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Mark Donley

NX Nastran Review

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Agenda

- Overview
- Special Topics
  - GPU Support
  - Glue and Contact Connections
  - Bolt Connections
  - Composites
  - Non-Linear Simulation
- Summary

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Overview

Special Topics

- GPU Support
- Glue and Contact Connections
- Bolt Connections
- Composites
- Non-Linear Simulation

Summary

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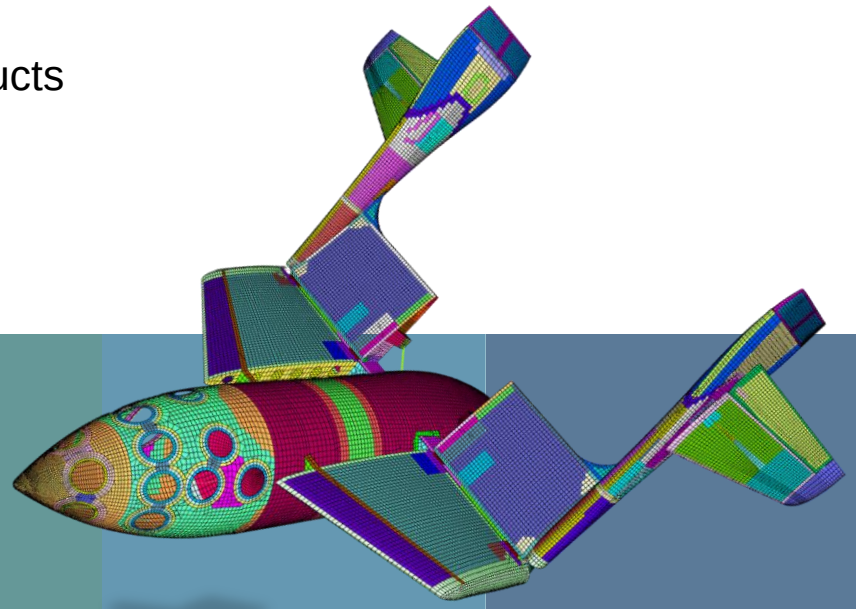
NX Nastran Timeline

NX Nastran – for the Enterprise

- Standalone solver for compute servers

NX Nastran Desktop – Integrated in Pre/Post Products

- NX Nastran Desktop for NX
- NX Nastran Desktop for Femap



NX Nastran 1 – 2003 (equivalent to MSC Nastran v2001)

…….

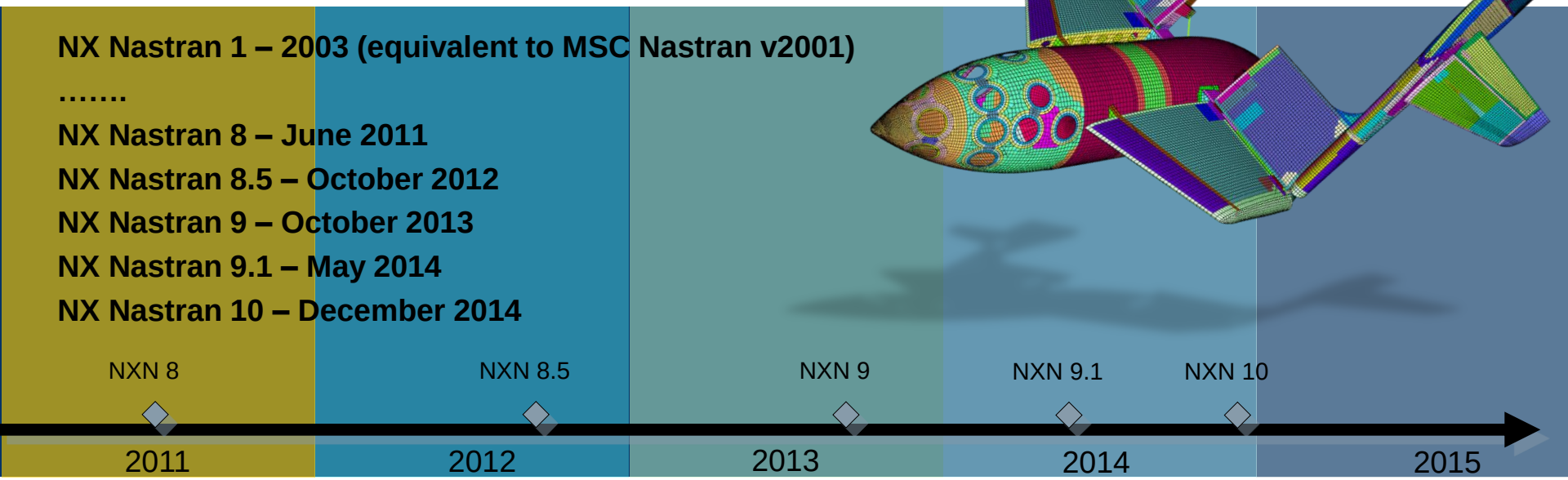
NX Nastran 8 – June 2011

NX Nastran 8.5 – October 2012

NX Nastran 9 – October 2013

NX Nastran 9.1 – May 2014

NX Nastran 10 – December 2014



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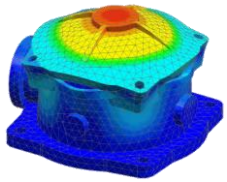
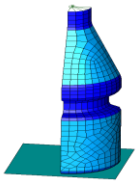
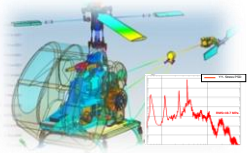
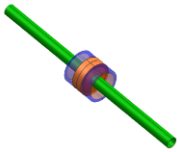
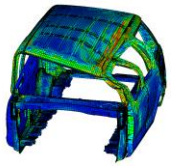
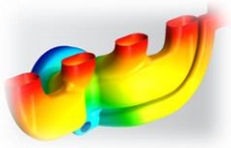
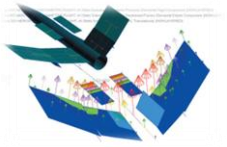
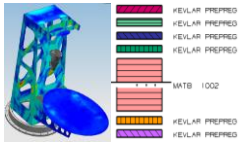
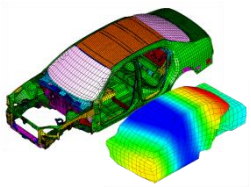
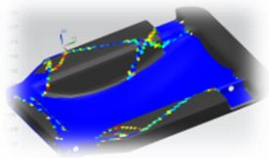
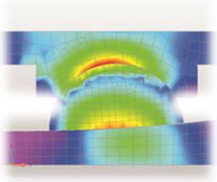
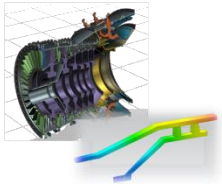
Multiple Solution Domains – One Solver

Linear Stress	Modal	Buckling	Dynamics	Rotor Dynamics	Parallel Processing
					

Nonlinear Analysis		Thermal
	NX NASTRAN	

Aeroelasticity	Laminate Composites	NVH	Optimization	Custom Solutions	Multi-physics
					

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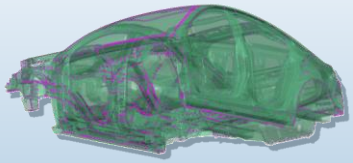
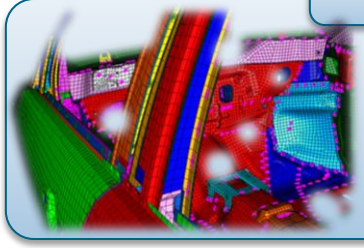
NX Nastran Development Focus

Performance



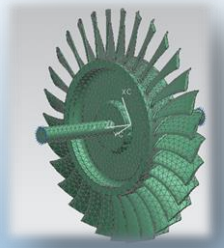
- Large Modal
- Fast Frequency Response
- Large Optimization

Process Improvement



- Easier Modeling
- Greater Accuracy

Discipline Extensions



- Additional physics solutions
- Common modeling format

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Large Model Performance

Distributed Memory Parallel Solutions

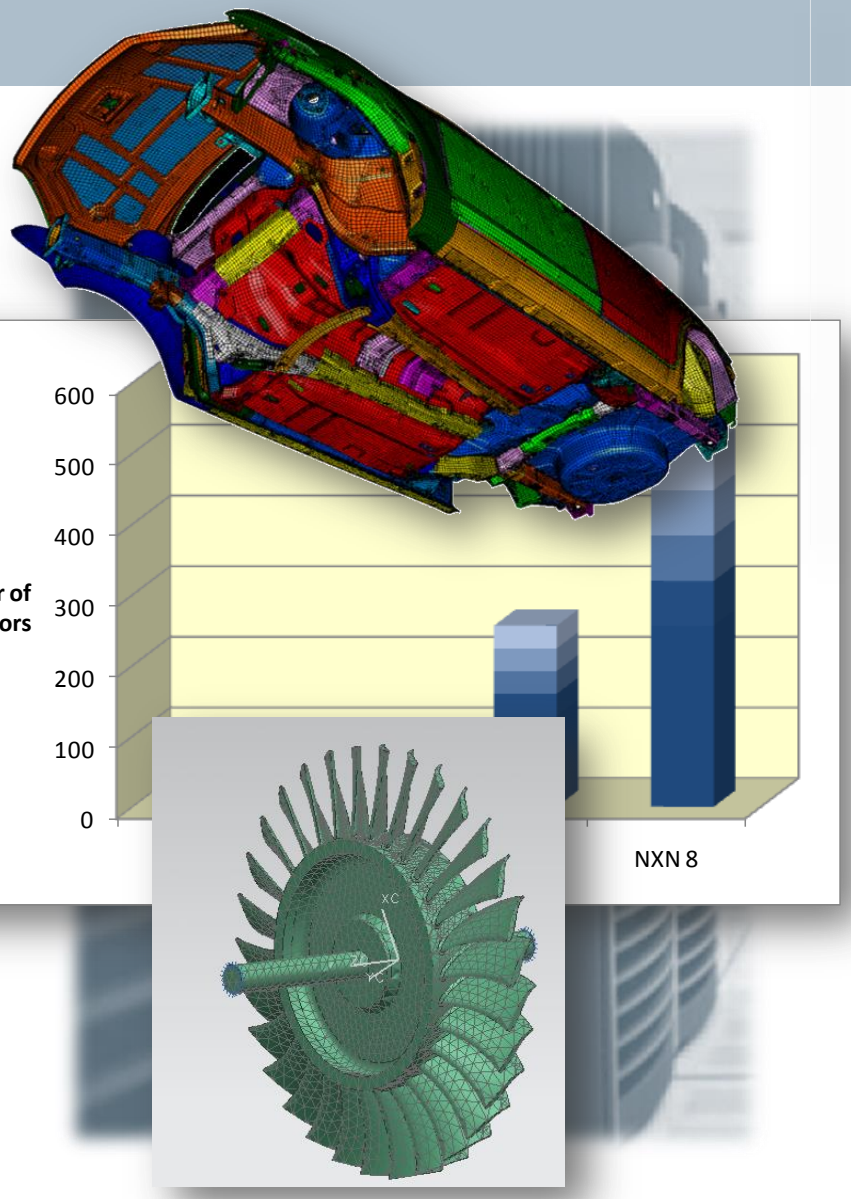
- HDModes - Most scalable Lanczos Modal parallel processing
- RDModes – Most scalable automated substructuring

Large Memory Solution Improvements

- First Nastran provider with full support 64-bit integers (ILP-64) – eliminate previous 8 GB RAM limit

Algorithm Improvements

- Iterative Solver Implementation
- Lanczos Eigen Solver Performance Improvement
- Complex Eigen Solver
- Sparse Date Recovery
- Acoustic C
- I



"I can drive the analysis so that results are available in time to influence the design"

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Development Focus
Process Improvements

Linear Contact
- Linear surface-to-surface contact in SOL 101
- Shell and solid element faces
- Wide range of applications
  - Bolted components and Bearings

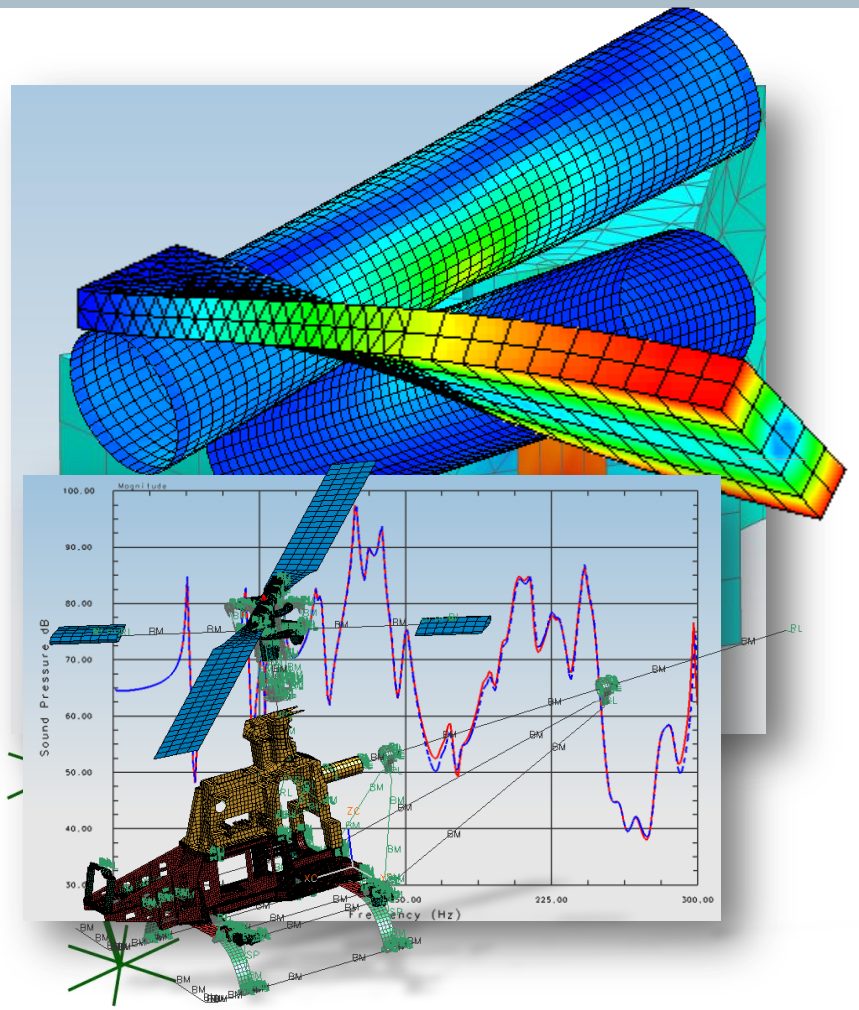
Glue Connections
- Easy way to connect dissimilar meshes.
- Surface-to-surface, Edge-Surface, Edge-Edge connections

Bolt Preload Connections
- Easy to input bolt loadings
- Preload for modal analysis

Dynamics Enhancements
- Acoustics
- MBD Interfaces
- Modal Contributions
- Random Analysis
- Initial Conditions for Transient

Element Enhancements
- CQUADR Enhancement
- CPYRAM for pyramids
- Axis-symmetry / Plane Stre
- Composites
- C
-

Ge
-
-
- ponse for SOL 200



"Glue connections are a huge step forward and are saving us significant modeling time."

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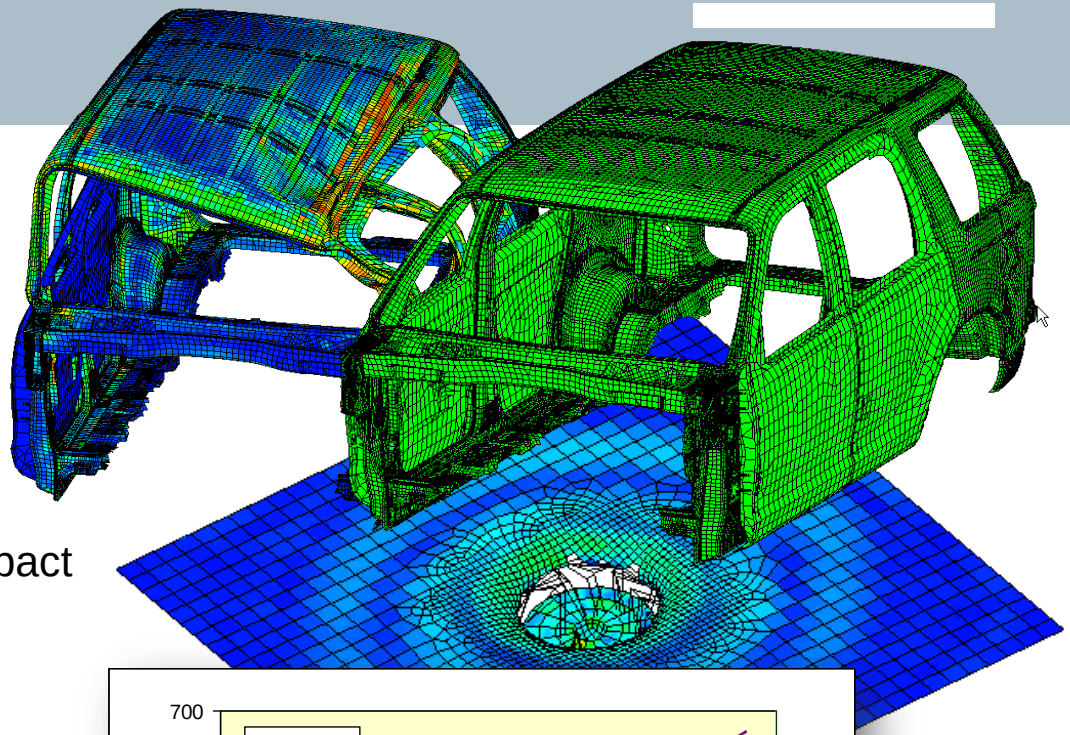
Discipline Extensions



Advanced Non-Linear Solution

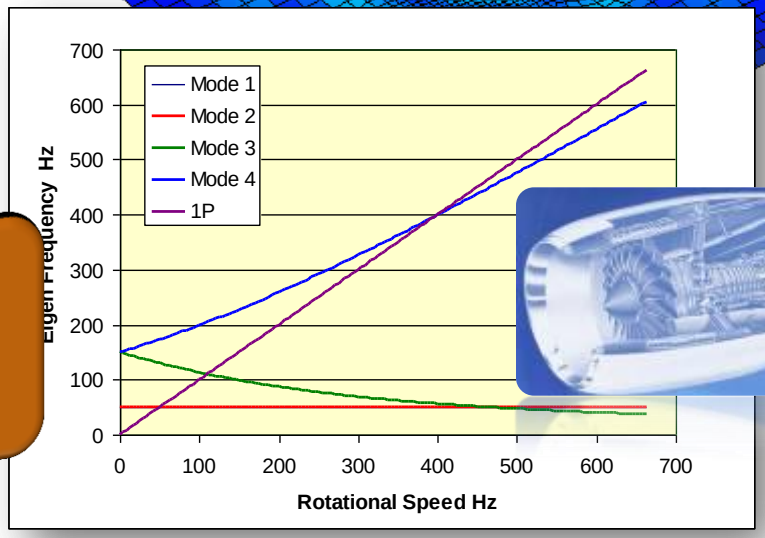
- Complete non-linear capabilities
- Multiple Material Models …
- Static and Dynamic Solutions

Explicit Non-Linear Solution

- Efficient simulation of high-speed impact events or metal forming events

Rotor Dynamics

- Dynamics for rotating systems – shafts, turbines, propellers ….
- Predict whirl frequencies and criti… speeds



"I can do all my simulations in a common modeling format "

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Overview

Special Topics

- **GPU Support**
- Glue and Contact Connections
- Bolt Connections
- Composites
- Non-Linear Simulation

Summary

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GPU Support

Description

- Support GPU hardware for increasing performance

Supported Hardware:

- NVIDIA Tesla K40
- AMD Firepro W9100
- Intel Xeon Phi 7120D

Applications

- Large modal frequency response solution
- Large static solutions with sparse matrices

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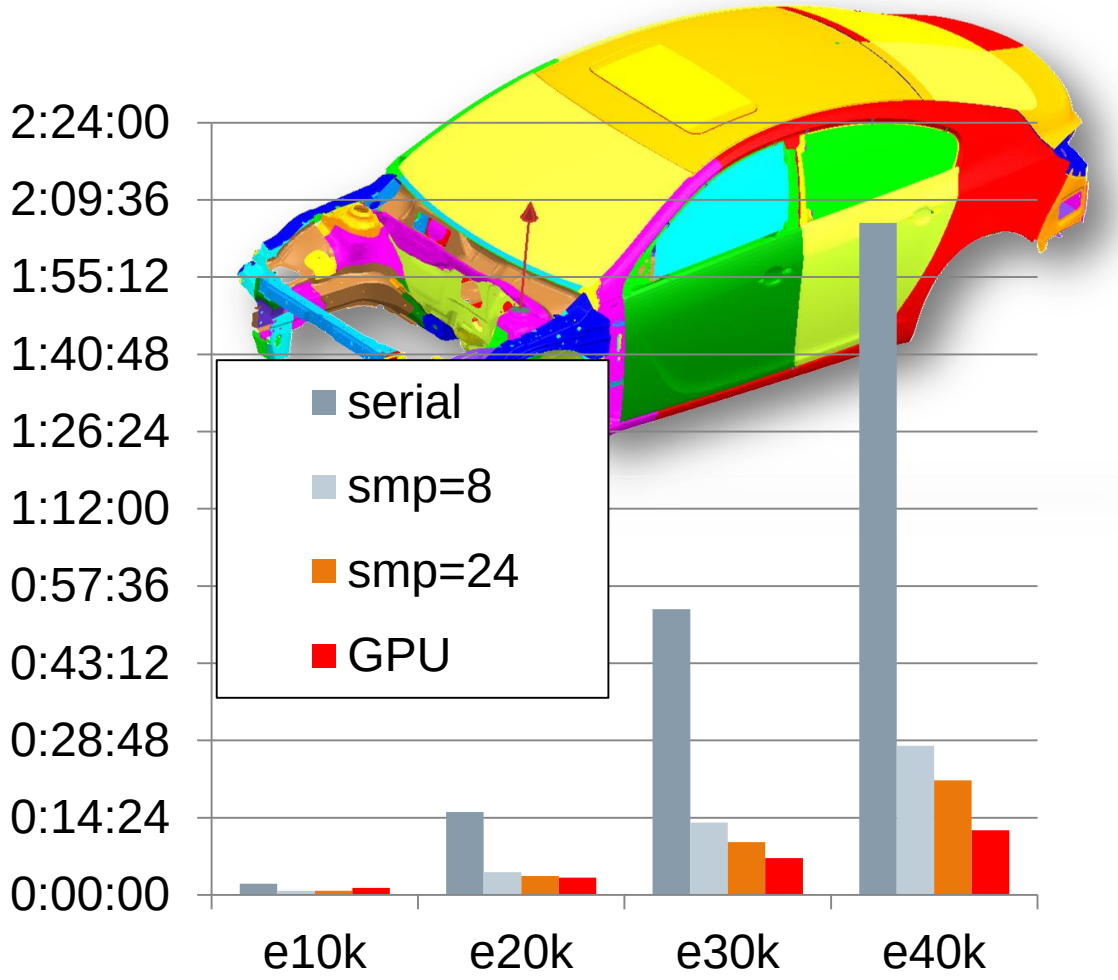
Example GPU Performance
Modal frequency response (FRRD1 module)

- FRRD1 demo
  - 24 core Magny-Cours
  - Tahiti GPU (4GB)
- Modes up to given frequency
  - E10k = 1785 modes
  - E20k = 3631 modes
  - E30k = 5576 modes
  - E40k = 7646 modes
- GPU memory exhausted at ~10k modes



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Overview

Special Topics

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Summary

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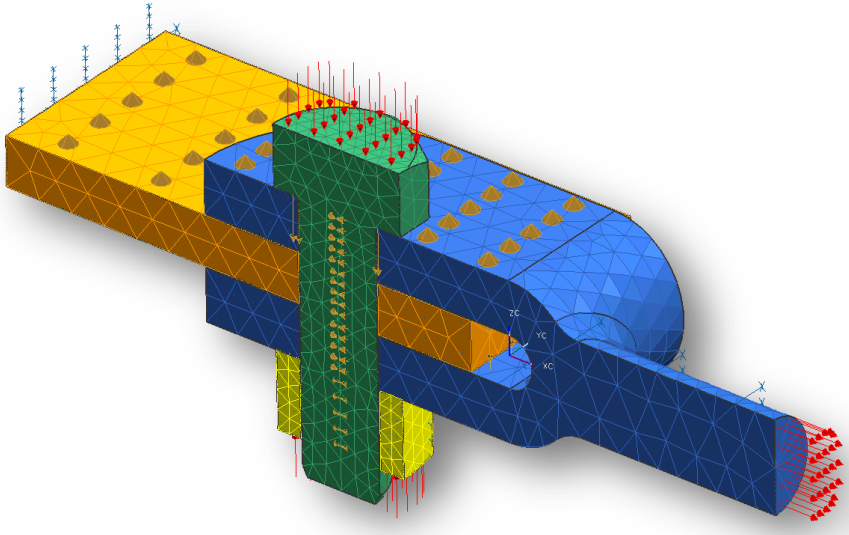
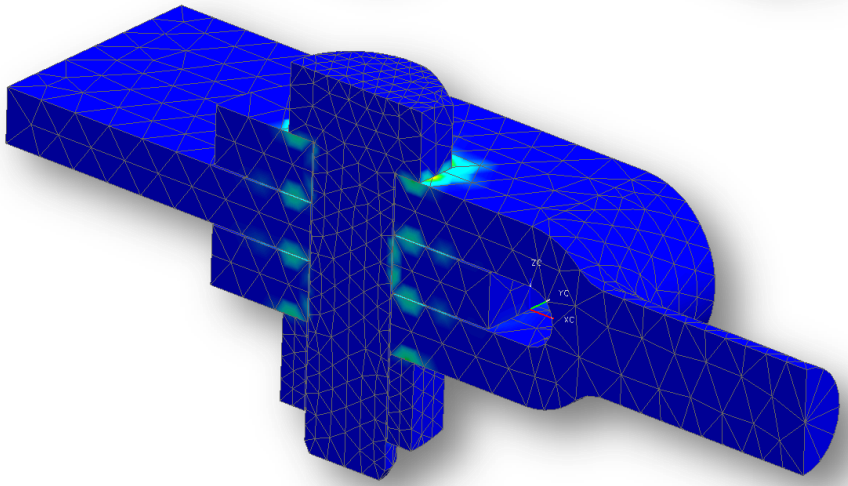
Linear Contact





Description

- Surface-to-surface contact in linear statics solution
- Shell and solid element faces
- Non-compatible mesh faces
- Friction effects
- Use as static differential stiffness in dynamic solutions

Benefit

- Fast, accurate contact solution for simulations that are otherwise linear

Typical Applications

- Bolted components
- Bearings

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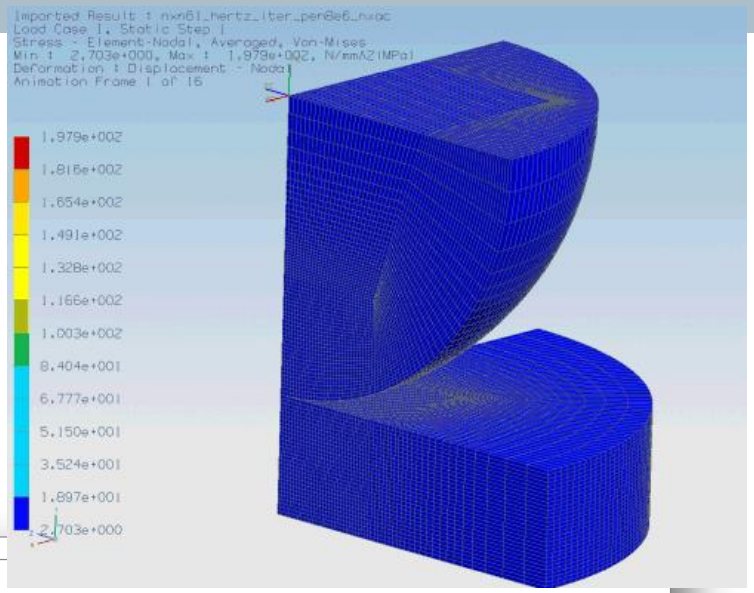
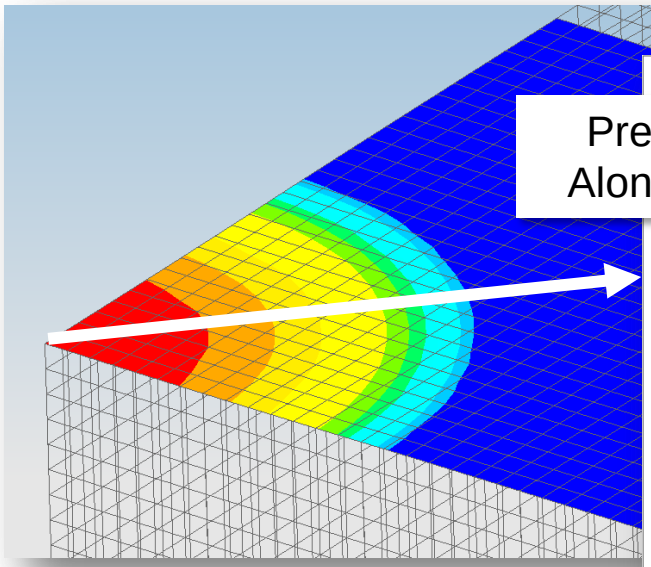
Contact Accuracy

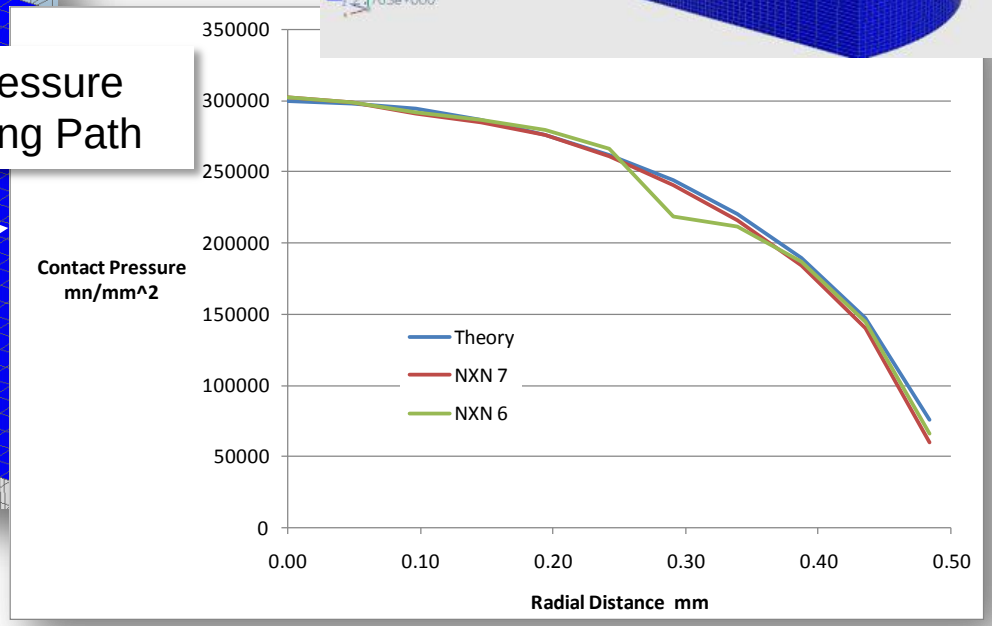
Advanced Technology

- Proprietary mesh refinement technique
- Gives smooth, accurate pressure contours
- Validated with hertzian contact analytical solution





Pressure Along Path



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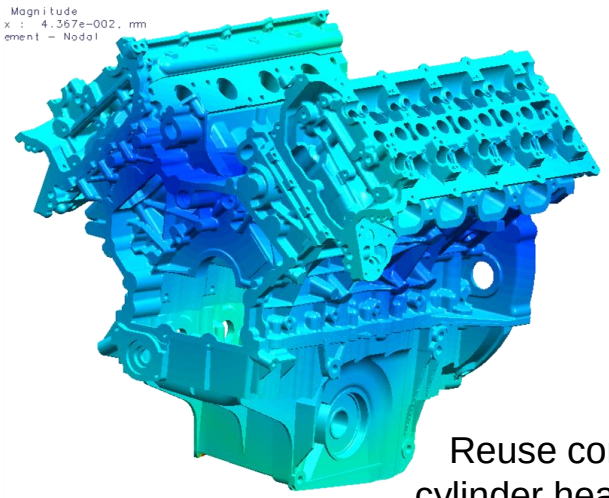
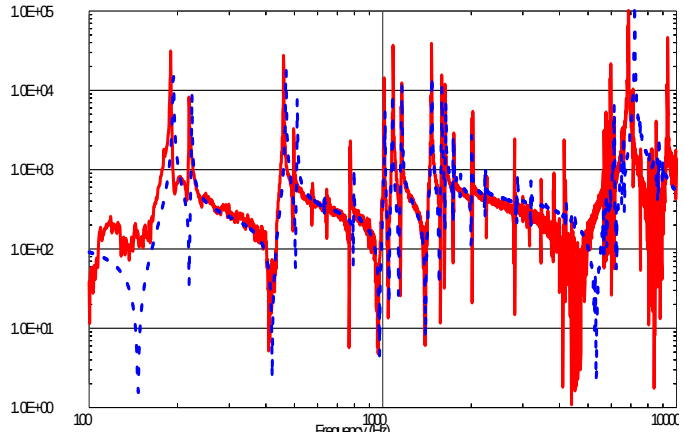
Contact Reuse



Reuse contact from cylinder head bolt loads analysis in a dynamic analysis



Description

- Optional output of DMIG matrix of final contact stiffness connections
- Reuse contact connectivity in subsequent solutions

Implementation

- Set PARAM, KGGCPCH, 1 in contact solution
- Include DMIG matrix in subsequent analysis bulk data by including case control:
  - K2GG = KGGC

Benefits

- Include effect of contact without having to re-solve contact condition
- Saves solution time

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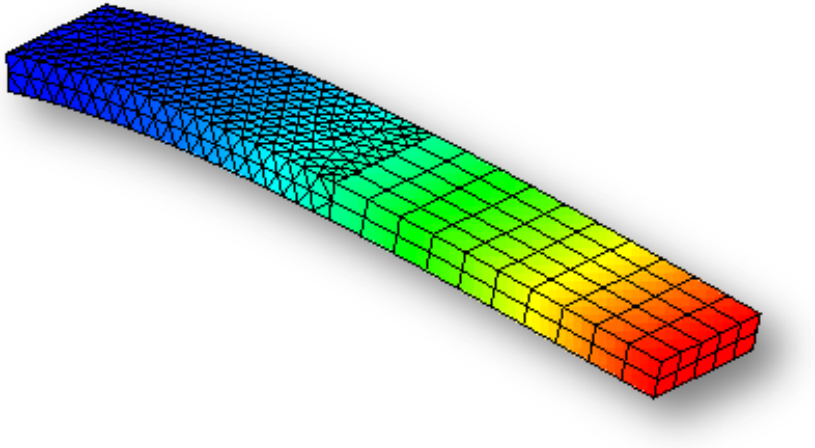
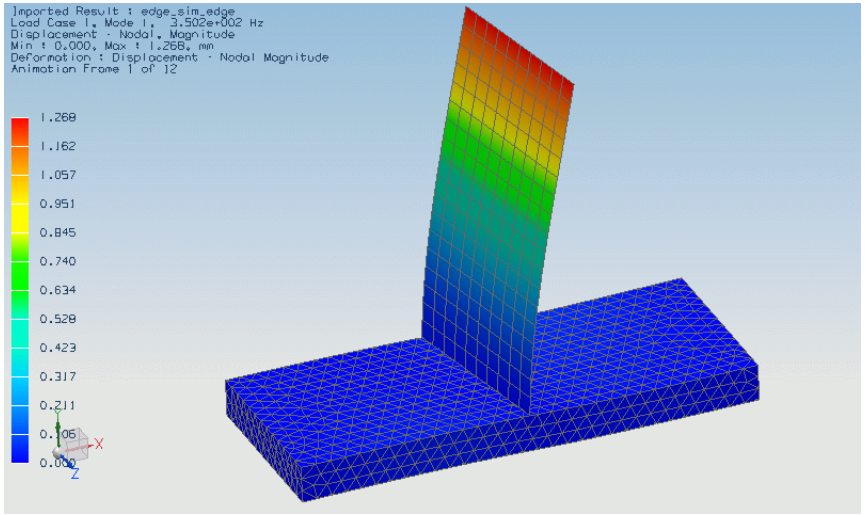
Glue Connection





Description

- Easy to connect dissimilar meshes.
- Types:
  - Surface-to-surface
  - Edge-to-surface
  - Edge- Edge
- Uses same cards to define contact surfaces
- Applies to all NX Nastran Solution

Benefits

- Significantly simplifies modeling
- Accounts for moment transfer between shells and solids
- Improved accuracy for mid-surface modeling

Applications

- Powertrain systems/Automotive body
- Aerospace systems

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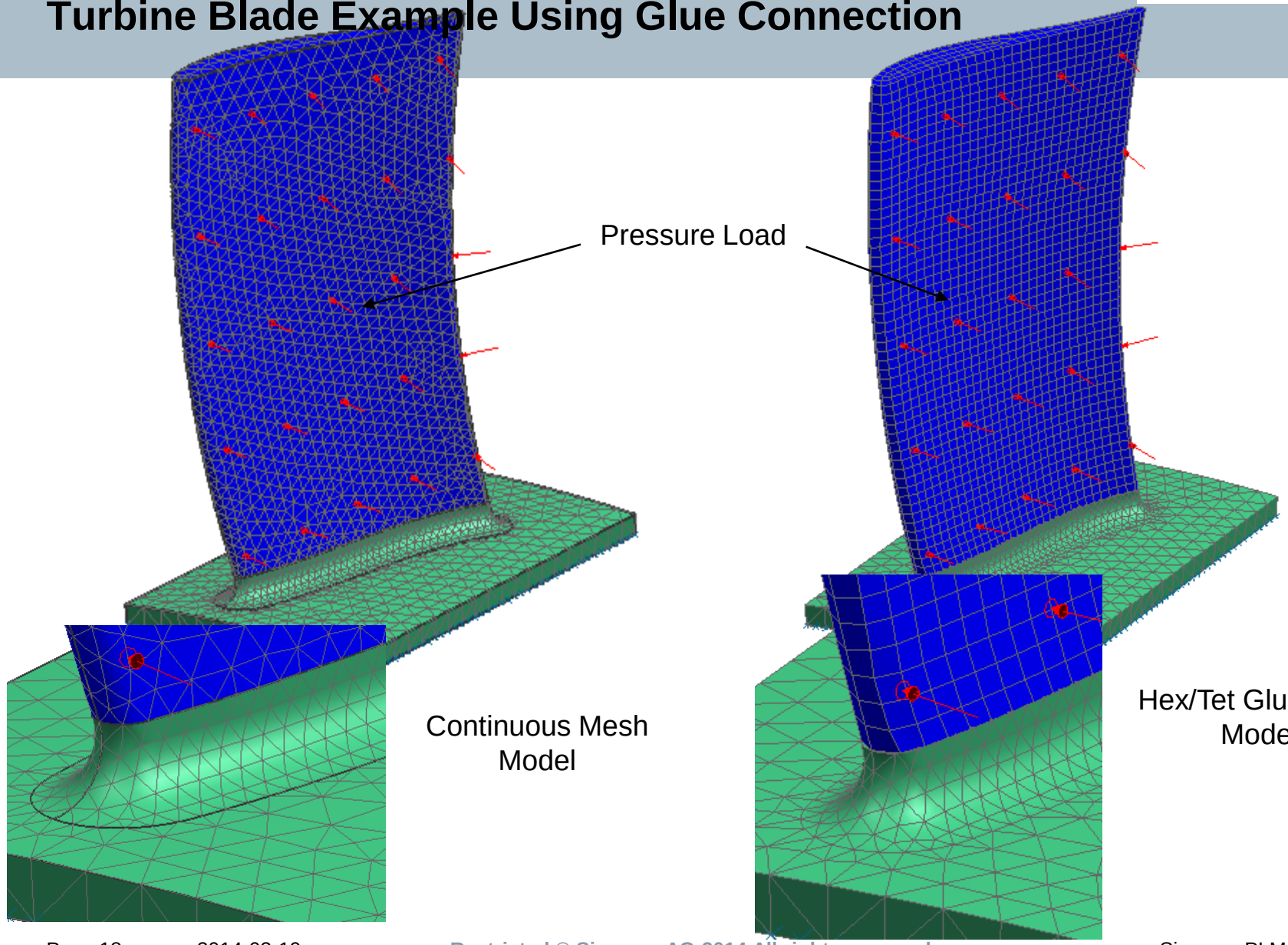
Turbine Blade Example Using Glue Connection



Continuous Mesh Model

Hex/Tet Glue Mesh Model

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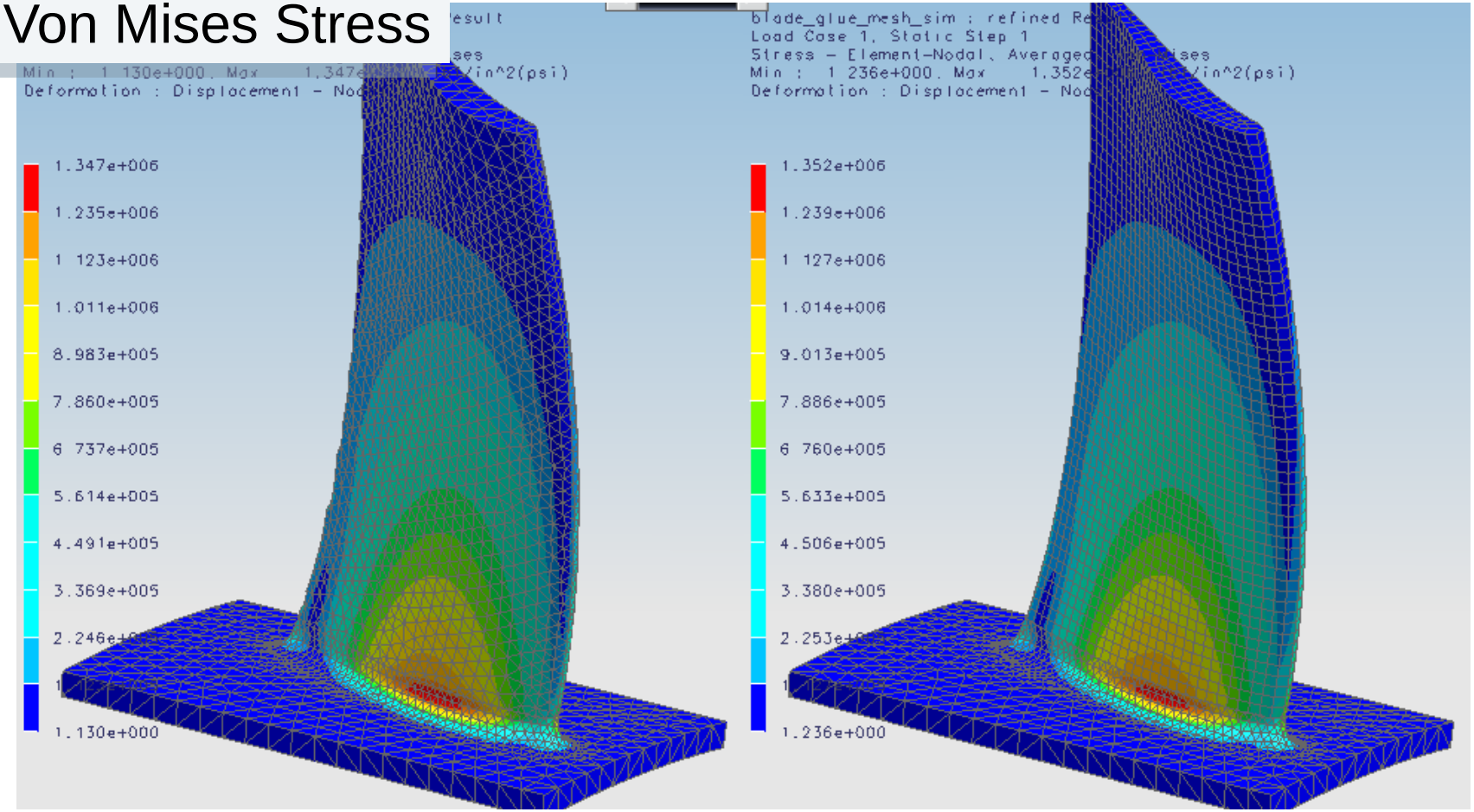
Turbine Blade Example Using Glue Connection

Von Mises Stress



Continuous Mesh Model

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Turbine Blade Example Using Glue Connection

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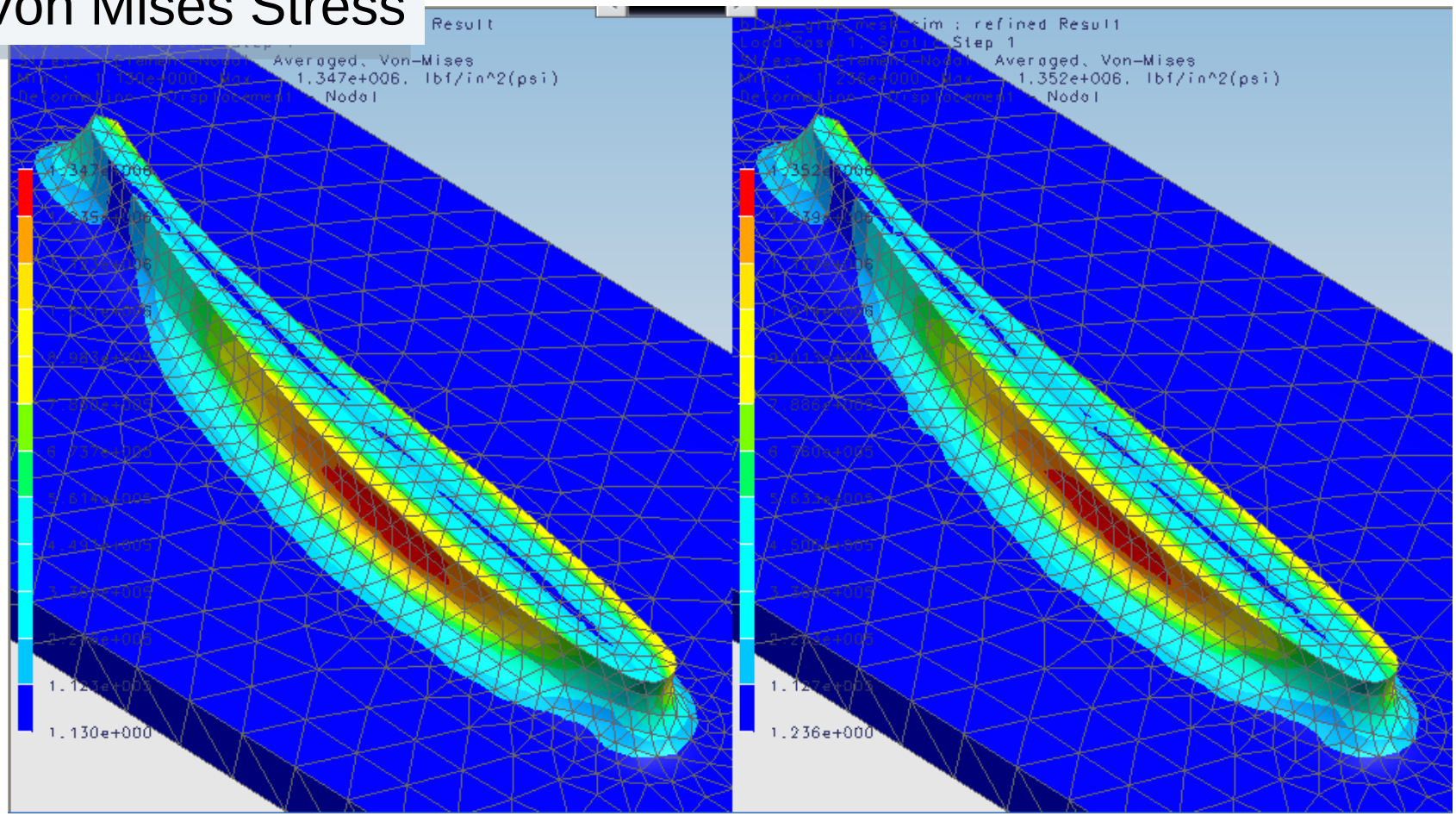

Continuous Mesh Model

Hex/Tet Glue Mesh Model

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Edge-to-Surface Glue for More Accurate Mid-Surface Modeling

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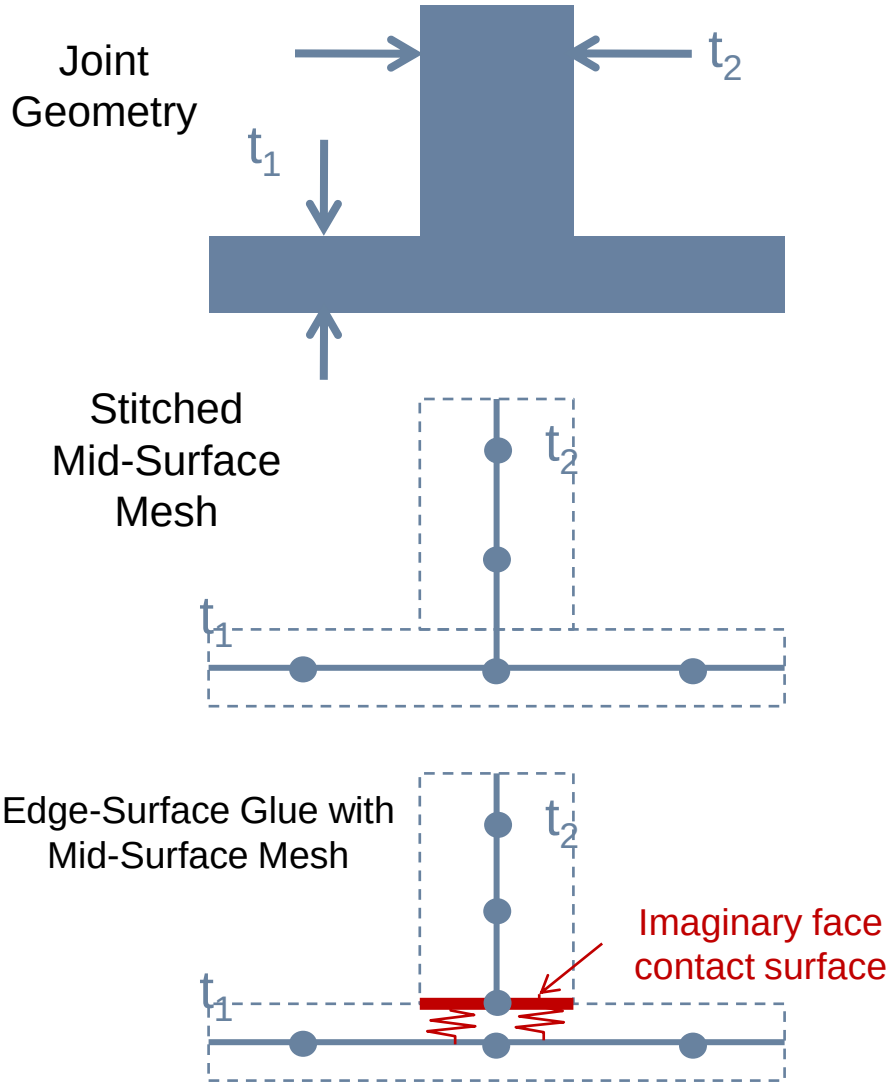
Standard Mid-Surface Modeling
- Requires stitching mesh
- Joint stiffness is too flexible

Mid-Surface with Glue Connection
- Mesh stitching not required – simplifies modeling
- Thickness effects at joints more accurate

Glue connection details
- Imaginary rigid face created perpendicular to glue edge
- Surface-surface contact made between imaginary face and glue face



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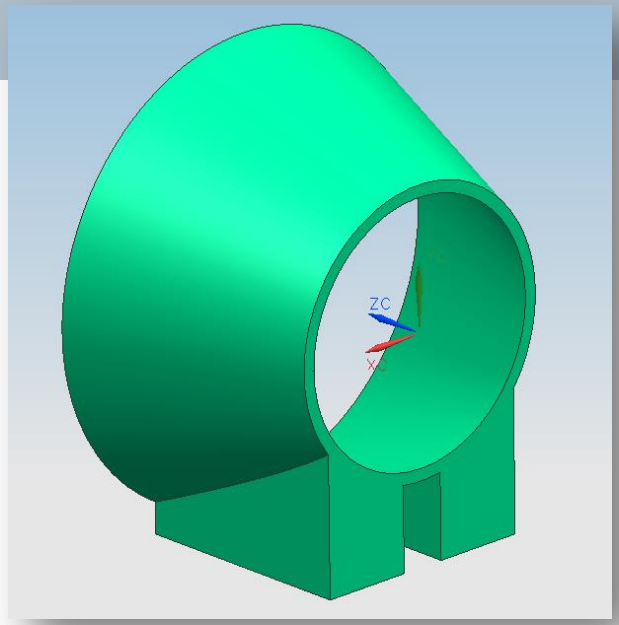
Mid-Surface Example

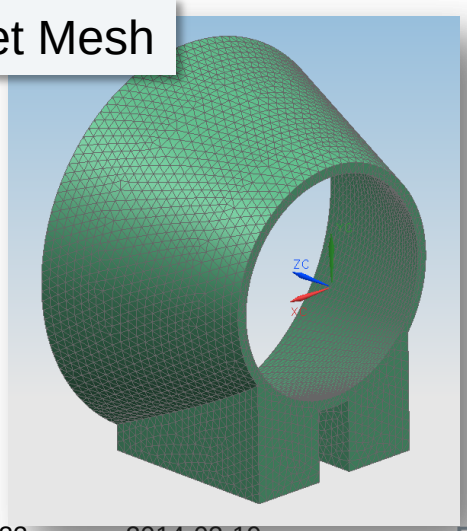


Geometry
- Thin cone with thick pedestals

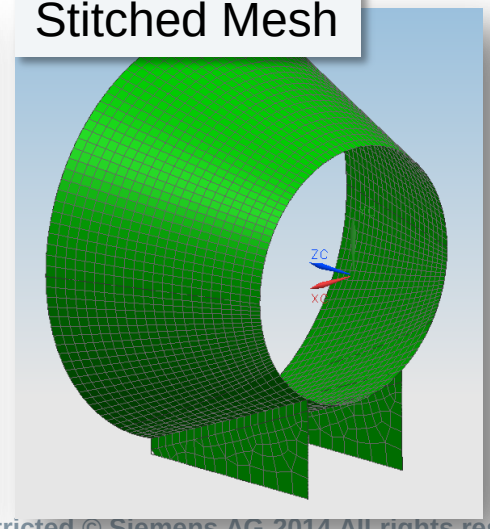
Model Mesh
- Solid parabolic tets – Exact
- Mid-surface stitched
- Mid-surface with edge-face glue connection

Solution
- Modal analysis of free-free modes

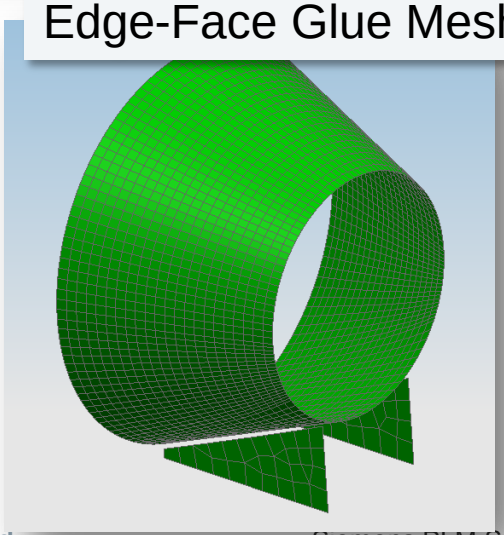
Tet Mesh



Stitched Mesh



Edge-Face Glue Mesh



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Mid-Surface Example – Frequency Comparison

Mode Number	Tet Mesh Modes (Hz)	Stitched Mesh Modes (Hz)	Stitched Mesh Modes %Diff	Glue Mesh Modes (Hz)	Glue Mesh Modes %Diff
7	2440	2046	16.15	2384	-2.28
8	2572	2099	18.39	2573	0.05
9	5155	3560	30.94	5088	-1.29
10	5768	4332	24.90	5645	-2.13
11	6883	5162	25.00	6810	-1.07
12	7481	5778	22.76	7396	-1.13
13	10460	8743	16.41	10714	2.46
14	12690	8771	30.88	12286	-3.22
15	12730	9669	24.05	12547	-1.41
16	15750	13090	16.89	15388	-2.32
17	18260	13110	28.20	18157	-0.55
18	20140	14260	29.20	19778	-1.78
19	23530	17510	25.58	22830	-2.99
20	24510	19280	21.34	24061	-1.82
21	28540	20290	28.91	28402	-0.49
22	30380	22530	25.84	29876	-1.64
23	31010	24580	20.74	31566	1.79
24	32770	25690	21.61	32809	0.11
25	35330	27300	22.73	35605	0.77
26	37050	33000	18.22	36970	-0.22
RMS Error			23.90		1.73

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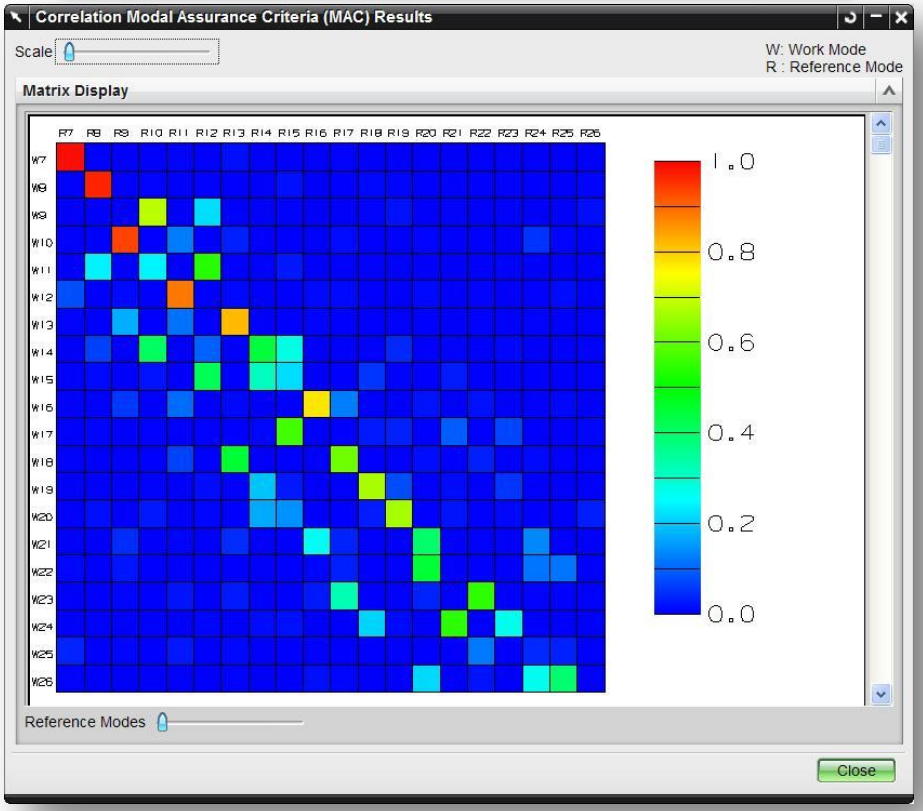
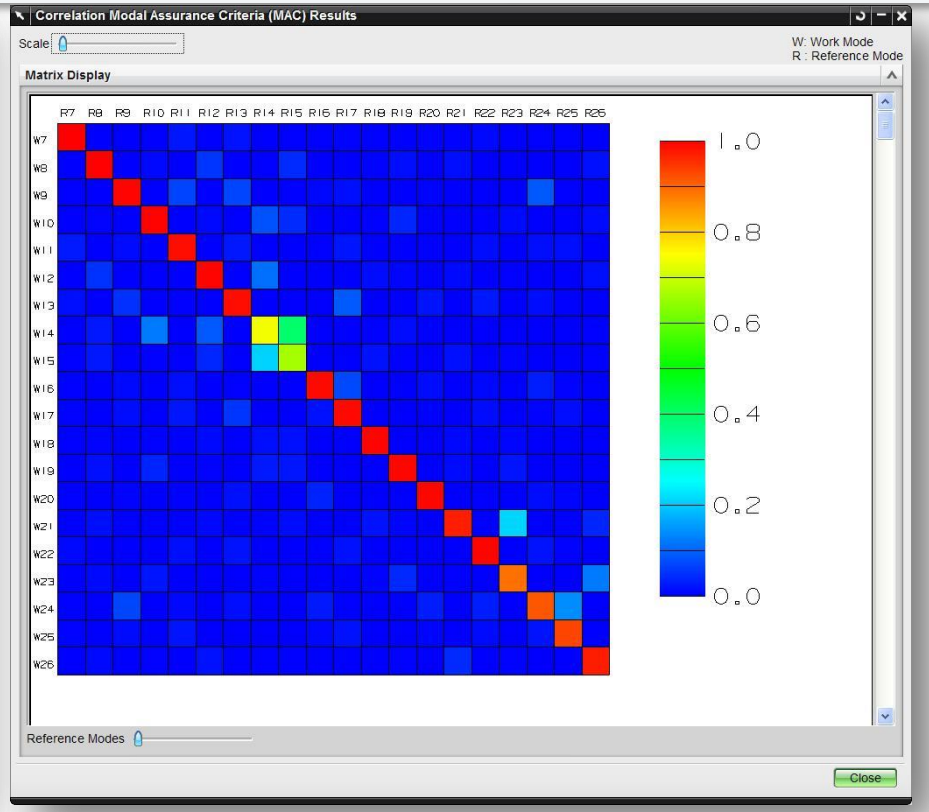
Mid-Surface Example – Mode Shape Comparison

MAC – Tet Mesh vs. Stitched Mesh



MAC – Tet Mesh vs. Edge-Face Glue Mesh



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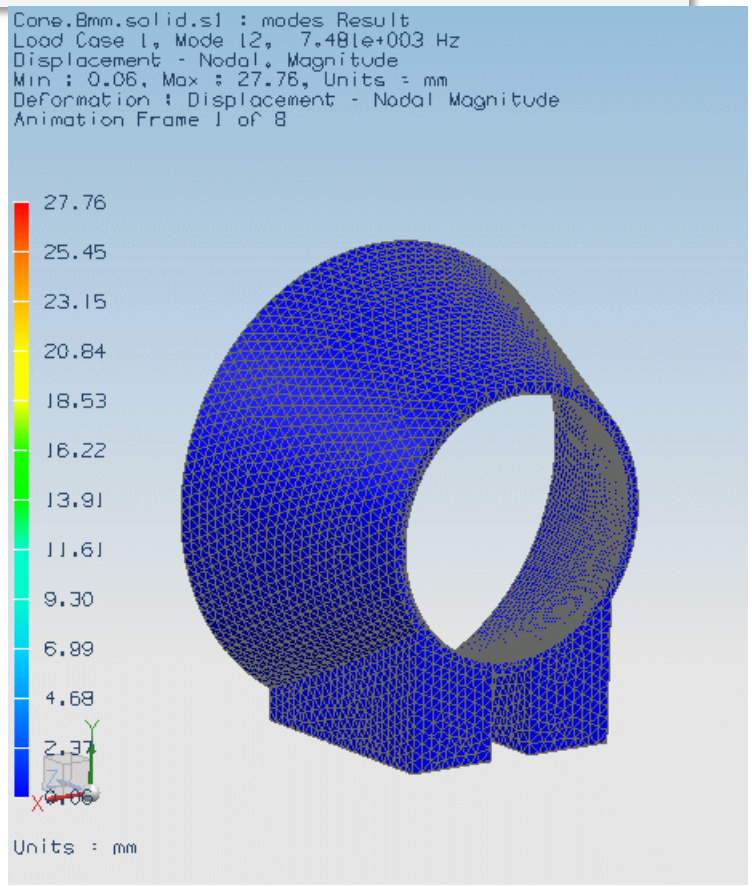
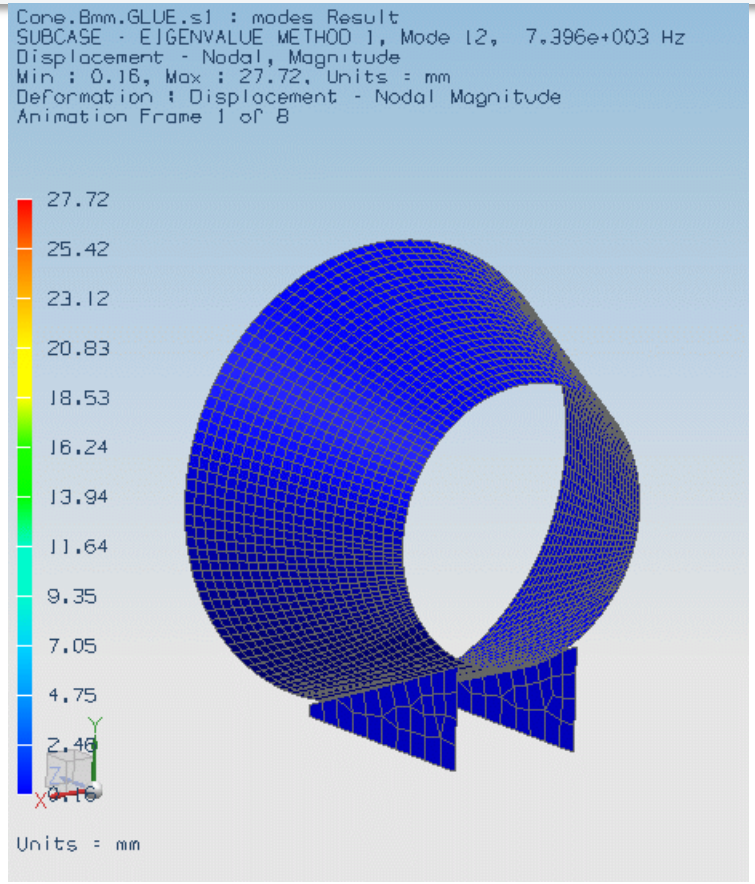
Mid-Surface Example – Mode Shape Comparison

Mode 12 – Tet Mesh vs. Stitched Mesh



Mode 12 - Tet Mesh vs. Edge-Face Glue Mesh



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Overview

Special Topics

- GPU Support
- Glue and Contact Connections
- **Bolt Connections**
- Composites
- Non-Linear Simulation

Summary

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Bolt Preloads

Description

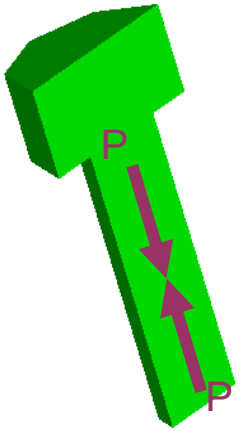
- Pre-tension loads on beam elements or solid elements to simulate bolt preloads
- Used in SOL 101 and as static preload in other solution sequences
- Works with contact
- Internal solution steps
  - 1 – Solve Preload Strain
  - 2 – Apply Preload Strain + Applied Load

Benefits

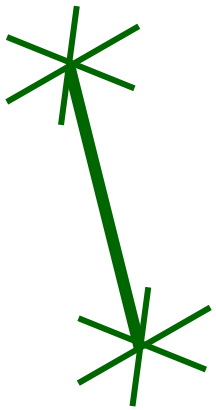
- Easy to set-up bolt loadings

Applications

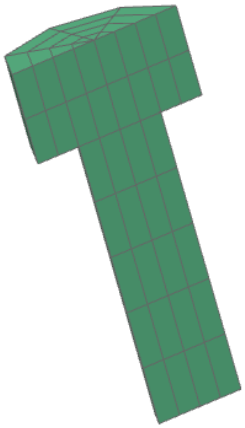
- Powertrain components
- Axle Components
- Machinery



BOLTFOR Load



CBEAM or CBAR Element Representation



CHEXA, CPENTA or CTETRA Element Representation

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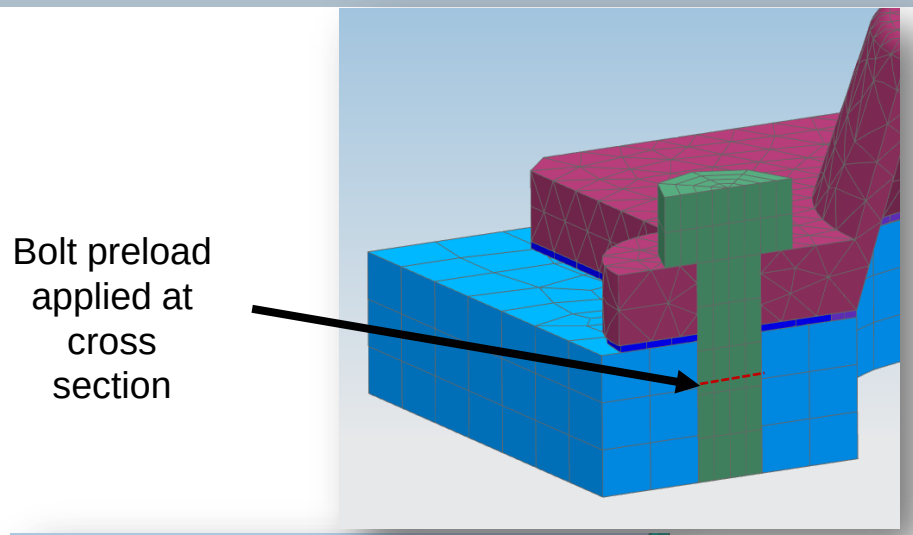
Bolt Preload with Contact

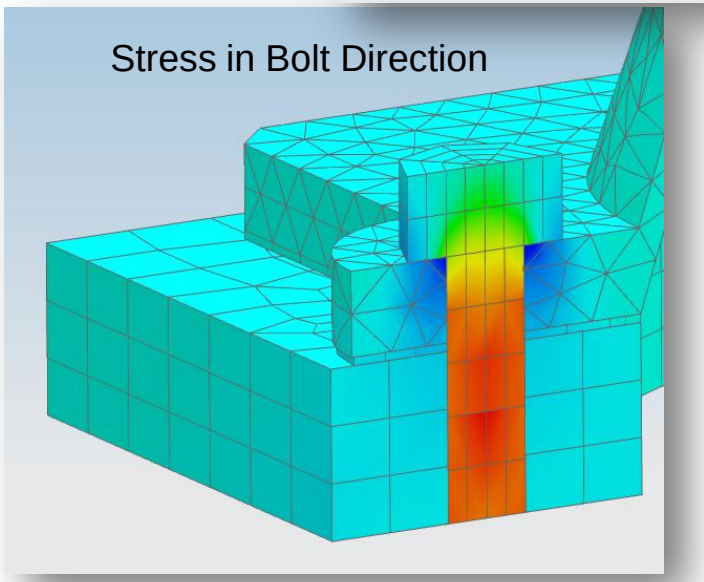
Description

- Typical to model bolts with contact
- Bolt preload establishes contact

Example

- Explicit bolt with Hex and Wedge elements
- Contact between bolt head and cover





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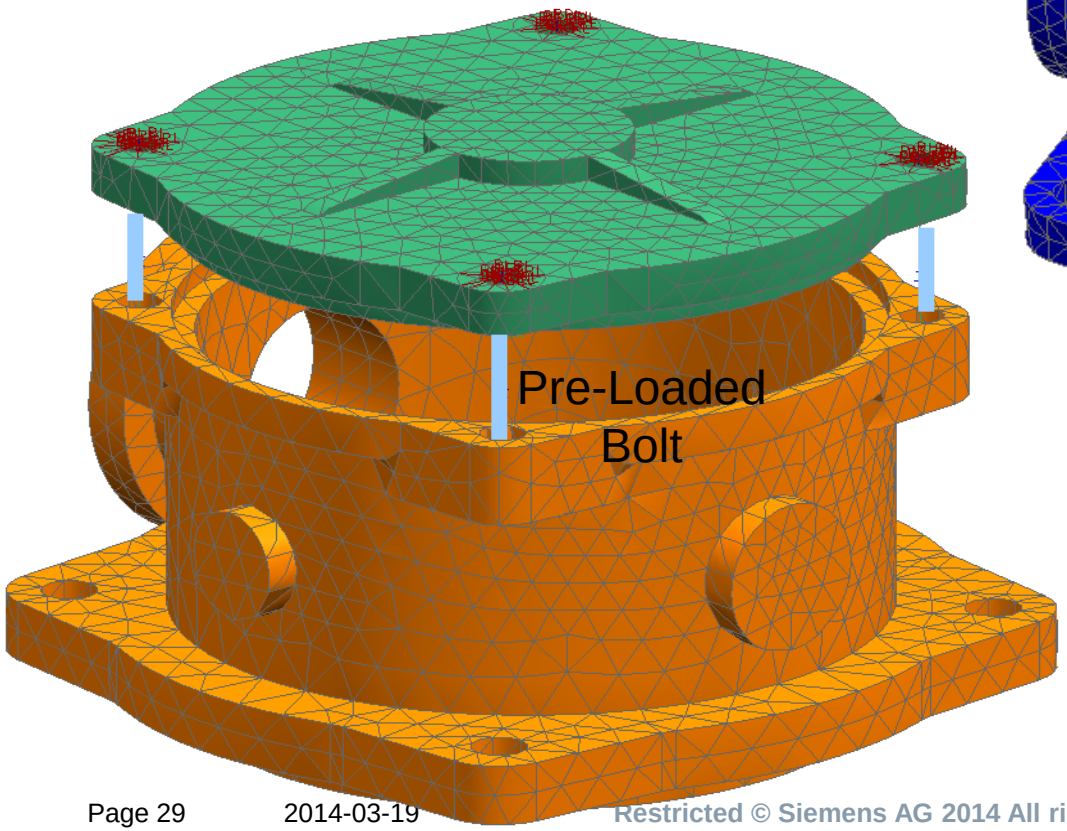
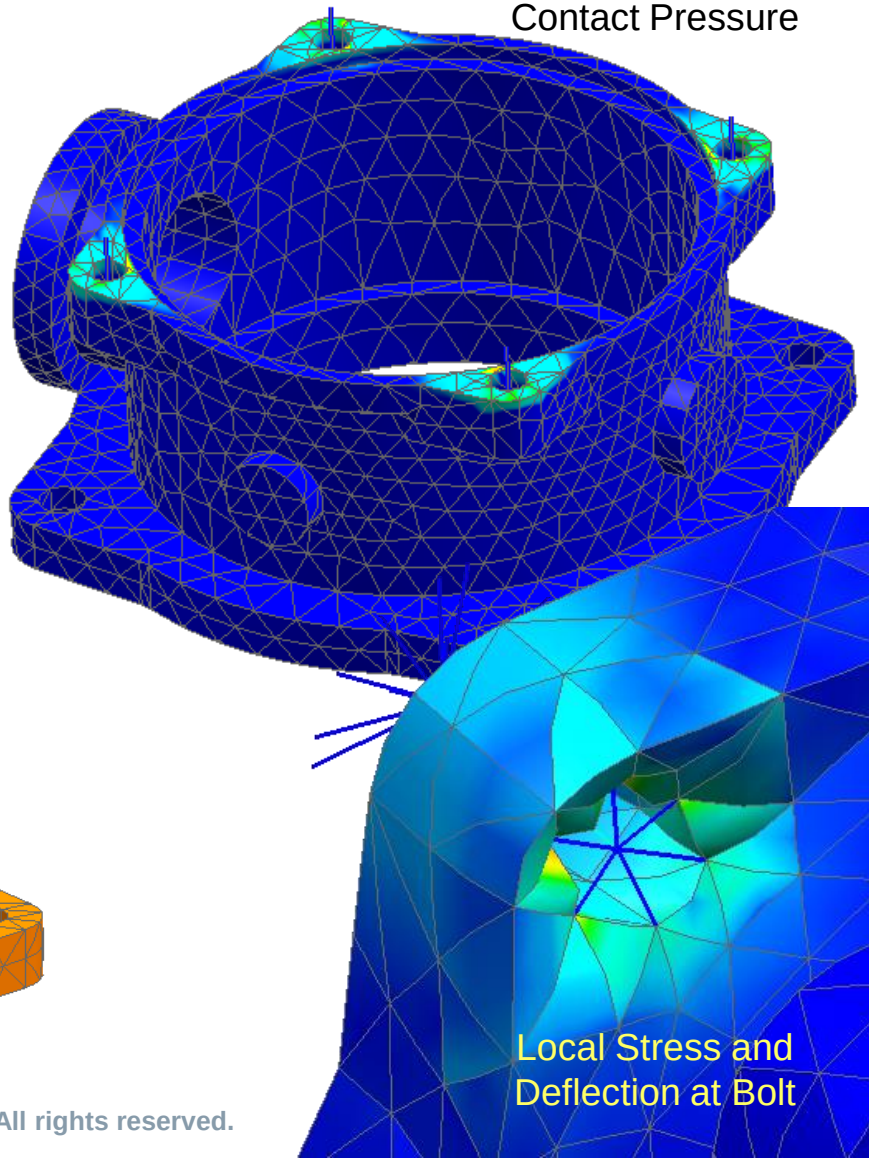
Bolt Preload Example

4 bolts with 500 N preload

Contact between cover and tube casting



Contact Pressure



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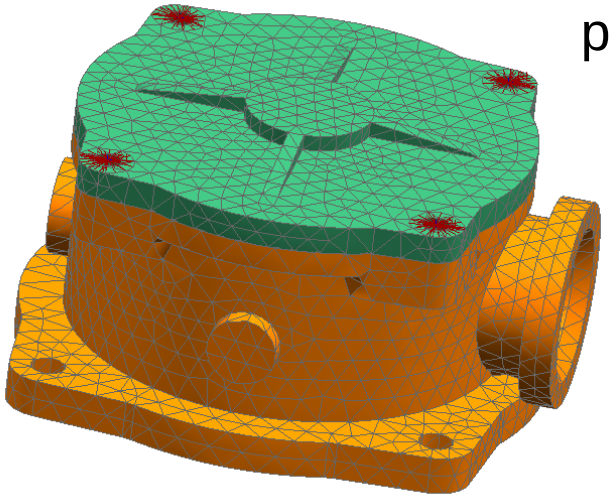
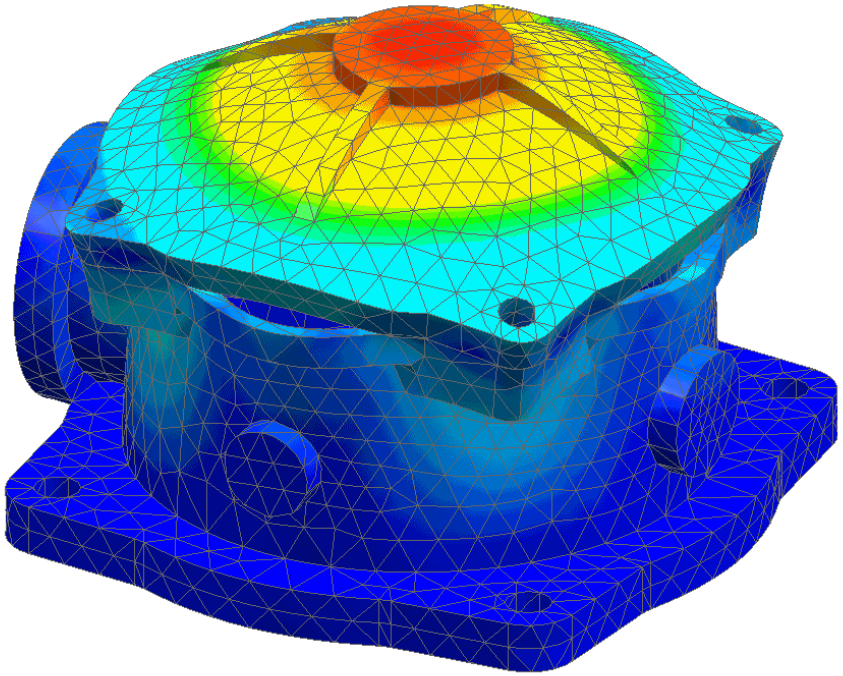
Bolt as Preload for a Modal Solution

Bolt preloads with contact used as preload for modal solution.



Modal Solution with Contact



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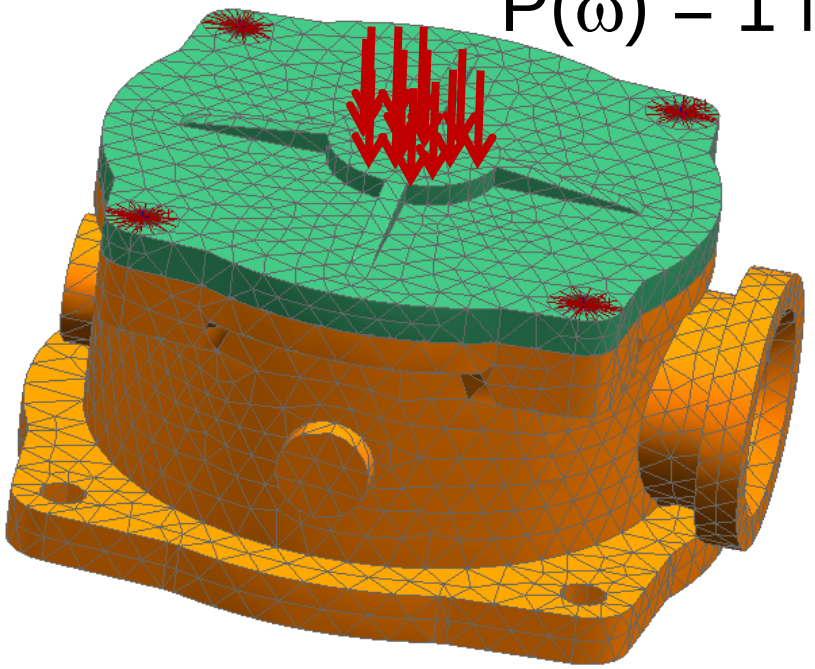
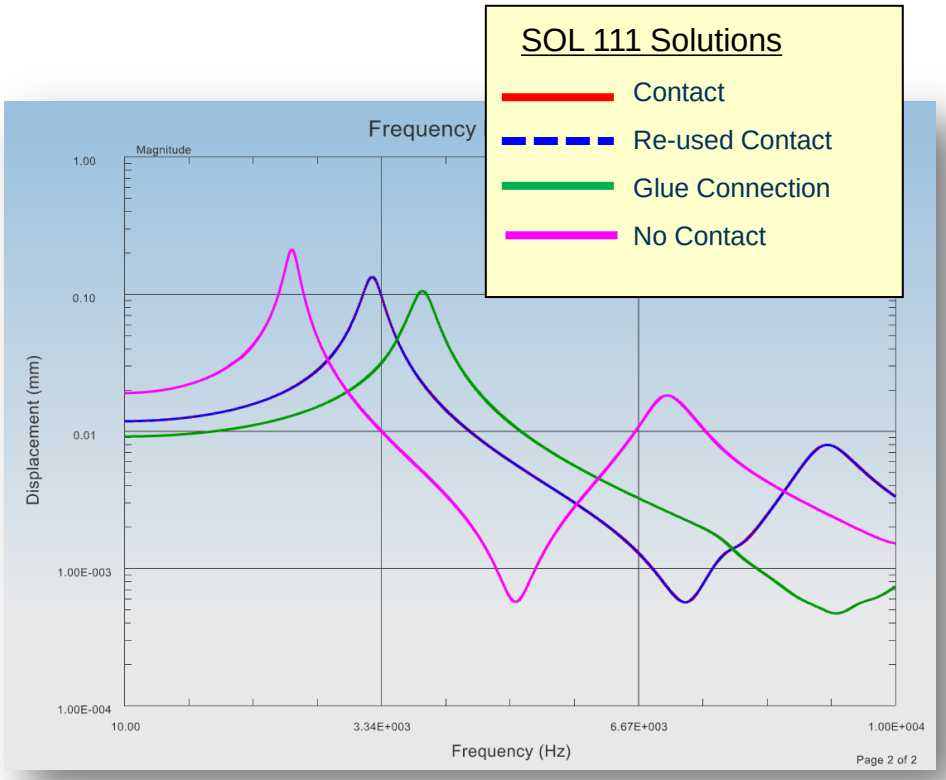
Dynamic Forced Response with Contact

$P(\omega) = 1\ N/mm^2$





- Contact and Re-Used contact give identical results
- Re-Use contact solves 9x faster

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Overview

Special Topics

- GPU Support
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- Bolt Connections
- **Composites**
- Non-Linear Simulation

Summary

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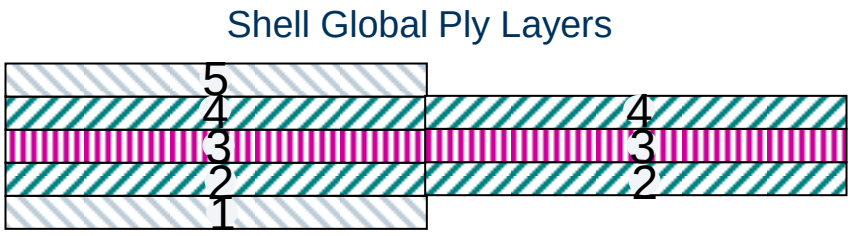
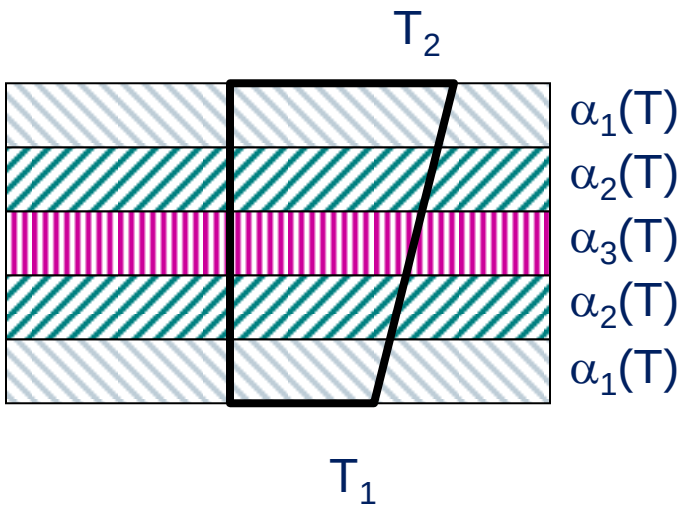
Composite Shell Element Improvements



Global Ply Layers

- User can define ply ID number to individual plies. PCOMPG bulk data.
- Makes possible for post processors to display results on a continuous ply

PCOMPG	PID	Z0	NSM	SB	FT	TREF	GE	LAM	
	GPLYID1	MID1	T1	THETA1	SOUT1				
	GPLYID2	MID2	T2	THETA2	SOUT2				



Temperature Dependence

- Compute smear laminate properties based on temperature gradient
- Created temperature dependent orthotropic materials

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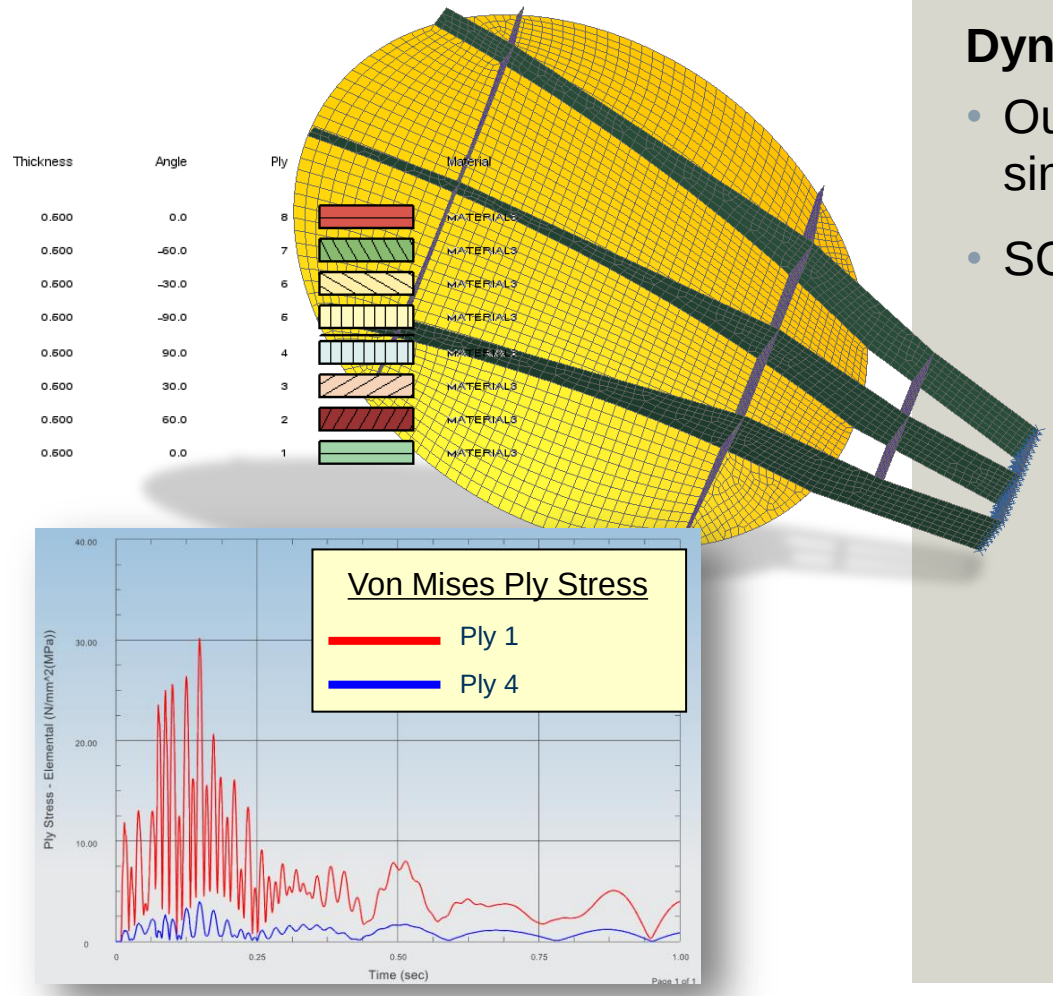
Composite Shell Element Improvements



Dynamic Stress

- Output ply stress for transient simulations
- SOL 112 and 109

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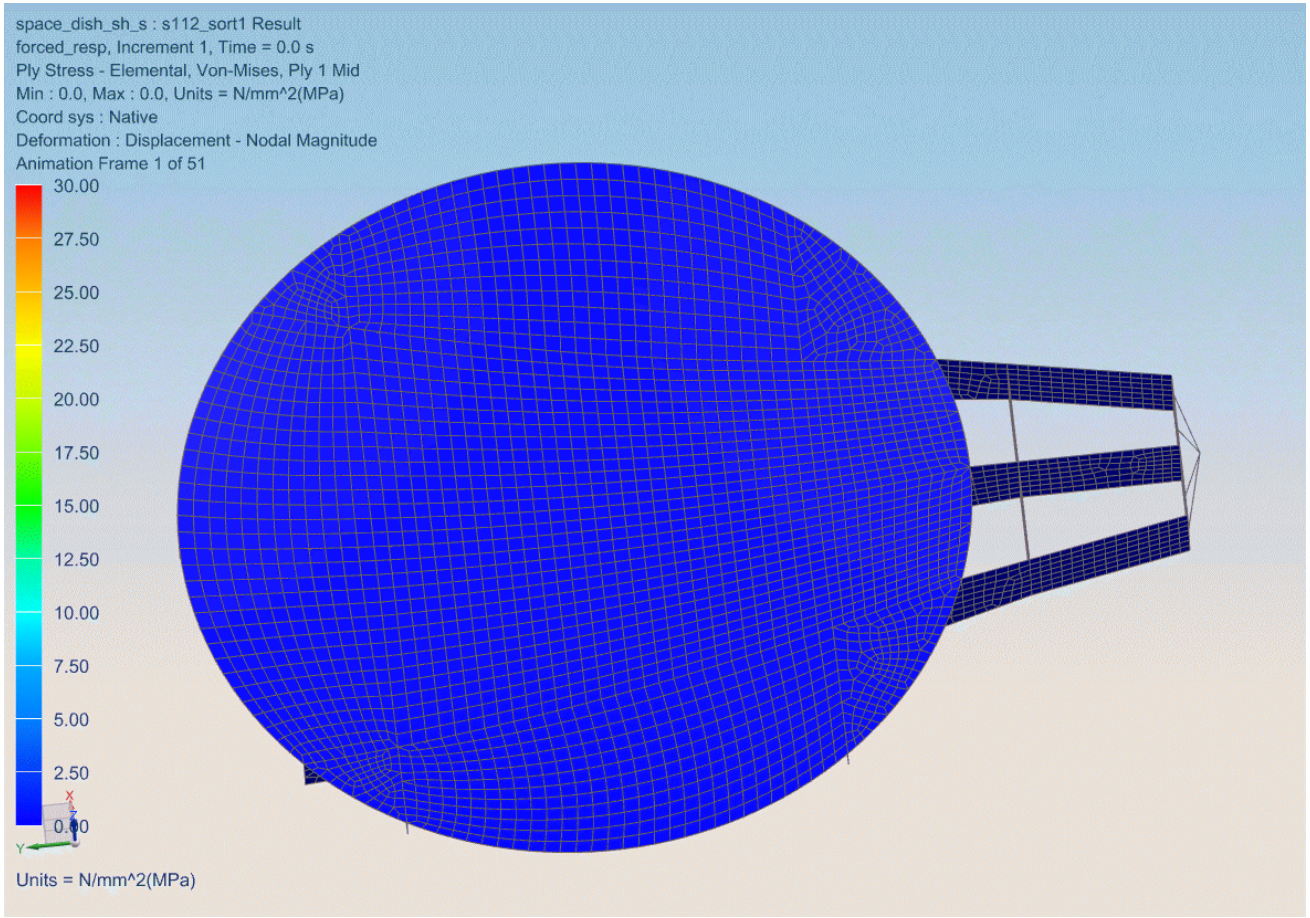
Ply Stress Animation



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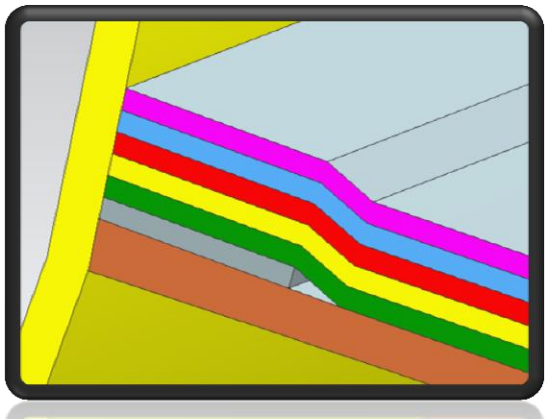
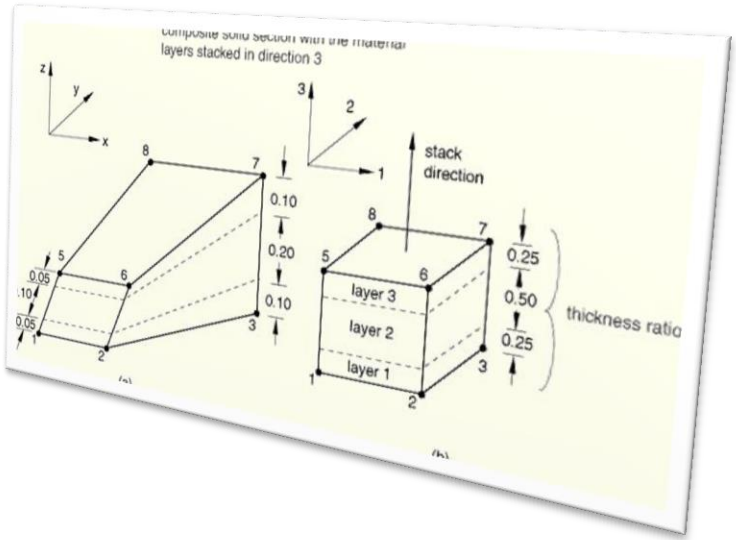
Composite Solid Element





Description

- Model composite ply layers on solid elements
- PCOMPS physical property for composites with solid elements – Hex and Wedge
- Easier method to input material orientation for solids – MATCID

Benefit

- Solid composites give a more geometrically precise representation

Application

- Turbine engines
- Windmill blades
- Automotive bodies of the future

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More Composite Dynamic Output

Description

- Output composite results for frequency domain solutions

Implementation

- Support SOL 111 and SOL 108
- Random and non-random solutions
- Support composite solid and shell elements

Output stress and strain results by ply layers

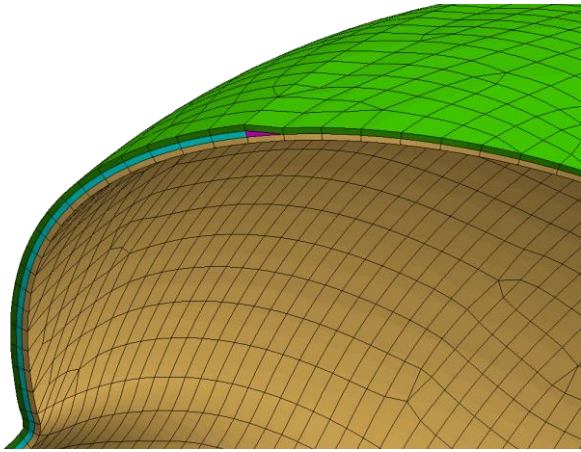
- Real and imaginary for normal and shear

Output Failure Index and Strength Ratio by ply layer

- Output is real
- Use search method to find worst case at each frequency

Value:

- **Composites are often analyzed in dynamic conditions – need to output the results.**



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Overview

Special Topics

- GPU Support
- Glue and Contact Connections
- Bolt Connections
- Composites
- **Non-Linear Simulation**

Summary

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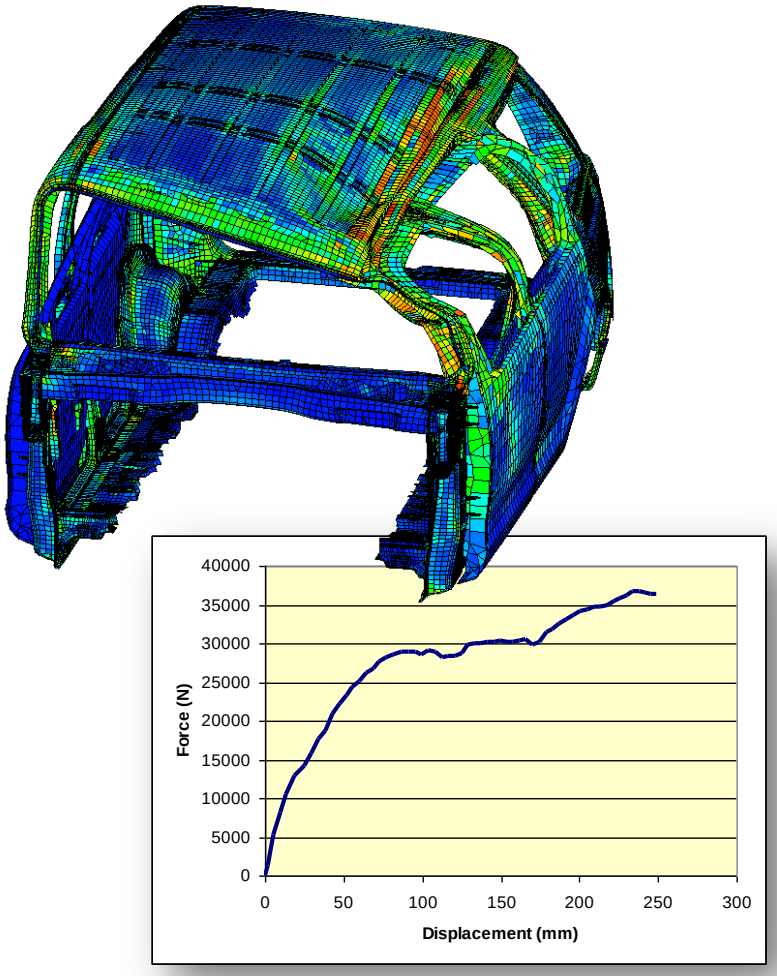
Advanced Non-Linear Solver



Description

- Embedding of an established, recognized non-linear technology - ADINA
- Complete non-linear capabilities
- Large Deflection, Contact Surfaces, Material Nonlinearity
- Materials: Linear, Elastic-Plastic, Gasket Materials, Hyper-elastic, Shape memory alloys
- Static and Dynamic Solutions
- Implicit and Explicit Solutions

Implementation

- Uses NX Nastran input and output formats.
- SOL 601,106 – implicit static
- SOL 601, 129 – implicit dynamic
- SOL 701 – explicit dynamic

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Example – Drop of Thermal Camera

Device

- Thermal imaging camera for detecting heat
- Analyze configuration without handles

Load

- Drop from a height of 1 meter
- Assume lands on side with screen

Evaluate

- Stress and deflections of internal boards

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Camera FE Model

Components

- Case (blue)– polycarbonate material modeled as elastic-plastic
- PCB (green) – epoxy material modeled as linear material
- Electronic Chips (red) – nominal material

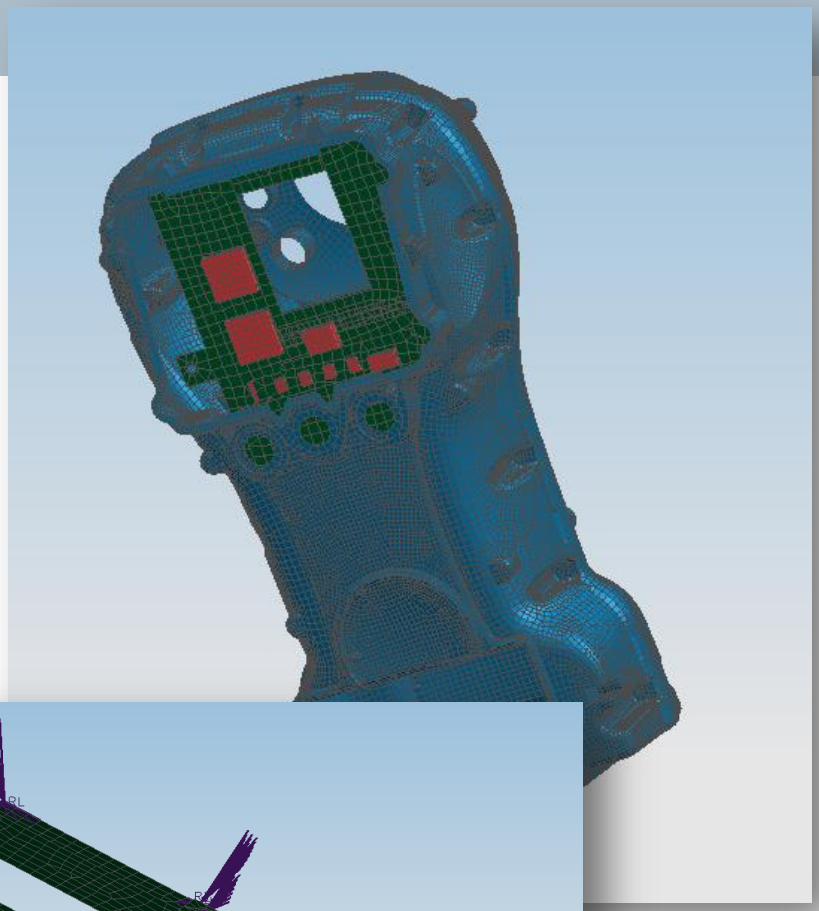
Connections

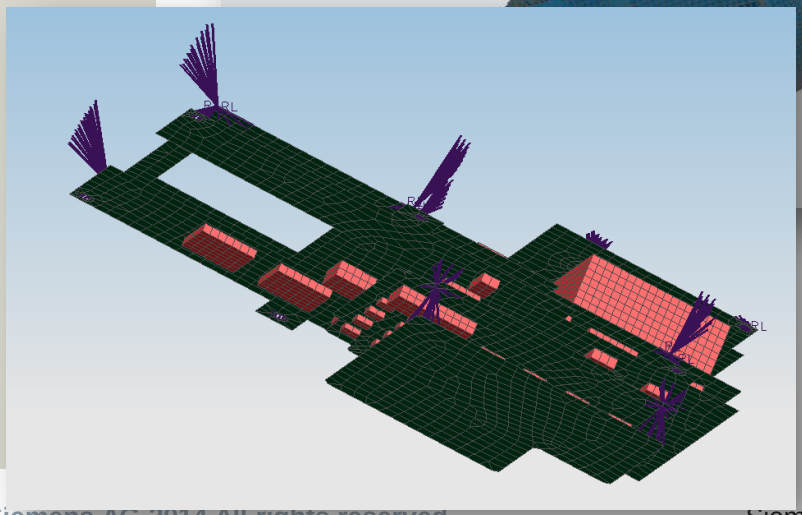
- Rigid elements connect PCB to case
- Glue connects chips to PCB

Solution 601, 129

Model Size

- 52,000 nodes
- 50,000 elements





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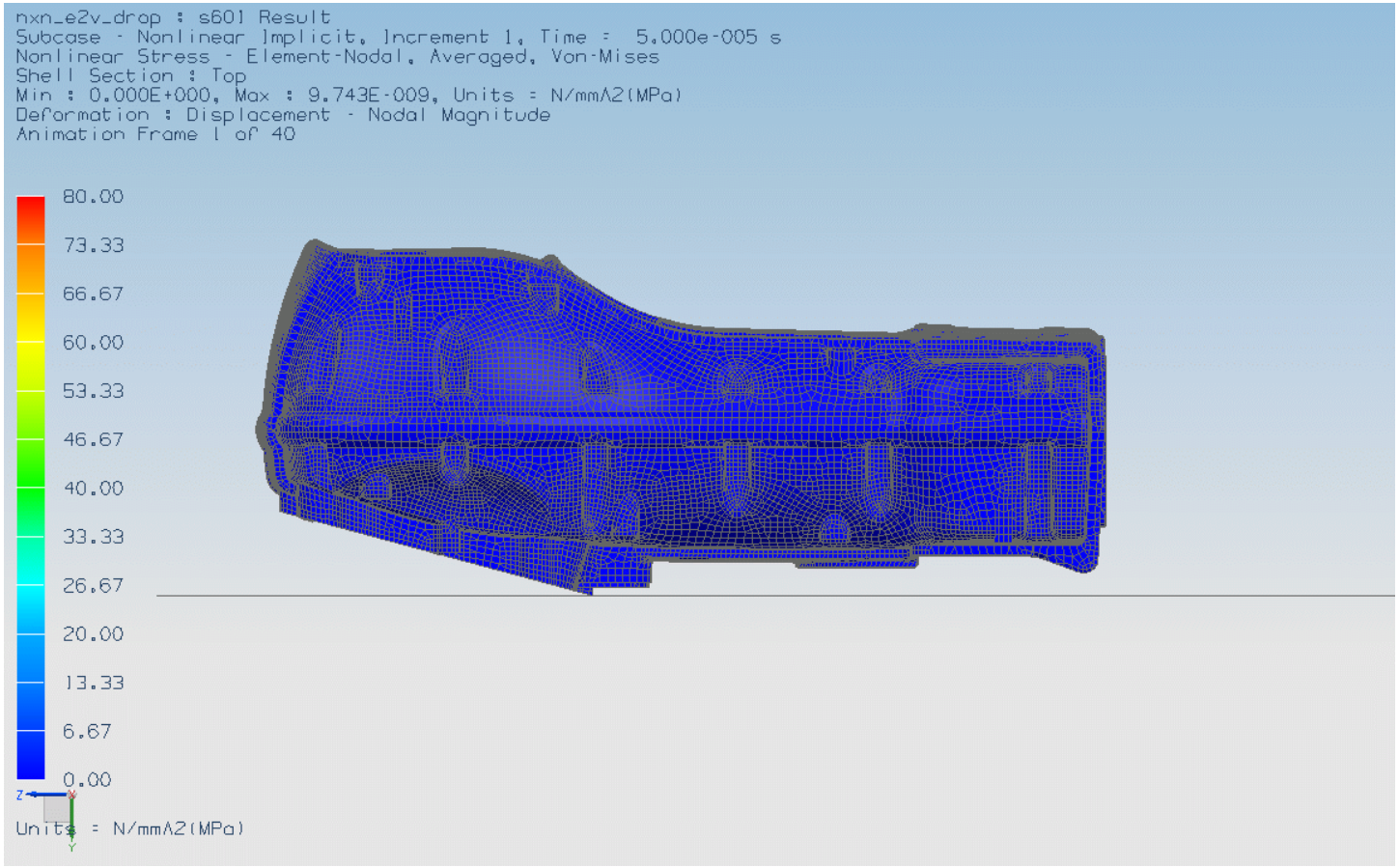
Example – Thermal Camera



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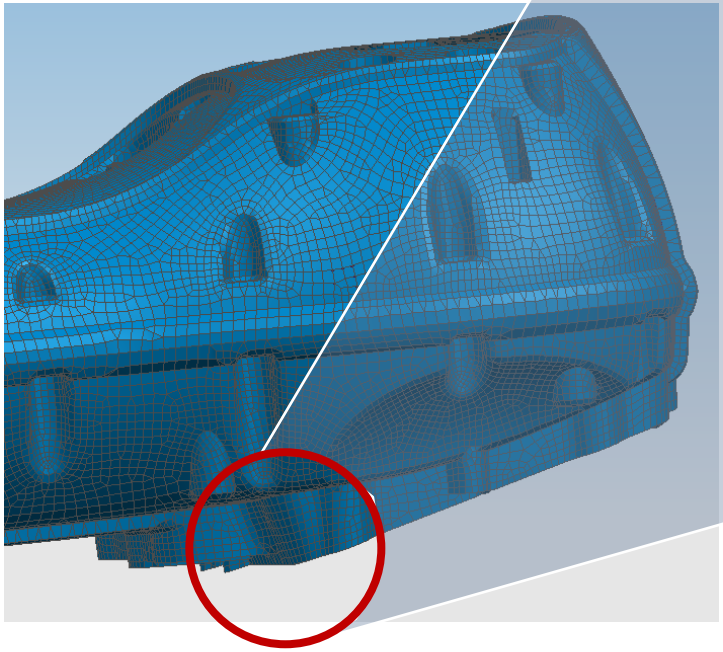
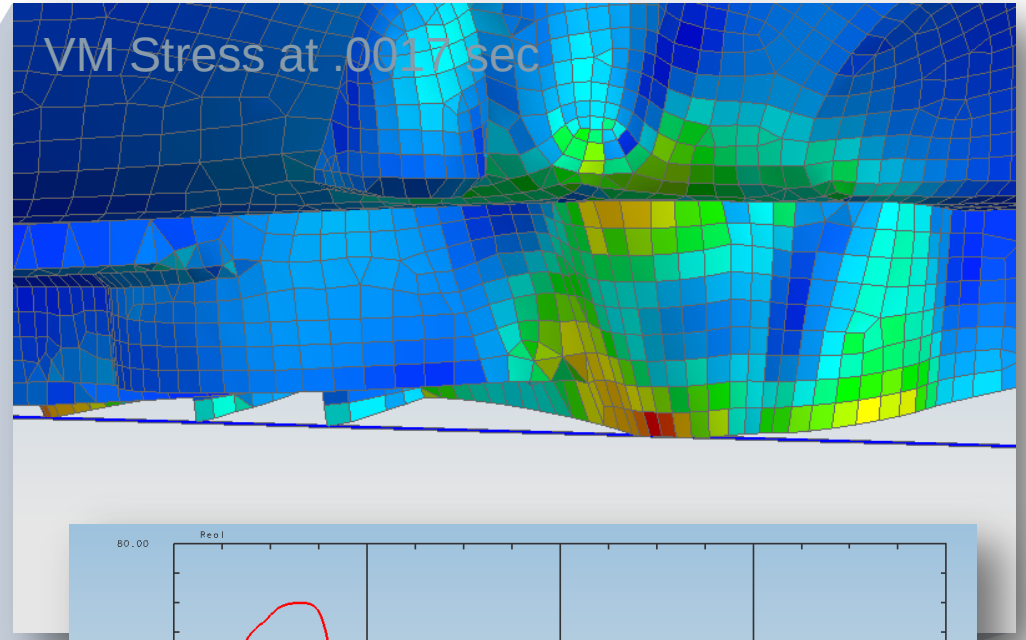
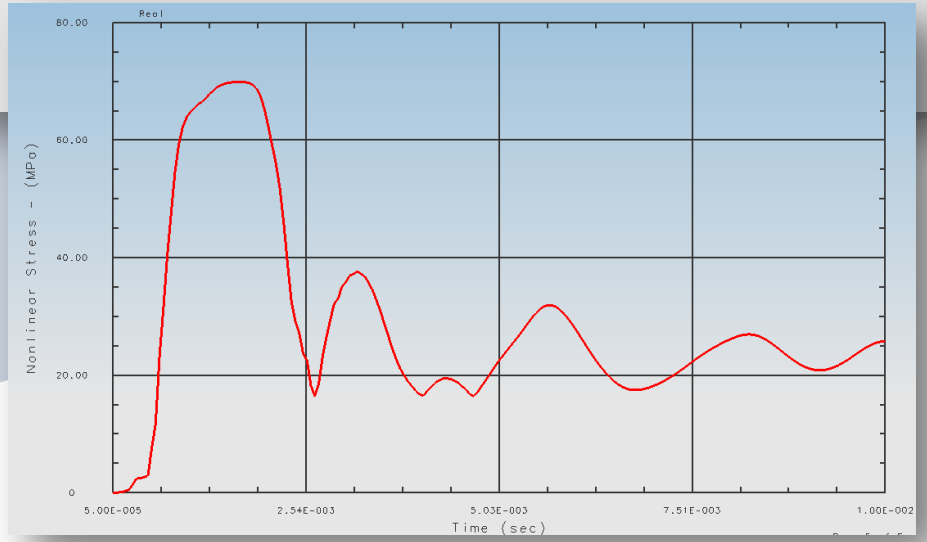
Stress on Case

Stress at contact

- Max Von Mises:
  - Corner of camera screen
  - 70 MPa at .0017 sec







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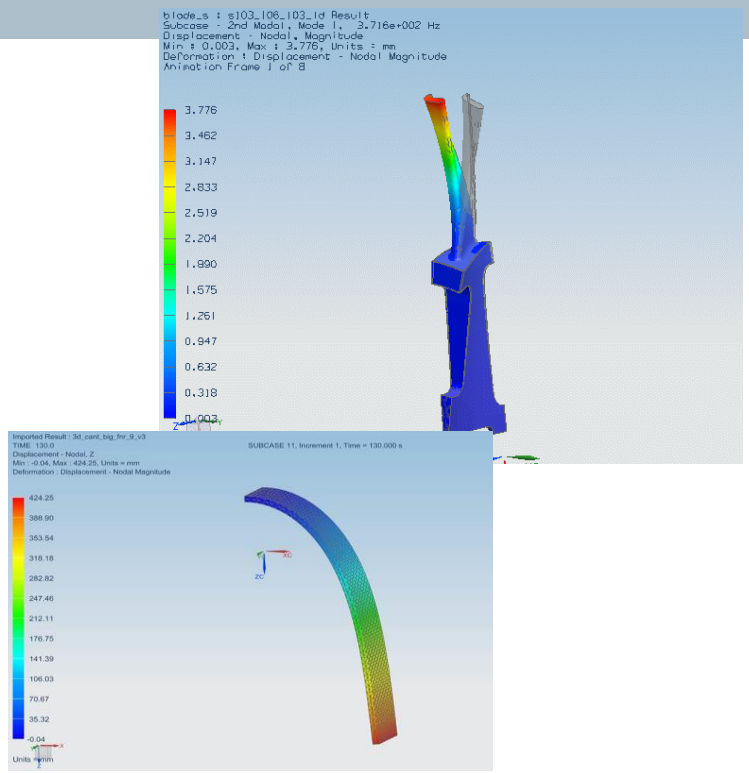
Coming in NX Nastran 10
Multi-step Nonlinear Solution – Sol 401

- New in NX Nastran 9 – significantly expanded for NXN 10
- Multi-step non-linear solver
  - Stepped solution approach: nonlinear static subcases and linearized modal subcases
  - Complements SOL 601
- Based on DMAP architecture
- Consistent element formulations with existing linear solutions
- Packaged with NX Nastran Advanced Bundle



Value: One NXN solution that performs multiple types of analyses – including multi-physics solutions.

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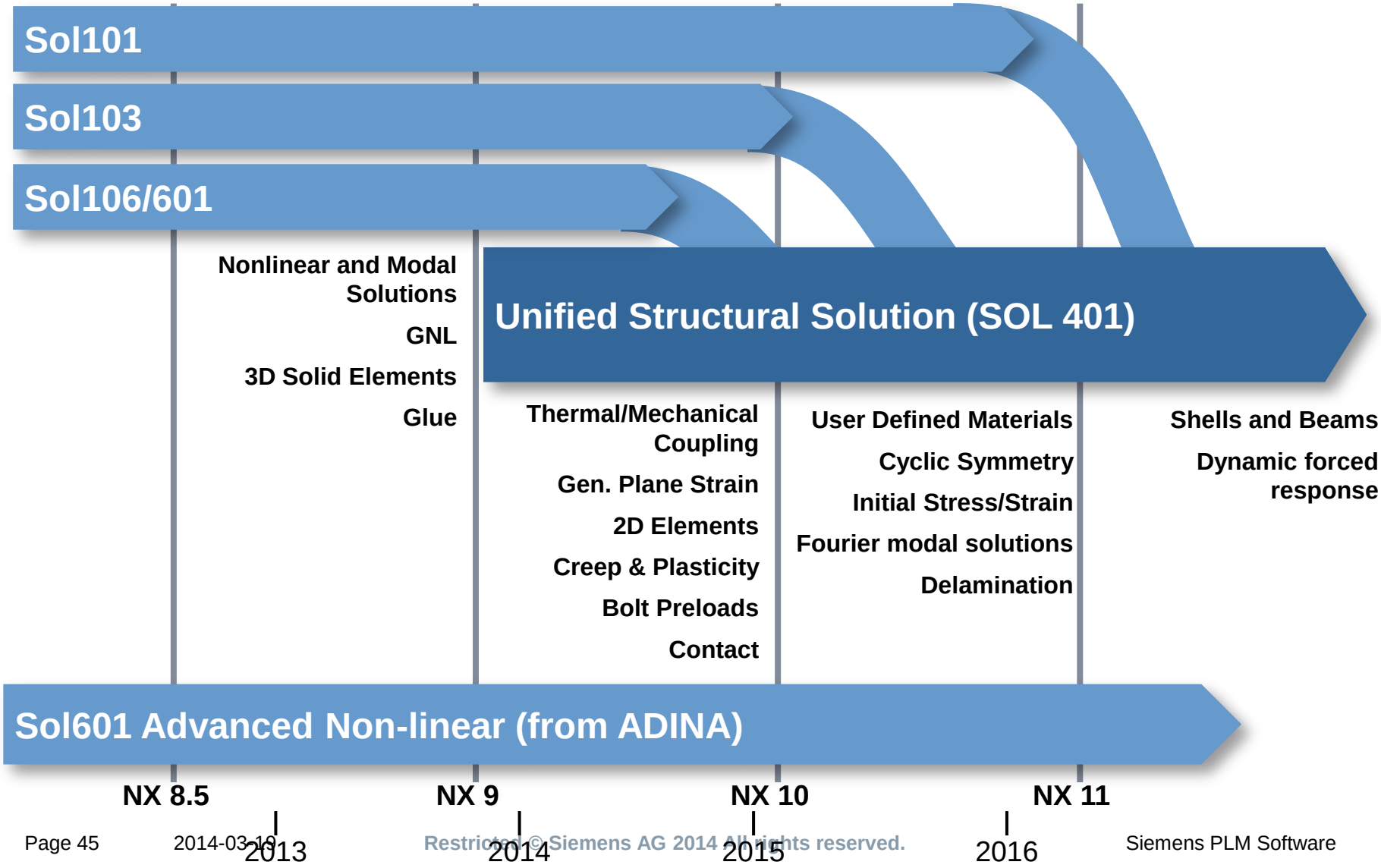
SOL 401
Schedule of Capabilities



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Overview

Special Topics

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- Bolt Connections
- Composites
- Non-Linear Simulation

Summary

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Summary

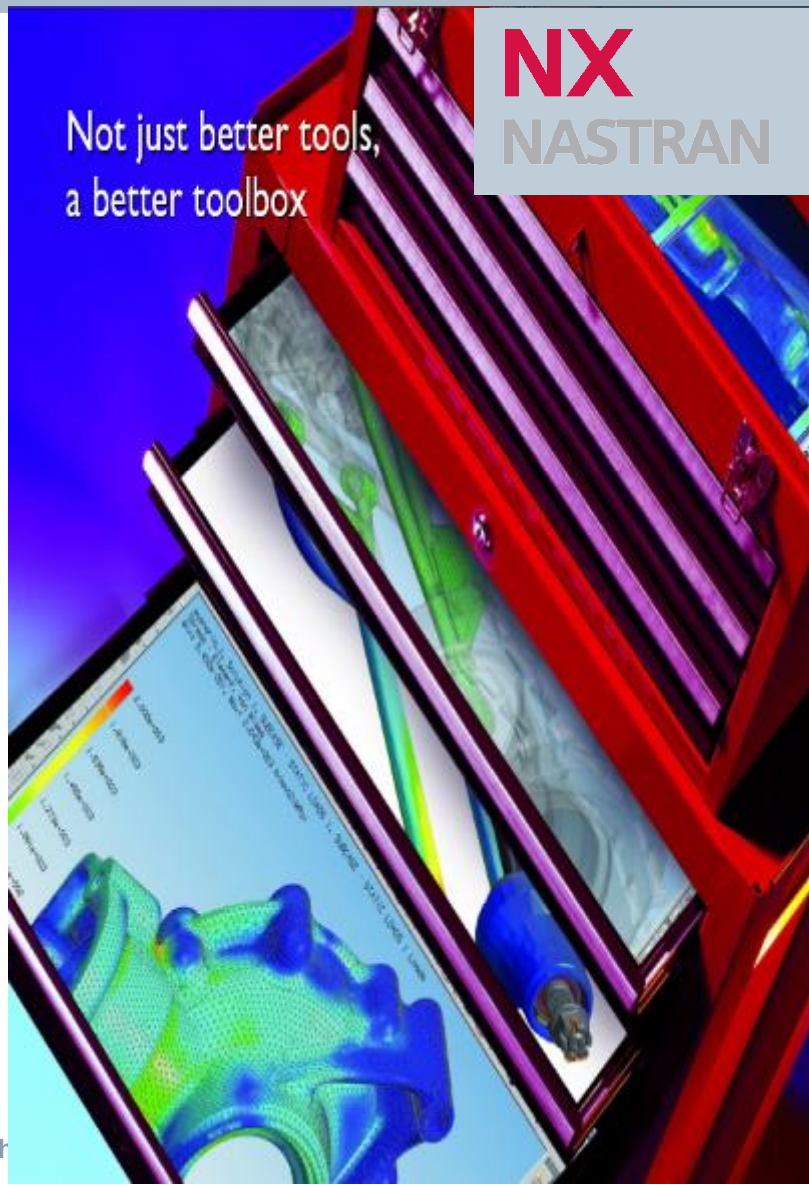
Leading Advancements in FE Technology

- Performance
- Process
- New Physics

Highlighted Capabilities

- GPU for Performance
- Glue and Contact Connections
- Bolted Joint Connections
- Composites
- Nonlinear

Continued Investment and Growth



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