Vanderplaats Research & Development, Inc.

Creators of Design Optimization Technologies

VR&D Summer 2009 Newsletter

Index

1 New Employees In Novi Office

1.1 Dr. L. Shrinivas joined VR&D in August 2008, as R&D Engineer. Shrinivas earned his Ph.D in Mechanical Engineering from North Carolina State University. He received a masters degree from Indian Institute of Science, Bangalore, India and undergraduate degree from Goa University, Goa, India. Before joining VR&D, Shrinivas was a postdoctoral researcher for 2 years at Rensselaer Polytechnic Institute and worked for 4 years in the industry as a finite element software developer. He will be working on GENESIS software development, provide technical support for GENESIS and Design Studio, and help with training.

1.2 Dr. Santosh Tiwari joined VR&D in June 2009, as R&D Engineer, after receiving his PhD in Mechanical Engineering from Clemson University. His PhD research was on the Development and Integration of Geometric and Optimization Algorithms for Packing and Layout Design. He received his Bachelors of Tech. in Mechanical Engineering from the Indian Institute of Technology, Kanpur, India in 2004. He will work on VisualDOC software development, design process integration, and research on optimization methods. He will also assist clients in the use of VR&D technology to support commercial applications.

2 New Intern at VR&D

2.1

Shreeganesh Sudhindra, a graduate student from the State University of New York at Buffalo, joined VR&D in May 2009 as a student intern. He is a Mechanical Engineering major specializing in Engineering Design and Optimization and plans to graduate in December 2009. At VR&D, Shreeganesh is helping the engineers in our Novi office with several tasks including creating example problems, quality assurance, and solving engineering problems concerning design and optimization.

3 Recent Events

3.1 COFES Conference

Our CEO, Gary Vanderplaats, and our President, Juan Pablo Leiva, attended the 2009 Congress On the Future of Engineering Software (COFES) April 16-19, 2009 in Scottsdale, Arizona at the Scottsdale Plaza Resort. COFES is an engineering software think tank event which brings executives from design, engineering, architectural, development and technology companies together to understand the role engineering technology will play in the future survival and success of our business. CEO Gary Vanderplaats gave a presentation entitled, "*Optimization A Design Tool to Save Time, Corporate & Natural Resources.*" In this presentation, Gary gave a brief summary on what optimization is. He asserted that optimization is no longer for wizards as graphical interfaces have greatly evolved, and in just a few days engineers can learn how to apply optimization to their daily jobs. He finished his presentation by describing some examples with time and cost savings.

3.2 2009 SAE World Congress

Vanderplaats R&D attended the 2009 SAE World Congress held in Detroit, Michigan at the Cobo Conference/Exhibition Center.

We take this opportunity to recommend the following paper which was presented at the SAE World Congress, "*Case Study of Topography Optimization on Automotive Body Structure*." The paper was written by Dr. Rajan R. Chakravarty from General Motors Corporation. The abstract for this paper is as follows: "A methodology to improve the structural performance of an automotive body structure by large scale Topography Optimization is presented. Topography, an established technology, is a special class of shape optimization, which can be used to change sheet metal shapes. The paper will highlight the advantages of Topography optimization - easy optimization setup, large number of design variables, identification of sheet metal shape morphing locations, and a mass neutral or mass efficient solution. A case study on the application of Topography on the full Body Structure is illustrated."

The SAE number for this paper is 2009-01-1233. To obtain a copy of this paper you can go to: http://www.sae.org/technical/papers/2009-01-1233

3.3 5th Annual AIAA MDO Specialist Conference

This conference is part of a group of conferences associated with the 50th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference that was held in Palms Springs, CA on May 4-7, 2009.

Garret N. (Gary) Vanderplaats was invited to give the Keynote Lecture. The title of his lecture was "Saving Energy Through Optimization." The abstract of his lectures is as follows:

As the nation and the world are coming to recognize the need to conserve our natural resources, we are celebrating the 50th SDM Conference and 5th MDO Specialist Conference. As we seek to provide engineering tools and technologies to contribute to this conservation effort, we can say that we have already achieved a great deal. Most notably, the optimization tools that have been developed and promoted by the AIAA are uniquely able to meet energy conservation goals, whether we apply it to current or future designs. It is notable that this technology is not limited to aerospace applications. It is equally useful throughout the engineering design industry whether for aerospace, automotive, oil production, computer circuits or virtually any other corporate or consumer product. A one percent reduction in fuel consumption of U.S. automobiles will result in about a five billion dollar annual savings at the pump. A 100 Kg reduction in the mass of a 200 passenger aircraft will add one passenger for the life of the aircraft and will reduce the per passenger mile pollution by one half of one percent. A one percent reduction in cruise drag of an aircraft will reduce fuel consumption by perhaps one half of one percent. Thus, this mass reduction can come from structural weight or fuel efficiency improvements. Whether we reduce mass directly, improve lift/drag ratios, improve combustion efficiency or any combination of these, optimization provides the tool to achieve these goals. The purpose of this talk will be threefold. First, we will offer a brief overview of the development of optimization technology, leading to the current state of the art. This will show the generality and efficiency of using optimization. Second, we will offer examples to demonstrate the energy savings possible if we apply optimization in the design process. Finally, we will consider the energy savings and economic benefits achievable through the use of optimization in the future. It is concluded that, whether we apply optimization to current designs of conventional vehicles and products or future designs requiring new and innovative technologies, optimization is a design tool whose time has come.

4 *Recent Software Releases*

4.1 Design Studio for GENESIS v.10.1

Design Studio for GENESIS is a design oriented pre- and post-processor graphical interface for the GENESIS Structural Analysis and Optimization Software. Following is a list of the new features that we recently released:

- All new entries in GENESIS v.10.1 are supported. Here is a list of some of the new data supported:
  - Equivalent Static Load libraries (ESL Readers) can be specified. These readers are plug-in modules that support the equivalent static load method by reading displacements from third-party analysis codes.
  - Static load cases that use loads from the equivalent static load method can be created and edited.
  - DSELECT data entry. This allows users to find out which design variables from a list should be increased and which design variables should be reduced.
  - BEADFR data for topography regions. This allows users to get more discrete beads.
  - RMSDISP, RMSVELO and RMSACCE responses. This allows users to optimize random responses.
- Powerful New filters that facilitate easier searches:
  - List find filter
  - Group list find filter
- Post processing Improvements:
  - Selective import of PUNCH/OUTPUT2 results
  - Import CBUSH dynamic forces
- Load case Improvements
  - Edit boundary conditions on multiple load cases
- New Documentation
  - A new Design Studio How-To manual that gives step-by-step instructions for how to perform many common tasks with Design Studio is now available.
  - A new Design Studio Examples manual that provides step-by-step instructions for some of the less-frequently-used capabilities of Design Studio is available. The Analysis portion demonstrates how to create simple finite element models from scratch. The Design portion demonstrates how to solve several special-case optimization problems using Design Studio and GENESIS.

Released: December 2008

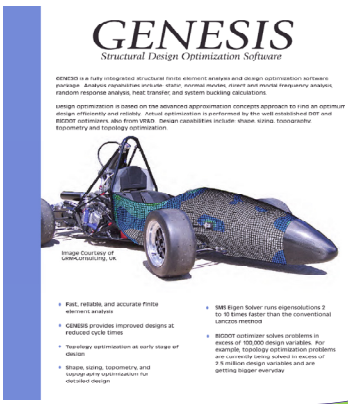
GENESIS v.10.1

GENESIS is a fully integrated finite element analysis and design optimization software. GENESIS allows users to perform sizing, shape, topology, topograpy and topometry optimization. We recently released a new version, and some of the most important new features and enhancements are listed below:

- ESL readers: (ESLDISP(reader control), ESLCONF(reader configuration) and ESLOAD(ESL Selection)
- Internally calculated ESL
- Topology improvements: Nodal based topology with minimum member size, mirror and cyclic symmetries
- Topography improvement: BEADFR options
- DSELECT data entry. This allows users to find out which design variables from a list should be increased and which design variables should be reduced.
- DRESP3 now supports new built-in equations
- DVBASIS small number controls (DOPT parameters)
  - RPERT1 – Relative value of cut off perturbation norm or zero. Zero is to ignore this cut off.
  - RPERT2 – Absolute value of cut off perturbation norm or zero. Zero is to ignore this cut off.
- Long "include" file names
- Avoid writing matrices on certain cases: this is to improve I/O time for large models
- More efficient handling of rigid element/mpc constraints. Now if there is no shape optimization of rigid element grids, then the constraint equations are processed only once and the results saved for use in later cycles.
- Random response optimization with the following options
  - DRESP1-RMSDISP, RMSVELO & RMSACCE (Parametric root mean responses)
  - TRESP1-RMSDISP, RMSVELO & RMSACCE (Topology root mean responses)
- More efficient frequency response calculation when few Responses are requested. Much less disk space will be required.
- Update RBE3 formulation to be closer to other codes. Now weights on rotation dofs are scaled by the square of the average distance of the Gi grids to the REFGRID. Note that this may change the results if nonzero weights on rotation dofs are present (but the results should more closely match other codes). DIAG=791 will revert to the old (v10.0 and lower) behavior.

Software upgrade packages have been sent out. If you would like to be able to download the upgraded version please email Jennifer Krejci, at jennifer@vrand.com.

Release Date: December 2008



VisualDOC and Visualscript v.6.1.1

VisualDOC is a general-purpose optimization tool that allows the user to quickly add design optimization capabilities to almost any analysis program. All optimization settings and integration with analyses are completed through the graphical interface, so in general it is not necessary to do any programming. Visualscript is a companion program to VisualDOC for process integration. VisualDOC v.6.1.1 is the latest build of VisualDOC v.6.1 and includes resolution of known issues as well as some minor yet useful new features. Enhancements can be seen in both VisualDOC and VisualScript within the respective GUI as well as the underlying design optimization algorithms. Some of the more prominent enhancements include:

1. **Automatic Backup of Original Input/Output Files in VisualScript** - The security of original input and output files when using VisualScript for process integration has been enhanced. VisualScript will automatically create a backup of the original input and output files and use these files when a previously created project is opened or when a new project is created. While the original files are modified during the optimization process, users will now have access to their original problem definitions in the backed-up files.

2. **Backup of Intermediate Input/Output Files Used in** VisualScript - Users can now select an option that would backup the input and corresponding output files that are used for all design points within the optimization process. This allows the user to revisit all points evaluated in the optimization process at a later time as well as have access to all completed analyses in the event the task run is prematurely terminated.

3. **VisualScript Generated Python File for International Language** OS - Python files generated by VisualScript resulted in an error when used on international language OS. This error pertained to the format of the date written in the python file. This error has now been fixed and works on operating systems in all languages.

4. **Improved Handling of Pass/Fail Feature for Responses** - The use of responses as Pass/Fail has been enhanced, especially for RSA optimization. With these enhancements, Users can now use Pass/Fail responses more efficiently for a wide variety of problems.

5. **Using DOE Approximations from Previous Tasks as Analysis** - This new feature enables users to further exploit VisualDOC's DOE capabilities. Approximations created by DOE tasks can now be directly used as analyses in new design optimization tasks. This eliminates the need for users to create Synthetic functions and attach previously created approximations to these synthetic functions.

6. **Improved Design Optimization Run Monitoring** - The default setting when running a task in VisualDOC will now display the number of points analyzed for optimization tasks or the number of points created for DOE tasks. This provides additional feedback to the user when a task is running. Instead of displaying the task information, users can choose to display the output from the command prompt of the analysis run by selecting the check box within the Run Task window.

7. **Designating Input in VisualScript as an Integer** - Users can now set the modified inputs within VisualScript to be integers. This will ensure that during the optimization process, integers within the input files are written as integers and not in floating point notation.

8. **Enhanced Examples and Documentation** - VisualDOC 6.1.1 comes with completely new documentation. The new User's Manual, Getting Started Manual and Advanced Examples Manuals along with new examples will allow new users to get easily started with VisualDOC. Additionally, VisualDOC 6.1.1 has updated the online context help.

Release Date: January 2009

5 New Training Classes

5.1 New Training Being Offered at VR&D

In 2007 we opened a new training room in our Novi office. This training area has multiple computers that allow us to provide classes to engineers who want hands-on experience. We now offer several new classes, among them:

- **Advanced Topology Optimization** - This training is intended to provide a comprehensive understanding of topology optimization concepts. Students will work with several hands-on exercises and learn how to interpret and use topology optimization results. During the class, students will be exposed to industrial applications and examples.
- **Advanced Sizing and Topometry Optimization** - This course covers in detail the techniques involved in sizing and topometry optimization. Several hands-on exercises are solved by the students. This course also goes through how to interpret and use topometry optimization results.
- **Advanced VisualDOC Integration** - This is an in depth course which covers the details of integrating VisualDOC with different types of analysis programs. Students will explore and understand the different integration methods, the benefits, and even how to embed VisualDOC in their analysis using the VisualDOC API.
- **Design of Experiments (DOE)** - This short course is intended to introduce students to techniques for Design of Experiments (DOE). DOE techniques are useful for planning studies in which inputs to a system/process can be varied and the outputs are observed. This course begins with DOE fundamentals and moves to advanced concepts, principles and requirements. Different techniques are explored for determining which inputs have statistically significant effect on outputs. This includes analysis of variance, full and fractional factorial experiments, etc.

We will continue offering on-site and custom classes. Check our website for information on all classes and schedules: http://www.vrand.com/Training.html or simply contact us for more details at training@vrand.com or call (248) 596-1611 x101.

6 New Workshops

6.1 New Workshops Being Offered at VR&D

If you do not have time for our training classes we also offer one-day workshops. These workshops are intended to give attendees a brief overview of our software capabilities and features. Hands-on exercises will be solved by the attendees. Please contact us for more information or simply wait for our announcements to be sent to your e-mail address. Currently we offer two workshops:

- **Structural Optimization Workshop** - This workshop is designed to demonstrate the ease of running optimization using Design Studio and GENESIS. The workshop covers sizing, shape, topology and topometry optimization problems. Hands-on exercises will be solved by the attendees.
- **General Optimization Workshop** - This workshop is designed to highlight how VisualDOC can be used to add design optimization capabilities to existing analyses. An overview of features present in the software along with several analysis integration techniques is presented. Attendees will have the chance to solve example problems for better understanding.

VR&D Now Offers Free Seminars

Our upcoming seminars will be presented by Gary Vanderplaats and Juan Pablo Leiva.

Dr. Vanderplaats, our CEO, is a widely recognized expert with over 40 years experience in the optimization field. Dr. Vanderplaats is a Fellow of the AIAA and recipient of the 2002 AIAA Multidiscipline Design Optimization Award, *"For his great impact on the application of optimization to engineering design through teaching, algorithm development, and the creation of outstanding software."*

Mr. Juan Pablo Leiva, our COO and President will also be contributing to the seminars. Mr. Leiva will be presenting a brief overview of our design optimization software and their capabilities. Some of the new features included in the latest version of the software will also be presented.

Some details about the seminars are provided below. If you have any questions regarding the content, please contact, Dr. Phani Adduri, (e-mail: padduri@vrand.com) (Ph: 248-596-1611 x101) or for registration questions please contact, Jennifer Krejci, (email: jennifer@vrand.com) (Ph: 719-473-4611 x100).

"*SAVING ENERGY THROUGH OPTIMIZATION*"

Abstract:

As the nation and the world are coming to recognize the need to conserve our natural resources, design optimization is an engineering tool which can contribute to this effort. This technology is available now to improve efficiency of existing and future vehicles while satisfying requirements for safety, emissions and reliability.

The purpose of this talk will be threefold. First, we will offer a brief overview of the development of optimization technology, leading to the current state of the art. This will show the generality and efficiency of using optimization. Second, we will offer examples to demonstrate the energy savings possible when we apply optimization in the design process. Finally, we will consider the energy savings and economic benefits achievable through the use of optimization in the future.

It is concluded that, whether we apply optimization to current designs of conventional vehicles and products or future designs requiring new and innovative technologies, optimization is a design tool whose time has come.

This seminar is intended for managers and decision makers seeking the best possible design technology as well as practitioners who seek an overview of these design tools.

"*OPTIMIZATION THEORY AND APPLICATIONS*"

About:

The purpose of this seminar is to provide a brief introduction to modern design optimization theory. We will begin with an overview of general concepts. Following this, we will discuss effective algorithms for unconstrained and constrained minimization. Examples of general applications will be offered to demonstrate the breadth of design tasks amenable to optimization.

The second half of this seminar will focus on the specialized area of structural optimization. Here, we have sophisticated approximation techniques that allow us to solve very large optimization tasks for the cost of only about 15 finite element structural analyses. Examples of modern structural optimization will be presented to demonstrate the state of the art.

This seminar is intended for practitioners or potential practitioners of optimization who wish to gain a better understanding of the methods contained in our software.

8 GENESIS: Tips and Tricks

8.1

To learn how to use GENESIS and Design Studio ask us for step by step examples on what you are trying to do. Today we have nearly 5 dozen unpublished examples that we can send you.

GENESIS Memory Usage

The amount of memory used by GENESIS can be controlled using the LENVEC executive control statement. For most computers, using a large value for LENVEC (based on the physical available memory) will give the best performance. For example in a Linux PC, the time taken by GENESIS (using SMS) to compute 717 eigenvalues on a 2.5 million degree-of-freedom model is 63 min with a LENVEC of 500 (equivalent to 2GB) as opposed to 49 min using 1750 (equivalent to 7GB).

However, care should be taken to not use more LENVEC than the amount of available memory as virtual memory would be used thereby degrading the performance. Also, one should make sure that the amount of memory allotted to GENESIS is available and is not used by the operating system or other processes. Recommended LENVEC values are based on the memory available and the system type. Contact VR&D for more details about the optimal configuration for your system or simply test your system by running the same problem using different amounts of memory.

EIGR/SMS Usage

To achieve better performance while using SMS as the eigenvalue solver, use an appropriate maximum frequency value on the EIGR input statement.

9 VisualDOC: Tips and Tricks

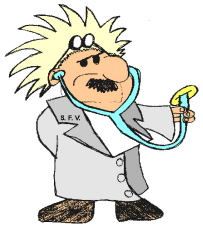
9.1 **Use Approximations from Previous DOE Tasks as Analysis Program**

Loading DOE approximations and specifying responses as synthetic functions one by one is tedious. Now the user has the "Use Approximations" option to directly input this data. Here are the steps:

- Create an approximation using one of VisualDOC DOE design and approximation methods.
- Define the optimization parameters.
- In the Create Task Advanced Options section, select "Use Approximations" option and the corresponding DOE task ID.
- Create and run the optimization task.

This option is mostly useful in the case that the real analysis is computational expensive and the user wants to use the approximated analysis as a replacement. When using this option there are two aspects the user needs to pay attention to:

- The number of design variables and responses should be the same as the selected DOE approximation task. Internally, VisualDOC uses the DOE approximation matrix to evaluate the responses, so it will not be valid if the number of design variables and responses are different, or the orders of the design variables/responses are changed.
- After optimization, the user should verify the optimal solutions by performing the real analysis.



Structural Optimization Corner

During the last World Congress on Structural and Multidisciplinary Optimization Conference (WCSMO8) that was held in Lisbon, Portugal, in June of this year, several papers using VR&D software were presented. Among them one caught our attention as it has several interesting examples and results. The results were obtained using GENESIS. The paper gives data that shows companies that let CAE lead the design can save time and costs. The title of the paper is. "*The application of FEA in the Optimisation of Die Cast Components & the Consequent Reduction in Development Costs & Time*." The paper was presented and written by Kevin Lake of Swansea Metropolitan University, co-authored by Richard Thomas (Swansea Metropolitan University), Martin Gambling (GRM Consulting Ltd – VR&D distributor in UK) and Tony Lawson (Meridian Lightweight Technologies). We asked Martin Gambling to provide a short article describing the paper and its' main ideas.

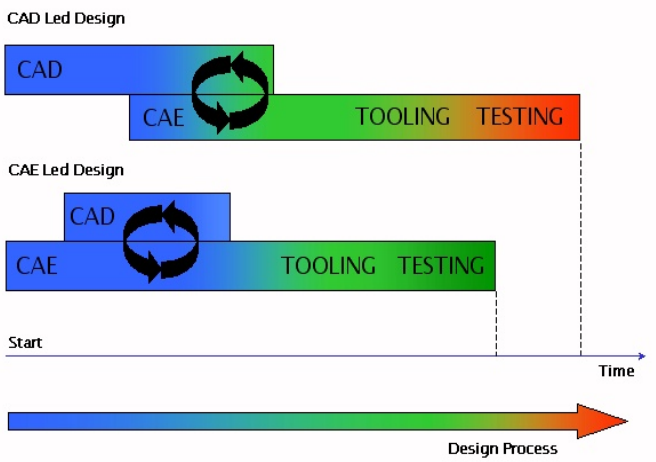
A New Approach to Product Design

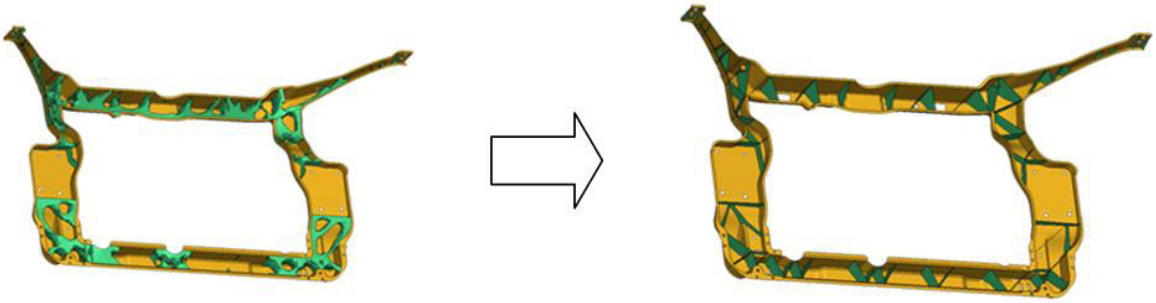
By: Martin Gambling, GRM Consulting

With the increasing focus on the environment and product costs, it is ever more imperative that designs are developed to be as efficient as possible. Design optimization techniques provide an important route to achieving these goals and are now mature enough to provide real savings, whilst reducing product development cycle times.

However, despite optimization techniques being well understood, readily available and relatively cheap to implement, they are still relatively under-utilized within industry.

For those companies adopting a CAE and optimization led design process significant product development time and cost savings have been achieved, as described in a recent paper by GRM Consulting Ltd and Swansea Metropolitan University. The paper gives reference to the application of CAE and optimization led design by Meridian Lightweight Technologies, where the process is shown to provide a reduction in development costs of 66% (£268,000 in real terms). This is achieved through the application of optimization, developing a right first time design, reducing the number of costly CAD->CAE iteration loops. If you would like to receive a copy of the paper, please contact us at (genesis.support@vrand.com)





Topology Optimization Results

Interpreted Design

Automotive Front End Console Casting

A Discussion on Consistent, Lumped, and Coupled Mass Formulations

GENESIS users have a choice of using consistent or lumped masses when running certain types of analysis. In the next version of GENESIS (version 11.0), for key higher order elements (TETRA, HEXA,TRIAX6) the choice will be extended further to include coupled mass. In this technical note, we would like to discuss what each of the choices mean.

Mass matrices are computed for normal modes and frequency response analysis. A mass matrix can be consistent, lumped or coupled. Consistent mass matrices are full and are obtained by integration over the element volume. Lumped mass matrices are diagonal and are obtained by assigning particle masses to the element nodes such that the total mass adds up to element mass. A coupled mass matrix is a hybrid combination of the lumped and consistent mass matrices.

Consistent mass matrices provide upper bounds to the exact values of natural frequencies provided the structure volume is correctly represented by the mesh, the element is compatible and not softened by reduced integration. With consistent mass matrices, the natural frequencies typically converge from above. With lumped mass matrices, the natural frequencies converge either from below or above. This can be attributed to the ad-hoc nature of lumping. Coupled mass matrices result in errors in natural frequencies which are in between the errors from consistent and lumped matrices.

To demonstrate the differences between the mass matrix formulations, we have performed a normal modes analysis of a beam with square section with higher order TETRA elements of GENESIS. Results were obtained with the three different mass matrix formulations. Figure 1 shows a typical result of percentage errors in the 3rd natural frequency with TETRA elements. Figure 2 shows the corresponding mode shape. It can be seen that the coupled mass matrix results in the least error. Additionally, the consistent mass matrix converges from above while the lumped mass matrix converges from below. Similar trends were exhibited by all the tested elements.

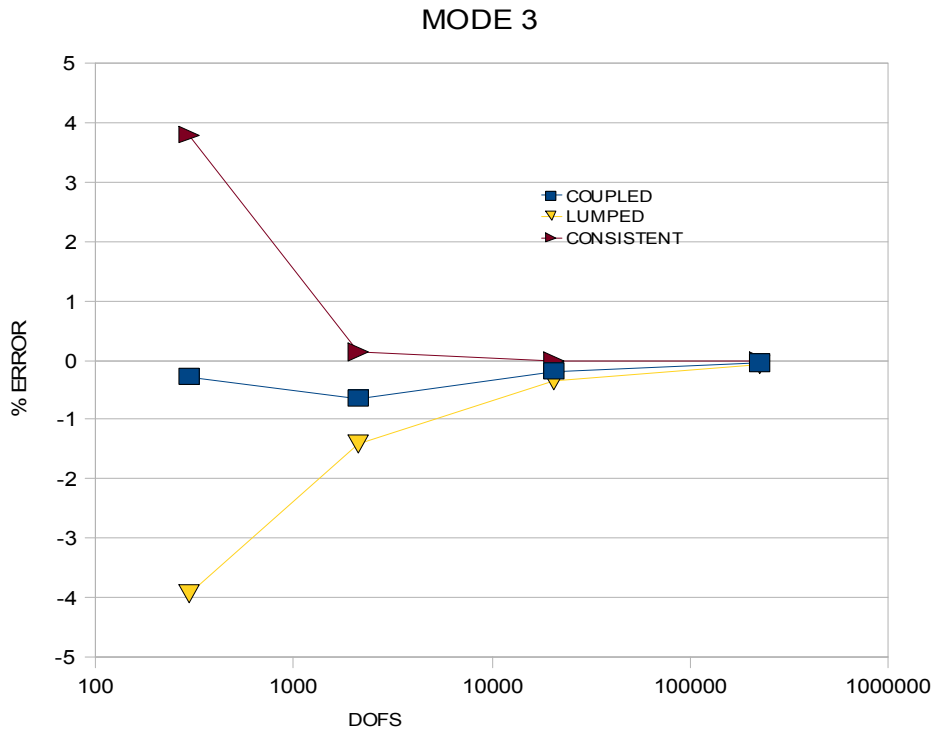


Figure 1: Percentage errors in the 3rd natural frequency

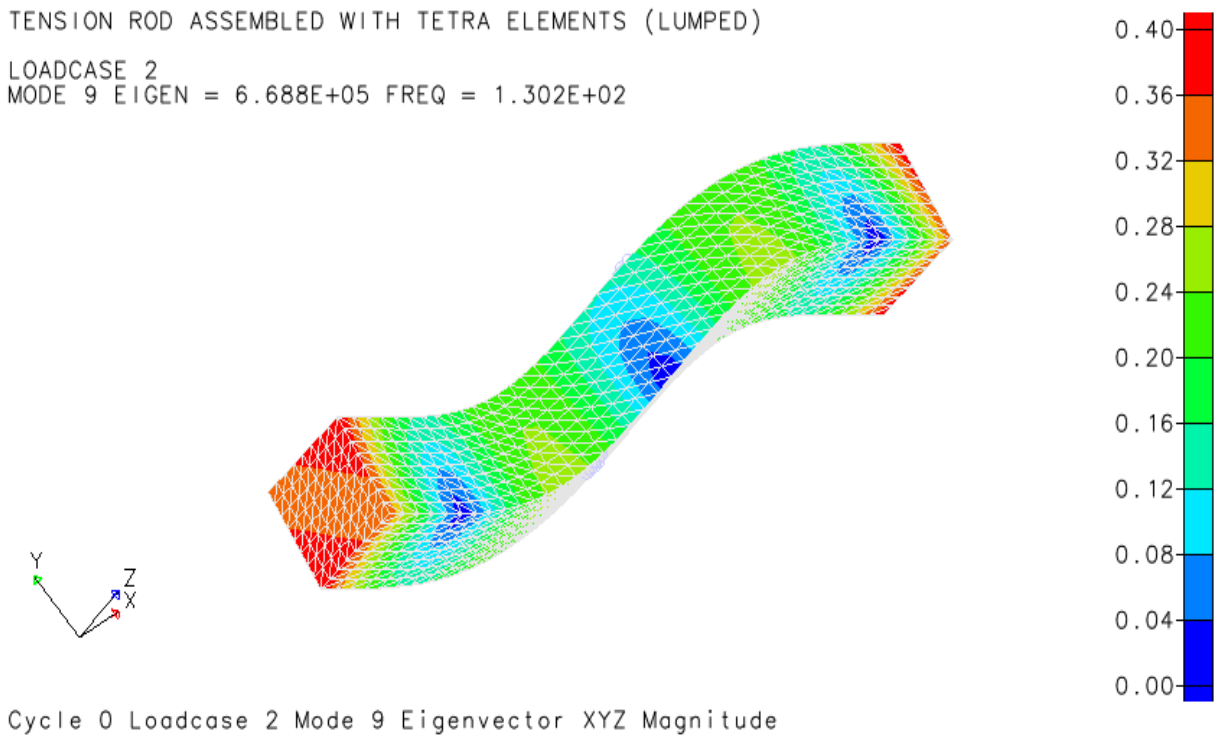


Figure 2: Mode shape associated with 3rd natural frequency

According to the above results, the user has to be concerned about the right choice of mass only when the mesh is coarse (small number of degrees of freedom) or when trying to obtain an answer using high frequencies (as large relative displacements can occur in a small region). It should be observed that as the number of degrees of freedom increases all three formulations converge to the same number. For the cases studied, the coupled mass matrix gave the least error. Hence, it is recommended to use coupled mass matrices with higher order elements in GENESIS.

Contacting VR&D

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