ANSYS News

The Seventh International ANSYS Conference and Exhibition

ANSYS

The Future of Simulation Tools—
CAE in the 21st Century

See related article on page 3.

Inside this Issue

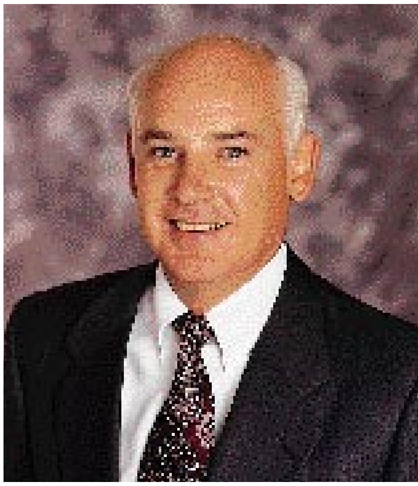
First Issue

1996

Message from the CEO

Building on the Momentum

In the last issue, I reviewed the company's third quarter results. I am pleased to report the company continues to perform strongly. Our fourth quarter performance brought 1995 to a close with a record revenue year. The fourth quarter alone represented a 70 percent increase in new business over the same quarter of the previous year.



Peter J. Smith
President and CEO

We attribute this growth to our significant investment in research and development; improvements to business operations, sales/marketing, as defined in our strategic business plan; as well as increased investment and focus by the worldwide ANSYS Support Distributors (ASDs). We set out in 1995 to become the open provider of industry-leading, flexible engineering software solutions, and the results speak for themselves.

International Data Corporation (IDC) confirms that the computer-aided engineering (CAE) market growth for 1995 was 13 percent. Our 21 percent growth over 1994 clearly shows that we are winning market share.

We attribute this growth to our significant investment in research and development; improvements to business operations, sales/marketing, as defined in our strategic business plan; as well as increased investment and focus by the worldwide ANSYS Support Distributors (ASDs).

Last year, ANSYS® and ASDs helped more companies reach higher levels of productivity than ever before. As the first ISO 9001 certified CAE software development process in the world, ANSYS, Inc. produces software of the highest quality possible, helping all size companies improve their effectiveness. Once again, our results speak for themselves. Our customer base includes 62 percent of the *Fortune* top 100 companies in the world, and our international business channel has grown to be responsible for 58 percent of overall ANSYS sales.

Our open business strategy remains unique in the industry, and is gaining worldwide recognition. We continue to partner with the best third-party software technologies and leading computer-aided design (CAD) vendors. We work hard to make the ANSYS family of products easy-to-use and more open than any other design analysis and simulation software in the world.

In 1996, we will continue to invest heavily to provide industry-leading technology and innovation in the most flexible framework. ANSYS 5.3, due out this summer, will deliver world-class solver technology. New solvers include a very fast linear structural solver *(see related article on page 12)*; a robust and efficient eigensolver, for frequency extraction; and an explicit solver for highly nonlinear structural dynamic analyses, called ANSYS/LS-DYNA.

We will continue to expand and lead the industry in Windows-based and multiphysics analysis capabilities. In addition, we will continue to integrate with strategic software partners providing leading-edge technologies to our users. We continue to be the most compatible data structure on the market, from upfront design optimization to high-end, coupled-field, multiphysics analysis. We are consistently meeting the flexible engineering needs of more and more companies every day.

The 1996 ANSYS Conference and Exhibition represents the ANSYS user's best opportunity to learn more about the program, meet other users, and see where the future of ANSYS is heading. May 20th marks the beginning of the Seventh International ANSYS Conference and Exhibition. I would like to remind you and take this opportunity to personally invite you to attend and experience "The Future of Simulation Tools: CAE in the 21st Century."

Sincerely,

Peter J. Smith
President and CEO

Published four times a year for ANSYS customers and others interested in the field of design analysis applications. There is no charge for a subscription; contact Mary Al Caldwell at 412.873.3063 to be put on the mailing list or to change your address.

The Seventh International ANSYS Conference and Exhibition:

The Future of Simulation Tools: CAE in the 21st Century

The Future of Simulation Tools— CAE in the 21st Century

What is the future of computer-aided engineering (CAE)? The CAE industry is in a state of transition and ANSYS, Inc. knows that yesterday's answers are not tomorrow's solutions. Many companies are re-engineering their design through manufacturing processes with ANSYS design analysis and simulation tools to provide better products, faster, and at lower cost.

The ANSYS family of products provide the most flexible engineering environment in the industry, defining a truly open software system. The ANSYS program is integrated with more computer-aided design (CAD) packages than any other analysis software in the world and is available on everything from PCs to supercomputers. To see where CAE is heading, ANSYS, Inc. invites you to be a part of the Seventh International ANSYS Conference and Exhibition. This three-day event will be held at the Pittsburgh Hilton & Towers on May 20-22, 1996.

This conference is your best opportunity to meet ANSYS users from around the world, see how others are using the program, and understand the engineering challenges of the 21st century. ANSYS developers, executives, product managers, and other staff members will be on hand to share future technologies and discuss users' needs. Space is limited, so register TODAY!

Why Attend

If you had the opportunity to see the inside track on where the industry is heading, why pass that up? Then don't miss this conference. You will not see another showcase of leading-edge engineering software and hardware technology anywhere. The ANSYS conference contains everything from new product releases, to American Society of Mechanical Engineers (ASME) sponsored courses, to a keynote speech on "Engineering in a Changing World." This conference is one of the most important events to anyone who uses ANSYS or is interested in ANSYS technology.

Attendees

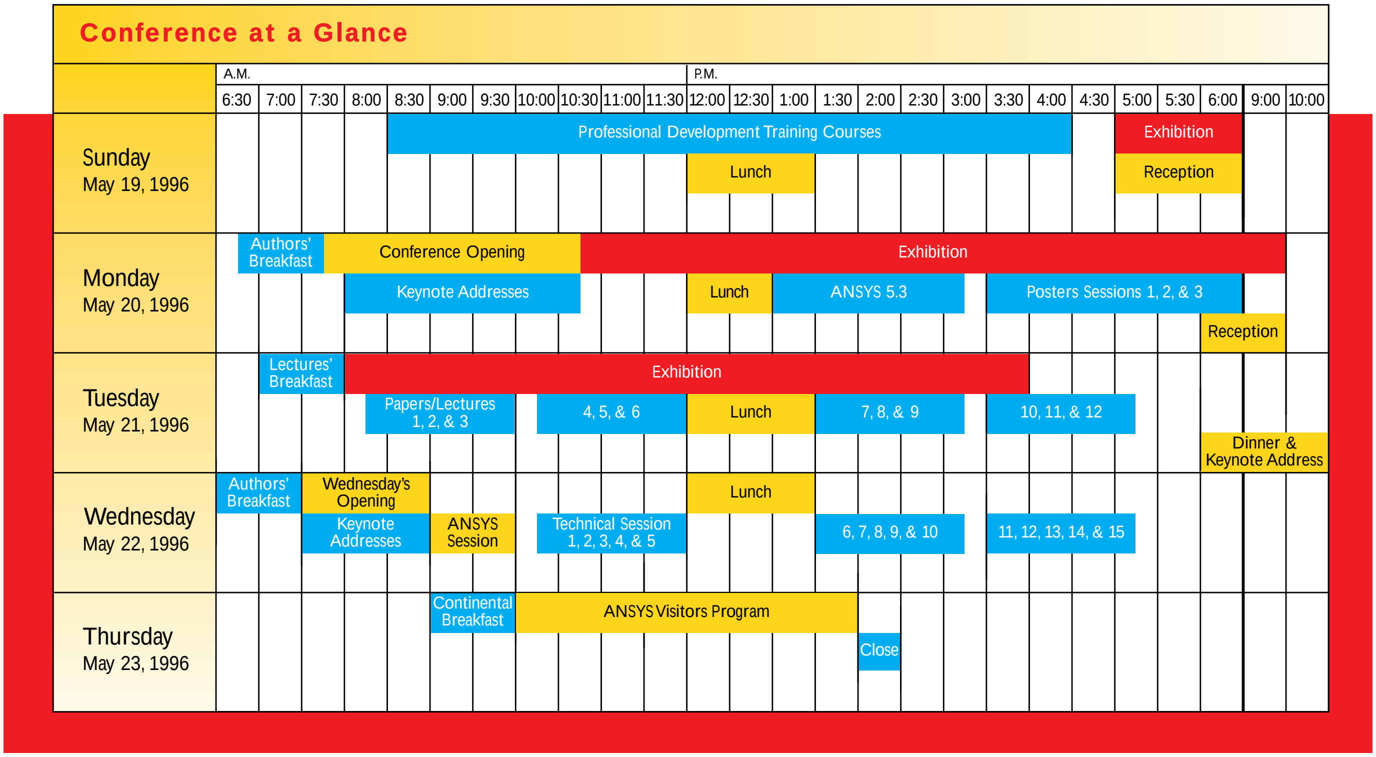
The 1996 conference marks the first conference geared towards design engineers and analysts, as well as business and engineering managers. Attendees can learn more about the ANSYS program's capabilities, simplifying their product design processes, and maximizing the benefits of their CAE investment.

Registration and Costs

Several admission packages exist for the conference. Discounted rates only apply if you pre-register with payment by mail. The Professional Development Training Courses offered on Sunday, May 19 are full-day courses for a fee of $295 if you attend the three-day conference and $395 if you do not. The three-day conference fee is $475, and a single day technical session pass is available for $275. Students receive a discounted rate of $95 for a three-day pass. Everyone who attends the conference will receive a free copy of ANSYS/ED™. The conference social on Tuesday evening is free to three-day attendees, and $55 for single-day attendees and all guests. All fees listed are in U.S. currency. If you do not pre-register, fees at the door increase by $50 for the three-day conference and $25 for a single day.

Accommodations

Hotel rooms are provided at the Pittsburgh Hilton & Towers for a discounted rate of $107 for single, double (1 bed), or double (2 beds). Special accommodation rates also exist, such as $137 for a towers single room or double room, and $350 for one-bedroom and parlor. To secure a room, return the



hotel reservation card included before April 28, 1996, or call 412.391.4600.

Travel

USAir is the official carrier for the 1996 ANSYS Conference and Exhibition, offering an exclusive low fare for all attendees. This special rate includes a five percent discount on first class and published promotional USAir round trip fare, and ten percent off any unrestricted coach fare with seven days advanced reservation and ticketing required. Discounts are only valid May 16-25, providing all rules and restrictions are met. Offer available when traveling from the Continental United States, Bahamas, Canada, and San Juan. Additional restrictions may apply on international travel. To obtain your travel discount, contact Cosmopolitan Travel at 1.800.235.1114 or fax to 412.824.6464, and refer to GOLD FILE 15280015.

Professional Development Training Courses

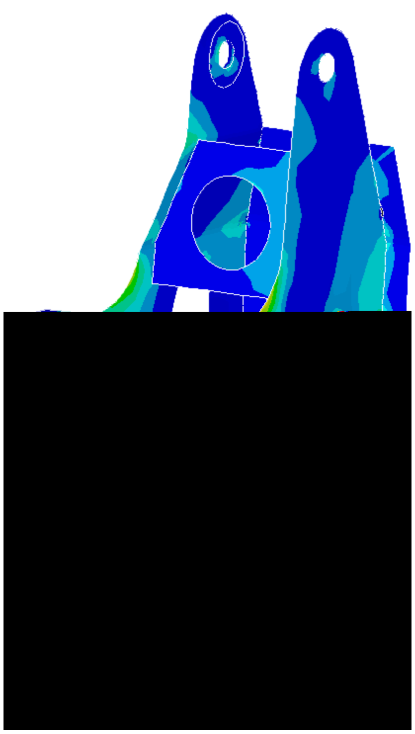
In addition to the conference activities, ANSYS, Inc. has developed a full day of training courses as an early bird special. On Sunday, May 19, training courses are being offered on “ANSYS/AutoFEA™,” “STEP,” “Explicit Dynamics with ANSYS/LS-DYNA,” “Achieving Quality in Software,” and ASME’s “Taking Technology to Market.”

“ANSYS/AutoFEA” teaches use of the ANSYS/AutoFEA product for design analysis inside AutoCAD®. This course is geared for design engineers, end users, technical support personnel who will be teaching or supporting, and resellers or distributors of ANSYS/AutoFEA. Attendees require a basic understanding of AutoCAD Release 12 or 13 and fundamentals of engineering mechanics. This course is not intended for experienced analysts.

“STEP” offers training in the new international data exchange standard. Attendees will learn the fundamentals of STEP, its various components, and how it differs from existing standards. David Mattei, a senior member of International TechneGroup Incorporated’s (ITI) product data integration business, will be hosting this course. ITI’s products and services are used by organizations of all types and sizes to improve data exchange between dissimilar engineering systems.

“Explicit Dynamics with ANSYS/LS-DYNA” introduces users to explicit dynamics technology that will be released with ANSYS 5.3, in partnership with Livermore Software Technology Corporation. This course offers attendees the opportunity to learn the explicit method and the types of problems that can be solved with this technology. This session is geared toward end-users and engineering managers with some experience of finite element method and an interest in the explicit method.

"Achieving Quality in Software" offers guidance for developing an effective quality system for software development, based on ANSYS, Inc.'s experience in developing the industry's first ISO 9001 compliant on-line quality system. Attendees will learn some unique requirements for an effective quality system, and how people and processes relate to the success of quality initiatives. Focusing on the ISO set of quality standards, this course applies to anyone interested in quality systems in the workplace.



Optimization of the control mount from a truck cab air suspension. Image courtesy of DRD Corporation and Link Manufacturing Ltd.

"Taking Technology to Market" is an intensive one-day course on how you can capitalize on new technology for financial and strategic gain. Obtain the tools and techniques needed to effectively move new ideas to market. The course is geared towards engineers, scientists, R&D technology professionals, product development managers, operations managers, and business executives. This course is an American Society of Mechanical Engineers' Professional Development Short Course.

CEO Presentation

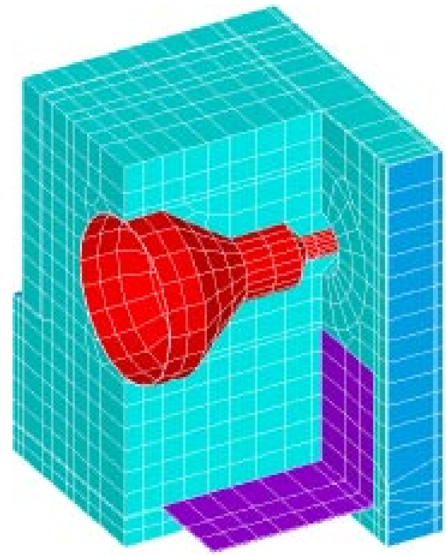
The conference kicks off with a multimedia presentation by Peter Smith, President and CEO of ANSYS, Inc. This fully interactive program discusses the paradigm shift that is occurring in the CAE industry and what the future has to offer ANSYS users. Peter Smith takes the stage after the author's breakfast on Monday, May 20, at 7:45 a.m.

ANSYS 5.3 Preview

Join Prashant Ambe, ANSYS 5.3 Release Manager, as he speaks on some of the new enhancements in ANSYS 5.3. This presentation will cover explicit dynamics, meshing, solver technology, geometry transfer, multiphysics, and ease-of-use. The 5.3 preview takes place on Monday, May 20, at 1:00 p.m.

The Hands On Room

This is your opportunity to get your hands on ANSYS 5.3. Visitors can actually sit at a workstation or PC and solve several real-life problems that demonstrate the new features in ANSYS 5.3. Each problem will have detailed instructions for the



Analysis of commercial off-the-shelf equipment in military systems. Image courtesy of Kollsman, Inc.

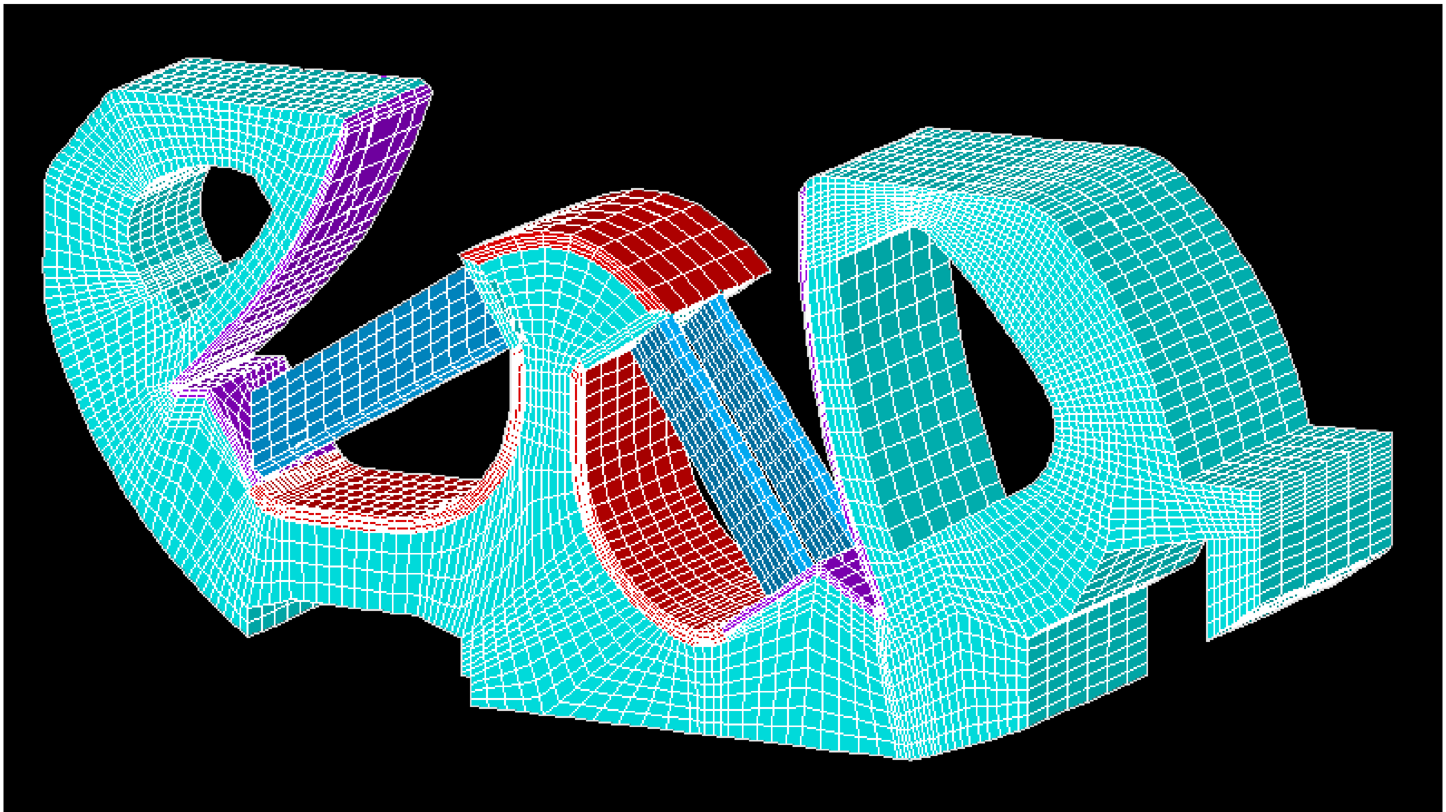
user to follow, and qualified ANSYS engineers will be available to discuss these problems along with new features. The Hands On Room opens Wednesday, May 22, at 9:00 a.m.

Conference Social

This year's conference dinner and social will take place at the Soldiers and Sailors Memorial Hall of Allegheny County. In addition to hearing Dr. Burt Rutan speak, this historic landmark setting offers a breathtaking experience to all visitors. War memorials are displayed throughout the building with ceilings fashioned after Greek architecture. The ballroom boasts a 32-foot high pyramid ceiling and winding staircases.

The Exhibition

In addition to being the best place to meet ANSYS users, learn about the ANSYS family of products, and discuss business



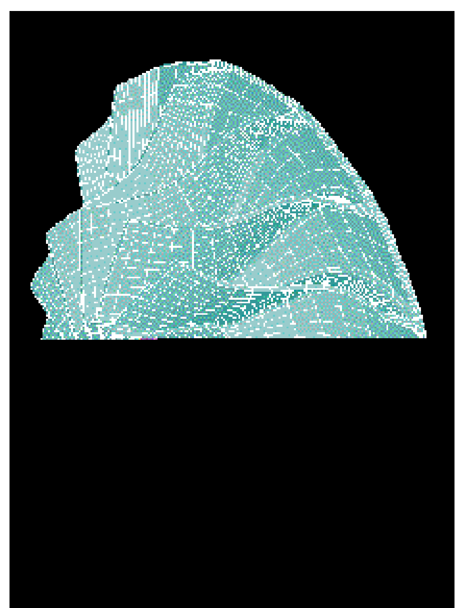
A model of the diverter cassette of a fusion reactor. Image courtesy of ITER Joint Central Team.

and technical issues, the exhibition includes some of the industry's leading-edge hardware and software companies. Some of the exhibitors for the 1996 Conference and Exhibition include:

- Autodesk, Inc.
- Automated Analysis Corporation
- Bentley
- Digital Equipment Corporation
- EDS Unigraphics
- Enhanced Solution Partners (ESP) Pavilion
- Fluid Dynamics International, Inc.
- HAL Computer Systems
- Hewlett-Packard Company
- IBM Corporation
- Intergraph Computer Systems
- Intergraph Corporation
- Mechanical Dynamics, Inc.
- NetPower
- Numerical Integration Technologies
- Silicon Graphics, Inc.
- SolidWorks Corporation
- Sun Microsystems, Inc.

ANSYS Visitors' Day

Spend an extra day in Pittsburgh and visit ANSYS, Inc. headquarters. ANSYS Visitors' Day begins on Thursday, May 23, at 9:00 a.m. with a continental breakfast and will continue through 2:00 p.m. See firsthand how ANSYS, Inc. functions on a daily basis. During the day, there will be many activities and programs, including an overview presentation from Peter Smith and each of the ANSYS product creation teams. This event is free, but pre-registration is required.



Solid model of a compressor wheel. Image courtesy of Advanced Technology Design and Analytical Services, Inc.

Keynote Addresses

Setting the theme of this year's International ANSYS Conference and Exhibition are the keynote speakers. ANSYS, Inc. has put together a group of six dynamic speakers to address many of the needs of today's business professional. Discussions will range from innovation and change in the workplace to the future of hardware and software.

Dr. Robert Kriegel

Author of the best seller, *If it ain't broke ... BREAK IT!*, will lead a discussion on "Engineering in a Changing World." *US News and World Report* considers Dr. Kriegel one of the country's leading authorities in the field of change. In addition to being a *New York Times* best selling author, he is a commentator on National Public Radio and ESPN, and has recently completed two specials for PBS. Dr. Kriegel will be speaking on Monday, May 20, at 8:00 a.m.

Dr. Burt Rutan

Founder of the Rutan Aircraft Company and Scaled Composites, Incorporated, and developer of such engineering projects as the world-circling Voyager aircraft, the America's Cup wingsail, and lightweight military aircraft and rockets, will discuss "Innovation: Use it or Lose it." A topic of many science journals and magazines, and the recipient of many awards for his innovative work, Dr. Rutan will speak at the conference social on Tuesday, May 21, at 7:30 p.m.

Mr. James Fusaro

Team Leader, Power Hybrid Modules Operation, at Motorola will be discussing "The Future of CAE in the Electronics Industry" on Monday, May 20, at 9:15 a.m. Mr. Fusaro will focus on reducing product development time using finite element analysis and Motorola's own experience in using this technology.

Mr. Joe Dinucci

A representative from Silicon Graphics, Incorporated, will lead a discussion focused on "The Future of Computer Design." Mr. Dinucci is responsible for defining and promoting the benefits of Silicon Graphics' visual technologies, and will be speaking on Wednesday, May 22, at 7:30 a.m.

Mr. Bill McClure

Vice President of Mechanical Software Solutions for Intergraph Corporation will present "The Impact of Windows and Object Linking and Embedding (OLE) on CAE." Mr. McClure will discuss Windows as a CAD platform, what is OLE, and how it applies to integrating the design analysis process. He will be speaking on Monday, May 20, at 10:00 a.m.

Mr. Paul Tomaszewski

An analytical development engineer from DuPuy Inc., will discuss a range of topics related to "Computer-Aided Technology in Orthopedics." His presentation will cover recent developments in the general field as well as DePuy's own experience using FEA. Mr. Tomaszewski is scheduled for Wednesday, May 22, at 8:15 a.m.

Don't miss this opportunity to save on conference fees. Fill out the registration cards found between pages 8 and 9, and pages 20 and 21.

by William J. Bryan, Conference Coordinator
ANSYS, Inc.

Daniel Parrish, Marketing Specialist
ANSYS, Inc.

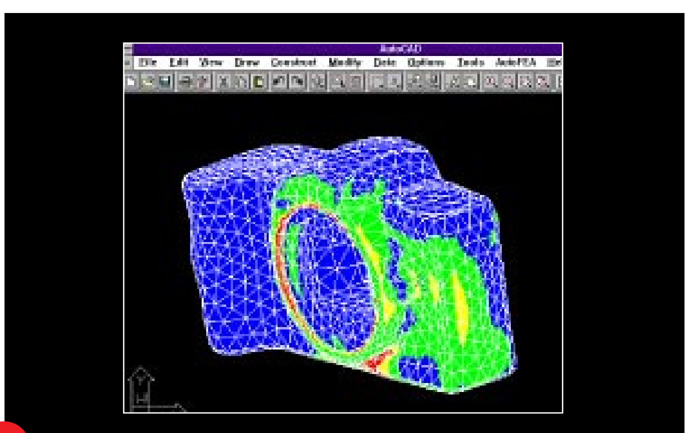
Introducing ANSYS/AutoFEA 3D:

Improving the Traditional Approach to Design Analysis

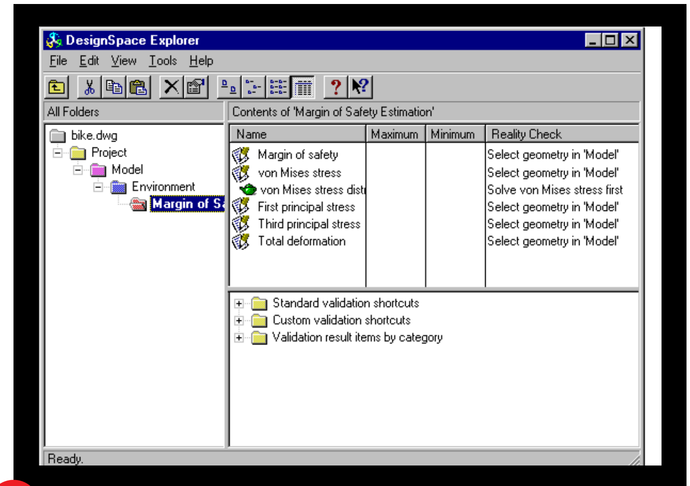
ANSYS, Inc.'s next-generation technology represents a paradigm shift, offering engineers and designers unprecedented tools for understanding their designs. ANSYS/AutoFEA 3D (Figure 1) functions inside of AutoCAD Release 13 and Mechanical Desktop, and is a natural and intuitive addition to the designer's methods and practices. ANSYS/AutoFEA 3D redefines the traditional approach to design analysis. The designer states up front what results are needed. Using familiar terminology, all work is done inside the AutoCAD package directly on the CAD model. There are no complex series of functions or data transfer processes required to move geometry.

Windows Technology

Inside AutoCAD, analysis projects are started by using a familiar Windows 95-like Explorer interface. Project information is organized in a hierarchy with many defaults and shortcuts. Users select up front a set of goals, material choices, and the physical environments that are important considerations to the final design. Results are displayed in familiar terminology. Both contour and section plots showing important results can also be included in the CAD drawing.



1 The Cannon EOS Rebel 35mm camera 3D image in ANSYS/AutoFEA.



2 A view of the ANSYS/AutoFEA 3D Explorer.

The Explorer

The ANSYS/AutoFEA 3D Explorer (Figure 2) allows users to develop complex projects, organize engineering information, and document the design process. The Explorer is accessed from a toolbar, menu pick, or command in AutoCAD. It is viewed exactly like the Windows 95 Explorer. The hierarchical structure makes it very easy to try many "what if designs"- changing materials, changing physical environments, or combining environments by simply dragging and dropping.

The first version of ANSYS/AutoFEA 3D, Validation, is integrated into Autodesk's Mechanical Desktop, and will be available 60 days after its release. This revolutionary product will provide important design information, such as response to known static structural loading, known steady-state thermal loading, simultaneous structural and thermal loads, and the resonant frequencies of the design.

As corporations worldwide face increasing pressures to bring their products to market faster, at lower cost, and at higher quality, ANSYS, Inc. introduces groundbreaking tools such as ANSYS/AutoFEA 3D, that ease the designer's workload and reveal a universe of possibilities in each design. ■

by Sue Batt, Vice President
Design Business Unit
ANSYS, Inc.

The Power of Choice. This concept embodies the philosophy of ANSYS, Inc. and our products. This carries over into hardware platforms, as well as CAD systems. Seamless, transparent access to CAD data is essential to decrease time to market by increasing productivity and accuracy of new product designs. The ANSYS program shares data with many leading CAD vendors, and ANSYS, Inc. is actively working with many more to develop improved means for our mutual users to work productively. A summary of existing and future products is listed in Table 1 (Page 10). The nature of the products generated from these relationships between ANSYS and CAD companies is dictated by the needs of our mutual users. These products can fit into any of the following categories: services, products, or OEMs.

CAD Integration Services

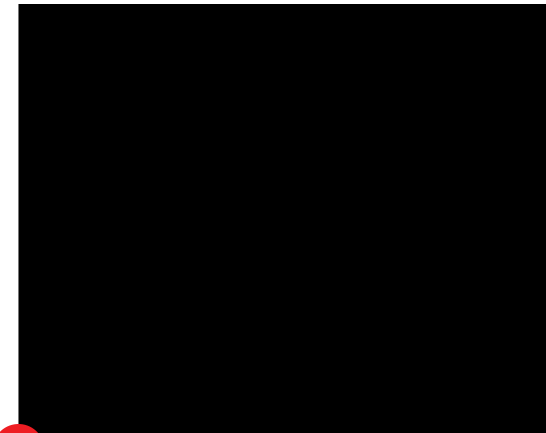
CAD integration services provide solutions for today's existing CAD products. New products and parts are analyzed without requiring the costly and time-consuming efforts involved in rebuilding the model in the analysis system. Users gain direct access to the high-level functionality in the ANSYS program, such as nonlinear behavior, electromagnetics, and computational fluid dynamics (CFD) solutions.

Service products can be categorized into two groups, connection products and integrated products. Connection products transfer geometry from the CAD system to ANSYS and these products exist for CADDS®5, Pro/ENGINEER®, and SolidWorks™. Development is underway with Unigraphics®. Integrated products put ANSYS functionality inside the CAD environment. Integrated products include CADDS (Figure 1), with development underway with EDS Unigraphics. Discussions are underway with Dissault's CATIA® and Applicon's BRAVO®.

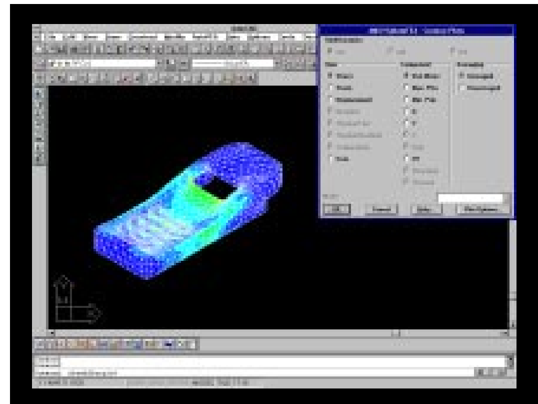
Design Products

To enable the designer to verify the behavior of parts and products early in the design process, ANSYS has developed two CAD-embedded simulation products. Integrated products are available for AutoCAD and Pro/ENGINEER. These tools enable a design engineer to verify critical properties of their product designs early in the process. To achieve this productivity, it is critical that the simulation tools look, act, feel, and are integrated inside the CAD package. This has been the central development philosophy of ANSYS. A screen shot of the AutoCAD interface is shown in Figure 2.

By providing design verification early in the process, integrated simulation tools enable the design engineer to uncover the behavior of their parts or products early enough to allow cost-effective changes. Since all integrated ANSYS simulation products use identical data structures and files, work done early in the process can be used later for more advanced analyses.



1 An analysis using the CADDS integrated product.



2 The AutoCAD interface showing an analysis of a cellular phone.

OEMs

ANSYS is currently working with a number of CAD companies to embed ANSYS analysis and simulation technology inside CAD systems. Since the primary users of these products are CAD users, the CAD supplier is in the best position to develop a graphical user interface and determine optimal distribution channels that can make the product readily available to all its users. ANSYS, Inc. and its sales channel are uniquely positioned to provide the high-end analysis expertise and products to complement the CAD company's software offerings. Some of these products exist today, while others are in the initial stages of development.

Intergraph distributes a design optimization product called I/ANSYS™, which provides a bi-directional interface between I/FEM™ (the EMS™ pre- and post-processor) and ANSYS. This product supports parametric optimization for ANSYS, as well as the component products. Applicon also offers an integrated analysis product based on ANSYS technology, called BravoANSYS™. Additionally, ANSYS and Applicon are working together to develop a new BravoANSYS product that works with the latest technology from both companies.

The ANSYS relationship with Intergraph extends beyond the connection between EMS and ANSYS. ANSYS and Intergraph are working together to define the extensions for OLE/COM needed for design and analysis products. This effort is centered around the Solid Edge™ product from Intergraph and the next generation technology from ANSYS. This partnership is expected to produce an integrated simulation tool for Solid Edge by the end of 1996.

The future of design simulation is in the designer's hands. To maximize productivity gains from simulation, the designer must have access to simulation tools early in the development process and the tools must be familiar and easy to learn. ANSYS is developing numerous OEM relationships with CAD vendors to produce intuitive, up-front solutions. These relationships will capitalize on the respective strengths of the CAD vendors and ANSYS to produce simulation products based on best-of-class ANSYS simulation technology using the intuitive, familiar look and feel of the CAD system.

Conclusion

ANSYS, Inc. has the technology and the vision to meet your analysis and simulation needs now and in the future. By partnering with leading CAD vendors, ANSYS provides the intuitive tools you need to maximize your productivity. No matter what your application or CAD system, ANSYS is your design simulation solution. ■

by Michael Morris, OEM Relations
Design Business Unit
ANSYS, Inc.

Table 1 — **ANSYS-CAD Interfaces**

CAD Program	Finite Element Interface	Direct Geometry Transfer	Integrated Analysis	Integrated Optimization
Applicon Bravo	Applicon's BravoANSYS	Applicon Product - Under Development	Applicon Product - Under Development	Applicon Product - Under Development
Autodesk AutoCAD	N/A	N/A	ANSYS/AutoFEA	Under Development
CV CADDS 5	CV's FEA Interface	ANSYS Connection for CADDS	ANSYS for CADDS	Under Development
Dassault CATIA	CATIA's FEA Interface	N/A	N/A	N/A
EDS Unigraphics	EDS' GFEM ANSYS FEA Interface	Q2 1996 - ANSYS Product	Q3 1996 - ANSYS Product	Under Development
Intergraph EMS	Intergraph's I/ANSYS	N/A	Intergraph's I/ANSYS	Intergraph's I/ANSYS
PTC Pro/ENGINEER	ANSYS Pro/E Interface	Q1 1996 - ANSYS Product	ANSYS/ProFEA	ANSYS/ProFEA®
SDRC IDEAS	SDRC's FEA Interface	N/A	N/A	N/A
Solid Edge	N/A	Under Development	Under Development	Under Development
SolidWorks	N/A	Q2 1996 - ANSYS Product	Q3 1996 - product	Q3 1996 - product

Scopus at ANSYS:

ANSYS Technical Support Group's New Call Tracking and Knowledge Base

The Technical Support Group at ANSYS recently implemented a call tracking system from Scopus Technology. This state-of-the-art software provides a centralized database for all customer support issues and product enhancement requests.

From the information collected, technical support can build a knowledge base of crucial ANSYS information accessed by the entire ANSYS support network and maintain much greater control of all the issues that come into and out of the Technical Support Group.

Phase I of Scopus includes automatic confirmation of receipt of inquiries via e-mail. ANSYS, Inc. will send automated reports to both front-line support organizations and customers in the near future. Connections to the customer database will allow technical support to maintain and track data on all ANSYS customers. End-user information will be recorded for every call that logs into the ANSYS Technical Support call center. Technical support will update each caller's name, phone number, and company name. For international customers, the user's fax number is needed as well. On subsequent inquiries from repeat callers, all the customer's data can be brought on-screen immediately, allowing the support engineer to know the status of any outstanding issues.

"Scopus will provide the tools needed to tightly connect all ANSYS Support Distributors into a powerful, worldwide support structure which no other competitor can offer. We will have a knowledge database of crucial information collected throughout the world which can be accessed by all ANSYS Support Distributors. This database can then be used to search for a problem resolution immediately, providing efficient and responsive service to our customers," says Paul Chilensky, Manager of the Customer Services Business Unit. *"With the worldwide structure, customers with multiple remote locations can now monitor all of their support requests from a central location,"* he adds.

Another feature of this new software will allow technical support to build a knowledge base of ANSYS technical questions and resolutions. All calls and related documents will be added to the knowledge database and will provide a resolution. These resolutions are valuable to the support engineer. Information in the knowledge base can then be summoned through various query and search capabilities included in Scopus. Automatic keyword generation of crucial documents makes it easy to reliably archive ANSYS technical information. As a result, technical resolutions are shared with the entire support channel. This cooperative effort will avoid the need to resolve identical questions independently and will aid everyone in answering repeat questions.

For more information please contact Jerry Bittner at 412.873.3073 or jbittner@ansys.com. ■

by Paul Chilensky, Manager
Customer Services Business Unit
ANSYS, Inc.

Jerry Bittner, Manager
Technical Support
ANSYS, Inc.

Pure Power:

An Inside Look at the Engine Driving ANSYS

An analysis solver is a lot like a jet engine. The power needed to lift a plane into the air is analogous to the power needed to solve large linear equation sets. As with a jet engine, the more powerful the solver, the faster the solution. To get your designs really soaring, you need the most powerful engine available.

The ANSYS program has empowered engineers with industry-leading, technologically advanced solutions for more than 25 years. The ANSYS program's frontal solver has been a workhorse, performing near the limits of computational theory, yet engineers have been able to solve complex, real-world problems with minimal memory requirements.

But the solver that pushed the envelope, just as rocket-powered engines pushed flight to the limits of the atmosphere, was the PowerSolver. Added to the ANSYS program at Release 5.1, this Preconditioned Conjugate Gradient (PCG) solver brought a whole new type of solution method to engineers.

The ANSYS frontal method solves the [K] {U} = {F} equations directly. Unlike a direct solver, the PowerSolver firsts converts the set of equations. $[K]\{U\} = \{F\}$ becomes $\{P\} = \{U\}^T [K]\{U\} — \{U\}^T \{F\}$ by pre-multiplying both sides by $\{U\}^T$ and collecting terms on one side. To arrive at a solution, the PowerSolver iteratively minimizes the residual {P} in the previous set of equations.

The PowerSolver represents a whole new realm of solution possibilities. The PowerSolver's solution times increase linearly with model size (Table 1). In contrast, the frontal solver's solution times increase quadratically with model size. This means the PowerSolver's speed advantage increases with model size.

Table 2 compares the frontal solver to the PowerSolver in terms of hard disk, memory, and CPU times. The PowerSolver solves problems that, from both an operating system and a practical standpoint, are not feasible with the frontal solver. This has enabled engineers to reach new plateaus in analysis.

For example, Engineering Cybernetics, Inc., an ANSYS Support Distributor performed an analysis of a valve body as part of their consulting services. An SGI R8000 Power Indigo with 320 Mb of memory was used for this job. The finite element model had 237,101 elements, 363,345 nodes, and 1,090,035 degrees of freedom. For this type of very large analysis, approximately one Gb of memory is required to avoid paging.

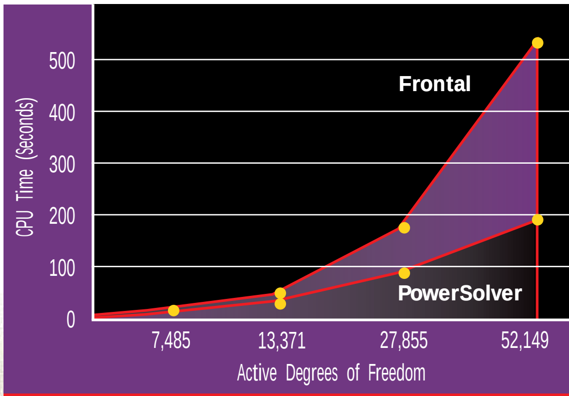


Table 1

CPU Solution Times

With only 320 Mb available, this problem is extremely memory limited. The PowerSolver came through with flying colors. CPU time was 6.17 hours, while the wall-clock time was 33.91 hours. The result, **over one million degrees of freedom solved on the desktop!**

The ability to utilize system swap memory if real memory is insufficient is another feature of the PowerSolver. Wall-clock time typically increases by a factor of between four and six when system swap memory is used. In Engineering Cybernetics' case it was a factor of 5.5, with only one third of the desired memory available.

Because the PowerSolver minimizes a function instead of solving the equations directly, the PowerSolver needs to know when to quit. This is specified in the TOLER field. For nonlinear or transient problems, solution errors tend to be cumulative and can even cause divergence of the solution. For these types of problems, the ANSYS default of 1.0e-8 for the solution tolerance provides highly accurate solutions. Static linear problems need only one solution pass, and therefore, this tolerance can be loosened. A general recommendation is 1.0e-4. Table 3 shows the comparative CPU times for the same analysis performed with two different solution tolerances. The change in solution accuracy for both displacements and stresses is negligible, while decreasing the solution time by 14 percent (Table 3). Time-savings are typically greater for p-element analyses.

Having a two-processor machine typically speeds up solution by approximately 30 percent even with single thread applications. This is because the operating system's functions can be carried out by one processor while the application's functions can be carried out by the other. The application itself may be multi-threaded (parallel), for additional speed improvements.

ANSYS 5.2 introduced additional parallel performance. Three separate major steps occur during the solution process: the element formulation, the matrix solution, and the recovery of element solutions. Multi-threading adds performance above the use of a multi-processor machine. Table 4 (Page 14) compares a run using one and two processors, all on a multi-processor machine. The single processor runs are approximately 30 percent faster than the same runs on single processor machines of the same clock speed and chip set. Table 4 shows the additional improvement due to the ANSYS program's multi-threading feature. This means that the overall improvement between a single processor machine and this dual processor machine running ANSYS multi-threaded is 46 percent.

Comparisons in Table 4 are wall-clock time, not CPU time. Most companies no longer track project costs based on CPU time. Wall-clock time determines overall productivity. On multi-threaded applications, the CPU time can easily exceed the wall-clock time, and due to overhead, the total CPU time for a multiprocessor run may be more than that for a single processor run.

ANSYS Inc. released four parallel versions of the ANSYS 5.2 program, all of which included three multi-threaded solution steps. Additionally, the Intel P6 technology, with multi-threaded capabilities, is planned to be supported. The 5.2 fully parallel solution versions are:

- CRAY
- Digital AlphaStation (AXP275 and AXPEV5)
- HP Exemplar
- SGI R8000

Additionally, other versions of the ANSYS program, including SUN with Solaris and IBM RS6000, have partial parallel solution support.

In continuing its commitment to technological excellence, ANSYS, Inc. introduces new solver technology. At ANSYS 5.3, another new level of performance will be brought to ANSYS users. Just as the PowerSolver issued in a new realm of analysis possibilities, ANSYS 5.3 capabilities will push the envelope on analysis solutions.

These new capabilities increase speed and reduce disk space. Within the three major steps of the analysis solution process, ANSYS 5.3 improves the speed of element formulation and stress recovery, while working in conjunction with the PowerSolver for the matrix solution. Working with the PowerSolver, the new capability is only applicable to linear analysis and only available for tetrahedral SOLID92 elements. In subsequent releases, more elements will be adapted. ANSYS 5.3

Table 2 Frontal Vs. PowerSolver Comparison

Model (dof) Element Type	Hard Disk (Gb)			Memory (Mb)			CPU Time (Seconds)		
	Frontal	Power	Ratio	Frontal	Power	Ratio	Frontal	Power	Ratio
Carrier (105k) SOLID72	2.3	0.6	0.26	85	142	1.7	6,530	1,670	3.9/1
Cube (27k) SOLID45	0.4	0.1	0.25	24	32	1.3	960	109	8.8/1
Shell 1 (87k) SHELL63	0.75	0.2	0.27	32	85	2.7	1,250	310	4.0/1
Ray 1 (103k) SOLID92	1.9	0.34	0.18	65	134	2.1	1,341 Est.	370	3.6/1 Est.

Table 3 PCG Solution Tolerance Comparisons

Model (dof) Element Type Solution Quantity	Value of Solution Tolerance Ray 1 (103k) SOLID92		
	TOLER = 1.0e-8	TOLER = 1.0e-4	Ratio
CPU Time (Seconds)	370	324	1.14/1
Y Displacement (In)	-0.0009079324359	-0.0009079324213	0.999999984
X Stress (Psi)	4381.63147	4381.62891	0.999999416
Eqv Stress (Psi)	3344.45203	3344.45314	1.00000033

will greatly reduce the necessary disk space required to run an analysis. This brings the required disk space to almost negligible amounts.

Table 5 shows that ANSYS 5.3 is 50 percent faster than the PowerSolver alone, and saves an incredible 86 percent of disk space. This heralds a new era in analysis possibilities and will be available in parallel. ANSYS 5.3 wall-clock times for both one and two processors are shown in Table 6.

Tremendous improvements have been made in the solution technology available to ANSYS customers. These “powerful engines” combined with steady improvements in hardware capabilities bring unprecedented levels of solution power to engineers and analysts. Note the dramatic decreases in solution times (Table 7). For this example, from the original frontal solver to the latest 5.3 capability, solution times have dropped by 85 percent and are now 6.7 times faster. The dramatic decreases in disk space requirements are shown in Table 8. For this example, disk requirements have dropped by 98 percent and are now 41 times smaller.

ANSYS, Inc. is committed to providing its customers with technological excellence. The ANSYS 5.3 program dawns the era of the newest and most powerful engine ever offered by ANSYS, Inc, see it “take off” at the Seventh International ANSYS Conference and Exhibition. ■

by Ray Browell, Technical Liaison
ANSYS Business Unit
ANSYS, Inc.

Table 4 PowerSolver Parallel Processing Comparisons

Model (dof) Element Type	Wall-Clock Time (Seconds) Number of Processors		
	1 Processor	2 Processor	Ratio
Ray1 (103k) SOLID92	399	355	1.12/1

Table 5 PowerSolver Only vs. ANSYS 5.3 Comparison

Model (dof) Element Type	CPU Time (Seconds)			Hard Disk (Mb)		
	PowerSolver Only (Tol=1e-4)	ANSYS 5.3 (Tol=1e-4)	Ratio	PowerSolver Only	ANSYS 5.3	Ratio
Ray1 (103k) SOLID92	324	219	1.5/1	340	47	7.2/1

Table 6 ANSYS 5.3 Parallel Processing Comparisons

Model (dof) Element Type	Wall Clock Time (Seconds) Number of Processors		
	1 Processor	2 Processor	Ratio
Ray1 (103k) SOLID92	225	187	1.2/1

Table 7 Wall-Clock Times with Respect to Solution Technology

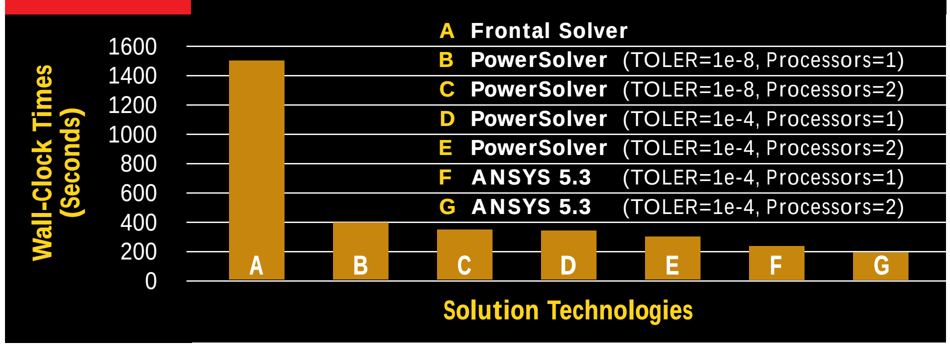
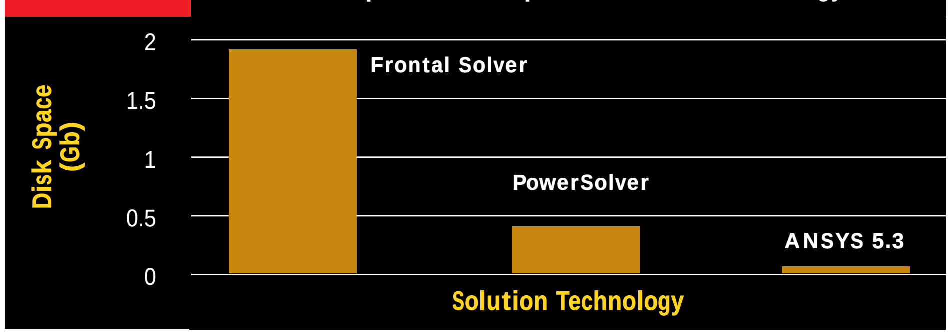


Table 8 Disk Space with Respect to Solution Technology



ANSYS in the Biomedical Industry:

Optimizing an Artificial Knee with FEA

DePuy Inc., an orthopedic manufacturer located in Warsaw, Indiana, uses ANSYS software to find ways to decrease stress between the upper and lower articulating surfaces of an artificial knee joint (Figures 1A and 1B). One of DePuy's critical design goals in trying to develop a new artificial knee joint is optimizing the contact area between the upper and lower portions of the joint. They hoped to better distribute the stresses in the joint by increasing contact area, ultimately producing a product that lasts longer when implanted into patients. DePuy engineers used ANSYS finite-element analysis (FEA) to precisely determine the interaction between the top and bottom segments of the joint, rather than investigate contact primarily with pressure-sensitive film, as they have in the past. The engineers convey analysis results to the designer who uses the information to revise the solid model of the joint components.

Figure 1A

Three components of a typical artificial knee system.

Figure 1B

Polymer (bearing) component of a typical system.

"We considered combinations of two different bearing polymers, five different geometric configurations for the bearing surface, and multiple simulated flexion angles for the new implant," says Paul Tomaszewski, an analytical development engineer at DePuy who performed the analyses. If the components are oriented such that there are stem-like protrusions at the top and bottom, zero degrees flection (or full extension) would be when the stems are parallel. Ninety degrees flection would have the stems perpendicular to each other, such as your upper and lower legs when you are properly sitting in a chair. *"Not only did FEA give us a better picture of stresses in the joint than the pressure-sensitive film, it didn't require building a prototype, which the film process requires."* ANSYS FEA helped DePuy create a new knee implant with twice as much contact area as its predecessor by making it feasible to evaluate stresses on the joint while the design was in progress.

Defining the Knee Joint

DePuy, which celebrated its 100th anniversary last year, makes orthopedic implants and the surgical instruments used to install them. Like any orthopedic manufacturer, DePuy will agree that the knee is the most difficult primary joint to duplicate, probably because the natural model is so tricky.

The joint, real or artificial, includes an upper portion that attaches to the femur (upper leg), and a lower portion that attaches to the tibia (lower leg). The region of contact between the top and bottom parts of the joint is anything but regular. *"Because of the complex surfaces involved, this joint is very* *incongruent,"* says Tomaszewski. *"While the natural joint has a compliant, intra-joint third component, called the meniscus, to help distribute load, in most two-component replacement designs the two surfaces are not closely matched and contact is sparse. In this way, the knee is very different from the shoulder and hip, which basically resemble ball-and-socket joints."*

The compound curve, which describes the upper surface of the lower component, is a series of four tangent segments (Figure 2). The upper component, represented by another set of continuous curves, can be rotated clockwise to simulate various knee flexion angles. Ninety degrees of flection is when your upper and lower legs are at right angles. The length and/or radius-of-curvature of any or all of these segments may be altered to achieve the desired "play" between the two components. In two dimensions, this "play" involves primarily side-to-side motion.

Motion in and out of the plane of the quad mesh and rotation about a vertical axis become important as the polymer bearing is expanded into its true three-dimensional form. Curves/flats that are in planes perpendicular to the plane of the quad mesh (Figure 2), control these parameters. The "play" in the system is generally referred to as its constraint. The drawback in solving the contact issue by simply increasing the congruity of the mating surfaces is that it can lead to an over-constrained design, which poorly mimics the behavior of the natural joint.

Designing an Artificial Knee

In an artificial knee, typically the upper portion of the joint is made of a metal such as a cobalt-chrome-molybdenum alloy, while the lower portion consists of a polymer material such as UHMWPe (ultra high molecular weight polyethylene), often attached to a metal base. In designing an artificial knee, the engineer must understand the degree of contact between the polymer and metallic components. It is important to evaluate the stresses that develop on, and in, the polymer component, because the higher the stresses, the sooner the joint is likely to wear out. In incongruent contact such as this, where the opposed bearing surfaces lack a high degree of coincidence on conformity, theoretical peak shear and equivalent stress values often occur subsurface, making the evaluation of these stress quantities important. (This phenomenon has been validated by inspection of retrieved components, which show degradation at this location.)

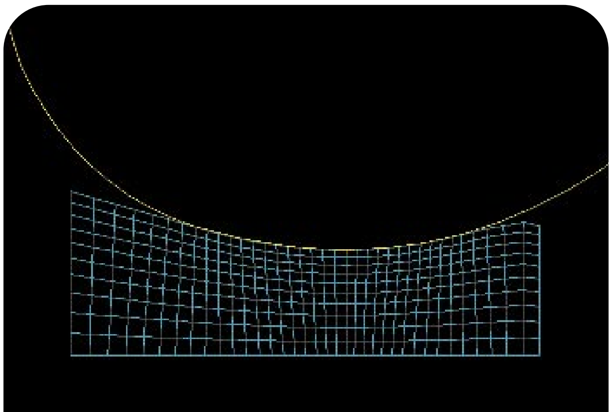


Figure 2

Two dimensional representation of the contacting artificial joint components; the upper "component" is represented as a rigid surface.

The best way to obtain contact area and stress determinations before the availability of efficient finite-element contact algorithms was to build a prototype, and then make an assessment of contact using pressure-sensitive film. This film shows the shape of the contact area and the intensity of pressure as loads are applied to the prototype joint by displaying varying intensities of red. One disadvantage of this approach is that it requires building a prototype, which has associated time requirements and costs. Another disadvantage is that the peak stresses which occur below the surface of the knee (internally) are inaccessible using the pressure-film technique.

DePuy uses ANSYS FEA as a design tool to evaluate implant design parameters and reduce prototype testing. The company chose the ANSYS program for several reasons. First, its design problems typically involve both material and geometric nonlinearities, so they need an FEA package that can handle nonlinear analysis. According to Tomaszewski, another reason was, *"We wanted a multi-purpose finite-element code that was widely used and respected."*

More Contact, Better Joint

The goal in designing this knee implant was to create a new surface on the polymer side that would increase contact between the upper (metallic) and lower (polymer) portions of the joint. In addition to changing the shape of the polymer surface, the design engineer was able to experiment with different materials, thanks to DePuy's affiliate organization, DePuy-DuPont Orthopedics. This company develops polymers for use in artificial joints, with the goal of finding new materials that will increase the longevity of these devices.

DePuy-DuPont generates customized blends of mechanical properties for the UHMWPe through proprietary processing techniques. These include such items as stiffness, elongation, and crack resistance. While a stiffer polymer may have an advantage of better dimensional stability and reduced cold flow, a more compliant one generally provides increased contact and lower stresses. This treatment of the considerations involved, though cursory, indicates the importance of material characterization as an additional design parameter.

The designer on the project worked closely with a project engineer who, in turn, worked with orthopedic surgeons to determine the requirements for the implant. The designer modeled each design iteration in Intergraph's I/EMS solid modeling system, since this was the most efficient way to incorporate parametric changes in the complex blending of the surface patches. Variability and incompleteness still necessitate that analysts employ flexibility in the methods utilized for mesh generation, despite the cohesiveness of the IGES standard. Tomaszewski opted to mesh the joint's articulating surfaces in Intergraph's finite-element modeler, I/FEM, then transfer the analysis model to ANSYS using the I/ANSYS translator. This Intergraph translator, accessible within the I/FEM environment, creates PREP7 identities for the mesh, as well as for materials and boundary conditions.

This approach improved the efficiency of the modeling process, in addition to replicating the joint surfaces accurately. Tomaszewski explains, *"The I/FEM mesh gave a high percentage of uniform quadrilateral elements, which could be extruded into linear bricks."* He adjusted the lowest layer of nodes to be planar, as in the actual component, at an extrusion distance beyond which stress information was not critical. The I/FEM model he created contained about 3,000 solid elements.

ANSYS Reduces Production Time

In ANSYS, Tomaszewski described material properties, accounting for the nonlinear behavior of the polymer by entering a stress-strain curve derived from test data. He also defined contact parameters, with the goal of increasing the efficiency of the solution. He reduced the number of contact pairs, wherever possible, using the RADC variable of the GCGEN command to indicate that points separated by a distance of 0.10 of an inch would not contact each other. Contact stiffness was set using the polymer modulus and standard guidelines. After that, Tomaszewski defined half-symmetry boundary conditions on the vertical planar surface and added other constraints to prevent rigid body motion. He derived load information from published data of peak joint forces experienced during a variety of normal activities. Setting up the problem in ANSYS took about an hour, and the solution time for the problem was about 10 hours on a Silicon Graphics Indigo R4000 workstation.

The existence of subsurface peak nonlinear equivalent stress is reflected in the section plot of Figure 3 (Page 18). This plane is parallel to the symmetry plane, though offset from it by the transverse distance to the center of contact. The arbitrarily-oriented view in Figure 4 (Page 18) shows the contact area, as defined by a minimum principal stress threshold of 2 MPa. These images were easier to evaluate than the shades of red on the pressure-sensitive film. Also, they were available sooner since no prototype was needed, which allowed the project engineer to use the information to make decisions about the design.

DePuy Inc. chose the ANSYS program for several reasons: Its design problems typically involve both material and geometric nonlinearities, and they wanted a multi-purpose finite-element code that was widely used and respected.

"We would study the analysis results and play with SLA (stereolithography) models, then go back and tweak the design," says Tomaszewski. *"After numerous iterations that included preliminary 2D work, we increased the contact area to more than twice that of the previous implant. Yet we maintained the response and feel that we and the surgeons wanted,"* he adds. *"For early iterations, no prototypes were built, and our estimate is that the overall cycle for this product was reduced by about 20 percent by using FEA."* Eventually, some prototypes were film-tested and the contact information correlated very well with ANSYS FEA results.

The new knee implant, called the AMK Congruency PS (Posterior-Stabilized), is now undergoing FDA review. *"We'll continue to test prototypes as long as the FDA requires it,"* says Tomaszewski. *"And they provide an important evaluation tool during development. But by using ANSYS, we have cut the number of prototypes significantly."* ■

by Paul Tomaszewski,
Analytical Development Engineer
DePuy Inc.
Warsaw, Indiana

Jennifer Valachovic, Marketing Specialist
ANSYS, Inc.

The Voyage of Starship ANSYS:

New Interactive CD-ROM Explores the Universe of ANSYS Software and Services

Multimedia computer technology launches design analysis software into a galaxy of fun, interactive information exchange with the production of ANSYS, Inc.'s first promotional CD-ROM, "Experience the Power of ANSYS."

Developed under the premise that learning is most effective when it's fun, this multimedia CD elevates the traditional, linear means of providing information in written form to a nonlinear, highly interactive, enjoyable experience. The CD employs live-action video, animations of analysis results, music, and sound effects to convey a variety of information about ANSYS, Inc.

From a corporate vision of the engineering system of the future, to the new customization service, to a demonstration of ANSYS 5.2, this CD provides the answers to nearly any question about ANSYS.

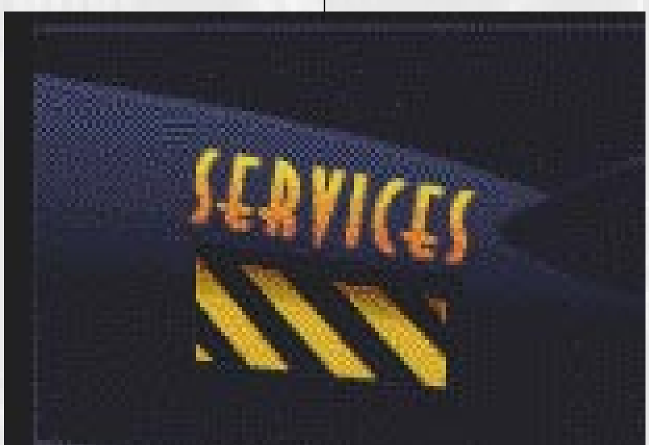


Figure 1 The view from the bridge of Starship ANSYS.

Because this interactive multimedia experience breaks new ground for ANSYS, Inc., a space theme is utilized as the means for achieving entertaining interfaces for learning about ANSYS software and services. Like space travel, interactive multimedia is the next frontier of simulation software. ANSYS is more than a program or a corporation. It's a technological journey into the future of engineering software, and this space-based interactive experience represents the launch of a mission into unexplored areas of usability, capability, and productivity.

A viewer of the CD goes through an initial countdown sequence and the launch of the U.S. National Aeronautics and Space Administration's (NASA) space shuttle before arriving on the bridge (Figure 1) of "Starship ANSYS," the primary interface for the entire CD. From the bridge, the viewer can soar into the various subject areas of the program, which include:

- **Corporate Vision** — A presentation by President and CEO, Peter J. Smith on the corporation's vision for flexible engineering systems and how it is impacting the company's direction and benefiting customers.
- **Innovative Technology** — An illustration of how ANSYS technology brings speed, power, and flexibility to the engineer's toolkit.
- **Flexible Products** — Descriptions, representative animations, and customer examples for the entire ANSYS family of products, including a demonstration of ANSYS 5.2.
- **Services** — An explanation of how ANSYS services add value to the software, including Program Customization Services.
- **Quality** — A look at the importance of quality and ISO 9001 certification in the development of engineering software.
- **Business Opportunities** — A listing of potential business opportunities with ANSYS, including technology exchange and third-party software development.

In addition to the bridge interface, a search engine (Figure 2) provides a map of the entire program. Depicted as a constellation map in space, the search engine allows the viewer to immediately access any part of the program through "hot" topic headings. The search engine represents the program's "warp" drive and supplies its nonlinear characteristic.

The minimum platform for the "Experience the Power of ANSYS" CD is a 486/66 Mhz PC with a 256-color, 640 x 480 display, and a sound card, running Windows 95 or Windows 3.x. For a copy of the "Experience the Power of ANSYS" CD, contact ANSYS, Inc. at 412.746.3304 or ansysinfo@ansys.com. Strap yourself in and blast off to a new ANSYS destination: the ultimate, interactive, multimedia experience. ■

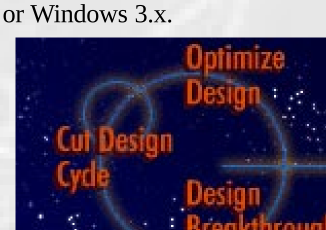


Figure 2 The Search Engine

by Tim Trainer, Manager
Marketing Programs
ANSYS, Inc.

White Paper Focus:

Assessing Numerical Sensitivity of Engineering Software Solutions

Occasionally, ANSYS users obtain different results when they are running identical or nearly identical finite element solutions. Often, the solutions compared differ in one or more of the following three ways: the results compared are obtained using different releases of the ANSYS program; are obtained on two different hardware platforms; or are due to making minor changes to the program input and resolving. Varying degrees of numerical differences are expected, depending on the nature of the analysis being performed. This article addresses some of the reasons behind these observed differences, and suggests ways to reduce these effects on the final results.

Quality Solutions

As we evolve the technology and improve ANSYS, engineers in product development continually evaluate numerical results due to differences in hardware platforms, enhancements to geometry creation and meshing, improvements to solution algorithms, and changes to test case inputs. Judgment in comparing results in these situations involves a good deal of experience with the algorithms, computer systems, and underlying theoretical assumptions. We know from experience that the number of significant digits that can be obtained in certain types of analyses will vary some-

what from computer to computer.

Every finite element solution performed is based on numerical algorithms designed to solve sets of equations. Some of these equations are nonlinear, requiring iterative solutions that terminate when a convergence criterion is met. Because computers deal with finite precision and because different computers can produce results of varying accuracy, small numerical differences that can occur in an algorithm can be magnified by certain conditions common in many engineering analyses. These phenomena include nonlinear solution convergence criteria, path dependent solutions (e.g.- those associated with friction), numerical noise associated with "chatter" in undamped or weakly damped dynamics analyses, extremely large numbers of incremental solutions that build upon the previously converged solution, auto-time stepping (where the path to solution depends upon predictive traits of the algorithm), solution points that fall on a "singularity" in the solution, and sensitivity of some algorithms to computations involving differences between large numbers. These conditions play directly into the hands of machine dependencies to produce results of varying precision.

Modeling Variations

Before we discuss the behavior of numerical algorithms used in finite element solutions, it is important to realize that operations and algorithms used in geometry creation and model discretization can have an effect on the solution results. Boolean operations as well as meshing algorithms (especially for tetrahedral meshing) may result in a different finite element mesh being created on different systems. These differences range from slight variations in placement of nodes to significant variations in the mesh pattern, depending on the complexity of the model and the sequence of operations used to prepare the finite element model. The virtue of such variations alone causes differences in solution results across machines. Adaptive meshing based on error norms is a tool that handles machine dependencies of this type, if the analysis is linear static. Unfortunately, this is not the most typical analysis type where numerical sensitivity is an important consideration.

The Role of Machine Precision

The hardware platforms that the ANSYS program runs on have differences in the fundamental precision at which the computations are performed. Various supported hardware and operating system environments can provide as many as 80 bits of precision to 64 bits of precision. Eighty bits of precision are available in double-precision computations on Intel 386, 486, and Pentium processors. Sixty-four bits of precision is common on large supercomputers, such as the Cray in single precision mode, other differences within this range can be seen, depending upon the number of bits associated with the mantissa versus the exponent in the floating point numbers represented. Any numerical representation with this many bits is more than sufficient for engineering accuracy in a simple, linear static analysis without other numerical complications. However, when hundreds of thousands or millions of operations are repetitively performed on such numbers, the differences in final results affect significant digits that interest the engineer.

Computational Accuracy

The disappearance of significant figures by subtraction of nearly equal quantities, and the computational singularities caused by functions that become infinite or acquire an infinite derivative are two of the most persistent difficulties in numerical computations (Reference 1). Some numerical algorithms are sensitive to perturbations in initial data which lead to a loss in accuracy due to inherent sensitivity of the equations. These perturbations could originate in the representation of geometry, and/or result from Boolean and meshing operations.

Errors due to "round off" and the inability of carrying, in a given calculation, more than a certain number of significant digits are of particular significance. Also, rounding procedures vary a little from one computer to another resulting in varying accuracy on different machines (References 2 and 3).

The Effect of Cumulative Precision Drift

Since numerical results begin to differ in the least significant digits in the solution results, the amount of times numbers are re-used for later computations is directly proportional to the likelihood of seeing a difference in results from computer to computer. This can occur in large iterative solver linear solutions, any type of non-linear solution, and dynamic analyses with many time points. All these contribute to the number of successive computations being made with these numbers. If there are path dependencies to the solution, or if there are automatic time stepping options being chosen, the end results can begin to drift apart. In some cases, the numerical algorithms employed in the solutions can branch down different paths in the program logic, depending on inequalities between double precision numbers or on small tolerances that are presumed to be numerically zero.

Sensitivity Studies

Because of the reasons outlined, it makes sense for an engineer performing a new type of analysis (where the numerical sensitivity is unknown) to perform numerical experiments to determine the solution sensitivity to small changes in the input. For instance, if small changes in geometric locations (tolerances), material properties, convergence criteria, or damping, make large differences in the solution output, then it is likely that the answers obtained from the program are suspect. On the other hand, if small numerical changes in such input quantities have little effect on the end result, then the sensitivity of the solution to numerical inaccuracies can be eliminated as a concern.

Concluding Remarks

Engineers look for results they can rely upon within the level of certainty of their input. Because of unknowns associated with geometric tolerances, material properties, true load levels, and time histories, engineers are often satisfied when they are within five to ten percent of the "actual" answer. Performing the kind of numerical experiments described above can provide the level of assurance an engineer needs to be confident that the results obtained from the program fall within a reasonable range.

The next time you see changes between solutions run on the ANSYS program between different releases of the program, between different hardware platforms, or due only to a small change in the input to the program, consider the phenomena described in this paper and determine the likely sensitivity of the results to those effects. A relatively simple numerical study can quantify the magnitude of those effects and give the engineer the kind of confidence needed to make appropriate engineering decisions based on the result of the analysis. ■

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by Prashant Ambe, Release Manager
ANSYS 5.3
ANSYS, Inc.

Mark Imgrund, Vice President
Corporate Quality
ANSYS, Inc.

Expanding ANSYS Channels

ANSYS, Inc. delivers unparalleled engineering solutions through a worldwide network of ANSYS Support Distributors (ASD). As the ANSYS customer base continues to grow, so do the channels of support. ANSYS, Inc. welcomed several new ASDs at the end of 1995.

Neil Automation Technology Ltd.

Neil Automation Technology Ltd., with corporate headquarters in Pune (the industrial center of India), and six additional offices in Delhi, Madras, Hyderbad, Bangalore, Calcutta, and Coimbatore, was founded in 1992 by a group of professionals led by Mr. Ketan Bakshi. Mr. Bakshi has many years of professional experience in the computer-aided design, manufacturing, and engineering (CAD/CAM/CAE) industries.

Neil Automation currently has a customer base of more than 300 mechanical companies. The firm established a strong reputation for being a highly technical and customer-oriented company. In addition to distributing ANSYS products in India, Neil Automation supplies Autodesk mechanical products. In less than two years, the company has installed 650 modeling seats of AutoCAD Designer.

Mr. Shirish Sathe leads the experienced technical team consisting of five engineers specializing in analysis applications. This team is involved in projects spanning multiple industries, including automotive, electrical, material handling equipment, and pressure vessels.

CAD-IT Consultants Pte. Ltd.

CAD-IT Consultants Pte. Ltd., a company formed in 1991 by Terence and Florence Chan, with headquarters in Singapore, has grown to be one of the leading CAD/CAM/CAE system integrators in the Asia Pacific region. With the mission to be the preferred CAD/CAM/CAE solution supplier and partner in Asia, CAD-IT has built a customer base of 1,000 customers by enabling them to design and manufacture better products in a more effective and efficient way through high-quality, state-of-the-art products coupled with excellent service, training, and support.

The company has offices in Singapore, Penang, and Kuala Lumpur and plans to add more over the next two years in Indonesia, Vietnam, China, and the Philippines.

William Liu, Support Manager; Dr. Moses Chan, Application Consultant; and Md Shahrum, CAD/CAM/CAE Engineer, interact with ANSYS customers on all ANSYS applications, and share the philosophy that close customer service is of the utmost importance.

"We believe our customers are purchasing an on-going relationship of which software is just a component. Their excellent relationship with CAD-IT is the factor that will continue to enable them to improve their operations and engineering processes," said Managing Director Terence Chan. CAD-IT has received several awards in recognition of their marketing, sales, support, and services excellence. They recently won the 1995 Singapore Marketing Award. This award is based on contestants' track records, marketing strategies, market share, and level of customer satisfaction.

H.G.Engineering Adds On

Canada's population spans a large geographical area. H.G.Engineering, the ANSYS Support Distributor in Canada, recently assumed the role of Country Manager and appointed two existing engineering and consulting companies in Montreal and Calgary as H.G. Engineering Support Associates, to ensure better coverage of the territory. ANSYS specialists now exist in regions where they previously were not available. This partnership means better support for ANSYS customers.

H.G.Engineering selected Farnell-Thompson Applied Technologies in Montreal to take responsibility for the Quebec region. The ANSYS contact is Mr. Philippe Vidori, a specialist in finite element analysis (FEA), with a Masters degree in Mechanical Engineering from Ecole Polytechnique.

Farnell-Thompson offers many services, including mechanical design and analysis of industrial machinery, in particular, rotating equipment. The company has a worldwide reputation for their work with grinding mills used in the mineral processing industry. The company is based in downtown Montreal.

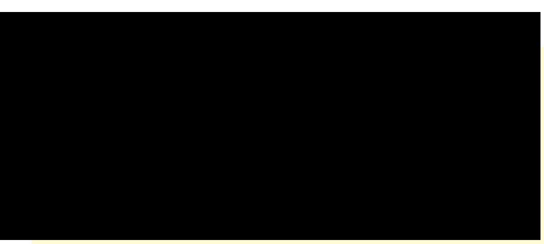
H.G.Engineering most recently

appointed Compusim Inc. in Calgary as a H.G.Engineering Support Associate. This company was founded by Mr. Imad Tabsh four years ago and specializes in design analysis using ANSYS. Compu-sim provides sales and front-line technical support to users in Alberta, Saskatchewan, and Manitoba. Mr. Tabsh is currently developing and marketing specialized software that is complementary to the ANSYS program, for use in the design of aluminum reduction cells and, as such, is a big user of the ANSYS macro language. Compusim's offices are located in Calgary.

This synergistic relationship enables the sharing of resources across the vast Canadian territory, and links the ANSYS market through a unified effort. The responsibility for account management in all business matters and territory sales management will remain in the Toronto offices of H.G.Engineering.

For complete address information, reference the ASD Locations on page 27 of this issue.

Short Course on FEA Methods and Practices



1995 Course Attendees

Design engineers and analysts apply different design analysis tools at different stages of the design process. To address this need, our design and analysis programs have become very user-friendly, containing graphical user interfaces, powerful modeling tools, and robust formulation. Users still need to understand the concepts and fundamentals underlying these programs.

The University of Maryland hosts a short course developed to cover these concepts and fundamentals. The course is "Introduction to Finite Element Analysis Methods and Practices" and is organized by Mallett Technology, Inc., the ANSYS Support Distributor in the Mid-Atlantic region.

The course is tailored for engineers, scientists, and managers who are new to finite element technology. It is taught by experienced professionals who have outstanding backgrounds in both industry and higher education.

This eighth annual offering of the "Introduction to Finite Element Analysis Methods and Practices" will be May 6-8, 1996. This three-day course takes place at the University College Conference Center at the University of Maryland, College Park Campus. To obtain information regarding the content and arrangements for this course, contact David Dietrich II, at 301.725.0060 extension 18, or e-mail dedii@wdc.mallett.com.

International ANSYS

The magnetics seminar preceding the 1995 user meetings in China.

Worldwide ANSYS Support Distributors held more users' meetings in 1995 than any other year in ANSYS history. Dynamic conferences occurred internationally at sites such as Brazil, Japan, Korea, Taiwan, China, India, Germany, Italy, Norway, Russia, Netherlands, France, England, and the United States. ANSYS, Inc. staff including Peter Smith, President and CEO, and Ray Browell, Brian Butcher, Dave Conover, Dave Looman, Frank Marx, Scott Owens, John Swanson, and Jim Tung, all contributed their expertise to make these meetings a success.

Joint cooperation of high-quality engineering and management staff allowed these engaging meetings to proceed smoothly. ANSYS, Inc. staff and ASDs, working in concert, presented information on ANSYS 5.2, as well as specific tutorials on advanced capabilities as design optimization, the p-method, PowerSolver, solid modeling, and ANSYS/Emag™. Users also received an overview of ANSYS 5.3 and future releases.

Marketing and sales strategy planning sessions helped convey the ANSYS approach to the transitioning computer-aided engineering (CAE) industry.

Look for ANSYS worldwide in 1996. Best-of-class ASDs and ANSYS, Inc. staff will again host extensive global users' meetings to inform customers of new, leading-edge ANSYS technologies.

by Jennifer Valachovic and Daniel Parrish
Marketing Specialists
ANSYS, Inc.

Eliminating the Weak Link:

Motorola Uses ANSYS to Optimize the Manufacturing of Hybrid Power Modules

One of the remaining packaging challenges for high-current power modules involves solder. Solder connects many components within these modules: the copper base plate to aluminum oxide (Al_2O_3) or alumina isolation layer, for example. So far, solder has been a weak link, with many failures of these modules being tracked to a disruption in the thermal path caused by cracking at the solder interface. Motorola engineers use the viscoplastic analysis capabilities of ANSYS to optimize the manufacturing of hybrid power modules.

Because solder is above half its melting point at room temperature, creep processes dominate its deformation. So understanding creep has become critical to the mechanical packaging design of hybrid power modules. At the Hybrid Power Modules (HPM) Operation of Motorola Inc.'s Semiconductor Products Sector (Phoenix, AZ), viscoplastic analysis of solder is performed using ANSYS finite-element analysis (FEA) software.

Not only does analysis help evaluate reliability of different types of solder for various operating conditions, it supports the group's design-for-assembly (DFA) approach by predicting how solder and the copper base plate will react when they are assembled. This has saved Motorola many thousands of dollars in tooling costs by allowing them to avoid prototype testing.

"We needed a means of predicting what would happen during the manufacturing process," explains James Fusaro, High Power Modules Team Leader at Motorola Inc. *"The alternative was to build and test, with tooling costs in the order of $5,000 to $10,000 per prototype. By the time you work out manufacturing issues for one module, you can spend nearly a quarter of a million dollars."*

Theoretical Foundation

Motorola has been using viscoplastic analysis on its Thor program, which involves the creation of a 1,200 amp 1,200 volt single-switch power module for high-powered industrial motor control applications. Viscoplasticity is a time-dependent phenomenon where the development of the plastic strains are dependent on the rate of loading. The primary application of viscoplasticity is high-temperature metal forming which involves large strains (50 percent or greater) and displacements.

As Fusaro explains, a great deal of theoretical background supports the application of viscoplastic analysis to solder. *"Anand's model in ANSYS is based on the work of Lallit Anand, a professor at MIT,"* explains Fusaro. His

The 1,200 amp, 1,200 volt power module discussed in the article.

The modules copper baseplate — the subject of the design optimization.

equations describe the elevated temperature deformation of metal, for which he credits the earlier work of Rice and Mandel.

"But it is Dr. Robert Darveaux's work that focuses on solder in particular," Fusaro adds. *"Darveaux did all his nonlinear material testing on actual soldered joints, so the exact microstructure could be duplicated."* This was important because it has been found that dispersed intermetallics and constraint at interfaces make actual joints significantly more creep resistant than bulk solder specimens. By applying Darveaux's deformation constraints to the Anand model in ANSYS, Motorola engineers can predict solder joint failure under a wide range of conditions. Fusaro has validated this approach against empirical testing. The ANSYS results were accurate to within eight percent.

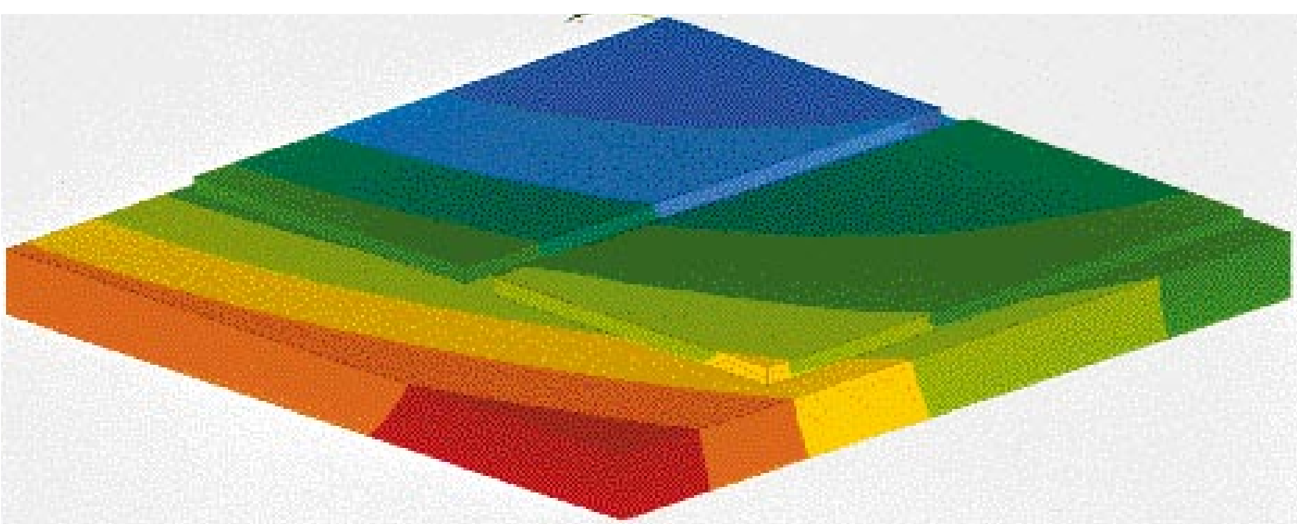
Manufacturing Concerns

The benefit of using viscoplastic analysis to evaluate solder is that once solder has been characterized (in terms of its activation energy, for instance, one of Anand's parameters), Motorola can use the analysis to identify solders that fit its process requirements. One of these involves the effect of solder on the amount of bow in the copper base plate. *"The copper base plate for modules in the Thor program is between three and five mm thick,"* explains Pablo Rodriguez, a design engineer in the group. *"It needs to have a certain amount of bow prior to manufacturing because when you solder down the direct-bonded copper ceramic, you flatten out the bow. We have to start with a certain amount of bow, but it is difficult to know how much."*

Prior to being able to model solder deformation accurately in software, they answered this question through prototype testing. Now, they use ANSYS to study various amounts of bow in the base plate and how they are affected when solder is applied. One iteration in software takes approximately four hours, compared to four months to get test data. And by defining the proper degree of bow using software, they bypass testing, getting a base plate configuration that works on the first pass.

"It's a huge cost saving," Rodriguez adds. *"By allowing us to look at different types of solder and different amounts of base plate bow, we are improving our design from both the process standpoint and in terms of reliability of the solder."*

"Using viscoplastic analysis for design activities and process characterization has been especially valuable for us being a start-up business," adds Fusaro. *"Without it, we would not be able to build functioning modules without incurring huge costs."* ■



The results of the ANSYS viscoplastic analysis on a quarter symmetry model of the copper baseplate.

by Caren Potter, Freelance Writer
McKinleyville, CA

North America

Advanced Engineering Technologies, Inc.
6525 The Corners Parkway, Suite 400
Norcross, GA 30092
Attn: Gerry Jones
Internet: aeta@aol.com
Telephone: (770) 409-7880
Fax: (770) 409-7881

Computer Aided Engineering Associates, Inc.
398 Old Sherman Hill Road
Woodbury, CT 06798
Attn: Dr. Lawrence Durocher
Internet: caea@pipeline.com
Telephone: (203) 263-4606
Fax: (203) 266-9049

Computer Aided Engineering Associates, Inc.
7 Berkmans Street
Worcester, MA 01602
Attn: Terry Davis
Internet: tdconsult@aol.com
Telephone: (508) 791-2925
Fax: (508) 791-5477

Computer Aided Engineering Associates, Inc.
475 West End Avenue, Suite V2
North Plainfield, NJ 07060
Attn: Dave Siwiec
Internet: caenj@aol.com
Telephone: (908) 412-1622
Fax: (908) 412-1894

Computer Aided Engineering Group
5240 Poinsettia Avenue
Winter Park, FL 32792
Attn: Richard Knapp
Internet: rvfk@aol.com
Telephone: (407) 677-8005
Fax: (407) 677-8770

Concurrent Engineering Corp.
Riverview Office Tower
8009 34th Avenue South
Suite 1291
Bloomington, MN 55425
Attn: Jeff Schrantz
Internet: schrantz@concurrent.com
Telephone: (612) 854-4499
Fax: (612) 854-4491

DRD Corporation
5506 South Lewis Avenue
Tulsa, OK 74105
Attn: Chris Andersen
Internet: canderse@drd.com
Telephone: (918) 743-3013
Fax: (918) 745-9037

Defiance-STS/SMC
Troy Technology Park
1960 Ring Drive
Troy, MI 48083
Attn: Debbie Vuckovich
Internet: defiance@usa.pipeline.com
Telephone: (810) 583-7117
Fax: (810) 583-0008

Engineering Cybernetics, Inc.
1856 Lockhill Selma, Suite 105
San Antonio, TX 78213-1558
Attn: Dr. Jack Maison
Internet: info@ecisa.com
Toll Free: 1-800-707-5461
Telephone: (210) 341-5461
Fax: (210) 341-5493

Engineering Cybernetics, Inc.
14811 St. Marys Lane, Suite 168
Houston, TX 77079-2908
Attn: Bill Baker
Internet: info@ecihou.com
Toll Free: 1-800-707-9798
Telephone: (713) 589-9798
Fax: (713) 589-8856

Engineering Methods, Inc.
Purdue Research Park
1211 Cumberland Avenue
West Lafayette, IN 47906
Attn: Jean Terry
Internet: emisup@holli.com
Telephone: (317) 497-4477
Fax: (317) 497-4776

JLR Computer Analysis, Inc.
111 S.E. Everett Mall Way
Building E, Suite 201
Everett, WA 98208
Attn: Jim Radochia
Internet: jpradochia@aol.com
Telephone: (206) 353-8089
Fax: (206) 353-593

Jordan, Apostal, Ritter Associates, Inc.
35 Belver Avenue
North Kingstown, RI 02852
Attn: Peter Kingman
Internet: kingman@jar.com
Telephone: (401) 884-3014
Fax: (401) 294-3826

Jordan, Apostal, Ritter Associates, Inc.
33 Boston Post Road West, Suite 270
Marlborough, MA 01752
Attn: Mark Kerrigan
Internet: kerrigan@jar.com
Telephone: (508) 485-8100
Fax: (508) 485-3123

MCR Associates, Inc.
111 West Evelyn Avenue, Suite 301
Sunnyvale, CA 94086
Attn: Mark Rodamaker
Internet: info@mcrfea.com
Telephone: (408) 736-1636
Fax: (408) 736-1664

Mallett Technology, Inc.
121 Hillpointe Drive, Suite 300
Canonsburg, PA 15317-9502
Attn: Brian Ball
Internet: bdb@pitt.mallett.com
Telephone: (412) 746-7000 Ext. 16
Fax: (412) 746-7001

Mallett Technology, Inc.
5 Great Valley Parkway, Suite 120
Malvern, PA 19355-1436
Attn: Sarah McCahill
Internet: slm@phila.mallett.com
Telephone: (610) 889-1340
Fax: (610) 889-1341

Mallett Technology, Inc.
Laurel Technology Center
14900 Sweitzer Lane, Suite 202
Laurel, MD 20707-2915
Attn: Mike Butz
Internet: mpb@wdc.mallett.com
Telephone: (301) 725-0060 Ext. 11
Fax: (301) 725-0061

Mallett Technology, Inc.
100 Park Drive, Suite 204
P.O. Box 14407
Research Triangle Park, NC 27709-4407
Attn: Kenn Yarina
Internet: key@rtp.mallett.com
Telephone: (919) 406-1500 Ext. 10
Fax: (919) 549-9679

Ohio Computer Aided Engineering, Inc.
1612 Georgetown Road
Hudson, OH 44236
Attn: Rufus Blackley
Internet: ocae@aol.com
Telephone: (216) 650-2057
Fax: (216) 656-4024

Stress Technology, Inc.
1800 Brighton-Henrietta
Town Line Road
Rochester, NY 14623
Attn: Mike Rieger
Internet: mrieger@stresstech.com
Telephone: (716) 424-2010
Fax: (716) 272-7201

SSC, Inc.
18700 Beach Boulevard, Suite 200-210
Huntington Beach, CA 92648
Attn: Dr. J.W. Jones
Internet: ssc@kaiwan.com
Telephone: (714) 964-1552
Fax: (714) 964-1156

SSC, Inc.
1S443 Summit Avenue, Suite 304B
Oakbrook Terrace, IL 60181
Attn: Tom Humrickhouse
Internet: ssc2@ix.netcom.com
Telephone: (708) 261-0246
Fax: (708) 261-0406

South America

SMI-Software Marketing International LTDA
Av. Brigadeiro Faria Lima,
613 - 10 Andar Cj. 101/2
São Paulo, CEP 01451-000 S.P.
BRAZIL
Attn: Jose Ricardo Nogueira
Internet: smisp@embratel.net.br
Telephone: 55-11-820-0388
Fax: 55-11-820-7361

SMI-Software Marketing
International Ltda.
Rua da Assembleia 10, 3701
Rio de Janeiro, CEP 20119-900
BRAZIL
Attn: Renaldo Pereira Nunes
Telephone: 55-21-531-2337
Fax: 55-21-531-2388

Europe

AT&T ISTEL
2, rue du Docteur Lombard
92441 Issy-les-Moulineaux-Cedex
FRANCE
Attn: Patrick Ramon
Telephone: 33-1-4662-2626
Fax: 33-1-4662-6578

AT&T ISTEL Rhône-Alpes
Les Bureaux Verts
22, rue Benoît Bennier
69260 Charbonnieres
FRANCE
Attn: Dominique Bonnecase
Internet: 100446.1577@compuserve.com
Telephone: 33-78-44-25-25
Fax: 33-78-87-62-33

Anker-Zemer Engineering A/S
P.O. Box 10 Voksenskogen
N 0708 Oslo 7
NORWAY
Attn: Jan Christian Anker
Internet: a-ze@oslonett.no
Telephone: 47-22-921-625
Fax: 47-22-142452

Anker-Zemer Engineering AB
P.O. Box 156
S-691 23 Karlskoga
SWEDEN
Attn: Eva Hyvärinen
Internet: 100140.2132@compuserve.com
Telephone: 46-586-52820
Fax: 46-586-56470

Bercom Software Development and Consultancy, Ltd.
88 Gissin St.
Kiryat-Arie
Petah Tikva 49222
ISRAEL
Attn: Amit Cohen
Internet: bercom@goldnet.net.il
Telephone: 972-3-9233522
Fax: 972-3-9233088

CAD-FEM GmbH
Marktplatz 2
D-85567 Grafing/München
GERMANY
Attn: Dr. Günter Müller
Internet: gmueller@cadfem.de
Telephone: 49-8092-70050
Fax: 49-8092-700577

CAD-FEM GmbH
Büro Hannover
Neue Torstr. 3
D-31303 Burgdorf
GERMANY
Attn: Clemens Groth
Internet: cgroth@cadfem.de
Telephone: 49-5136-85717
Fax: 49-5136-873179

CAD-FEM GmbH
Büro Stuttgart
Heidenheimer Str. 5
D-71229 Leonberg
GERMANY
Attn: Uli Göhner
Telephone: 49-7152-42084
Fax: 49-7152-72984

CAD-FEM GmbH
Büro Chemnitz
Cervantesstraße 89
D-09127 Chemnitz
GERMANY
Attn: Dr. Ulrich Stelzmann
Telephone: 49-371-267060
Fax: 49-371-742106

CAD-FEM AG
Büro Schweiz
Wittenwiler Str. 25
CH-8355 Aadorf
SWITZERLAND
Attn: Markus Dutly
Internet: 101447.1344@compuserve.com
Telephone: 41-52-611723
Fax: 41-52-612546

Figes, Ltd.
Petek-Bozkaya Is Merkezi c/304
Celal Bayar Cad. No. 6
16220 Bursa
TURKIYE
Attn: Dr. Tarik Ögüt
Internet: figes@uu20.bim.uludag.edu.tr
Telephone: 90-224-2508454
Fax: 90-224-2508457

I.N.A.S.
1, Tehnicii Street
1100 Craiova
ROMANIA
Attn: Radu Tircomnicu
Telephone: 40-051-410719
Fax: 40-51-410715

Ingeciber S.A.
Avda. Monforte de Lemos, 189
28035 Madrid
SPAIN
Attn: Honorato Girau
Internet: 100763.1224@compuserve.com
Telephone: 34-1-386-22-22
Fax: 34-1-386-45-80

ITALCAE SRL
Via Panciatichi, 40
50127 Florence
ITALY
Attn: Antonio Mancino
Internet: italcae.@fi.pisoft.it
Telephone: 39-55-432010
Fax: 39-55-4223544

SVS FEM s.r.o.
Cechynska 16
657 01 Brno
CZECH REPUBLIC
Attn: Miroslav Starek
Internet: jsch@svs-fem.anet.cz
Telephone: 42-5-45214572
Fax: 42-5-45214572

Structures and Computers Ltd.
Strucom House
188-196 Canterbury Road
Croydon CR0 3HF
Surrey, ENGLAND
Attn: Stewart Morrison
Internet: stewartm@strucom.co.uk
Telephone: 44-181-683 3999
Fax: 44-181-683 3933

Structures and Computers Ltd.
Strucom House
40 Broadgate, Beeston
Nottingham NG9 2FW
ENGLAND
Attn: Alan Perry
Internet: 100321.2052@compuserve.com
Telephone: 44-1159 677622
Fax: 44-1159 677620

Structures and Computers Ltd.
Postbus 323
3700 AH Zeist
THE NETHERLANDS
Attn: Jurgen Mathijssen
Internet: strucom@euronet.nl
Telephone: 31-30-6928800
Fax: 31-30-6924921

Structures and Computers Ltd.
18 Windsor Place
Lr. Pembroke St.
Dublin 2
REPUBLIC OF IRELAND
Attn: Derek Sweeney
Internet: strucomi@irishoff.win-uk.net
Telephone: 353 1 676 3765
Fax: 353 1 676 3766

Structures and Computers Ltd.
2 Haw Street
Wotton-under-Edge
Gloucestershire GL12 7AQ
ENGLAND
Attn: Dr. Tim Brown
Internet: tbrown@strucom.co.uk
Telephone: 44-1453-521655
Fax: 44-1453 521755

Asia Pacific

CAD-IT Consultants Pte. Ltd.
629 Alijunied Road #08-04/05
Cititech Industrial Building
SINGAPORE 1438
Attn: Florence Tan
Internet: cadit@singnet.com.sg
Telephone: 65-741-7527
Fax: 65-741-8761

CEMA International Corp.
38-C/2, Central Commercial Area
P.E.C.H.S., Karachi-75400
PAKISTAN
Attn: Amir Abbas
Internet: ideas@biruni.erum.com.pk
Telephone: 92-21-455-4794
Fax: 92-21-455-4794

Cybernet Systems Co., Ltd.
Nissay Otowa Bldg. (6-9 Floors)
15-6, Otsuka 2-chome, Bunkyo-ku
Tokyo 112
JAPAN
Attn: Shigehisa Inoue
Internet: sinoue@cybernet.co.jp
Telephone: 81-3-5978-5400
Fax: 81-3-5978-5440

Cybernet Systems Co., Ltd.
Nihon-Seimei Midosuji Bldg.
4-2-4, Minami Senba, Minamiku
Osaka, 542
JAPAN
Attn: Takao Daimyo
Internet: daimyo@cybernet.co.jp
Telephone: 81-6-241-5241
Fax: 81-6-241-1255

IMAG Industries, Inc.
IMAG Beijing Office
Peking Hotel, Room 1222
33 East Changan Avenue
Beijing 100004
PEOPLE'S REPUBLIC OF CHINA
Attn: Wang Bonua
Internet: imagbj@public.bta.net.cn
Telephone: 86-1-0513-7766 Ext. 1222
Fax: 86-1-0513-9945

IMAG Shanghai Office
Int'l. Equatorial Office Building
Room 409, 65, Yanan Road West
Shanghai 200040
PEOPLE'S REPUBLIC OF CHINA
Attn: Ning Jie
Internet:
shanghai.imag.sh@shanghai.shspt.china-mail.sprint.com
Telephone: 86-21-248-8144
Fax: 86-21-248-8534

IMAG Chengdu Office
Jin Jiang Hotel, Room 851
No. 36, Ren Min Nan Avenue
Chengdu, Sichuan, 610012
PEOPLE'S REPUBLIC OF CHINA
Attn: Zhao Fang-yuan
Internet: chengdu@imag.com
Telephone: 86-28-558-2222 Ext. 3851
Fax: 86-28-627-5074

IMAG Asia Pacific Limited
Room 406, Wing On Plaza
62 Mody Road, Tsimshatsui East
Kowloon
HONG KONG
Attn: Paul Chang
Internet: sylchan@imag.com.hk
Telephone: 852-2721-4083
Fax: 852-2722-5637

JIN Young Technology, Inc.
3rd Floor, Daechi Building
#965-16 Daechi-dong
Kangnam-ku Seoul
KOREA
Attn: Jin Park
Internet: ANSYS@hitel.kol.co.kr
Telephone: 82-2-565-2015
Fax: 82-2-568-2250

Neil Automation Technology Ltd.
1201/C/4, 'Shivtirth', F.C. Road
Shivajinagar
Pune 411 004
INDIA
Attn: Ketan Bakshi
Internet: shirish.neil@sml.sprintrpg.sprint.com
Telephone: 91-212-321443
Fax: 91-212-328537

NIIT
Engineering &
Geomatics Solutions Group
NIIT Ltd., NIIT House
C-125 Okhla Phase I
New Delhi 110 020
INDIA
Attn: B. Sridhar
Internet: bsridhar%niit@iris.ernet.in
Telephone: 91-11-681-7341
Fax: 91-11-681-7344

Taiwan Auto-Design Co.
10F, 635-2 Chung Hsin Rd.
Sec. 5, San Chung City
Taipei Hsien, Taiwan
REPUBLIC OF CHINA
Attn: Nerow Yang
Internet: tadc1378@ms1.hinet.net
Telephone: 886-2-9958036
Fax: 886-2-9957792

Australia & New Zealand

Worley Limited
Level 17, 300 Flinders Street
Melbourne, Victoria 3000
AUSTRALIA
Attn: Dr. Joseph Wong
Internet: jwong@worley.com.au
Telephone: 61-3-9205-0500
Fax: 61-3-9205-0505

Canada

H.G.E. Inc.
400 Carlingview Drive
Toronto, Ontario
CANADA M9W 5X9
Attn: Tony Firmin
Internet: tonyf@hge.com
Telephone: (416) 674-8505
Fax: (416) 674-8520

H.G.E. Support Associate
Compusim, Inc.
1003-D 55th Avenue N.E.
Calgary, Alberta
CANADA T2E 6W1
Attn: Imad Tabsh
Internet: tabshi@cuug.ab.ca
Telephone: (403) 295-2912
Fax: (403) 274-6908

H.G.E. Support Associate
Farnell-Thompson Applied Technologies
2222, René-Lévesque O., Suite 1
Montréal, Québec
CANADA H3H 1R6
Attn: Philippe Vidori
Internet: farthom@cam.org
Telephone: (514) 937-2644
Fax: (514) 937-4966

Mexico

SSC de Mexico S.A.
Mesones #1, Int. 10
37700 San Miguel de Allende
Guanajuato, 37710
MEXICO
Attn: Fernando Balderas Lopez
Internet: sscmex@mail.mindvox.ciateq.mx
Telephone: 52-415-24279
Fax: 52-415-24279

Republic of South Africa

Wolhuter & Van Wyk
Consulting Engineering, CC.
Potchefstroom University for CHE
Dept. Of Mechanical Engineering
2520, Potchefstroom
REP. OF SOUTH AFRICA
Attn: Arno Wolhuter
Internet: mgiaw@puknet.puk.ac.za
Telephone: 27-148-299-1324
Fax: 27-148-299-1320

The following information represents a partial listing of ANSYS seminars and the dates the seminars will be presented. For complete details on the seminars listed below, contact the ANSYS Support Distributor (ASD) shown for that particular seminar. Contact your ASD if you are interested in a seminar not listed here. For seminars held at ANSYS, Inc., contact the Training Registrar at 412.873.2882. Reservations are recommended at least two weeks in advance.

DATE (Week of)	Introduction to ANSYS		Design Optimization	Dynamics	ANSYS/ProFEA	Heat Transfer	Introduction to FLOTRAN®	Structural Nonlinearities	Solid Modeling	Electomagnetics	Special Topics (See footnotes)	
Mar. 31- Apr. 6	ECI CSC	STR				CSC		DEF	SMI	AT&T	SMI[8] AT&T[20]	SMI[19]
Apr. 7-13	CSC			DEF SMI	DRD			ANS CSC	ECI HGE STR		AT&T[21]	
Apr. 14-20	ANS DEF CAD CSC BER	SSC ITAL AZE JIN AT&T		STI CSC		FIG SSC SMI	ECI SMI STR ITAL	AET JAR STR		CAEA	ANS[1] ITAL[22]	ITAL[4]
Apr. 21-27	CAEA MTI CAD	DRD STR	STR SMI	SSC AT&T	ECI	MTI AZE		EMI SSC DRD ITAL SMI	CAEA CSC	ANS	CAD[11] CAD[13] CAD[22]	CAD[12] SMI[17]
Apr. 28- May 4	SSC CSC	ECI STR	ANS DEF AT&T			DEF SSC	STR		SSC	ITAL STR	SMI[6]	CAD[14]
May 5-11	ANS JLR FIG CEC	EMI MCR CSC	CEC	CAD	ITAL	MCR	SMI	OCAE AZE	SSC EMI	CSC	ANS[1] CAD[15]	CAD[3]
May 12-18	AET DEF ITAL JIN	DRD ECI CSC SMI	AT&T	AET	DRD CAD	STI BER		CAEA SMI	STR	JAR	ITAL[5] SMI[10]	CAEA[6]
May 19-25	STR CAD	CSC AT&T	SMI			EMI STR					ITAL[6] ITAL[22] SMI[23]	SMI[9] ECI[23]
May 26-Jun. 1	CSC		EMI	ITAL				JIN		SMI		
Jun. 2-8	ANS MTI ECI SMI AZE	DRD SSC JAR CSC STR		AT&T	MTI	SSC		DEF AT&T	DRD CSC		ANS[1] ITAL[22]	CAD[16]
Jun. 9-15	CAEA MCR STI BER JIN STR	EMI OCAE HGE CSC ITAL		DEF SSC CAEA CSC		ECI STR	ITAL CAD	ANS SSC	EMI SMI	CSC	ANS[2] SMI[18]	OCAE[1]
Jun. 16-22	DEF CSC AT&T	STR CAD		ANS JIN	DRD EMI	JAR SMI ITAL	ECI	MCR CSC AT&T	SSC SMI		ANS[3] JLR[3]	AET[1]
Jun. 23-29	SSC			SMI	ECI	SSC CAD		FIG			CAD[3] SMI[7]	ITAL[7]

Company Key

- ANS ANSYS, Inc.
- AET Advanced Engineering Technologies, Inc.
- AZE Anker-Zemer Engineering
- AT&T AT&T ISTEL
- BER Bercom Software Development & Consultancy, Ltd.
- CAD CAD-FEM GmbH
- CAEA Computer Aided Engineering Assoc. Inc.
- CEC Concurrent Engineering Corp.
- CSC Cybernet Systems Co., Ltd.
- DRD DRD Corporation
- DEF Defiance-STS/SMC
- ECI Engineering Cybernetics, Inc.
- EMI Engineering Methods, Inc.
- FIG Figes, Ltd.
- HGE H.G.E. Inc.
- ITAL ITALCAE srl
- JAR Jordan, Apostal, Ritter, Assoc., Inc.
- JIN JIN Young Technology, Inc.
- JLR JLR Computer Analysis, Inc.
- MCR MCR Associates, Inc.
- MTI Mallett Technology, Inc.
- OCAE Ohio Computer Aided Engineering, Inc.
- SMI SMI-Software Marketing International LTDA
- SSC SSC, Inc.
- STI Stress Technology, Inc.
- STR Structures and Computers Ltd.

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8 Finite Element Methods
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10 Contact Surfaces
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12 Error Estimation
13 FEA Solvers
14 Fracture Mechanics
15 Shell Elements
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17 IGES Transfer
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ANSYS, Inc.
201 Johnson Road
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ansysinfo@ansys.com
T 412.746.3304
F 412.746.9494
Toll Free USA and Canada:
1.800.WE.R.FEA.1
Toll Free Mexico:
95.800.9373321

Regional Offices:
North America
lzera@ansys.com
T 810.585.5020
F 810.585.5730
International
jtung@ansys.com
T 412.873.3086
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