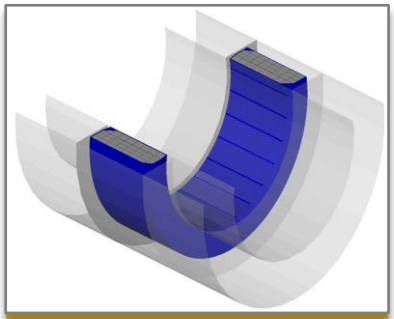
OptiStruct 14.0

Optimization-Driven Design

Drivers for OptiStruct 14.0

New Solutions

Design Better Products

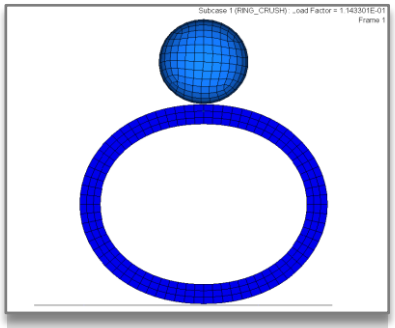


Solution Enhancements

Get Robust Answers More Easily

Performance

Get Products to Market Faster



Usability

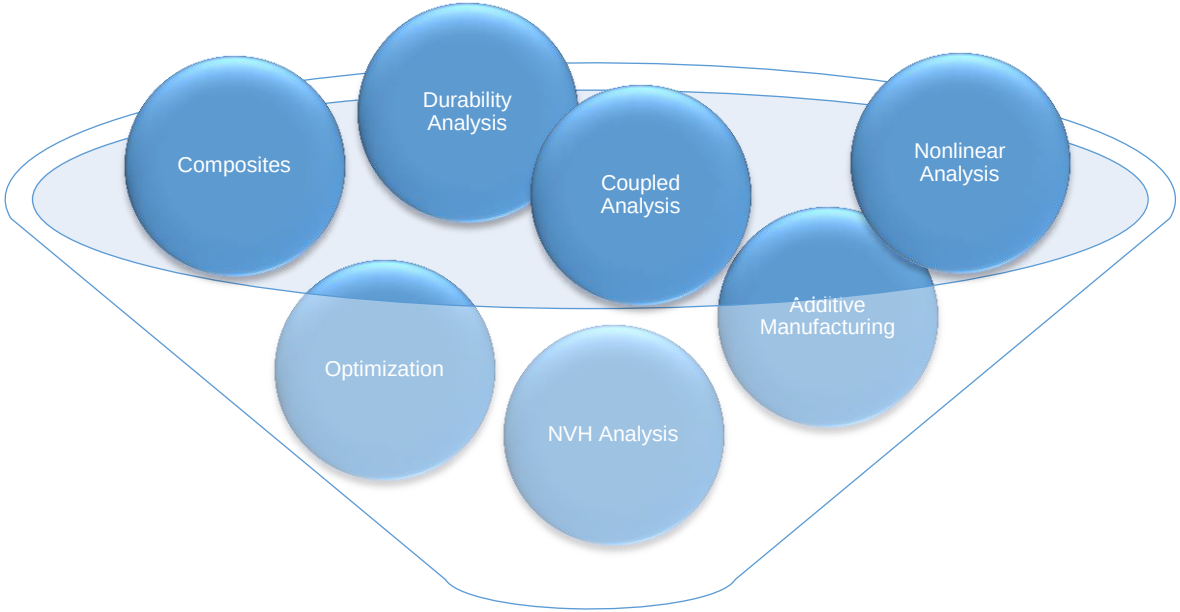
Save Time with Confidence

Over 70 New Features in OptiStruct 14.0

…to make your team more productive, effective and innovative

Altair

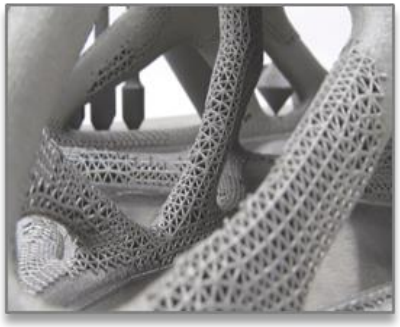
Focus for 14 – Better Designs and Better Processes



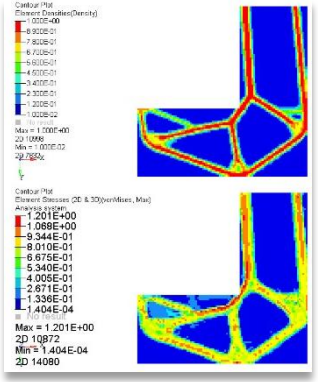
OptiStruct 14.0

Release Highlights – New Solutions

- Analysis
  - Fast Contact Analysis
  - Coupled Transient Heat Transfer and Static Analysis
  - Rigid Bodies

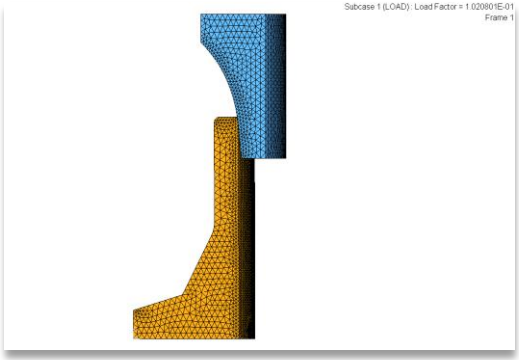


- Optimization
  - Stress Response for Topology/Free-Size Optimization
  - Multi-Axial Fatigue Analysis and Optimization
  - New Optimization Responses
  - New Manufacturing Constraints
  - Design and Optimization of Lattice Structures for Additive Manufacturing

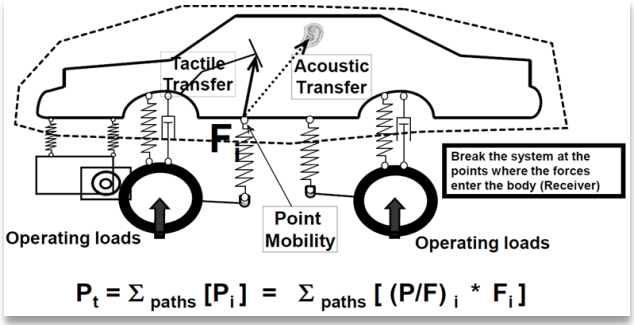


Release Highlights – Solution Enhancements

- Nonlinear Analysis
  - Contact
  - Material
  - Elements and Loading

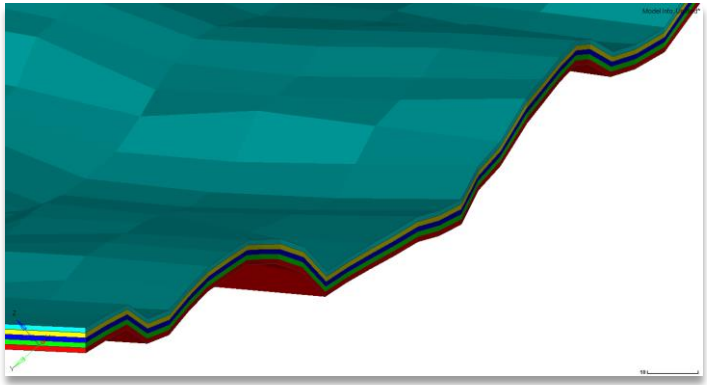


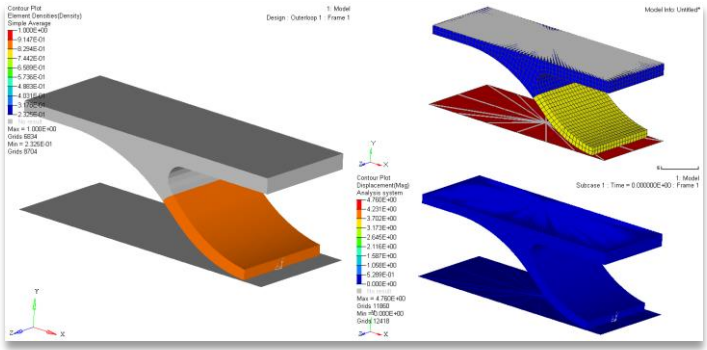
- NVH Analysis
  - BIOT Material
  - One-Step Transfer Path Analysis (TPA)
  - CMS with Preload



Release Highlights – Solution Enhancements

- Optimization
  - Large Shape Change Based Optimization
  - Topography Optimization for Laminate Composites
  - Composite Free Sizing with ESLM
  - Solid Topology in RADOPT
  - Multiple Slopes for Dang Van Factor of Safety (FoS)
  - Zero Crossing Response for Random Response Optimization
  - Topology Result Discreteness

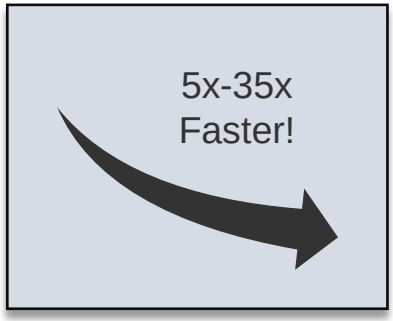




Release Highlights – Performance

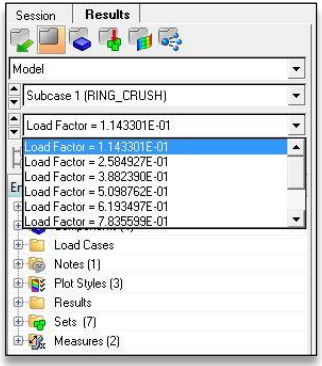
- NVH Analysis
  - Faster CMS SE Generation with AMSES
  - Improved Stability for FASTFR
  - Support for Larger Model Size in Modal Frequency Response Analysis

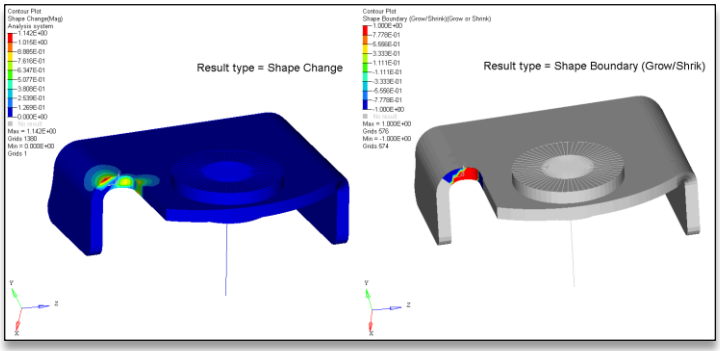
- Fast Contact Analysis



Release Highlights – Usability

- Nonlinear Analysis
  - Results Output
- NVH Analysis
  - Preloaded Modal FRA
  - Preloaded Direct/Modal Transient Analysis
- Optimization
  - DRESP2/3 Response Output in H3D
  - Turn Off Check for Negative and Large Compliance in Optimization
  - Free-Shape Optimization Results Output





New Solutions

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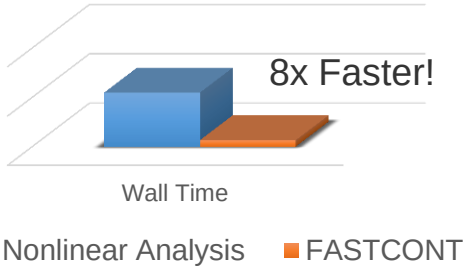
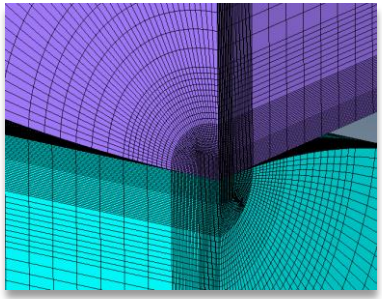
Fast Contact Analysis

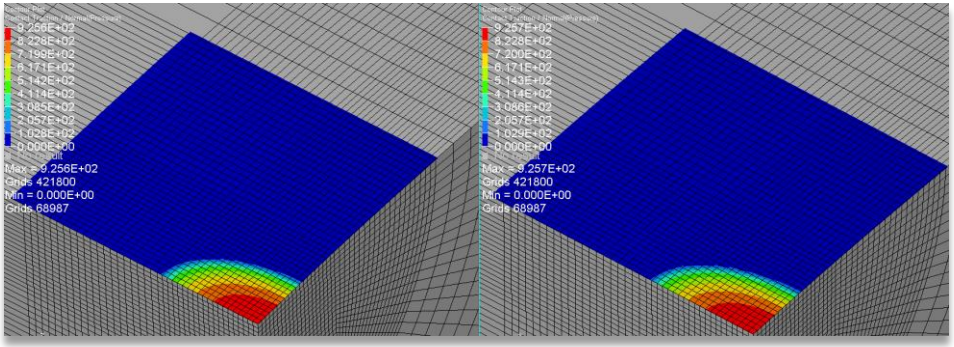
- Much faster than nonlinear analysis with contact and as accurate
- Can be used in models with no friction and no material and geometric nonlinearity
- Linear analysis solution
- Supports MPC-based GAPs, CGAP/CGAPG and N2S contact definitions





1031779 DOFs
1681 Contact Elements
4 Cores, SMP

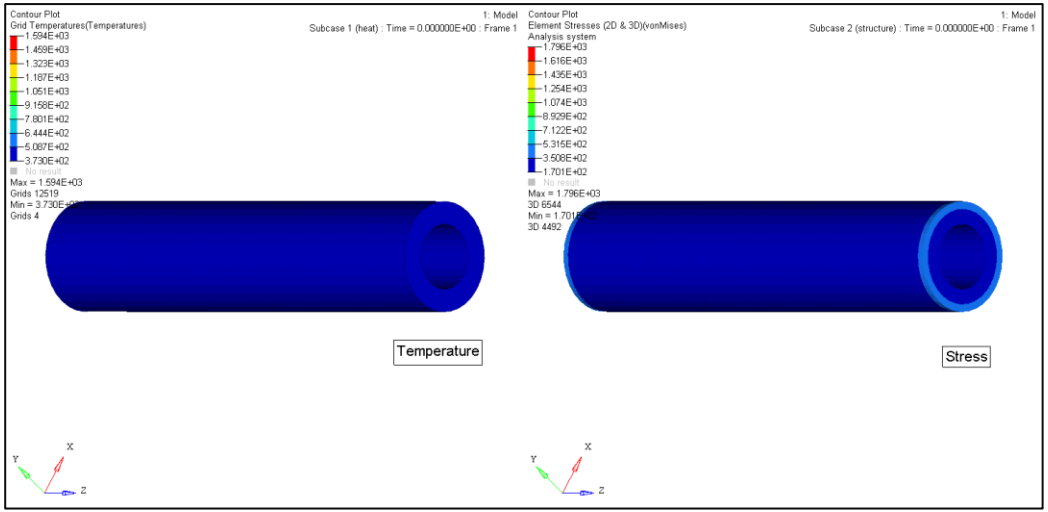
Contact Pressure



FASTCONT Nonlinear Analysis

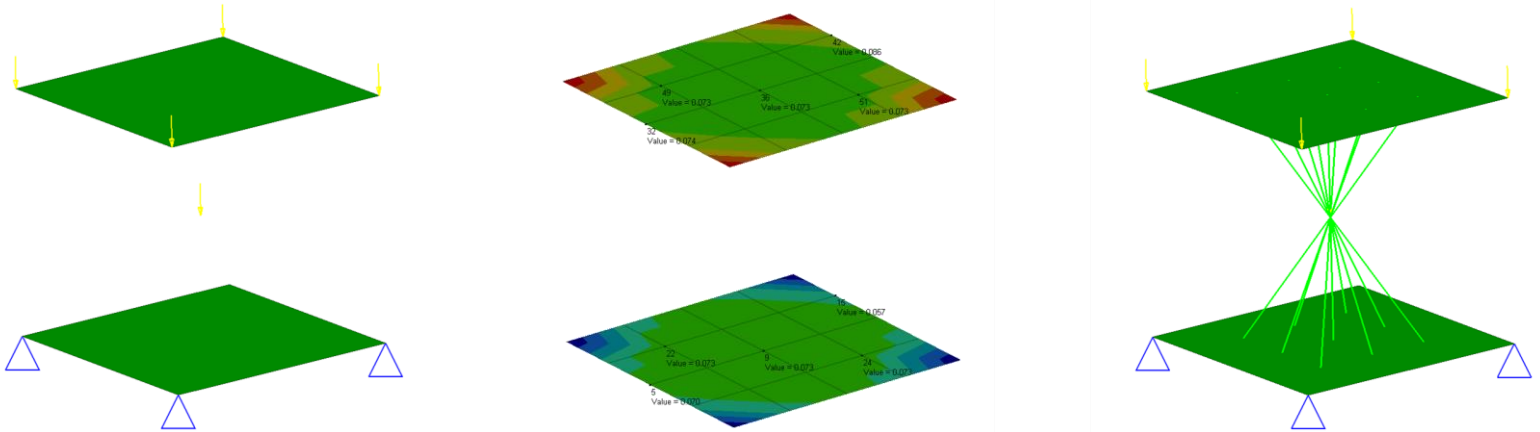
Coupled Transient Heat Transfer and Static Analysis

- Temperatures from a linear transient heat transfer analysis are used as thermal loading in a subsequent linear static analysis
- Better workflow to capture coupled thermo-mechanical behavior
- Temperature-dependent materials are supported



Rigid Bodies

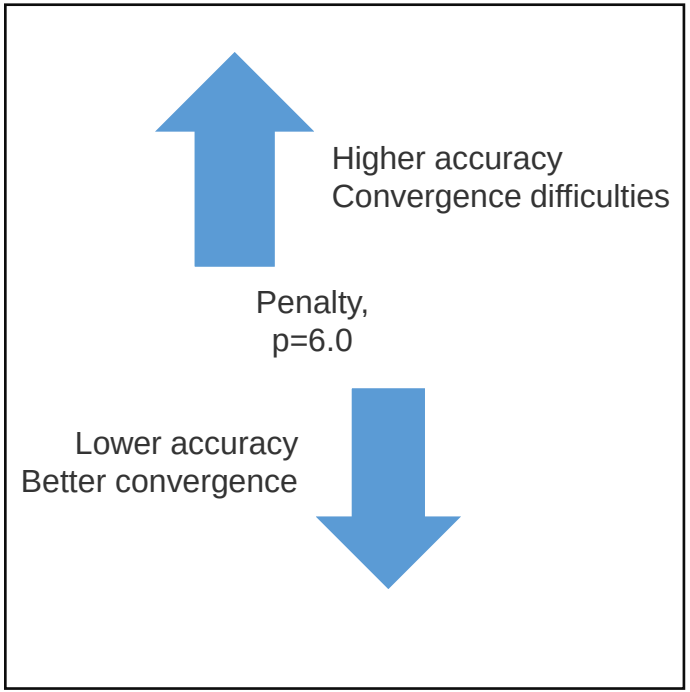
- Define sets of grids, elements or surfaces as rigid bodies
- Rigid bodies can be added
- Mass and inertia properties can be defined
- Can be used to rigidly connect parts without defining any connectors



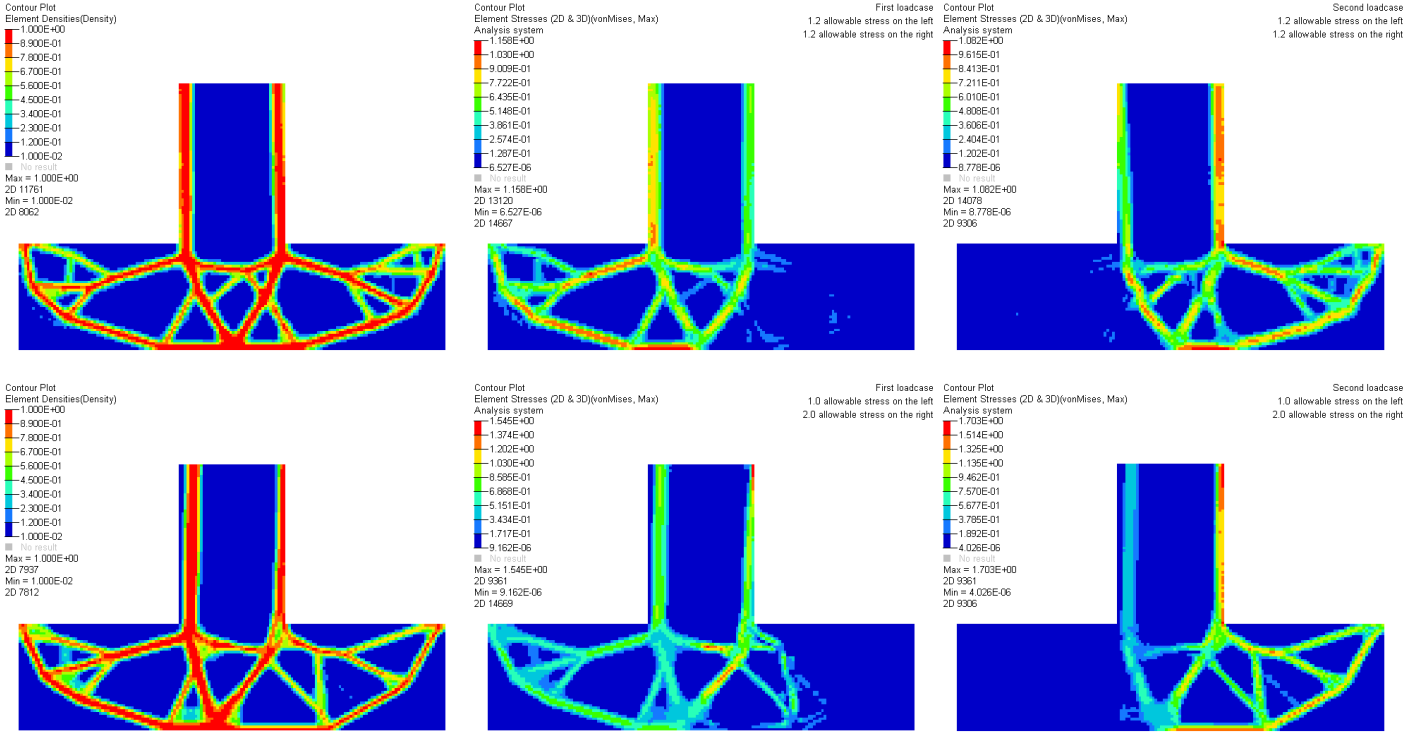
Stress Response for Topology/Free-Size Optimization

- Flexible definition of stress constraints
  - Subcase dependent
  - Material dependent
  - Regional/local
- Detailed constraints at the topology/free sizing stage
- Not limited to Von Mises stress

$$\sigma_{NORM} = \left[\frac{1}{n} \sum_{i=1}^{n} \left(\frac{\sigma_i}{\sigma_{bound}} \right)^p \right]^{1/p}$$



Stress Response for Topology/Free-Size Optimization



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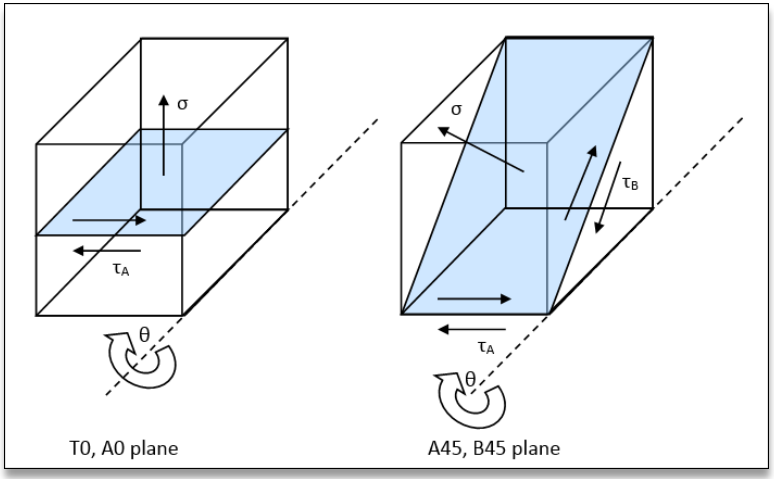
Multi-Axial Fatigue Analysis and Optimization

- High-cycle (SN) and low-cycle fatigue (EN) methods are supported

- Critical plane approach to capture the physical nature of damage
  - Experimentally, cracks initiate and grow on critical planes
  - Stresses and strains on critical planes
  - Can be either max shear or max tensile stress planes



Multi-Axial Fatigue Analysis and Optimization

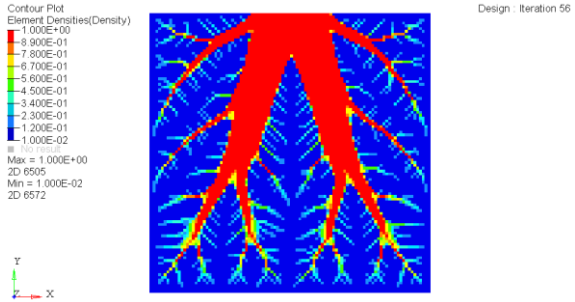
- Damage models
  - SN
    - Goodman (tensile crack)
    - Findley (shear crack)
  - EN
    - Smith-Watson-Topper (tensile crack)
    - Fatemi-Socie and Brown-Miller (shear crack)

- Smith-Watson-Topper mean stress correction can be used in optimization

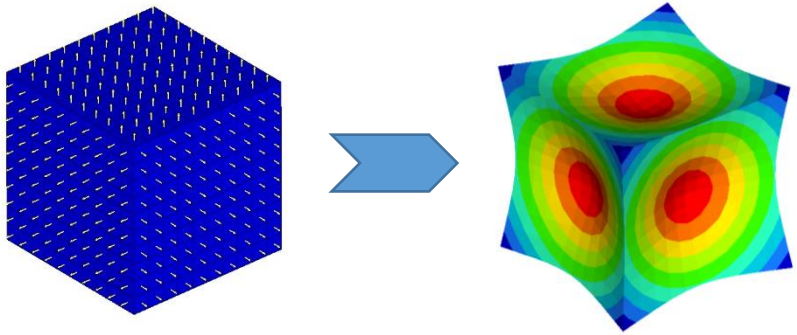
- Automatic use of surface stresses of solids for fatigue responses

New Optimization Responses

- Thermal Compliance
  - Global measure similar to static compliance
  - Maximizes conduction
  - Equivalent to minimum temperature



- Enclosed Volume
  - Of a closed shell structure
  - Applications include optimizing fluid containers like pressure tanks, fuel tanks and oil pans to contain a minimum volume



Uniform Pressure

Optimum Design

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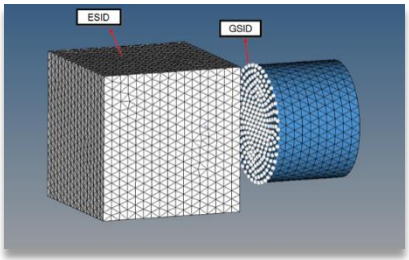
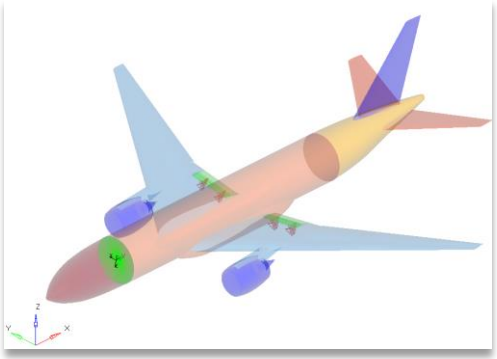
New Optimization Responses

- Vector-based Input of Responses
  - Works with equation responses
  - No need to create separate, individual responses to reflect a ‘vector’
    - E.g. Average element stress in a component with 1000 elements

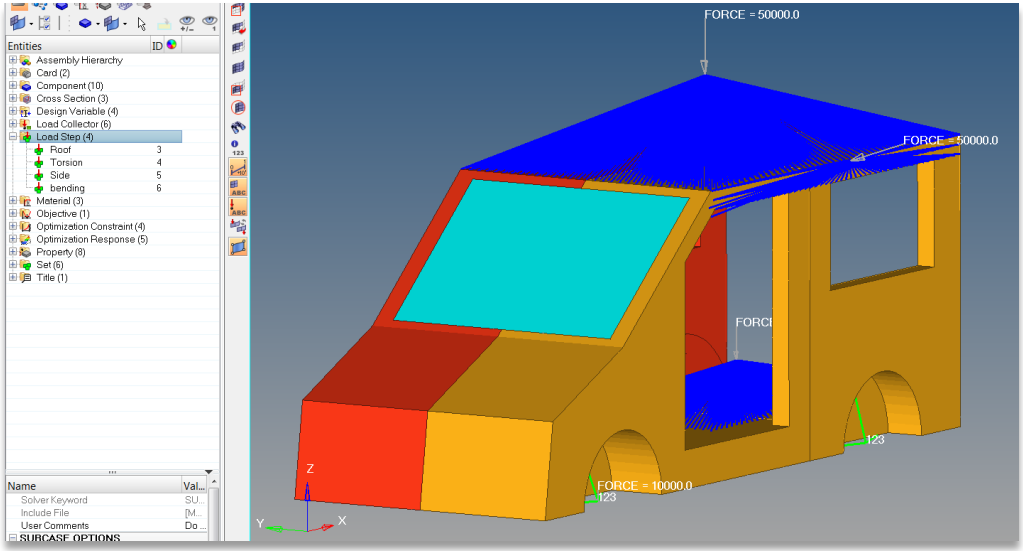


- Resultant Force and Moment
  - Requires a section definition on which forces/moments are calculated
  - E.g. Determine the effect of the cylinder at the circular cross-section face



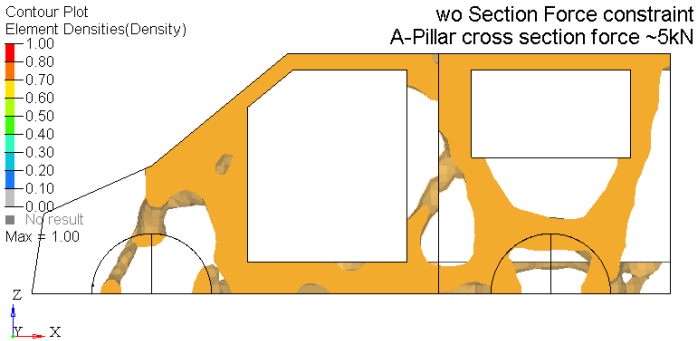
New Optimization Responses

- Resultant Force and Moment
  - Example using section force to drive the vehicle frame design
  - Multiple load cases (torsion, bending, linearized roof and side crash)
  - Evaluate the influence of the A-pillar cross section forces for roof crush

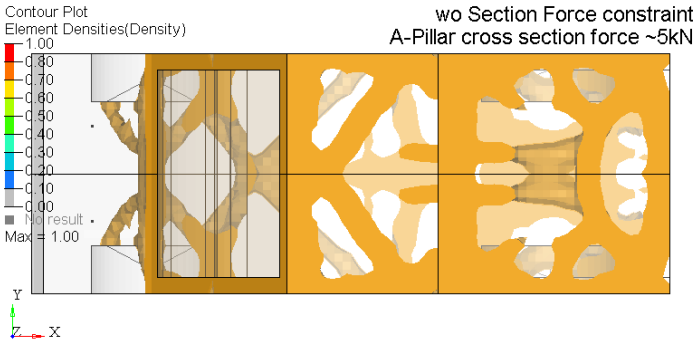


New Optimization Responses

- Resultant Force and Moment



wo Section Force constraint
A-Pillar cross section force ~5kN



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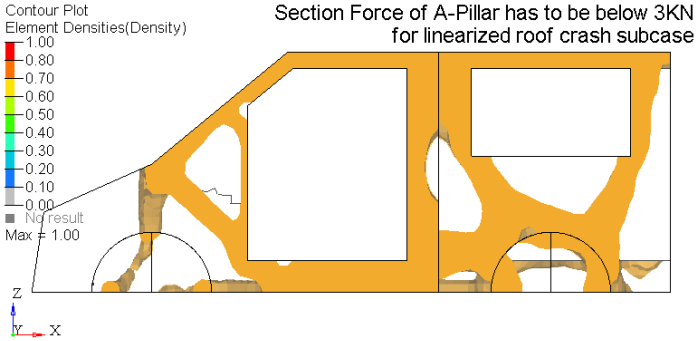
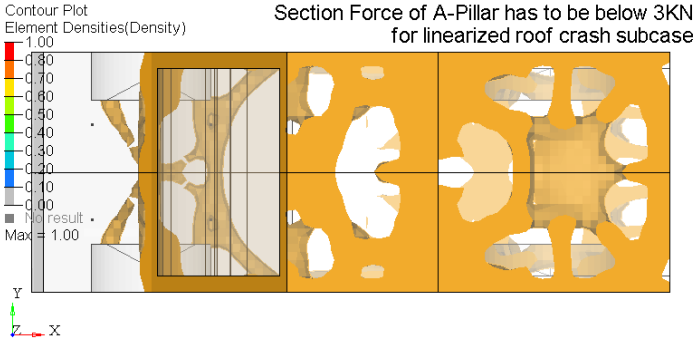


Section Force of A-Pillar has to be below 3KN
for linearized roof crash subcase



Section Force of A-Pillar has to be below 3KN
for linearized roof crash subcase

New Optimization Responses

- NVH Responses
  - Frequency range based response definition
    - Added benefit that allows sub-range based equations-of-responses definition
  - Response scaling: Log, A-, B- and C-weighting
    - Human ear is less sensitive at low and high frequencies
    - Weighting is aimed at capturing that sensitivity
    - A-weighting is most popular
      - E.g. Noise at 100Hz would sound about 20dB quieter than at 1000Hz at the same sound pressure level

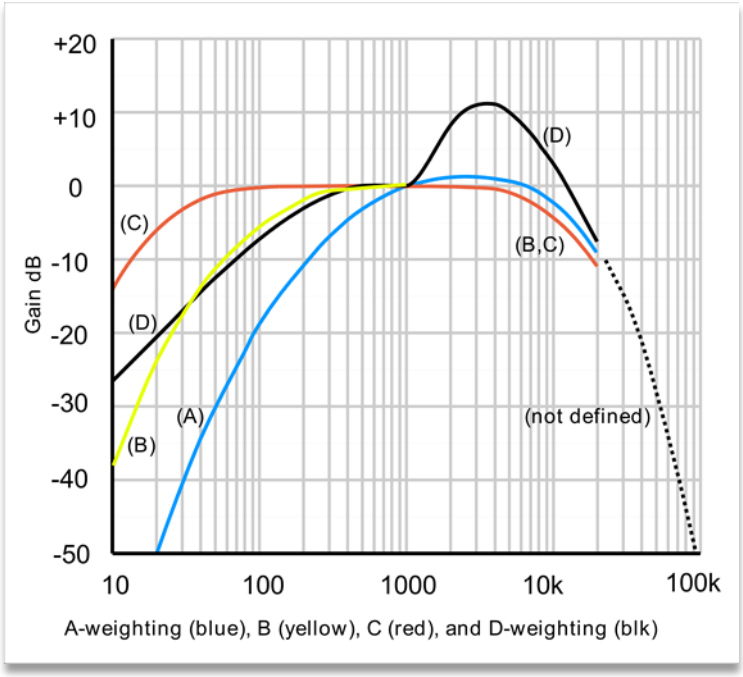
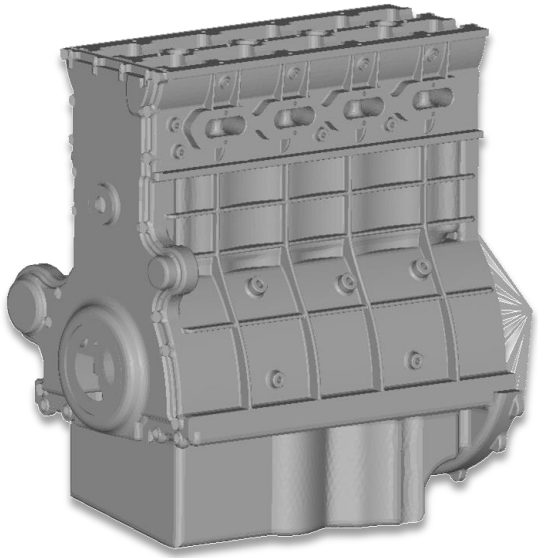


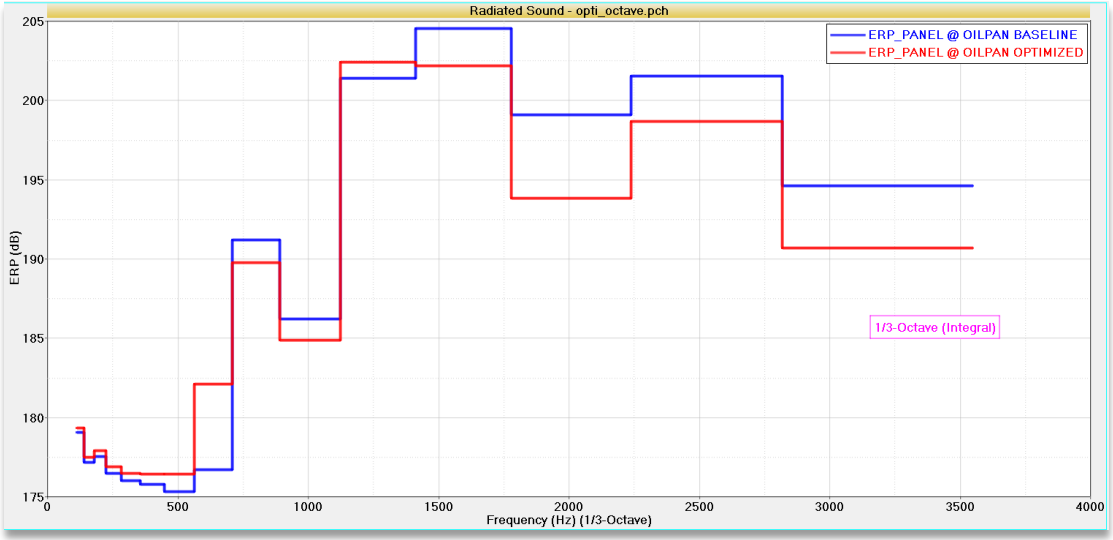
Image source: Wikipedia (A-weighting)

New Optimization Responses

- NVH Responses
  - Octave Bands: Full, 1/3 and 1/8 octave bands



Frequency sub-range:1500-3500 Hz



New Manufacturing Constraints

- Automated Tape Laying (ATL) of Composites
  - Higher rates of material deposition
  - Unidirectional and fabric prepreg tapes can be deposited
  - Versatile process allowing breaks and changes in fiber orientation
  - Can be used for flat or curved structures
  - Applicable for large structures such as wing spars
  - Strip width and minimum length can be defined

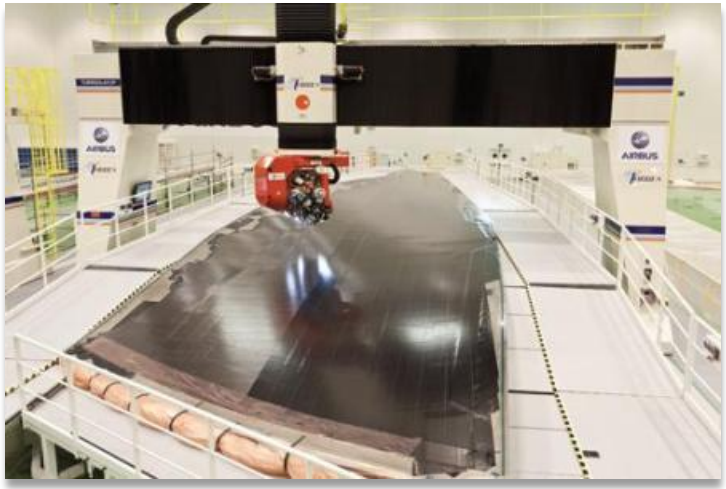
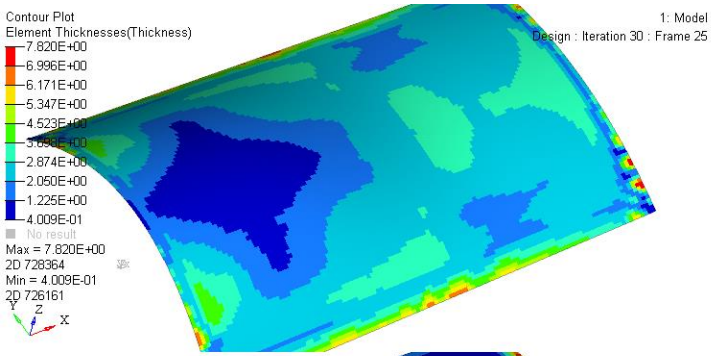


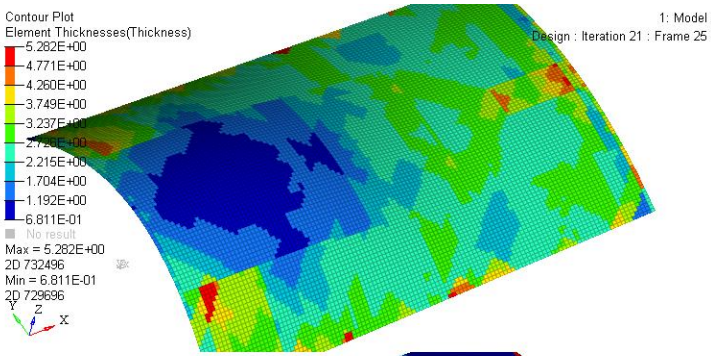
Image source: CW/Sara Black

New Manufacturing Constraints

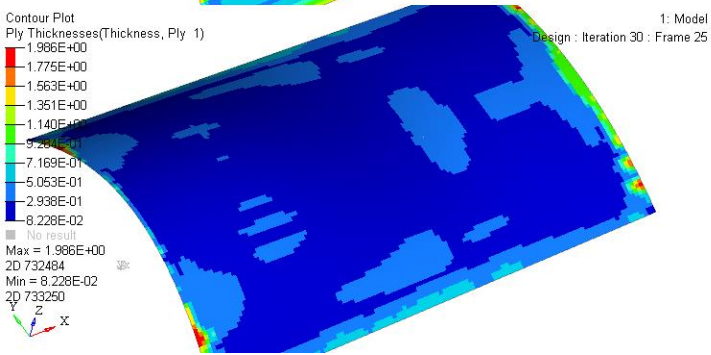
- Automated Tape Laying (ATL) of Composites

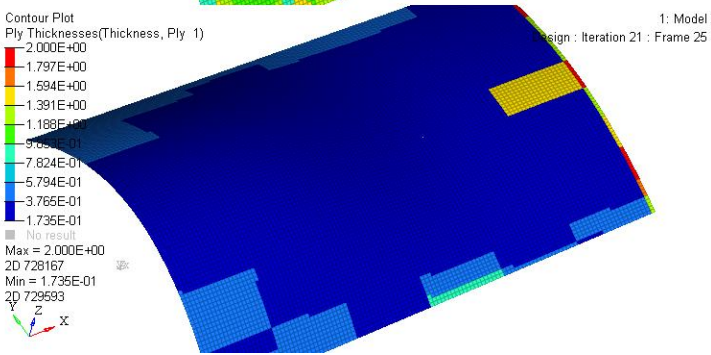
Laminate Thickness





0 Ply Thickness





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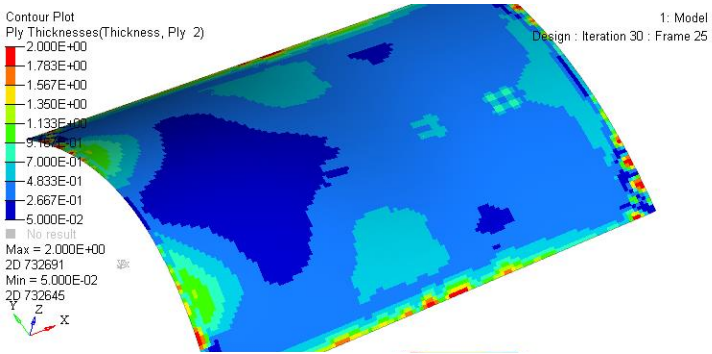
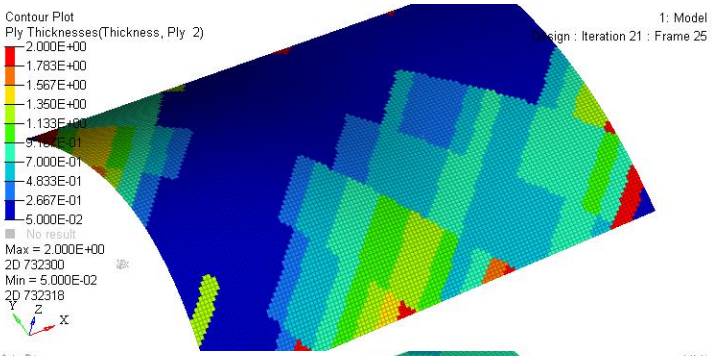
New Manufacturing Constraints

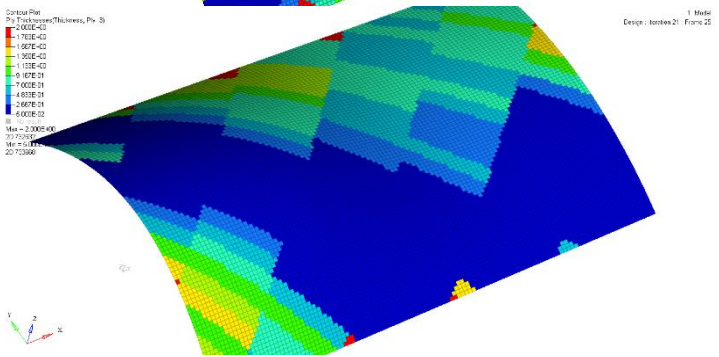
- Automated Tape Laying (ATL) of Composites

45 Ply Thickness





-45 Ply Thickness



New Manufacturing Constraints

- Components made from flexible rolling or Tailor rolled blanks
  - Continuous rolling process for sheet metals
  - Varying thicknesses with smooth transitions
- Linear/planar pattern grouping
  - Used with free size optimization

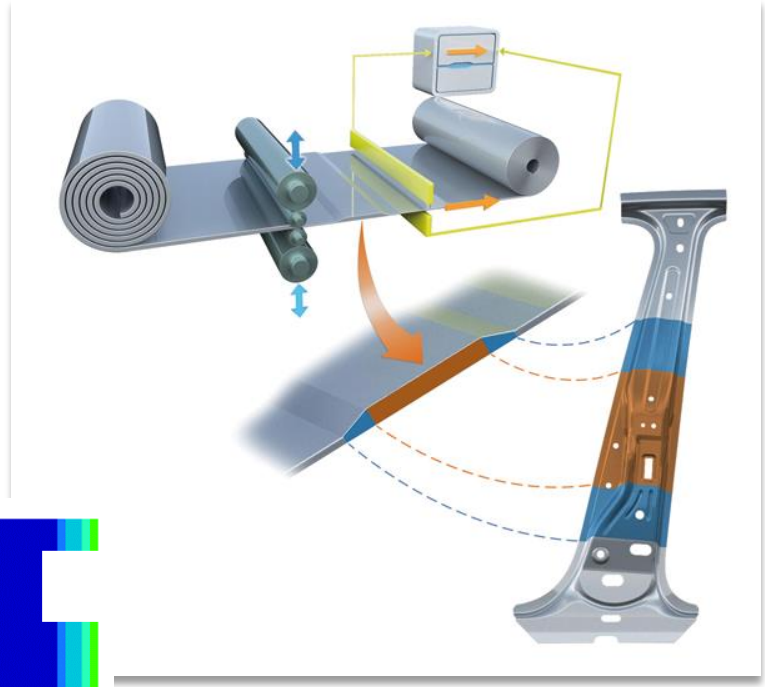
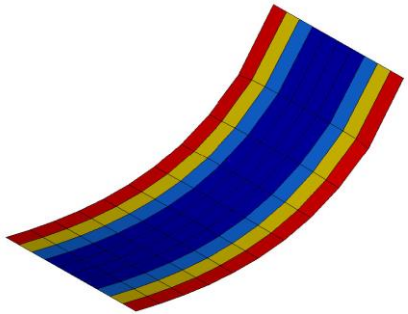
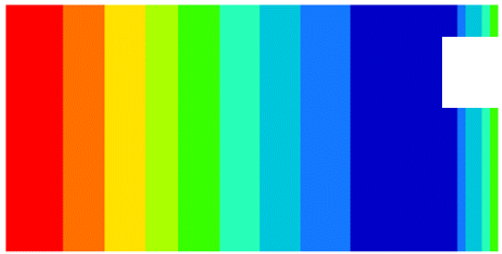


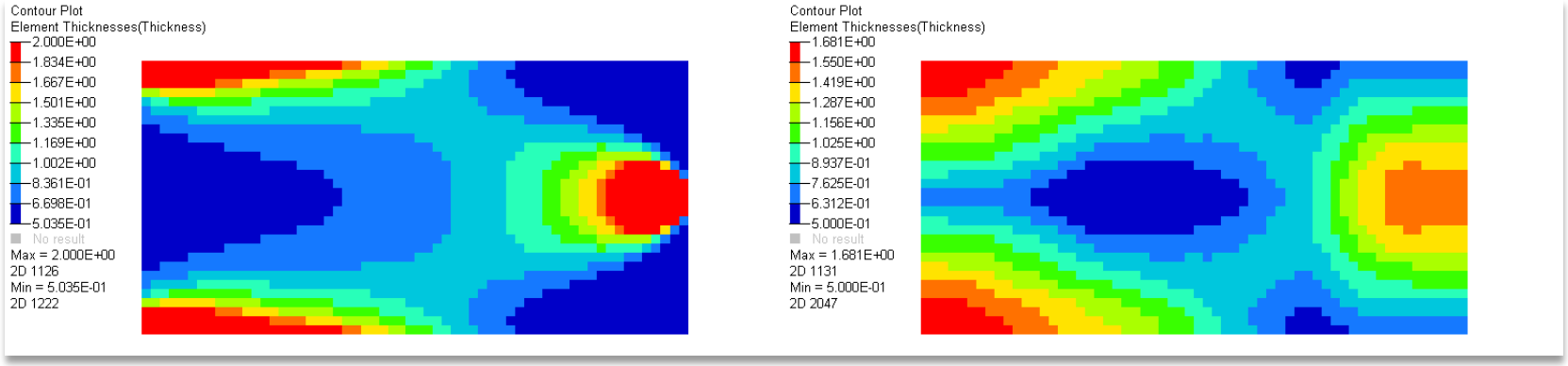
Image source: Volkswagen AG





New Manufacturing Constraints

- Thickness Gradient Constraint for Shells
  - Similar to ply drop-off constraints for composites
  - Overall or directional gradient control can be applied
  - Can be combined with linear/planar pattern grouping to create other TRB-related constraints



Additively Manufactured Lattice Structures

Lightweight

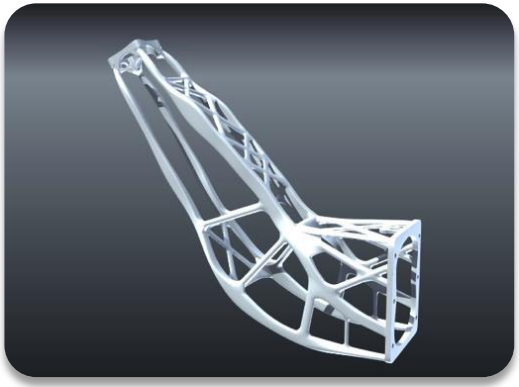
Good thermal behavior

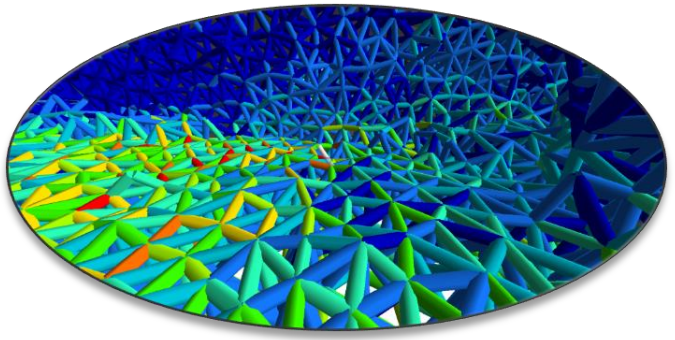
Porosity (for implants)

Functional integration

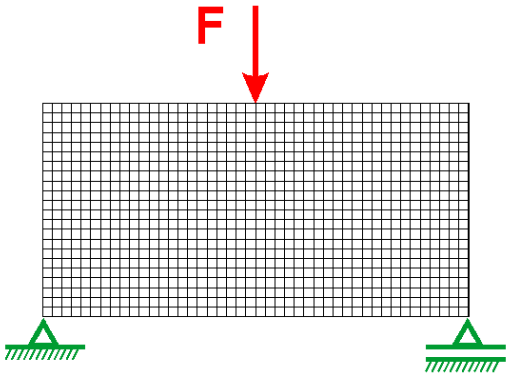
Parts count reduction

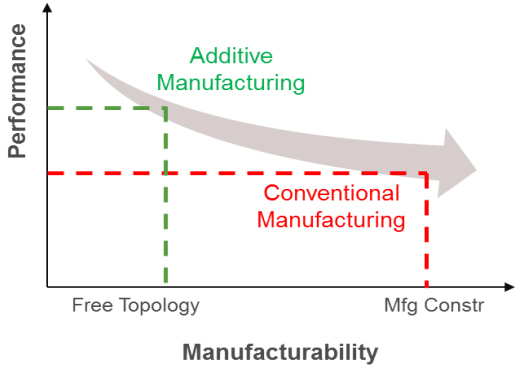
Geometric complexity

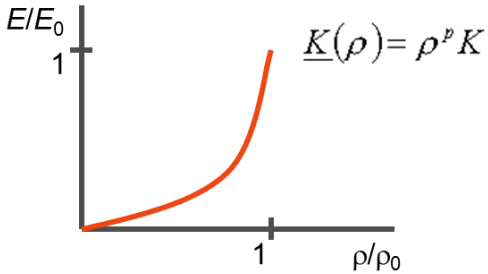




Enabling Technology







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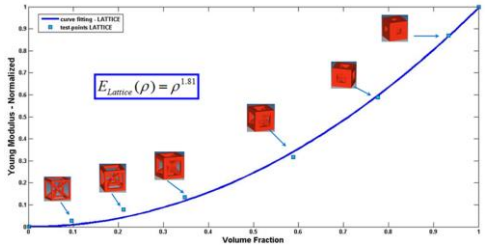
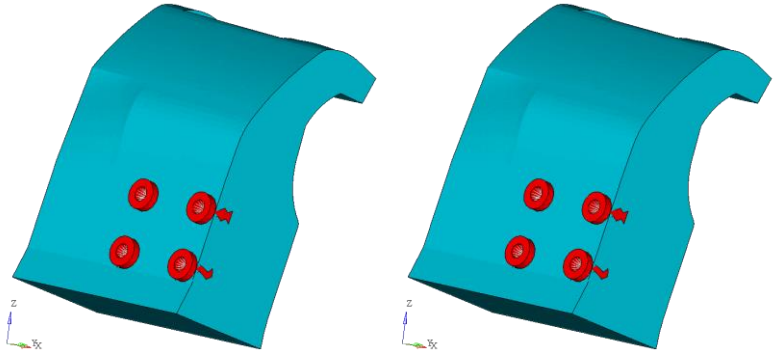
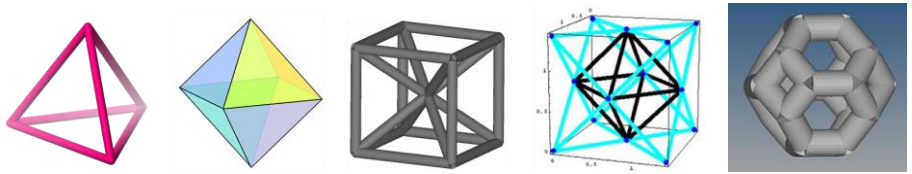
Designing for Additive Manufacturing

- Simultaneous multi-scale optimization of macro and ‘micro’ structures
- Two-phase optimization process
  - Topology with porosity to drive material distribution





  - Sizing optimization of lattice cell members
    - Including detailed constraints like stress and local buckling



3D Printed Hybrid Solid-Lattice Structure

Solution Enhancements

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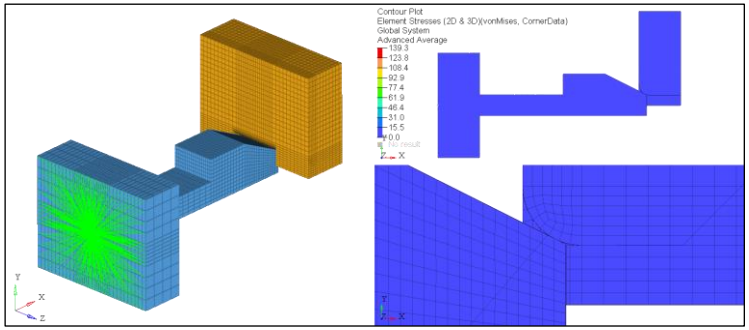
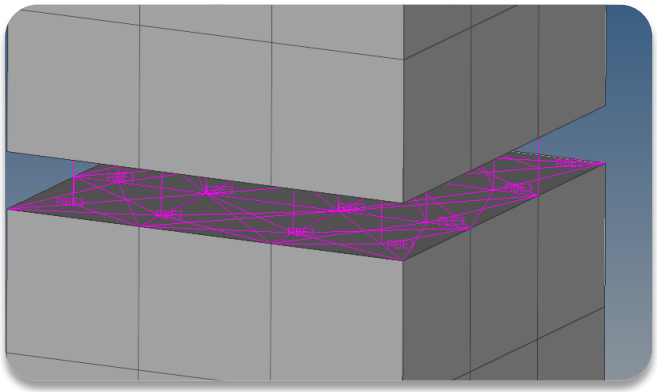
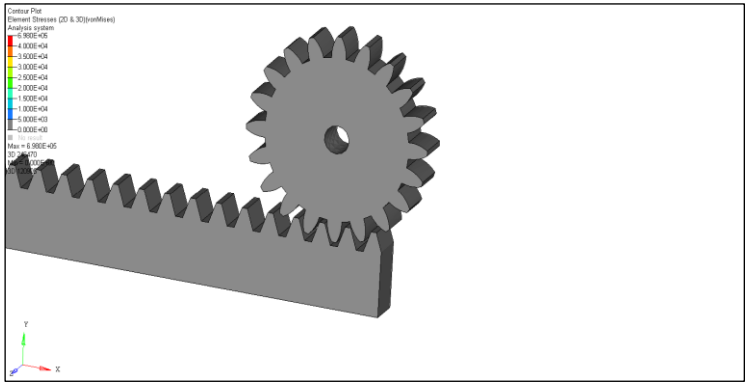
Nonlinear Analysis – Contact

- Finite sliding
- Buckling/Preloading analysis with S2S contact
- S2S contact visualization in HyperMesh





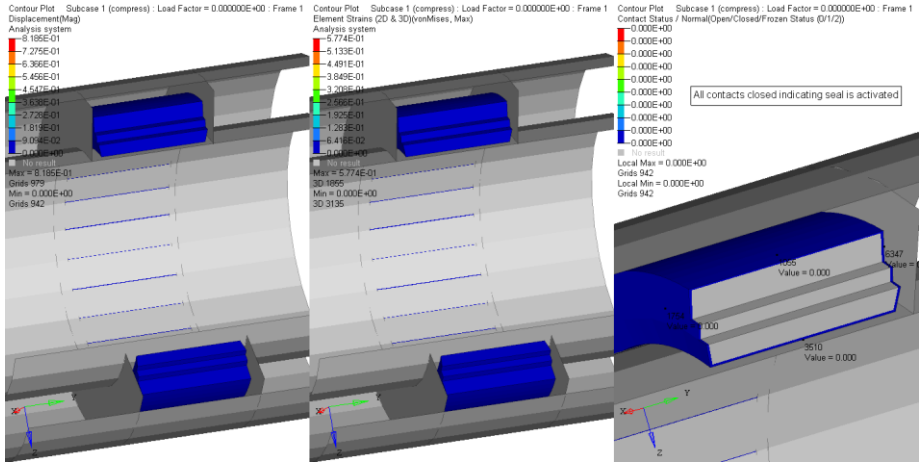


Nonlinear Analysis – Material

- Arruda-Boyce hyperelastic material
  - Good curve fitting with limited test data
  - Good for higher strains
  - Captures stiffening effects

- Anisotropic material for solids for large displacement analysis

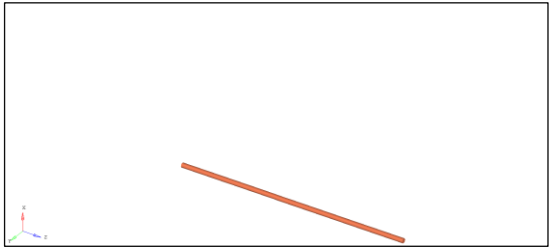
Displacement | Element Strains | Contact Status



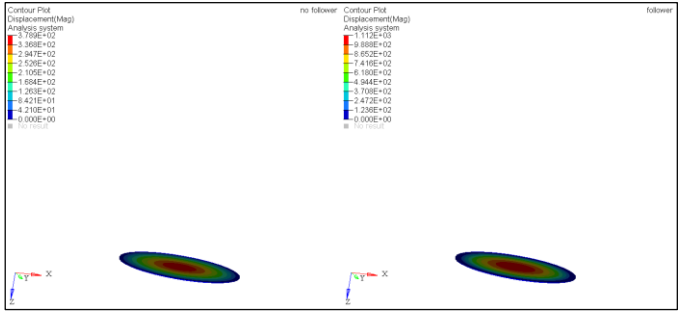
- Sealing analysis of a packer used in the oil and gas industry
- The packer is squeezed by the moving piston against a fixed wall so as to create an annular seal between the two pipes
- The contact status result-type indicates that the seal has been successfully created

Nonlinear Analysis – Elements and Loading

- 1D element support for large displacement analysis
  - CBAR, CBEAM and CROD



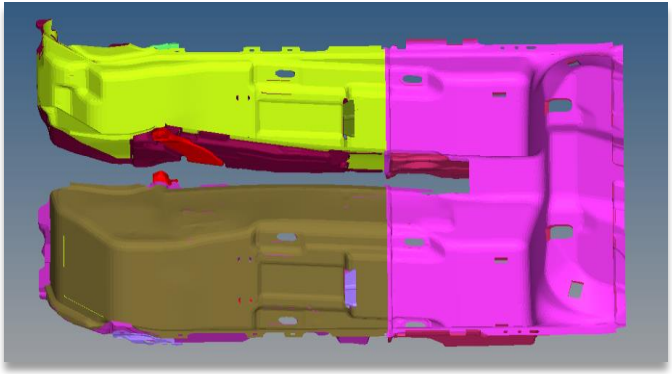
- Follower loads
  - Pressure and force are supported
  - Can be subcase dependent



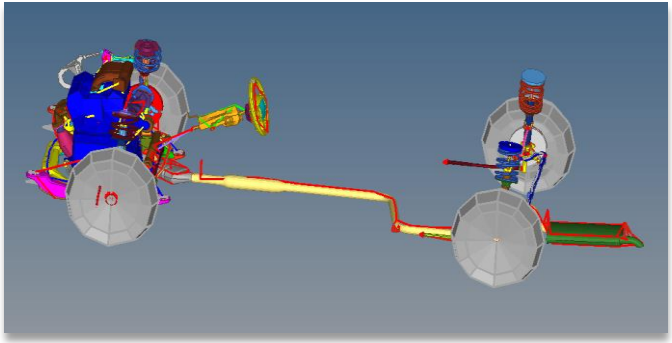
- Time dependent loading input
  - Amplitude of loading is defined through tables
  - No need to create multiple subcases to represent loading/unloading sequences

NVH Analysis

- BIOT (Poro-Elastic) Material
  - Better solution quality and stability
    - No “weak” modes from BIOT material
  - Improved run times

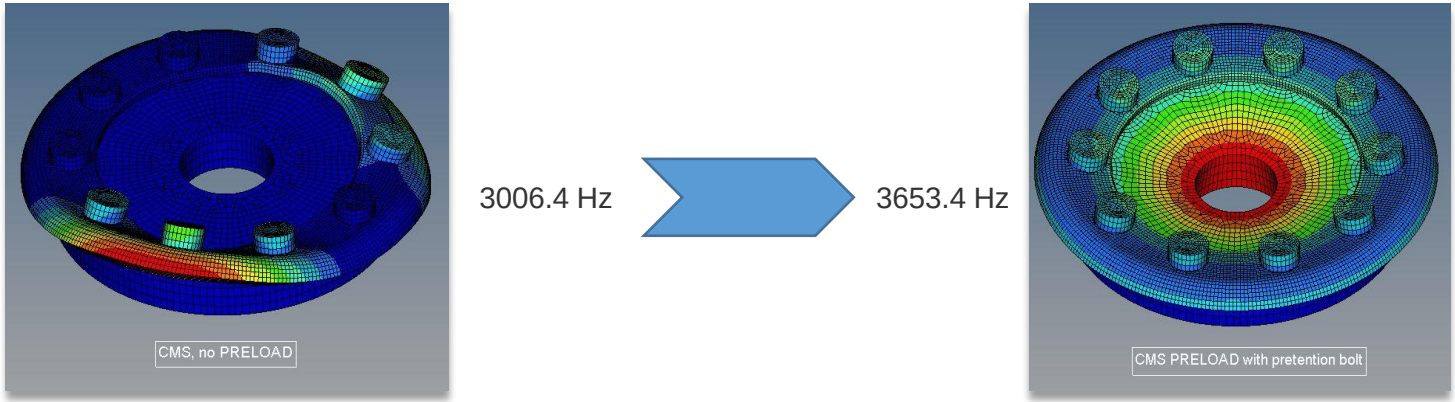


- One-Step Transfer Path Analysis
  - More accurate enforced motion based input can be defined
  - Direct frequency response solution is supported
  - Output and visualization of entities outside the control volume for better diagnostics



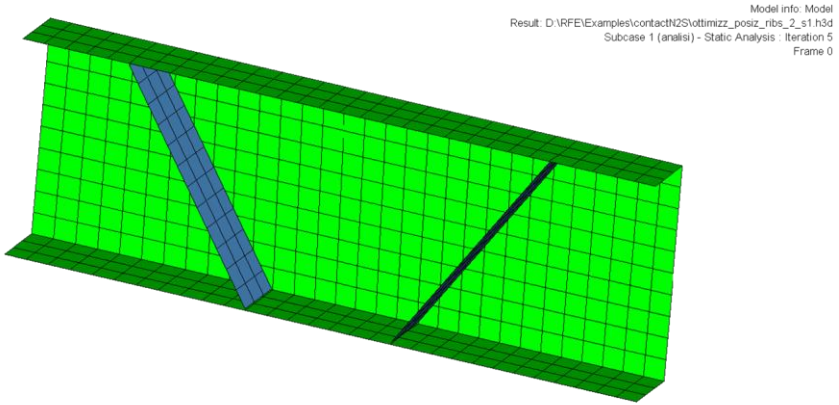
NVH Analysis

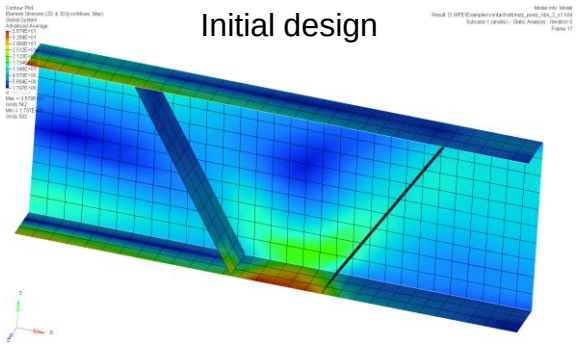
- CMS with Preload
  - Capture stiffening effects due to preloading
  - Pretension and contact in nonlinear analysis can be included
  - More accurate model representation

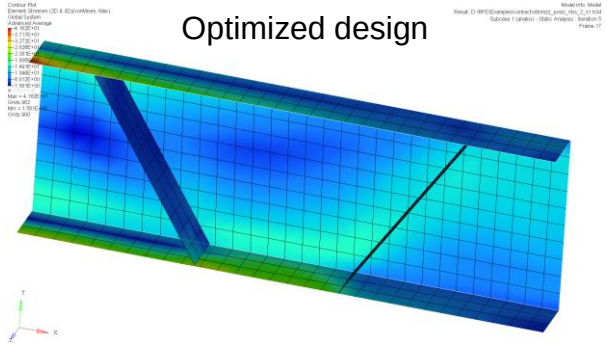


Optimization

- Large Shape Changes in Optimization
  - Linear Statics
  - Normal Modes
  - Buckling
  - Nonlinear Statics
- Applications include optimization of rib/stiffener locations

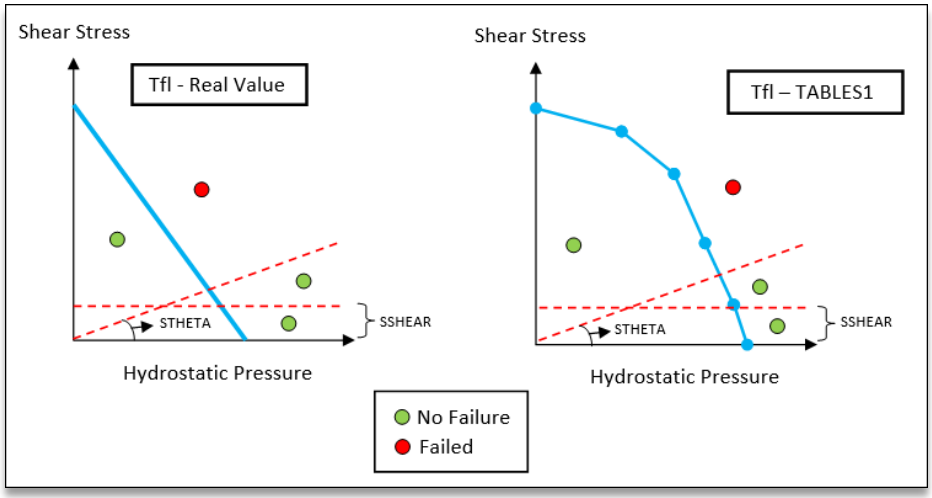






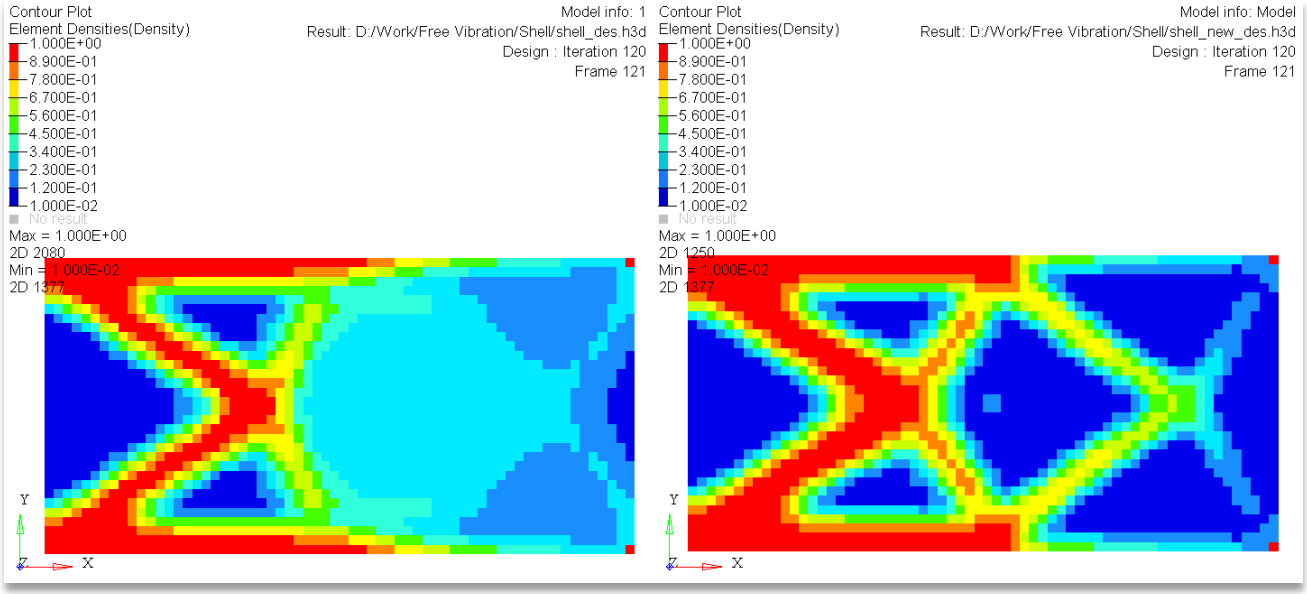
Optimization

- Multiple slopes for Dang Van FoS
  - Multi-axial fatigue criterion
  - Used to predict if a component will fail in its entire load history
  - Used where minimum cycles to failure is not applicable, e.g. propeller shafts



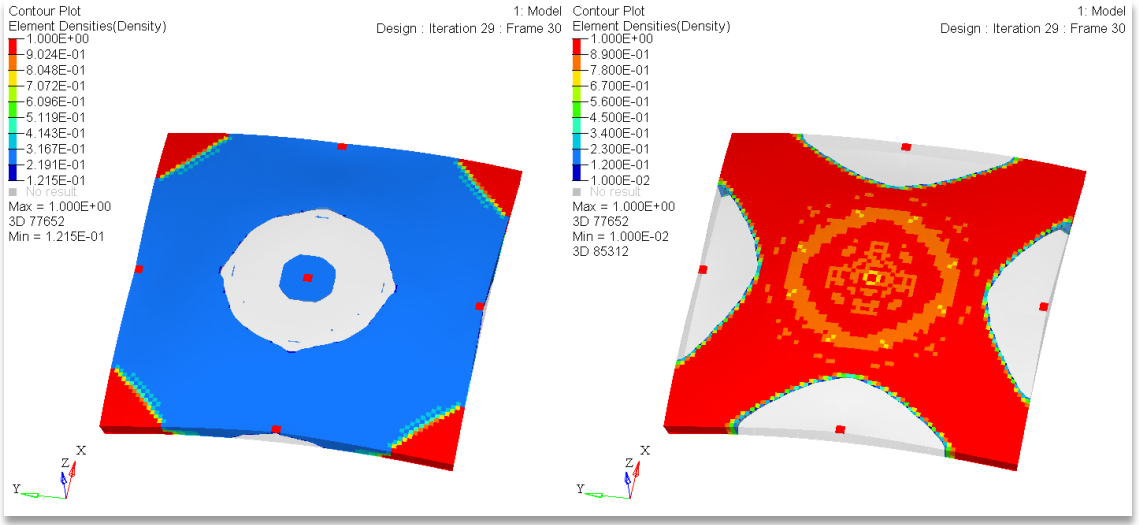
Optimization

- Topology Result Discreteness
  - Normal Modes and Modal Frequency Response Solutions



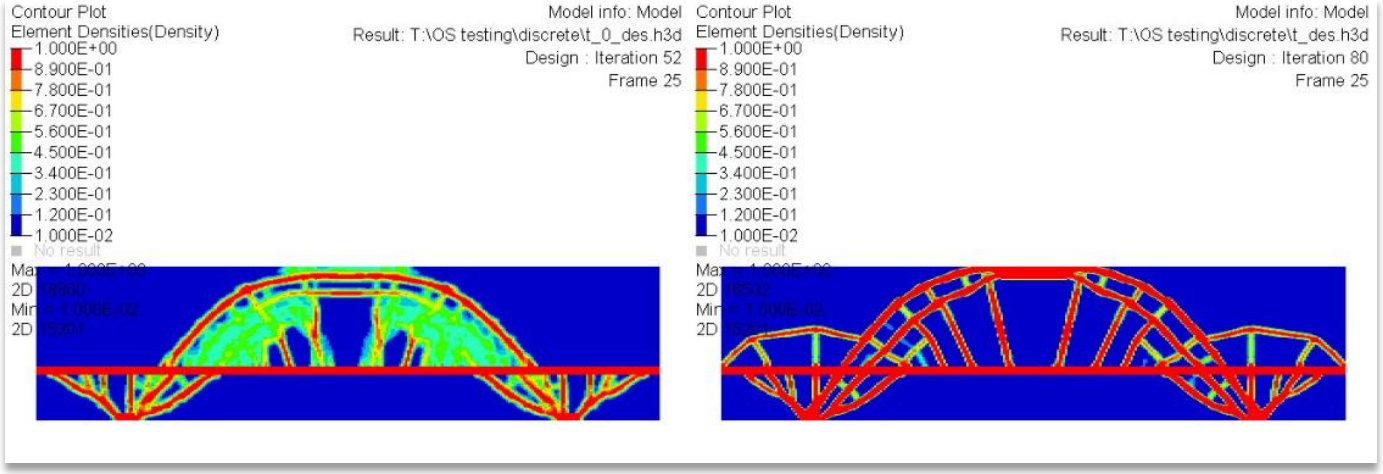
Optimization

- Topology Result Discreteness
  - No mass penalization under gravity and centrifugal loading
  - Accurate representation of body forces through the iteration history



Optimization

- Topology Result Discreteness
  - New optimization parameter to enable result discreteness
  - More discrete topology results for manufacturing constraints
  - Significant effect on non-discrete results with MAXDIM



Performance

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NVH Analysis

- CMS Super Element Generation with AMSES
  - New, much faster formulation
  - Very effective for models with many (thousands) ASET degrees of freedom
  - Applies to:
    - NVH applications including material damping and acoustic interface matrices
    - Flexbody generation for MBD analysis
  - Works with Craig-Bampton method (CB and CBN)

35x Faster!

CMS SE Generation with AMSES		
5M DOF Solid Model Number of Static Modes: 3318 Number of Dynamic Modes: 50	Original Formulation	New Formulation (OS 14.0)
Run Time	**41 Hours**	**70 Minutes**

Usability

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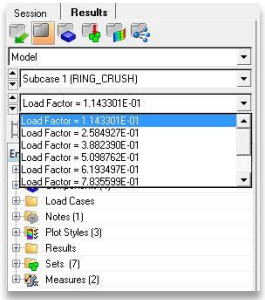
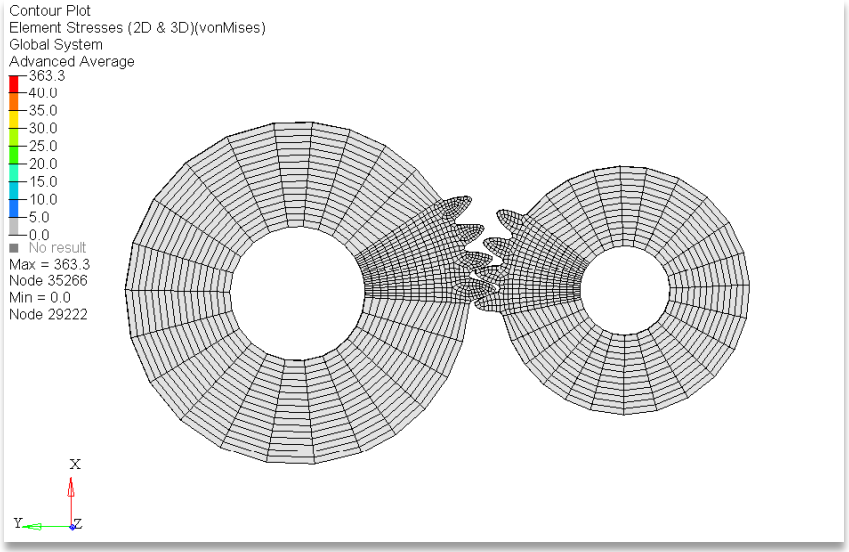
Analysis

- Nonlinear Analysis Results
  - Output at load increments



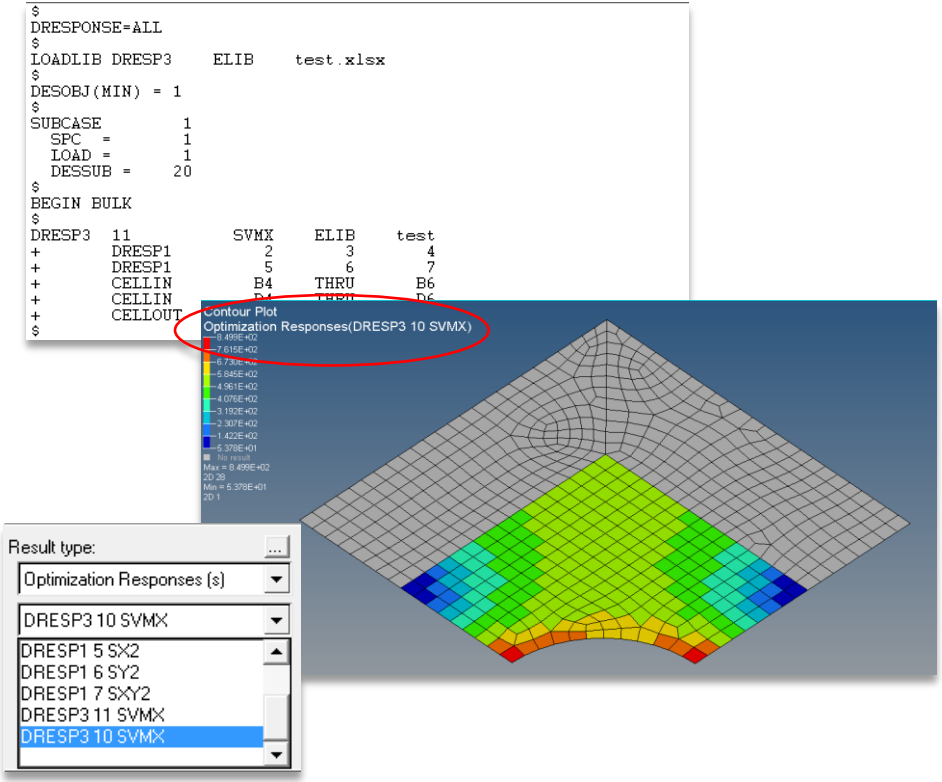


- Output of contact area

```
SUBCASE     400         8 LOAD:     201     Nonlinear Load Factor:    9.134375E-01 LABEL: NLSTAT
 CONTACT INTERFACE: TOTAL FORCE ACTING ON MASTER SURFACE (BASIC SYSTEM) AND TOTAL CONTACT AREA
 CONTACT#     FORCE-X      FORCE-Y      FORCE-Z      MAGNITUDE         AREA
      41   -2.3439E+02 -1.3370E+02  5.1207E-12  2.6984E+02  1.4902E+00
      42   -5.6508E+02 -2.5674E+02  2.9756E-11  6.2067E+02  1.3910E+00
```

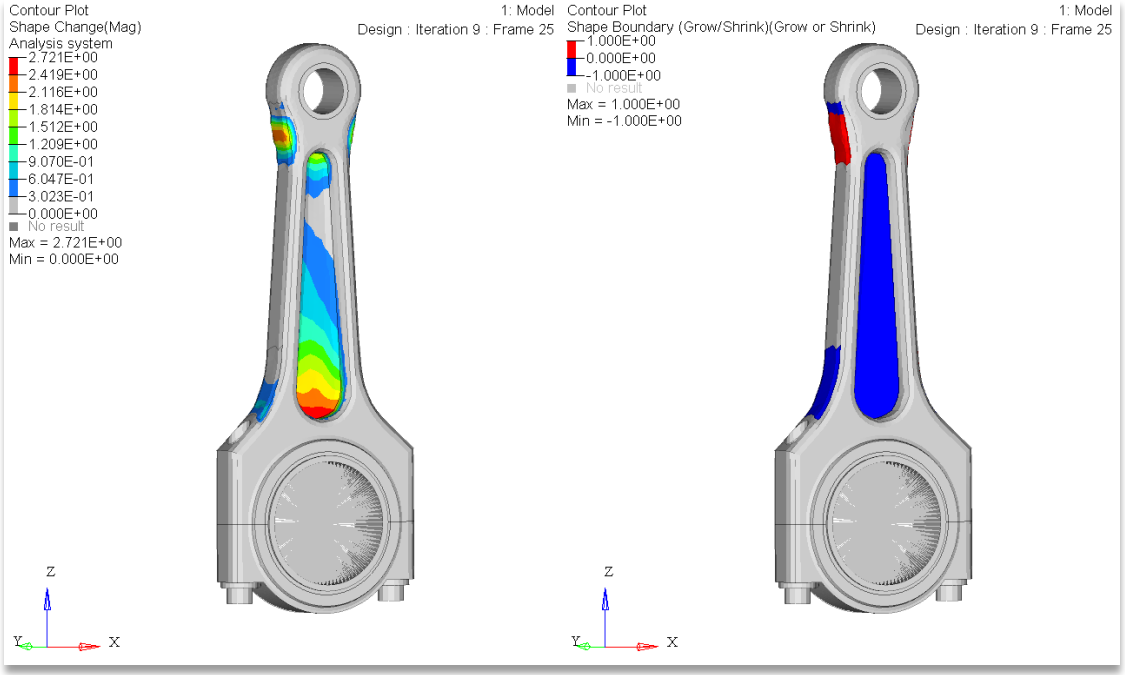
Optimization

- DRESP2/3 Response Output in H3D
  - Post-processing of user-defined responses
  - Can be used for analysis also

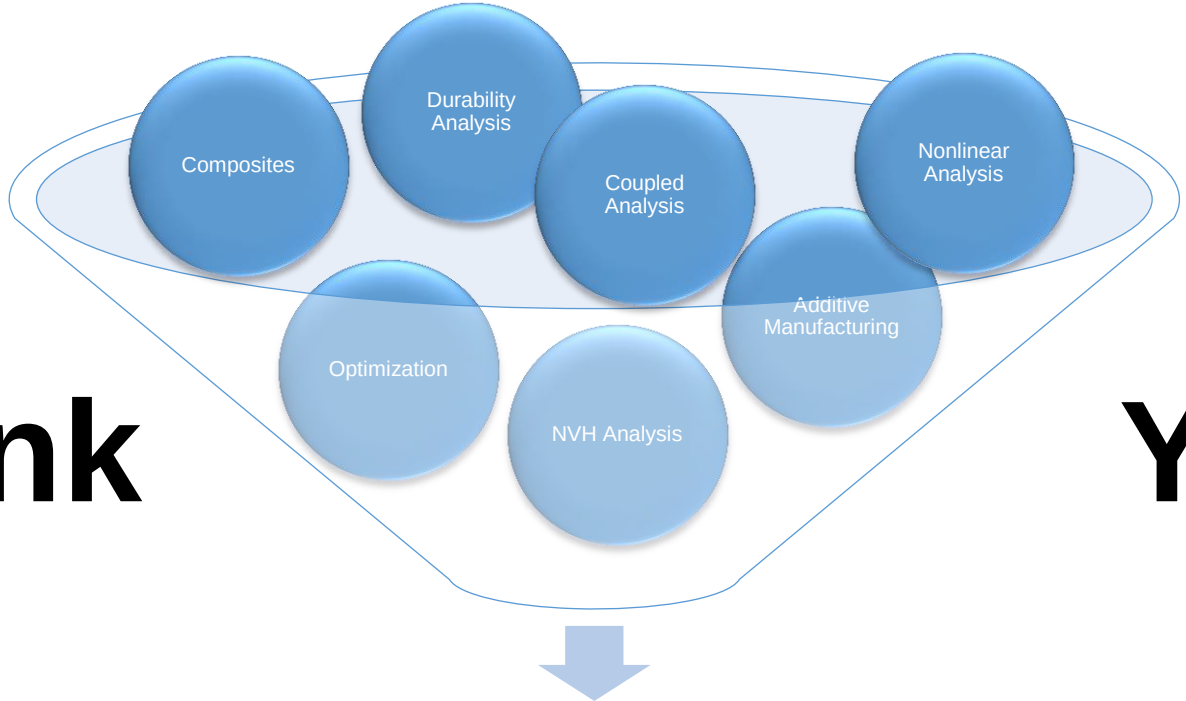


Optimization

- Free Shape Optimization Results
  - Grow or Shrink results type



Focus for 14 – Better Designs and Better Processes



Thank You