FEA Information International News

www.feainformation.com

Issue April, 2001

The news is a free e-mail publication mailed during the 3rd week of the month.

FEA Information would like to welcome MSC.Linux as a commercial participant.

MSC.Linux includes the Linux kernel and extensions, office productivity tools, engineering tools, Beowulf tools and engineering desktop.

FEA Information goals:

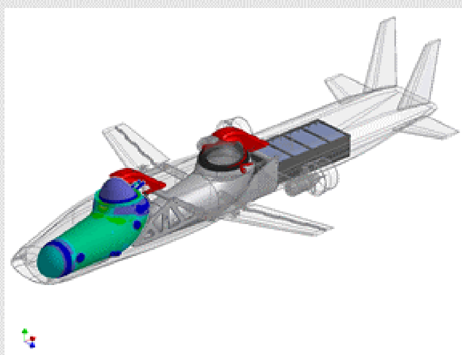
- A monthly synopsis of the additions/revisions to the FEA Information web sites.
- When available information from our commercial and educational participants

Feel free to have your associates notify me to be added to our FEA Information mailing list, Marsha – vic@lstc.com

CASE Study: DesignSpace® Helps Visionary Graham Hawkes Prepare For Underwater 'Flight' Reprinted with permission from the website of ANSYS, INC.

Approximately 70 percent of the earth's surface is covered by water. Mankind has flown over it for decades, sailed on it for millennia, but less than five percent of it has been explored. The main reason is that the available methods - scuba systems, submarines, and submersibles - have major shortcomings.

Scuba limits its users to the topmost slice of ocean since it does nothing about pressure. From an exploration standpoint, submarines are for all practical purposes blind. Submersibles solve the pressure and blindness challenges but they are kludgy, slow, noisy, and lit up like Christmas trees. Any organism that can flee does.



The above picture shows the two person watercraft with the individual operators' PODs exposed. The stress result of the POD design is superimposed for clarity.

"Even the best of today's submersibles are equivalent to scouting the jungle for tigers with a marching band," says Graham Hawkes, who has dedicated his life, fortune, and considerable talents to this challenge.

Hawkes is just the kind of visionary engineer to do something about this. His solution is Hawkes Ocean Technologies (HOT) and its DeepFlight Aviator, which combines:

The freedom of movement of scuba;
The depth capability and underwater viewing of a submersible; and
The mobility and low intrusiveness of a submarine.

Hawkes has garnered praise and awards worldwide. His work has appeared in Scientific American, National Geographic, Time, Business Week, the New York Times, and dozens of scientific and engineering journals. HOT products have been on National Geographic TV and a Public Broadcasting System (PBS) special. Prestigious honors and nominations attest to his creativity and success, including the 2000 Science Award from the Computerworld-Smithsonian Awards program, "A Search for New Heroes." A Hawkes craft, the Mantis, even played a role in the James Bond film, "For Your Eyes Only."

DeepFlight Aviator is Hawkes' most sophisticated project to date - and the basis for another Hawkes first, a school for underwater aviation. The craft "flies" underwater using inverted airfoils and positive buoyancy. It is "flown" to its depth rather than sinking to it as conventional submersibles do.

Conceptually, the craft combines a rigid diving suit with the simple, practical workings of a remotely operated vehicle (ROV). DeepFlight Aviator will be able to dive to 1,500 feet, enduring pressures of 670 pounds per square inch (PSI).

Withstanding pressure is, of course, the primary design criterion of DeepFlight Aviator. An aluminum pressure hull encases the pilot's body. (Just days before the Computerworld-Smithsonian ceremonies, a foundry successfully poured the first set of three pod castings.) The "helmet," a thick acrylic bubble, provides unparalleled 360-degree visibility and minimizes distortion due to water boundary refraction.

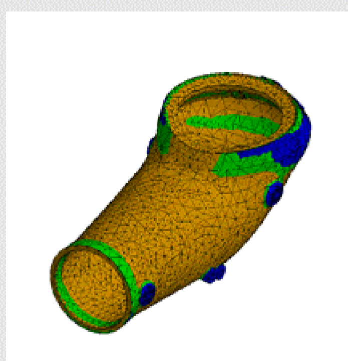
The key to DeepFlight Aviator is the way Hawkes' design optimizes the tradeoffs between power, weight, and mass. The problem to be addressed is that of achieving sufficient speed underwater - eight knots - to make the airfoils effective in overcoming DeepFlight Aviator's positive buoyancy.

Water may be frictionless but it is extremely dense. Increasing an underwater craft's speed to five knots from one requires a 100-fold increase in power. DeepFlight Aviator is self-propelled by eight 24-volt batteries. The low power-to-mass ratio of batteries dictates a very efficient hydrodynamic shape to minimize drag.

Submersibles move under their own power, but slowly; they rarely exceed speeds of two knots. They reach depth slowly, too. Ballast is loaded until the submersible is slightly heavier than the water it displaces. To return to the surface, the ballast is jettisoned. Hawkes estimates that a submersible spends 95 percent of its underwater time getting to and returning from the research site.

Submersibles are costly. Their size and crew require a mother ship, a specially equipped vessel 200 or more feet long. Charter rates are $20,000 or more per day and researchers may have to wait months for mother ship and submersible availability. These factors put submersibles out of reach of all but the heftiest R&D budgets.

Negative buoyancy, as in submarines, means bulky air tanks; redundant compressors, valves, and



Hawkes used factor of safety as a critical guide to the best design. Through numerous associative iterations, the optimum conditions of safety and minimal ballast requirements were met.

pumps; plus lots of piping, extra batteries, and a plethora of redundant, fail-safe controls.

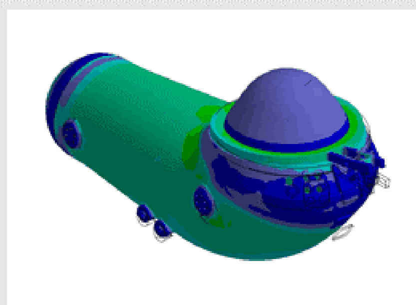
Another major design feature of DeepFlight Aviator is its life support system. To win certification from the American Bureau of Shipping (ABS), DeepFlight Aviator must be able to keep its pilot alive for 72 hours in case of trouble.

Crucial to the design's success is the engineering analysis software, DesignSpace® from ANSYS, Inc., Canonsburg, Pa, USA. (NASDAQ: ANSS). "Like DeepFlight Aviator itself, the software is easy to use, tough but flexible, and very sophisticated," said Eric Hobson, mechanical engineer responsible for the craft's detailed design. Hobson uses DesignSpace in conjunction with new Autodesk Inventor design software.

The Computerworld-Smithsonian judges cited the Deep Flight projects for their use of engineering analysis and 3D design tools in "creating a small, inexpensive submersible craft that can take scientists deep into the ocean, making the exploration of this vast resource economical for the first time."

DesignSpace primarily is used to ensure that the drag of DeepFlight Aviator's components is minimized and that the craft can withstand nearly 700 PSI of pressure. Much of DeepFlight Aviator's simplicity is achieved by protecting only sensitive components from the pressure. This is done by "canning" them in oil-filled canisters whose sizes are carefully optimized with DesignSpace and Inventor.

Because of water density's effects on speed and power, DeepFlight Aviator has to be small and maneuverable. Explained Hobson, "As soon as you make any one component bigger, everything else seems to grow exponentially in size and weight. This growth has to be accommodated or compensated for. That triggers another round of design adjustments and size increases. It can go on forever. This is why submersibles are so clunky," he noted. "It is vital that DeepFlight Aviator move quickly without big motors and a lot of batteries and surfacing tanks. If we have to go that route, we cannot keep the mass and bulk down."



The pressure loads on the POD were calculated using the maximum potential depth of the vehicle during use.

Naturally, most of the pressure management effort goes into protecting the pilot. DeepFlight Aviator uses a rigid cast aluminum body. More than anything else, the pod resembles a bent cocoon. It is a cylinder tapering from 26 inches in diameter at the pilot's shoulder level to 18 inches at the feet.

The upper end of the pod cylinder is curved away from the cylinder's centerline, or "revolved," 30 degrees to accommodate the seated pilot. It was at the most inward curving section of the pod that DesignSpace indicated maximum stress. Hobson designed the pod to be three inches thick at that point. At the pilot's waist the metal in the pod's wall is one inch thick, at the pilot's feet, three-quarters of an inch.

"The design actually was optimized for the comfort of the user rather than for stress," said Hobson. Comfort was a significant design factor because one tends to become cramped, and possibly claustrophobic, after an hour or two beneath great masses of water.

"The stresses easily were within the capabilities of the 356 aluminum alloy for the pod castings and the 6061-T6 we used for the cast machined parts," such as the canisters, Hobson said.

Using DesignSpace, Hobson was able to run many design iterations in conjunction with Autodesk Inventor quickly. "Our design environment is straightforward," Hobson pointed out. "We know that the greatest stress on our pressure hulls is going to be from the ocean's pressure. Effectively, this is a static load that can be applied easily to our conceptual designs."

"But," he continued, "the results of our analyses are extremely important since there is no room for error when you dive deep. The key advantage of working with the latest DesignSpace and Inventor is that we are able to seamlessly attach our models to the DesignSpace database and retain all the associativity when we make changes to the Inventor models."

"Being able to bring changes made in Inventor directly into DesignSpace saves considerable time," Hobson explained. "Without this tight associativity, the constraints, loads, and supports would have to be reapplied to the geometry of the model in DesignSpace after almost every change. Reapplying takes perhaps ten minutes, but when repeated becomes very time consuming, very distracting and irritating. In the critical designs we might run 20 to 30 iterations. For us, this associativity works beautifully.

"DesignSpace," he said, "lets us bring in the entire assembly, throw the depth pressure on all surfaces, and know that the problem is solved correctly. It's a real time saver."

Essential to the design project's success is DesignSpace's ability to handle components in an assembly and not just individual parts. This was crucial in analyzing the stresses where a metal locking ring clamps the fittings for the acrylic bubble helmet to the pod. "With a system this complex, the results from analyses of individual components would be meaningless," Hobson pointed out.

"Sure, we could show that the locking ring would not deform under 670 pounds of pressure," he continued, "but what about seal for system integrity? That's what's important. There is no way to show that without analyzing the entire pod with all its parts. That's why the DesignSpace assemblies capability is so important," he added. "We really give it a workout."

The DesignSpace analyses were linear, stress, and noncontact. Solving variants of the pod model, even though it is 140 megabytes (MB), takes just five minutes at DesignSpace's standard tolerances. The method used was convergence to maximum stress. HHKW runs DesignSpace and Inventor on a customized Core Systems PC with dual 400 MHz. Intel Corp. Pentium III CPUs. The machine has 256 MB of RAM, a 9.2-GB disk drive, and a 200 MB SCSI interface.

Critical to the project's ultimate success is ABS certification. Hobson noted that ABS accepts analyses from designers and developers rather than requiring this work to be done on its own systems. As the classification society for all U.S.-registered ships, ABS represents the insurance industry's interests. It takes no chances. ABS will require radiographic tests to verify the integrity of the metal. Pressure tests to verify the DesignSpace results will be performed at a U.S. Navy facility in San Diego.

Hawkes has designed more than 70 percent of all manned underwater vehicles ever built for R&D or industrial uses, as well as more than 300 ROVs. He holds the record for the deepest solo ocean dive, 3,000 feet, reached during his testing of Deep Rover submersibles.

DesignSpace is particularly useful in designing the pressure hulls of our submersibles," Hawkes told the Computerworld-Smithsonian judges. "We are now confident [that we can] depart from simplified geometry. Whereas, in the past, we relied on conventional pressure hull geometries - spheres and cylinders - because we did not have the confidence in [the ability to analyze] complex geometries. DeepFlight Aviator's hull is optimized for a human pilot by form fitting his/her natural sitting position.

"This configuration creates a complex hull that is very difficult to analyze with simple hand calculations," Hawkes continued. "However, with FEAs, we not only can analyze this new hull, we can freely test new configurations to find the true optimum design. Due to our limited budgets," he added, "we always try to use off-the-shelf components. However, we do use emerging technologies to produce superior products."

Finite Element Vehicle / Dummy Interaction

Ala Tabiei, Director, Center of Excellence in DYNA3D Analysis
and
Alan McGowan, Graduate Student

Dept. of Aerospace Engineering and Engineering Mechanics
University of Cincinnati, Cincinnati, OH 45221-0070

Computations were performed using LS-DYNA on the Cray T94 at the Ohio Supercomputer Center. The visualizations were done using LS-POST on the Origin2000.

Background and Significance of Work

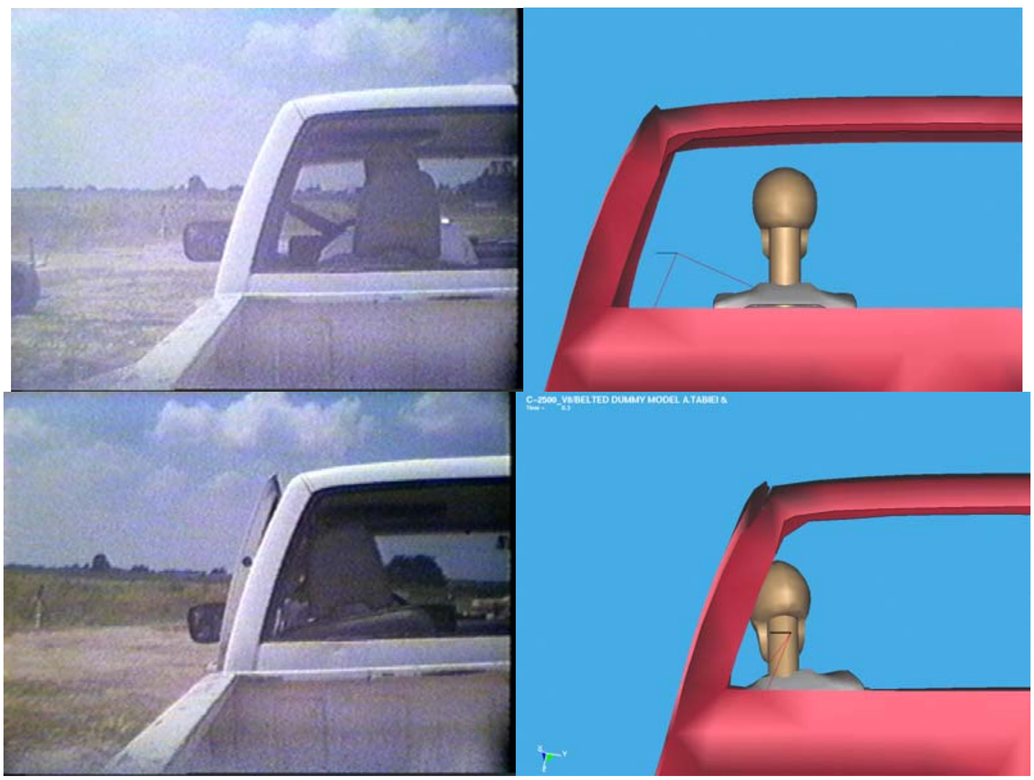
In recent years, most of the emphasis has been on conducting full-scale tests in order to gain insight into potential safety problems and to develop new and improved roadside hardware. Since the number of vehicles on the roads and the roadside obstacles continue to increase, traffic barrier analysis and design remains am important aspect of public safety. The design of highway hardware (guard rails, sign posts, bridge rails, Light poles, etc.) under vehicle impact are performed experimentally through an iterative process of design, build, test, redesign and retest, until the product meet the design criteria. Recent advancement in computer technology and the availability of cheap and efficient computational power has made it possible to tackle many of the design iterations of such highway hardware numerically. Experimental evaluation of new or modified highway hardware is expensive and time consuming. On the other hand, numerical simulation of impact behavior of highway hardware under different impact scenarios is cheaper and efficient. It is economically impossible to perform full scale vehicle impact tests on a wide range of parameters. An effective tool in vehicle impact simulation is nonlinear finite element analysis.

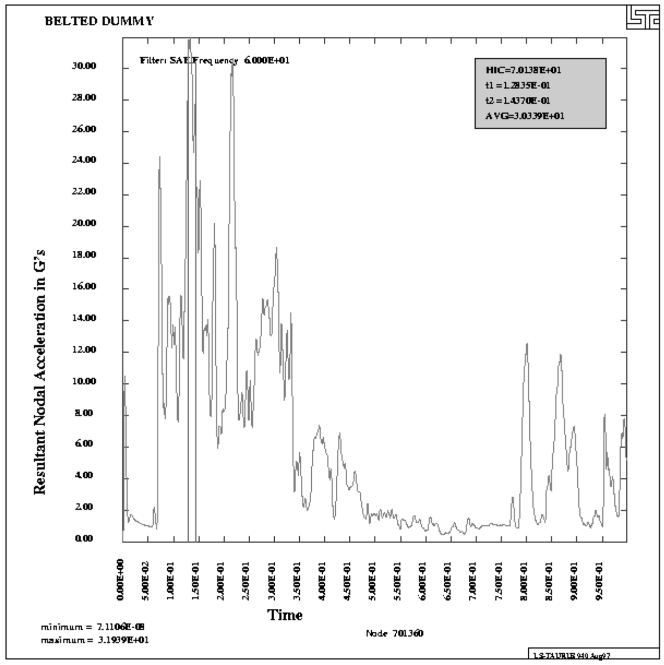
Objective of Study

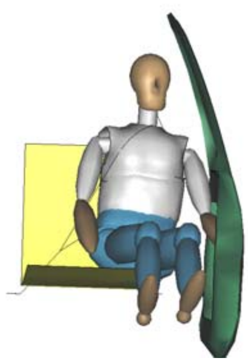
The main objective of the study is to quantitatively determine the effects on an occupant in a pickup/guardrail impact. The areas of focus for the quantitative analysis are Head Injury Criteria and Chest Deceleration. Values for these two criterions are determined using LS-DYNA and compared to reasonable values to determine the probability of severe injury. Both belted and unbelted dummies are used. The following figures show the complete model of full size pickup model, a dummy, and the G4 (1S) strong post, w-beam guardrail system. This arrangement, minus the dummy, was previously modeled in [1,2]. The dummy, which represents a Hybrid III dummy commonly used crash analysis, was positioned using information from [3]. This positioning was chosen so as to give more natural seating to the dummy. LS-Post allows for parts to be rendered transparent, hence the pale blue in the side window area. A model has also been developed using the pickup, guardrail and dummy, which contain an unbelted occupant. The results for the belted and unbelted occupant are compared to see if one configuration provides a higher probability of severe injury.

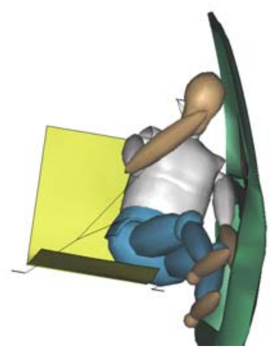
Simulation Platform

These finite element models were developed to test the strong post guardrail system, which is the most common system on most highways in the US. The simulation is run on the Cray T94 and Cray T3E at the Ohio Supercomputer center and takes about five days to be completed (about 1.5 second simulation). The results of the simulation are compared with full-scale crash tests for model validation and finally guard rail system improvement.









Reference

1. Tabiei, A., and J. Wu, "Validated Crash Simulation of the Most Common Guardrail System in the USA", Int. J. of Crashworthiness, Vol. 5 No. 2, pp. 153-168, 2000.
2. Tabiei, A., and J. Wu, "Roadmap For Crashworthiness Finite Element Simulation Of Roadside Safety Structures", Int. J. Finite Element in Analysis and Design, Vol. 34, No. 2, pp. 145-157, 2000.
3. Manary, Miriam A., Reed, Matthew P., Flannagan, Carol, A.C., Scheider, Lawrence, W., ATD Positioning Based on Driver Posture and Position. In Proc. 41st Stapp Car Crash Conferene, pp 287-299. SAE Technical Paper 983163. Warrendale, PA: Society of Automotive Engineers, Inc.

THEORY: Convergence Tests During Nonlinear Equilibrium Iterations

In nonlinear implicit analyses, LS-DYNA uses Newton's method to iteratively search for equilibrium. The illustration in figure 1 describes the progress of a typical load step, advancing the solution from time "n" to time "n+1". In the figure, a norm of force is plotted against a norm of displacement. Norms are evaluated as the square root of the sum of the squares of forces or displacements at each node point.

The curve in figure 1 represents the nonlinear internal force norm as a function of displacement. In the example, the solution is known at time "n", and the external load is advanced to time "n+1". A search is performed to find the displacement solution, which satisfies equilibrium, i.e. the internal and external forces are balanced.

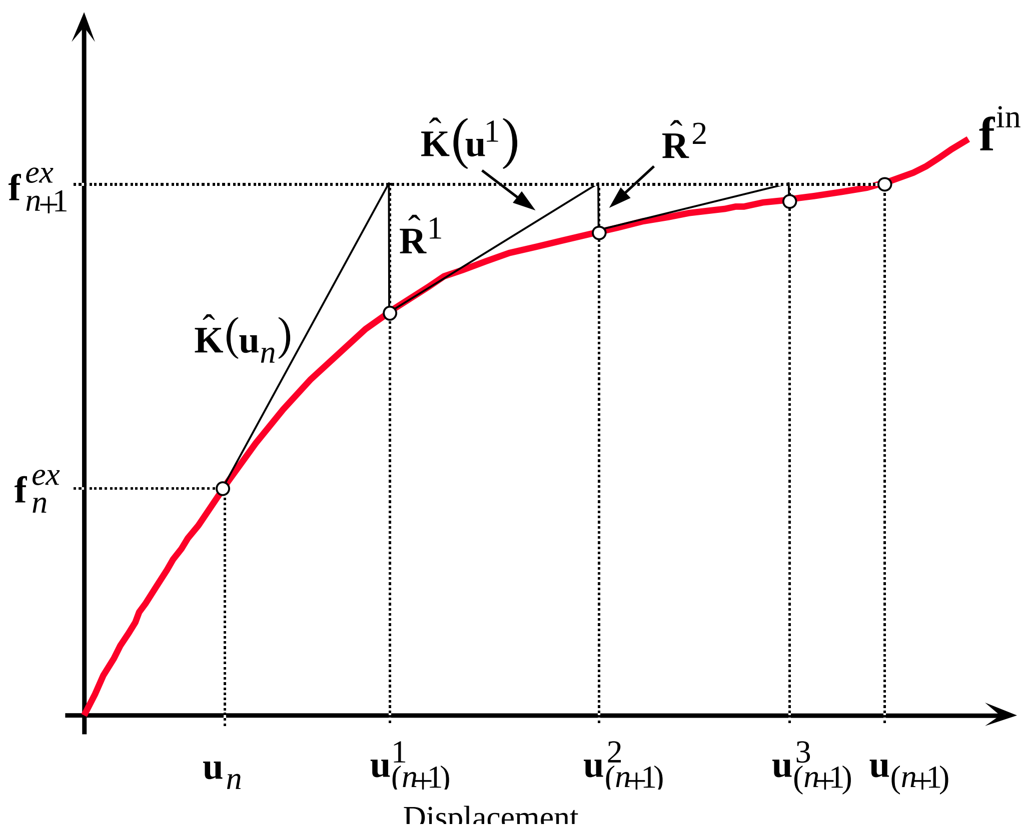


Figure 1 – This figure shows the progress of nonlinear equilibrium iterations advancing a solution from time "n" to time "n+1". Superscripts on displacement variables indicate nonlinear iterations.

At iteration *i* in the equilibrium search, a stiffness matrix **K** is evaluated as a function of the current displacement. This matrix is inverted and applied to the out-of-balance force *R* to obtain a new increment in displacement Δu .

$$\mathbf{K}(u)\Delta u^i = R^i \quad \Rightarrow \quad \Delta u^i = \mathbf{K}^{-1} R^i$$

The solution is updated with the new displacement increment, a new internal force is computed for this solution, and a new residual vector is formed:

$$u^{i+1} = u^i + \Delta u^i \quad , \quad R^{i+1} = f_{n+1}^{ext} - f_{n+1}^{\text{int}}\left(u^{i+1}\right)$$

At this stage, a convergence test is performed. LS-DYNA uses two measures of convergence, an energy norm and a displacement norm. Both of these tests must be satisfied to achieve convergence:
The energy test compares the current energy norm to that at the start of the step:

$$\frac{\left\|\Delta u^{i+1} * R^{i+1}\right\|}{\left\|\Delta u^1 * R^1\right\|} < \mathrm{E}CTOL$$

There are two options for the displacement norm. These are selected using the parameter DNORM on second card of the *CONTROL_IMPLICIT_SOLUTION keyword. The options are:

$$\mathrm{DNORM} = 1: \quad \frac{\left\|\Delta u^{i+1}\right\|}{\left\|u_{n+1} - u_n\right\|} < \mathrm{D}CTOL$$

$$\mathrm{DNORM} = 2: \quad \frac{\left\|\Delta u^{i+1}\right\|}{\left\|u_{n+1}\right\|} < \mathrm{D}CTOL \quad \text{(default)}$$

Two observations can be made considering these convergence tests. If the external load does not change from the previous step, then the out-of-balance force R will be initially zero. This causes trouble for the energy convergence test since a zero appears in the denominator. In this case, LS-DYNA displays an energy norm of 1.000. It is recommended to avoid this case by applying load, which varies in each step. Solving twice for the same load value is unnecessary anyway. A similar argument explains why convergence can become difficult as the load increment decreases toward zero.

If the total displacement in the problem becomes large, then the denominator in the default displacement test will also become large. This “weakens” the test since a large displacement increment will satisfy the convergence tolerance. In simulations which involve large displacements, the optional displacement convergence test DNORM=1 will provide more consistent results during the simulation. However, a larger value of DCTOL may be needed. Values of DCTOL=0.010 have worked well in many cases.

NEW FEATURES: Drilling DOF Control for Shells

The drilling degree of freedom in shell elements is a rotation about the normal vector at each node. If adjacent elements all lie in a plane, this drilling DOF must be somehow constrained, since drill rotations will not generate any element stress.

Until recently, LS-DYNA automatically constrained drilling DOF by adding a small rotational stiffness to the element stiffness matrix. This approach can create convergence problems, and can restrict the free rigid body motion of the model. Roger Grimes has added several new options for controlling drilling DOF, which should eliminate these problems. New input parameters have been added to activate and control these new features:

The new constraint option (DRILL=2) eliminates drilling rotation by imposing a constraint on the linear system [K]{x}={f}. The constraint is applied if adjacent elements are flat to within a tolerance DPARM.
The AUTOSPC option is applied independently, and searches the global stiffness matrix for nodes whose rotational degrees of freedom are rank deficient. If an eigenvalue is found which is below the tolerance ASPCTL, a constraint is automatically imposed.

User feedback is needed to evaluate the effectiveness of these new features.

```
*CONTROL_IMPLICIT_SOLVER
$   lsolvr   prntflg    negeig     order     DRILL     DPARM   AUTOSPC    ASPCTL
         0         0         0         0         0         0         0         0
$
$ DRILL = shell drilling DOF constraint method
$    eq.1: stiffness method (default)
$    eq.2: constraint method
$    eq.3: none, unless AUTOSPC is active below
$
$ DPARM = drilling DOF parameter
$
$  if DRILL.eq.1 (stiffness method) then
$    DPARM = stiffness scale factor
$       for linear analysis, default =   1.
$       for nonlinear analysis, default = 100.
$       for eigenvalue analysis, dparm = 1.e-8 always
$
$  if DRILL.eq.2 (constraint method) then
$    DPARM = flatness tolerance in degrees (default = 10)
$
$ AUTOSPC = flag to activate AUTOSPC constraints
$    eq. 1: activate AUTOSPC
$    eq. 2: do NOT impose AUTOSPCs
$
$ ASPCTL = AUTOSPC tolerance
$    for single precision, default = 1.e-4
$    for double precision, default = 1.e-8
```

FEA Information Web Sites
March Work Synopsis
March News is archived on the News Page

March 23, 2001

- **Welcome**: MSC.Linux as a Commercial Participant with information on the Linux for PC web site www.linuxforpc.com and www.linuxforservers.com
- **Site**: opened the web site Implicit FEA, directed by Dr. Bradley Maker www.implicitfea.com
- **Site**: on the events page we added a table for Classes

March 19th, 2001

- **Showcase** – participant – Hewlett Packard: HP's World e—Inclusion

March 12, 2001

- **Site**: addition - Drop Testing – added avi's of circular saws
- **Site**: revision - Heat Transfer Analysis – revised the jpg to thumbnails for faster loading
- **Showcase:** software - LS-Post – free post processor from Livermore Software Technology downloadable from LSTC's FTP site. Contact Dr. Wayne Mindle – wlm@lstc.com
- **Site**: started our web site Under Water Shock Analysis with a definition of the application – www.underwatershockanalysis.com

March 5, 2001

- **Welcome**: Dr. Ala Tabiei as an Educational Participant
- **Site**: addition - added AVI #60b – Bird Strike on a leading edge of a wing
- **Showcase**: participant - ANSYS: ASP from ANSYS, Inc. e-CAE

March Publications: (if you need a copy e-mail vic@lstc.com)

- Study on the Effects of Numerical Parameters on the Precision of Springback Prediction – Zhongqin Lin, Gan Liu, Weili Xu, Youxia Bao (Shanghai Jio Tong University
- Global and Local Coupling Analysis for small Componenets in Drop Simulation – Jason Wu, (Motorola)
- Smooth Particile Hydrodynamics (SPH) – Jean Luc Lacome (Dynalis)
- Simulation of Cold Roll Forming of Steel Panels – Fei-chen and Oladipo Onipede Jr. (Univ. of Pittsburgh)

The month of April I will be mainly concentrating on the site Implict FEA

Marsha

Courses and Events will be limited to 1 page
For full courses please visits the listed web addresses

Events/Conferences

2001	
May 6-11	Precision Metal Forming Association Tradeshow in Cleveland, OH, USA. Please visit our participant (ETA) Engineering Technology Associates exhibiting DYNAFORM in Booth 612.
June 5-7, 8 Poland	Third International Conference on Thin-Walled Structures (Cracow, Poland) Workshop on FEM Applications to the Analysis of Thin-Walled Structures
June 18-19 France	Third European LS-DYNA Conference will take place in Paris at the La Maison de la Chimie. 28, rue Saint Dominique, Paris, France For information email: dynalis@dynalis.fr
Aug 1-4 USA	Sixth US National Congress on Computational Mechanics, Dearborn, MI, USA. For information visit the site - USNCCM
May 19-21, 2002, USA	7th International LS-DYNA User's Conference at the Hyatt Regency Hotel & Conference Center - Fairlane Town Center, Dearborn, MI 48126

Classes/Seminars -April - May

2001	Country	Information	Class Title
May 1	USA	www.eta.com	DYNAFORM - This class will be PC focused.
May 7	KOREA	www.kostech.co.kr	Pre-Post Processing
May 8	USA	www.ansys.com Headquarters	Basic Structural Nonlinearities
May 8	KOREA	www.kostech.co.kr	Introduction to LS-DYNA
May 10	KOREA	www.kostech.co.kr	Implicit Training
May 17	KOREA	www.kostech.co.kr	Sheet Metal Forming
May 14	USA	profdev@sae.org	Fundamentals of Finite Element Linear Analysis in Solid/Structural Mechanics
May23	USA	www.lstc.com	Introductory LS-OPT
May 23	UK	www.arup.com	Oasys Primer V. 8.0a
May 24	UK	www.arup.com	Oasys D3Plot & T/HIS V. 8.0a
May 30	USA	www.ansys.com Headquarters	Electromagnetic Analysis

FEA Information Commercial & Educational Participants

Livermore Software Technology:

Develops and supports LS-DYNA, LS-Post, LS-OPT. LS-DYNA, a highly advanced multi-physics simulation code. Implicit, Explicit, SMP and MPP imbedded in one code. Headquartered in Livermore, CA, USA

Engineering Technology Associates, Inc.

An engineering consulting company specializing in automotive Computer Aided Engineering (CAE). Providing services, software, training and technology. Headquartered in Troy, Michigan, USA.

Oasys, Ltd.

Markets engineering software products. A global organization of consulting engineers, planners and project managers working in all areas of the built environment. Headquartered in the UK

Japanese Research Institute, Ltd.

Specializing in Research & Consulting; System Consulting, Frontier Business, System Integration and Science Consulting. JRI is located in Tokyo, Japan.

EASi Engineering:

A global provider of integrated solutions for Fast-to-Market product development. Easi Engineering is headquartered in Madison Heights, Michigan.

ANSYS, INC:

ANSYS, Inc. develops, markets, supports and delivers collaborative analysis optimization software tools. Headquartered at Southpointe in Canonsburg, Pennsylvania.

Hewlett-Packard:

A worldwide leader in personal computing, in such areas as mobile computing, network management, 3-D graphics and information storage. Headquartered in Cupertino, CA, USA.

SGI:

A worldwide leader in high-performance computing technology, from desktop workstations and servers to supercomputers, delivering advanced computing and 3D visualization. Headquartered in Mountain View, CA, USA.

MSC.Linux:

MSC.Linux offers a wide range of Linux products and services. MSC.Linux is a lean distribution delivering all the required pieces (kernel plus extensions). Headquartered in Costa Mesa, CA, USA

Dr. Ted Belytschko:

W.P. Murphy Professor and Chair at Northwestern University in Chicago, Illinois.

Dr. David Benson:

Associate Professor, University of California, San Diego Research on computational methods for nonlinear, large deformation problems in solid mechanics.

Dr. Bhavin V. Mehta:

Completed his doctoral work in the Ohio University Individualized Interdisciplinary Program involving chemical engineering, mechanical engineering, and mathematics.

Dr. Taylan Altan:

Professor, Mechanical Engineering - Director, ERC for Net Shape Manufacturing, The Ohio State University.

Professor Ala Tabiei:

Assistant Professor, University of Cincinnati, of Aerospace Engineering and Engineering Mechanics. Director, Center of Excellence in LS-DYNA.