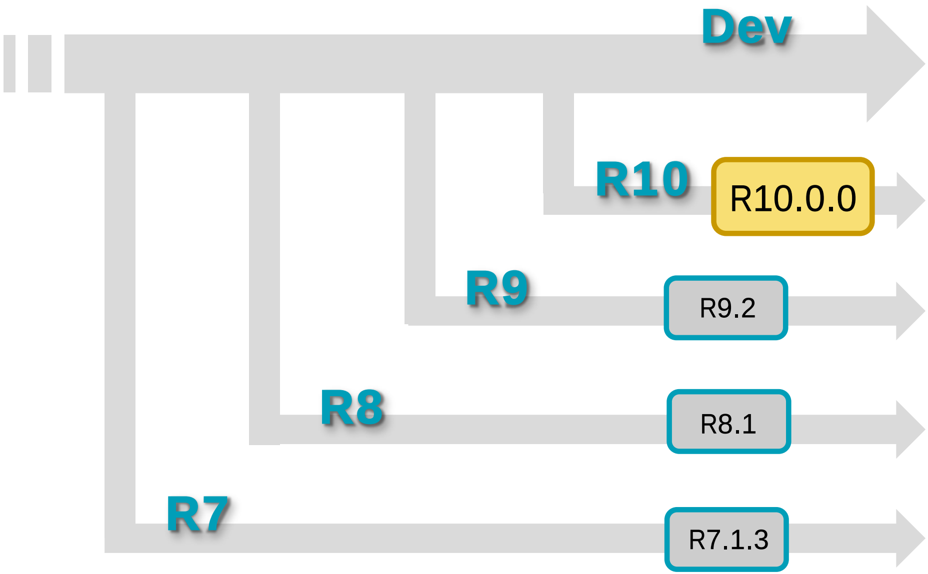
New Features in LS-DYNA R10.0.0

LSTC & DYNAmore, October 2017

LS-DYNA Versions

- Version numbering scheme
  - Major branches called R6, R7, R8, R9, R10 ...
  - Official releases such as R6.1.2, R7.1.3, R9.2.0
- Robust release
  - Release R9.2 from summer 2017
  - Recommended production version
- Latest official versions
  - Release R8.1 from February 2016
  - Release R9.2 from September 2017
  - Release R10.0.0 from September 2017: New features shown in this presentation



Introduction

- R10.0.0 Released September 2017
  - Main Focus
- Presentation by Topic
  - Classical Lagrangian FE
    - Contact
    - Elements
    - Materials
      - Presentation by David Koch
    - Implicit
      - Presentation by Anders Jonsson
- Multiphysics omitted
  - ICFD/CESE
    - Presentation by Marcus Timgren
  - EM
  - SPH/SPG/DEM/Particles
    - Presentation by Jimmy Forsberg and Daniel Hilding
  - Forming and Thermal
    - Presentation by Mikael Schill

Contact

SRNDE on *CONTACT

SRNDE=0 SRNDE=1 SRNDE=2

- By default, edges on shells are extended by a cylindrical shape with a radius corresponding to the thickness of the shell
- For SRNDE=1, spurious initial penetrations due to automated meshing of cad geometries is avoided by not extending it beyond the actual geometry of the shell
- For SRNDE=2, a more realistic geometry representation is provided for cases where small penetration detection are of significant importance

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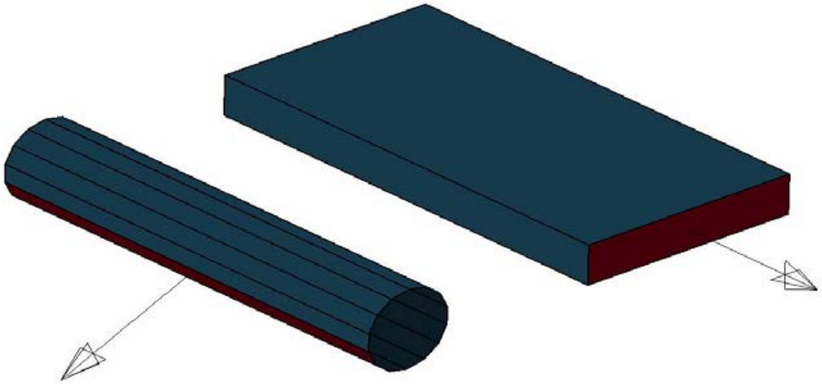
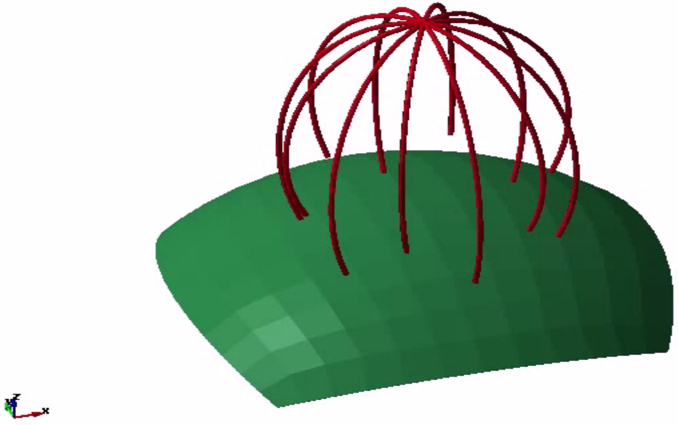
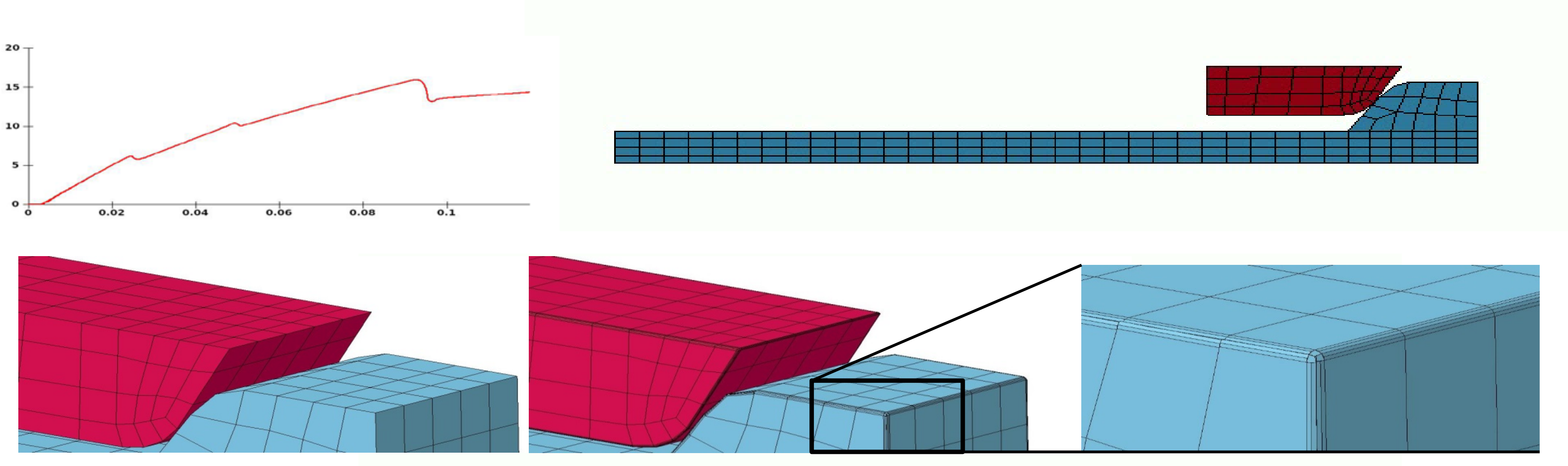
Mortar Contact Edge Treatments – Shells and Beams





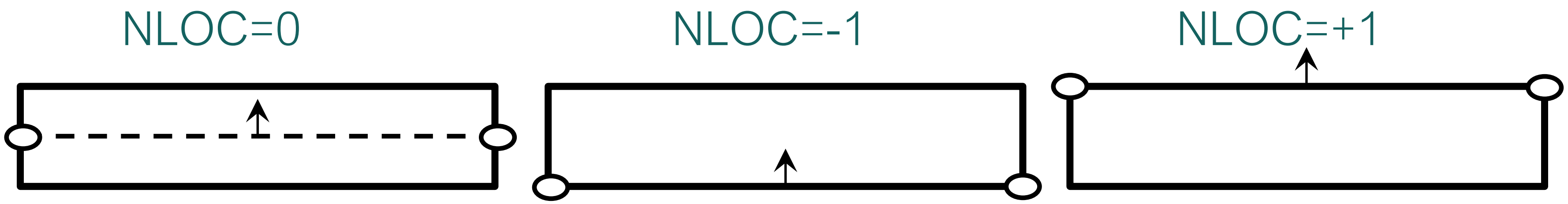
- SRNDE=2 mandatory, shell edges are
  flat and presumably consistent with geometry
- Beam lateral surfaces are discretized into segments
- In R10 any free end point is treated as a flat surface

Mortar Contact Edge Treatments - Solids



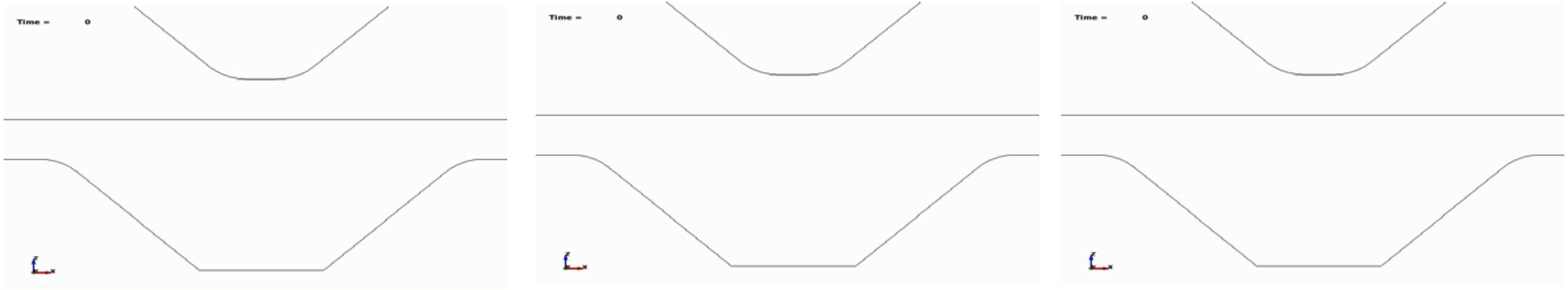
- Mortar Contact creates internal contact segments to deal with edges
- In R10, high order solids are supported

CNTCO on *CONTROL_SHELL



- Using NLOC on *SECTION_SHELL and CNTCO will provide a contact treatment that is consistent with the geometry of the shell elements
  - Support and fixes for many contacts, Mortar Contact will automatically apply CNTCO
- For the node to surface contact treatment, contact nodes are moved half the thickness in normal direction to the physical mid surface of the shell, followed by a double sided contact treatment
  - Sensitive to curved geometries and large thickness to mesh size ratios

CNTCO on *CONTROL_SHELL



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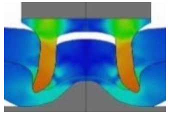
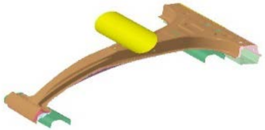
Mortar Contact – Explicit Analysis

- A nonzero bucket sort frequency implemented in R10
- Mortar Contact will never be as fast as the traditional SOFT contacts
  - Goal is to not fall too far behind and provide a decent alternative in those cases when called for



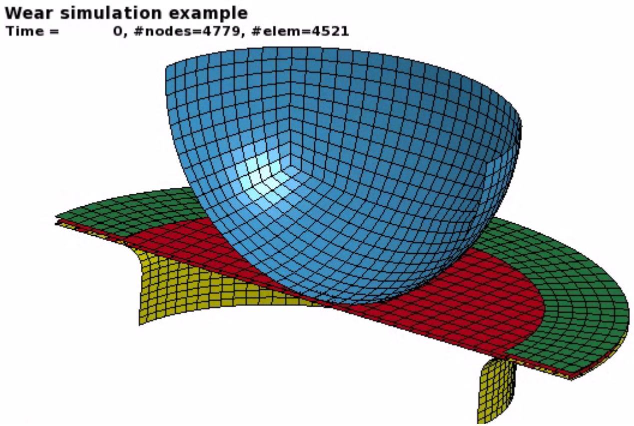


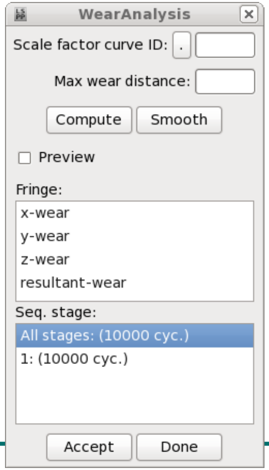
Problem	SOFT=0		SOFT=2		MORTAR	
SPR detachment (24 cores, MPP single)	1.13	2.02	1.00	1.00	1.89	6.27
					2.68	11.38
B-pillar bend (8 cores, MPP single)	1.13	1.47	1.00	1.00	2.32	10.03
					7.48	45.76

R10 total time | R10 contact time | R9 total time | R9 contact time

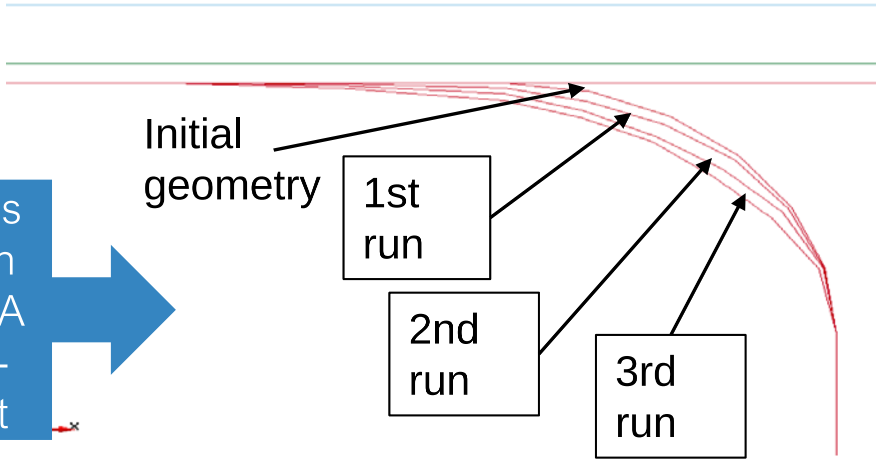
Wear Processes

- *CONTACT_ADD_WEAR
  - Archard and User wear laws
  - Post process wear in LS-PrePost
  - Modify geometry in LS-PrePost
    based on wear, using *INITIAL_CONTACT_WEAR
  - Feature supported in Mortar Contact





Iterations between LS-DYNA and LS-PrePost



Pressure Tube

- Models pressure waves in gas filled tube
  - tubular beam elements
  - 1D acoustic solver
  - pressure generated by area change
  - area given by contact penetration
  - independent of tube mechanics

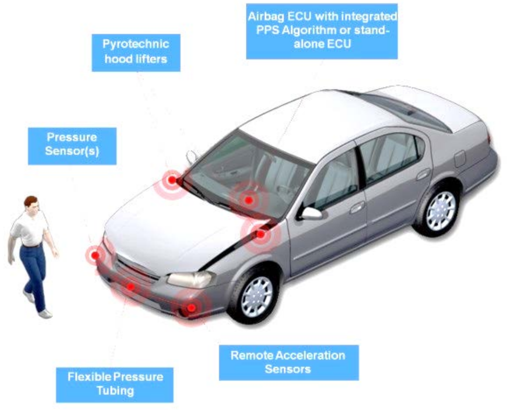
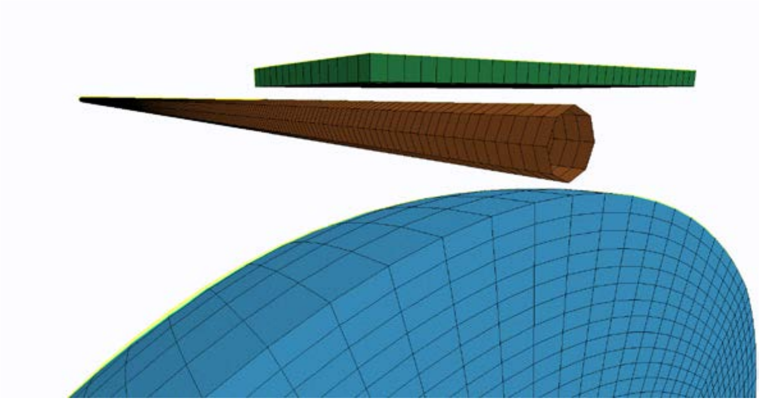
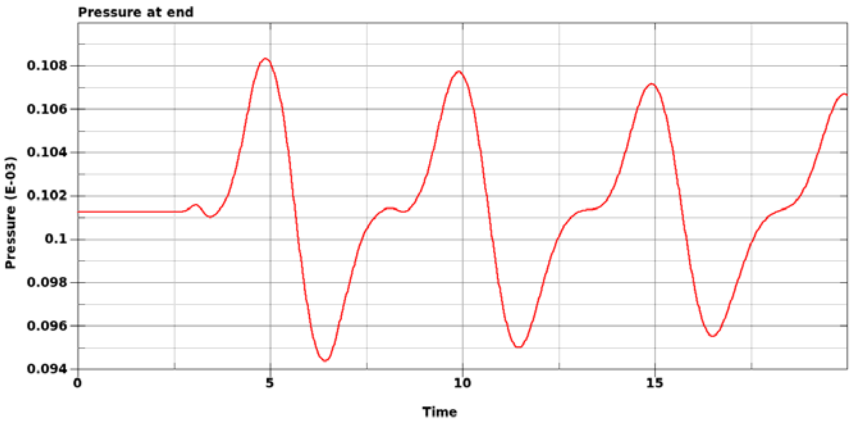


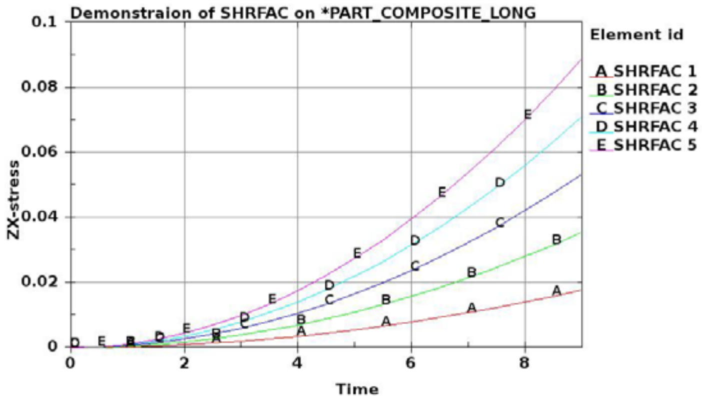
Photo: ZF TRW.





Elements

Thick Shell Enhancements



- Use of thick shells in composite modeling has lead to new developments, in particular the transverse shear treatment is affected
  - SHRFAC added as option to *PART_COMPOSITE_..._LONG to provide a general transverse shear stiffness profile
    - TSHEAR=1 (constant stress profile) fixed in the process
  - Enable recalculation of shear stiffness based on a yielding of individual integration points, yielding in one layer will result in lower elastic stiffness in others due to a coupling effect
    - Applies to materials 3, 18, 24, 123 and 165

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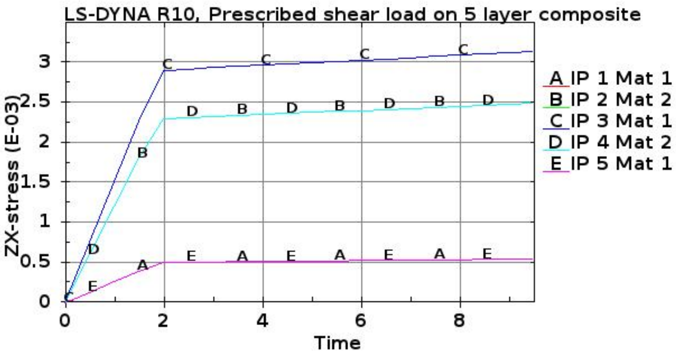

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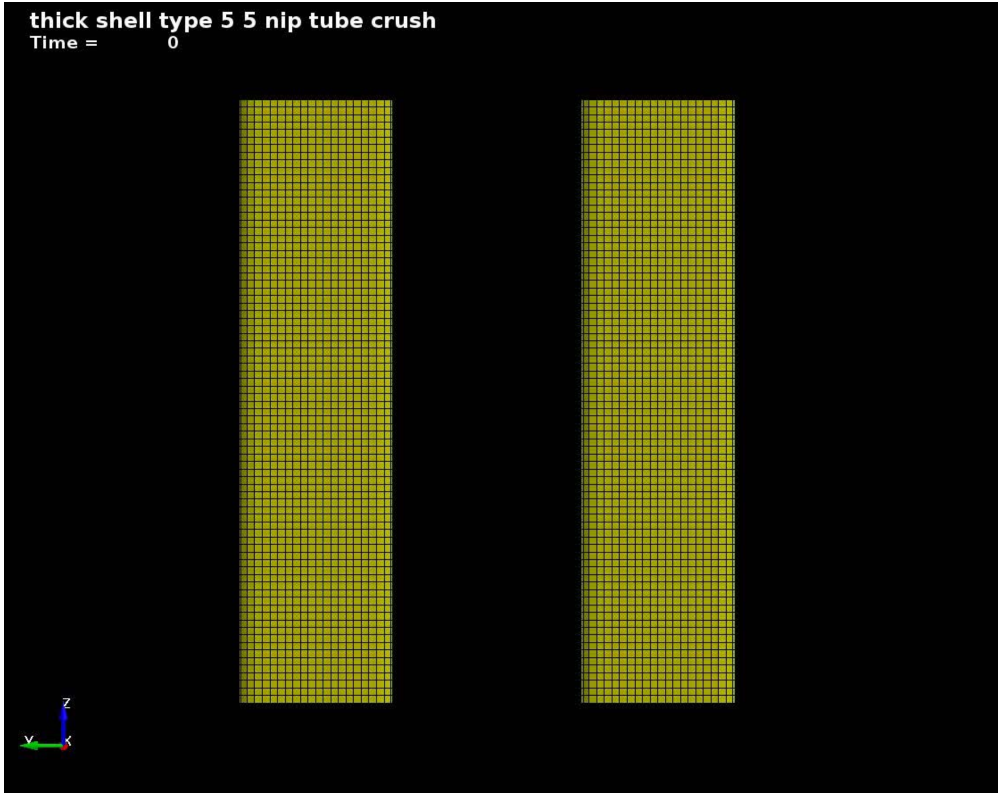
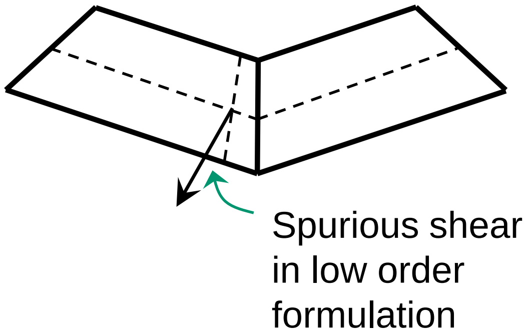
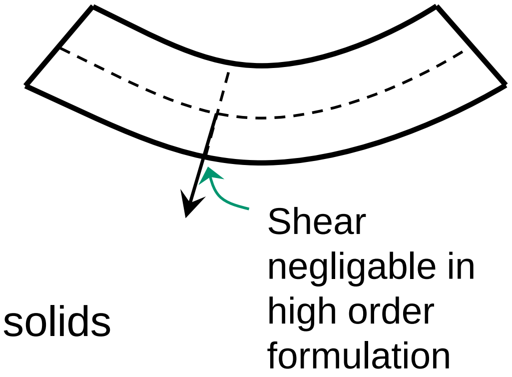
Thick Shell Tube Buckling – R9 vs R10

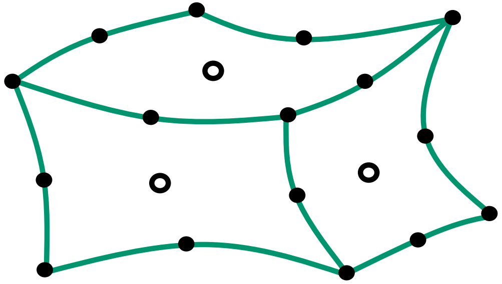


High Order Solids

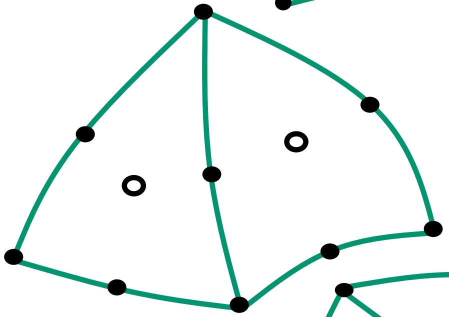




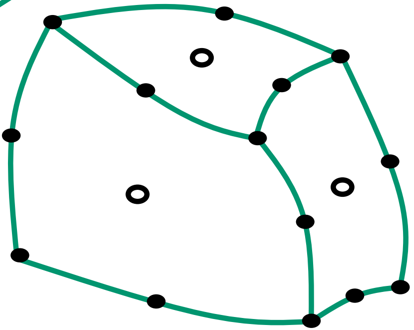
Solid Element 23/24



Solid Element 16/26



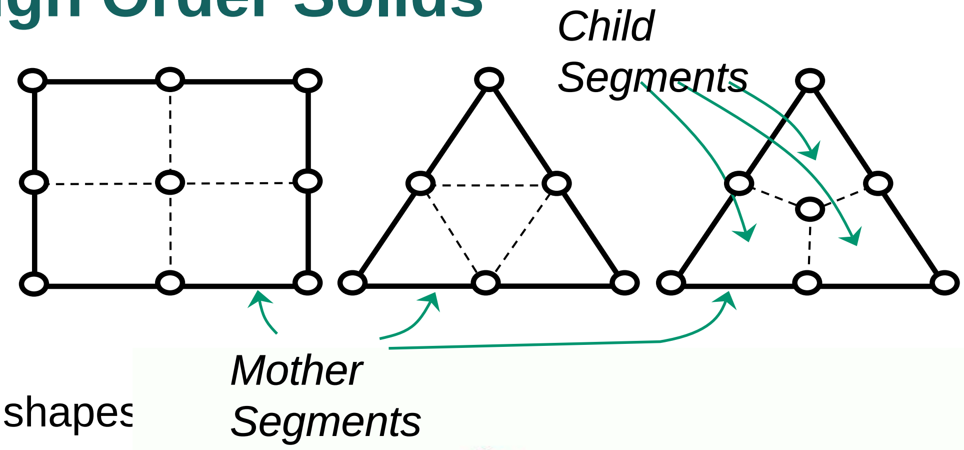
Solid Element ?/25

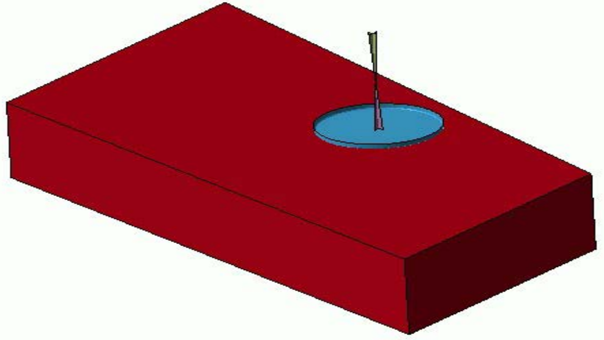


- 20-noded and 27-noded solids available before R10
- Element recoded to increase speed (explicit)
- Consistent mass matrix implemented (implicit)
- Automatically apply boundary conditions for H8TOH27 option
- *SET_NODE_GENERAL supported for high order solids

Contact in High Order Solids

- Segment based contact supported with 27-noded solids
- Mortar Contact supported with 27-noded solids
  - Kinematics performed on child-segments, assuming linear or bilinear shapes
  - Kinetics assumes quadratic shape functions, pressure is assembled to all nodes consistently to mother segment
  - Accurate for reasonably flat surfaces
  - Will not capture the curvature of cylindrical axes, etc.





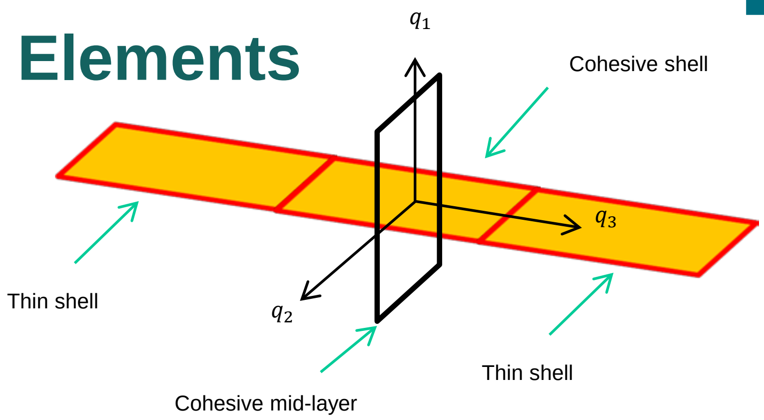
Cohesive Solid Elements

- ELFORM=19-22 on *SECTION_SOLID
  - Used for planar connections such as adhesives, composite interlayers, etc.

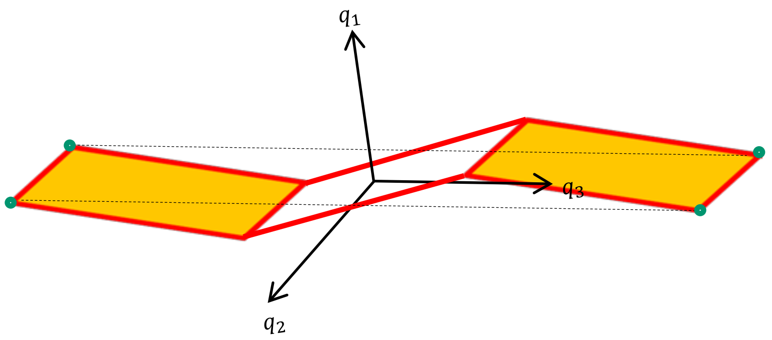
- New in R10
  - Increase accuracy of ELFORM=19 and 21 by using double precision for local coordinates and other internal variables (also ported back to R9.2)
  - Alternative mass calculation for critical time step estimate of cohesive elements to improve their robustness, defined via ICOH on *CONTROL_SOLID
  - *MAT_ADD_COHESIVE now works in implicit analysis
  - *MAT_USER_DEFINED_MATERIAL_MODELS for cohesive elements (umatXXc) can now be used in implicit analysis and a few more input variables are provided: temperature, element size, implicit rejection flag, integration point identifier, and total number of integration points

Cohesive Shell Elements

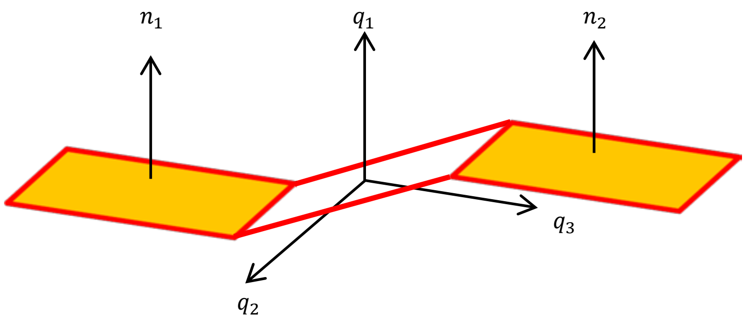
- New mid-layer coordinate system ELFORM=-29 (suitable for pure shear)
- MAT_240 now supports ELFORM=+/-29
- Fixed absence of part mass in d3hsp



ELFORM=+29 (q_3 from nodes)



ELFORM=-29 (q_1 from normals)



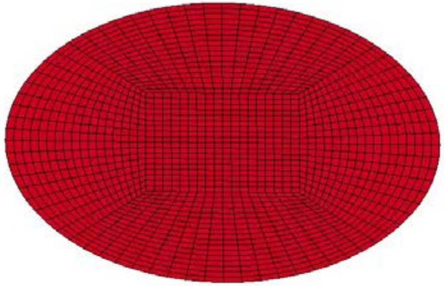
Materials

Generalized damage model

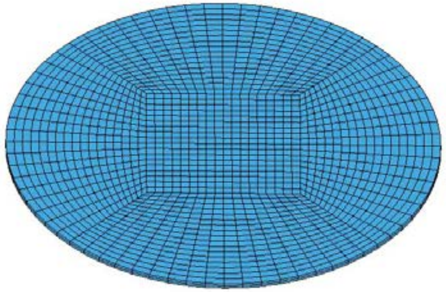
- *MAT_ADD_GENERALIZED_DAMAGE (MAGD)
  - General damage model as add-on for other material models
  - Intention: non-isotropic damage
  - Up to 3 history variables as damage driving quantities
  - Very flexible due to input via *DEFINE_FUNCTIONs

$$
\begin{bmatrix} \sigma_{11} \\ \sigma_{22} \\ 0 \\ \sigma_{12} \\ \sigma_{23} \\ \sigma_{31} \end{bmatrix} = \begin{bmatrix} D_{11} & D_{12} & 0 & D_{14} & 0 & 0 \\ D_{21} & D_{22} & 0 & D_{24} & 0 & 0 \\ 0 & 0 & D_{33} & 0 & 0 & 0 \\ D_{41} & D_{42} & 0 & D_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & D_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & D_{66} \end{bmatrix} \begin{bmatrix} \tilde{\sigma}_{11} \\ \tilde{\sigma}_{22} \\ 0 \\ \tilde{\sigma}_{12} \\ \tilde{\sigma}_{23} \\ \tilde{\sigma}_{31} \end{bmatrix}
$$

- New in R10
  - Support of solid elements (only shells in R9)
  - Option for pre-defined damage tensors (lowers CPU cost)
  - Optional damage limitation curve (as function of triaxiality and Lode parameter)



shell elements
type 16, NIP=5



solid elements
type -1, 2 over thickness

Extended Barlat Model

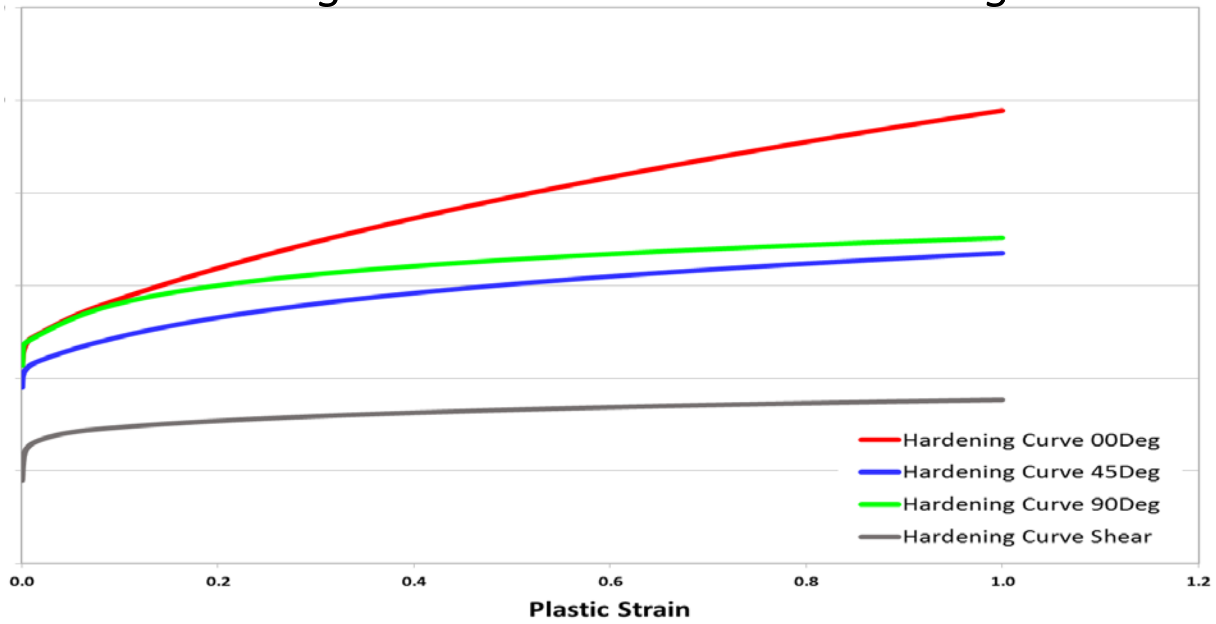
- New *MAT_EXTENDED_3-PARAMETER_BARLAT formulation
  - 10-inputs to define a single material for strength/stiffness:
    - 5 Strain Hardening load curves
    - 5 R-Value load curves (or constants)
  - Novel shear and biaxial R-value definitions
  - Yield surface adapted to fit more input data points, smoother interpolation

- Material testing required
  - Tensile tests in 0,45,90
  - Shear test *(new in R10)*
  - Bi-axial test *(new in R10)*
  - Flow Stress and R-Value Data can be generated from the same test

	σ^0	σ^{45}	σ^{90}	σ^s	σ^{bi}	R0	R45	R90	RSHR	RBIAX
MAT36= HR3	YES	X	X	X	X	YES	YES	YES	X	X
MAT36= HR7	YES	YES	YES	X	X	YES	YES	YES	X	X
Mat36E	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Test Mode	T_0	T_{45}	T_{90}	Shear	Biaxial	T_0	T_{45}	T_{90}	Shear	Biaxial

Material Model Input Parameters

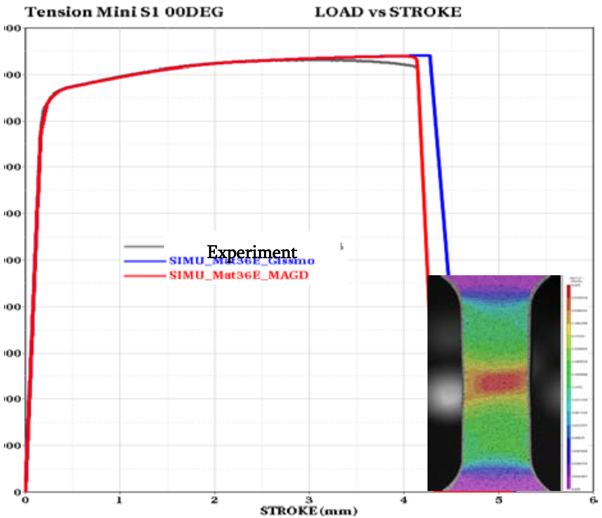
Hardening curves – biaxial taken as 0 degree

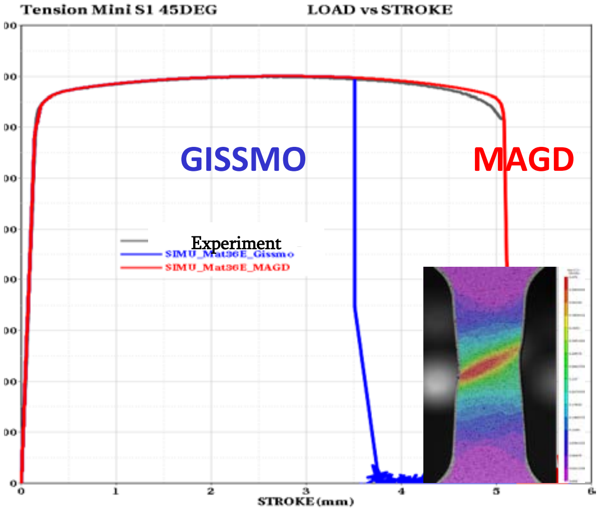


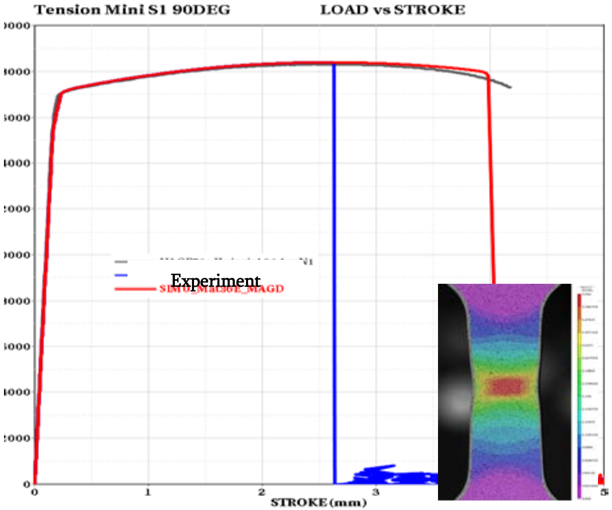
Sample Dir.	0 Degrees	45 Degrees	90 Degrees	Shear	Biaxial*
R - Value	0.47	2.5	1.9	0.92	1.0

Uniaxial Tension

Load vs Stroke in 3 directions
Gissmo vs Magd

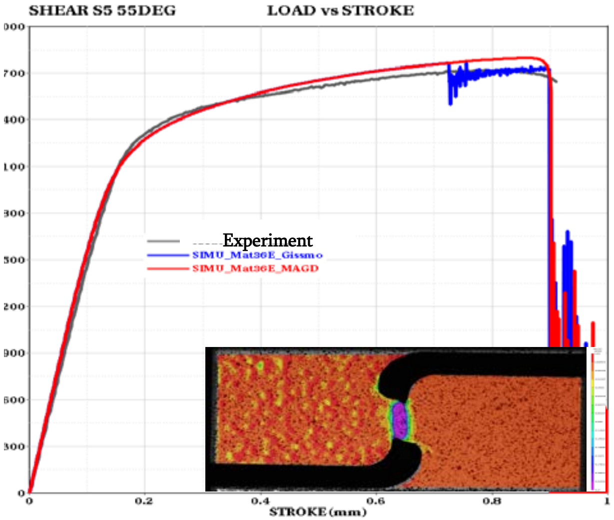


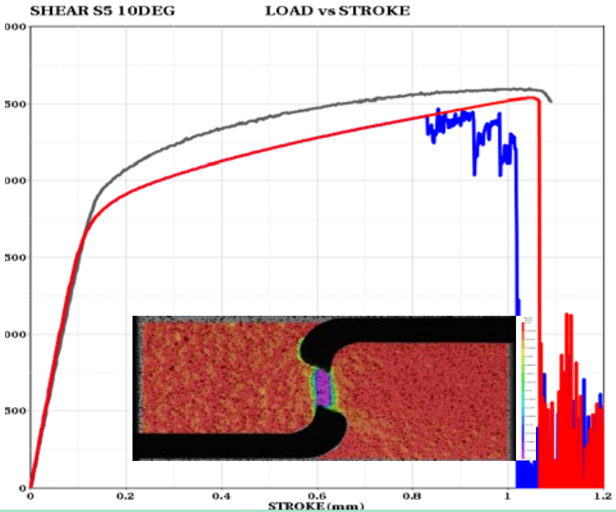




- *Material Tensile Strength can be matched to experiments in all 3-directions (0, 45,90)*
- *Coupling with MAGD helps to match failure also in all 3-directions*

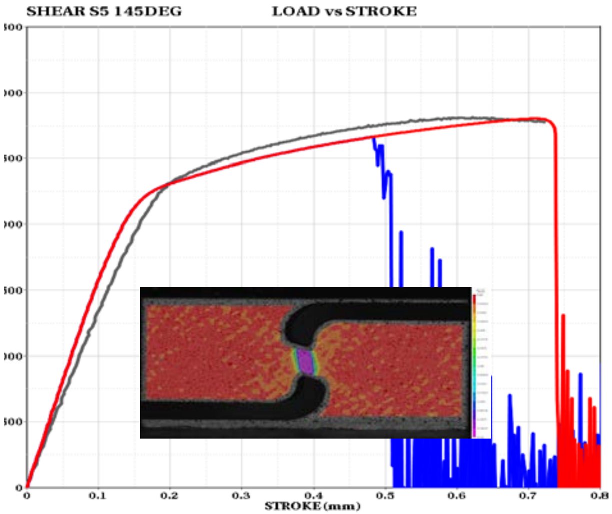
Mini Shear Specimen





Load vs Stroke in 3 directions

Gissmo vs Magd



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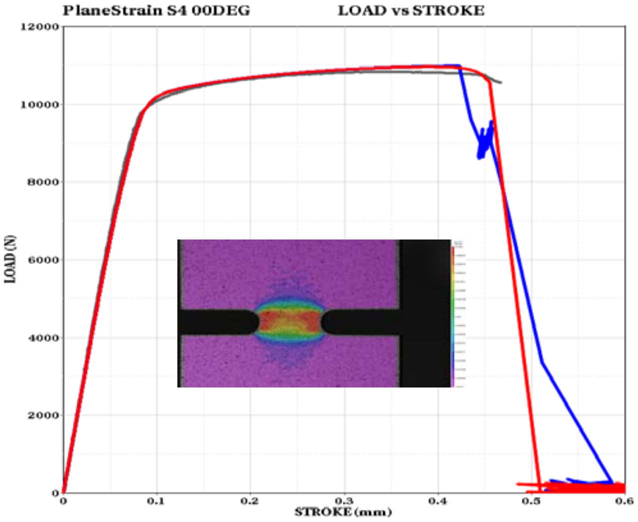
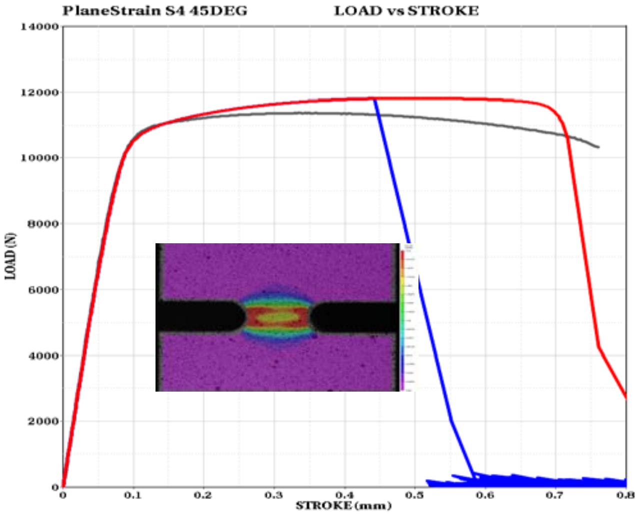
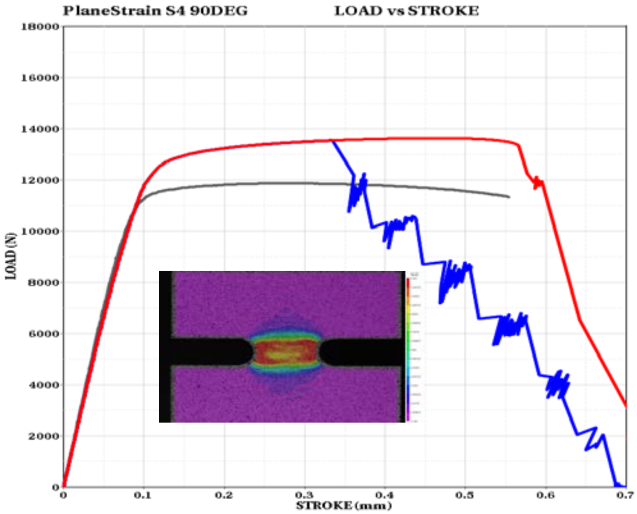
- *Coupling with MAGD helps to match failure also in all 3-directions*

Plane Strain Specimen



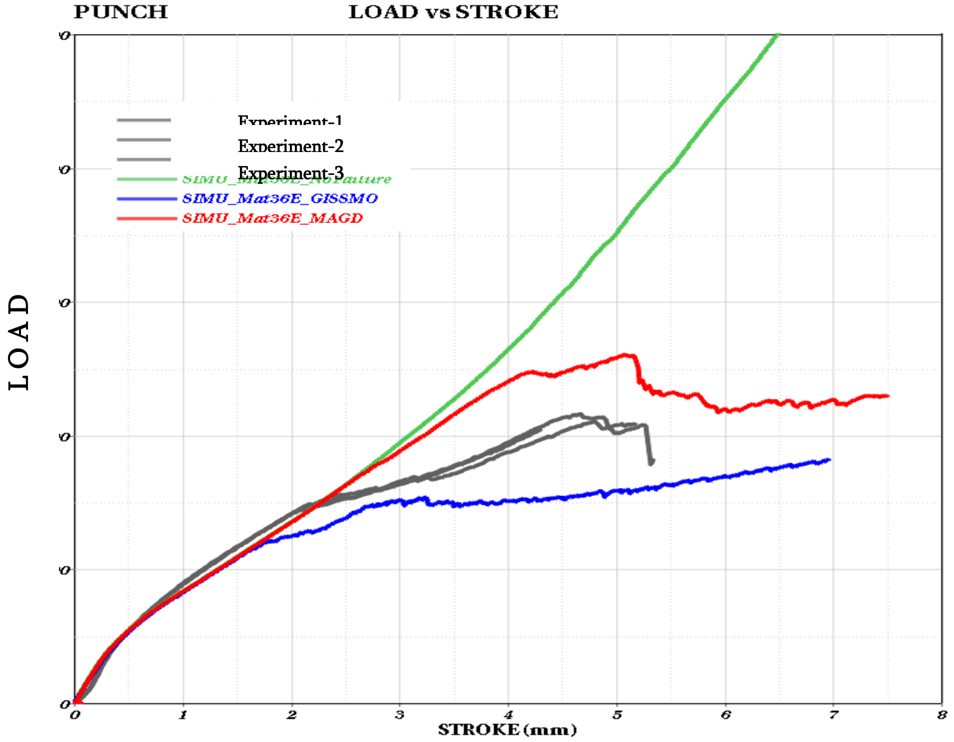




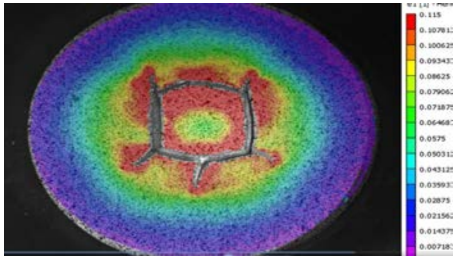
Courtesy of Honda

Biaxial Punch Test

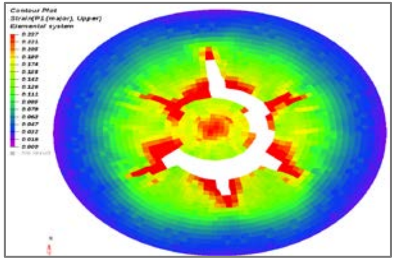
Load vs Stroke / Gissmo vs Magd



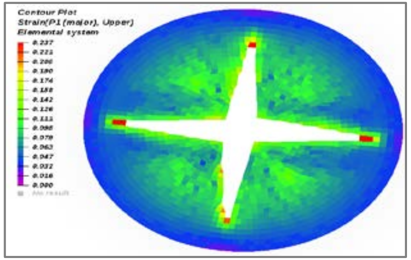
TEST



MAGD



Gissmo



Courtesy of Honda

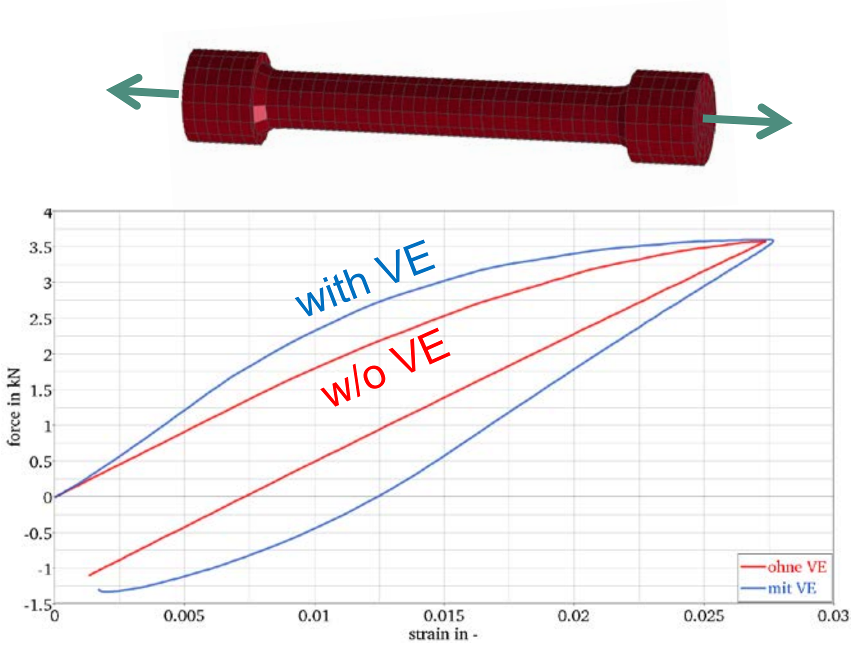
SAMP for Polymers

- *MAT_SAMP-1
  - Semi-Analytical Model for Polymers
  - Uses an isotropic C-1 smooth yield surface

- New in R10
  - Further speed-up of algorithm
  - Viscoelastic option allows definition of rate-dependent Young's modulus

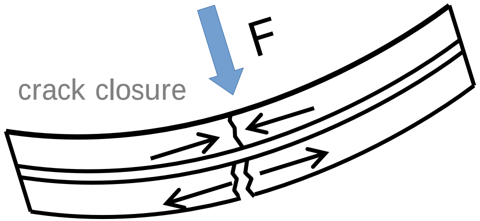
$$\dot{\sigma}(t) = -\beta \cdot \sigma(t) + E(\dot{\varepsilon}(t)) \cdot \dot{\varepsilon}(t)$$

  - Presented by Paul Du Bois in Salzburg 2017



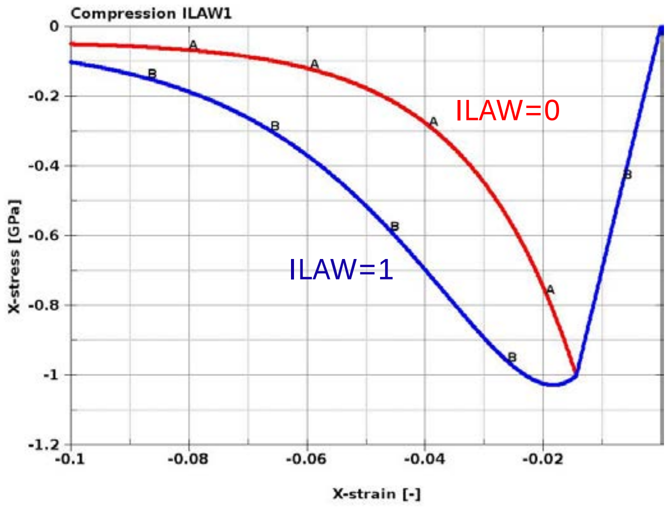
Glass

- *MAT_GLASS (*MAT_280)
  - Brittle smeared fixed crack model for shell elements (plane stress), added in version R9



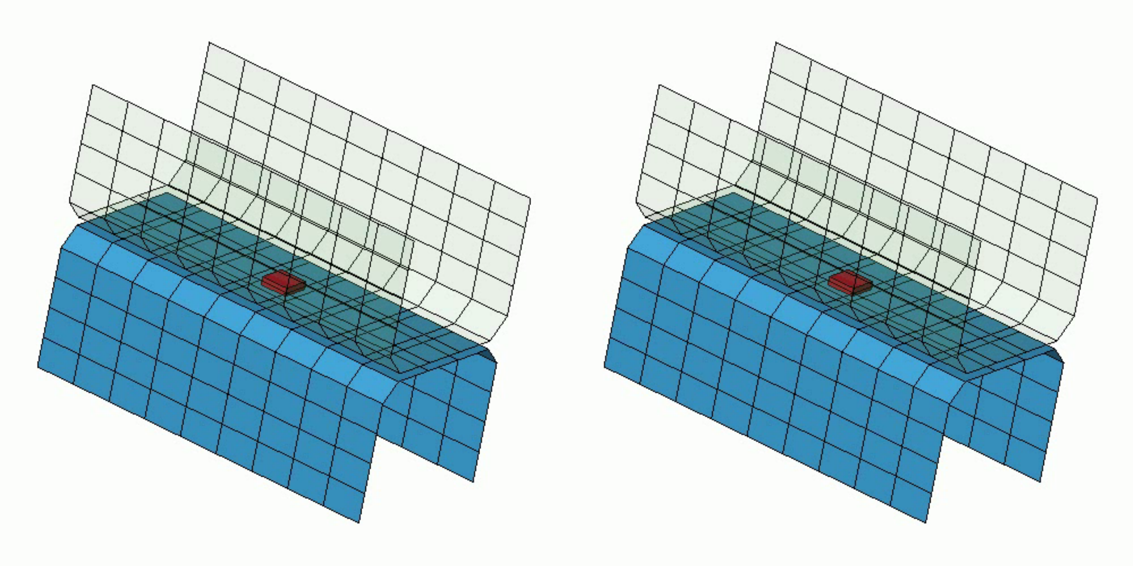
- New in R10
  - Optional damage model for stress and stiffness softening
  - Possible distinction between tensile and compressive damage
  - Might be preferrable for compression dominated problems

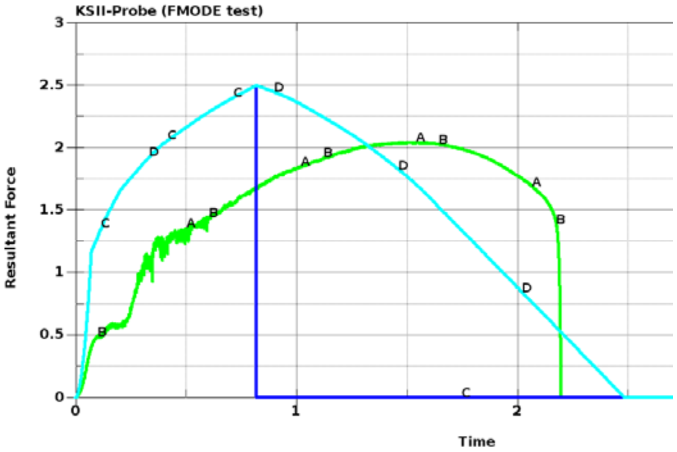
Stress-strain behavior for compressive loading and IMOD=1 (damage)



Spotwelds

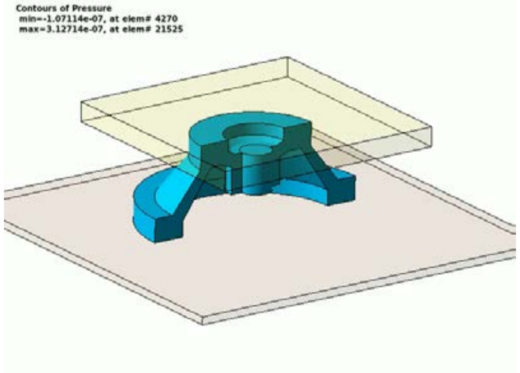
- FMODE available for DMGOPT=10,11,12
  - Allows ductile or brittle shear failure by way of initiating damage
- Damage initiated by the failure option only if EFAIL=0

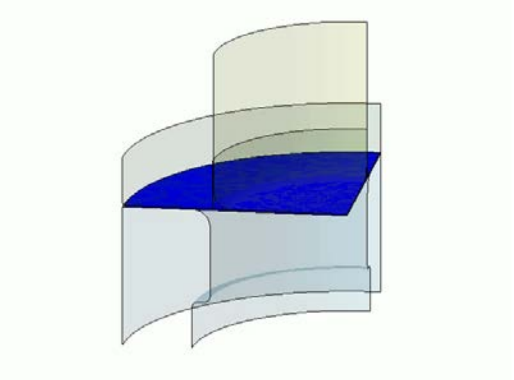




Implicit

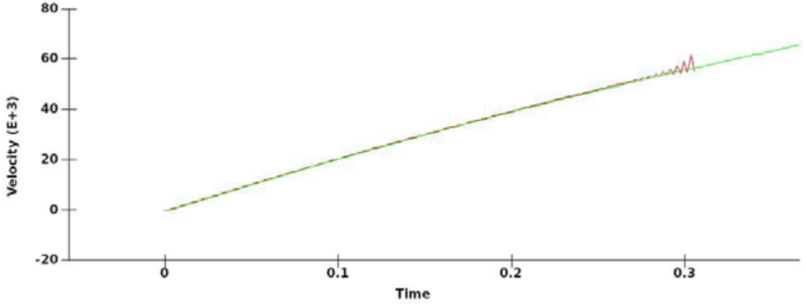
Rigid Bodies with Prescribed Motion



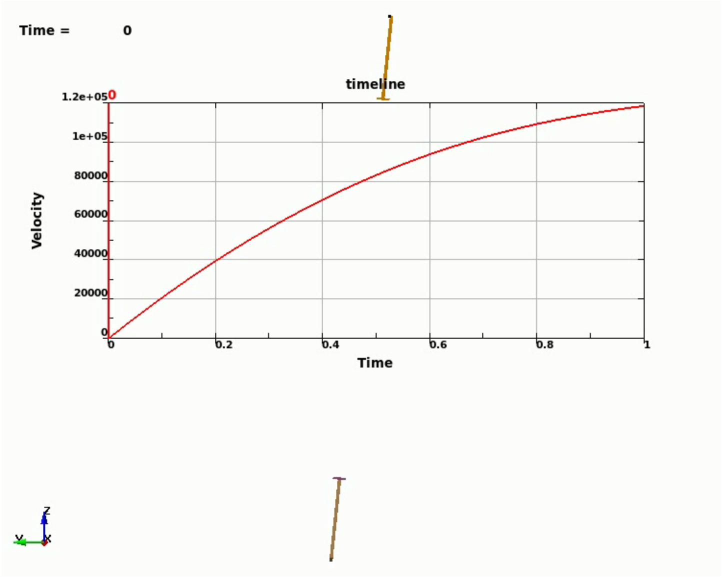


- Enforcing the motion of a rigid body into a stress free deformable structure provides a problem
  - Line search convergence based on relative measures breaks down when the initial values are exactly zero (or close thereto), and the forces from the initial contact are significant
  - As a result, the simulation never gets off the ground, the implicit solver simply does not allow the body to go in contact, and if it does then this is credited to luck and coincidence rather than anything else
- As of R10, prescribed motion on rigid bodies induce a fictitious force that properly resolves this issue

HHT Time Integration



Newmark breaks down at 30% into the simulation



- Newmark Time Integration is unstable for large or fast rotational motion
  - Bathe 3-point integration was introduced in R9
- ALPHA<0 on *CONTROL_IMPLICIT_DYNAMICS activates HHT (Hughes-Hilbert-Taylor) method
  - Stabilizes the overall scheme

Strict Tolerance Option for Increased Accuracy

- Currently, DCTOL is the main important tolerance parameter for nonlinear implicit
  - Convergence is based on relative reduction of Euclidian norm of displacement vector
  - Default values will in most situations provide good results
- Experienced users with demand for high accuracy is benifitted from a more flexible input
  - DCTOL, RCTOL and ABSTOL can be used to tighten the tolerances
- Maximum tolerances introduced as a mean to explicitly control the accuracy
  - DMTOL, EMTOL and RMTOL are relative measures in max norm
  - NTTOL, RTTOL, NRTOL and RRTOL are absolute measures in max norm
- Tolerance settings are found on *CONTROL_IMPLICIT_SOLUTION where DNORM<0 will activate the new ones

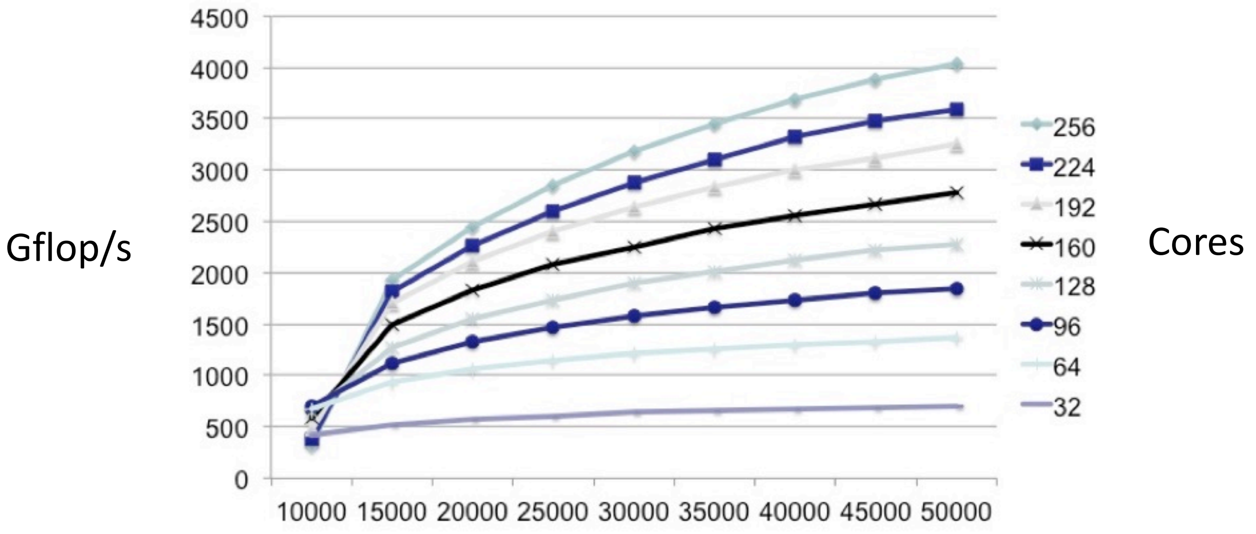
LS-DYNA Implicit Linear Solver

- Solving large sparse linear systems is the bottleneck for implicit calculations
  - Multifrontal method is the default as it is robust and reliable
  - Super linear growth in operations dominates overall run time
  - Super linear growth in storage creates the peak memory requirement

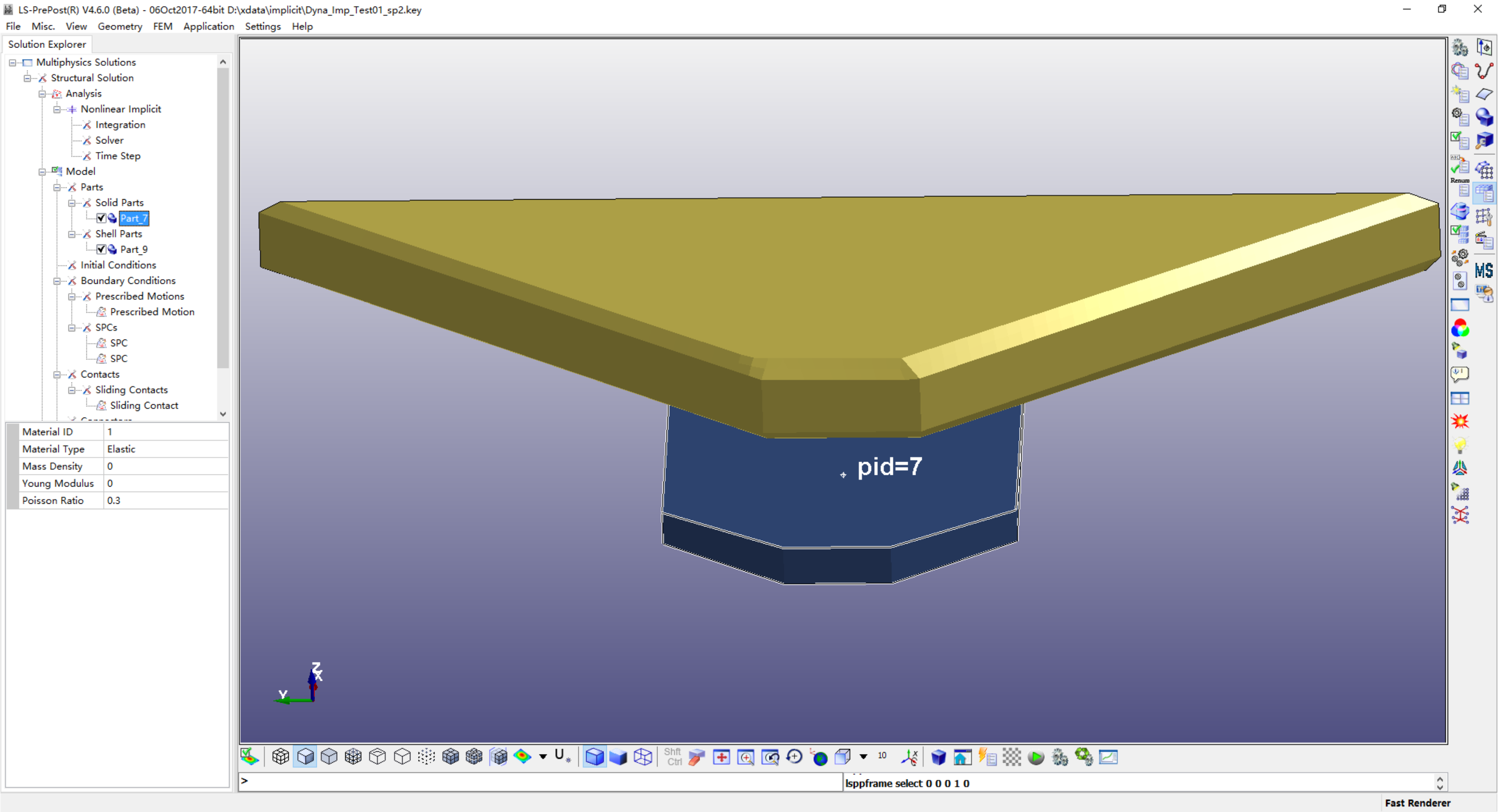
- LSTC is responding to this challenge in two ways
  - Increasing scalability to enable thousands for cores to be brought to bear
  - Research into reducing the storage and operations required

LS-DYNA Implicit Linear Solver

- New scalable arithmetic kernels enable LS-DYNA implicit calculations to exploit the power of thousands of processor cores.



Size of simulated dense frontal matrices, measurements taken on Cray XC40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Solution Explorer
Multiphysics Solutions
Structural Solution
Analysis
Nonlinear Implicit
Integration
Solver
Time Step
Model
Parts
Solid Parts
Part_7
Shell Parts
Part_9
Initial Conditions
Boundary Conditions
Prescribed Motions
Prescribed Motion
SPCs
SPC
SPC
Contacts
Sliding Contacts
Sliding Contact
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