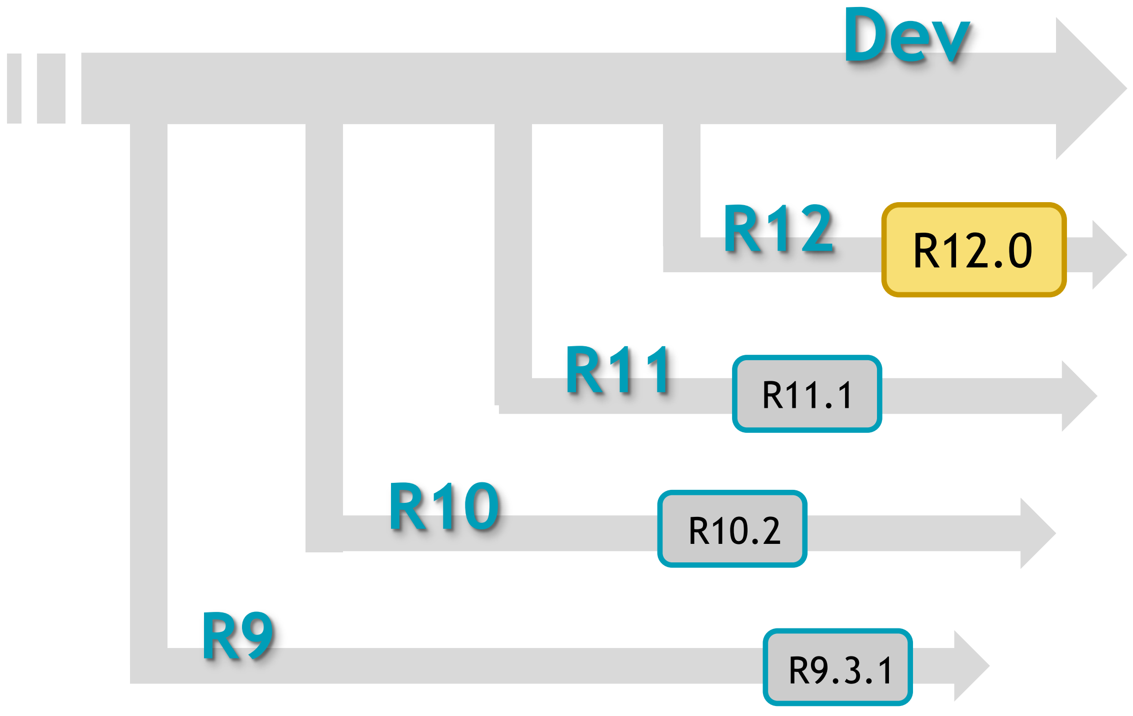
New Features in LS-DYNA R12.0.0

Ansys LST & DYNAmore, November 2020

- Release R12.0.0 published in June 2020
- This presentation about major changes since R11
- Slides put together by Ansys LST, DYNAmore, and Arup

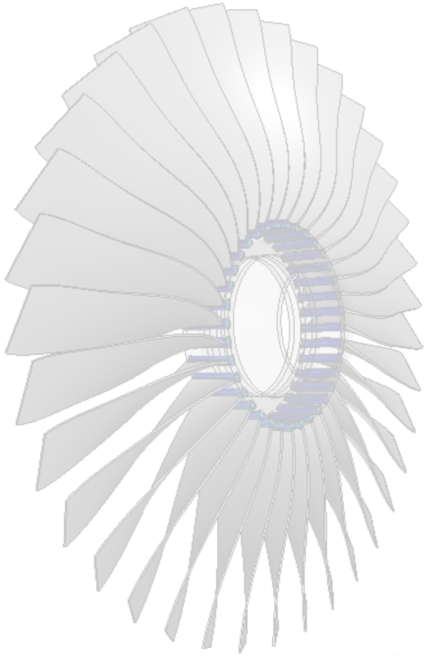
LS-DYNA versions

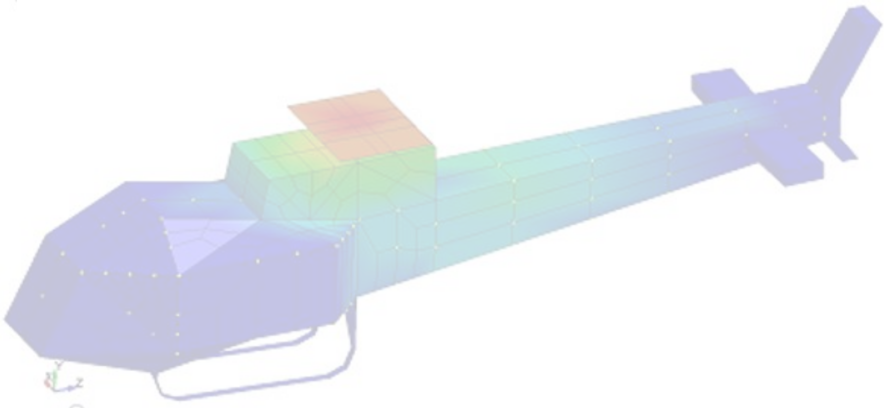
- Version numbering scheme
  - Major branches called R9, R10, R11, R12, …
  - Official releases such as R9.3.1, R11.1.0
- Robust release
  - Release R9.3.1
  - Recommended production version
- Latest official versions
  - Release R10.2 from March 2019
  - Release R11.1 from August 2019
  - Release R9.3.1 from September 2019
  - Release R12.0 from June 2020 New features shown in this presentation

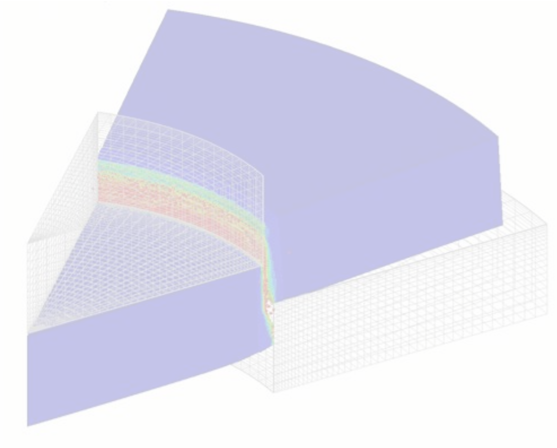


Content

- Occupants: Airbags & belts
- Implicit
- Contact
- Forming
- Additive Manufacturing
- Thermal
- Materials
- Isogeometric Analysis
- Miscellanous features
- Further topics briefly discussed
  - Fatigue, Frequency Domain, SPG, XFEM, ALE, S-ALE, SPH, ICFD, EM







Occupants: Airbags and belts

Push-out vent

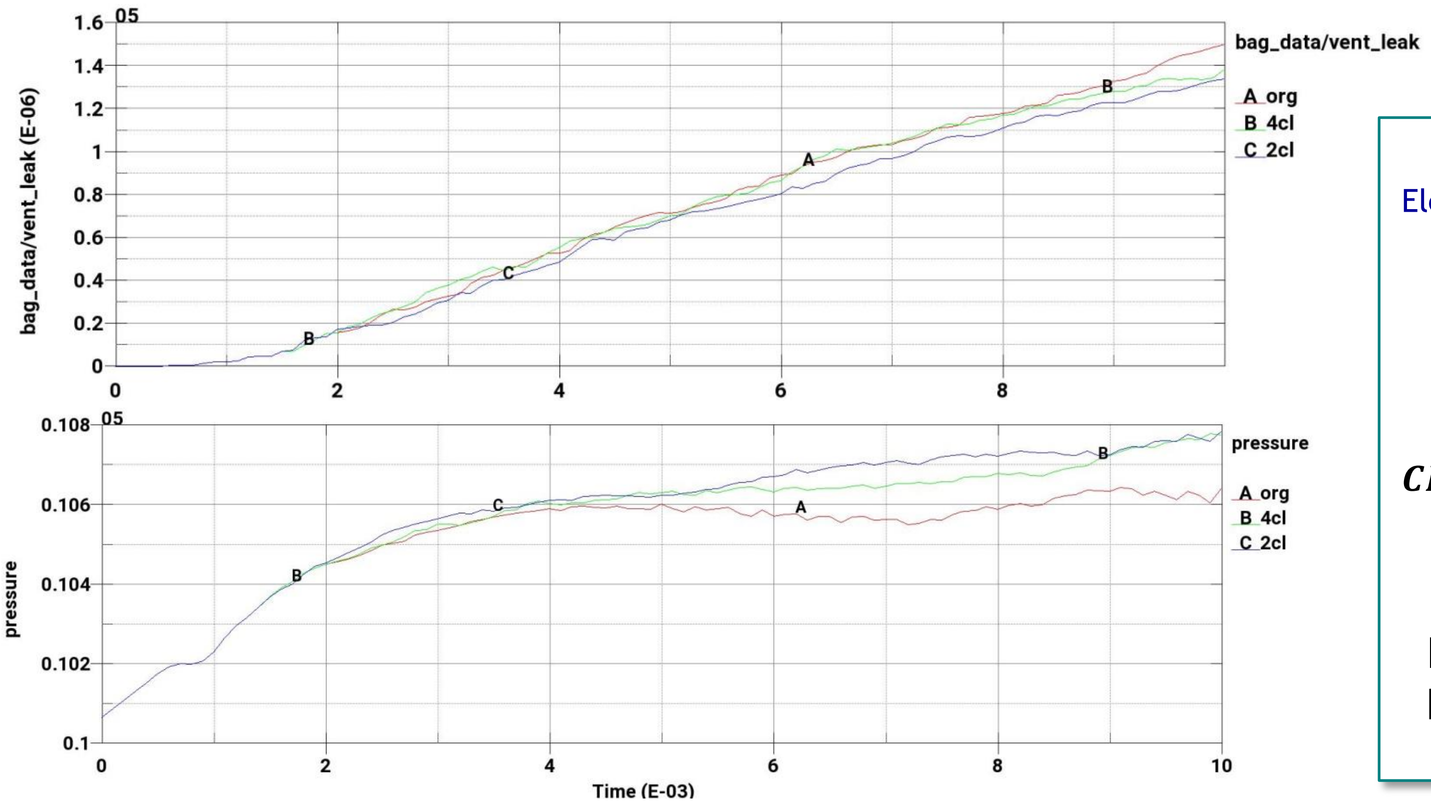
Miscellaneous CPM enhancements

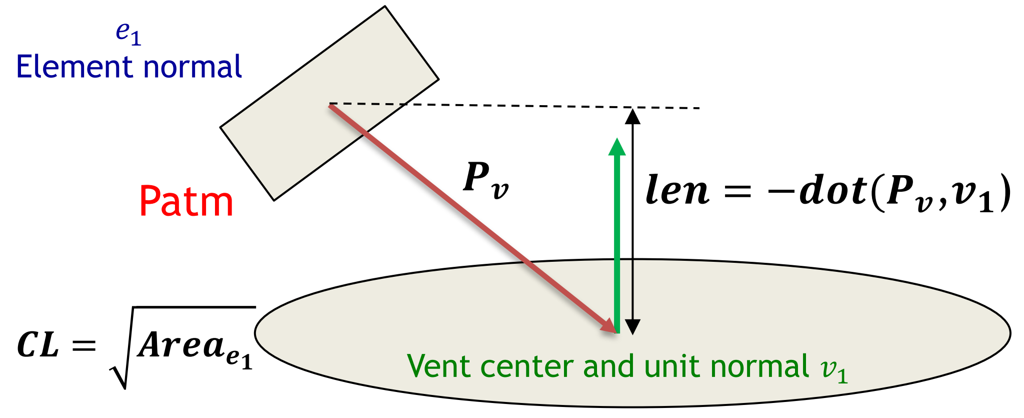
MAT_SEATBELT_2D updates

Retractor sensor

CPM (*AIRBAG_PARTICLE) - New features for push-out vent

- Keyword *DEFINE_CPM_VENT: push-out vent IOPT=200
  - New option to treat internal material being pushed through vent
  - To be used with part set (PSETPV) and sale factor (SFPV)





If $len > SFPV * CL$
Patm is applied to the e_1 surface facing the air.

CPM (*AIRBAG_PARTICLE) - More new features

- New keyword *DEFINE_CPM_NPDATA
  - To support more part-specific input for *AIRBAG_PARTICLE
  - Invoked by NPDATA>0 and STYPEH = 2 or 3

- Support inflator mass flowrate curve (LCTi)
using *DEFINE_CURVE, *DEFINE_CURVE_FUNCTION and *DEFINE_FUNCTION

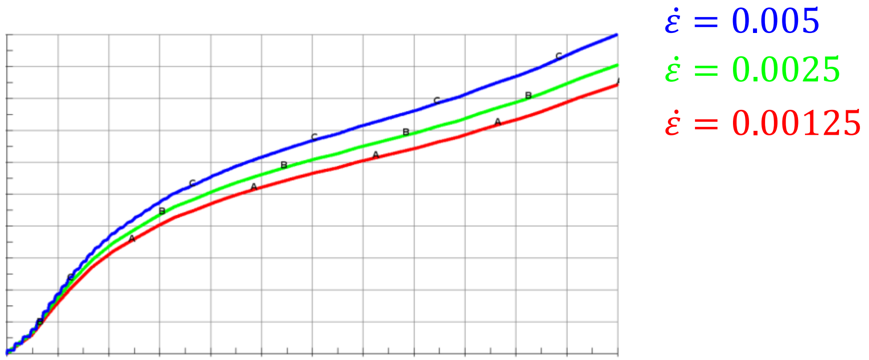
- Support C23 (discharge coefficient) as function of vent area

- Add tire inflation capability under CPM method
  - to maintain the target tire pressure during the initial setup

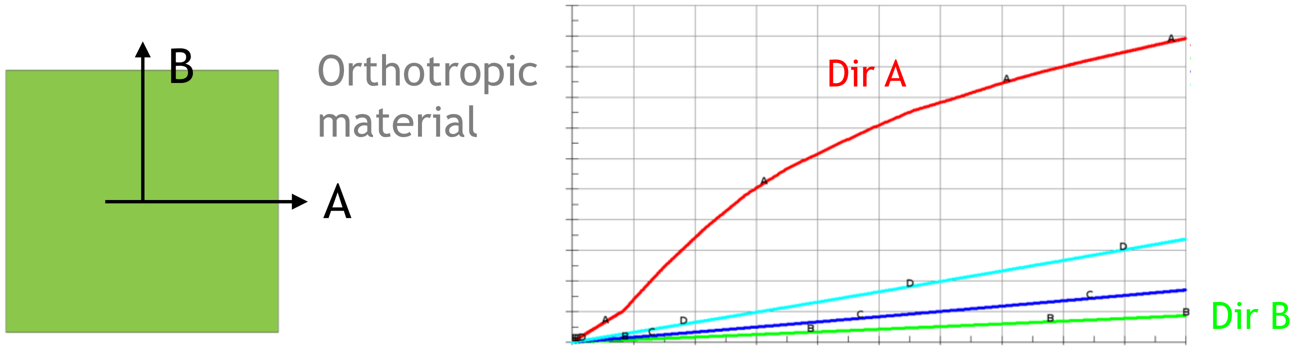
Ansys LST jointly developed
tire models with FCA
(lstc.com/products/models/tires)

*MAT_SEATBELT_2D

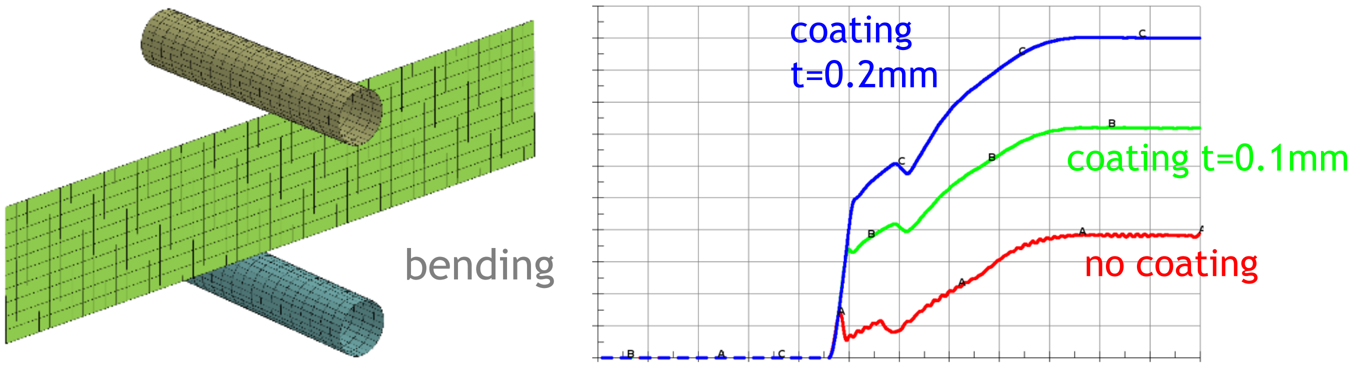
- Strain rate dependency
  - Table ID for LLCID
  - Applied in length direction of belt



- Orthotropic material behavior
  - New parameters to control the orthotropic material behavior: EB, PRAB, PRBA and GAB



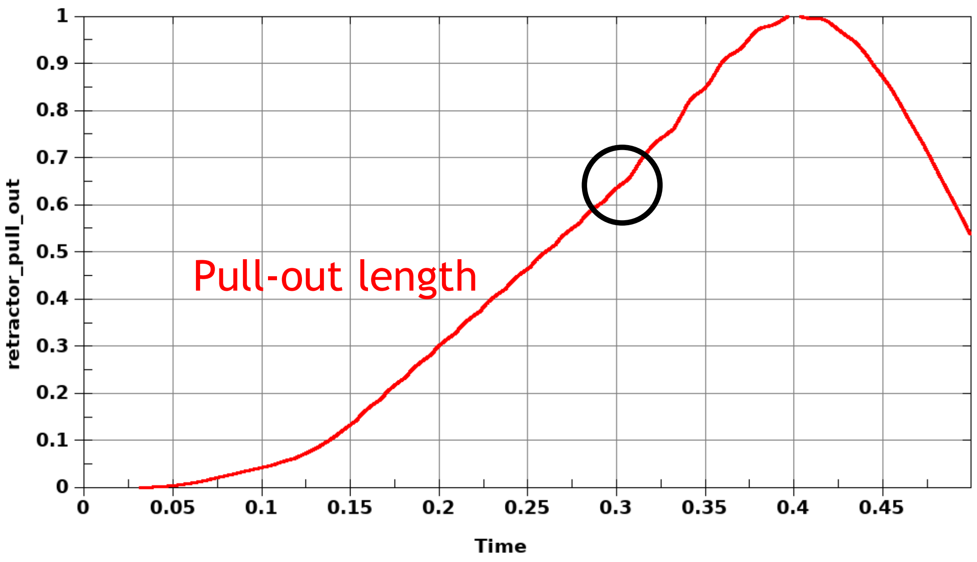
- Coating functionality
  - New parameters ECOAT, TCOAT and SCOAT
  - Coating – elastoplastic behavior

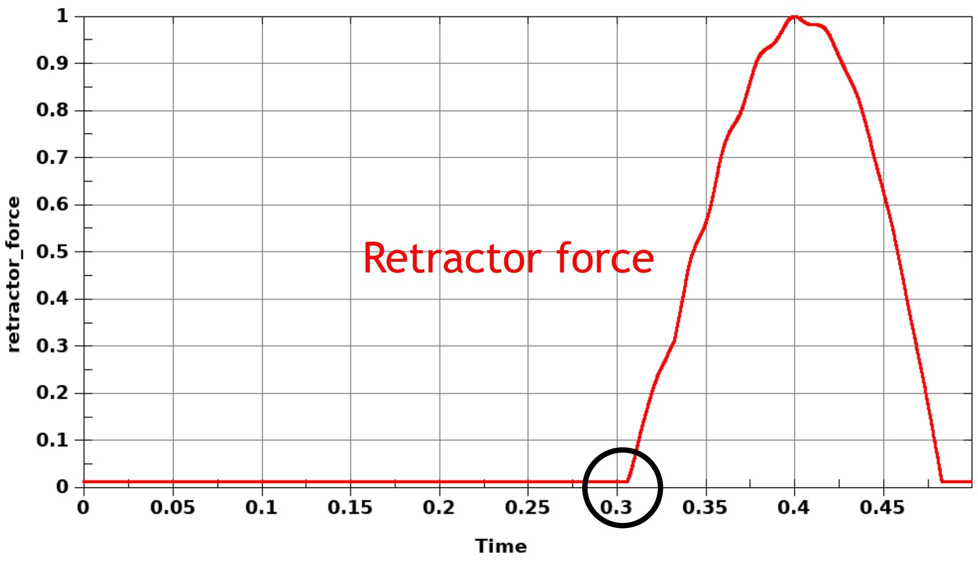


*ELEMENT_SEATBELT_SENSOR

- New sensor type SBSTYP=5
  - Retractor locking, and activation of pretensioners has been extended to support also tracing of retractor pull-out

- Example
  - Maximum pull-out PULMX=0.65 → sensor triggered at time 0.31





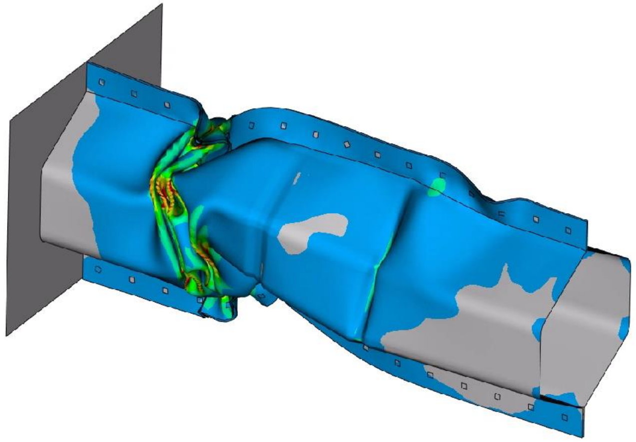
Implicit

General improvement/curve options/BC

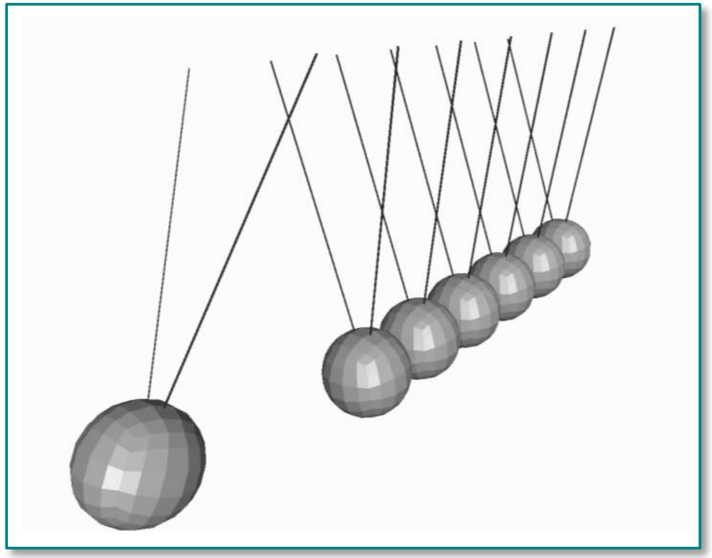
Rotations

Nonlinear Implicit

- General improvements for accuracy and robustness
  - Contacts, elements, material tangents added or improved as regular maintenance



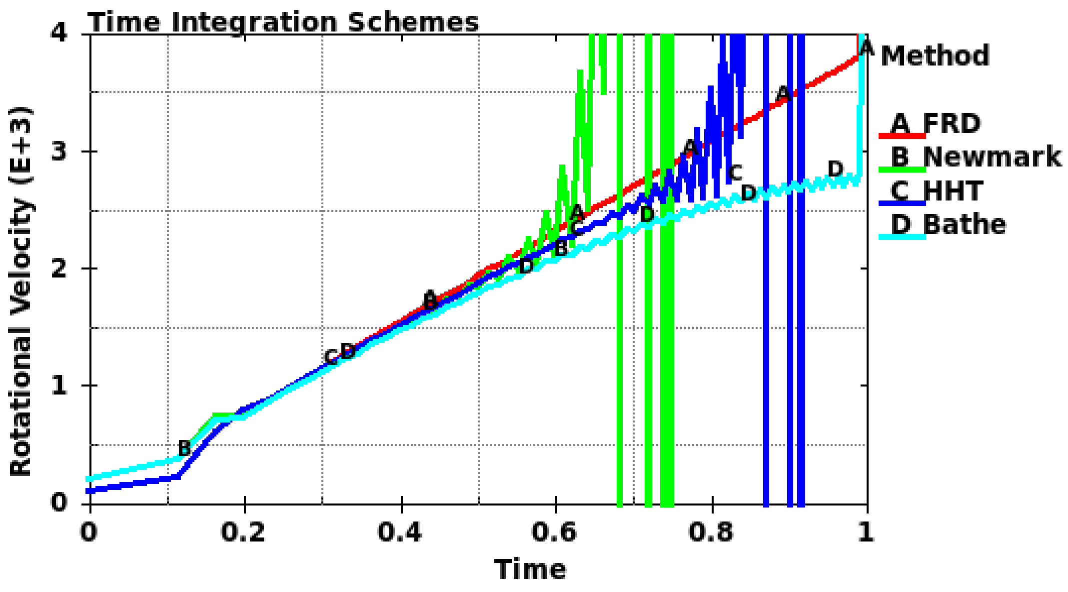
- Curve options
  - DTMIN.LT.0 on *CONTROL_IMPLICIT_AUTO – generating keypoints
  - ILIMIT.LT.0 on *CONTROL_IMPLICIT_SOLUTION – switching between BFGS and Full Newton
  - DCTOL/ECTOL/RCTOL.LT.0 on *CONTROL_IMPLICIT_SOLUTION – convergence tolerances as function of time
- Treatment of boundary conditions
  - Prescribed motion and constraints applied to rigid body nodes
  - Reaction forces of rigid body and nodal rigid body constraints can be requested (SPC2BND=1 on *CONTROL_OUTPUT)
  - BNDOUT2DYNAIN on *BOUNDARY_PRESCRIBED_MOTION_RIGID, for porting reaction forces as parameters between simulations

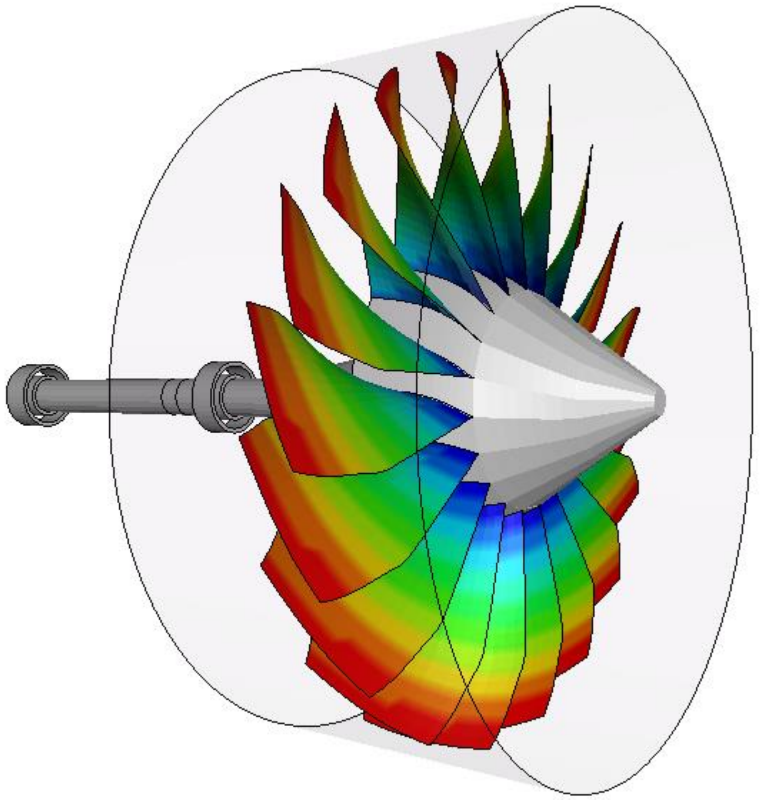


Rotations

"finite rotational dynamics"

- Time integration scheme for arbitrarily large rotational increments (FRD)
  - ALPHA ≤ -1 on *CONTROL_IMPLICIT_DYNAMICS
  - Generalization of Rotational Dynamics to nonlinear transient
  - Potential for long duration simulation





Contact

Mortar – friction/tied/2D

Mortar – New contact segment due to erosion

Mortar – Output penetration/energy

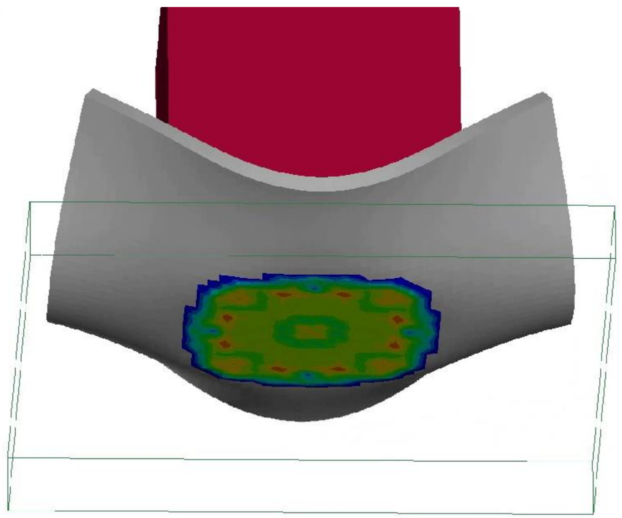
Mortar – eigenvalue analysis functionality

SOFT=2 edge contact penalty stiffness

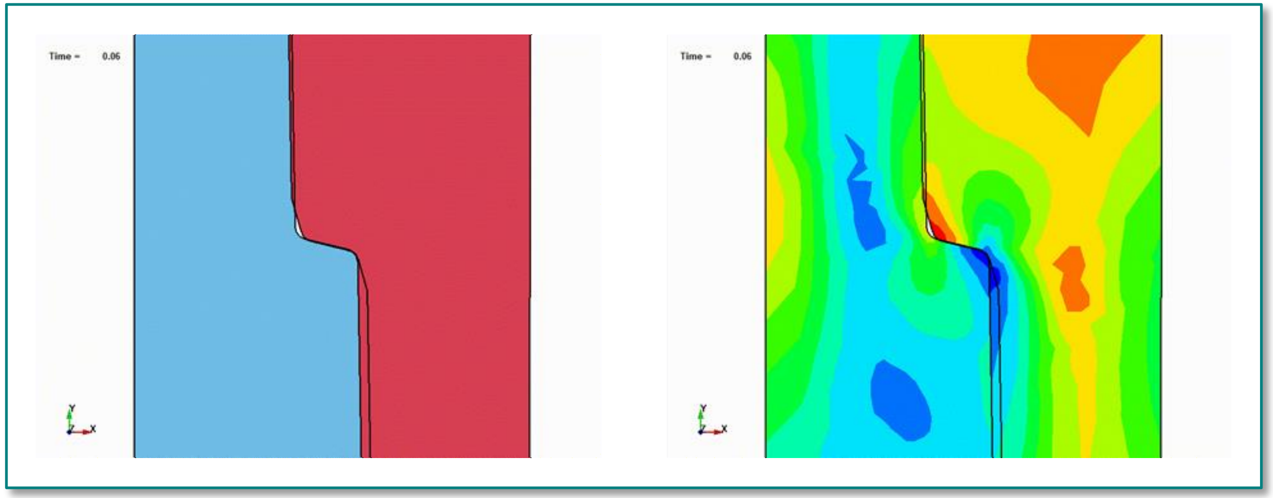
More enhancements for SOFT=2

Mortar Contact - General

- Friction
  - history variables in user friction can be post-processed
  - frictional stress limit (VC on *CONTACT) supported

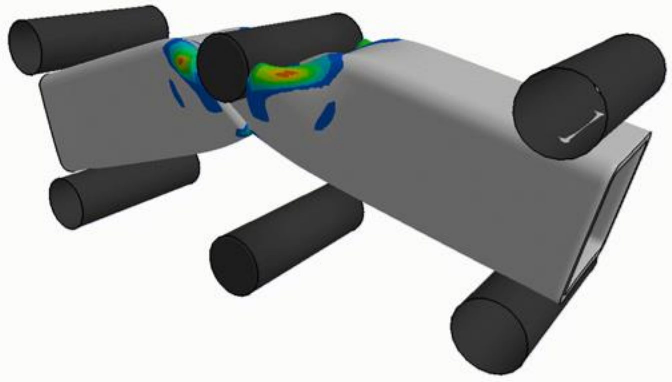


- Tied weld
  - allow general lamination modeling through user interface
- 2D mortar contact
  - TDPEN introduced, giving the time for depenetration in interference
  - This is the analogy to IGNORE=3 for 3D mortar contact

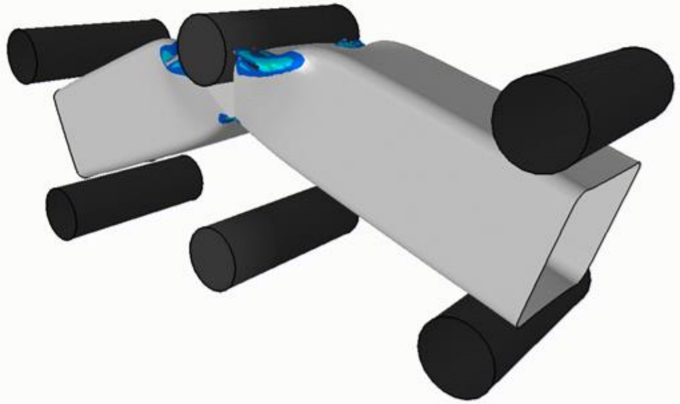


Mortar Contact - Eroding

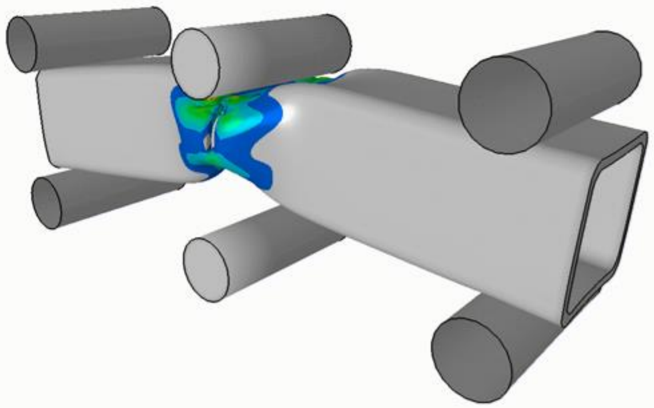
Thick shells



Shells



Solids

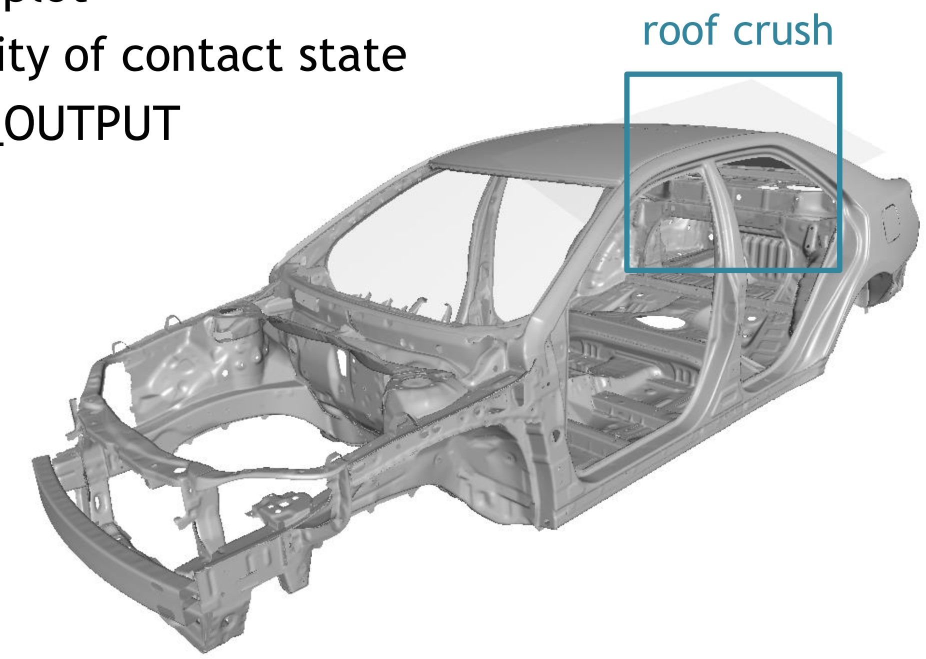


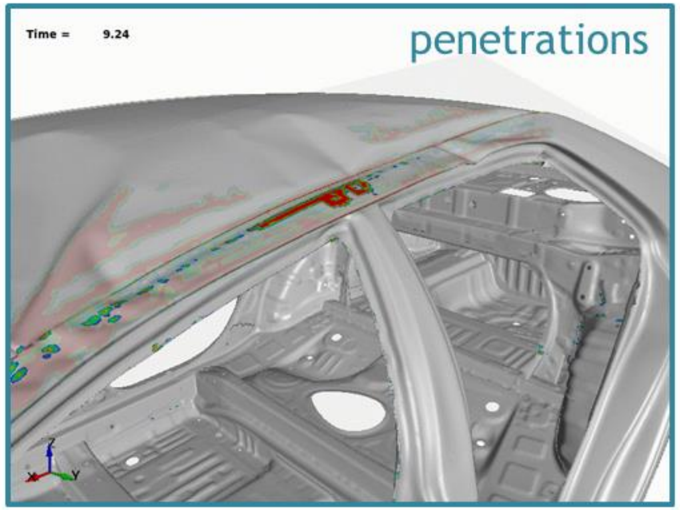
- Exposed segments due to erosion added to the contact
  - Works for solids, shells and thick shells

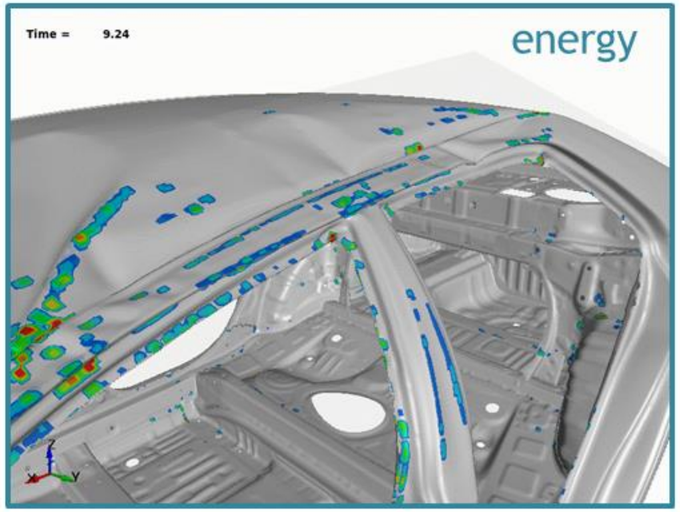
- For shells, edges of eroded elements are exposed
- Supported for automatic_surface_to_surface and single_surface

Mortar Contact - Output

- Penetrations
  - relative and absolute penetrations can be monitored in d3plot
  - assessment of the quality of contact state
  - PENOUT on *CONTROL_OUTPUT



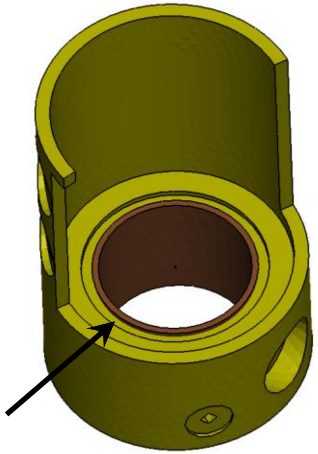




- Energy
  - Contact sliding energy can be monitored in d3plot
  - ENGOUT on *CONTROL_OUTPUT

Mortar Contact - Eigenvalue Analysis

- Active contact (non-zero contact pressure) won't affect rigid body modes in an eigenvalue analysis



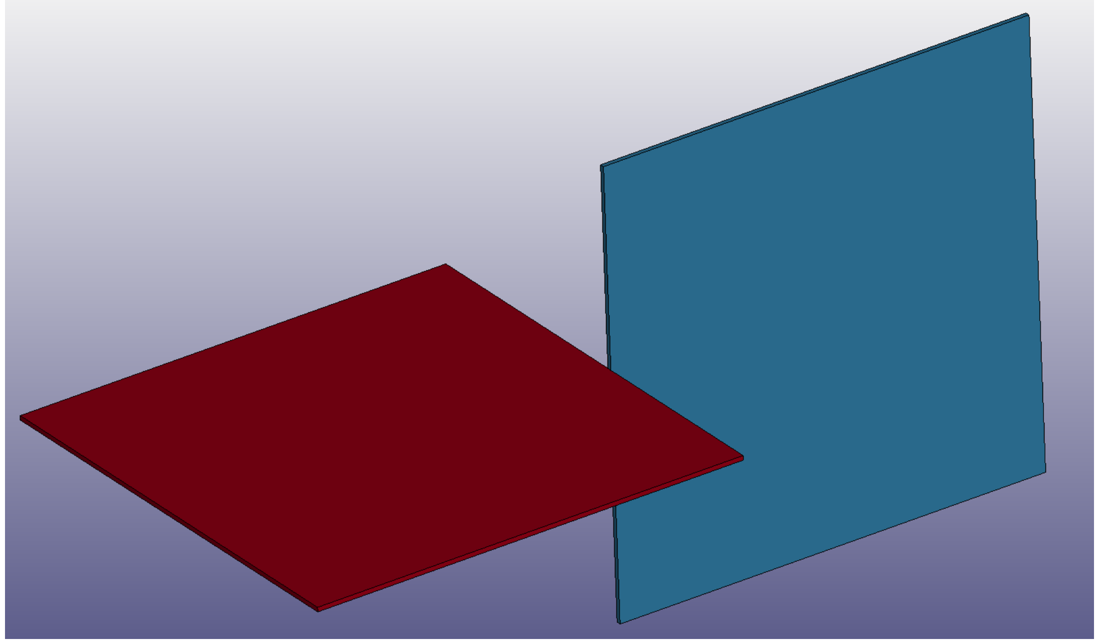
Interference in interface

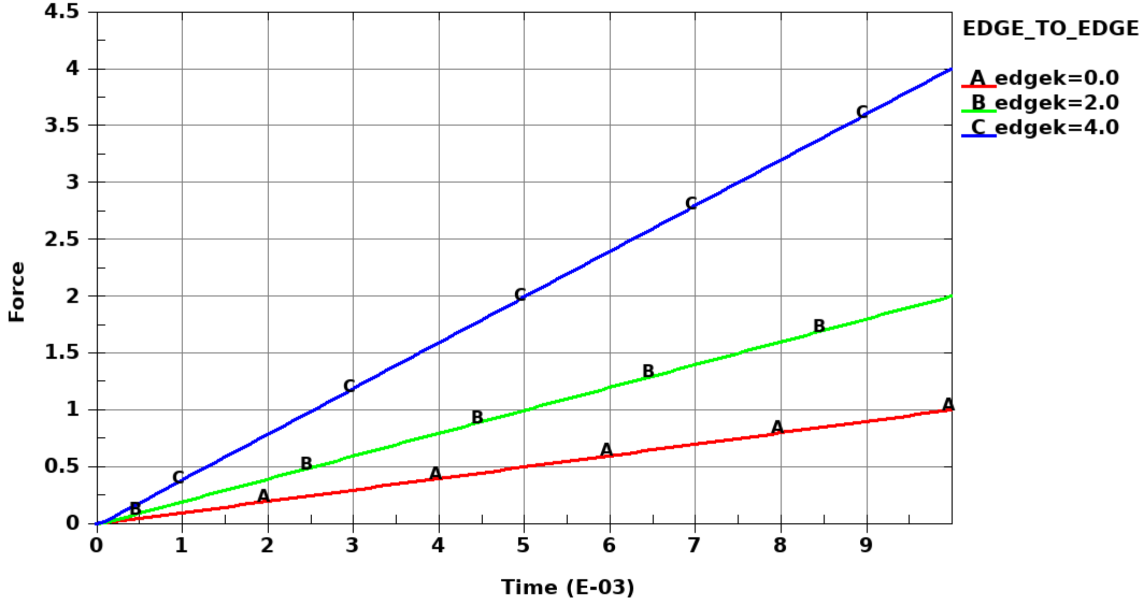
First deformation mode

Modes with 0 Hz

Scale edge-to-edge contact (SOFT=2)

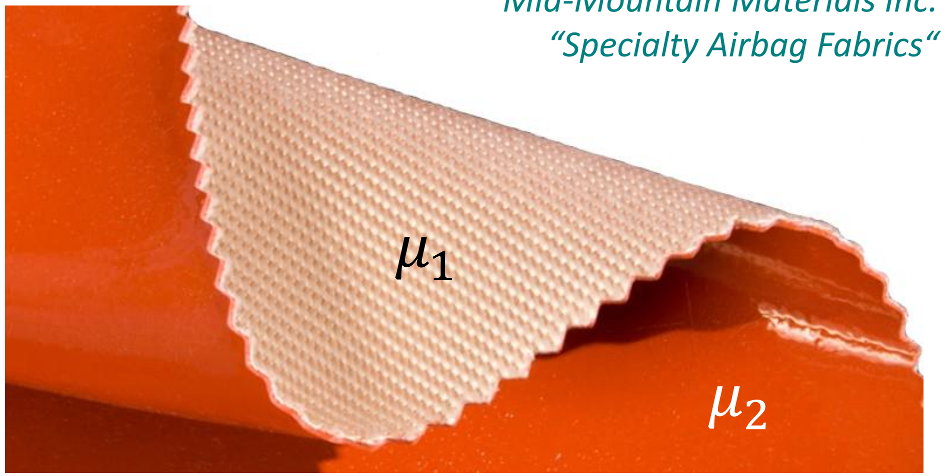
- New variable EDGEK on card C of *CONTACT
  - Scale factor for edge-to-edge contact when SOFT=2 and DEPTH = 5, 15, 25 or 35





More enhancements for SOFT=2

- Spotwelds share nodes with shells
  - support SPOTHIN in this case as well
- Different friction coefficient for the inner and outer surface of shell elements
  - new keyword *DEFINE_FRICTION_SCALING
- Frictional torque correction with FTORQ=2
- Support orthotropic friction
- Support MPP groupable contact (combine individual contacts for speed-up)

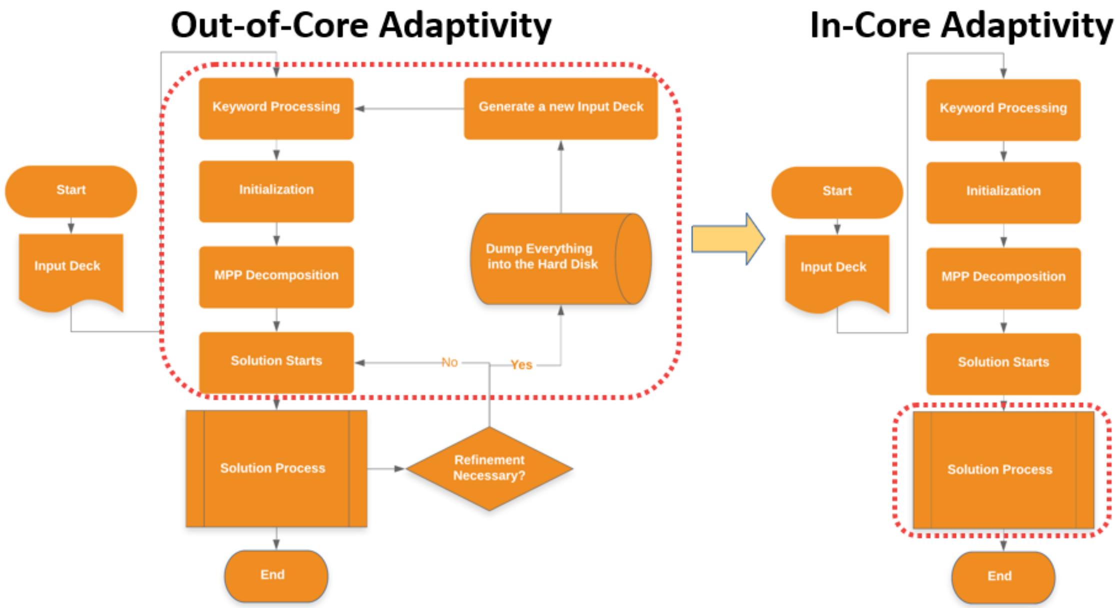


Forming simulations

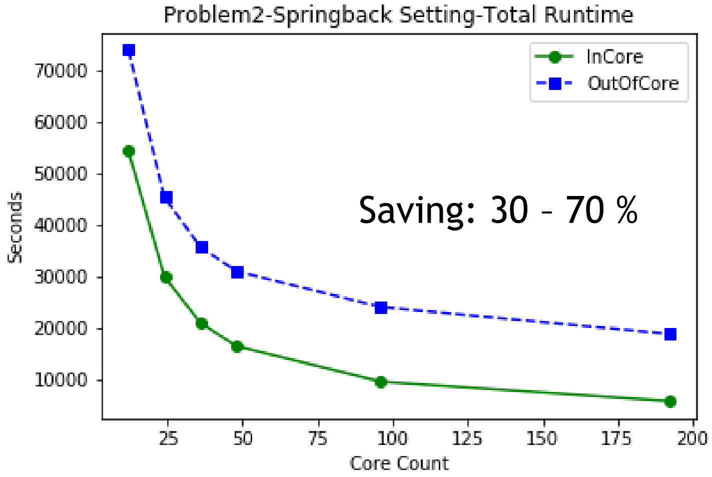
- In-core adaptivity
- One step method for carbon fiber reinforced composites
- Fluid cell forming
- Solid to solid mapping
- Moving Temperature Boundary Condition

In-core adaptivity

- Speed-up for adaptive mesh refinement
  - No more dumping to hard drive
  - No more remeshing, re- initializing and performing mpp decomposition each adaptive step
  - Mesh adaptivity is done in-core without shutting down and restarting the simulation
- Activated by INMEMRY flag on *CONTROL_ADAPTIVE (*currently mpp, shell h-adaptivity*)

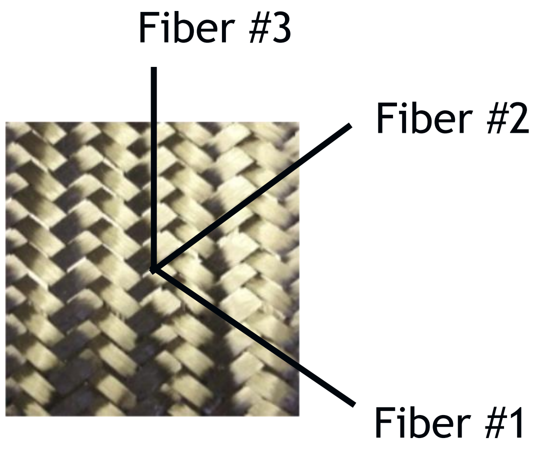


Example: 151000 cycles, 435 adaptive steps, from 8000 to 1 Mio. elements

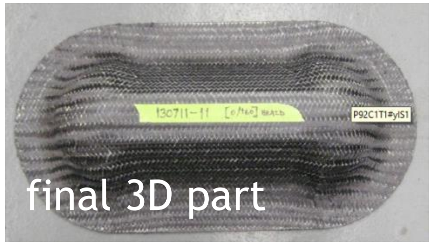


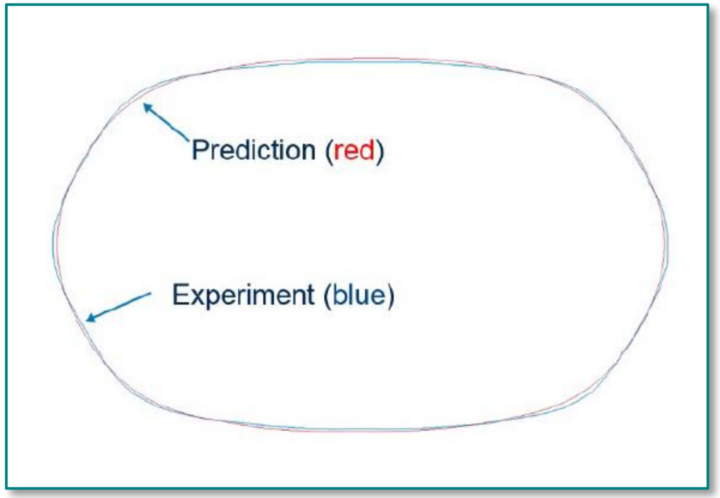
One step method for carbon fiber reinforced composites

- Inversely predict the initial blank size/shape and fiber angle for carbon fiber-reinforced composites
  - Matrix (*MAT_024 or *MAT_037) and fiber (elastic) behavior separated
  - The fiber directions and normal/shear stiffness through *DEFINE_FIBER keywords
  - To better account for the effects of the embedded fibers,
    the rotation of a local representative “fiber” within a generic element is considered



(Courtesy of Dr. D. Zeng from Ford)

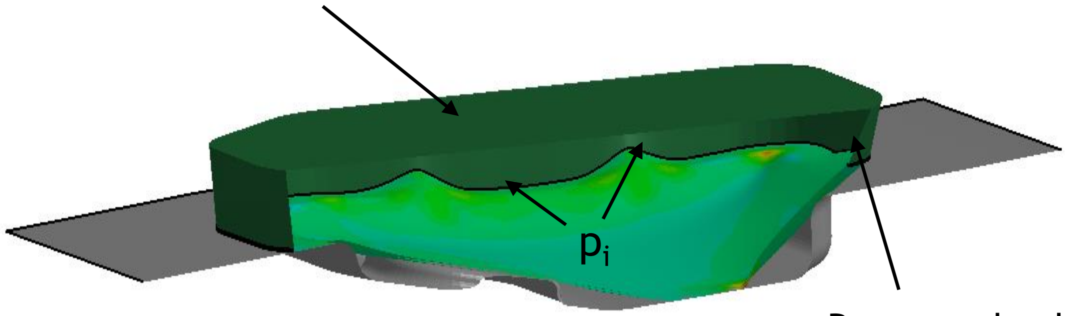




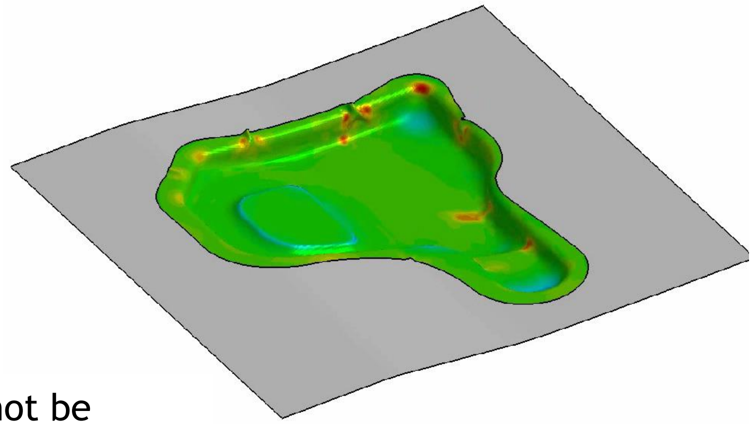
Airbag modification for fluid cell forming

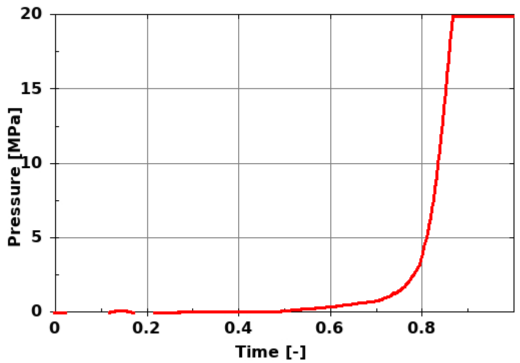
- Fluid cell press to form sheet metal on to a die by pressurizing a rubber diaphragm
  - Prescribing a pressure makes this a force controlled process and thus difficult to control
  - By defining a cavity using null elements and using the *AIRBAG_LINEAR_FLUID keyword with a prescribed mass flow into the cavity, the process becomes displacement controlled
  - By using the NONULL option on the *AIRBAG_LINEAR_FLUID keyword, the pressure is only applied on the blank which removes the unphysical stretching of the blank due the pressure load on the null elements

Null elements define the cavity



Pressure should not be applied to the null elements since it stretches the blank

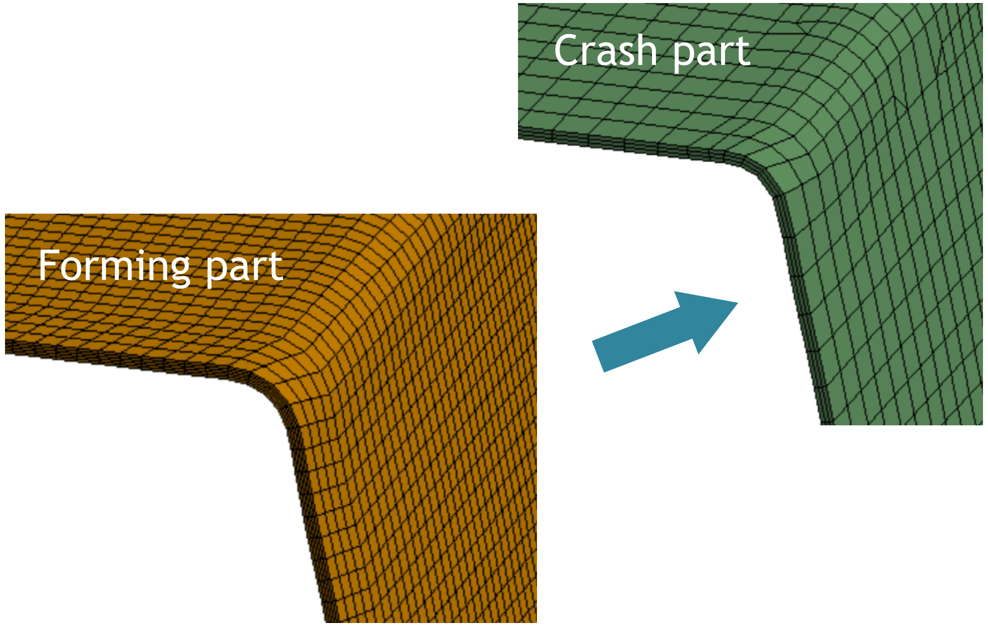


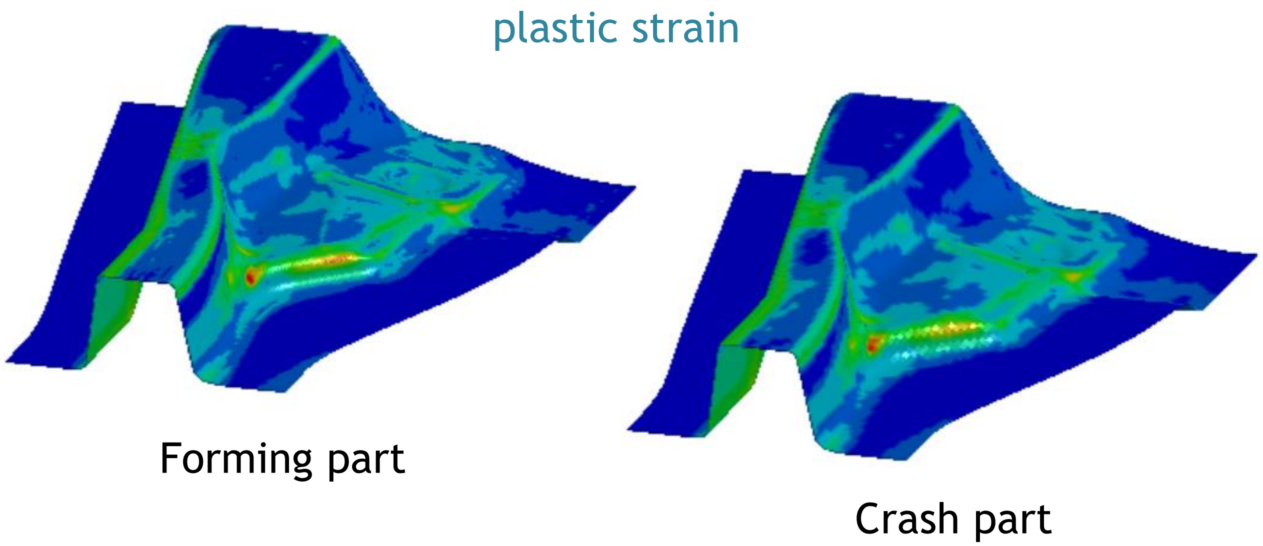


Solid to solid mapping

- New keyword *INCLUDE_STAMPED_PART_SOLID_TO_SOLID
  - maps stress and strain tensor, history variables and plastic strain from a solid (source) part to a second solid target part (hex and penta elements)

- The total thickness of the target part is adjusted to match the thickness of the source part

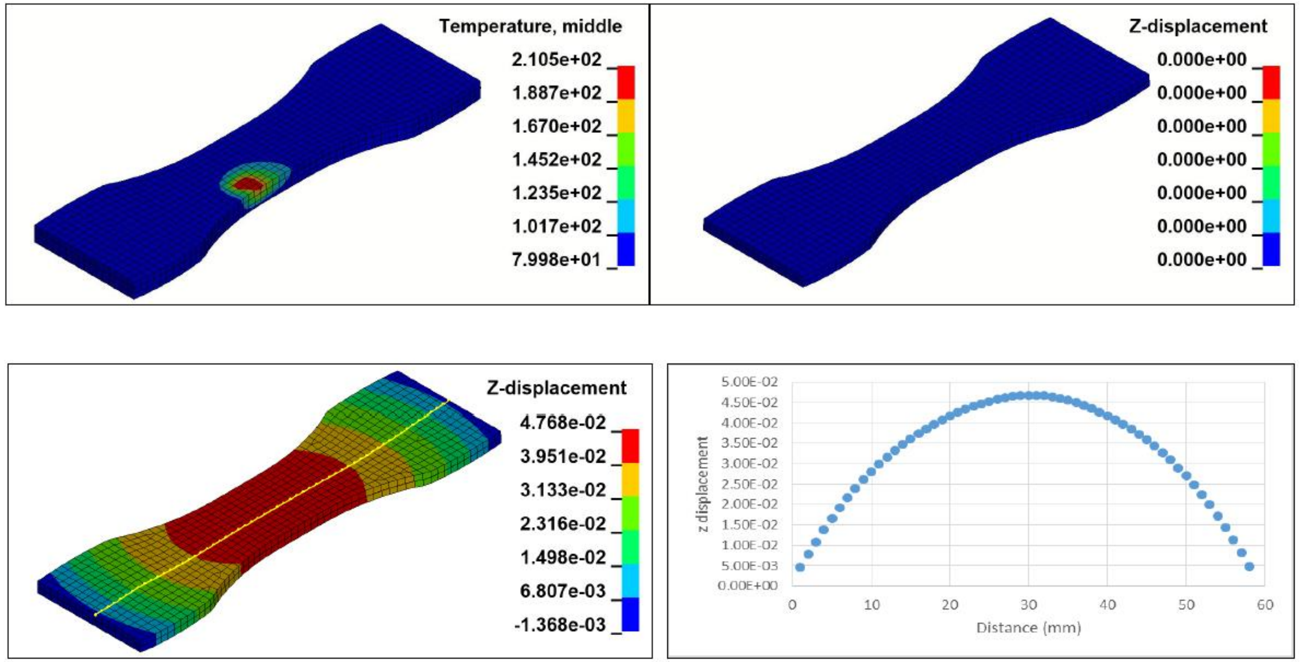




Moving Temperature Boundary Condition

- New keyword *BOUNDARY_TEMPERATURE_TRAJECTORY to apply temperature boundary condition on a moving volume
  - Fixed or time varying
  - Applied to nodes enclosed in a specified volume *(cylinder, block, etc)*
  - The volume is prescribed to move along a designated nodal path with fixed or time-varying speed

- Can be used together with e.g. *MAT_CWM and _TIED_WELD contact option to bond the layers to simulate fused filament fabrication



Additive manufacturing

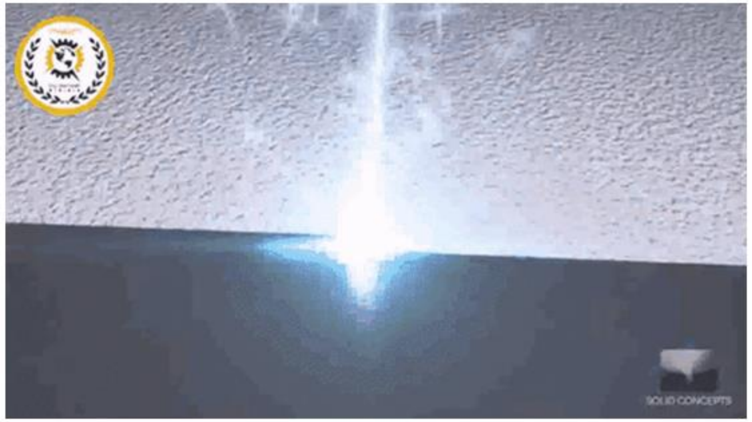
New remeshing algorithm/New remapping scheme

Adaptivity

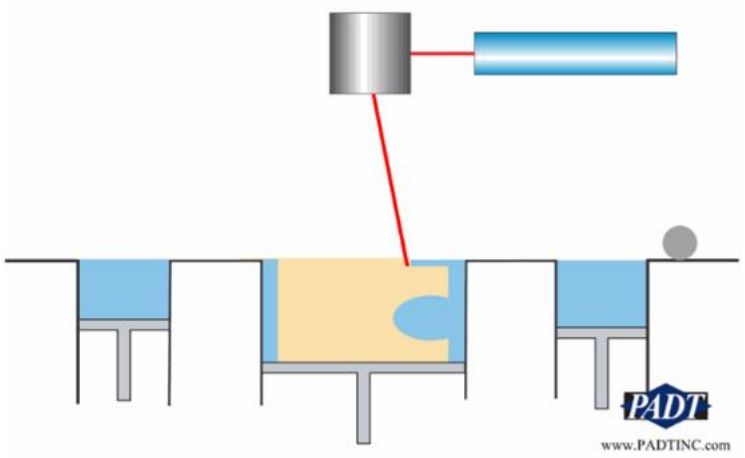
Thermo-mechanical coupling

Additive manufacturing

- New remeshing algorithm
  - Dynamic local refinement following heat source
  - Mesh activation through adaptivity
  - Multi-body and multi-part remeshing
- New remapping scheme
  - Mechanical and thermal internal variables
  - Deformation profile
- Multiple heat sources enabled
- Implicit thermo-mechanical couple analysis
- Spring back analysis
- Related keywords involving new development
  - *INCLUDE_AM_BLUEPRINT, *DEFINE_ADAPTIVE_BOX
  - *BOUNDARY_THERMAL_WELD
  - *BOUNDARY_CONVECTION_SET, *BOUNDARY_RADIATION_SET



Selective Laser Sintering (SLS)

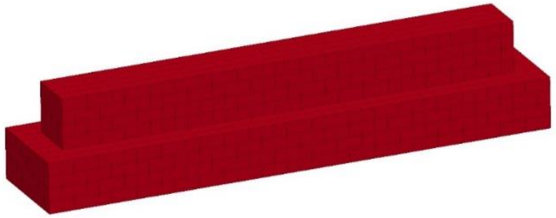


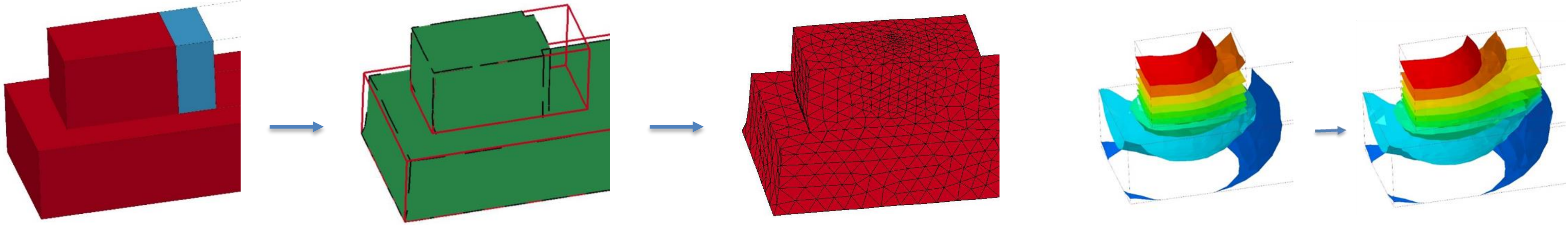
Ansys / LST

DYNA MORE

Additive manufacturing

- 3D adaptivity for AM process
  - *INCLUDE_AM_BLUEPRINT: mesh of final product (layered HEX mesh)
  - *DEFINE_ADAPTIVE_BOX: define boxes around heat source for additive remeshing and refinement
  - *BOUNDARY_THERMAL_WELD: define heat source
  - *BOUNDARY_CONVECTION_SET, *BOUNDARY_RADIATION_SET: define thermal convection and radiation of adaptive parts

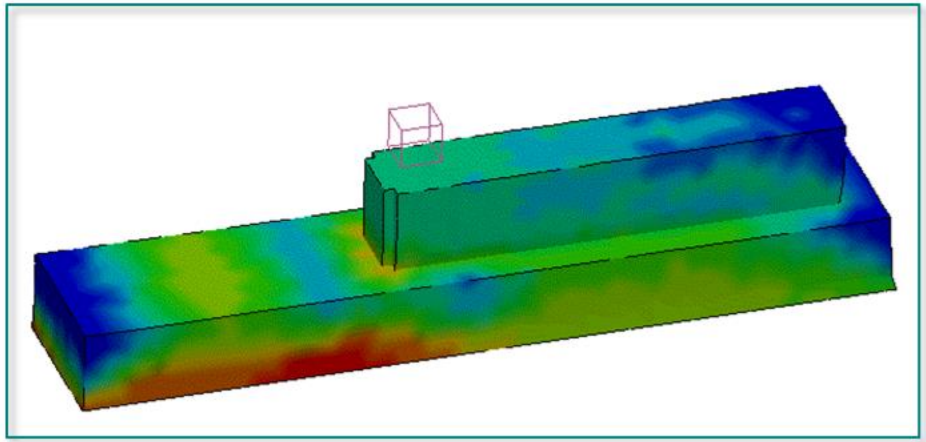




Blueprint model (Un-deformed) | Map to deformed shape (Thermal expansion) | Remesh (Local refinement) | Remap internal variables (Mechanical & thermal)

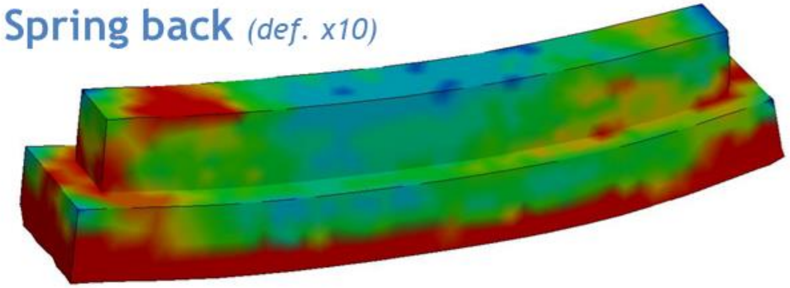
Additive manufacturing

- Numerical examples

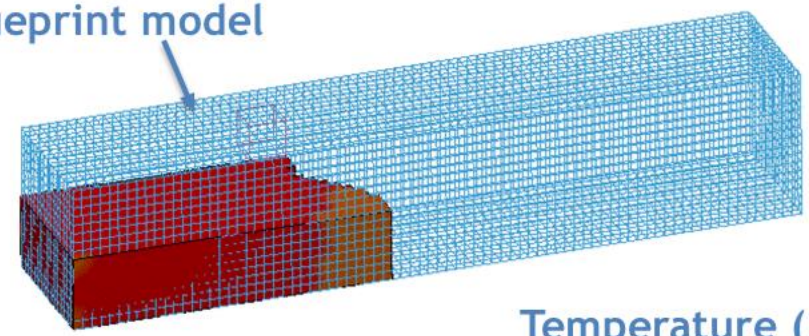


Von Mises stress

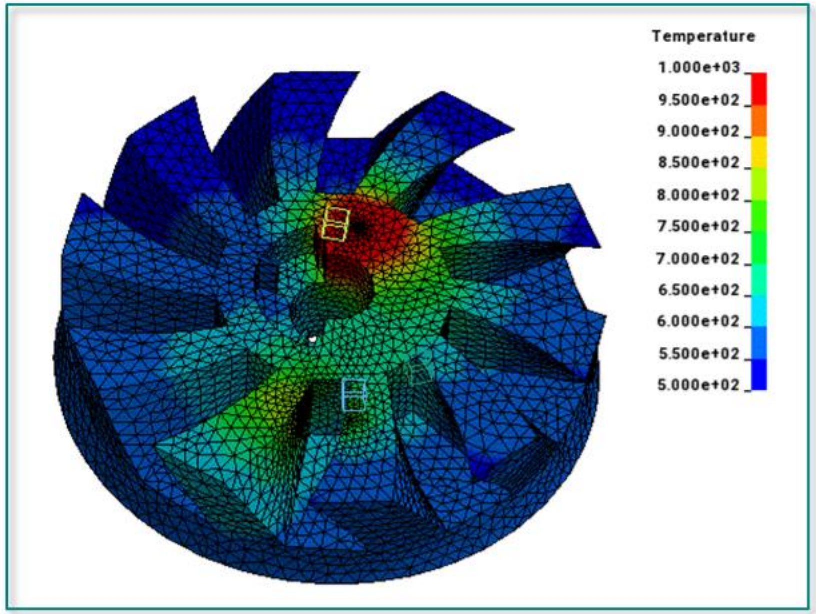
Spring back *(def. x10)*



Blueprint model



Temperature (20~1600 ℃)



Thermal

*BOUNDARY_CONVECTION/RADIATION/FLUX

*BOUNDARY_FLUX_TRAJECTORY

*LOAD_THERMAL_RSW

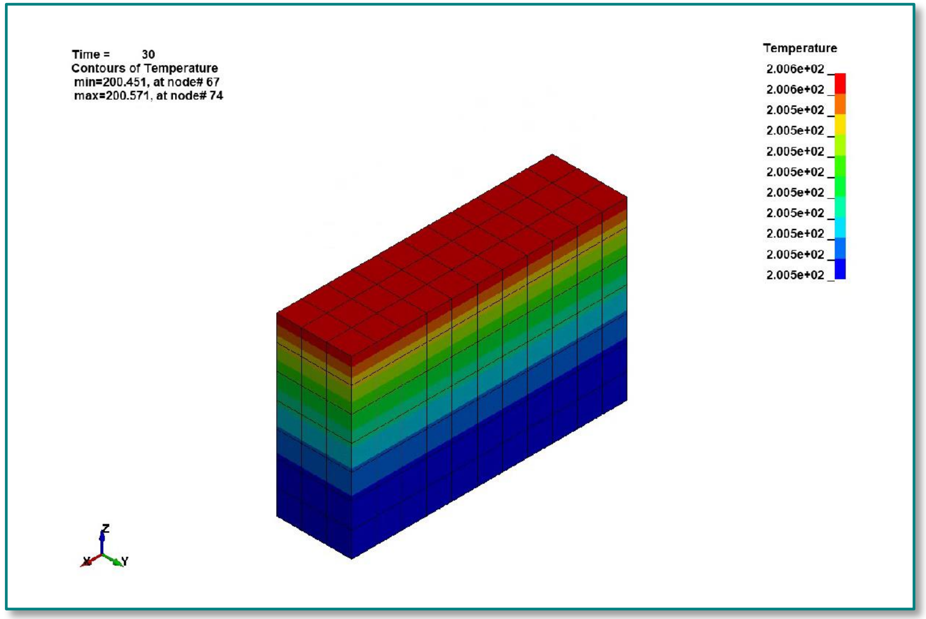
*MAT_GENERLIZED_PHASE_CHANGE (MAT_254)

*MAT_THERMAL_ISOTROPIC_TD_LC (MAT_T10)

Temperature dependent materials

Dealing with solid element erosion in thermal boundary conditions

- New parameter PSEROD for standard thermal boundary conditions (*BOUNDARY_CONVECTION, *BOUNDARY_RADIATION, *BOUNDARY_FLUX)
  - Points to a part set
  - Any new segment attached to an element in this part set, will inherit boundary condition
  - Original input data is used for newly segments

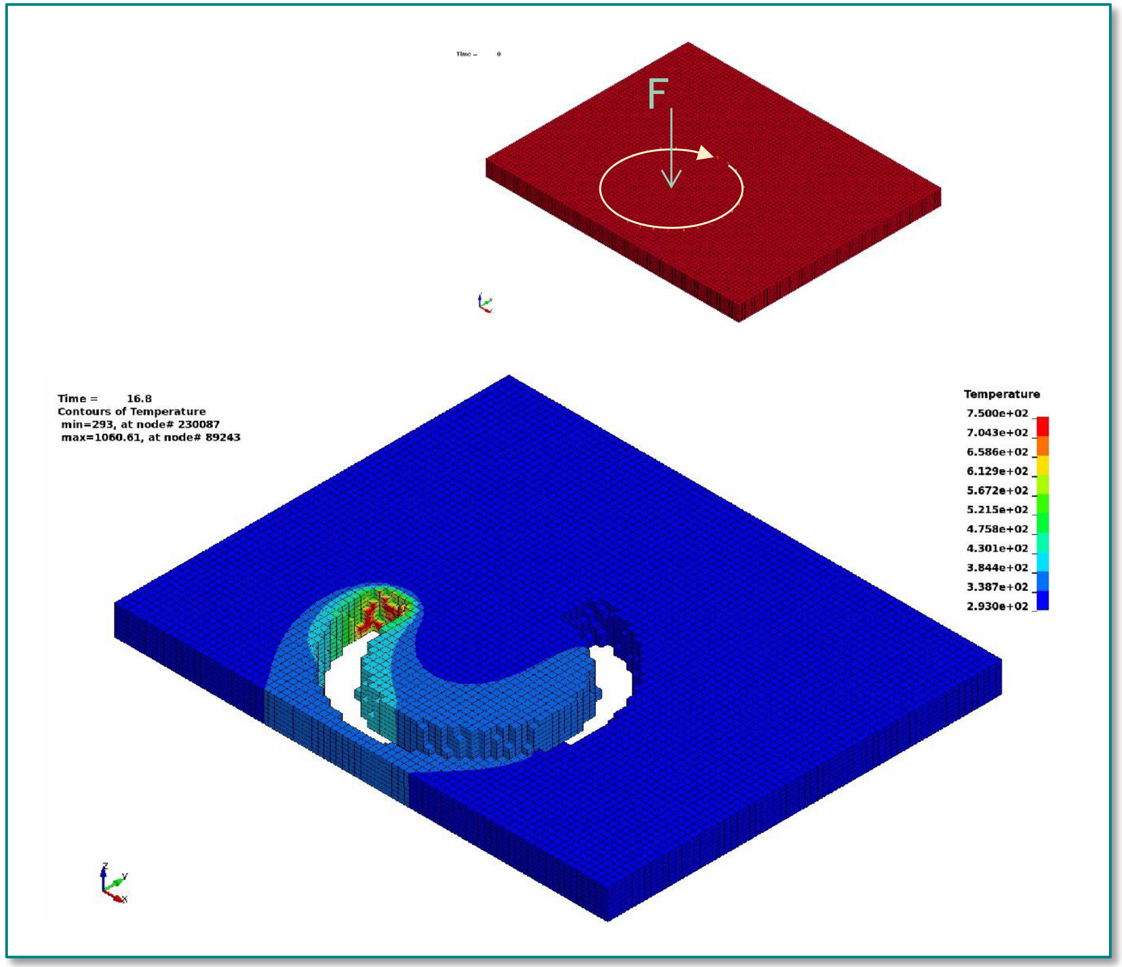


- *BOUNDARY_FLUX is now usable to simulate laser cutting applications
  - Definition of a moving heat source possible but very complicated
  - Rotation of the laser hard to capture

*BOUNDARY_FLUX_TRAJECTORY

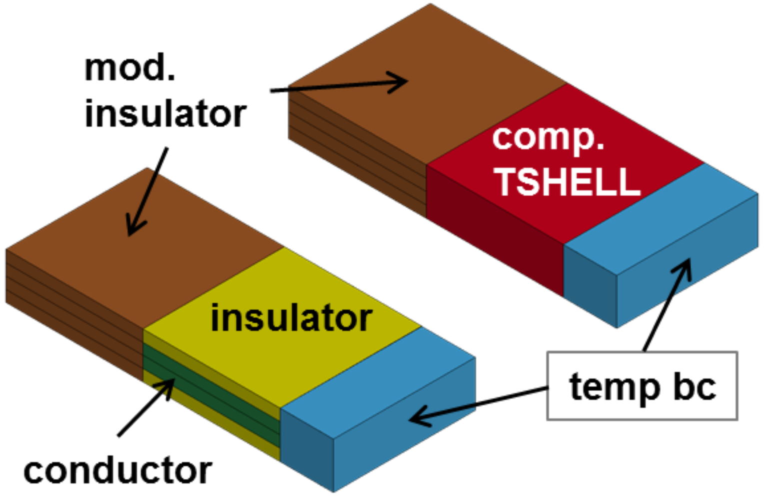
- Tailored boundary condition for laser heat treatment and laser cutting

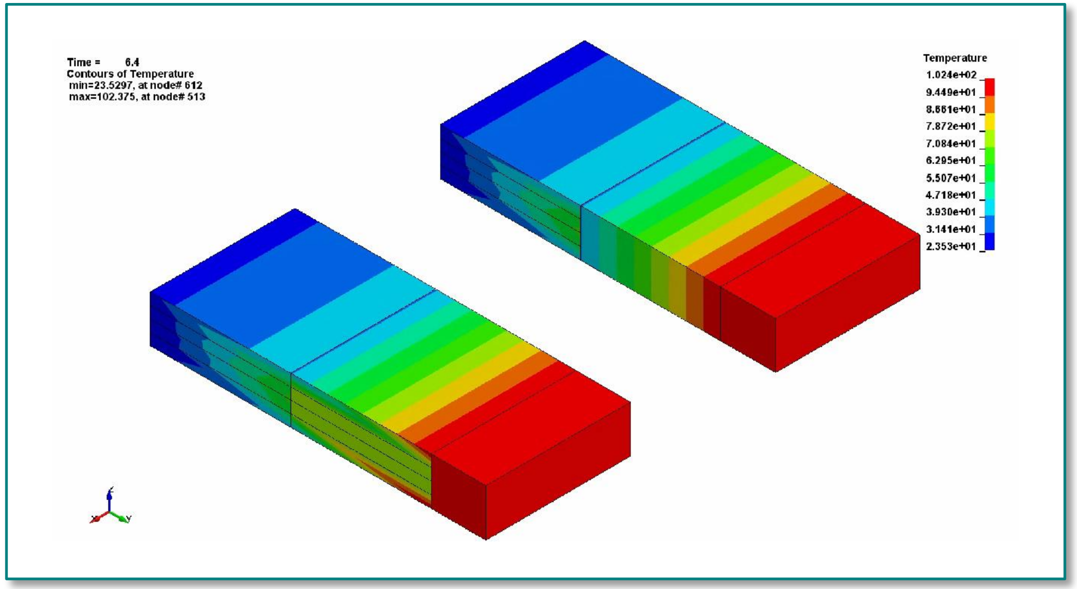
- Surface flux boundary condition that follows prescribed path and orientation
- Propagation to newly exposed segments after element erosion
- Surface heat density
  - Predefined distribution functions
  - User-defined functions
- Tilting of heat source is accounted for
  - Changes projection of beam on surface
  - Heat density can be automatically adapted



Thermal Solver - Miscellaneous

- Contact routines for thermal composite TSHELL elements
  - Composite lay-up internally reconstructed with virtual elements and nodes
  - For “edge”-contact virtual contact surfaces used



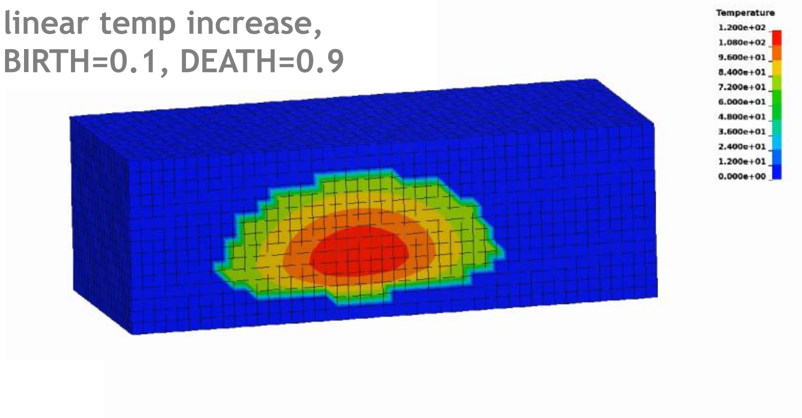


- Definition of heat generation function in local coordinates
  - *LOAD_HEAT_GENERATION accepts ID of a reference node in parameter RFNODE
  - Current coordinates of reference node can be referred to in user-defined function

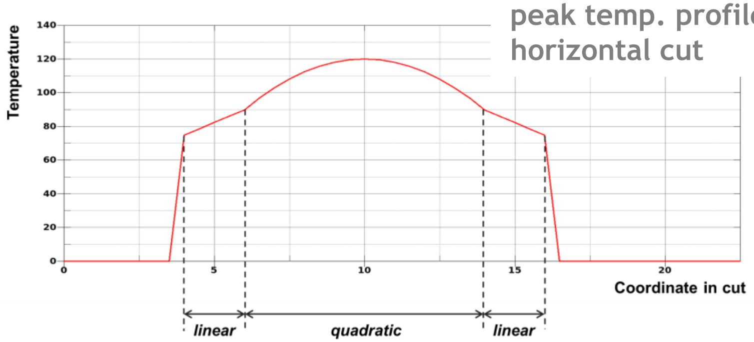
*LOAD_THERMAL_RSW for resistance spot welding simulation

- Simplification of thermal boundary condition *BOUNDARY_TEMPERATURE_RSW
- Direct definition of the temperature profile in the weld nugget as thermal load in structure-only simulation
  - Prescribed at the center, boundary of nugget, and boundary of HAZ
  - Default temperature used outside HAZ
  - Default temperature before birth time and after death time of loading condition
- No heat transfer into surroundings
- For early design phases

linear temp increase,
BIRTH=0.1, DEATH=0.9



peak temp. profile,
horizontal cut

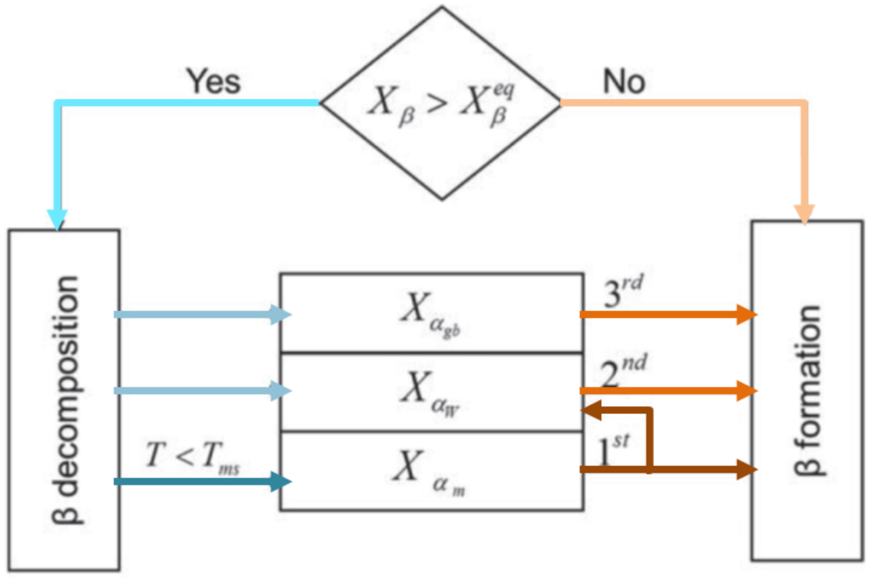


*MAT_GENERALIZED_PHASE_CHANGE / *MAT_254

- Plastic strain can accelerate/decelerate phase transformation speed
- Parameter ANOPT: define a cut-off temperature for thermal expansion
- Additional history variables for post-processing, e.g. accumulated (thermal) strain data; output controlled by parameter POSTV
- Enhanced annealing option: reset plastic strains based on evolution equation

- New phase transformation laws for titanium Ti-6Al-4V
  - Step-wise dissolution of a group of phases into one target phase
  - Interacting transformations from one common source phase

[C. Charles Murgau, PhD-thesis, 2016]



*MAT_THERMAL_ISOTROPIC_TD_LC (*MAT_T10)

- Load curves can now depend on **mechanical** history variables

This card is included if TGHSV > 0 (see Card 2).

Card 1b	1	2	3	4	5	6	7	8
Variable	TMID	TRO	TGRLC	TGMULT	TLAT	HLAT		
Type	A8	F	F	F	F	F		

VARIABLE	DESCRIPTION
TMID	Thermal material identification. A unique number or label not exceeding 8 characters must be specified.
TRO	Thermal density: EQ.0.0: default to structural density
TGRLC	Thermal generation rate curve number (see *DEFINE_CURVE): NE.0: function of mechanical history variable TGHSV EQ.0: use mechanical history variable TGHSV times constant multiplier value TGMULT.
TGMULT	Thermal generation rate multiplier: EQ.0.0: no heat generation

Card 2	1	2	3	4	5	6	7	8
Variable	HCLC	TCLC	HCHSV	TCHSV	TGHSV			
Type	F	F	F	F	F			

VARIABLE	DESCRIPTION
HCLC	Load curve ID specifying specific heat as a function of temperature, or, if HCHSV > 0, as a function of a mechanical material history variable HCHSV
TCLC	Load curve ID specifying thermal conductivity as a function of temperature, or if TCHSV > 0, as a function of a mechanical material history variable TCHSV
HCHSV	Optional: mechanical history variable # used by HCLC
TCHSV	Optional: mechanical history variable # used by TCLC
TGHSV	Optional: mechanical history variable # used by TGRLC

Temperature dependent materials

- *MAT_106 (VISCOPLASTIC_THERMAL)
  - Define up to eight user-defined history variables referencing to *DEFINE_FUNCTION
- *MAT_270 (CWM)
  - Parameter ANOPT that allows defining a cut-off temperature for thermal expansion
  - Additional history variables for post-processing, output controlled by parameter POSTV
- *MAT_277 (ADHESIVE_CURING_VISCOELASTIC)
  - Arrhenius shift function as alternative to the WLF shift function
  - Curing induced heating
- *MAT_278 (CF_MICROMECHANICS)
  - Curing induced heating
  - Reimplementation of solid formulation

Materials

*MAT_ADD_INELASTICITY
*MAT_ADD_DAMAGE_GISSMO
*DEFINE_ELEMENT_EROSION
*MAT_SHAPE_MEMORY_ALLOY
*MAT_LAMINATED_COMPOSITE_FABRIC_SOLID
*MAT_ANISOTROPIC_HYPERELASTIC
*MAT_DISCRETE_BEAM_POINT_CONTACT
*MAT_HYSTERETIC_BEAM
Miscellaneous materials

Materials and Elements

- *MAT_ADD_INELASTICITY

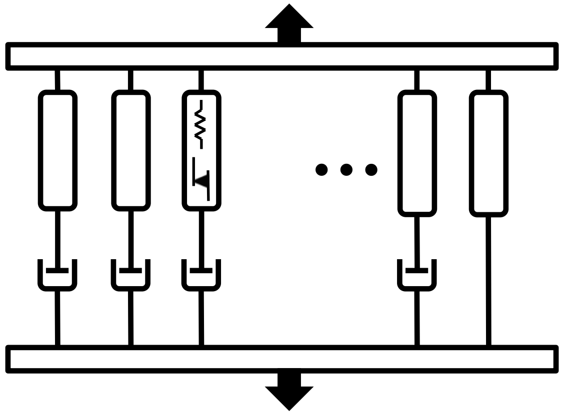
Norton-Bailey creep

von Mises plasticity

→ ***MAT_ELASTIC**

Prony viscoelasticity

→ ***MAT_PIECEWISE_LINEAR_PLASTICITY**



- Modular concept for introducing inelastic effects in standard material models
- Includes plasticity, creep and viscoelasticity models
- Not intended to replace standard material models but rather complement with missing features
- Models added on request

Ansys / LST

DYNA MORE

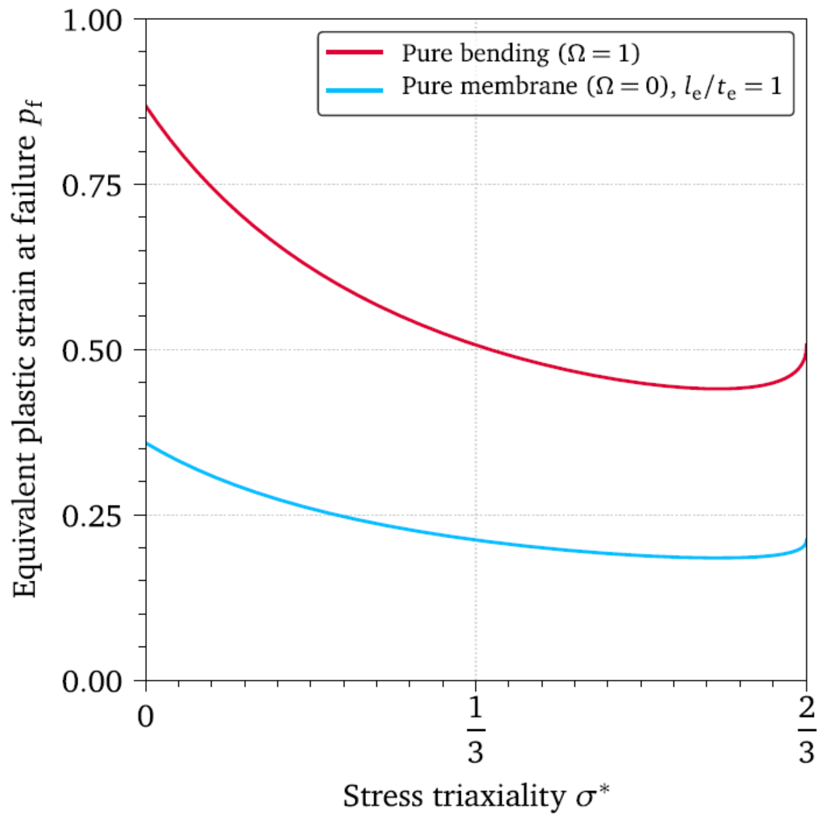
*MAT_ADD_DAMAGE_GISSMO

- New option LP2BI for *MAT_ADD_DAMAGE_GISSMO
  - For shell elements (with NUMFIP=1)
  - Lode parameter is replaced by bending indicator:

$$\Omega = \frac{1}{2}\frac{\left|\varepsilon^{T}_{p,33} - \varepsilon^{B}_{p,33}\right|}{\max\left\{\left|\varepsilon^{T}_{p,33}\right|, \left|\varepsilon^{B}_{p,33}\right|\right\}}$$

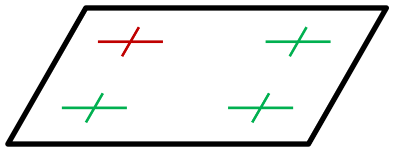
$\Omega = 0$: pure membrane
$\Omega = 1$: pure bending

  - For better failure prediction in (sharp) bending
  - Adopted from *MAT_258 (Costas et al. 2018) ⟶
  - Presentation at IDDRG Conference 2020 by Thornton Tomasetti, Novelis, and DYNAmore



*DEFINE_ELEMENT_EROSION_(SHELL/TSHELL)

- Define a rule to delete (layered) elements based on:
  - NIFP: Number of in-plane IPs that need to fail to indicate a failed layer

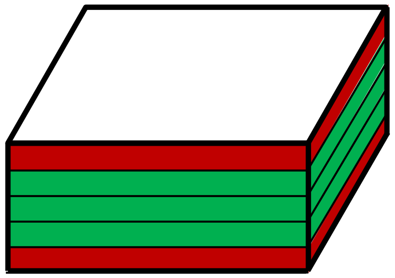


active IP

failed IP

#of failed IPs ≥ NIFP: layer marked as failed

  - NUMFIP: Number of layers which need to fail prior to element deletion



active layer

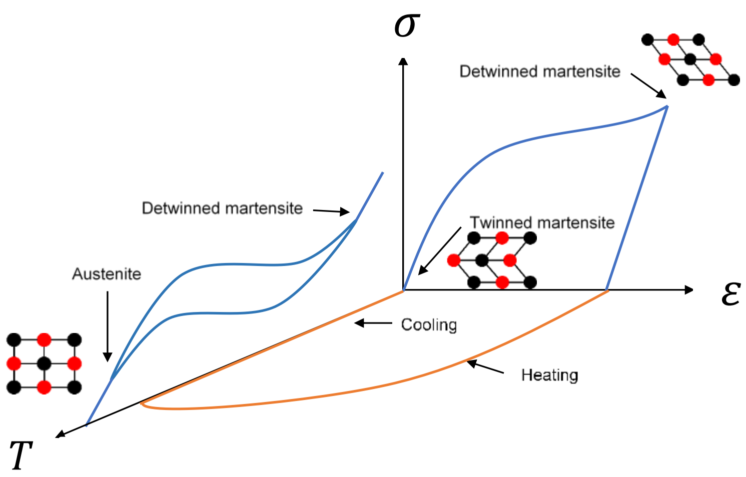
failed layer

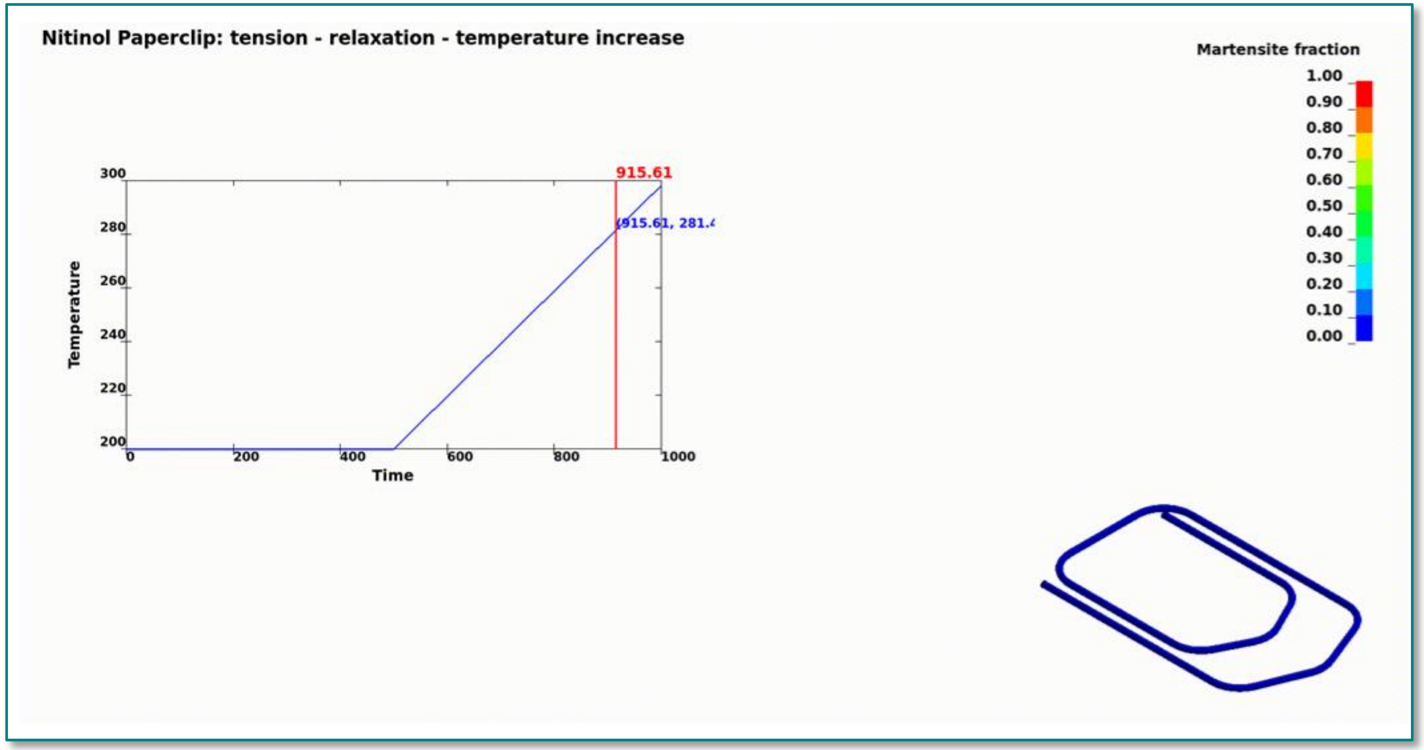
#of failed layers ≥ NUMFIP: element will be deleted

  - Might be useful in case of composite layered shells using different material models within the layers
  - Overwrites similar criteria defined within *MAT_ADD_EROSION or individual *MAT definitions
  - This keyword has to be used in conjunction with material models with failure options

*MAT_SHAPE_MEMORY_ALLOY (*MAT_291)

- New micromechanics-inspired model that models full (ε, σ, T)-space
  - Explicit/implicit, solids only
  - Shape memory effect, i.e., recovers original austenite configuration upon heating
  - Actuation, i.e., heating/cooling under applied load gives thermal hysteresis
  - Optional thermal coupling with *MAT_THERMAL_ISOTROPIC_TD_LC





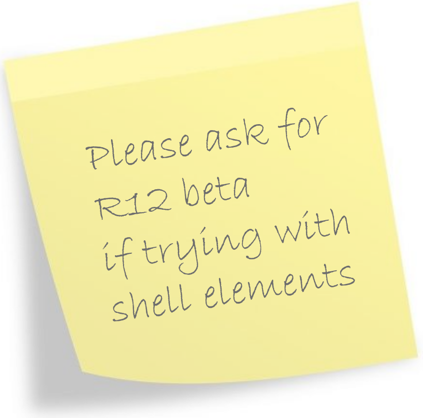
*MAT_LAMINATED_COMPOSITE_FABRIC{_SOLID} (*MAT_058)

- Now available for solids
  - Requires _SOLID option
  - Three additional keyword cards for _SOLID option

- New parameter LCDFAIL (shells and solids)
  - Allows direction dependent failure strains (defined within a *DEFINE_CURVE)

```
*DEFINE_CURVE
$#     lcid         sidr        sfa        sfo
$#                    a1                    o1
                       1                 ef_11T
                       2                 ef_11C
                       3                 ef_22T
                       4                 ef_22C
                       5                 ef_12
                       6                 ef_33T
                       7                 ef_33C
                       8                 ef_23
                       9                 ef_31
```

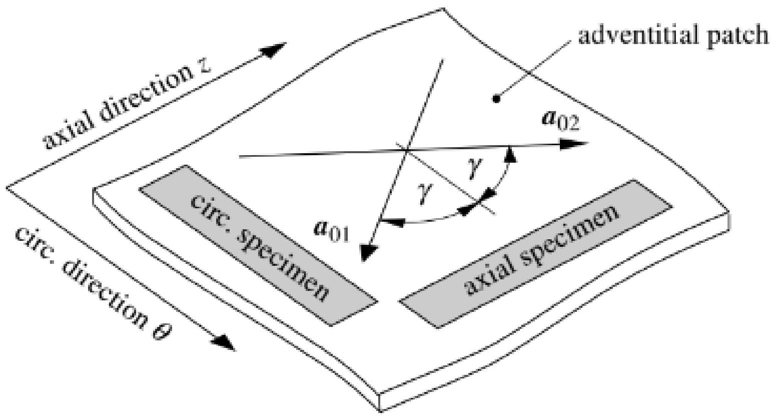
_SOLID option (ef_33T, ef_33C, ef_23, ef_31)

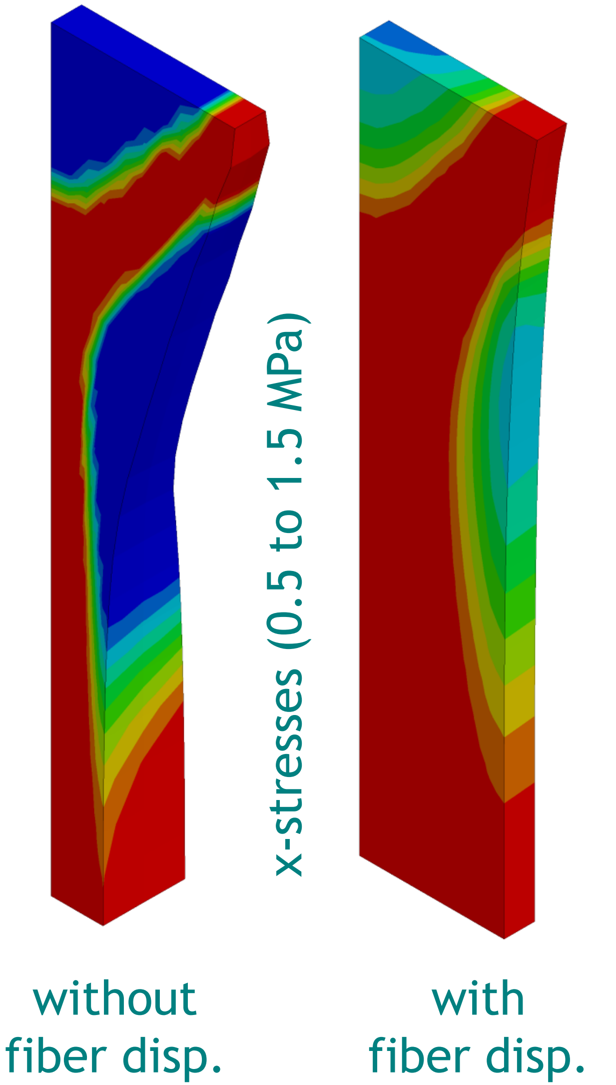


*MAT_ANISOTROPIC_HYPERELASTIC (*MAT_295)

- New modular material model for e.g. biological soft tissues or fiber-reinforced elastomers featuring:
  - Nearly-incompressible and compressible models
  - Rotationally non-symmetric fiber dispersion
  - Electro-mechanical coupling (muscle activation)

- Example problem - Gasser et al. (2006)
  - Uniaxial tension of an iliac adventitial strip (axial case)
  - Nearly-incompressible formulation
  - Two fiber families with and without fiber dispersion



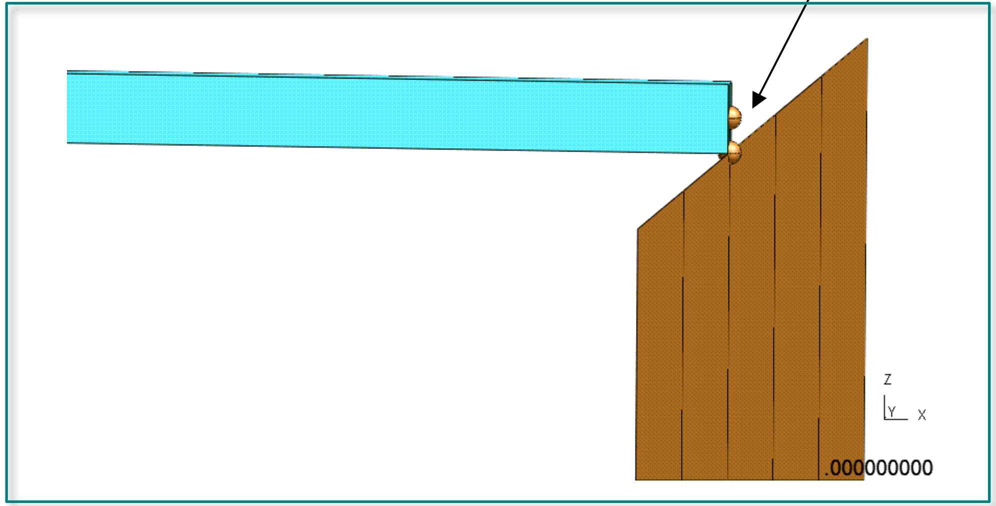


*MAT_DISCRETE_BEAM_POINT_CONTACT (*MAT_205)

- Discrete beam element representing contact with a flat plane
  - Beam element generates the same forces as if a plane were present
  - Plane is fixed to Node N1
  - Node N2 is a point that can slide on the plane, resisted by friction; uplift is not resisted
  - Dimensions/orientation of plane are specified on *MAT/*SECTION_BEAM cards
  - Options for tiebreak, damping, nonlinear contact deformation

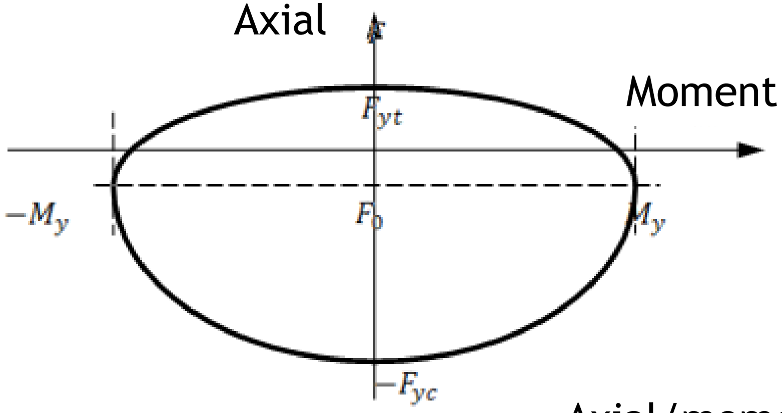
*MAT_D_B_P_C element

- Example: timber beam element resting on top of a wall made of shell elements



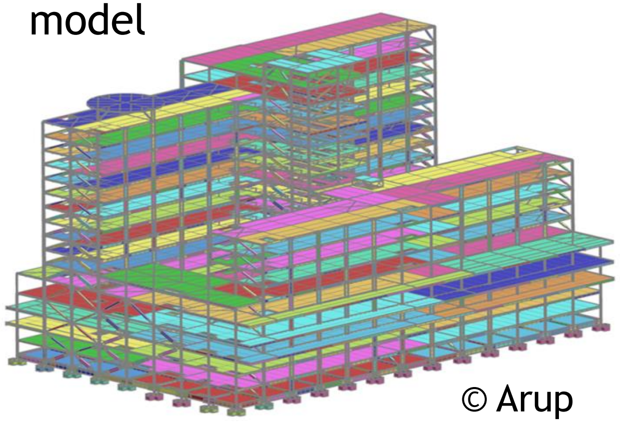
*MAT_HYSTERETIC_BEAM (*MAT_209)

- Improved version of *MAT_SEISMIC_BEAM
  - For seismic analysis of buildings
  - Suitable for steel or reinforced concrete
  - Plastic hinges at both ends (can be offset from nodes)
  - Nonlinear axial and shear behaviour
  - Hardening, softening and damage options

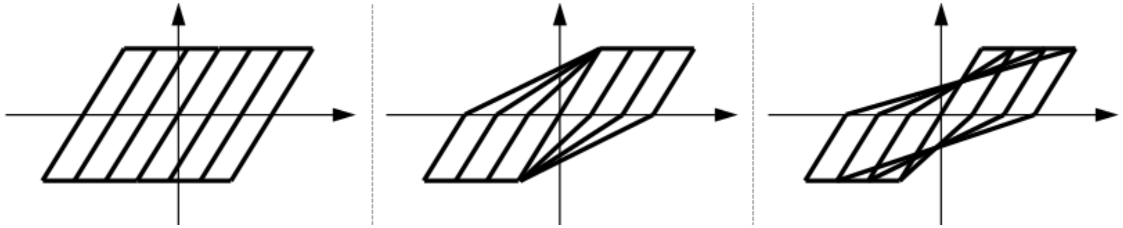


Axial/moment yield surface for reinforced concrete (various other options also available)

LS-DYNA model



© Arup



Options for pinched hysteresis, kinematic/isotropic hardening and degradation/damage

Miscellaneous material model enhancements

- New options for *MAT_NONLINEAR_PLASTIC_DISCRETE_BEAM (*MAT_068)
  - Nonlinear elastic translational and rotational stiffnesses TK{R,S,T} and RK{R,S,T}
- Make *MAT_BARLAT_YLD2000 (*MAT_133) available for solid elements
  - 3D extension of the Yld2000-2d function based on approach by Dunand et al. [2012]
  - Satisfies growing interest in accurate metal forming with solids
- Make *MAT_TAILORED_PROPERTIES (*MAT_251) available for solid elements
  - Yield stress as a function of strain, rate, and arbitrary history variables
  - For applications such as bake hardening, casting parts, etc.
- New options for *MAT_LAMINATED_FRACTURE_DAIMLER_CAMANHO (*MAT_262)
  - added transverse shear damage (similar to *MAT_054)
  - added flag (DSF) to control integration point failure based on in-plane shear

IGA - Isogeometric Analysis

Mechanical coupling of trimmed patches

Various other enhancements

Isogeometric Analysis

- *ELEMENT_SHELL_NURBS_PATCH_TRIMMED
- Mechanical coupling of trimmed patches
  - continuity at interface (strong form)

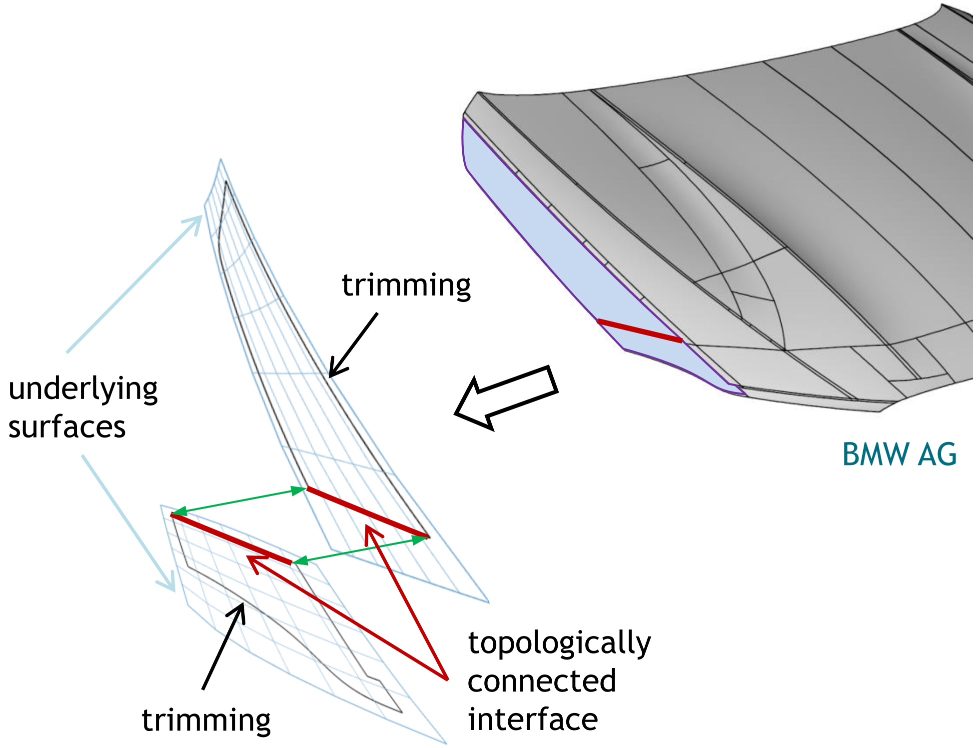
$$\boldsymbol{u}_1 = \boldsymbol{u}_2|_\Gamma \; ; \quad \boldsymbol{\theta}_1 = \boldsymbol{\theta}_2|_\Gamma$$

  - penalty weak form (translations and rotations)

$$\alpha^{disp} \int_\Gamma (\boldsymbol{u}_1 - \boldsymbol{u}_2) \cdot (\delta\boldsymbol{u}_1 - \delta\boldsymbol{u}_2) d\Gamma = 0$$

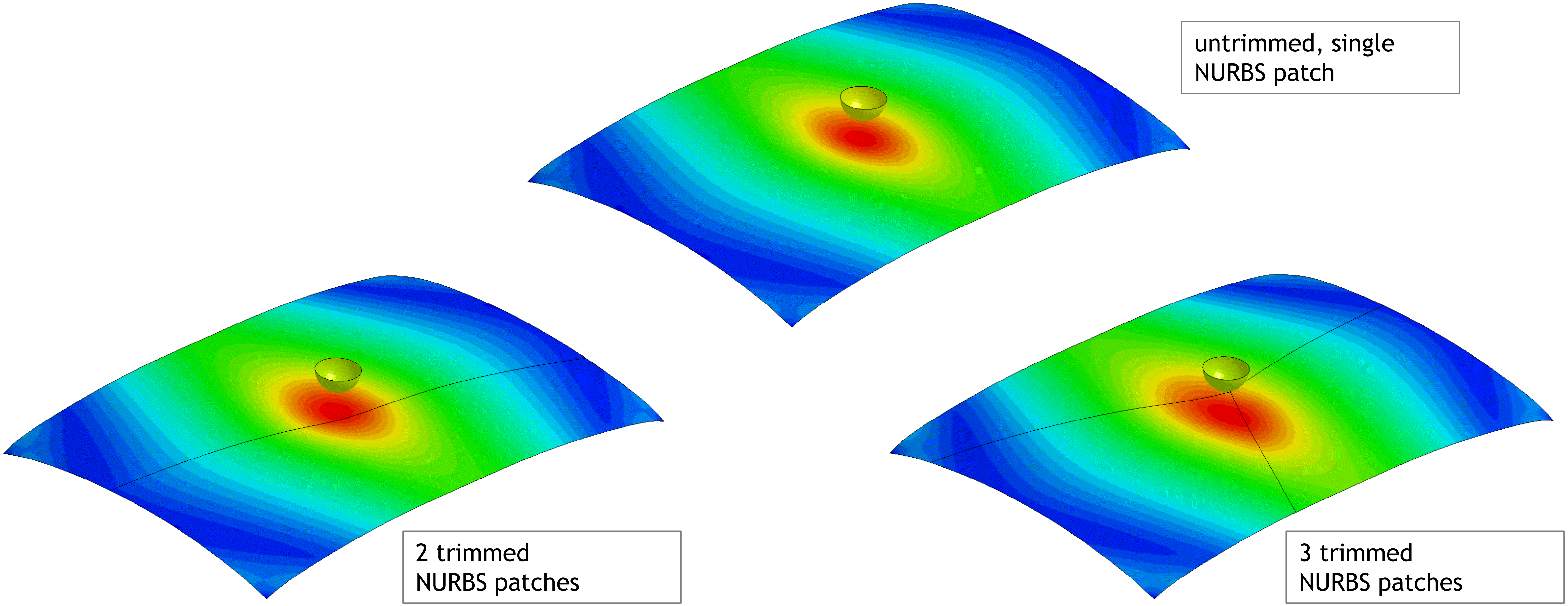
$$\alpha^{rot} \int_\Gamma (\boldsymbol{\theta}_1 - \boldsymbol{\theta}_2) \cdot (\delta\boldsymbol{\theta}_1 - \delta\boldsymbol{\theta}_2) d\Gamma = 0$$

  - various improvements and bug fixes
  - add support for thin (rotation free) shell formulations



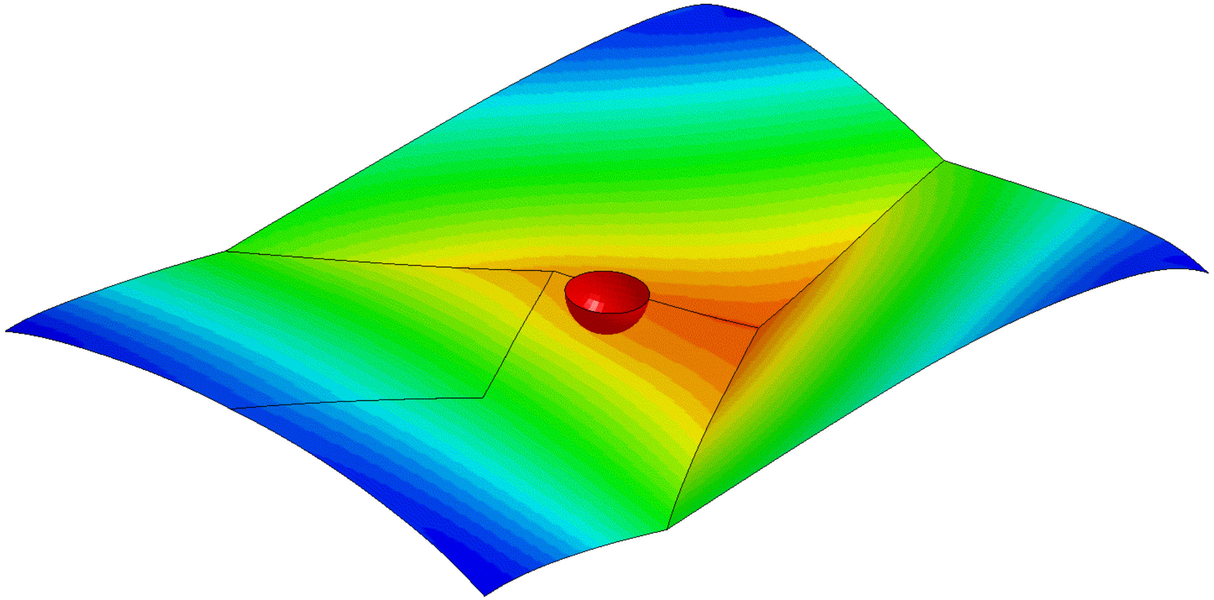
Isogeometric Analysis

- Mechanical coupling of trimmed patches (shells with rotational DOFs)

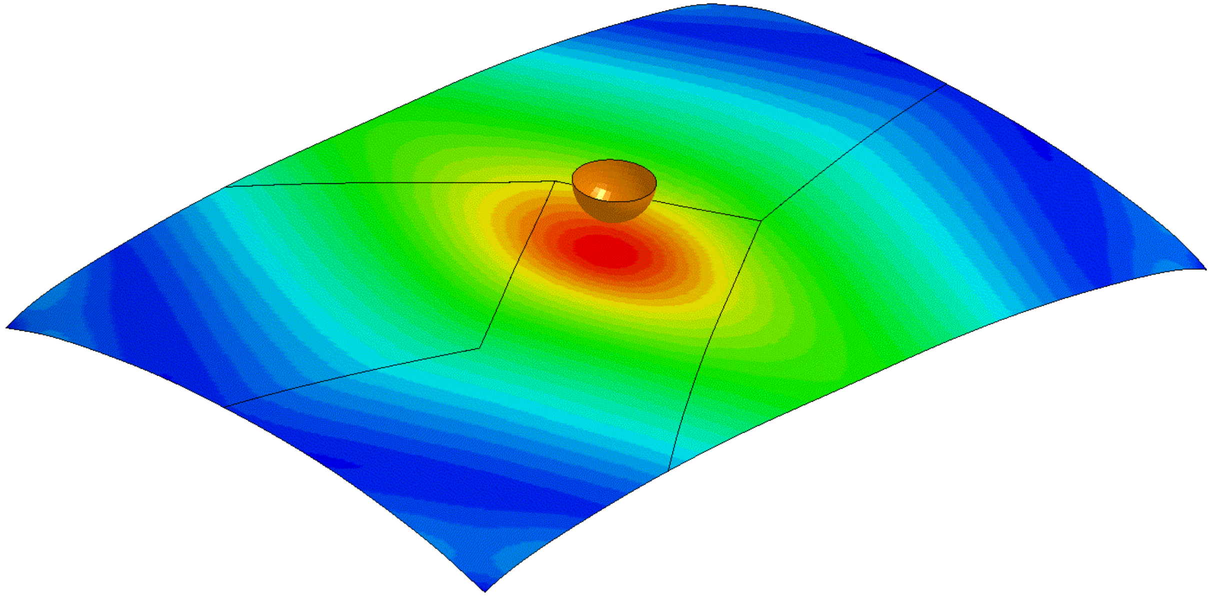


Isogeometric Analysis

- Mechanical coupling of trimmed patches (shells without rotational DOFs)



Without rotational constraints → Kinks!



4 trimmed NURBS patches

With rotational constraints → Continuity!

More IGA enhancements

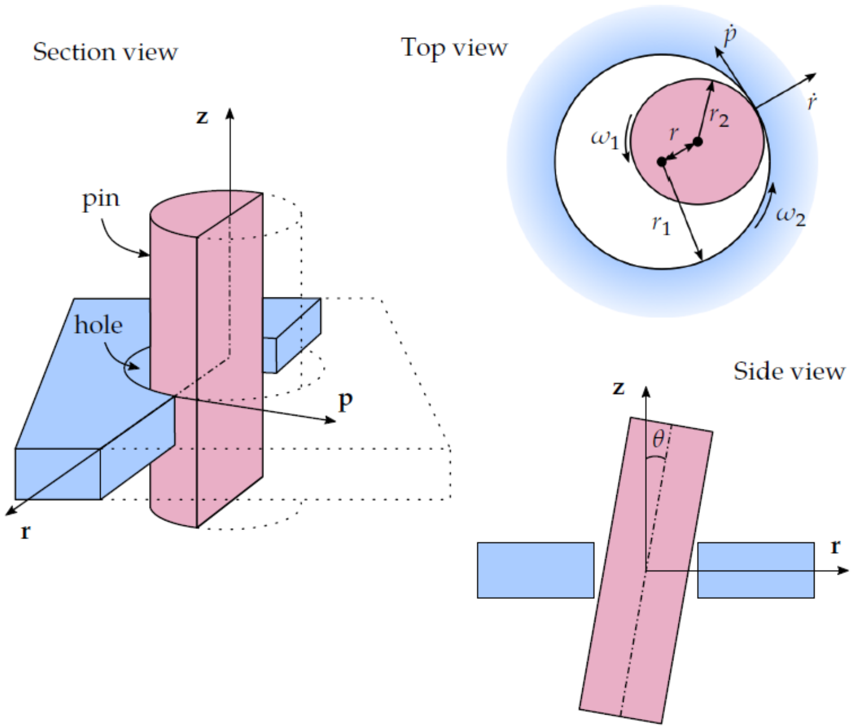
- Allow *DEFINE_SPOTWELD_RUPTURE to work with isogeometric shell elements
- Element erosion via *MAT_ADD_DAMAGE/EROSION (GISSMO) available for shells and solids
- Implicit contact is now supported via interpolation elements
  - IGA now works for implicit springback
- Thickness change options (ISTUPD in *CONTROL_SHELL) now supported for IFORM=3 IGA shells
- Add conventional mass scaling to IGA solids
- Add material models to be supported with IGA shells
  - *MAT_054 (*MAT_ENHANCED_COMPOSITE_DAMAGE)
  - *MAT_224 (*MAT_TABULATED_JOHNSON_COOK)
- Laminated shell theory is now supported for IGA shells

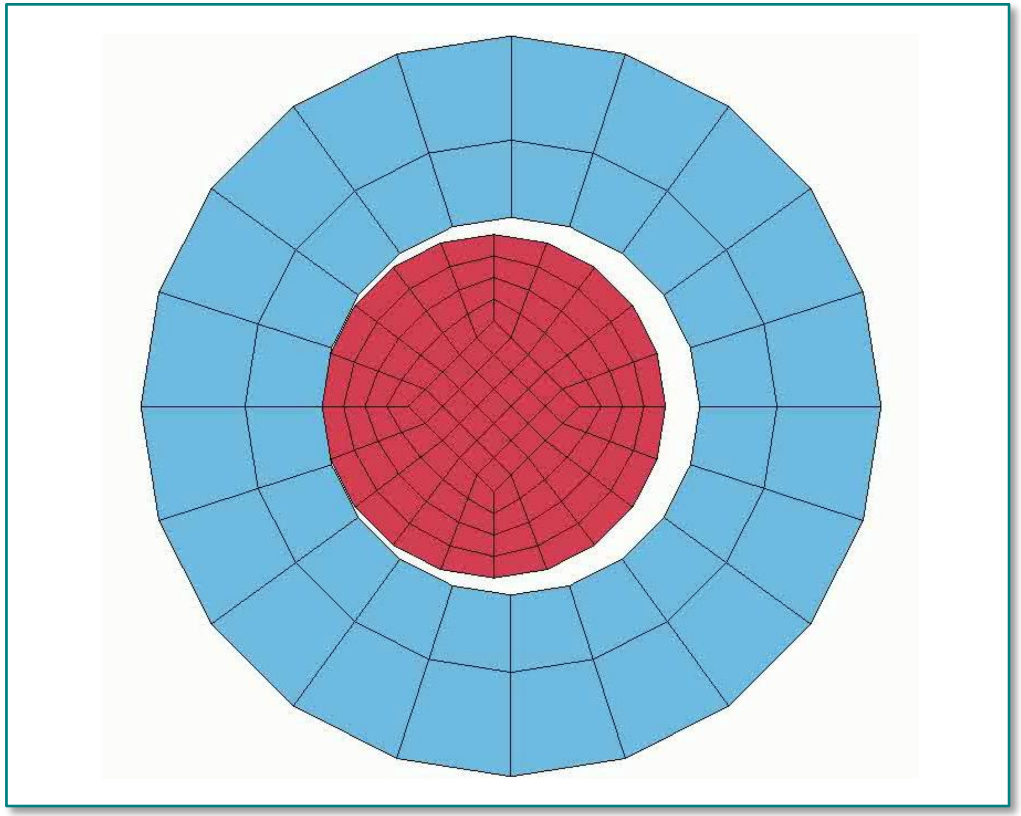
Miscellaneous

Analytical cylindrical joint stiffness
Bolt pre-stress ISTIFF
*SET_PART_TREE
Erode shells/beams due to low timestep
*CASE
FMI – co-simulation
*INITIAL_HISTORY_NODE
Miscellaneous

Cylindrical/revolute connections with play

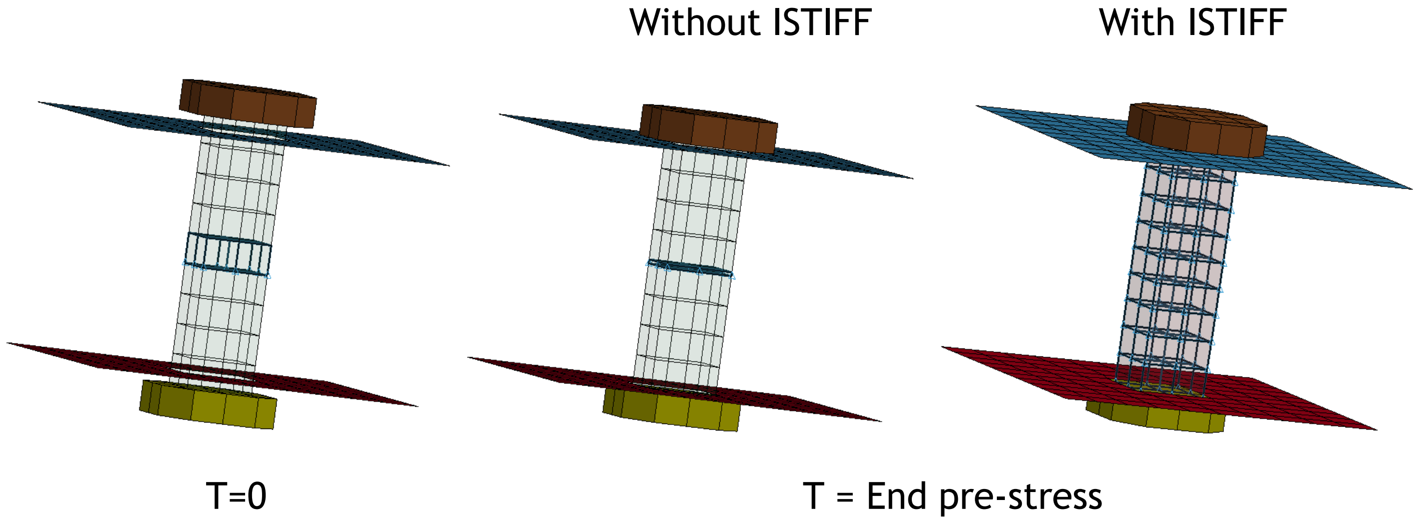
- Cylindrical Joint Stiffness for modeling play of axial bearings
  - *CONSTRAINED_JOINT_STIFFNESS_CYLINDRICAL
  - Perfect representation of geometry
  - Friction model and axial limit

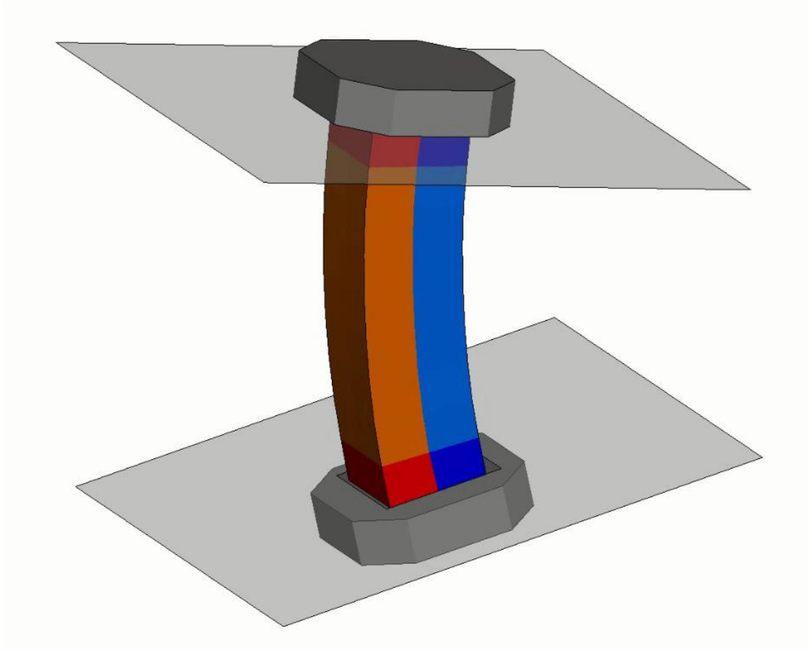




Bolt pre-stressing technique

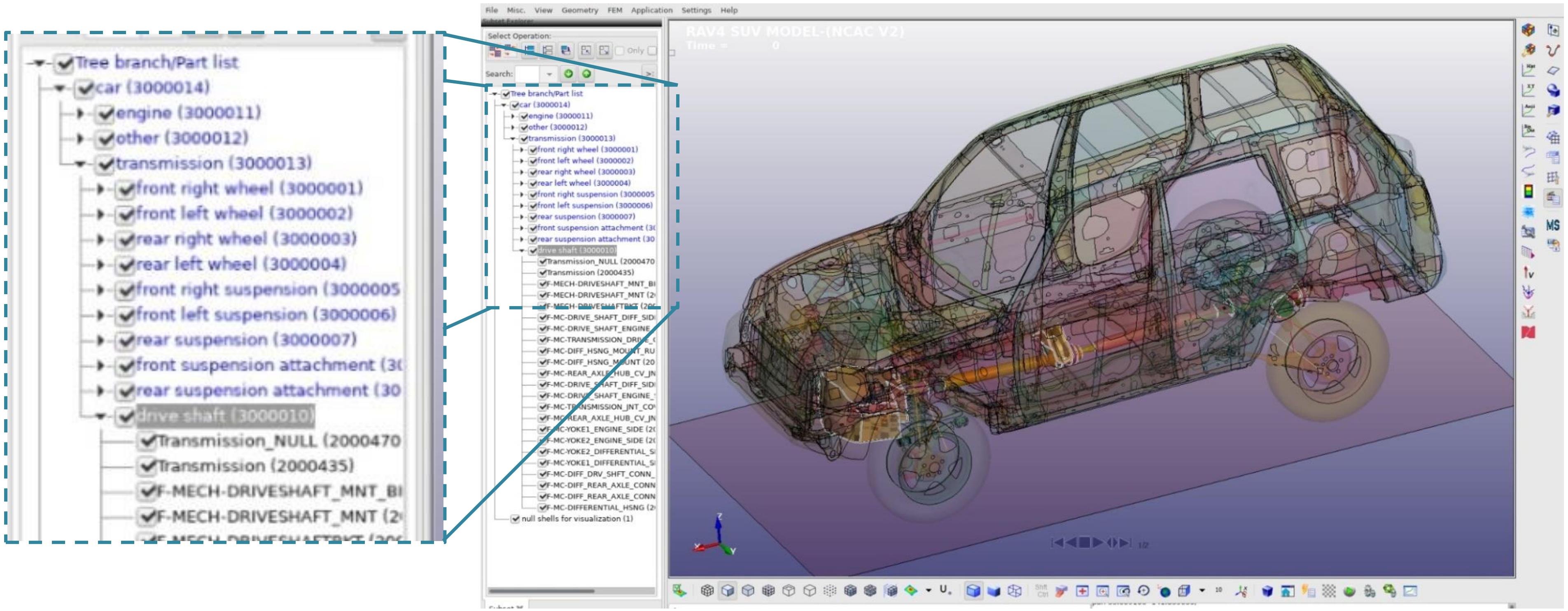
- *INITIAL_STRESS_SECTION
  - New option for pre-stress of solid meshed bolts through the ISTIFF parameter
  - Distribute the pre-stress deformation/distortion along shank of bolt (elastic “ghost” elements) instead of just one row of elements
  - Enhanced stability through artifical stiffness





*SET_PART_TREE

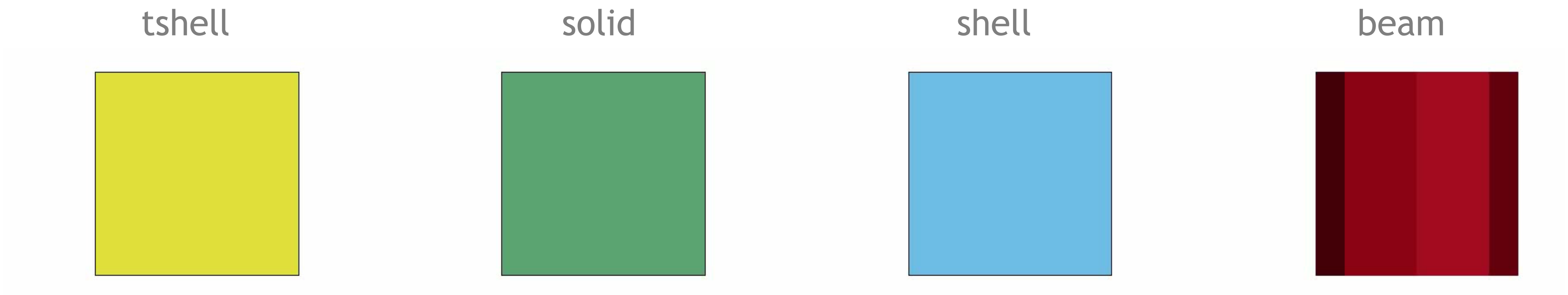
- SET_PART_TREE defines a branch in a tree structure
- With this keyword, the model can be modeled as a hierarchical tree structure
- BRANCH and DBRANCH can be used in *SET_NODE_GENERAL and *SET_SEGMENT_GENERAL



Acknowledgement to
George Washington University
National Crash Analysis Center

*CONTROL_TIMESTEP, ERODE

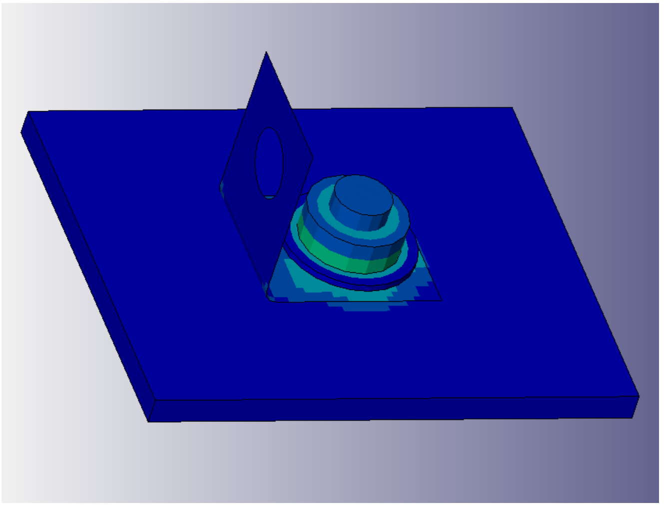
- Previously solids and tshells could be eroded based on element timestep
  - With ERODE = 1
- ERODE has now been extended to also support beams and shells
  - With ERODE = 10, 11, 100, 101, 110 and 111
- Below is an example with DTMIN = 0.5 and ERODE = 111



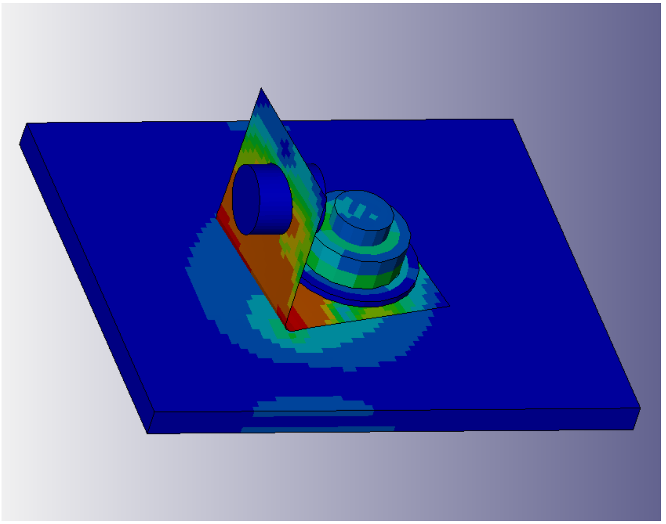
*CASE - run a subset of the cases

- To run a subset of the cases defined in the input deck
  - specify the case ID number following the word “CASE” on the execution line

- E.g. “CASE=1,3” will run only cases 1 and 3, in sequence



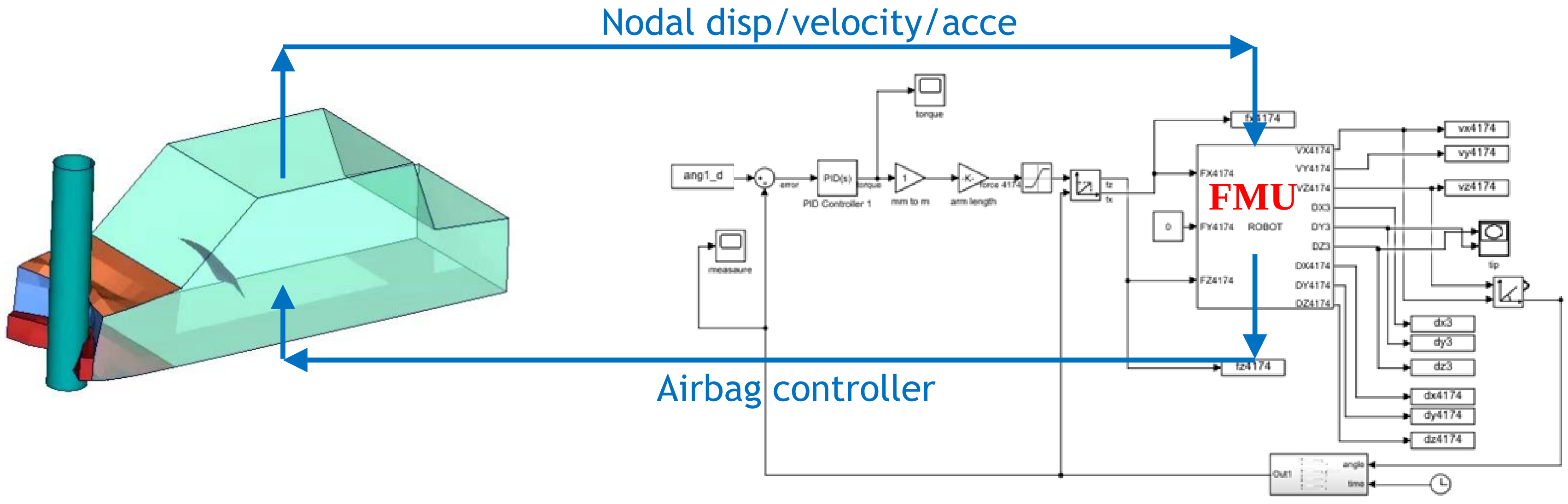
Case 1: Pretension



Case 3: Load in Y-direction

Co-Simulation with LS-DYNA Through FMI (Functional Mockup Interface)

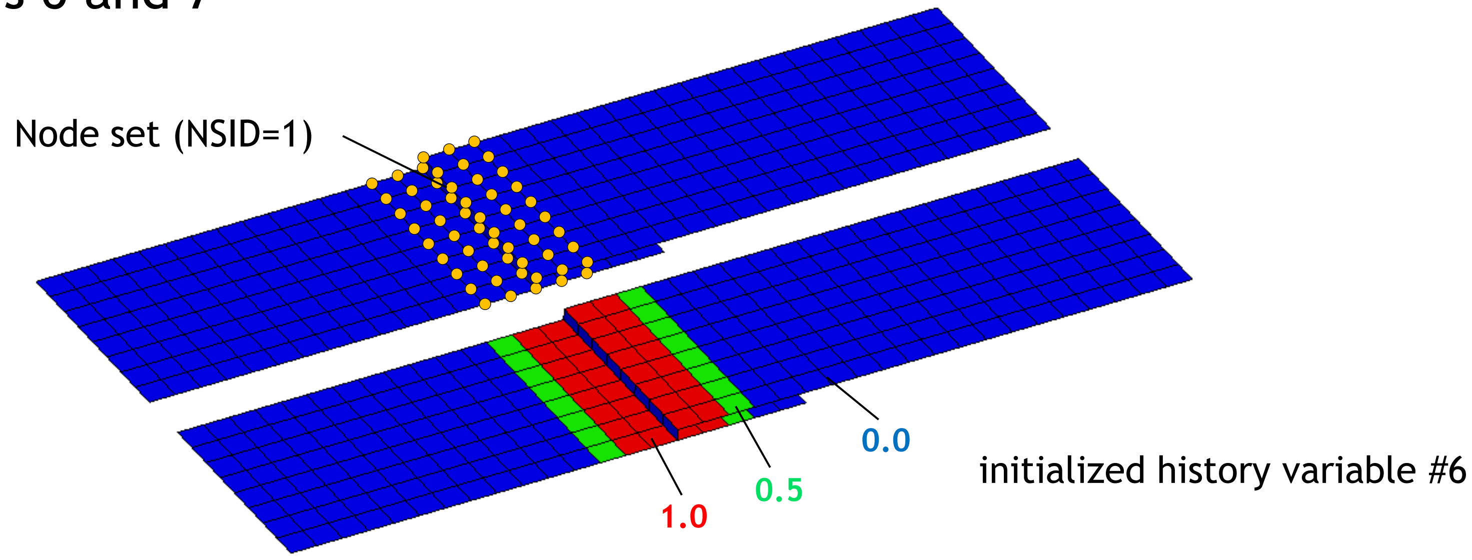
- New keywords *COSIM_FMI_CONTROL and *COSIM_FMI_INTERFACE
  - Adds capability to remotely co-simulate with other software supporting FMI standard
  - TCP/IP communication between solvers
  - Each software contributes their solution results to a coupled, multi-physics problem using specified communication time steps
- Example: LS-DYNA sends sensor data to airbag controller in another software, that determines when the airbag is fired in LS-DYNA.



*INITIAL_HISTORY_NODE(_SET)

- Initialize certain history variables on a nodal basis
  - Available for: shells, tshells and solids
- The nodal values are interpolated using standard FE shape functions
  - shells: interpolation w.r.t. to in-plane IPs, all IPs through the thickness receive the same value
  - values at uninitialized nodes are assumed to be ZERO
- In contrast to *INITIAL_STRESS_SHELL, individual history variables can be initialized
- Example: initialize history variables 6 and 7

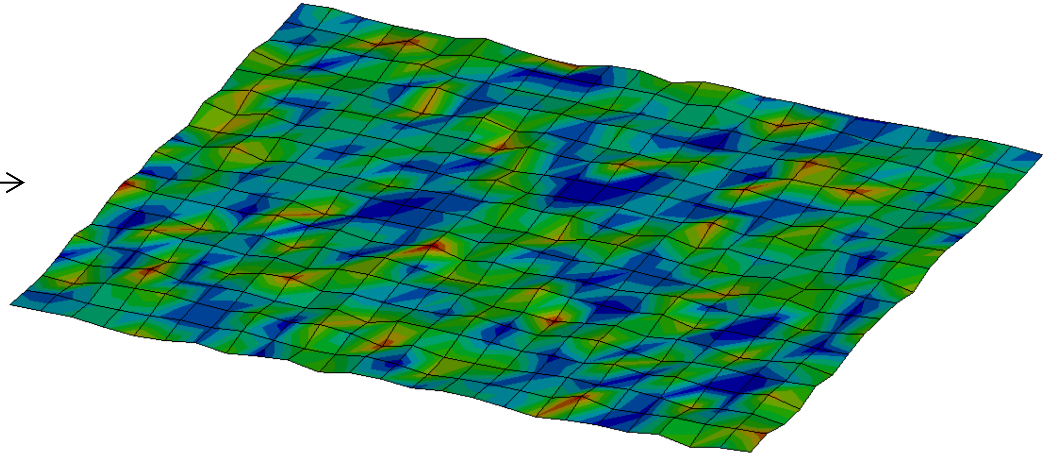
```
*INITIAL_HISTORY_NODE_SET
$     NSID     NHISV
         1         2
$  HINDEX1      VAL1
         6       1.0
$  HINDEX2      VAL2
         7       0.1
```



Miscellaneous

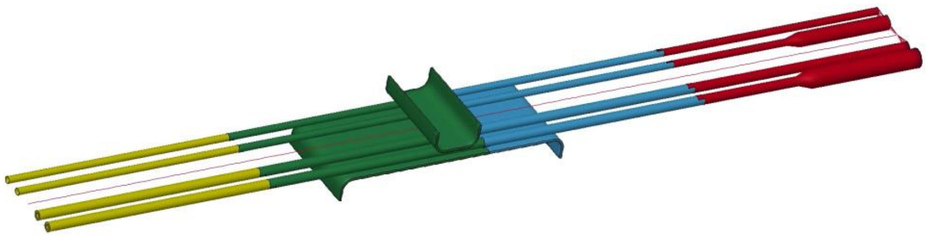
- New option TET13V on *CONTROL_SOLID
  - choose between the efficient or a more accurate version of the tet type 13 implementation (non-default TET13V=1 invokes previous behavior!)

- New option for *PERTURBATION_NODE
  - DTYPE=1 to allow uniform distribution between $SCL \times [-AMPL, AMPL]$ for random value perturbation (TYPE=8) →



- New options for *DEFINE_TRANSFORMATION
  - TRANSL2ND: translation given by two nodes and a distance
  - ROTATE3NA: rotation given by three nodes and an angle

- *DEFINE_PRESSURE_TUBE now supports decomposition of automatically generated solid/shell tubes in MPP →



Further topics

Fatigue / Frequency Domain

SPG / XFEM

ALE and S-ALE

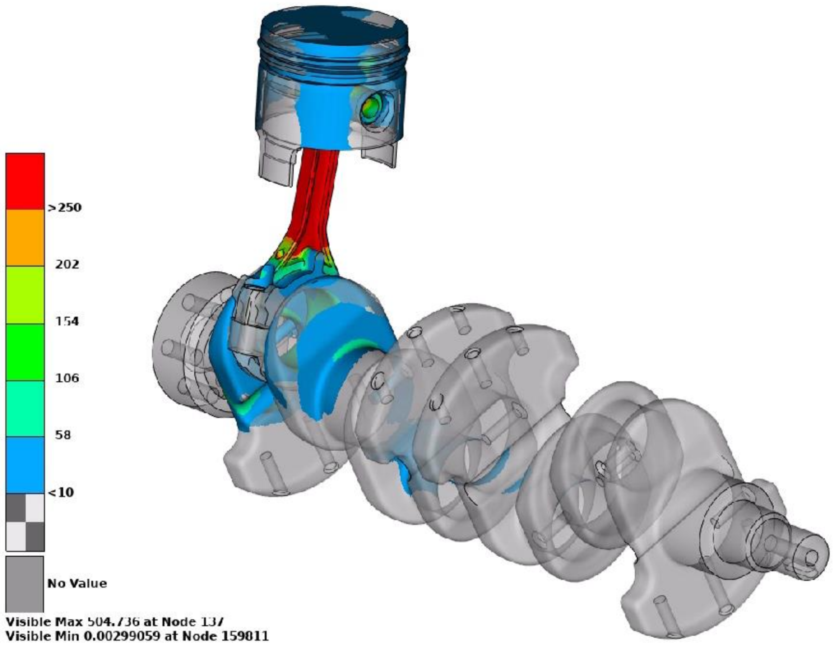
SPH

ICFD

EM

Fatigue / Frequency Domain

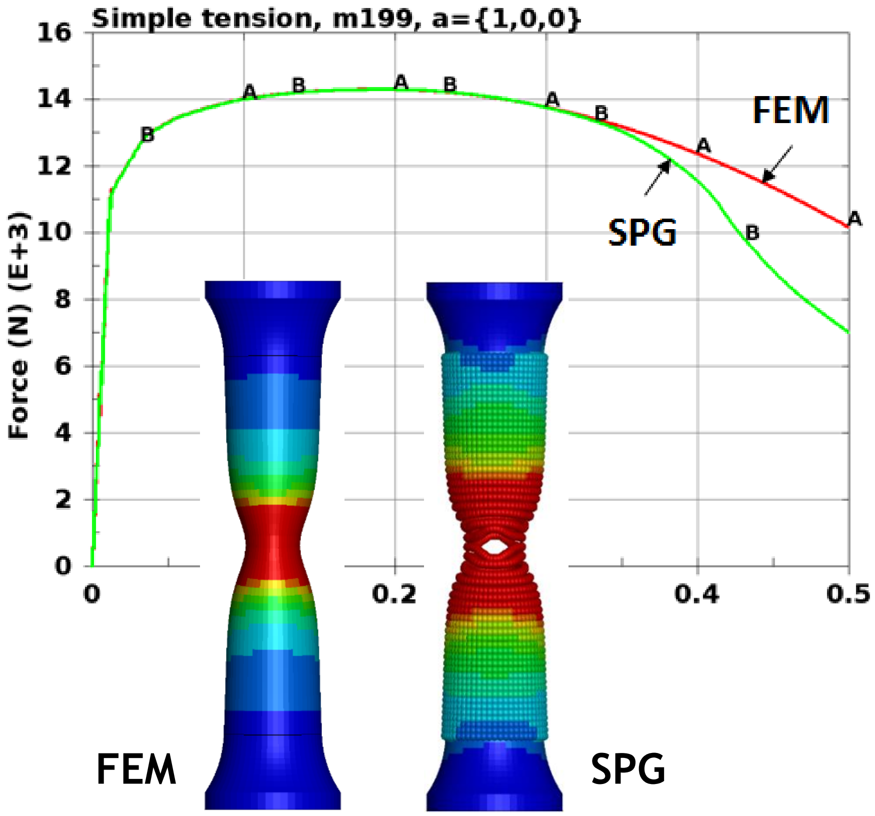
- New *FATIGUE_FAILURE
  - Remove failed elements from model
- New *FATIGUE_MULTIAXIAL
  - Run multiaxial fatigue analysis
- New *FATIGUE_LOADSTEP
  - Run fatigue analysis with multiple load steps
- New *FATIGUE_D3PLOT
  - Run time domain fatigue analysis based on d3plot



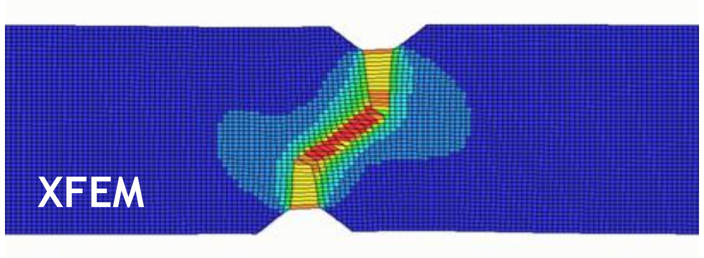
- Several enhancements for *FREQUENCY_DOMAIN
  - Option _LOCAL for frequency domain analysis on part of model
  - _SSD_ERP for radiation efficiency computation for ERP
  - _SSD_DIRECT_FREQUENCY_DEPENDENT to run direct SSD with frequency dependent material properties
  - …

SPG / XFEM

- SPG enhancements
  - More simplified user input
  - More material laws supported
    - 110, 122, 123, 126, 143, 199, 260a, 269
  - Added SPG bond failure criteria
    - Works with FAIL on *MAT_024, *MAT_ADD_EROSION, GISSMO



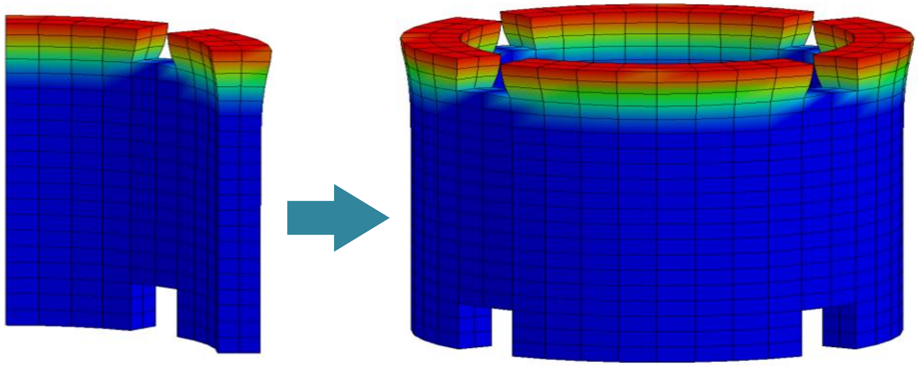
- XFEM enhancements
  - Added support of GISSMO damage model
  - *BOUNDARY_PRECRACK: Adjusted the location of pre-crack to avoid passing through nodal points
  - Example



Asymmetric V-notched Coupon under Tension

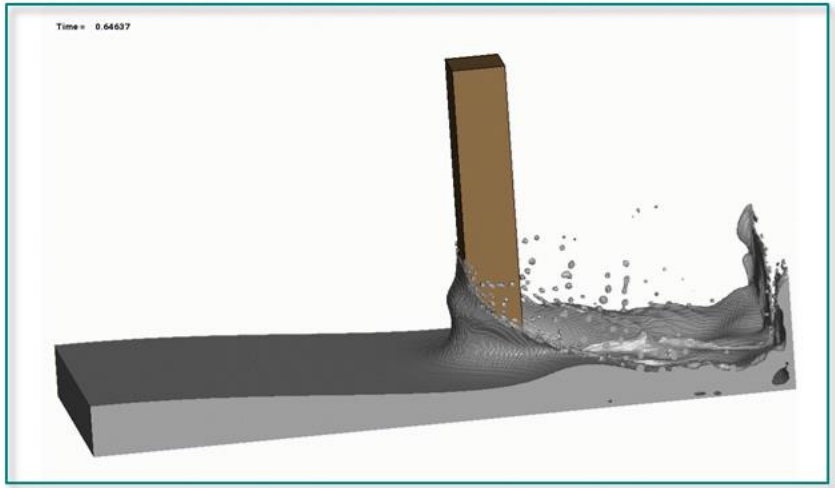
ALE / S-ALE

- New keyword *ALE_MESH_INTERFACE
  - mesh material interfaces with triangular shells
  - Outputs ALE simulation results as FEM tet-meshed bodies



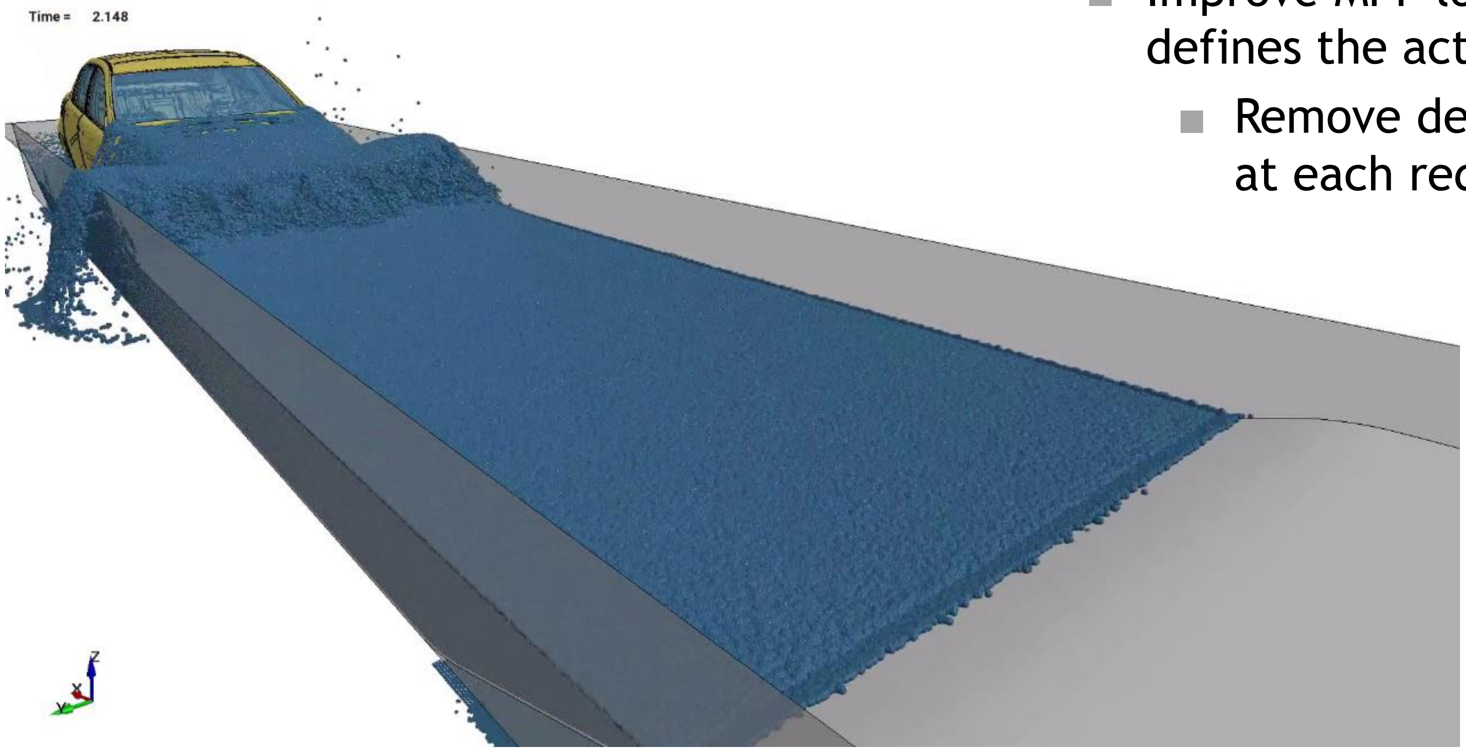
- New keyword *ALE_MAPPING
  - map data during a run
  - See also: *INITIAL_ALE/LAG_MAPPING: Powerful mapping of results from one solid model simulation to another: 2D to 2D, 2D to 3D, 3D to 3D, 3D to 2D

- S-ALE enhancements
  - Support *EOS_MURNAGHAN to model weakly incompressible water
  - *ALE_STRUCTURED_MESH_VOLUME_FILLING implementeded to fill ALE fluids into the initial S-ALE mesh



Implicit Incompressible SPH (IISPH)

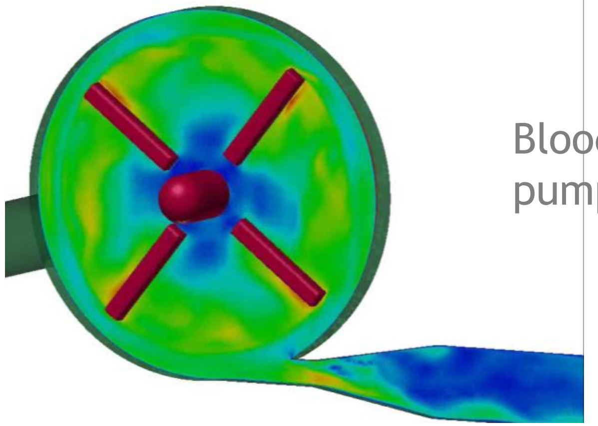
- Implicit, incompressible SPH formulation (FORM=13) allows larger timestep size
- Well-suited for automotive water wading, gearbox, ...
- *CONTROL_MPP_DECOMPOSITION_REDECOMPOSITION



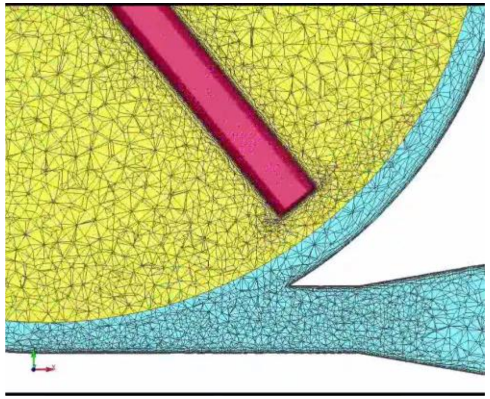
- Improve MPP load balancing when a moving box defines the activation region of SPH
  - Remove dead SPH particles from the model at each redecomposition step

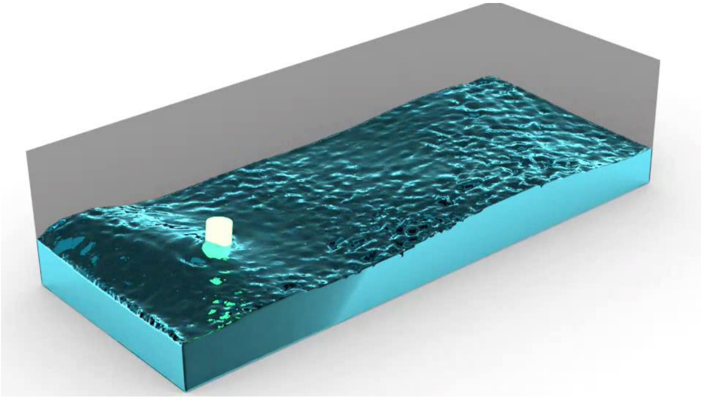
ICFD

- *ICFD_BOUNDARY_PERIODIC
  - Addition of periodic, reflective, and sliding mesh boundary conditions
  - Avoid mesh distortions when studying rotating machinery



Blood pump



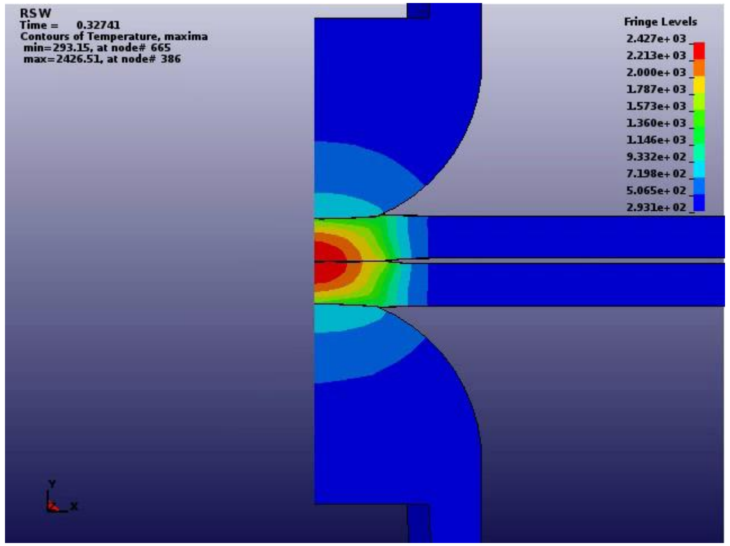


- New wave generation options (*ICFD_BOUNDARY_FSWAVE)
  - Fifth order Stokes wave
  - Solitary wave
  - Irregular wave

- Many other new functionalities
  - Check out papers on https://www.dynalook.com/conferences/16th-international-ls-dyna-conference

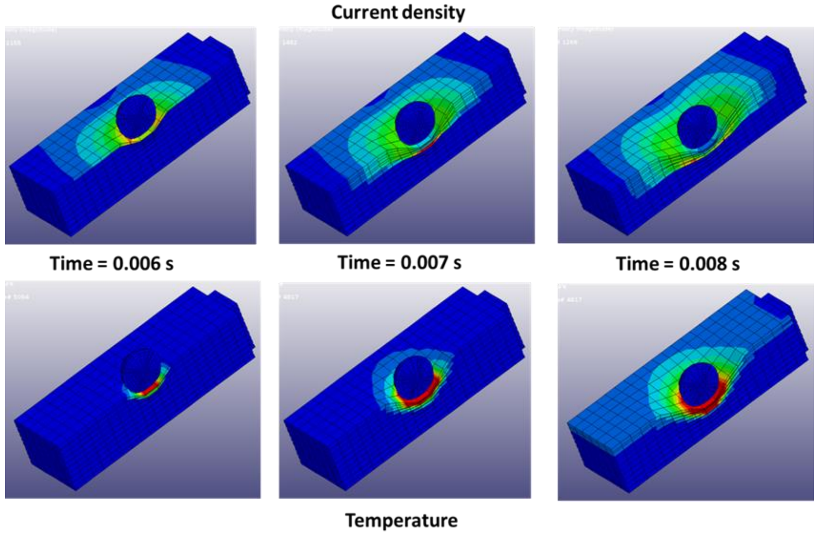
EM / Batteries

- Updates for EM solver
  - Added EM Mortar types to improve accuracy in RSW →
  - Support of eroding conductors
  - Added coupling with the ICFD solver



- Electrochemistry-thermo-mechanical coupling
  - New thermal and mechanical coupling with electrochemical LIB model

- Battery module
  - 4 models depending on scale/detail (solids, tshells, macro, and meshless) →



Sphere impacting 10 cells module

- State-of-charge expansion
  - New keyword *MAT_ADD_SOC_EXPANSION

Bug fixes

Selected code corrections

- Fix *CONTACT_AUTOMATIC_GENERAL for spot weld beams when using SSID=0 and CPARM8=2
- Fix THERMAL option of *CONTACT in MPP when some partitions don't participate in all contact definitions
- Fix incorrect stress output to d3plot and ASCII files when using tetrahedron solid types 10 and 13 with orthotropic materials and when CMPFLG=1 in *DATABASE_EXTENT_BINARY
- Fixed implicit element stiffness of shell elements when used with laminated shell theory
- Fixed a bug that made *INITIAL_VELOCITY_GENERATION_START_TIME not work for rigid parts
- Fix incorrect results when using *DEFINE_CURVE_FUNCTION with AX/AY/AZ for *LOAD_SEGMENT
- *MAT_ADD_PORE_AIR: fix an MPP bug triggered when input format is long=s
- Fix problem of solution hanging when using *MAT_024_STOCHASTIC and *DEFINE_HAZ_PROPERTIES (MPP)
- Fixed the use of *MAT_ADD_DAMAGE_DIEM with *MAT_024 and tetrahedral element formulation 13
- Fixes for GISSMO damage when used together with an equation-of-state (*EOS)
- Fix problem using *MAT_258 and *DAMPING_PART_STIFFNESS together with RYLEN=2 in *CONTROL_ENERGY
- *PART_DUPLICATE: Fix a bug in which 10-noded tet elements were not duplicated
- Fixed bug in reading long format if *KEYWORD long=yes is used in include file
- …

Conclusion: LS-DYNA R12.0.0

- Newest release contains variety of new features
- Comprehensive list of enhancements and corrections in https://www.dynasupport.com/news/ls-dyna-r12-0-0-r12-148978-released
- R12 Keyword User‘s Manual can be downloaded from www.dynamore.de/en/downloads/manuals
- More information in papers of last Conference https://www.dynalook.com/conferences/16th-international-ls-dyna-conference