Fertigungssimulation mit MD Nastran: Neue Technologien in der Baugruppenauslegung

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MSC Software GmbH

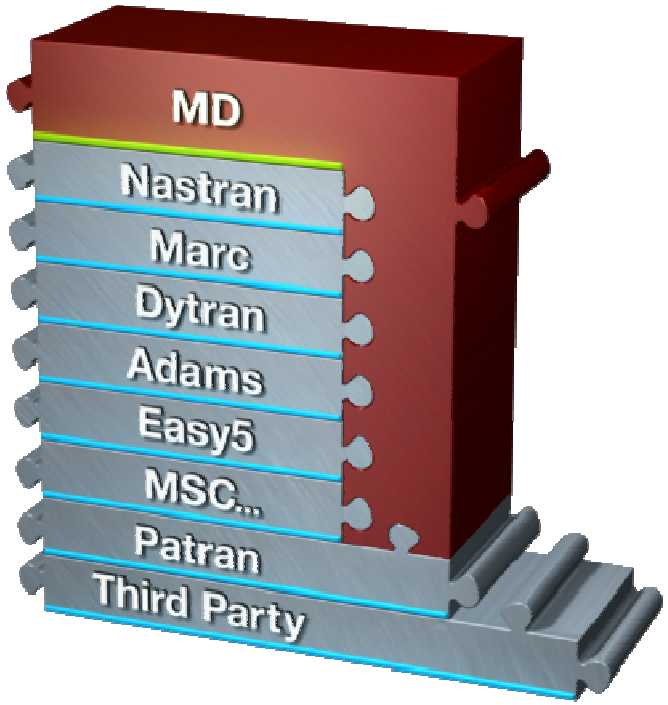
Agenda

- MD Nastran – Einführung und Überblick
- Neue Funktionalität in MD Nastran
- Multi-Disziplinäre Simulation
- SimXpert
- Contact
- Umformsimulatiuon

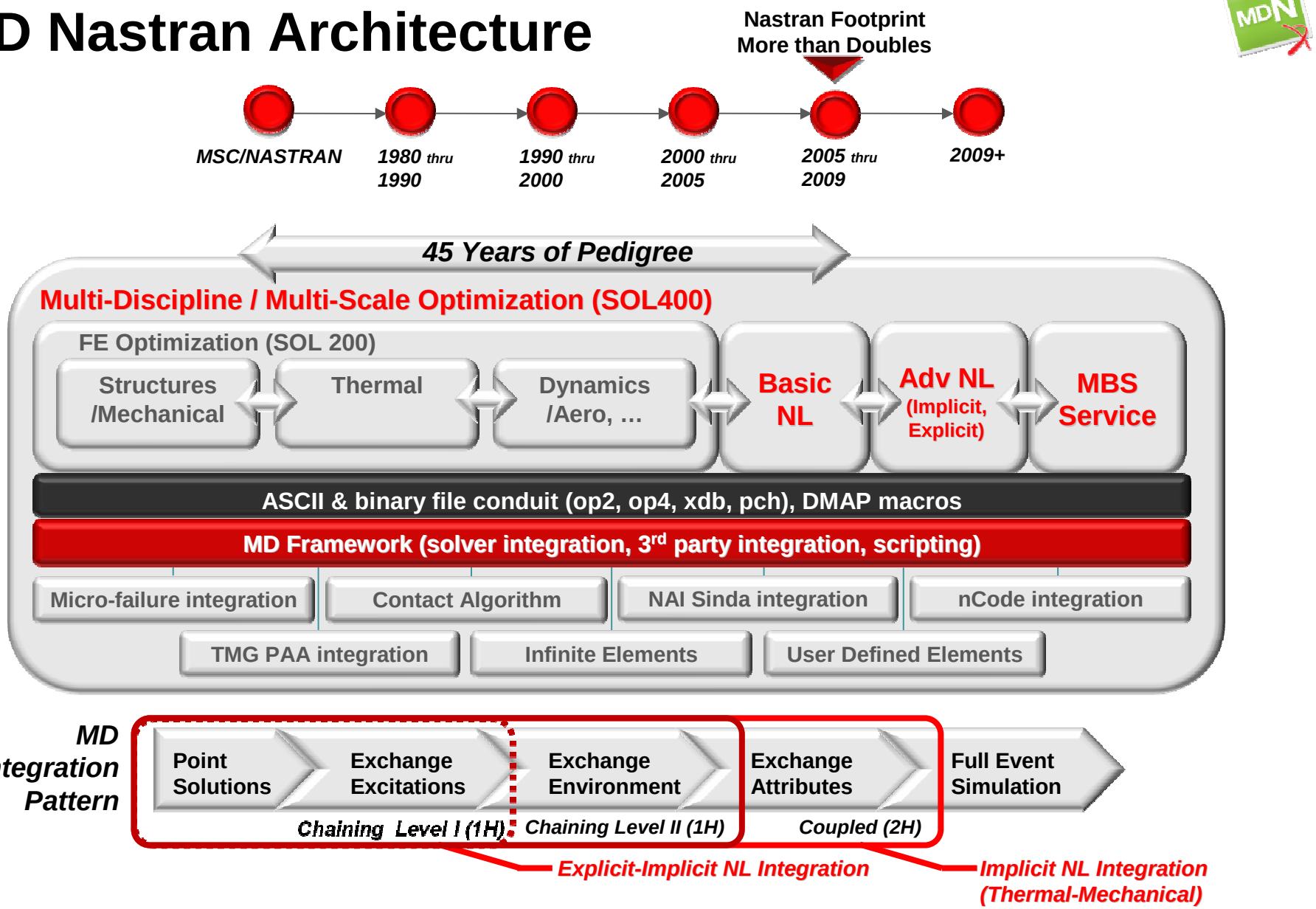
MD - Multidiscipline Products from MSC

The Next Step in Simulation

- Integrates foundation engineering solvers
  - Common solver framework
  - Common data model
- Leverages ongoing enhancements to engineering solver technologies
  - New solver enhancements naturally roll up to MD Solutions
- Enables 3rd party solver integration
  - Open architecture for complete flexibility
- **MD Nastran**
  - Advanced multidiscipline structural solution built with Nastran, Marc, Dytran, & 3rd party components
  - Fully integrated structural-thermal-acoustic, FSI, composites, MD optimization, motion-structures capabilities
- **MD Adams**
  - Seamless integration with MD Nastran for motion-structural coupling



MD Nastran Architecture



MD Nastran

Basics

MSC.Nastran 2004

Access to some Marc functionality by spawning the Marc process

Nastran

Marc .dat

Elements, materials, contact…

Marc

T16/XDB/op2

MD Nastran R2

Nastran

Elements, materials…

XDB/op2

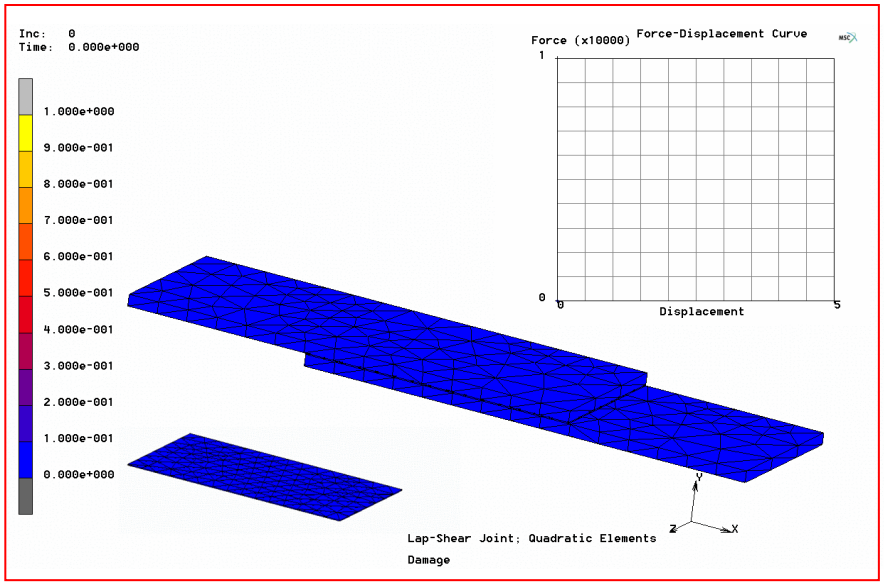
Functionality integrated into Nastran

Foundation for multi-disciplinary nonlinear and optimization

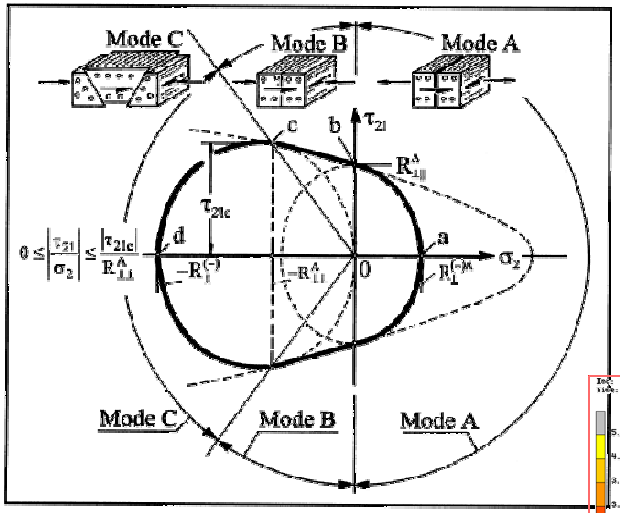
MD Nastran

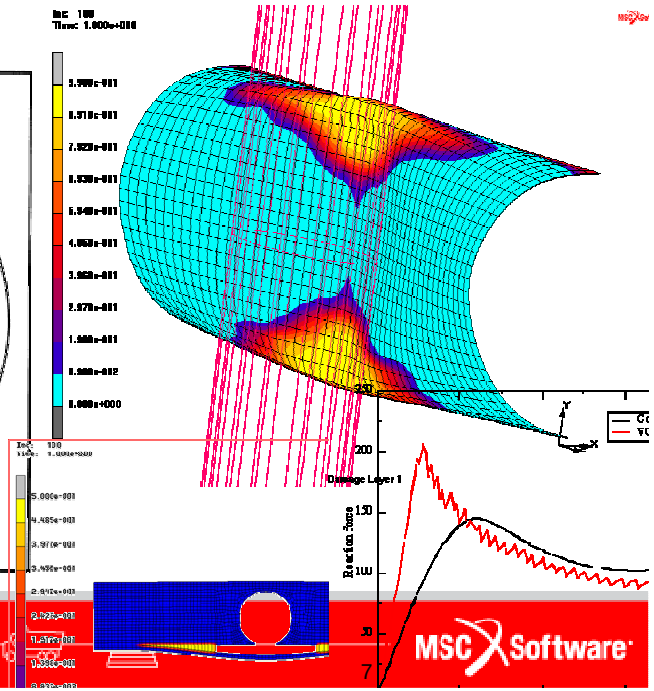
Composite Enhancements

- Delamination and failure
  - 2D, 3D, Cohesive zone model
  - VCCT (energy release rates in mixed mode fracture)
  - Progressive Failure Analysis
  - Additional failure criteria



  - Hill
  - Hoffmann
  - Tsai-Wu
  - Chang-Chang
  - Hashin
  - Puck
  - Hashin tape/fabric

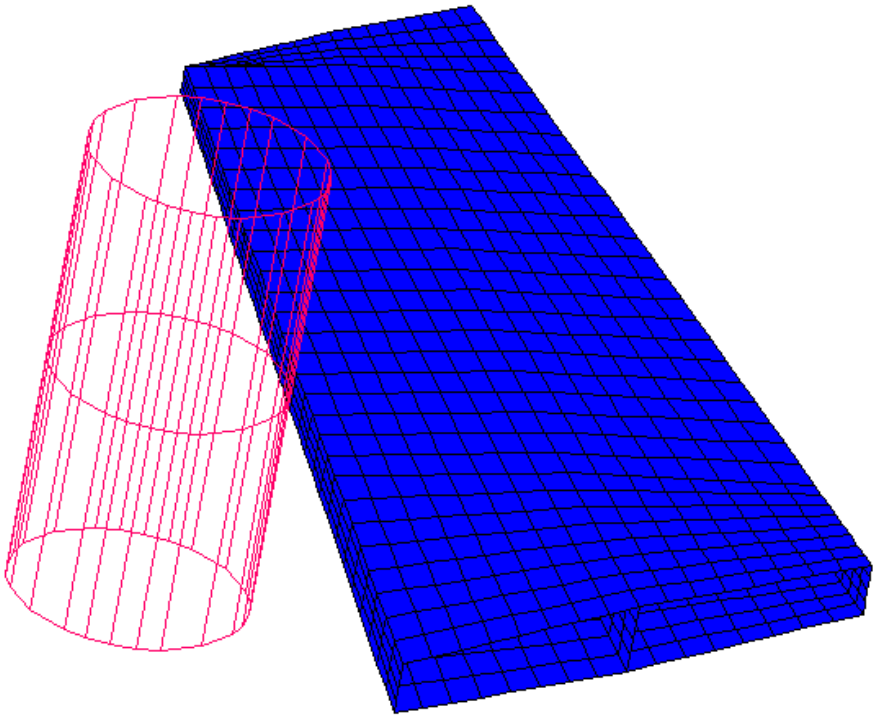




MD Nastran

Composite Enhancements

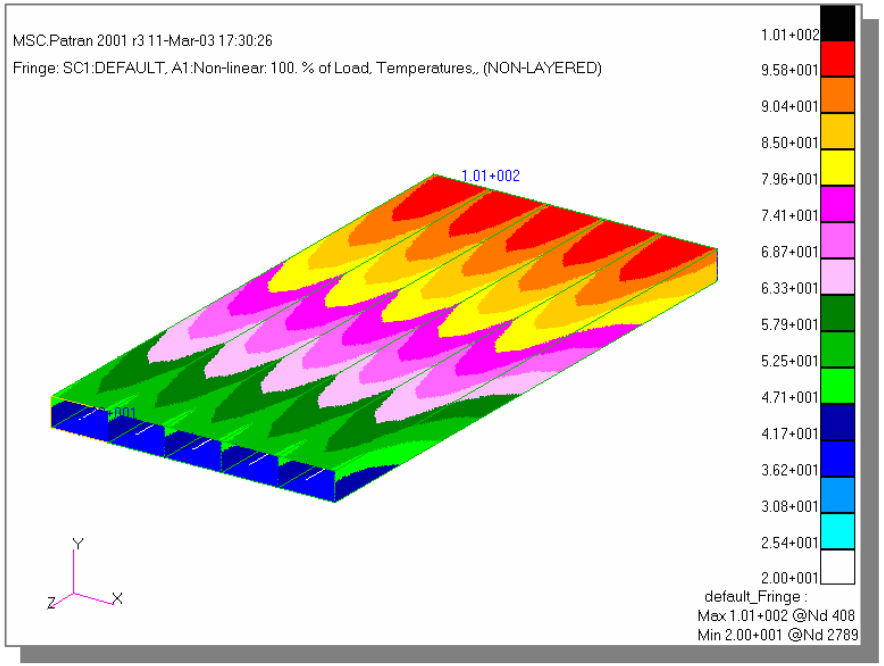
Example: PFA – Wing Model with Damage

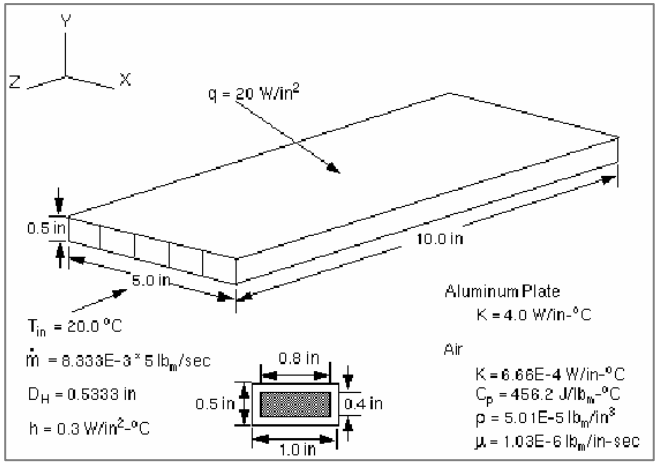


MD Nastran

Advanced Heat Transfer

- Steady State Thermal Advection Flow. Advection is the modeling of fluid flow in engine using fluid. The fluid takes away the heat by means of the energy transport.



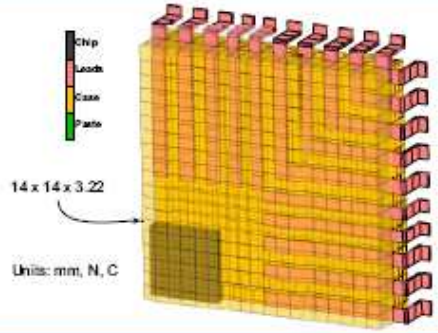
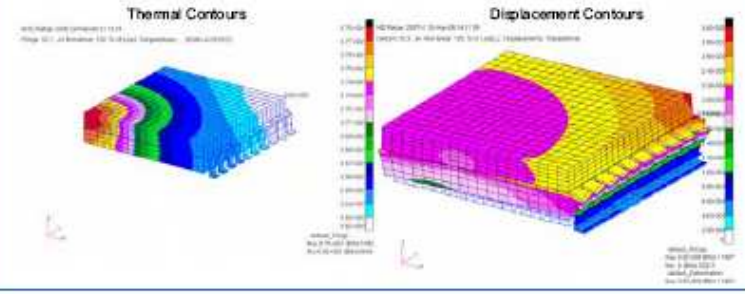


MD Nastran

Advanced Heat Transfer

Semiconductor Application:

1. **IC chip**
2. **Thermal-Stress**
3. **Thermal Analysis with convection heat loss**
4. **Followed by a Stress Analysis**

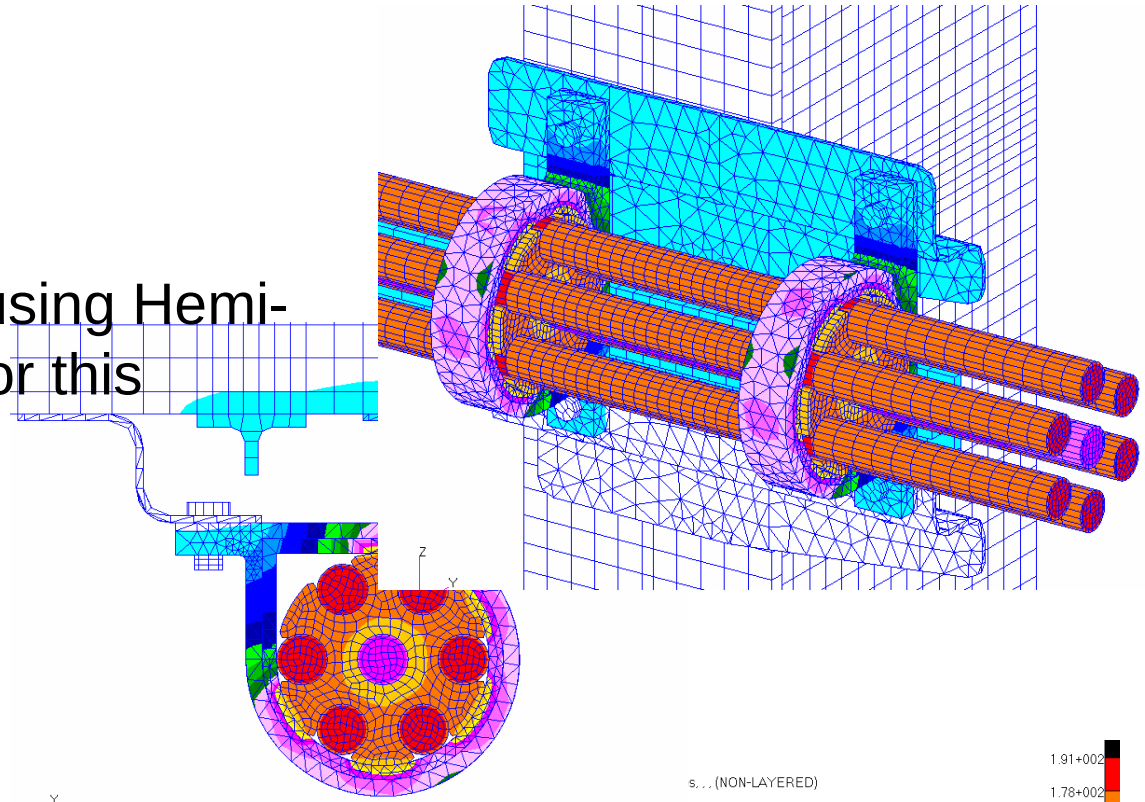
Title	Chapter 46: Thermal Stress Analysis of an Integrated Circuit Board
Features	Chaining thermal and stress analysis in one execution
Geometry	
Material properties	
Analysis characteristics	Nonlinear thermal analysis followed by a stress analysis
Boundary conditions	Thermal boundary conditions: The heat flux is applied on top surface of the chip with heat flux equal to 0.025 W/(mm^2 °C). The convection is loss to the ambient at 25 °C with H equal to 4.05x10^{-5} W/(mm^2 °C). There is radiation loss on top of the outer case to ambient at 40 °C with emissivity equal to 0.8 and view factor is 1.0. Structure boundary conditions: Fix the end of the lead frame.
Element type	8-node CHEXA
FE results	Thermal contours and resulting displacement contours 

Material	k $W/(mm/C)$	E $N/(mm^2)$	α $(1/C)$
Lead frame	0.147	6.9x10^4	1.0x10^{-6}
Chip	0.168	5.52x10^4	1.0x10^{-5}
Case	0.0714	4.5x10^4	1.0x10^{-6}
Paste	0.02016	2.0x10^3	1.0x10^{-5}

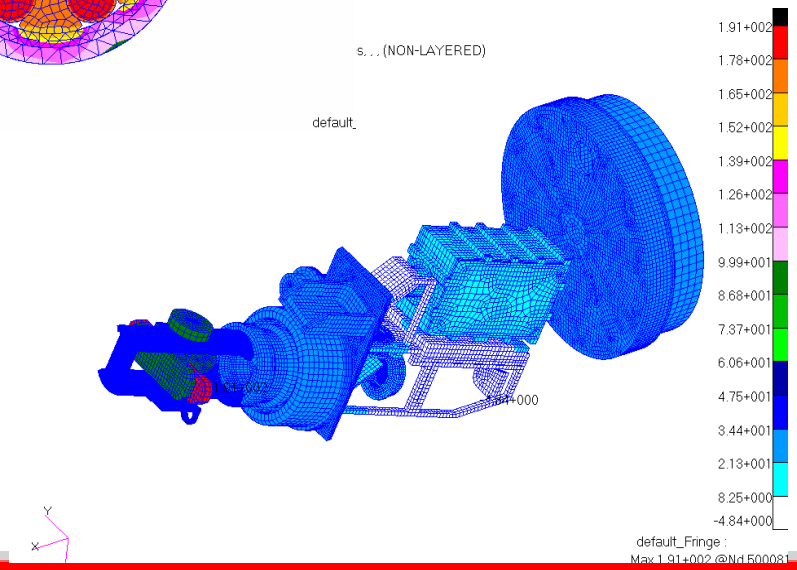
MD Nastran

Advanced Heat Transfer

- Radiation Viewfactor using Hemi-Cube (33 x speedup for this model)



- 2nd model took over 10 days to solve using Gaussian view factors, MD with Hemi-Cube: 4.5h



MD Nastran

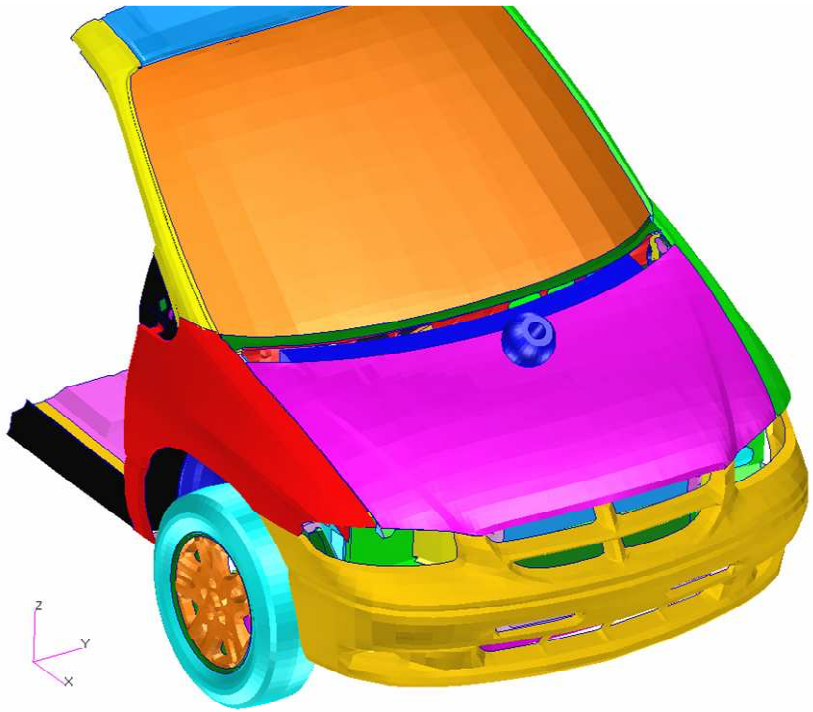
SOL700 Crash Examples

Pedestrian safety: head impact

- Mesh:
  - 1D elements : 15
  - 2D elements : 116104
  - 3D elements : 6475

- Material:
  - Linear elastic, elastoplastic, rigid

- Nonlinearity:
  - Geometric, material, contact



- Head diameter = 160 mm
- Head weight = 4.5 kg
- Head impact velocity = 40 km/h
- Head impact angle = 50°

*Head attributes and initial conditions are similar but not according to the physical test.

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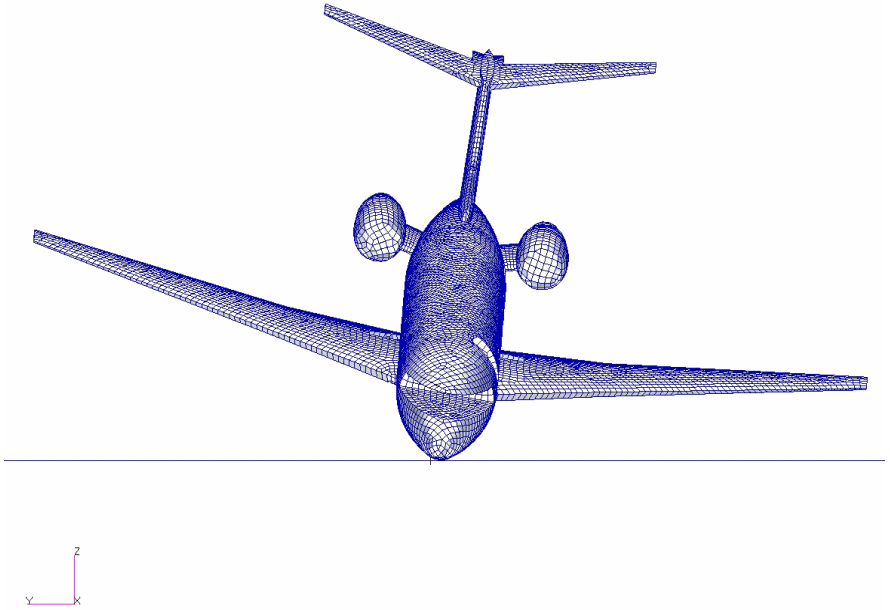
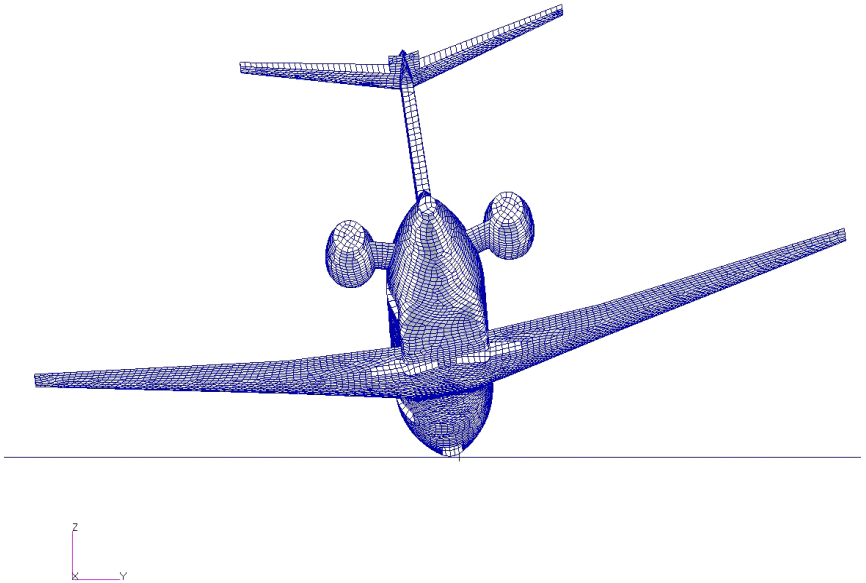
SOL700 Crash Examples

Front view



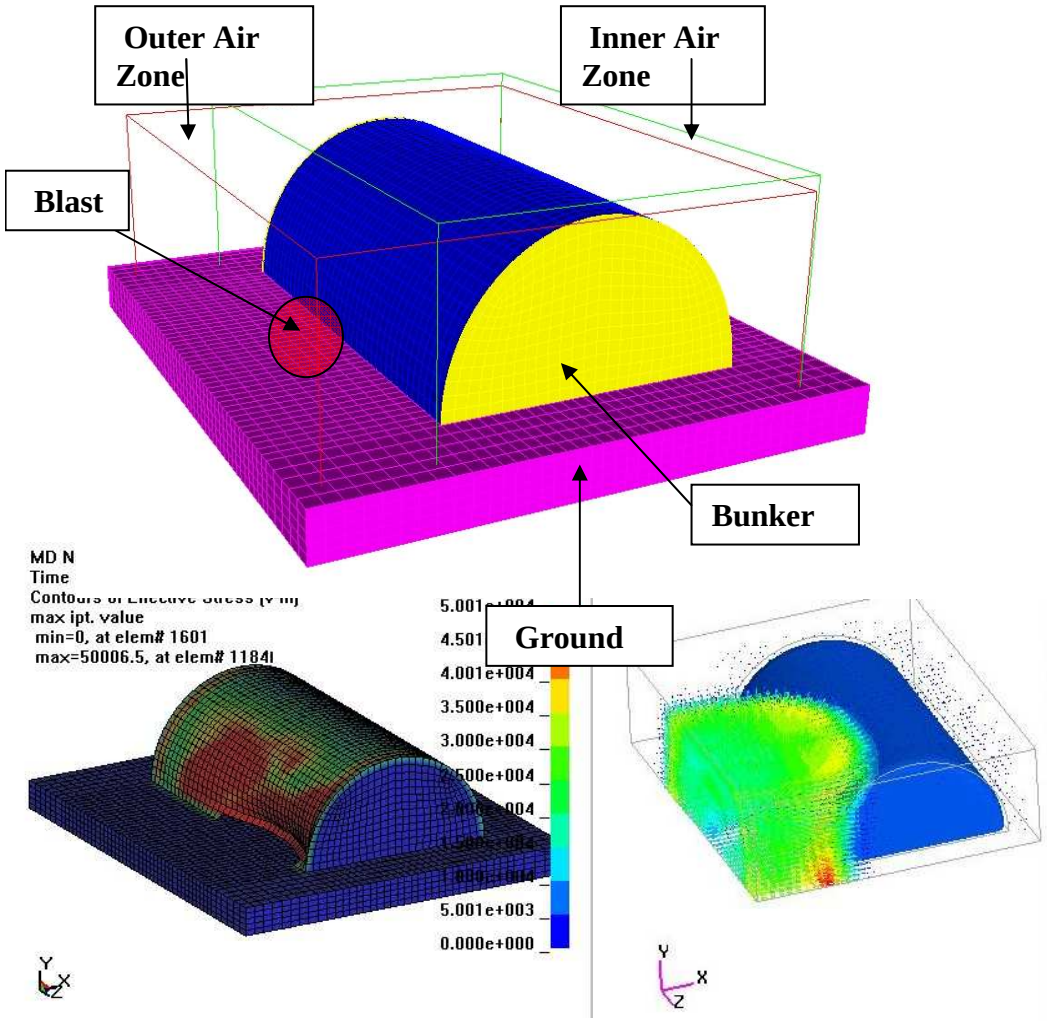
Rear view



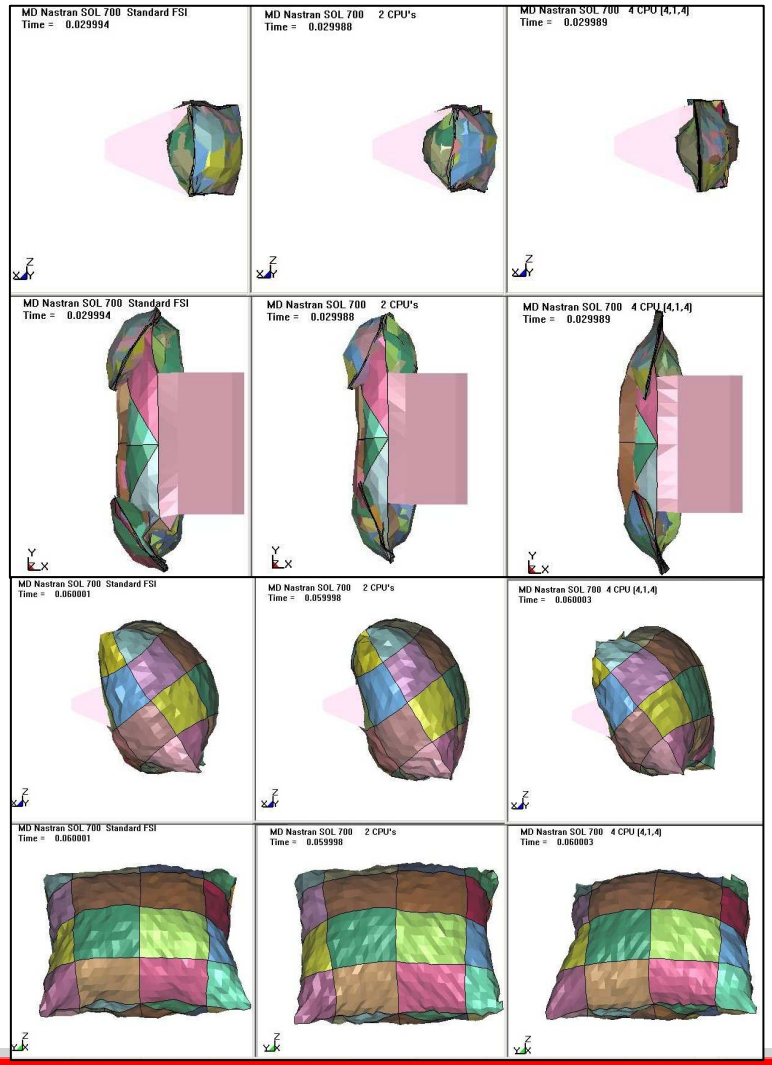
MD Nastran

SOL700 FSI Examples

- Bunker Blast



- Airbag



MD Nastran Basics

Analysis Chaining

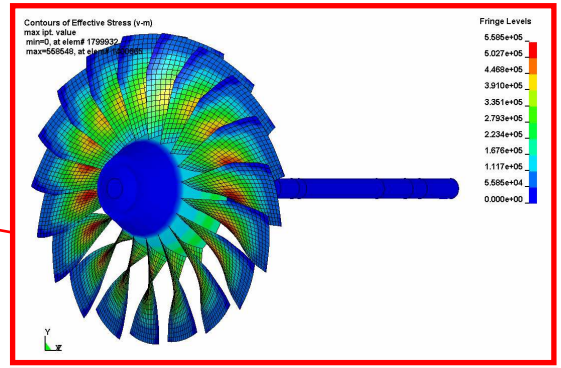
- Model a sequence or history of loading or analysis type
- Examples
  - Pre-stiffened normal modes
  - Static preload followed by transient analysis
  - Brake Squeal with preload and contact
  - Thermal preloading
- SOL 400 allows easy chaining with the STEP capability
- Allows initial conditions in any STEP or SUBCASE from any previous STEP of any SUBCASE (NLIC)
- Boundary condition changes (SPC, MPC, DMIG, TFL) from STEP to STEP

MD Nastran Examples

Chaining Example

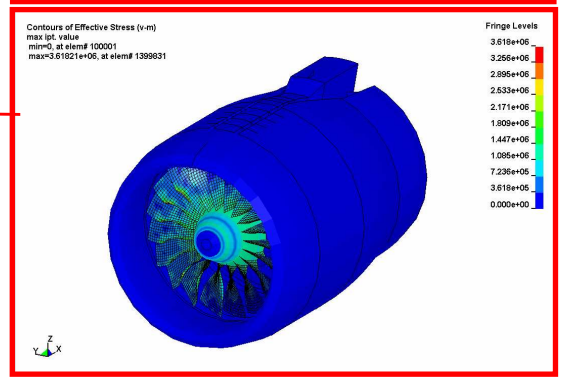
FBO-RD Solution

Prestress – Implicit simulation
Choice of MD Nastran SOL 106/400 or 700 (Implicit)



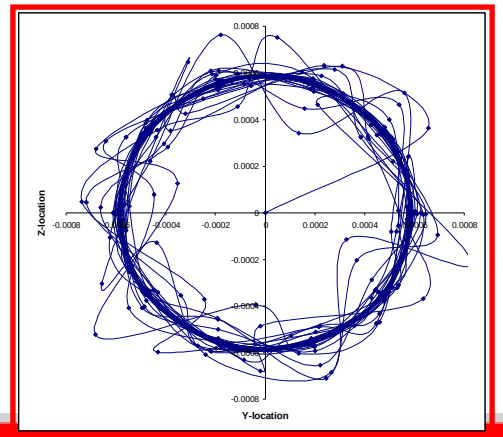
Initial Condition for explicit run

FBO/FOD – Explicit simulation
MD Nastran SOL 700 (bird strike)



Simulate Damage and extract mass, inertia and CG for rotordynamics unbalance

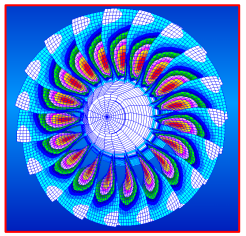
MD Nastran SOL400 RD (Unbalance loading)



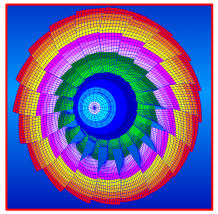
Extract final displacement after stabilization

MD Nastran Examples

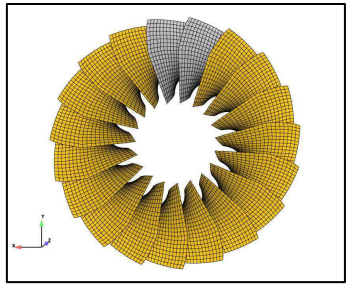
Aircraft Engine Use Case

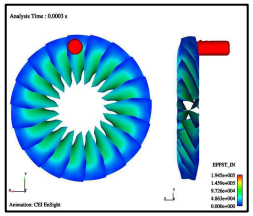


Hot/Cold Blade Shape Analysis

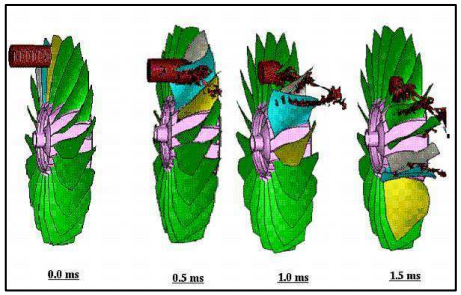


Normal Modes Analysis

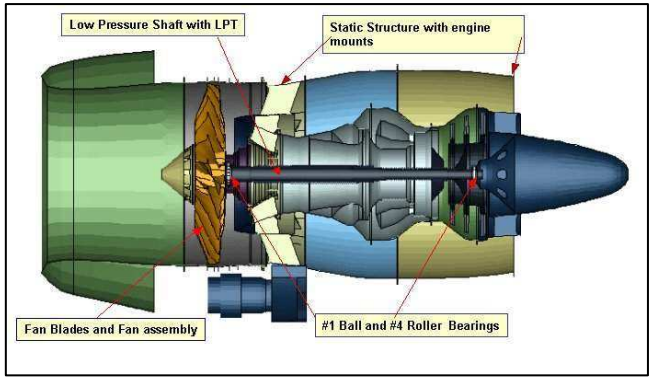




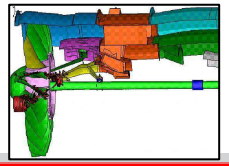
Apply Bird Impact
(Transient- Explicit)



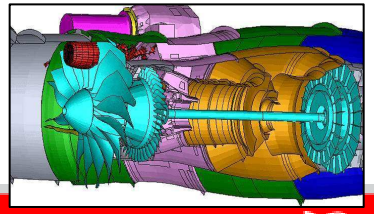
Pre-stress the blades
(Implicit)



Rotor Dynamics
for Stability Study
(Implicit)

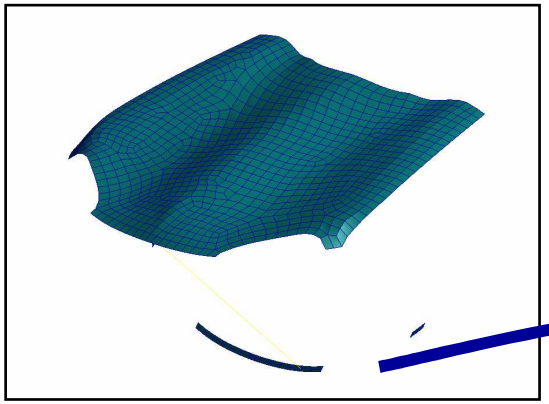


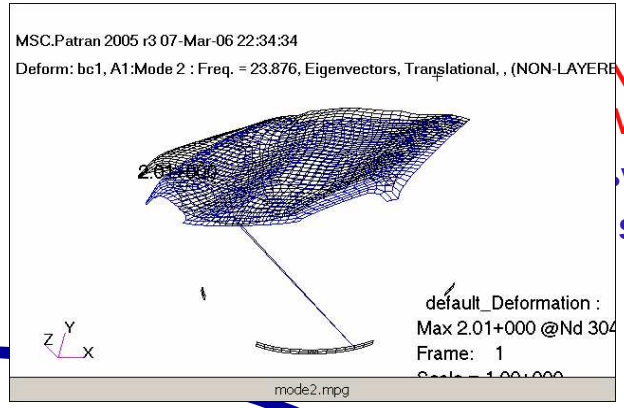
Study Blade-out
(Explicit)



MD Nastran Examples

Hood Slam Use Case





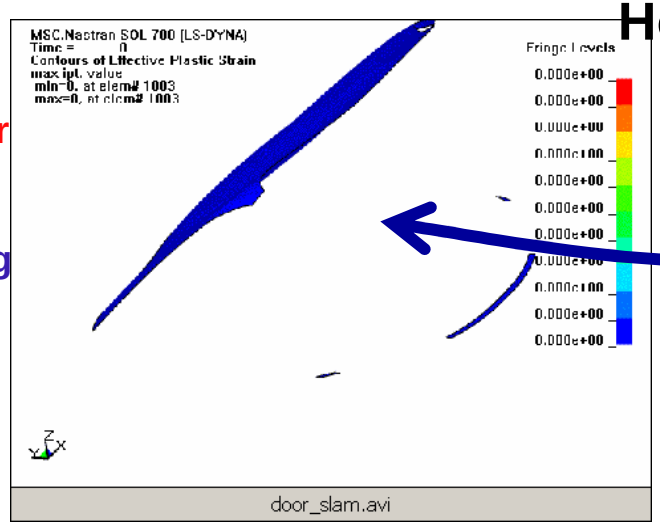
Normal Modes

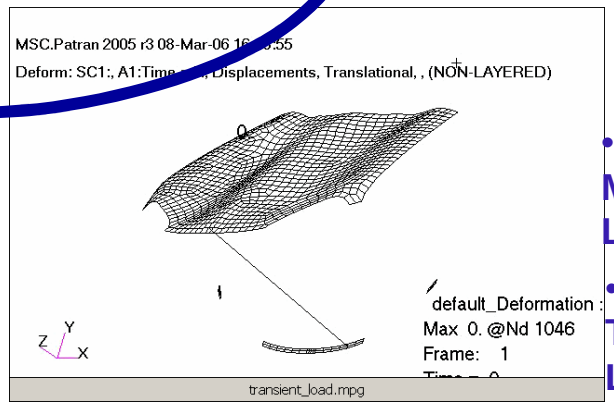
•Vibration ssues

Hood Analysis

Explicit Nonlinear

Hood slamming



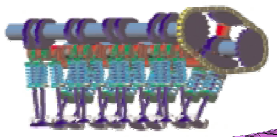


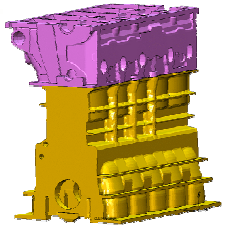
Implicit Nonlinear

- Transient Mechanical Load
- Transient Thermal Load

MD Nastran Examples

Engine Block Analysis

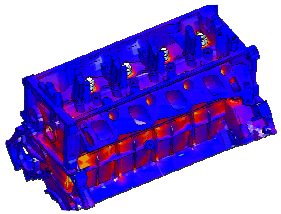




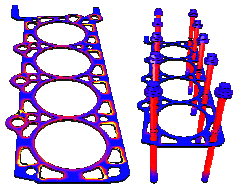
MBS – Bearing Loads

Stiffness - Normal Mode

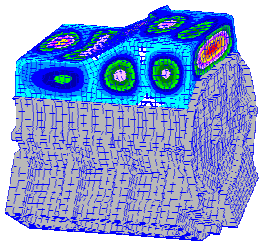
Thermal Load Cycling
Pressure Loads

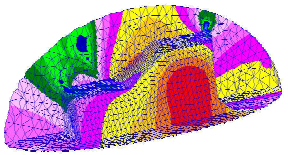


NL Gasket Analysis



Acoustic Analysis





Advanced acoustics for coupled structural-acoustics analysis to study radiated sound levels

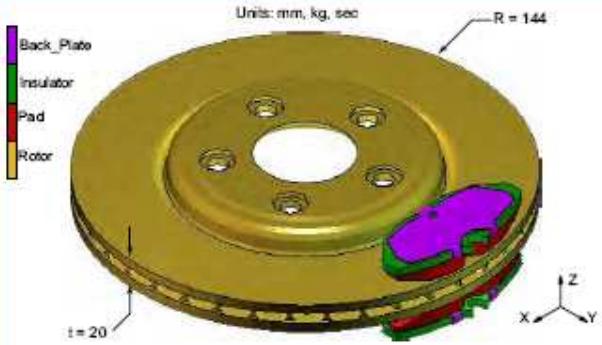
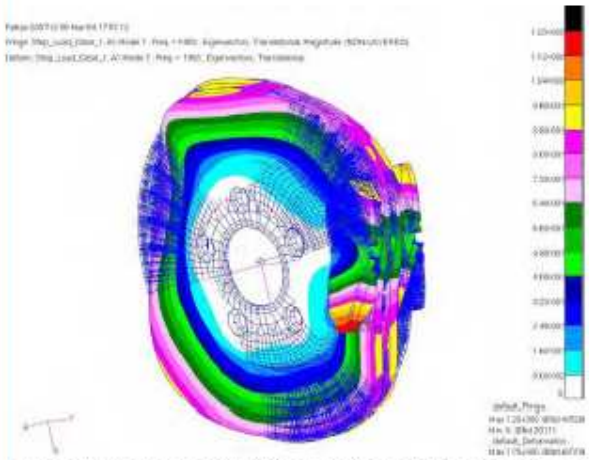
MD Nastran Examples

Break Squeal

User Guide 39

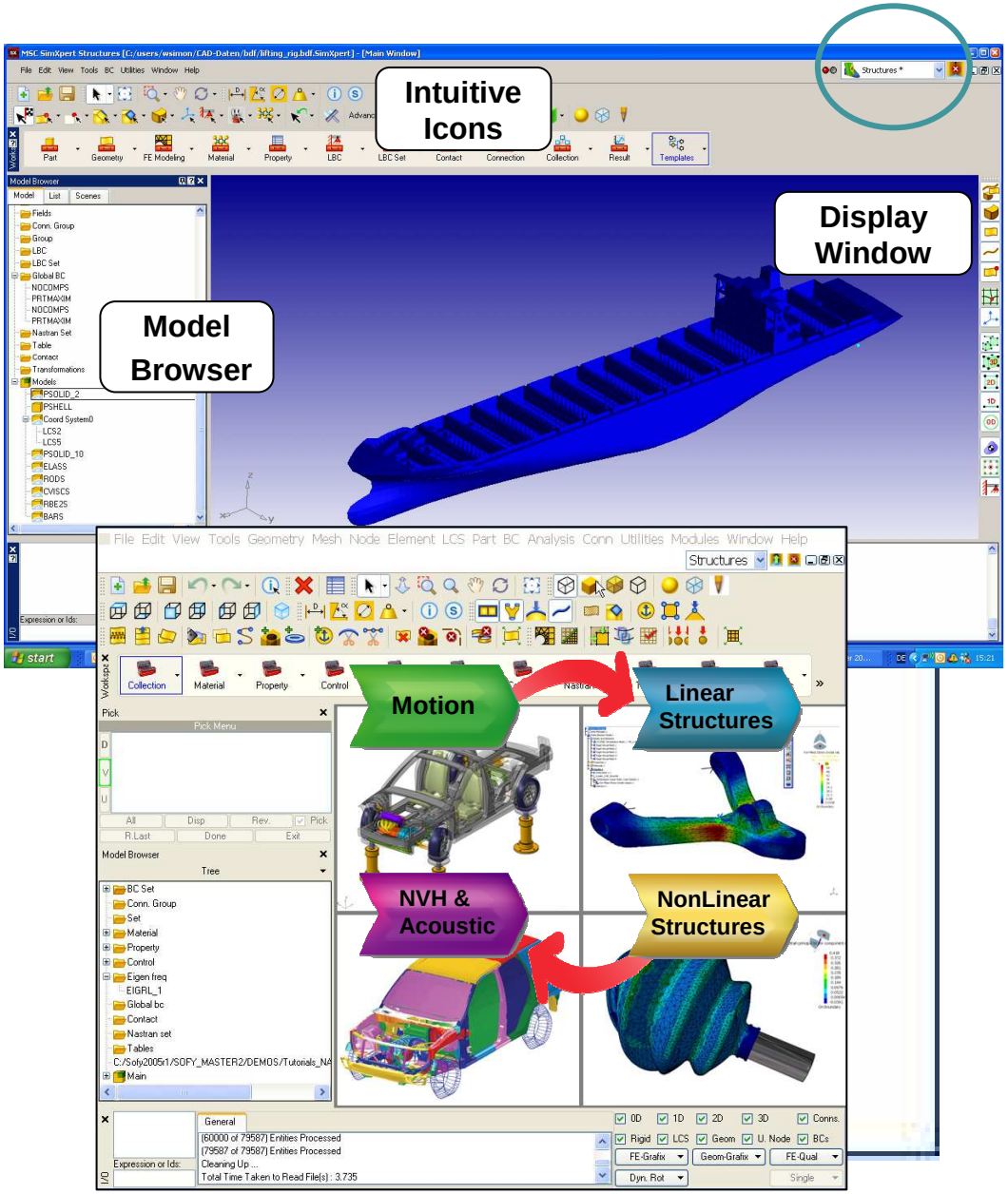
Acoustic Application:

1. **Brake Squeal Analysis**
2. **Frictional Contact**
3. **Complex Eigen-values**
4. **Mode Bifurcation**
5. **Dynamic Instabilities**

Title	Chapter 39: Brake Squeal Analysis
Contact features	Contact friction induced dynamic instability leading to brake squeal
Geometry Model Courtesy of Dr. Lin Jun Seng of TRW Automotive	
Material properties	Back plate E = 2.07×10^8 kg/(mm-sec^2), ν = 0.28, ρ = 7.82×10^{-6} kg/mm^3 Insulator: E = 2.07×10^8 kg/(mm-sec^2), ν = 0.28, ρ = 7.82×10^{-6} kg/mm^3 Pad: Anisotropic Organic Material Rotor: E = 1.25×10^8 kg/(mm-sec^2), ν = 0.24, ρ = 7.2×10^{-6} kg/mm^3
Boundary conditions	Constraints to simulate caliper guided brake pad motion Contact between the two deformable bodies with μ = user selected
Applied loads	Piston pressure normal to pad surface
Element types	8-node solid element HEXA and PENTA
FE results	 The unstable mode at 1.953 Hz in the analysis when μ = 0.3.

SimXpert
Overview

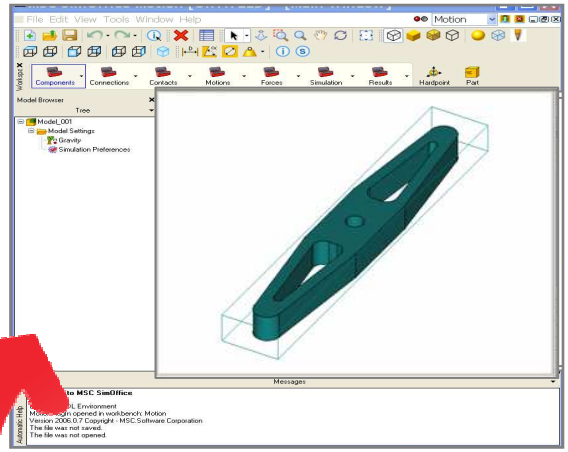
- Multidiscipline integration
  - Thermal-mechanical
  - Motion-structures-flex
- Tailored for expert
- Seamless data exchange
- Single and easy to learn GUI
  - Flexible toolbar
  - Modern windows
  - Intuitive icons and toolbars
  - Display filtering

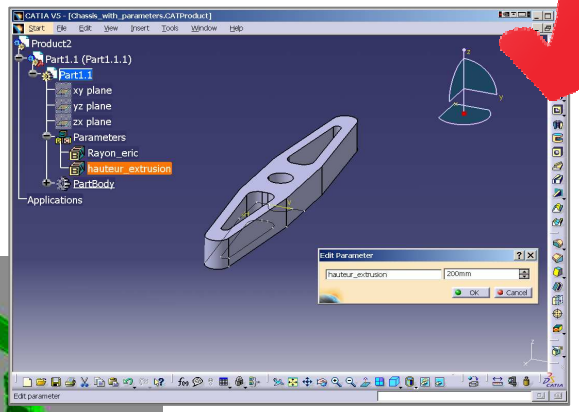


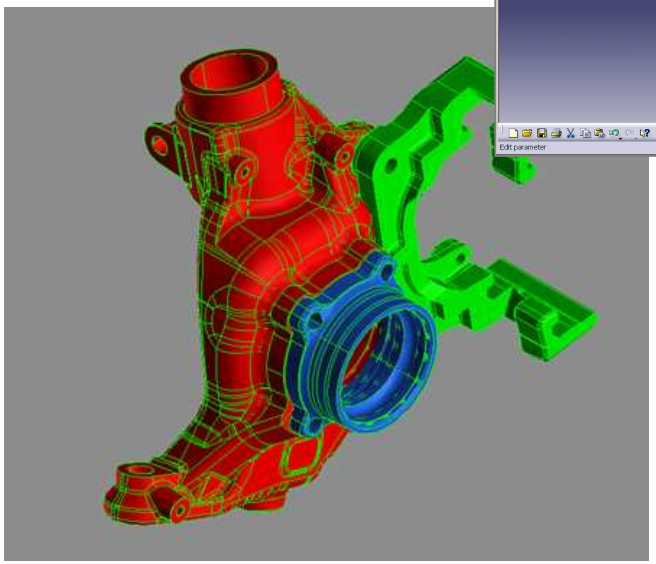
SimXpert

Overview

- **Native CAD Interoperability**
  - True Native CAD
    - No translations
    - Bi-directional associativity
    - Parametric
  - Multi-CAD
    - CATIA V5
    - Parasolids
    - Pro/Engineer
    - UG NX
  - Smart Update
    - Parameters
    - Topology
    - Loads / Constraints …
- **CAD Translation**
  - Parasolid
  - Catia V4, V5
  - ProE
  - STEP
  - IGES
  - …

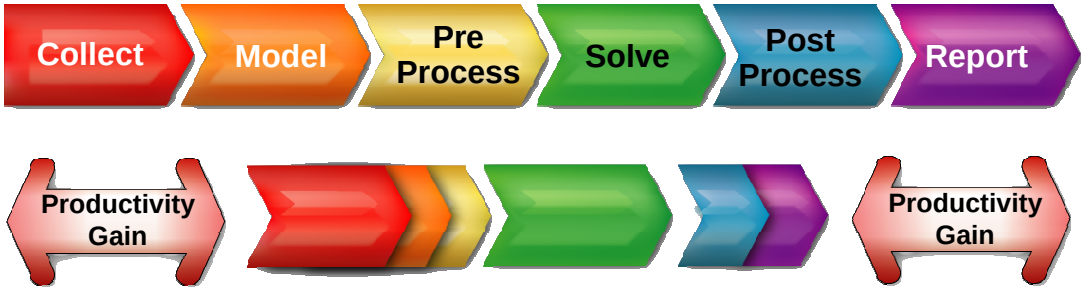


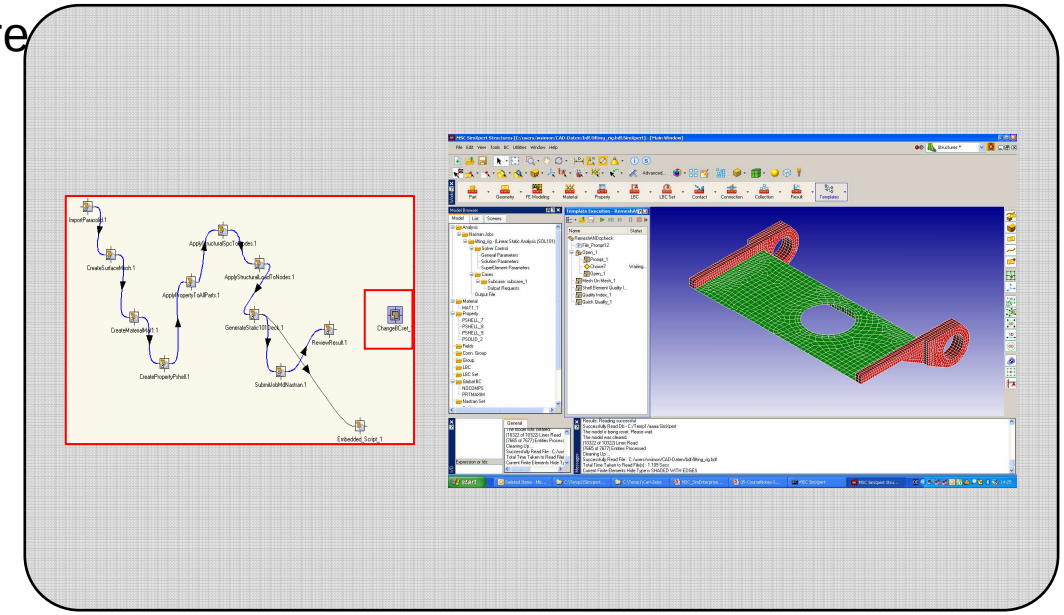




SimXpert
Templates

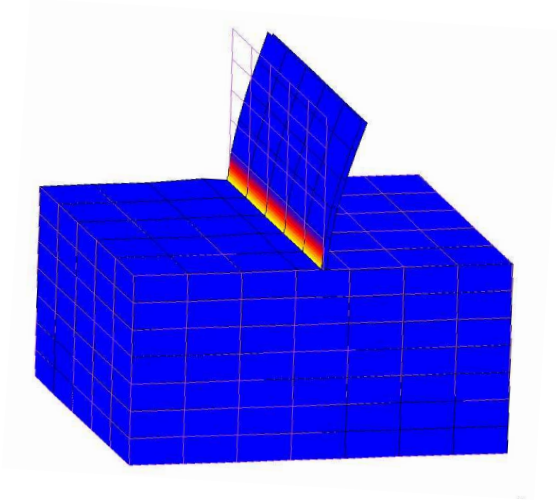
- Automate repetitive processes
- Eliminate process errors
- Reduces Workflow Time
- Flexible
  - Access non-templated core SimXpert functions during execution
  - Easily modified
- Not a rigid, hard-coded executable
- Step-by-step “wizard” for a simulation process





MD Nastran Contact

Overview

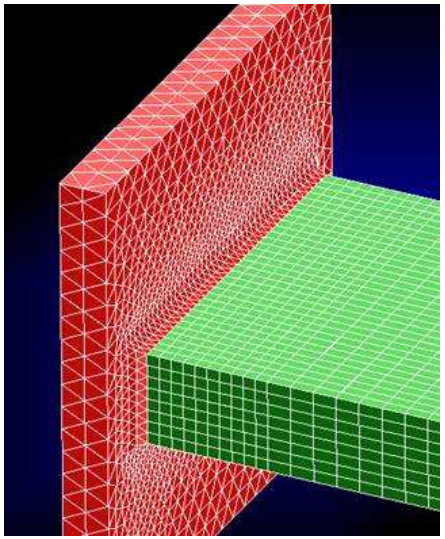


- 3D Contact capability is now available for the general nonlinear solution sequence, **SOL 400, 600 and 700**
  - Marc contact has been integrated into MD Nastran and enhanced
- The same 3D Contact capability is also available in **SOL 101** for linear contact analysis
- Permanent-Glue Contact, a special case of 3D Contact is supported in **SOL 101, 103, 105, 107-112, 200 and 400**
- The contact definition is ***COMMON*** to ALL solution sequences

MD Nastran Contact

Overview

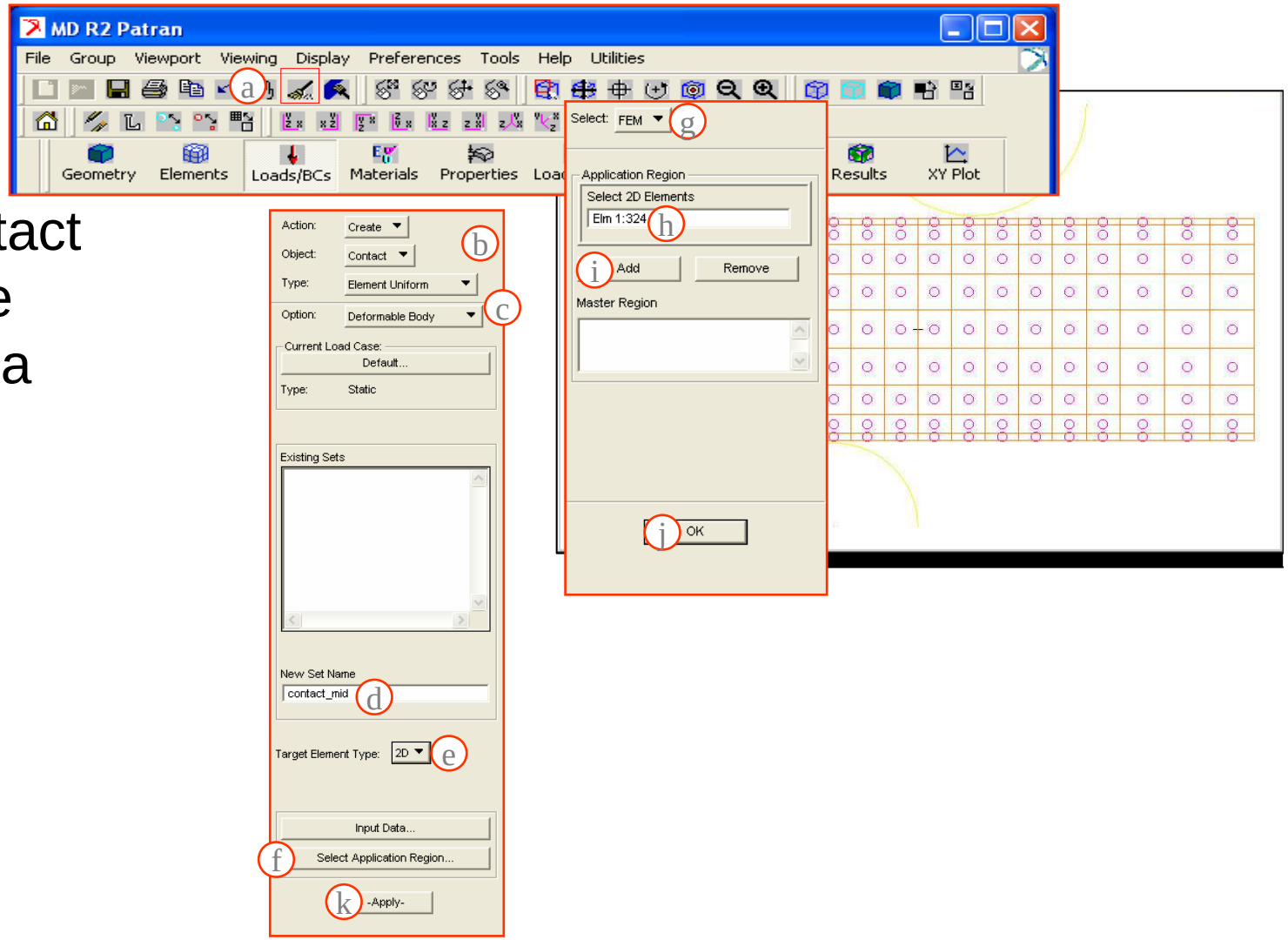
- Small and large displacement sliding contact :
  - Deformable-to-deformable and rigid-to-deformable
  - Friction and higher order elements
  - Contact post quantities (normal and friction force/stress and contact node status) – f06, OP2, XDB, DAC, t16 etc
  - Contact status information is stored in the database (DBALL)
  - Distance tolerance and initial motion of bodies to establish contact
  - Initial contact of approaching rigid body
  - Initial stress-free contact
  - Self-contact
  - Delay sliding-off
  - 2D or 3D contact



MD Nastran Contact

Creating Contact Bodies

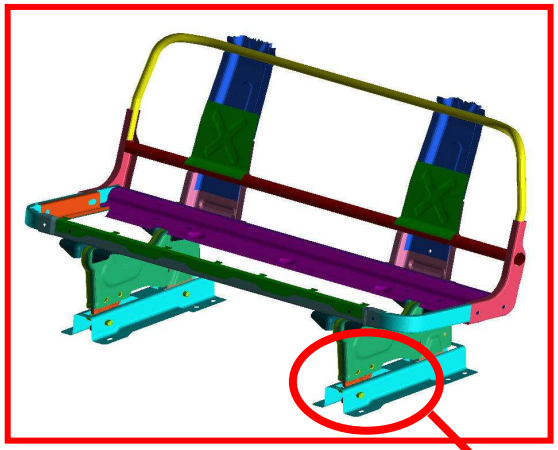
- Create contact body for the cylinder as a deformable body



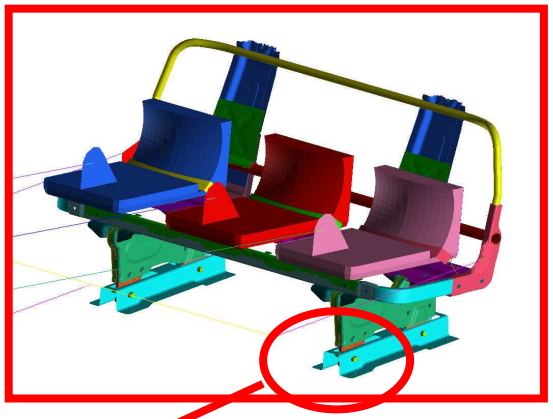
MD Nastran Contact

Multi-Discipline

NVH

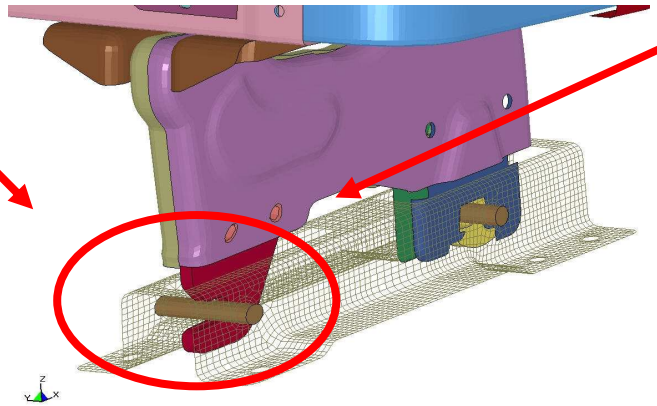


CRASH



Contact is treated as touching contact bodies

Contact is treated as glued contact bodies

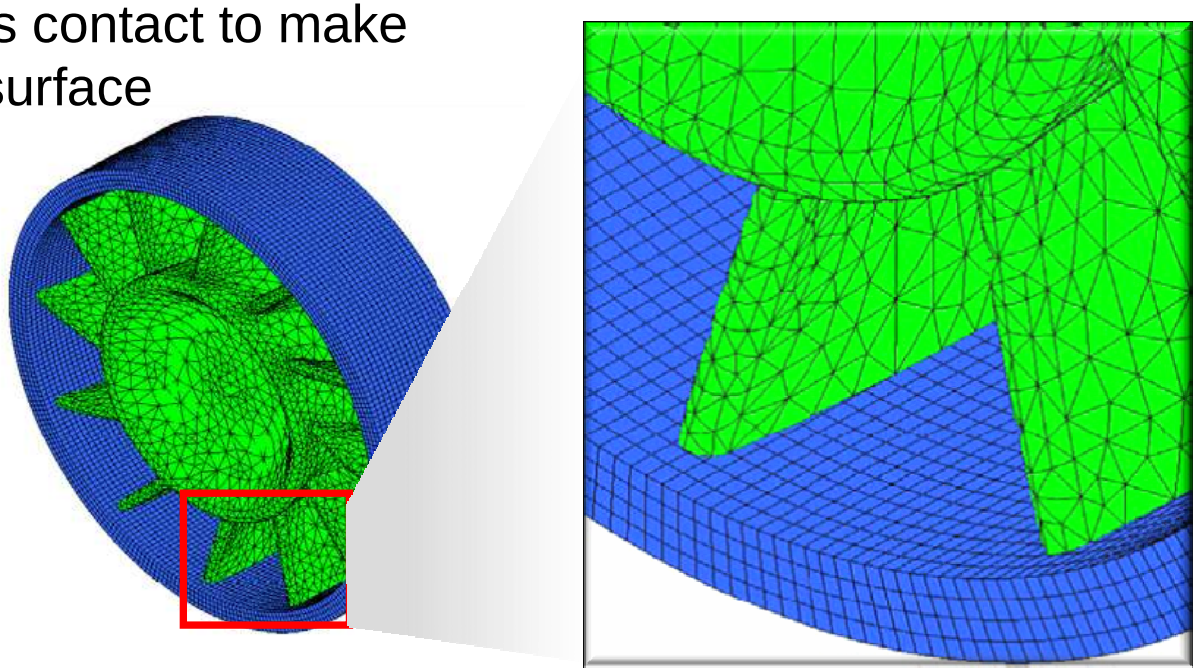


Contact is in BOTH Model Representations

MD Nastran Contact

Example – Modal Analysis with Glued Contact

- SOL 103
  - Free - Free
  - Glued contact between vanes and shroud with dissimilar meshes
  - Initial stress-free contact used
  - Quadratic elements contact to make smoother contact surface



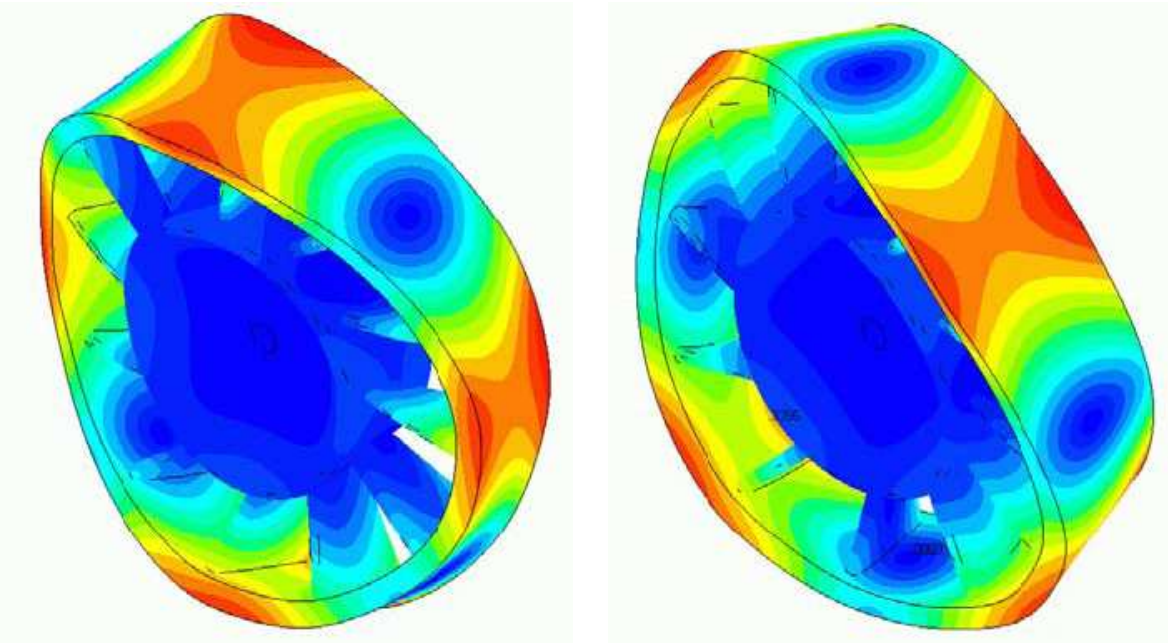
MD Nastran Contact

Example – Modal Analysis with Glued Contact

- Clean rigid body modes

1. 6.911939E-04
2. 6.290693E-04
3. 4.908829E-04
4. 4.434468E-04
5. 2.943299E-04
6. 7.051053E-05

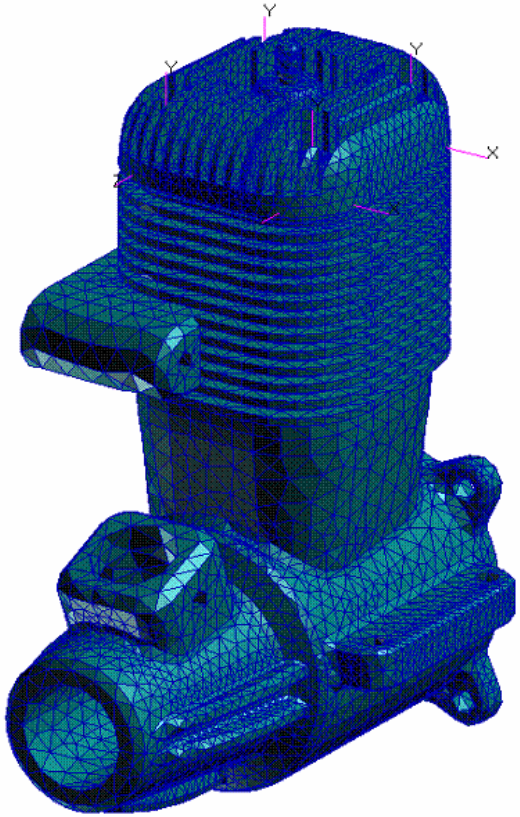
Elastic mode shapes 7 and 8

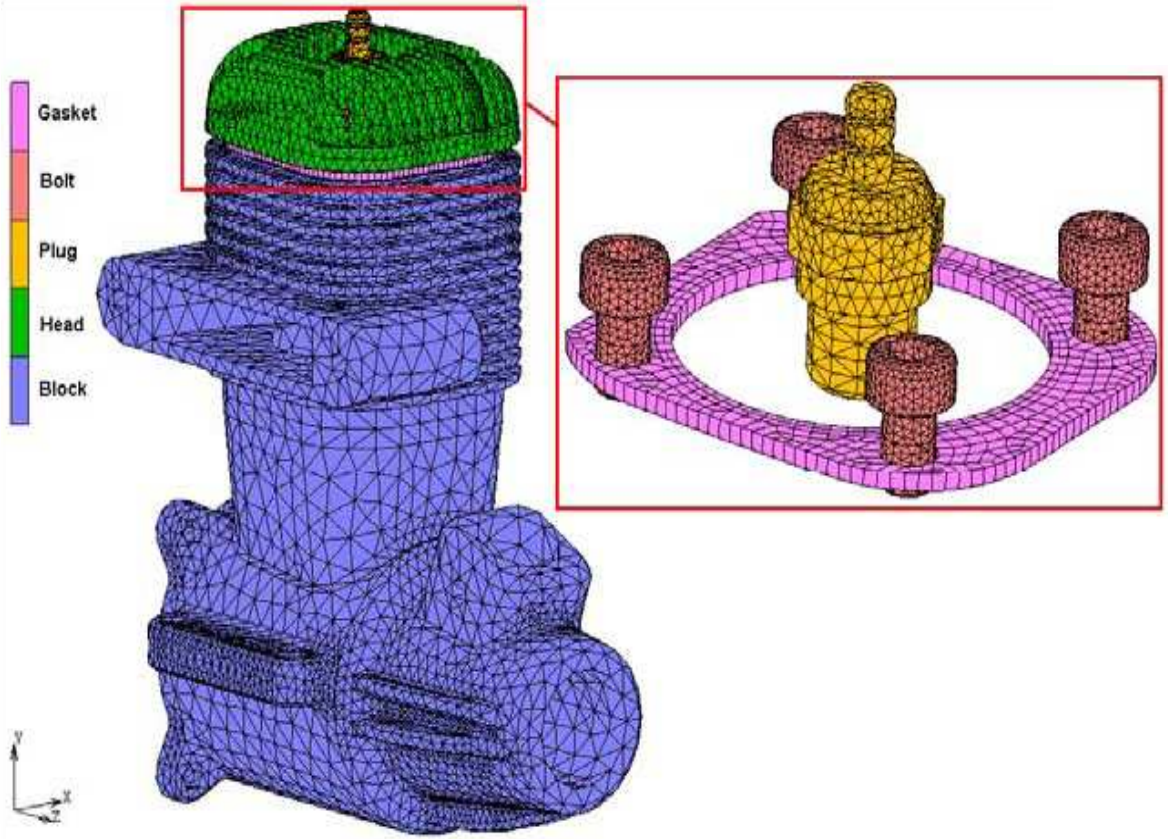


- Results compare well with a continuum mesh model

MD Nastran Contact

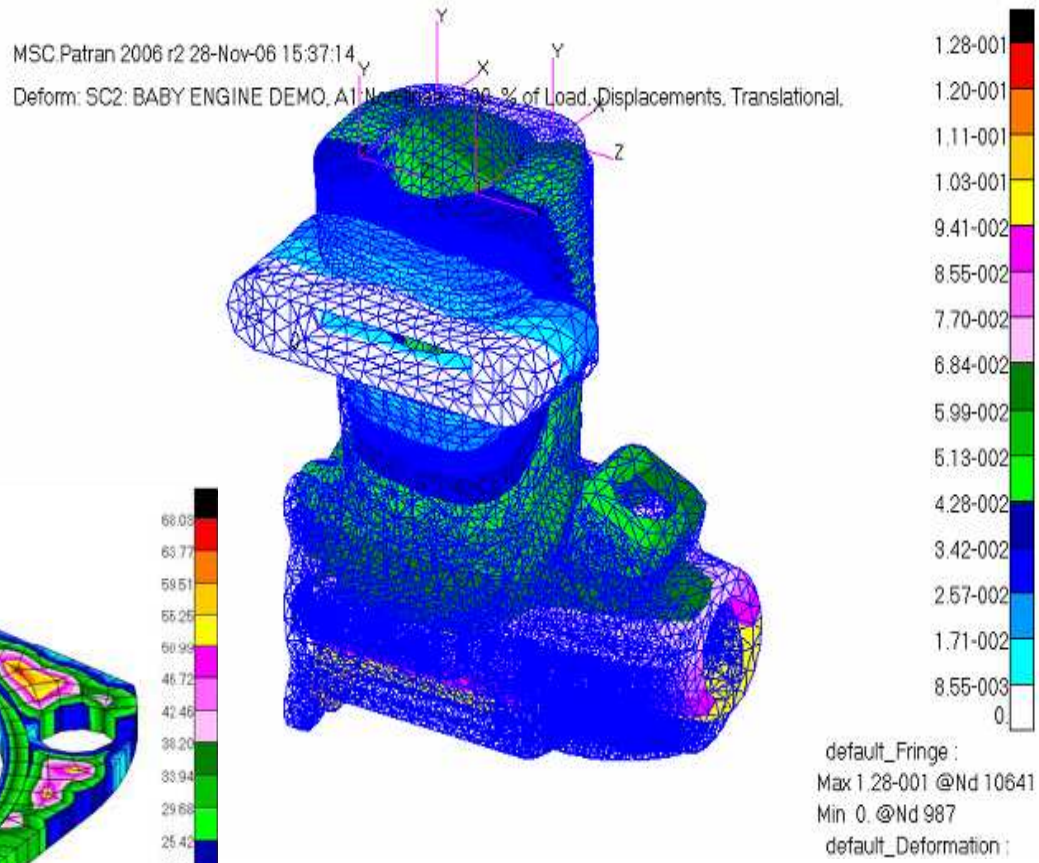
Example – Contact wit Gasket & Bolts

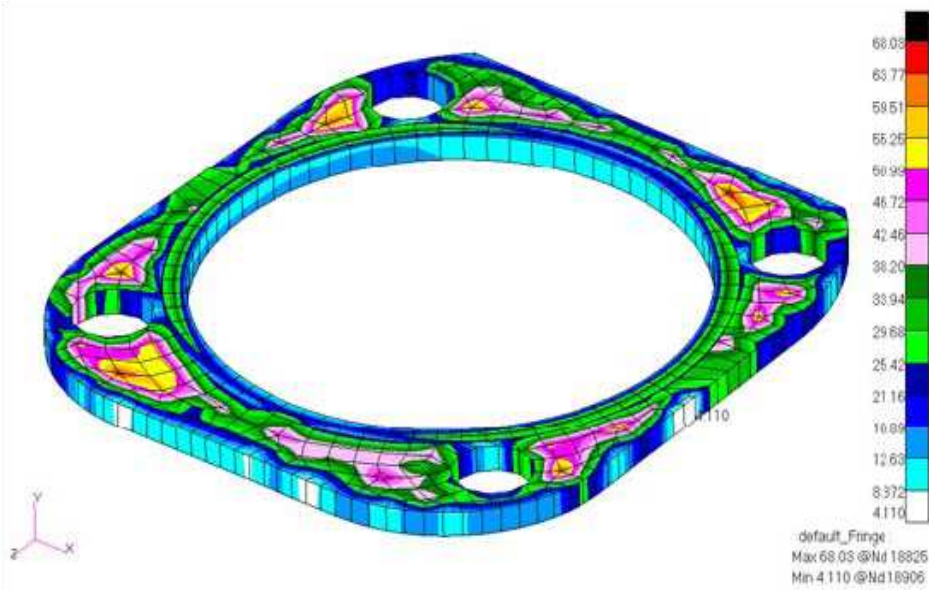




MD Nastran Contact

Example – Contact wit Gasket & Bolts





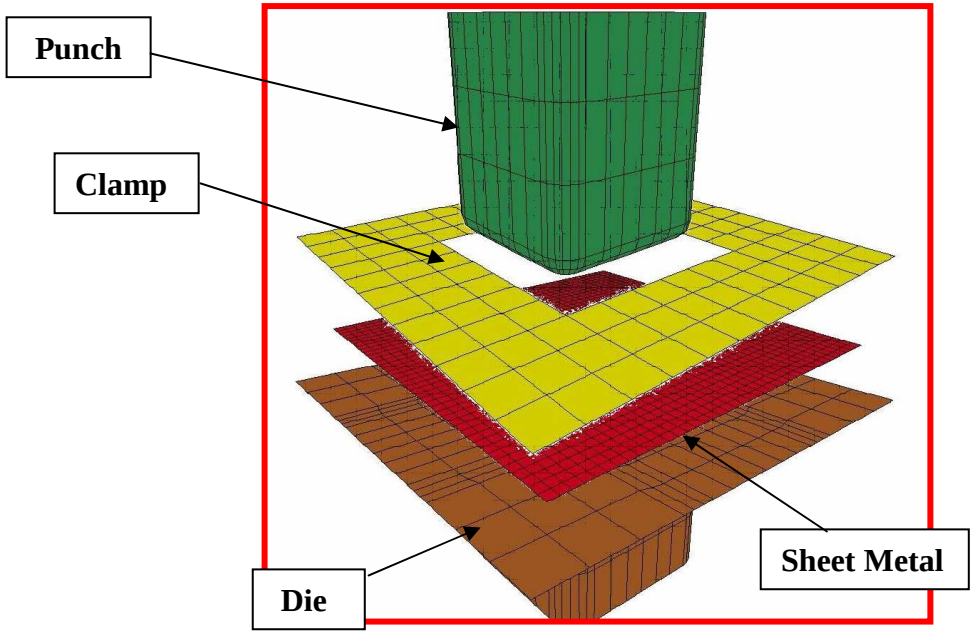
Gasket Forces

MD Nastran Contact

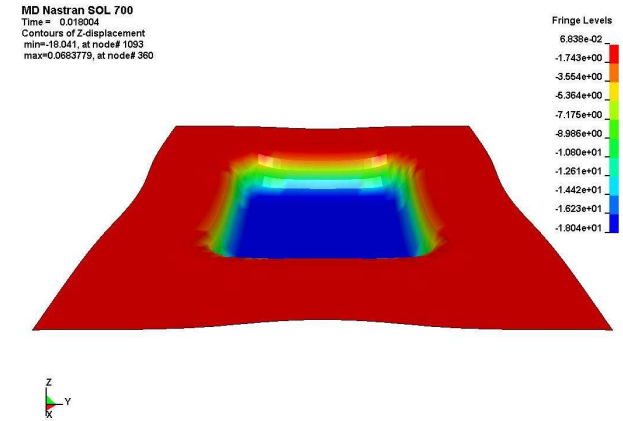
Customer Example

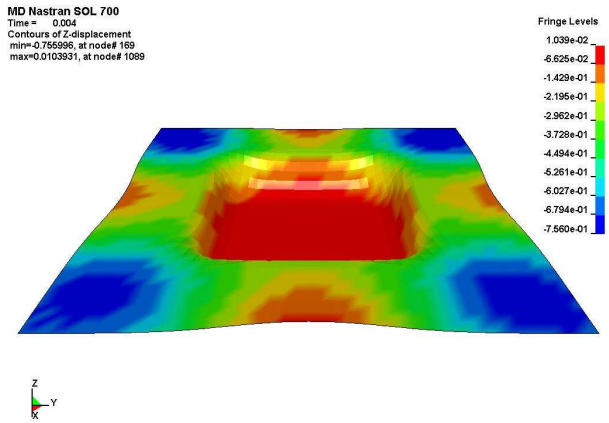
MD Nastran

Metal Forming



t=0.018 s (end of explicit run)





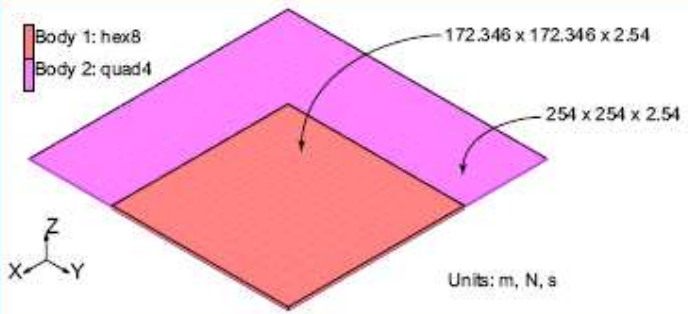
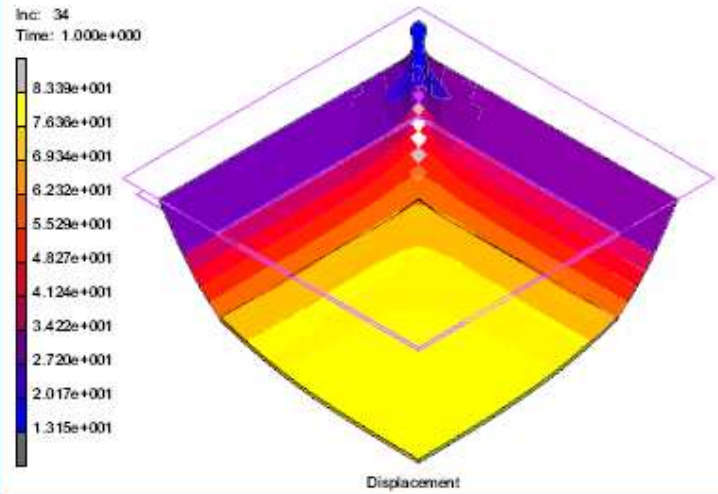
Final deformation after springback analysis
(end of Implicit run)

MD Nastran
Metal Forming

User Guide 52

Manufacturing Application:

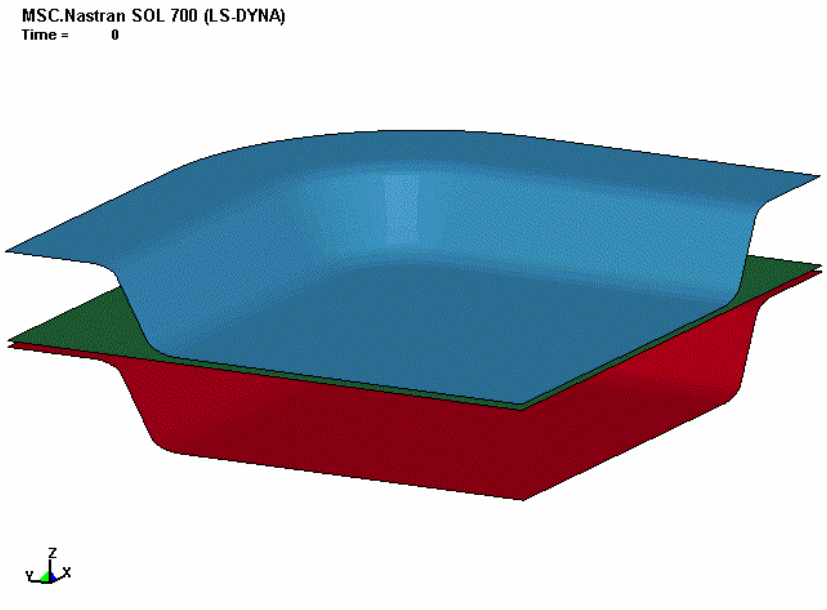
1. **Hydro-forming of a pan**
2. **Large Strain Deformation**
3. **Elasto-plastic Material**
4. **Frictional Contact**
5. **Automatic Time Stepping**
6. **Quasi-static Damping**

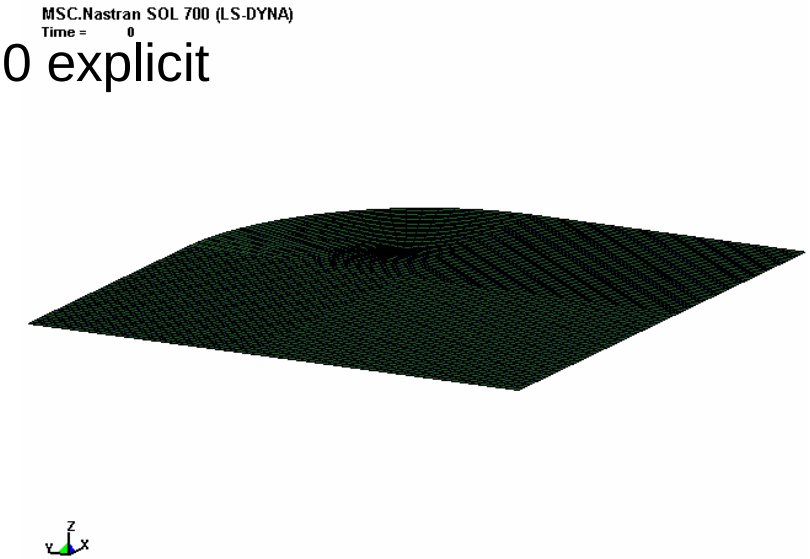
Title	Chapter 52: Hydro-forming of a Square Pan
Features	Large Deformation Hydro-Forming of Panels under Pressure loading
Geometry	
Material properties	$E = 69GPa$, $\nu = 0.3$, No hardening $Y = 240MPa$
Analysis characteristics	Quasi-static contact analysis using adaptive time stepping with artificial damping, geometric, and material nonlinearity due to large strain.
Boundary conditions	Only one quarter of the plates are modeled due to symmetry. Symmetric conditions are applied to suppress rigid body motions.
Applied loads	Pressure applied on the upper surfaces of the solid and shell elements, respectively.
Element types	CHEXA and CQUAD4 with assumed strain formulation
FE results	Displacement contours on formed shape 

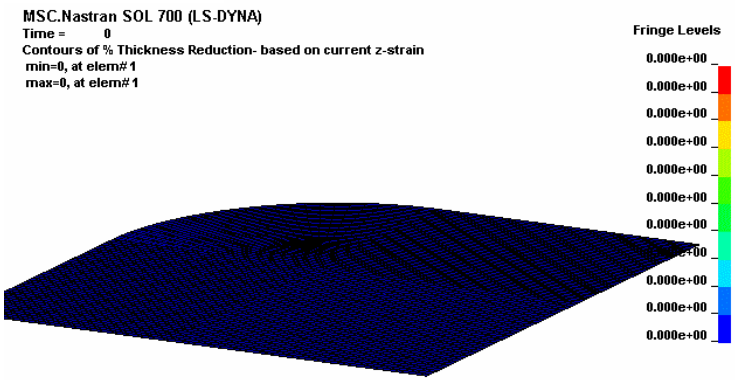
MD Nastran

Metal Forming

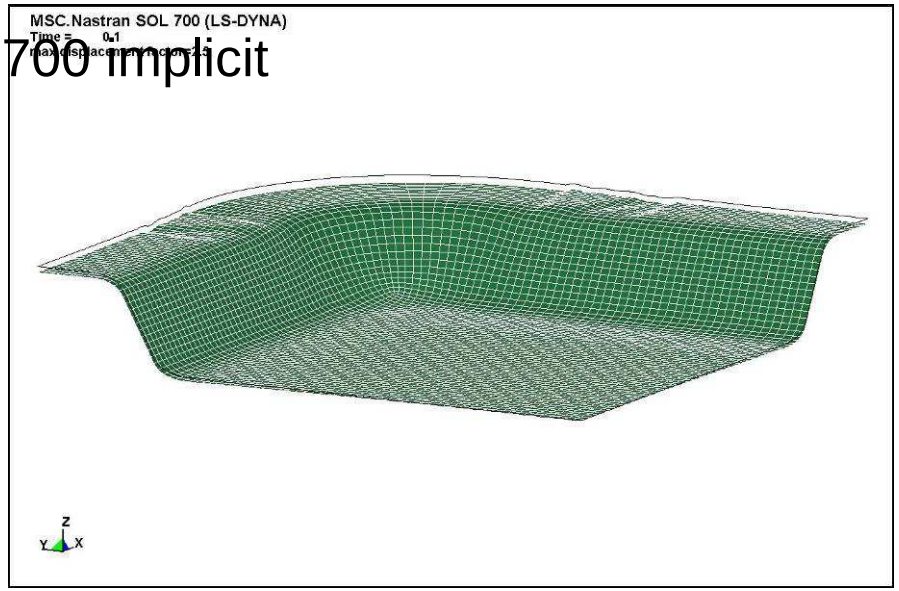
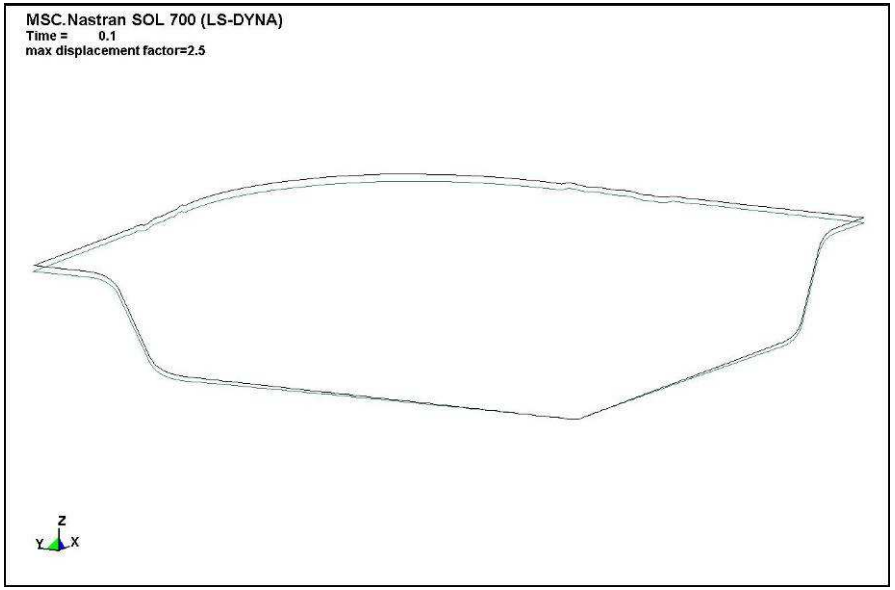
- Application: Forming simulation
  - Box forming with MD Nastran Sol700 explicit solver







MD Nastran

Metal Forming

- Application: Forming simulation
  - Springback with MD Nastran Sol700 implicit solver