engineers manipulated data of a code without the aid of graphics, having to rely on hours of data reduction to produce results. Today, analysis of a code output data has evolved to being viewed on a computer terminal where it is analyzed in 2D and 3D.

Comment on the interpretation of results produced by the solver.

Various post-processing techniques sort through huge amounts of data (numbers) and presents the results in various forms allowing engineers to make sense of the results. Various forms:

Test	Analysis
x-y plots	x-y plots
High speed films	Animation of deformed shapes
strain gauge measurements	fringe-contour plots or strain time histories
cross section cuts	section cutting
circle grid analysis -metal forming	circle grid analysis in ls-post
thinning plots - metal forming	line plots in ls-post
witness the test or theatre review of test films	virtual reality review in theatre or CAVE/RAVE

Why is post processing important for engineers today?

- The finite element models have become larger and larger, e.g. whole car models are simulated. This requires an efficient tool to investigate the response, not only for debugging error terminations but also in the validation phase of the obtained results. The possibility of making presentations for the management, illustrating overall model behavior using animation is quit important.

- Graphical post processing has been important ever since the advent of the Cray-1. Don Calahan, a professor in Electrical and Computer Engineering at the University of Michigan and a consultant to Seymour Cray, gave a talk on the future of scientific computing in 1982. At the time, the Cray computer was the largest machine around, having up to 16 MB of memory, an amount now inadequate to run Microsoft Word. Calahan said that pouring through printed output from a Cray was impractical, and, therefore, all its users would have to rely on graphical post processing. He predicted that most computers simulations in the future would be so large that printed output would be obsolete, and some analysis programs would not even have it. While we in the audience believed him about supercomputers, we had a hard time believing that printed output would ever be obsolete. Well, Don Calahan was right, and probably a lot sooner than even he envisioned.
- Solvers have become faster and computers have increased in speed performance. This increased in speed of the software and hardware has helped Engineers solve more complex and larger problems. Today's post-processors need to keep up with solvers and computers to turn the huge amounts of data produced in to presentable form without being a bottleneck in the system.
- In contrast to experimental results, which are often obtained only at a limited number of sensor locations, finite element analysis produces results at every node point in the finite element model. Result data includes a wide array of kinematic and state variables, including multi-component displacement, velocity, acceleration, and internal stresses. It is not humanly possible to review all of this data, especially in it's raw digital tabular form.
- Fortunately, high speed mass storage devices have evolved along with computing power to allow engineers to output and store these tremendous volumes of data, eliminating the need to anticipate exactly which information might be relevant. Post processors then provide a vital means of sorting through gigabytes of simulation data to extract meaningful results.
- Visualization in post-processing allows engineers to "see" simulation results which could only be imagined in laboratory settings. The remarkable ability to observe stress contours on the surface of a part is routinely taken for granted, but would have been an experimental marvel only a few decades ago. Through visualization, engineers can explore the behavior of their simulation models in great detail. Columns of numbers giving X-, Y-, and Z-direction velocity components are transformed through visualization into three-dimensional streamline curves in computational fluid dynamics, or into animations of material deformation in structural mechanics.
- Post-processing also provides engineers with a means to condense and output simulation data in meaningful formats, from simple X-Y plots of derived or cross-plotted results, to PC-formatted movies showing animations of the simulation. These outputs allow presentation of simulation results to a wider audience than ever before.

What do you recall as the first post processor?

- A stack of printout on 132 columns paper about 2 feet tall for each run

- ADAMS graphical interface on an Apollo workstation
- Pop plot of BYU movie files on an IBM terminal off of a mainframe
- SMUG internal graphics developed at General Motors
- The first major post processor for DYNA3D was TAURUS on a color tektronics
- ORION for DYNA2D was the best thing since hand plotting
- The first computer post processing I recall is graphing with characters on a line printer. The output looked something like

```
0.000E+00 |****************************|
1.000E-01 |      x                |
2.000E-01 |         x             |
3.000E-01 |           x           |
4.000E-01 |          x            |
5.000E-01 |         x             |
6.000E-01 |      x                |
```

- The first postprocessor that drew pictures on a screen that I recall was one that I wrote using the Tektronix graphics library called Plot10. The postprocessor was for two-dimensional rigid body simulations, and simply drew outlines of the different bodies on a Tektronix 4010 terminal. The screen was green, and every time the screen was erased, it gave off a bright flash. Drawing was slow; you could watch the lines being drawn like on an Etch-A-Sketch. At the time, I was working for a company that was providing an expert witness for a trial about a serious train accident where several people died. The expert wanted an animated film showing a box car crashing into a tank car and punching a hole into the tank car with the coupler. I sat in a darkened room with a photographer for several days while we generated the animation frame-by-frame. My job was to hit the erase button after the photographer had taken the single movie frame of the screen. Our eyes became so sensitized in the darkness that we were both soon wearing sunglasses and shutting our eyes before I hit the erase button.
- In the early 1980s, a version of NASTRAN included geometry and X-Y plotting as "post processing" options. Output was created in CalComp pen plotter language. A fundamental limitation was the requirement that all such output be requested in the simulation input deck. If, after reviewing the results, additional pictures or plots were needed, it was necessary to re-run the entire simulation
- Watching Anderson Jackobson teletypes printing results.
- Hand picking number and plotting graphs on the good old graph paper.

What features do you look for in a Post Processor?

- Animation of the model behavior
- Plotting important components at model, part, element, node and integration point level
- Good graph plotting capabilities
- Advanced interface e.g. zoom, pan, blanking option, section option etc.
- Ability to handle large models without being too slow

- Available and stable on a variety of platforms
- Generation of ASCII files
- Support of different plotting facilities (printer, files etc).
- Ability to easily plot any solution variable versus any other solution variable.
- Ability to define a surface through the mesh and generate contours of the solution on it.
- Ability to export graphical output in various formats (e.g., PostScript, tiff, or AVI)
- Command file input for automatically generating post processed output.
- Smooth interface to CAE packages
- Real time post-processing of the results while the solver is solving
- User friendly, intuitive interface
- Handle the output files of different solvers
- Support the latest Open-GL standard
- Provide fast rendering of fringe plots
- Recognize every problem or inefficiency within a model
- A flexible GUI
- High-end visualization tools must have as their foundation the ability to post-process in a flexible, scalable client-server architecture. This permits them to read data where it was generated, eliminating unnecessary file transfer and using the more powerful processor for data processing.
- While most post-processors can be used through X-window remote display, a far better solution is for the post-processor to run in a more efficient client server framework. This allows the client to use OpenGL libraries. If the client is not capable of handling large result files residing on the compute server, the post-processor may be run in "distributed" mode using a client and server running separately.
- The "client" process, including the GUI, rendering and animation features, reside on the desktop system. The "server" process remains on the system where the data resides, and handles memory, I/O and CPU-intensive tasks. Only a standard TCP/IP connection between the client and server is required, meaning that remote processing of data is made possible. Mixed computing environments should be supported, for instance the client on a WindowsNT system and the server on a Unix system. X-server software such as Hummingbird is not required and performance is greater.
- Multiple-server processes should be controlled by one client computer, allowing users to display different design variants and analyses simultaneously. For instance, results of two or more different analyses can be displayed at the same time. The results may be located on different servers of different manufacturer and OS.

What is the Future of Post Processing?

- The trend in the finite element analysis (FEA) market is toward increasingly complex analysis such as large-scale nonlinear contact, vehicle crashworthiness and rollover, and coupled fluid-structure analysis. These applications including airbag inflation, metal casting and forging require more advanced results visualization techniques than static loads analysis. Greater demands for precision, and increased use of optimization and sensitivity studies as in Noise, Vibration, and Harshness (NVH) analysis, is leading to dramatically larger datasets. Demands for faster turnaround and larger models is pushing for increased use of parallel processing and distributed processing. Yet analysis teams are expected to share resources and use the best price-performance hardware combinations. This is leading to increased interest in client-server systems, Windows clients, Linux clients and servers, and Beowulf clusters. A few years ago a high-end post-processor needed to support only the major UNIX platforms, which typically had no more than 8 CPUs. Obviously all these factors are making the task of high-end visualization developers more demanding.

- In addition to the increased complexity due to analysis types and hardware combinations are the greater need for collaboration and information sharing. Requirements for more advanced results visualization now include support for: more complex animations, web formats, Virtual Reality (VR) environments, and collaboration capabilities. Many current visualization tools were simply not designed for these new hardware, analysis-type, dataset size, and collaboration expectations.
- In addition to the increased complexity due to analysis types and hardware combinations are the greater need for collaboration and information sharing. Requirements for more advanced results visualization now include support for: more complex animations, web formats, Virtual Reality (VR) environments, and collaboration capabilities.

Conclusion:

All in all, the analyst often spends considerably more time on the pre- and post-processing phases of the problem than waiting for the simulation to run. With this in mind companies such as Livermore Software Technology Corporation, OASYS, CEI, MSC.Software, The Japan Research Institute, SGI, HP, Fujitsu and AMD are dedicated to development changes that are needed within the engineering industry.

See Product Showcase Page :

LS-POST, ENSIGHT, JVISION, OASYSD3PLOT

A Brief Introduction to Explicit Finite Element Methods

By Trent Eggleston

Explicit finite element methods were originally developed to solve problems in impact engineering, but they are currently used for many other applications such as sheet metal forming. The finite difference community developed the first impact analysis programs, commonly called "hydrocodes." Many of them, such as HEMP and TENSOR, pioneered computational techniques that are used in DYNA3D and other nonlinear finite element programs. In some cases, the finite difference methods differ from finite element methods only in that they are restricted to logically regular blocks of elements (i.e., the mesh blocks have their elements numbered by the element row and column). Beltyschko, for example, demonstrated that the plane strain stencil for HEMP was identical to the explicit finite element formulation for a 4-node quadrilateral with one point quadrature. Most of the hydrocodes, developed at the national defense laboratories, are classified. In contrast, DYNA3D was unclassified and freely distributed in the public domain until 1990. Restrictions have since been placed on newer versions of DYNA3D limiting its distribution.

Although the initial 1976 version of DYNA3D wasn't vectorized, the second release in 1979 benefited from a complete rewrite to take advantage of the Cray-1 supercomputer. For those too young to remember the Cray-1, it ran at 80 MHz, had 8 MB of RAM. Although few computers today contain vector floating point units, their RISC architectures perform best with vectorized code. The analyses that the Cray-1 made possible were too large to interpret from printed numerical output. DYNA3D was therefore one of the first finite element programs to rely almost entirely on graphical post processing instead of printed output.

Dynamic events usually occur over a short time period. For example, the duration of an automobile crash varies from 60-120 milliseconds. Small time steps must be used to accurately resolve the complicated deformation history of the buckling sheet metal in the automobile. Implicit finite element methods are prohibitively expensive when thousands of time steps must be taken because of the cost of the solving their large sets of nonlinear equations. The explicit finite element solution is advanced in time, without solving any coupled equations, by the central difference method

$$\dot{u}^{n+1/2} = \dot{u}^{n-1/2} + \Delta t \cdot M^{-1}(F^{external} - \int B^T \sigma dV)$$
$$u^{n+1} = u^{n-1} + \Delta t \cdot \dot{u}^{n+1/2}$$

where $F^{external}$ is the vector of applied forces associated with the boundary conditions and body forces, M is the diagonal mass matrix, B is the discrete gradient operator, and σ is the stress. Explicit finite element methods avoid the cost of inverting the mass matrix by using a diagonal, lumped mass matrix.

The original version of DYNA3D contained both linear and quadratic solid elements. The quadratic elements were extremely costly due to the number of operations they required per time step and their smaller stable time step size. The higher order elements were also impractical due to their numerical noise caused by the ad hoc way the mass was lumped to generate a diagonal mass matrix. Benchmarks demonstrated that constant stress elements with reduced integration and hourglass control were necessary for efficient, large-scale calculations. For a few problems, such as those involving spot welds with failure, no hourglass control method is entirely satisfactory, and fully integrated linear elements are therefore available in LS-DYNA.

Contact algorithms prevent surfaces from interpenetrating, and most nonlinear calculations now require them. They can be categorized by their 1) contact search strategy, 2) contact and release conditions, and 3) contact force calculation. The contact search is the dominant cost for most contact algorithms. The penalty method, which introduces a spring force to separate contacting surfaces, has proven to be the most versatile and robust method for contact with separation and slip in LS-DYNA.

LS-DYNA, with well over two million lines of code, now incorporates both explicit and implicit methods in 2 and 3 dimensions; runs in massively parallel and shared memory environments; has adaptive, arbitrary Lagrangian Eulerian (ALE), and Euler formulations; and heat transfer and fluids capabilities coupled to the solids solver. The strategies developed to make explicit finite element methods efficient have greatly contributed to the efficiency of all the recent additions.

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It is now possible to predict handling and ride characteristics of tyres by computer simulation using LS-DYNA. These techniques can be used by tyre manufacturers to reduce the time and cost to market for new tyre products, by short-circuiting the traditional prototype-and-test development cycle.

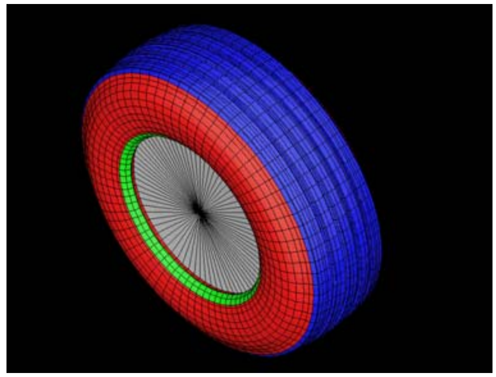
Until recently, it was too difficult to simulate the tests as they are carried out in practice: the tyres roll on a moving surface. The challenges of tyre modelling include the complexity of the tyre structure, the large deformations in the tyre, the constantly changing contact conditions, and the sheer volume of calculations needed to track the behaviour of the tyre as it performs several revolutions over the test surface. Now, advanced features in LS-DYNA and the power of modern computers have come together to offer the possibility to simulate the tests realistically.

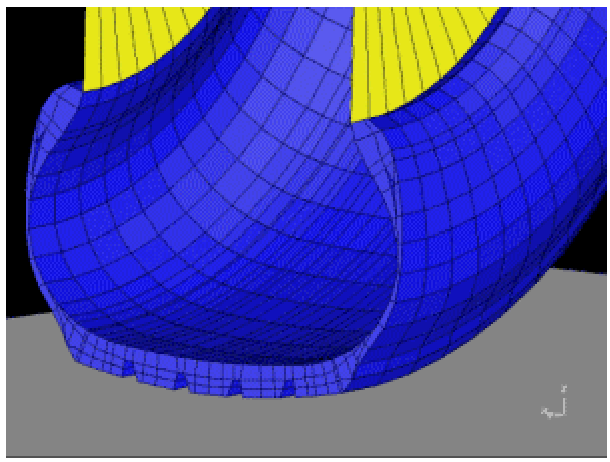
The models can be used to assess the effect of different layups, section shapes and bias angles on ride and handling characteristics. Forces and stresses can be calculated as the tyre rolls over an obstacle, leading to prediction and resolution of tyre durability problems and also providing an input to vehicle refinement calculations.

Model Construction

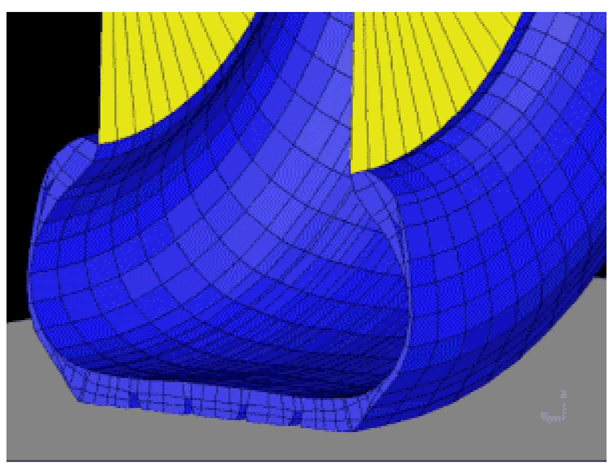
Figure 1 shows a model of a truck tyre, containing 13000 elements. The construction of the model (Figure 2) is brick elements representing the tread and

1. Model of truck tyre





2. Construction of tyre model



3. Application of internal pressure and downforce

sidewall, and shell elements representing the carcass. Each shell element is built up from a series of 10 to 15 layers that represent the liner, plies, ply topping, breakers, chafer, etc. Stiffness properties and bias angles are defined for each layer. The "layered shell" modelling method has the advantage of reducing the number of elements (and hence computing times); however, it does introduce the assumption of strains being distributed linearly with depth through the section.

Some researchers are creating more detailed models, in which each stiff layer (ply, breaker, etc) is modelled individually with shell elements, with the rubber layers between being represented with brick elements. It is also becoming common to model the tread pattern; with these enhancements, a tyre model can contain up to 100000 elements. Each step of added realism increases the accuracy of the results, but at the price of longer computing times to solve the models.

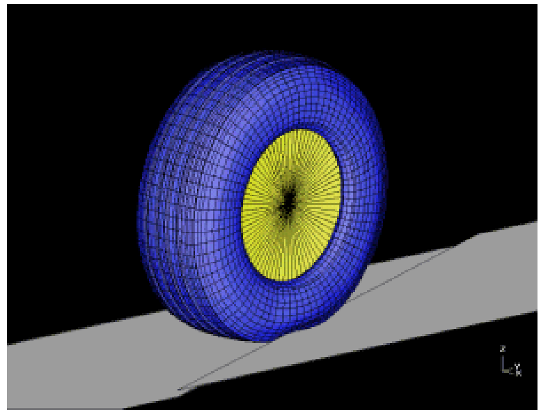
The road surface is modelled using rigid planes. In the examples shown, friction has been represented using a simple Coulomb factor.

Loads and Boundary Conditions

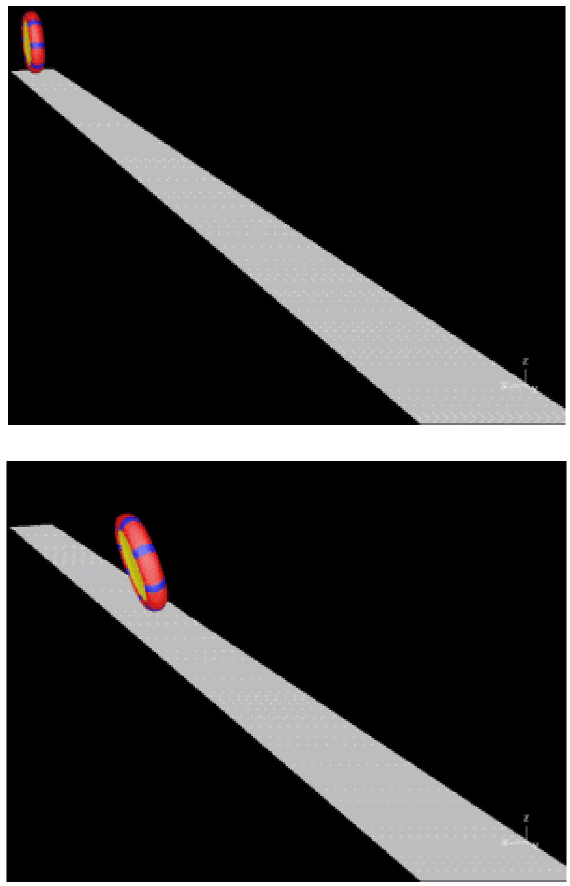
Loads and boundary conditions are applied in sequence:

- Start with the tyre oriented vertically (no camber or slip), with a small gap to the road surface
- Apply internal pressure and downforce, achieve a steady state
- Apply forward motion, accelerating from zero to the desired speed
- Apply slip angle, camber angle or include an obstacle in the road

4. Tyre model rolling over angled step

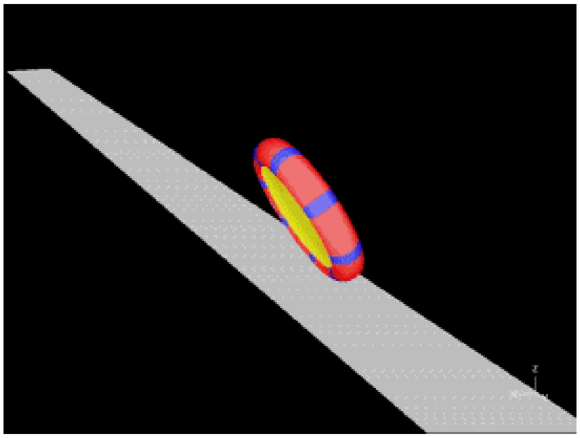


5. Motorcycle tyre with increasing camber angle

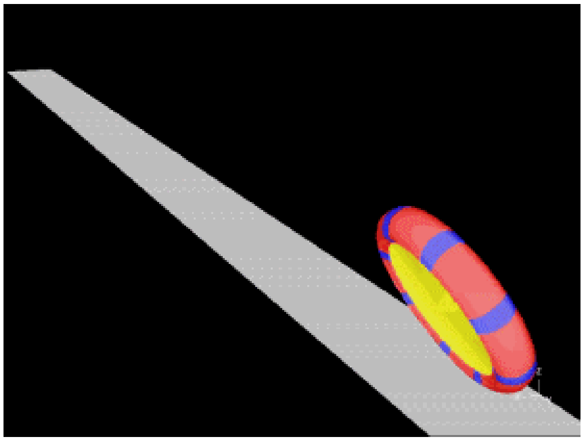


surface.

This process is illustrated in Figures 3 and 4 for the truck tyre mounting a 25mm step placed at 30 degrees to the rolling direction.



A further example is shown in Figure 5. A motorcycle tyre is rolled with constant slip angle, and gradually increasing camber angle.



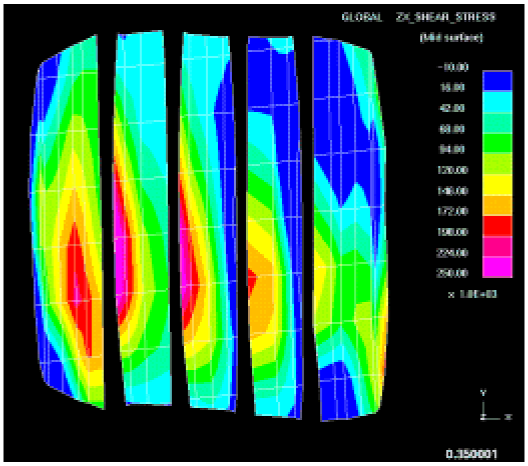
Sample of Results

The response of the truck tyre to an angled step was shown in Figure 4 above. Cornering studies have also been undertaken with the truck tyre model. Figure 6 shows lateral shear stress at the contact patch for a slip angle of 2 degrees. As expected from classical tyre theory, the stresses are concentrated behind the centre of the contact patch, leading to self-aligning torque.

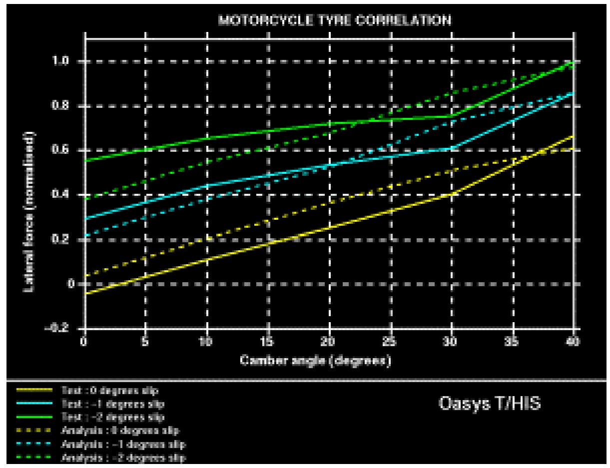
For the motorcycle tyre, cornering force was predicted by the model for a range of slip and camber angles and compared with test results (Figure 7). Forces have been non-dimensionalised to protect confidentiality. The graphs show the cornering force versus camber angle for zero slip (yellow lines), one degree slip (blue lines) and two degrees slip (green lines). The major steering mechanism for motorcycle tyres is camber steer, and it can be seen that the overall trend in camber steer stiffness (the slope of the lines) is well predicted. It is thought that the level of correlation could be improved by increasing the level of detail in the tyre model and by better representation of friction at the road/tyre interface.

Acknowledgement

The rolling tyre simulations shown on this web page were performed on behalf of and with the assistance of Dunlop Tyres Ltd.



6. Lateral shear stress at the contact patch



7. Cornering force correlation

FEA Information News Previously Showcased
Archived on the site on the News Page

February 04

Hardware	Hewlett-Packard	HP Workstation j6700
Software	LMS	LMS DADS
Distributor	Dynamaxe	Located in Troy, Michigan

Feburary 11

Software	ANSYS, Inc.	DesignSpace v6
Software	JRI	"Knowledge Engineering"
Distributor	ERAB	Located in Sweden

February 18

Software:	MSC.Linux	MSC.Linux OS
Software	LSTC	LS-OPT
Distributor	Theme Engineering	Located in Korea

February 25

Software:	ETA	VPG
Hardware	SGI	SGI Origin 3000
Distributor	ANSYS-China	Located in China

Special Participant Announcement from LSTC and ETA:

The 7th International LS-DYNA Users Conference May 19-21

Keynote Speakers:
Tsuyoshi Yasuki, Toyota Motor Corporation
Dr. Ted Belytschko, Northwestern University

Visit: www.ls-dynaconferences.com for complete information.
Registration and hotel accommodations should be made by April 11th
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News Showcase: Post-Processors

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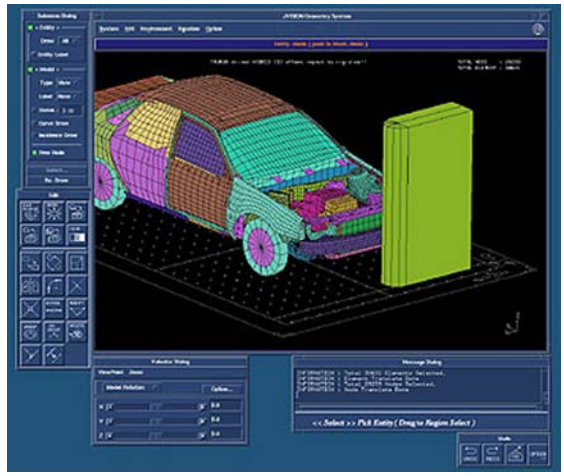

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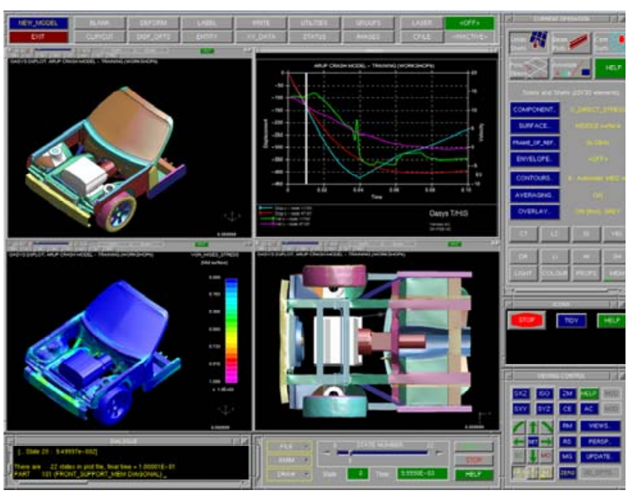

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