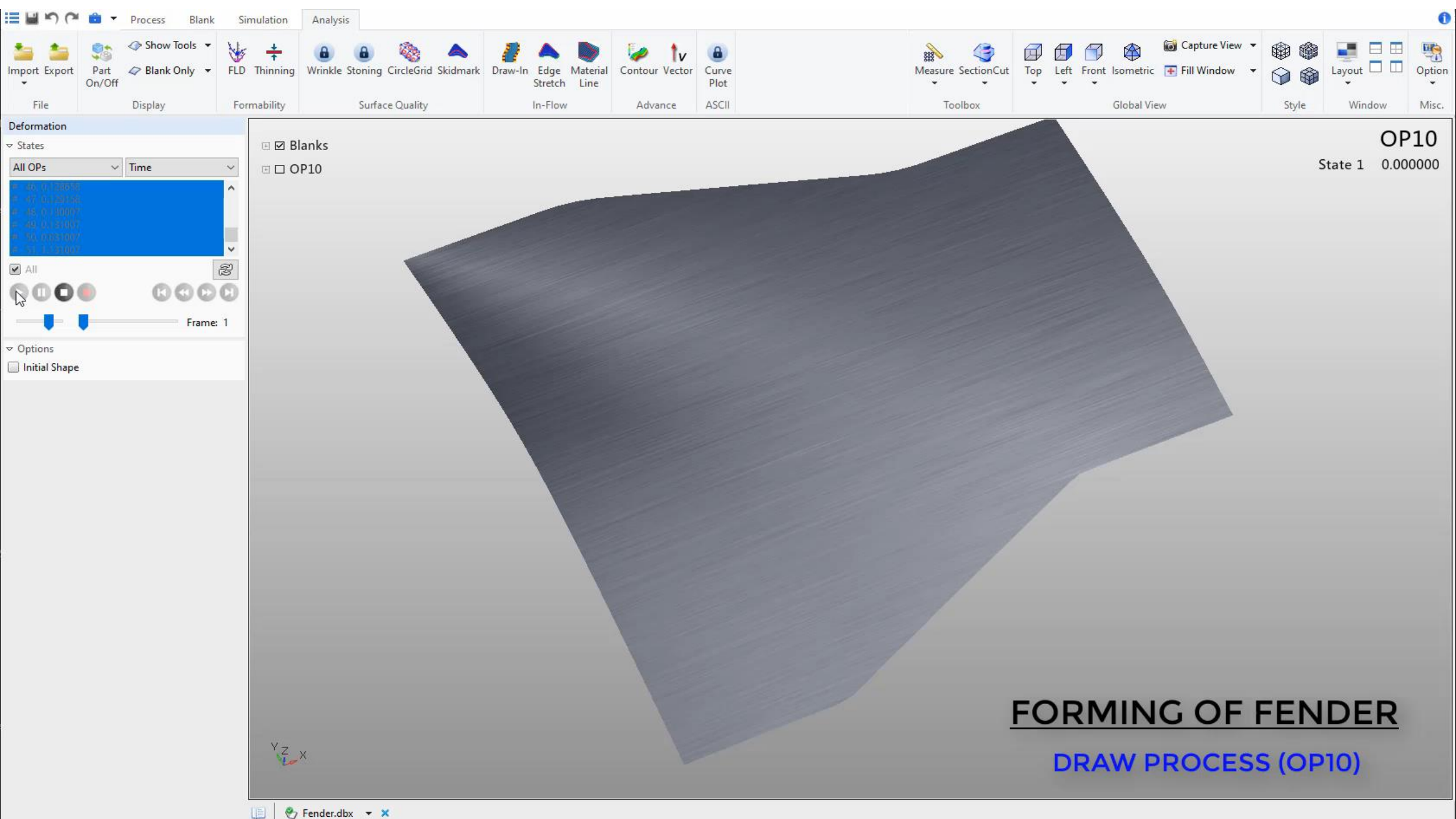
Ansys LS-DYNA新技術線上研討會
LS-DYNA Solver & Contact Enhancement

Agenda:

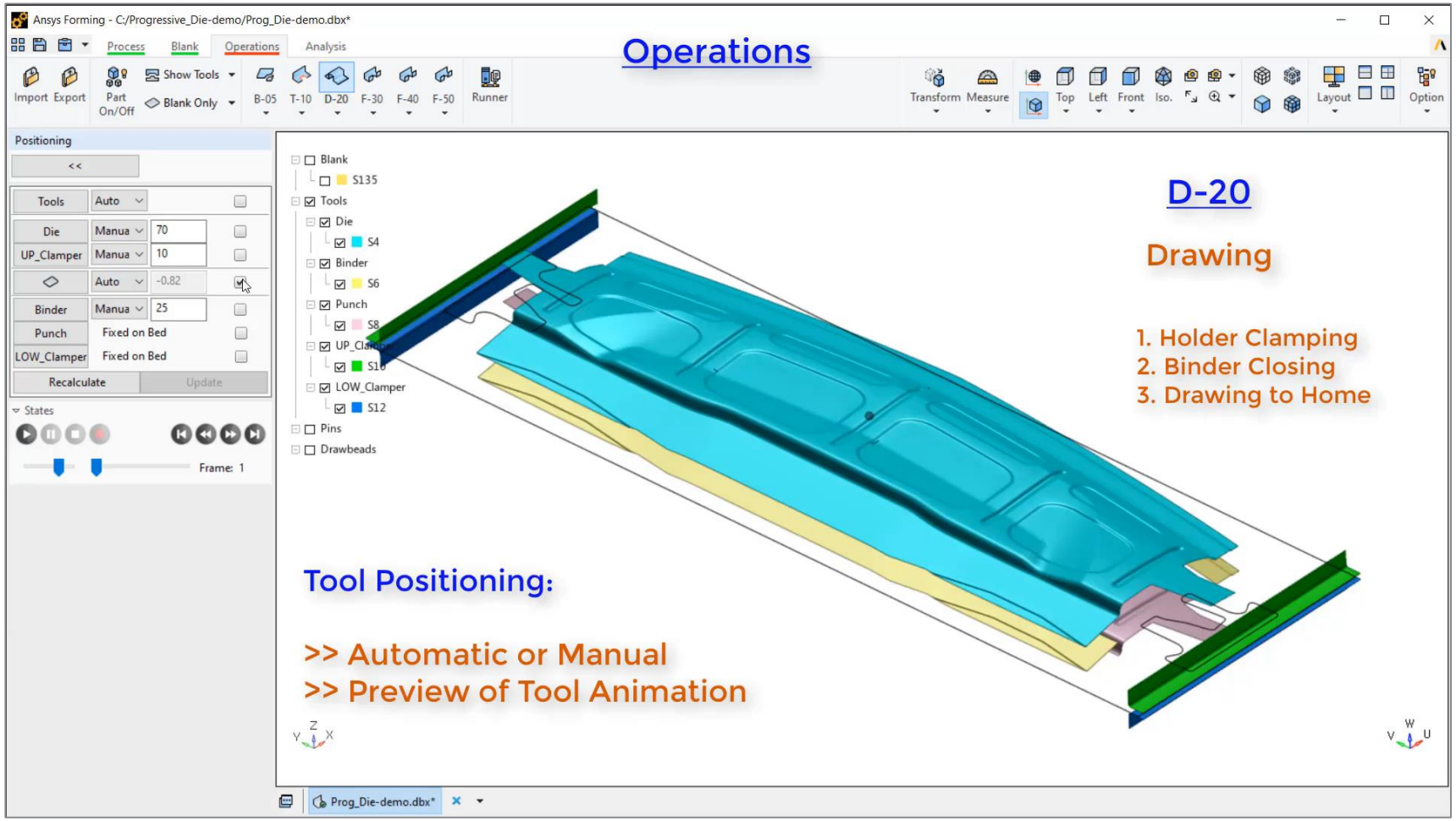
- **Ansys Forming**
- **Ansys Mechanical Integration:**
  - **Foam Material Support** New Material Models have been added in support of foam applications
  - **Cyclic Symmetry Support**
  - **Fluent to LS-DYNA Thermal Transfer(1 way)**
  - **Imported Displacement**
  - **Restart Improvements** Displacements and Remote Displacement can now be modified in a small restart calculation. In addition, initial velocities can be modified for parts in small restarts and full restarts.
  - **Support for Additional Contact Scoping Options**
  - **Additional Properties for Interference Contact**
- **LS-DYNA Solver R13:**
  - Element Enhancements
  - Element Free Galerkin Enhancements
  - Smoothed Particle Galerkin (SPG) Features
  - Materials
  - Contact
  - Electro-magnetics (EM)

Ansys Forming


Process
Blank
Simulation
Analysis
Import
Export
Part On/Off
Show Tools
Blank Only
FLD
Thinning
Wrinkle
Stoning
CircleGrid
Skidmark
Draw-In
Edge Stretch
Material Line
Contour
Vector
Curve Plot
Measure
SectionCut
Top
Left
Front
Isometric
Capture View
Fill Window
Layout
Option
File
Display
Formability
Surface Quality
In-Flow
Advance
ASCII
Toolbox
Global View
Style
Window
Misc.
Deformation
States
All OPs
Time
All
Frame: 1
Options
Initial Shape
Blanks
OP10
OP10
State 1 0.000000
FORMING OF FENDER
DRAW PROCESS (OP10)
Fender.dbx

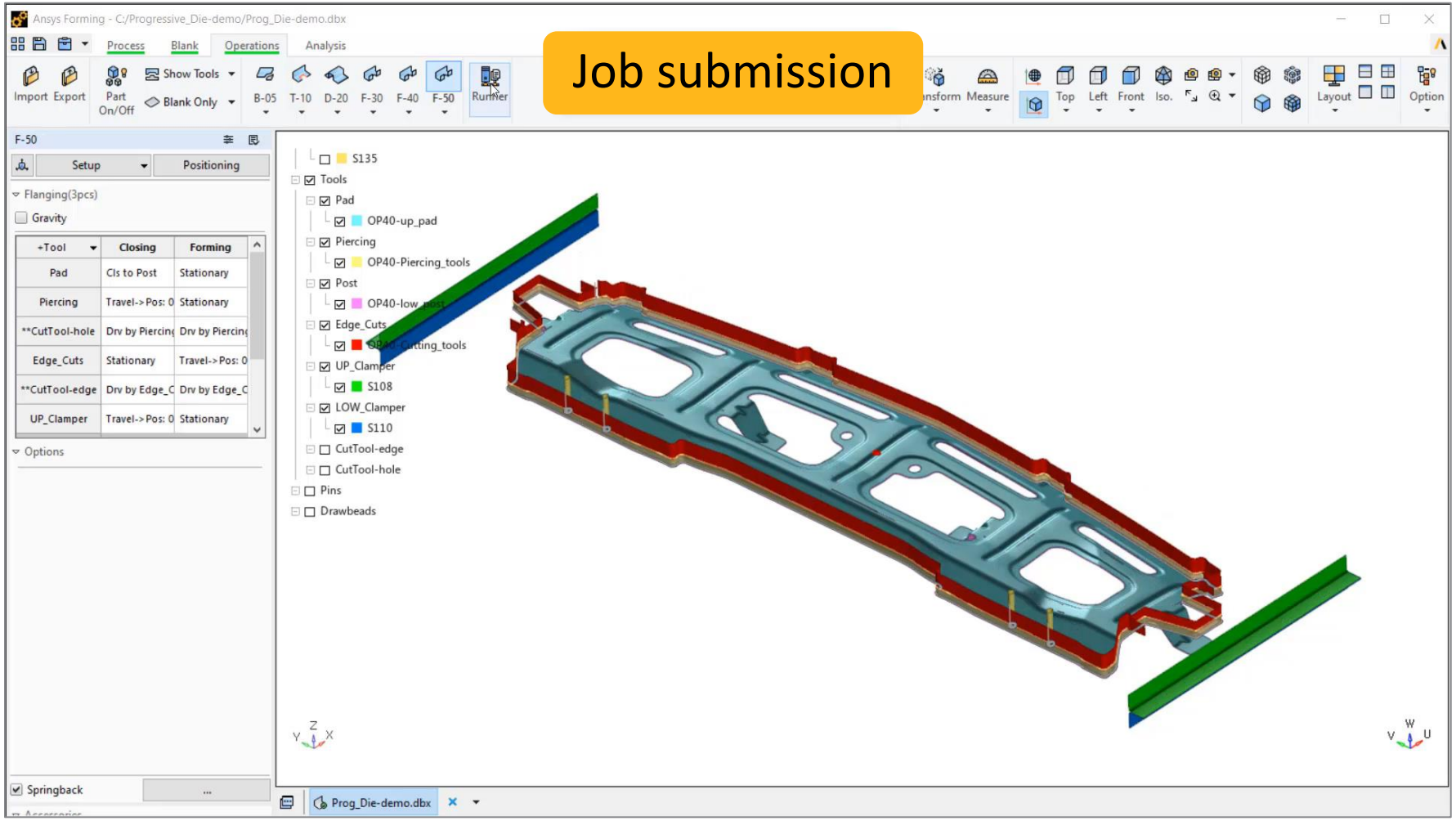
Animated Tool Motion Check

Preview of Tool Animation and Adjustment of Tool Position



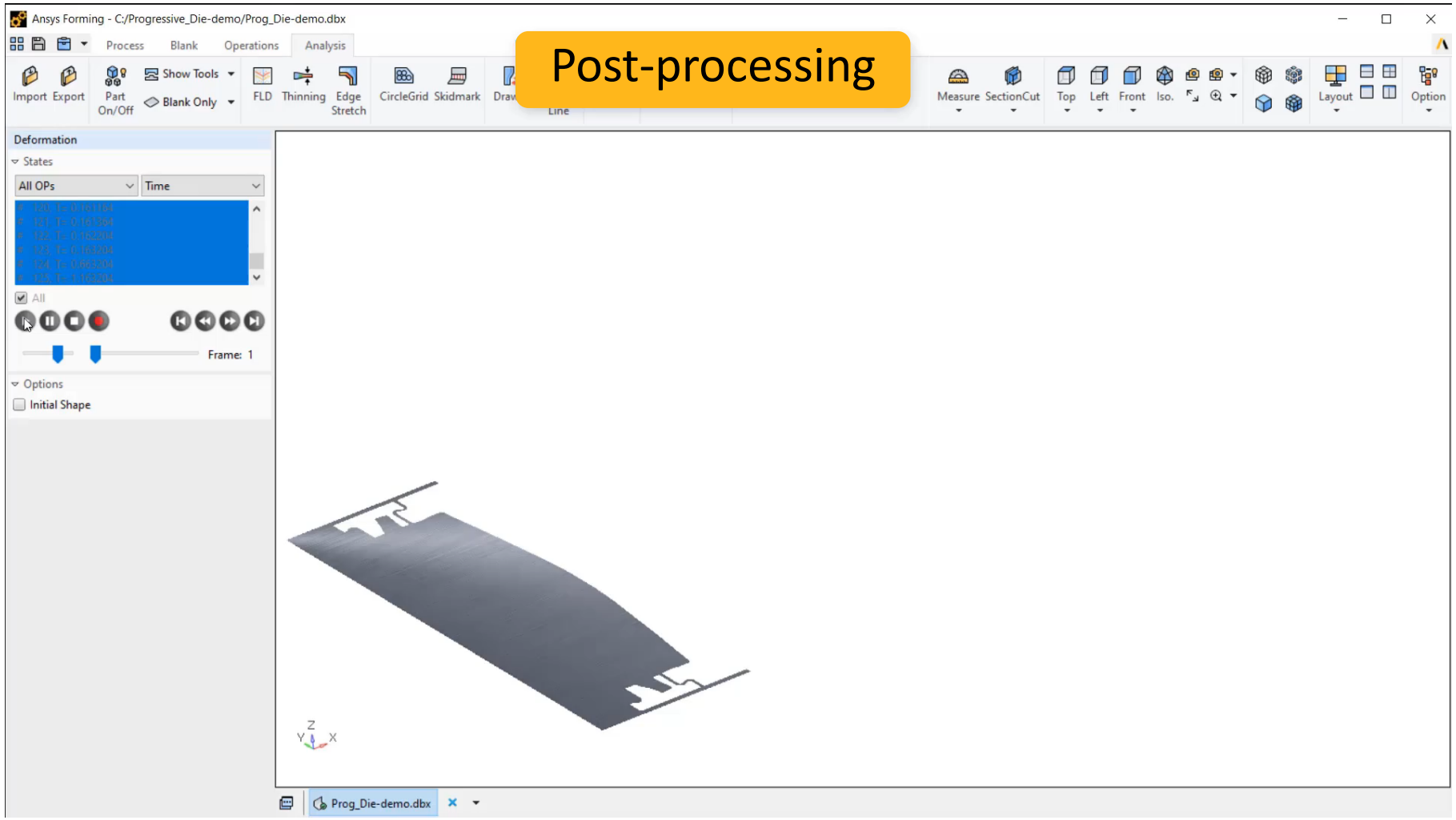
One Click to Submit Multi-stage Job

Auto start sequential jobs stage by stage



Dedicated Forming Post-Processing

- Intuitive GUI
- Special forming modules
- Integrated post-processing of multi-stage jobs
- Easy multiple-window management
- Up-to-date graphic rendering
- High software stability

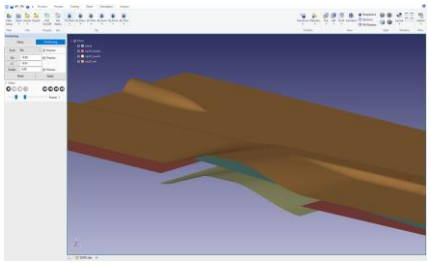


Fully Integrated Platform

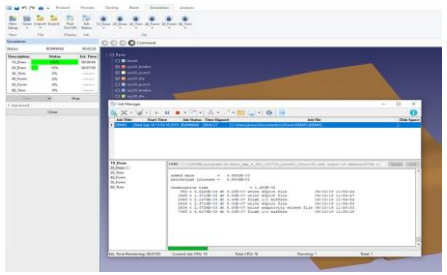
- In 2022 R1 release, Ansys Forming provides a unique platform which has a seamless fully integrated GUI with pre-post processing and uses LS-DYNA as a solver.
- Benefits of Ansys Forming:
  - Easy to setup multi-stage forming simulations
  - Customizable template-based method allows user to easily define different forming processes
  - A job-submitter allows user to run the job easily
  - User can seamlessly evaluate simulation results when the job is running

Pre-Processing → **Job Submission** → **LS-DYNA Solution** → **Post-Processing**

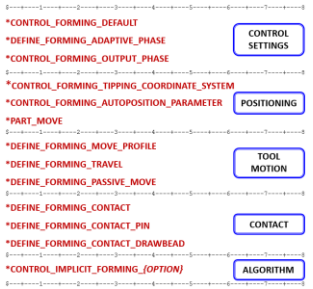
Model Setup



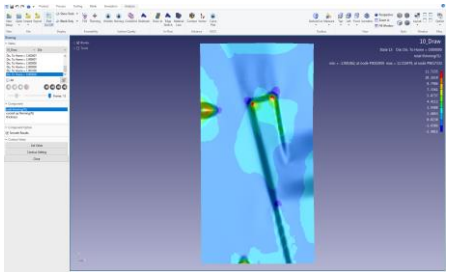
Job Runner



New Forming Keyword Features



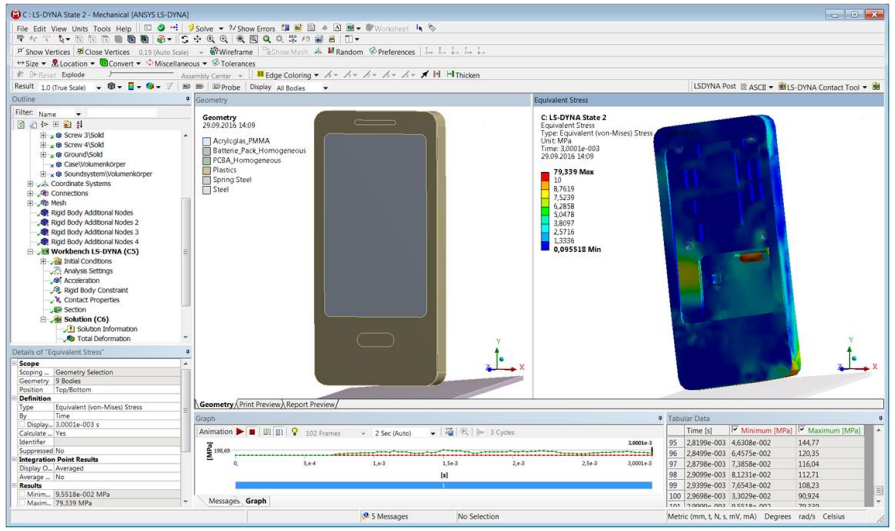
Analysis



模組比較

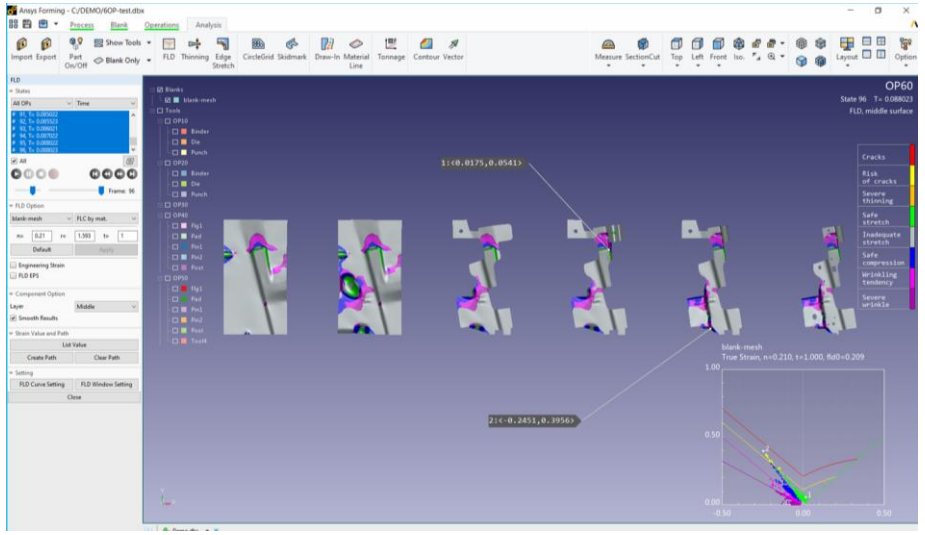
Ansys LS-DYNA

- 泛用型結構動態分析軟體
- 前後處理工具 : Ansys Workbench, LS-Prepost
- 求解器 : LS-DYNA
- 應用範圍 : 落下、衝擊



Ansys Forming

- 專家型鈑金成形分析軟體
- 前後處理工具 : Ansys Forming , LS-Prepost
- 求解器 : LS-DYNA
- 應用範圍 : 板金沖壓成形



LS-DYNA Ansys Mechanical Integration

Enhanced Material Support

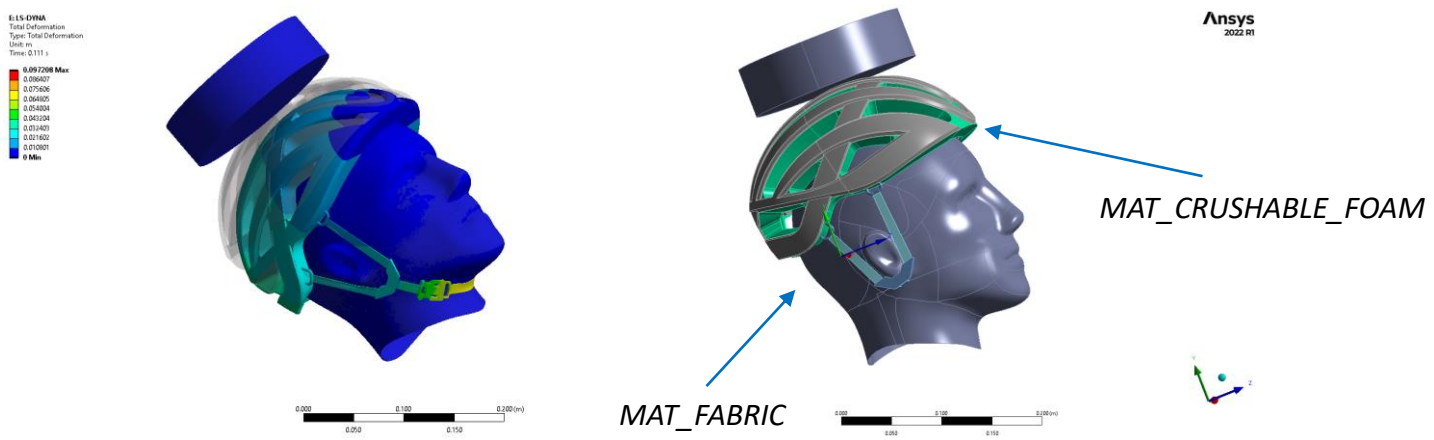
- 4 additional material models have been introduced for applications using Fabric\Foam
- Can be imported to Engineering Data from .k file using External Model
- These definitions generally follow the input card with the variable names added as a suffix

Properties of Outline Row 8: MAT_CRUSHABLE_FOAM

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	70	kg m^-3		
4	Isotropic Elasticity				
5	Derive from	Young's Mod...			
6	Young's Modulus	2.5E+07	Pa		
7	Poisson's Ratio	0.2			
8	Bulk Modulus	1.3889E+07	Pa		
9	Shear Modulus	1.0417E+07	Pa		
10	*MAT_CRUSHABLE_FOAM				
11	Definition				
12	Tensile Stress cutoff, tsc	3.9E+05	Pa		
13	Rate Sensitivity via damping coefficient, damp	0			
14	Yield Stress versus Volumetric Strain, lcid	Tabular			
15	Scale	1			
16	Offset	0	Pa		

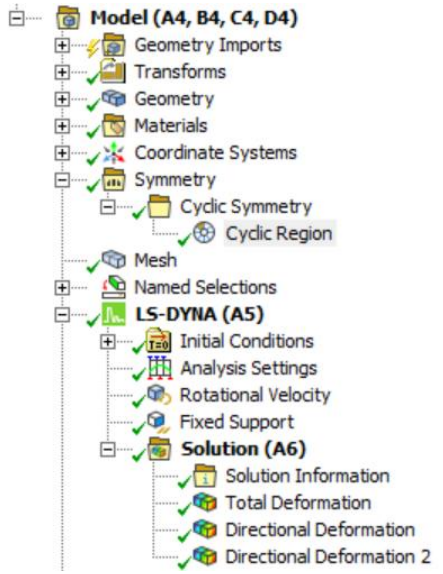
LSDYNA External Model - MAT

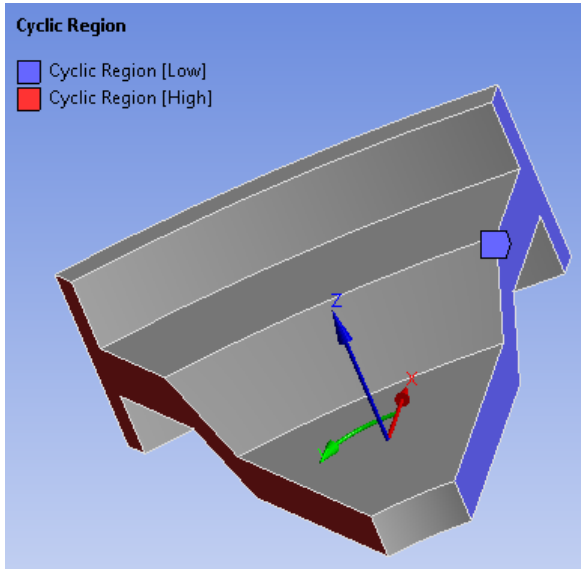
- *MAT_ELASTIC
- *MAT_ORTHOTROPIC_ELASTIC
- *MAT_ANISOTROPIC_ELASTIC
- *MAT_PLASTIC_KINEMATIC
- *MAT_BLATZ-KO_RUBBER
- *MAT_HIGH_EXPLOSIVE_BURN
- *MAT_NULL
- *MAT_JOHNSON_COOK
- *MAT_POWER_LAW_PLASTICITY
- *MAT_PIECEWISE_LINEAR_PLASTICITY
- *MAT_CRUSHABLE_FOAM
- *MAT_SIMPLIFIED_JOHNSON_COOK
- *MAT_MODIFIED_PIECEWISE_LINEAR_PLASTICITY
- *MAT_SIMPLIFIED_RUBBER/FOAM
- *MAT_BILKHU/DUBOIS_FOAM
- *MAT_FABRIC

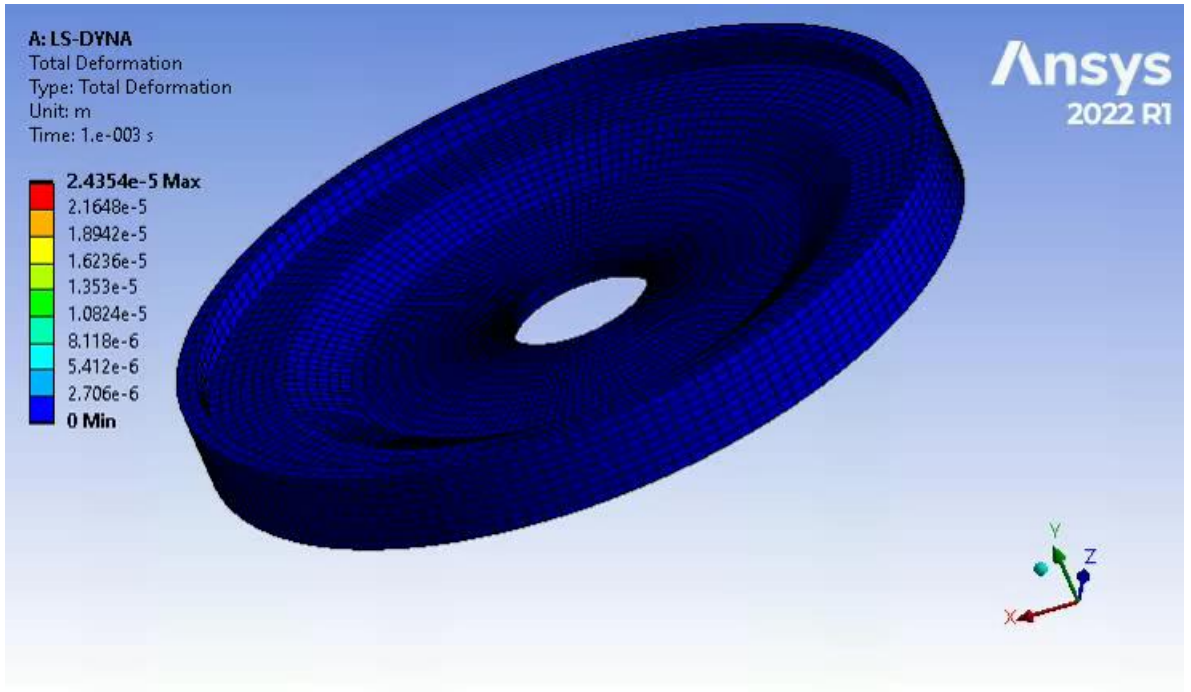


Cyclic Symmetry

- Cyclic Symmetry is now supported in the LS-DYNA Workbench system and can be used in turbomachinery applications for faster running times
- *BOUNDARY_CYCLIC
- Option to display the mesh and results with full symmetry (Beta)

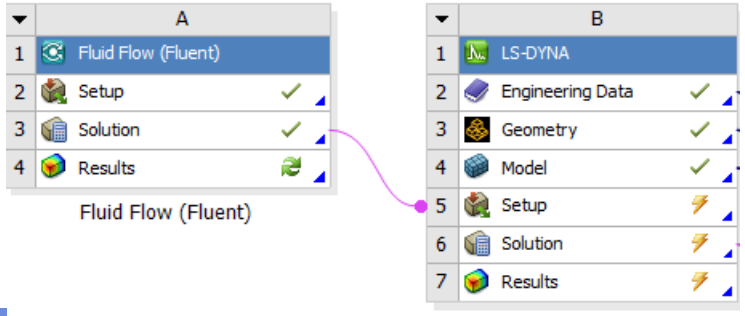


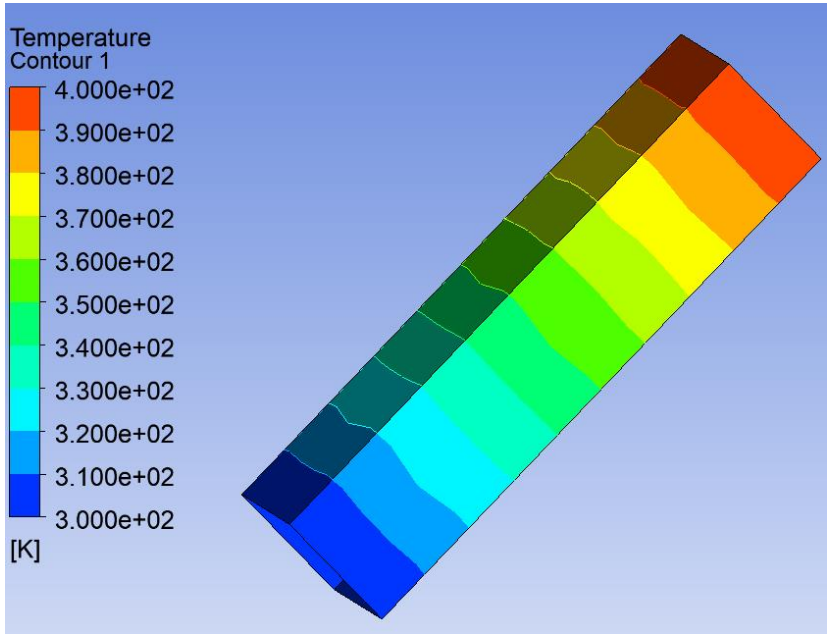




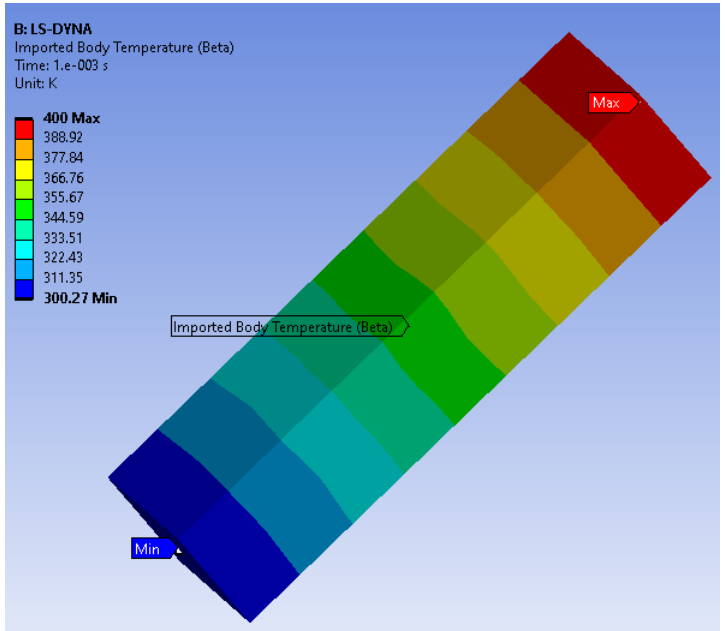
Fluent to LS-DYNA 1 Way Thermal Transfer

- Body Temperatures can be now imported from CFD calculations allowing to take in accurately temperatures effects in LS-DYNA simulations
- Link systems in the project schematic, imported load folder is added automatically, body temperature load can be inserted from the context menu
- Standard imported load features are available; Stepped\Ramped loading with the option to apply scale factor and offset

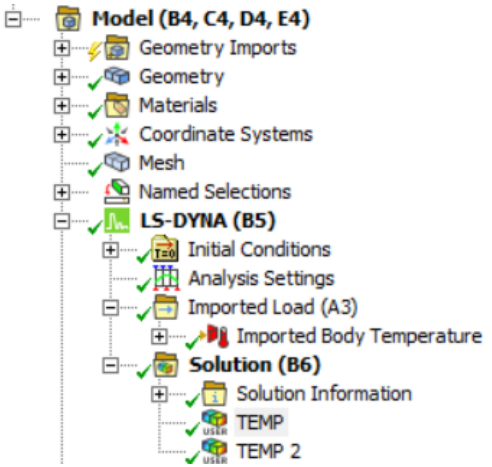




Fluent



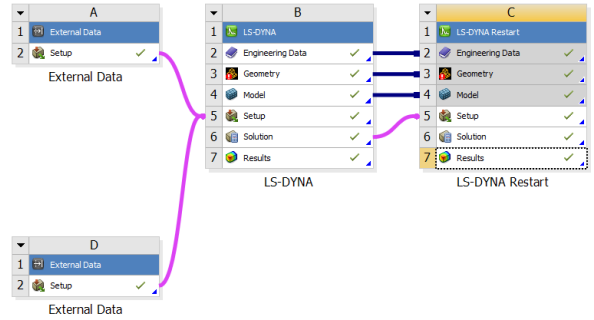
LS-Dyna

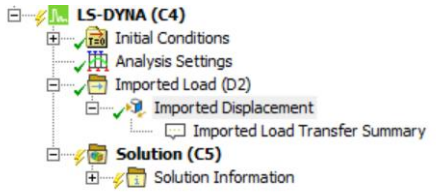


Imported Displacement

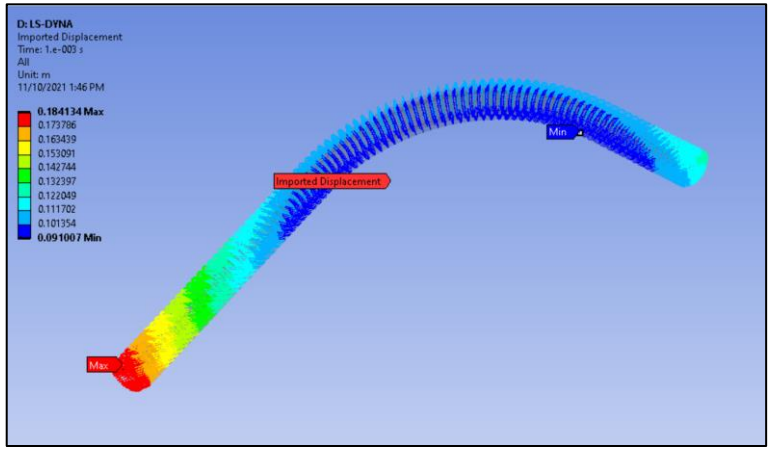
- LS-DYNA now supports Imported Displacement, allowing you to setup the model in non-trivial ways
- The mesh can either be initialized towards a final mesh, allowing the solver to prestress the model, or it can be used to specify the reference geometry in foams applications, if the user has the deformed mesh instead
- The solver will automatically calculate the stresses at the beginning of the calculation
- Create an external data system and import a file containing displacements defined by coordinates or mesh reference
- Link to an LS-DYNA system in the project schematic
- The Imported Load folder is automatically added and Imported Displacement is available for selection in the context menu along with the previously supported Imported Pressure
- Includes the standard options for mapping and display

	A	B	C	D	E
1	Column	Data Type	Data Unit	Data Identifier	Combined Identifier
2	A	X Coordinate	m		File1
3	B	Y Coordinate	m		File1
4	C	Z Coordinate	m		File1
5	D	Displacement	mm	Displacement1	File1:Displacement1



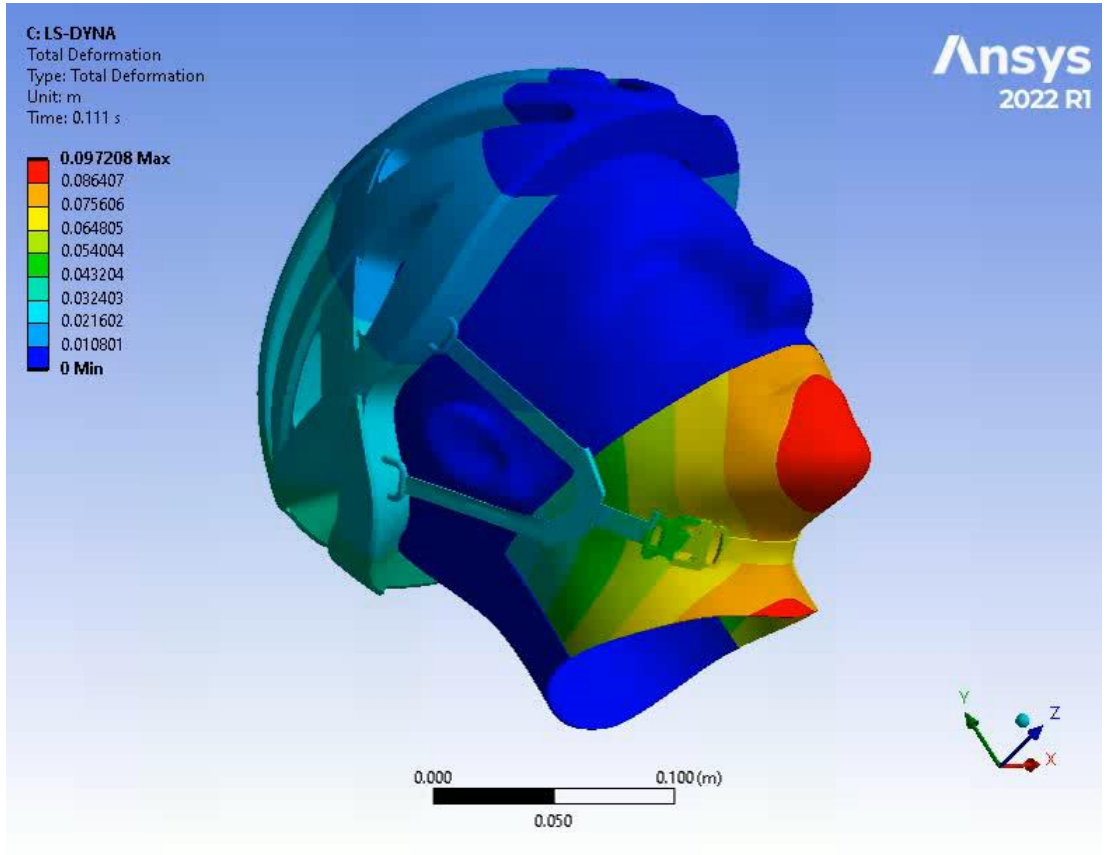


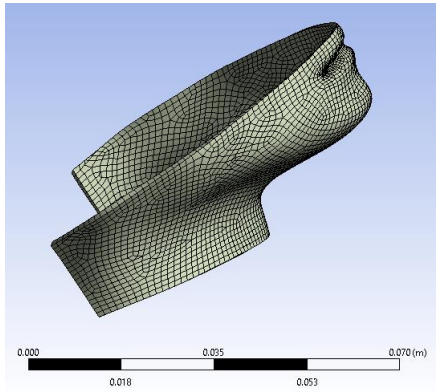
Graphics Controls	
By	Active Row
Active Row	1
Component	All
Display Source Points	Off
Display Source Point Ids	Off
Settings	
Mapping Control	Manual
Mapping	Profile Preserving
Weighting	Direct Assignment
Legend Controls	
Legend Range	Program Controlled
Named Selection Creation	
Unmapped Nodes	Off
Mapped Nodes	Off



Imported Displacement – Boundary Prescribed Final Geometry

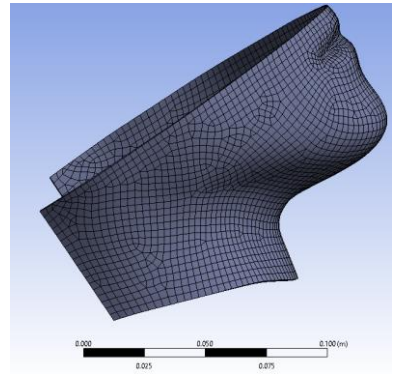
- The displacements between a scaled version of the chin and the full size geometry are calculated and imported via an External Data system
- An imported displacement load is used to apply the displacement from the initial to the final configuration pulling the helmet into place and pre-stressing the chin straps



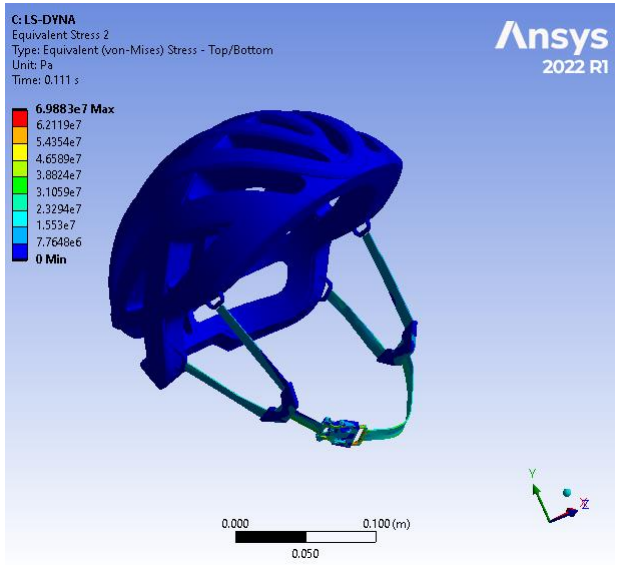


Initial Configuration

Apply Displacements

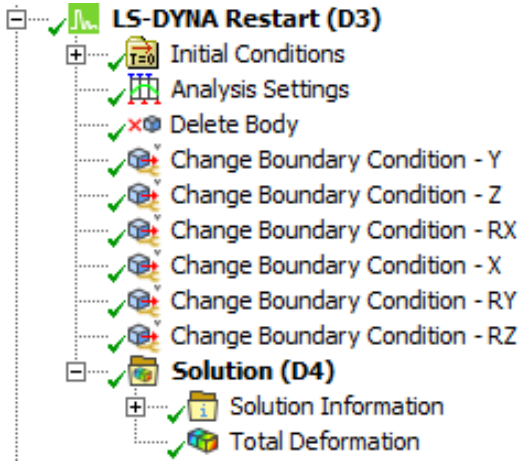


Final Configuration



Restarts Improvements

- Displacements and Remote Displacements can be modified in restarts allowing to simulate complex movements
- Location method allows the selection of a boundary condition or a curve (added using the keyword manager)
- Each component of a boundary condition can be independently redefined by a curve

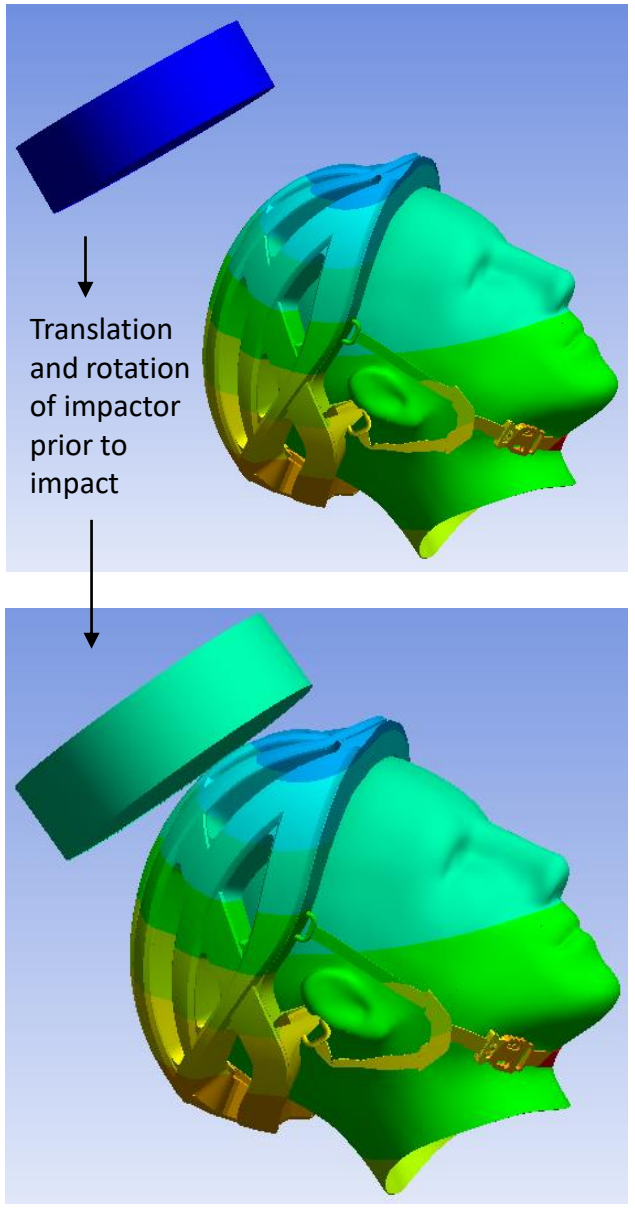


Details of "Change Boundary Condition 2"

Definition	
Location Method	Boundary Condition
Boundary Condition	Remote Displacement_Round_Impactor
Component	Y Component

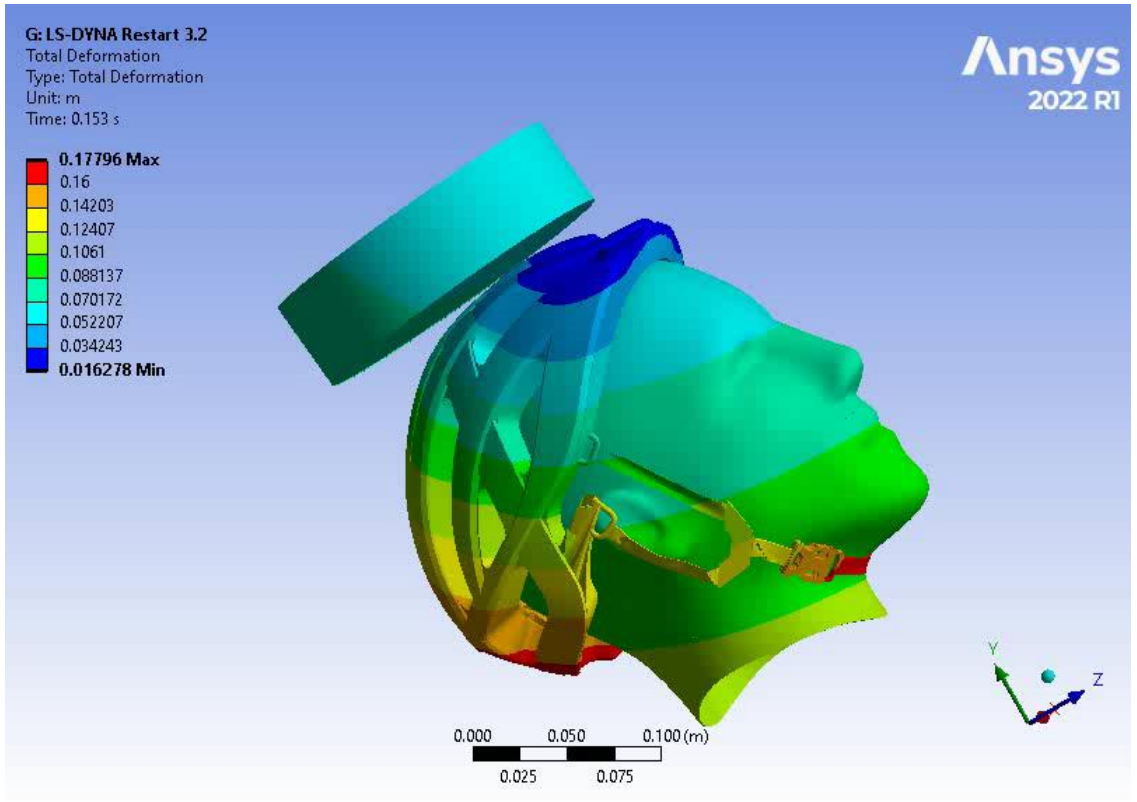
Tabular Data

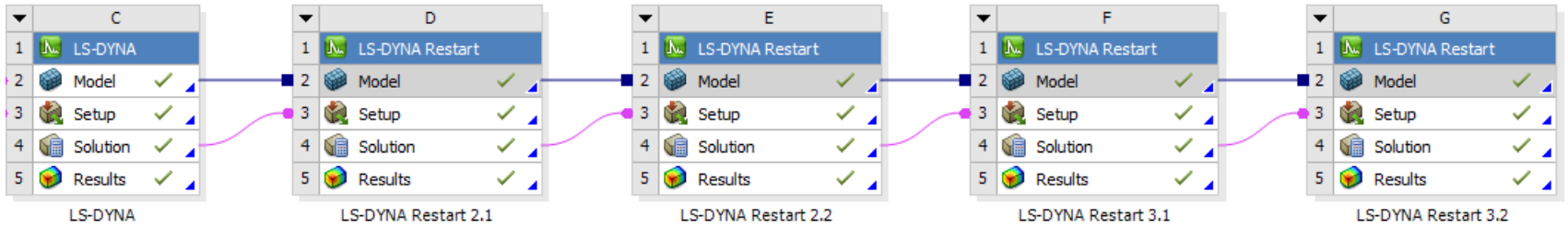
		Time [s]	Displacement [m]
1	1	0.	= 0.
2	1	0.132	0.
3	1	0.133	3.5e-002
4	N/A	3.	3.5e-002
5	N/A	4.	3.5e-002
*			



Restarts Improvements

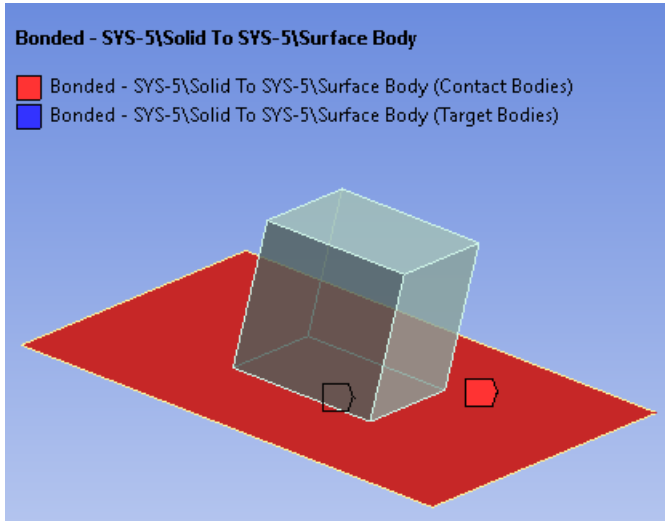
- Multi-step impact analysis using a series of small restarts
  - Pre-Stress
  - Impactor 1 Positioning
  - Impact 1
  - Impactor 2 Positioning
  - Impact 2
- Uses the new Change Boundary Condition object along with the Delete Body and Change Velocity objects





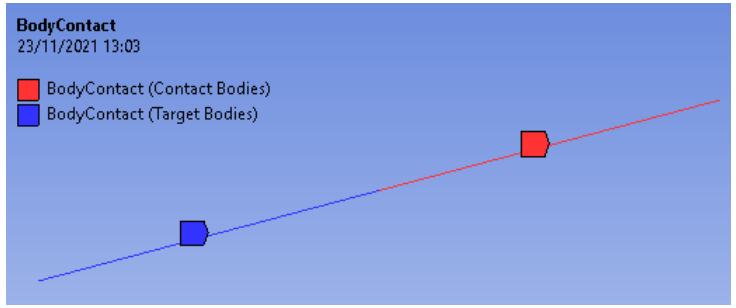
Contact Scoping

- Additional contact scoping options are available for LS-DYNA
- Contacts can now be scoped to Shell and Beam bodies in a 3D Analysis



Details of "BodyContact"

Scope	
Scoping Method	Geometry Selection
Contact	1 Edge
Target	1 Body
Contact Bodies	Beam2
Target Bodies	Beam1
Protected	No
Definition	
Type	Bonded
Scope Mode	Manual
Trim Contact	Program Controlled
Maximum Offset	1.e-002 m
Breakable	No
Suppressed	No
Advanced	
Formulation	Program Controlled

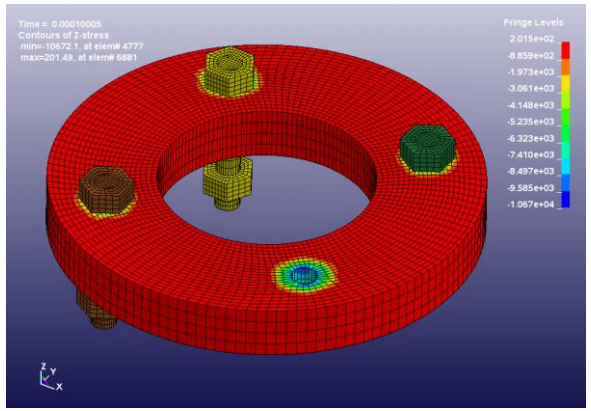


Details of "Bonded - SYS-5\Solid To SYS-5\Surface Body"

Scope	
Scoping Method	Geometry Selection
Contact	1 Body
Target	1 Face
Contact Bodies	SYS-5\Surface Body
Target Bodies	SYS-5\Solid
Contact Shell Face	Program Controlled
Protected	No
Definition	
Type	Bonded
Scope Mode	Manual
Behavior	Program Controlled
Trim Contact	Program Controlled
Maximum Offset	1.e-007 m
Breakable	No
Suppressed	No
Advanced	
Formulation	Program Controlled

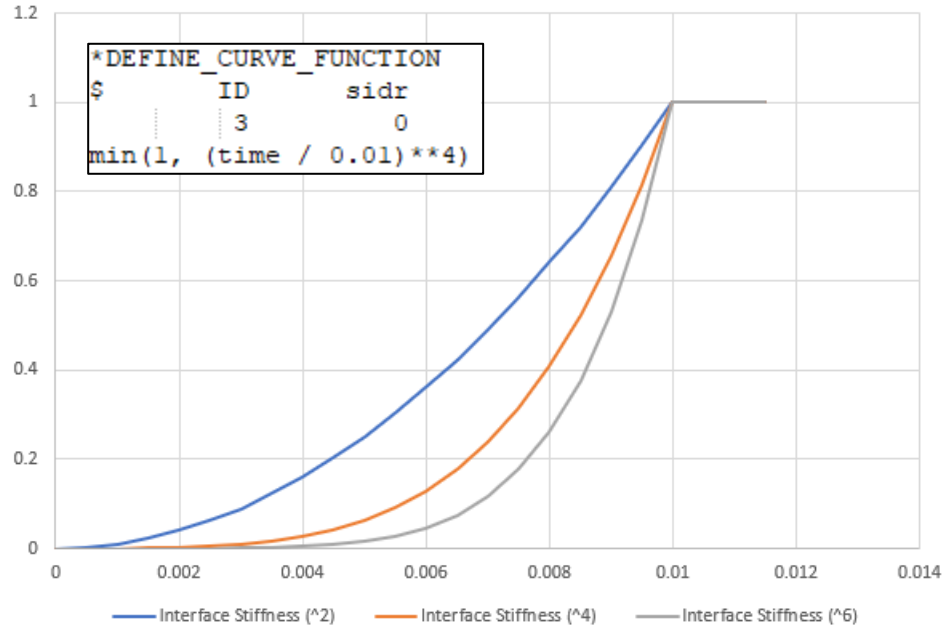
Interference Contact Properties

- New options added to give additional flexibility in contact stiffness curve definition
- End time for contact. Previously this just used analysis time
- Stiffness curve function exponent to vary the transition to peak stiffness



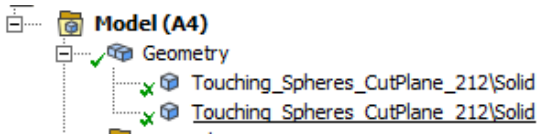
Details of "Contact Properties 2"

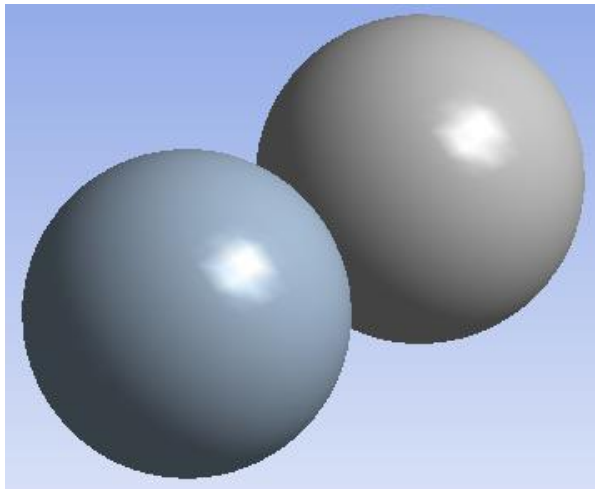
Definition	
Contact	Frictional - Multiple To Multiple (Interference)
Type	Interference
Formulation	SURFACE_TO_SURFACE_INTERFERENCE
Common Controls	
Birth Time	0 s
Death Time	0 s
Viscous Damping Coefficient	10
Contact Penalty Scale Factor	4
Target Penalty Scale Factor	4
Advanced Controls	
Optional Thickness for Contact Surface	0 m
Optional Thickness for Target Surface	0 m
Optional Solid Element Thickness	0 m
Soft Constraint Formulation	Program Controlled
Soft Constraint Scale Factor	0.1
Depth	5
Interference Controls	
Stiffness Scale factor At End of Dynamic Relaxation	1
Interference End Time	0.01 s
Stiffness Curve Exponent	4



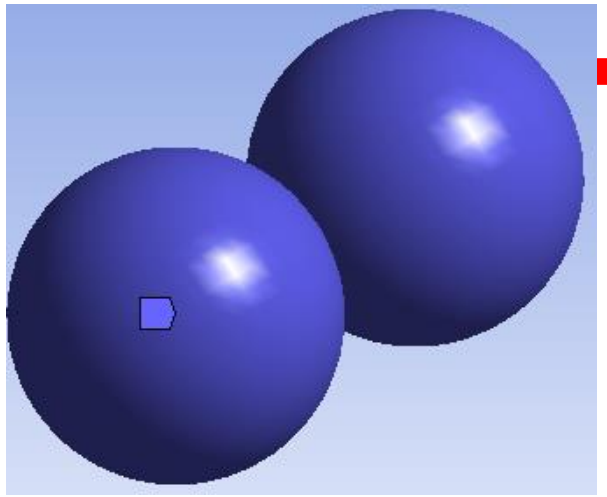
Better default mesh for cylinders, circles, and spheres

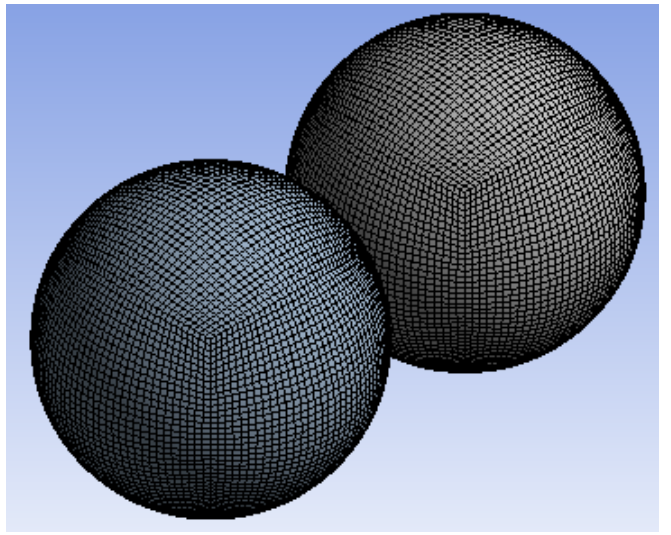
Touching Spheres

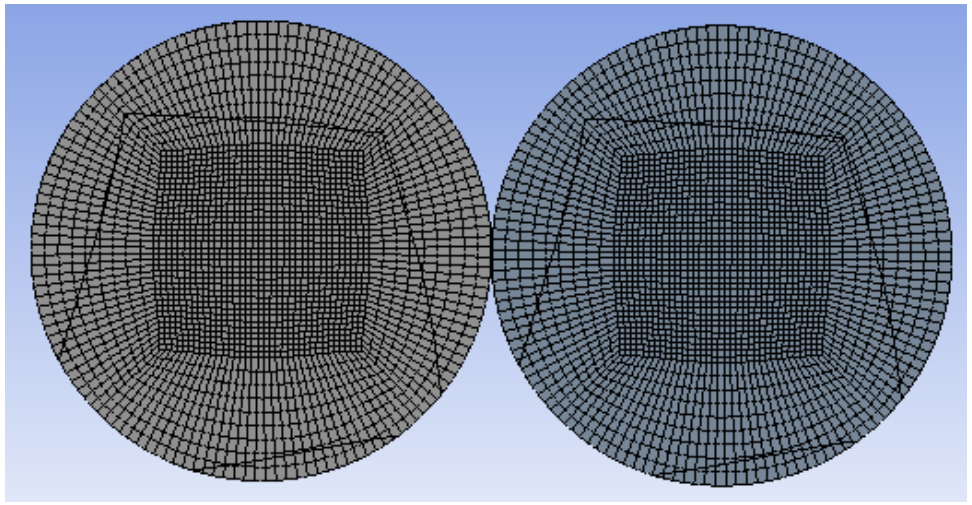




MultiZone Applied with no special inputs/selections – Automatic Hex



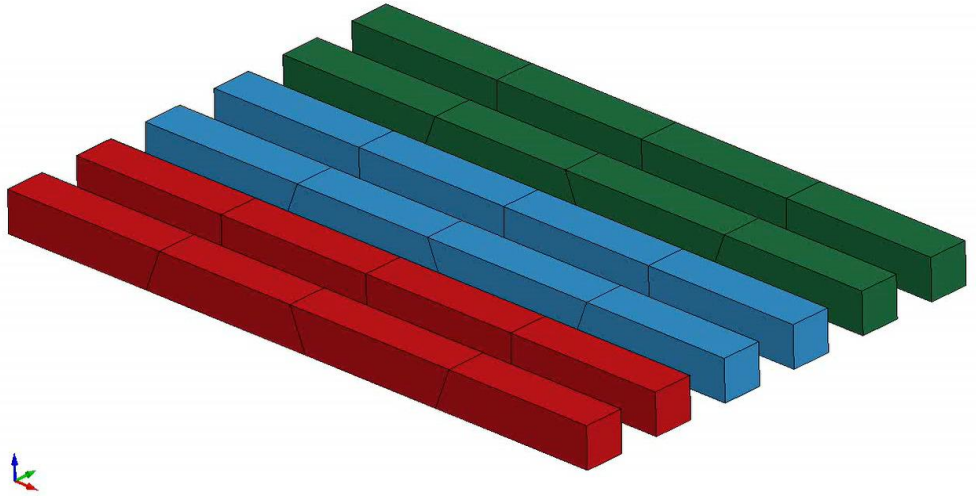


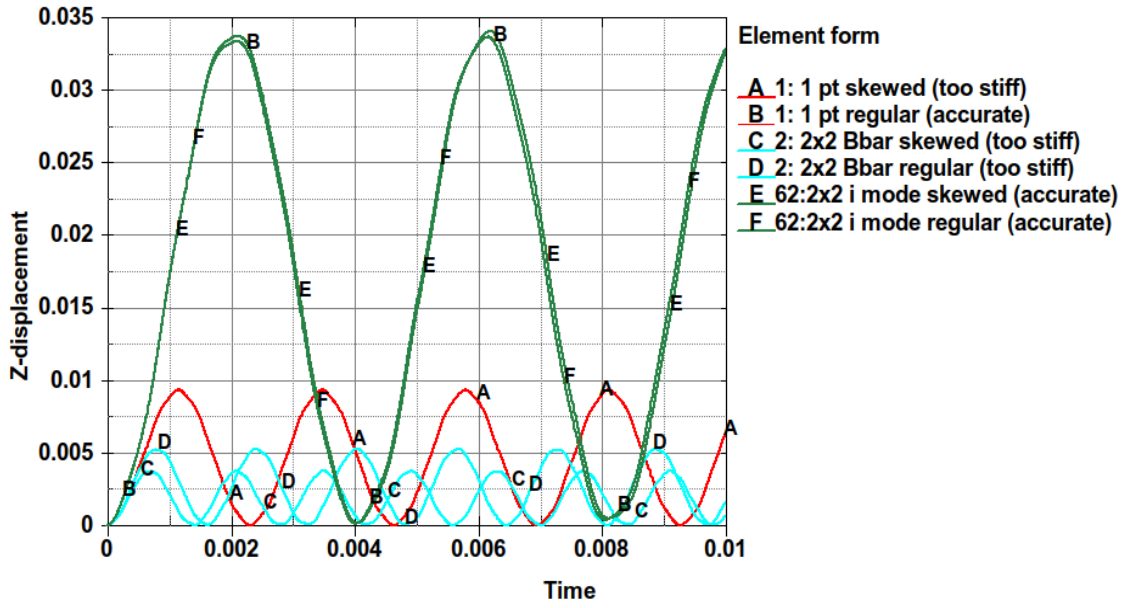


LS-DYNA R13 Solver Updates

Solid Element Formulation 62

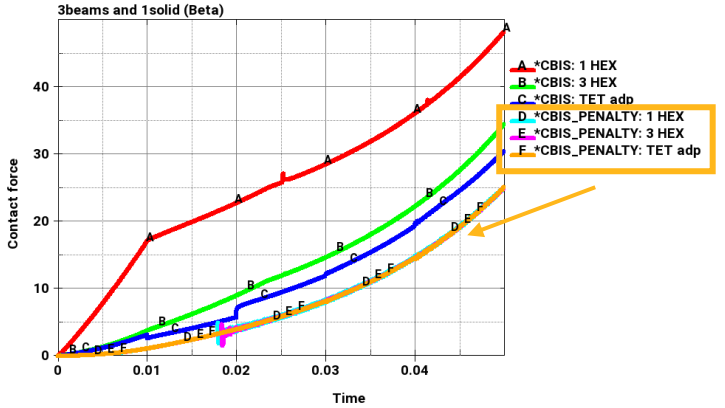
- Fully integrated brick element
- Incompatible modes by assumed strain
- Fast, accurate, and robust
- Accurate bending, even skewed
- That is not susceptible to volumetric locking or shear locking.

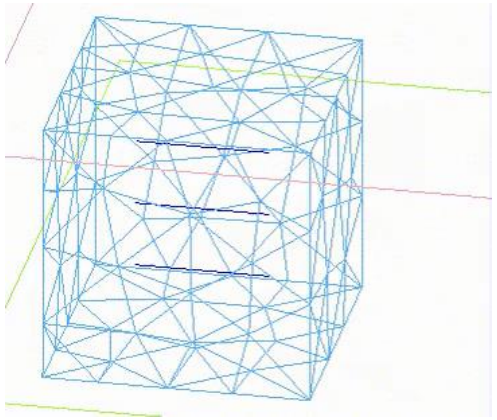


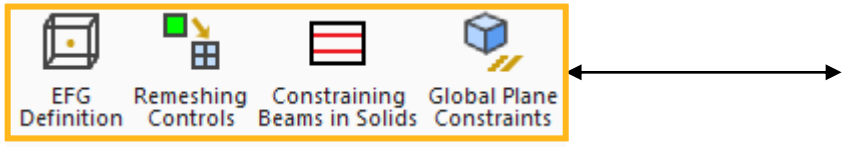


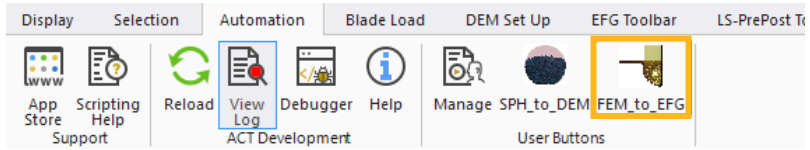
3D Adaptive FEM / EFG for Compression Molding

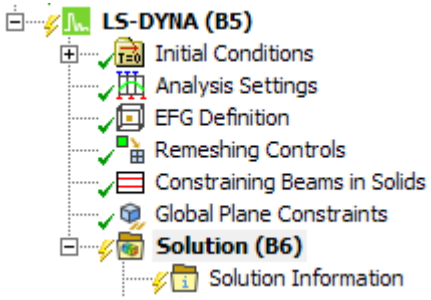
- New remapping capability (work with LST core team)
  - To transfer the internal variables of penalty-based non-conforming coupling formulation (*CONSTRAINED_BEAM_IN_SOLID_PENALTY) between fiber and matrix materials
  - Better numerical stability and accuracy compared to constrained-based coupling formulation
  - Rewrite remapping algorithm to directly transfer internal variables for non-adaptive parts
- ACT on Ansys Workbench (work with LST ACE team)
  - Capable to define all necessary keywords





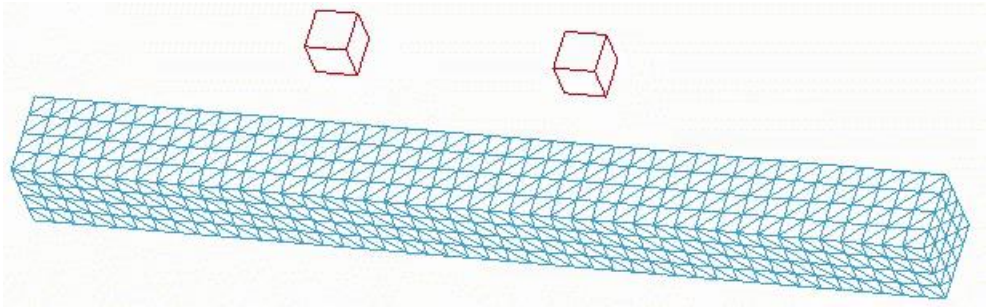


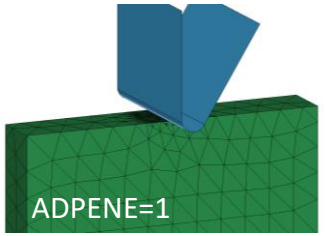


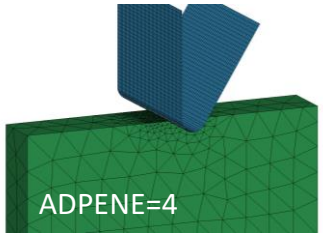


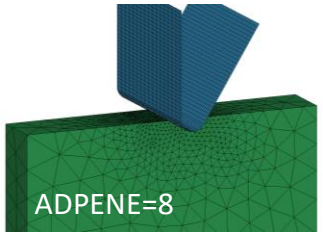
3D Adaptive FEM / EFG for Forging

- New feature in surface triangulation remeshing
  - Smooth transition from fine to coarse mesh when there is no contact curvature information available
  - The level of smoothing is defined through ADPENE in *CONTROL_ADAPTIVE
  - Better surface representation in large material deformation for forging simulation
- New option of defining moving box in *DEFINE_BOX_ADAPTIVE
  - Users are able to customize remeshing size within moving boxes



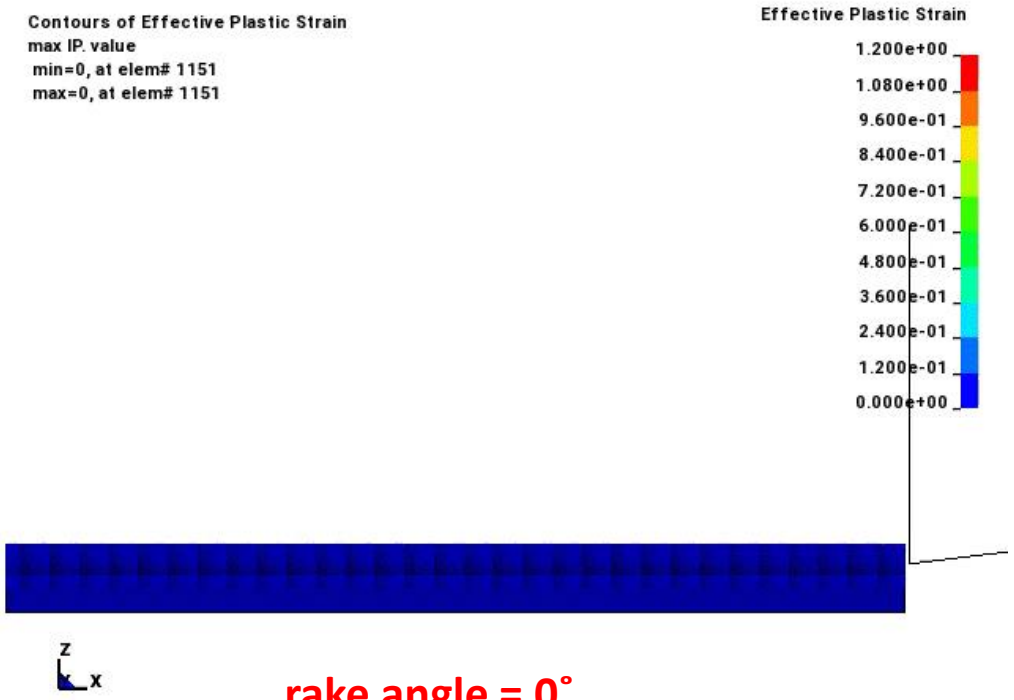




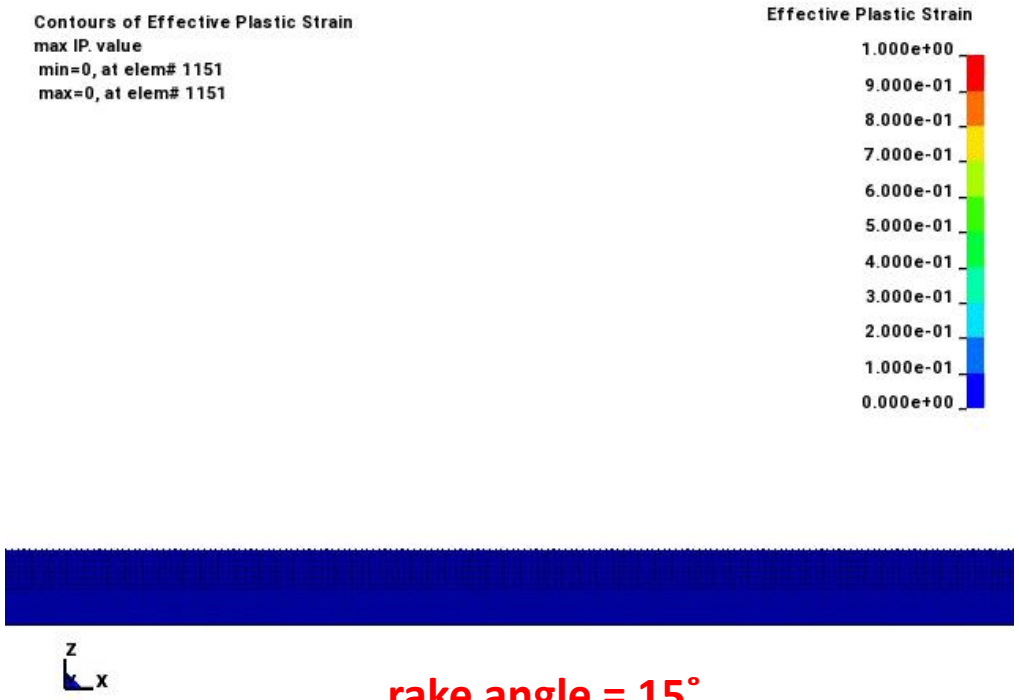


Coupled Thermal Mechanical Analysis of 3D Orthogonal Cutting of Steel in Automotive Applications

- Coupled thermo-mechanical analysis with MC-SPG
  - Material failure and separation at tool tip without element erosion
  - Shear band forming and chip bending (important for force prediction)
  - Conservation of mass/momentum



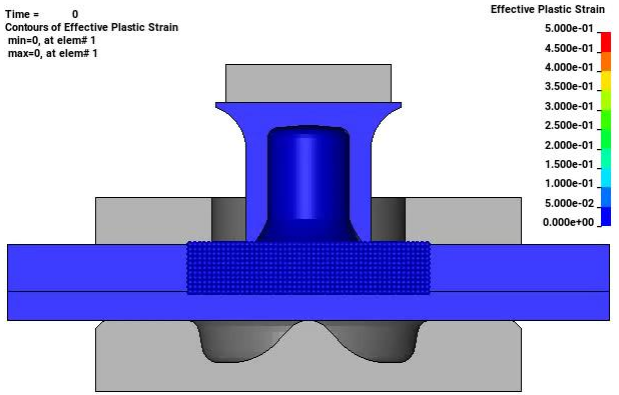
rake angle = 0˚



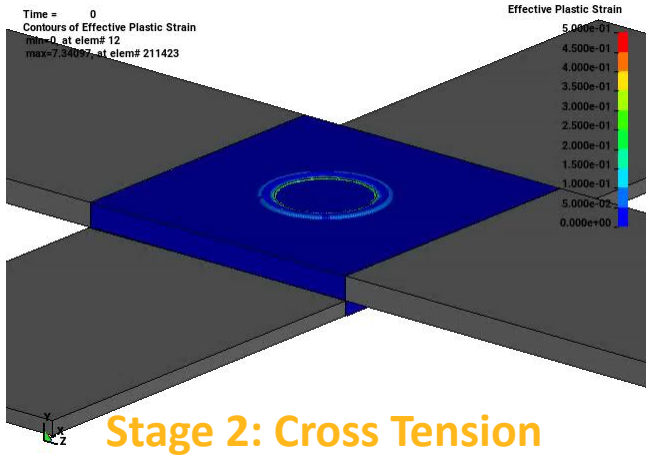
rake angle = 15˚

Analysis of Self-Piercing Riveting (SPR) Joining Process and Joint Strength in Automotive Applications

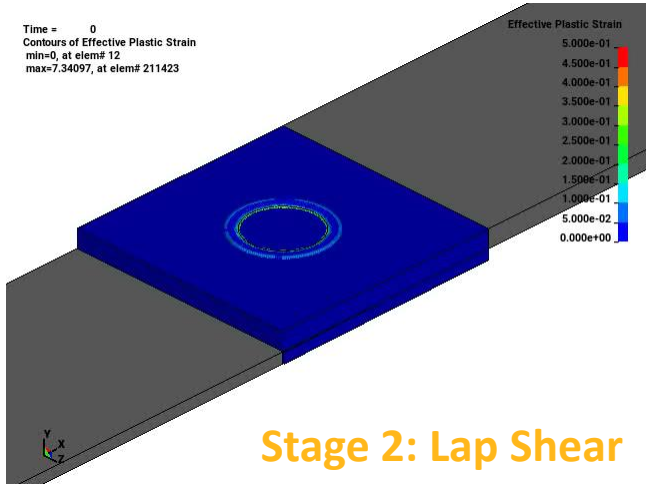
- Two-stage analysis
  - Stage 1: joining process, to form joint through mechanical locking
    - *INTERFACE_SPG_1
  - Stage 2: various strength analyses based on residual deformation from stage 1
    - *INTERFACE_SPG_2



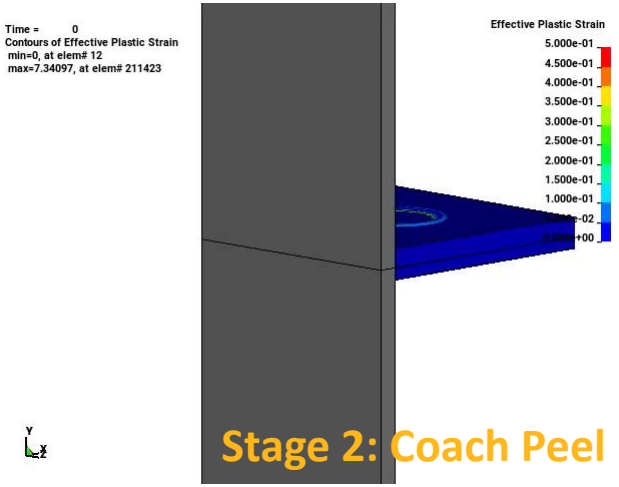
Stage 1: Joining process



Stage 2: Cross Tension



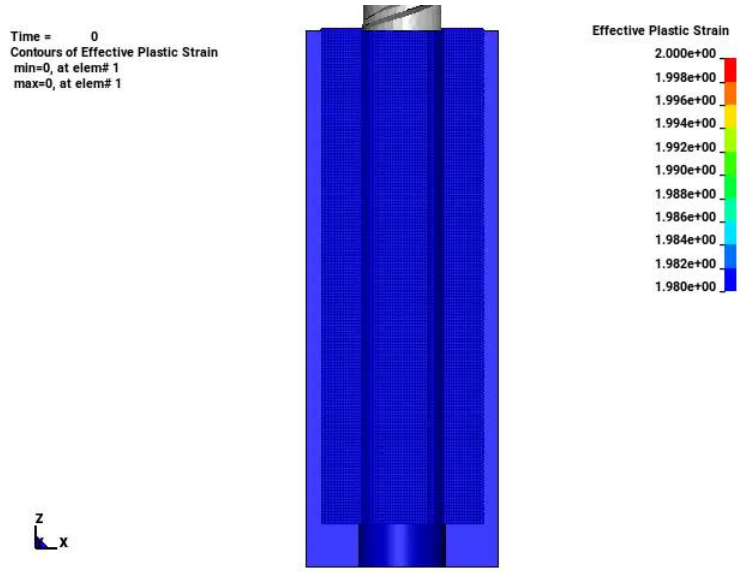
Stage 2: Lap Shear



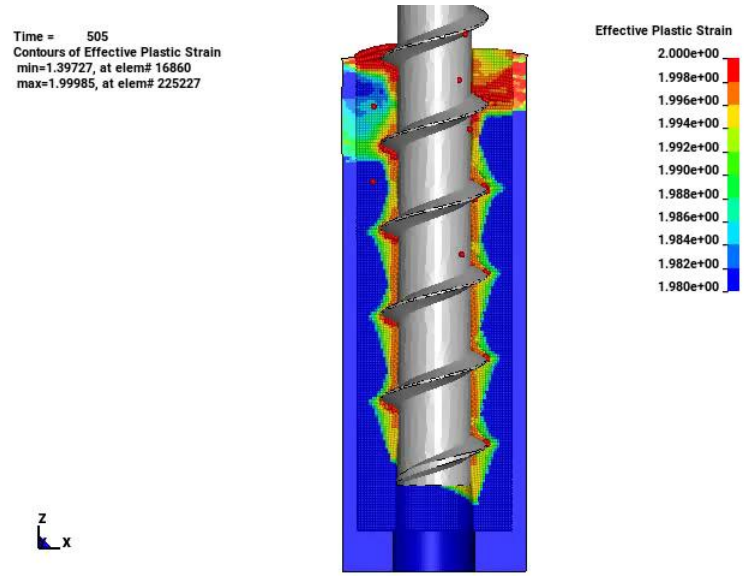
Stage 2: Coach Peel

MMPs Analysis of Concrete Drilling and Joint Strength

- Two-stage analysis
  - Stage 1: concrete drilling process
    - Capture new threads formed in concrete while concrete failure and separation occurring
  - Stage 2: anchor pullout to evaluate the strength of new formed threads



Drilling process

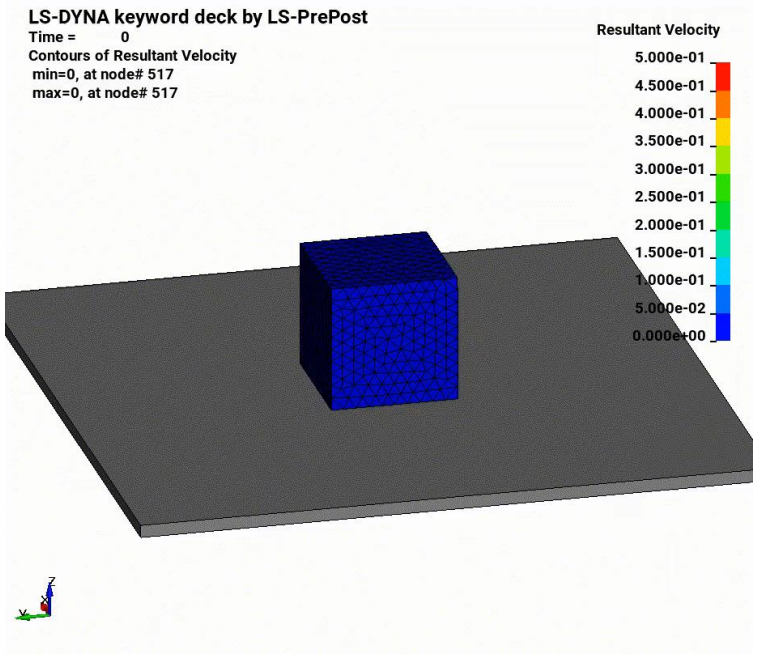


Anchor pullout

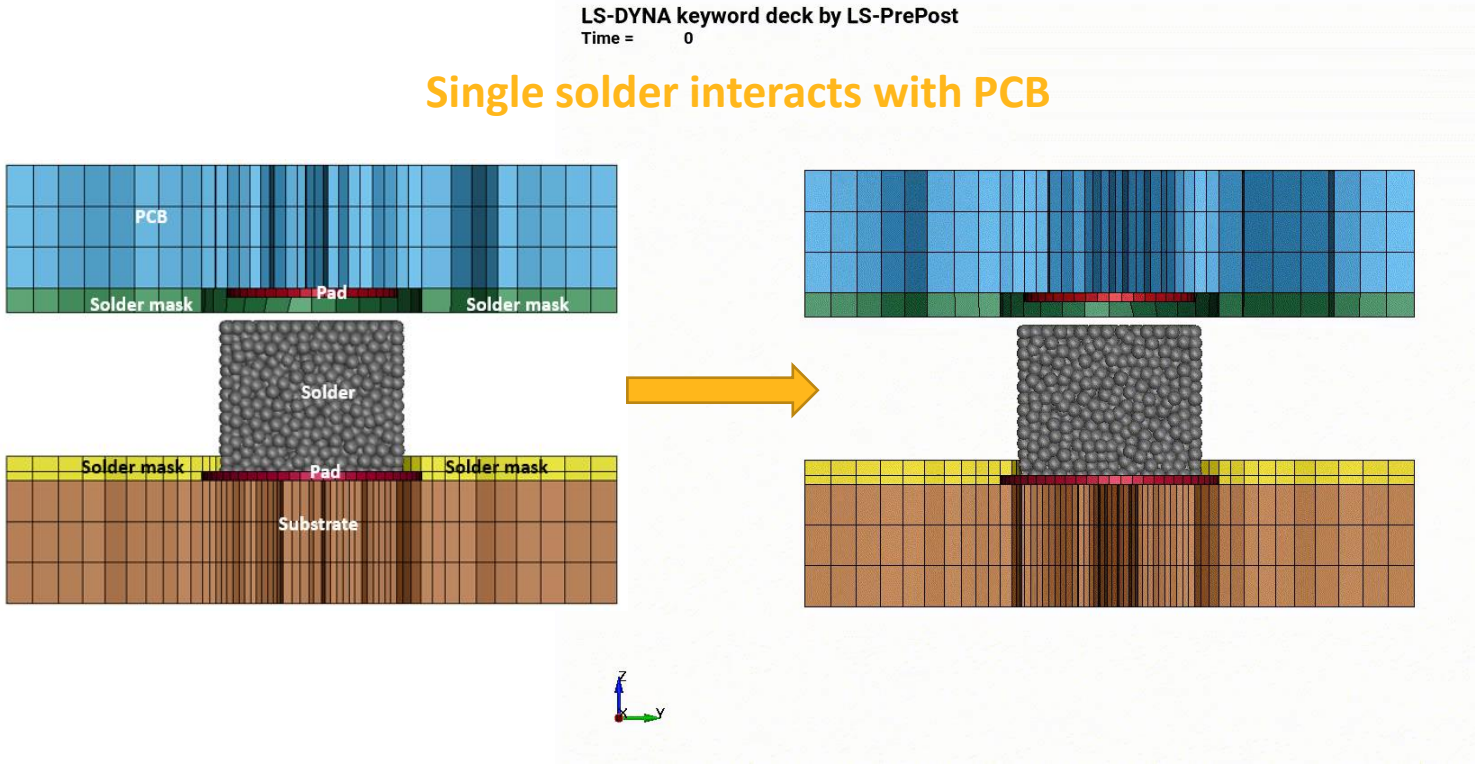
Fully Implicit Incompressible SPG (ISPG) Formulation

- Fully implicit ISPG formulation
  - A new Lagrangian Navier-Stoke solver
  - Can handle the surface tension and wall adhesion accurately and efficiently
  - Can simulate the solder reflow with complex models with the solder mask defined (SMD) pad and NSMD

Large deformation of droplet



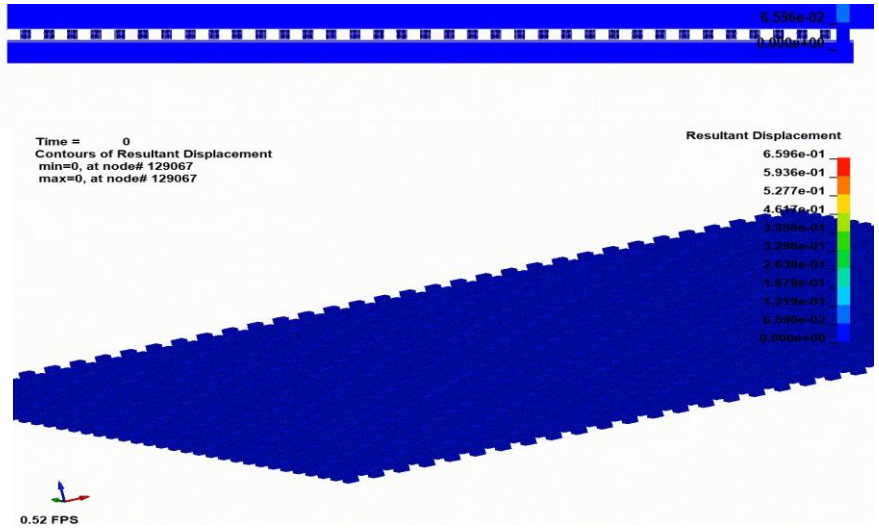
Single solder interacts with PCB



Fully Implicit ISPG Formulation

- Coupled with implicit thermal and structure solvers
  - for large scale thermal-mechanical PCB and solder reflow analysis (considering PCB warpage effect; SMP&MPP)

1225 solders (1.02M nodes) on PCB solved with MPP solver on 64 CPU cores (Run time – 7.5hrs)



- ACT on Ansys Workbench available
  - Capable to define all necessary keywords
  - *SECTION_FPD
  - *MAT_IFPD
  - *DEFINE_FP_TO_SURFACE_COUPLING

ANSYS Workbench ACT tool for ISPG setup

Details of "Material Properties"

Solder Properties	
Named Selection ID	1
Density	8.9E-06 kg/mm³
Viscosity	2.24E-07 MPa·s
Surface Tension	4.99E-06

Details of "Coupling parameters"

Coupling parameters	
Target Bodies NS ID	10
Slip B.C. [No: 1, Yes: 0]	0
Surface Contact Angle	2 rad
Normal stiffness coeff.	0.2

Details of "Gravity load"

General	
Parts NS ID	25
Direction [X:1, Y:2, Z:3]	3
gravity acceln.	9806 mm/s²
Mass damping factor	20

Improvement of *DEFINE_DE_INJECTION

Card 1	1	2	3	4	5	6	7	8
Variable	PID	SID	XC	YC	ZC	XL	YL	CID
Type	I	I	F	F	F	F	F	I
Default	none	none	0.0	0.0	0.0	0.0	0.0	0

Card 2	1	2	3	4	5	6	7	8
Variable	RMASS	RMIN	RMAX	VX	VY	VZ	TBEG	TEND
Type	F	F	F	F	F	F	F	F
Default	none	none	RMIN	0.0	0.0	0.0	0.0	10^{20}

Card 3	1	2	3	4	5	6	7	8
Variable	IFUNC	NID	**IMULTI**	**LCVX**	**LCVY**	**LCVZ**		
Type	I	I	**I**	**I**	**I**	**I**		
Default	0	0	**1**	**0**	**0**	**0**		

Include when IMULTI>1

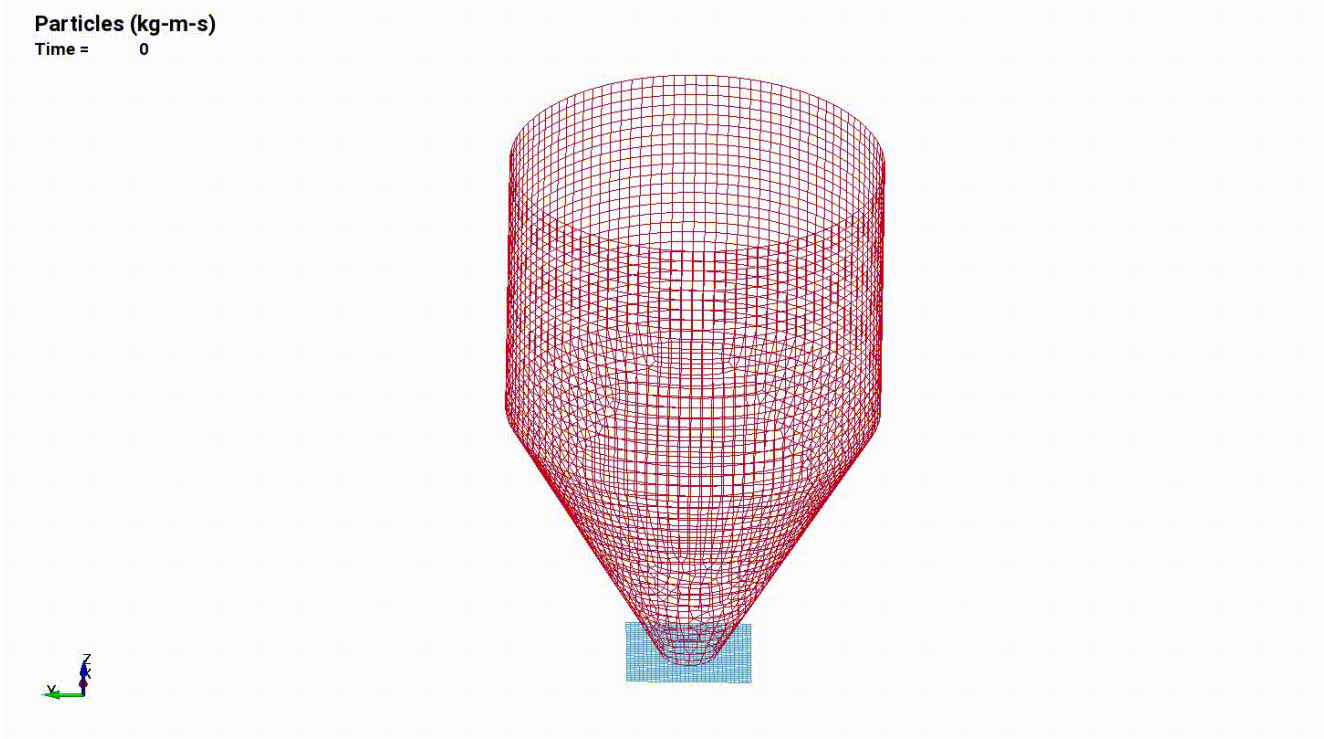
Card 3.1	1	2	3	4	5	6	7	8
Variable	**R1**	**P1**	**R2**	**P2**	**R3**	**P3**	**R4**	**P4**
Type	**F**	**F**	**F**	**F**	**F**	**F**	**F**	**F**
Default	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

1. The new option IMULTI enables the capability of simultaneous injection of particles of different size with specified mass ratio.

2. The option of LCVX, LCVY and LCVZ allow that the particle injection rate can be varied through user defined curve instead of remaining as a constant.

Example of DES injection with IMULTI=3

The injection consists of three different size DES particles with specified mass ratio - 22% 1.0mm particles, 28% 2.0mm particles and 50% 3.0mm particles

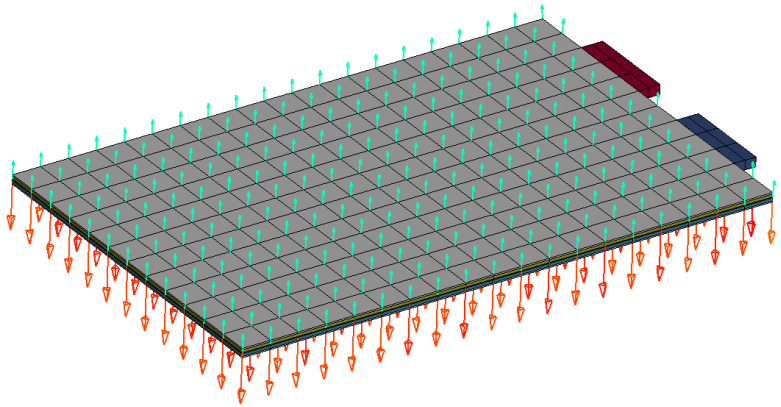


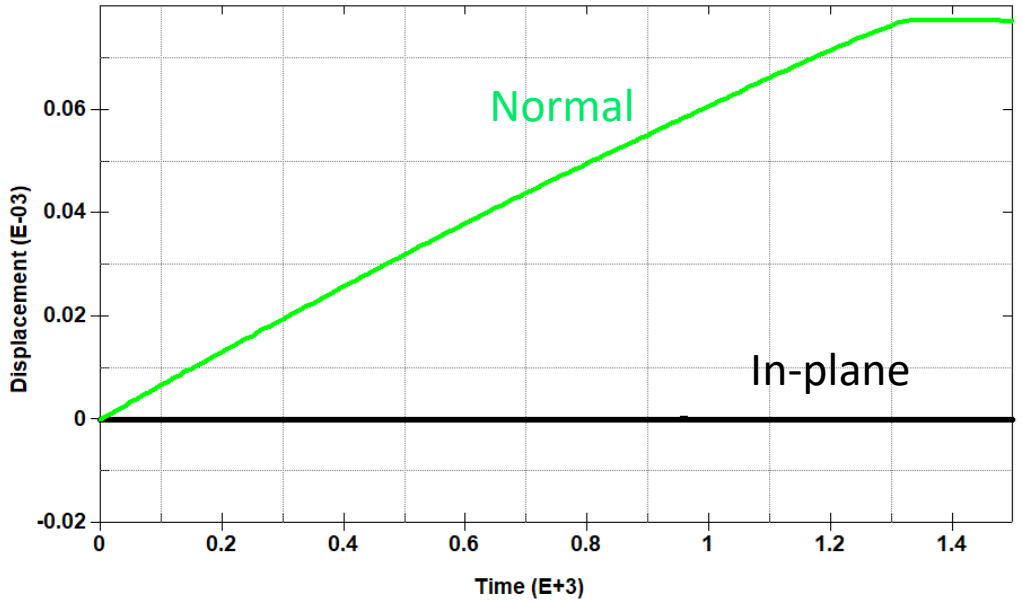
Materials

State of charge expansion with orthotropy

- New orthotropy options for *MAT_ADD_SOC_EXPANSION
  - State of charge (SOC) from EM module induces structural displacements
  - Independent expansion coefficients MULT, MULTY, MULTZ for orthotropic materials
  - Or as curve input LCID, LCIDY, LCIDZ as function of current state of charge

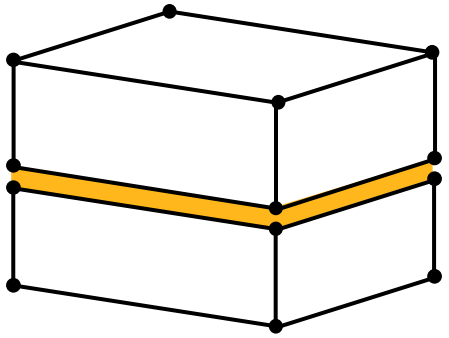
- Possible application: Battery modeling
  - Example: Unit cell with discharge
  - Consider swelling in thickness direction



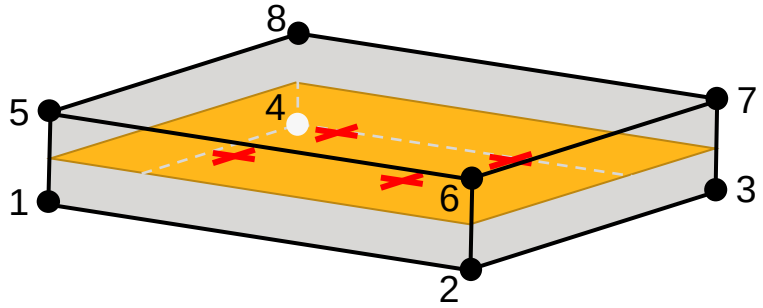


Enhancements for cohesive elements / materials

- Support of foam materials
  - *MAT_ADD_COHESIVE now works with *MAT_ LOW_DENSITY_FOAM and *MAT_ FU_CHANG_FOAM
  - For thin layers (pads) of highly compressible foam



- Support ICOH=1 (*CONTROL_SOLID) for *MAT_ ARUP_ADHESIVE
  - This is automatic deletion of cohesive elements if neighboring shell or solid elements fail
  - Already available for genuine cohesive materials (138, 240, …), but now also for this “special” *MAT_ARUP_ADHESIVE



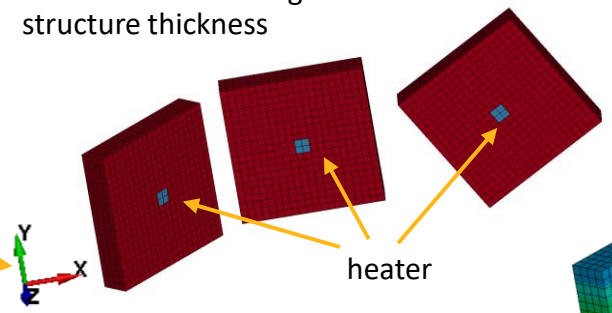
Anisotropic thermal materials

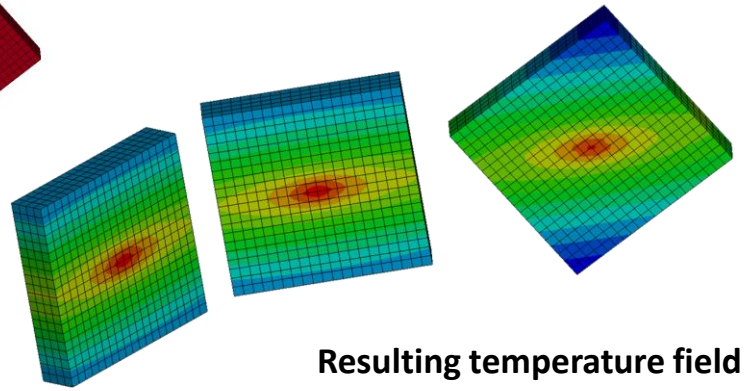
- Consolidation of anisotropy option
  - Added anisotropy option (AOPT=3) to define a material coordinate system with first direction being orthogonal to the element normal and to a given vector
  - All anisotropy options (AOPT between 1 and 4) now available for all materials with anisotropic thermal conductivity
  - Affects materials *MAT_T02, *MAT_T04, *MAT_T08,*MAT_T11-15, *MAT_T17

```
*MAT_THERMAL_ORTHOTROPIC
$#     tmid        tro      tgrlc     tgmult       aopt
         2        1.0          0        0.0          3
$#       hc         k1         k2         k3
       1.0       10.0        1.0        1.0
$#       xp         yp         zp         a1         a2         a3
      0.0        0.0        0.0        0.0        0.0        0.0
$#       d1         d2         d3
      0.0        1.0        0.0
```

Setup

Element normals aligned with structure thickness



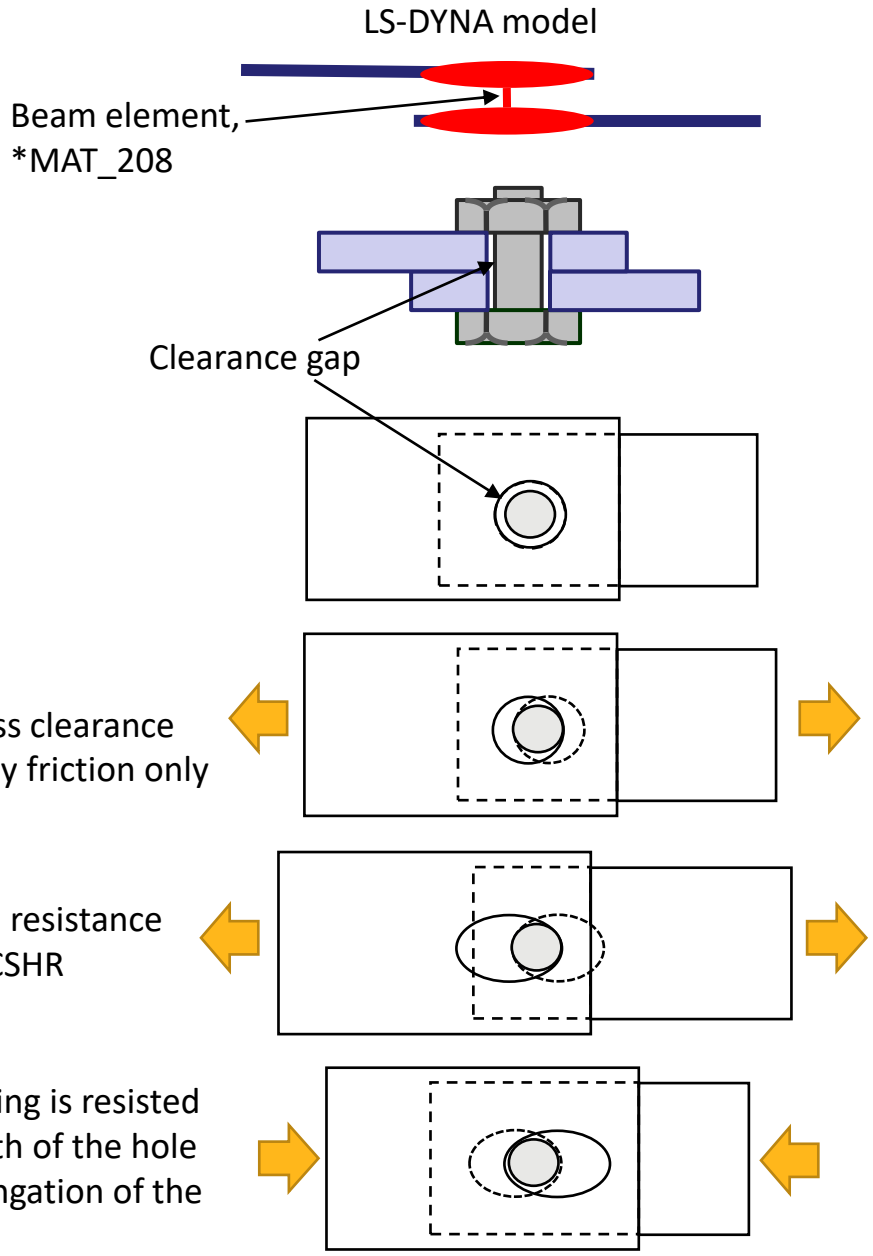


Resulting temperature field

*MAT_BOLT_BEAM (*MAT_208)

- Models the forces transmitted across a bolted joint, including preload, clearance gap and other features.

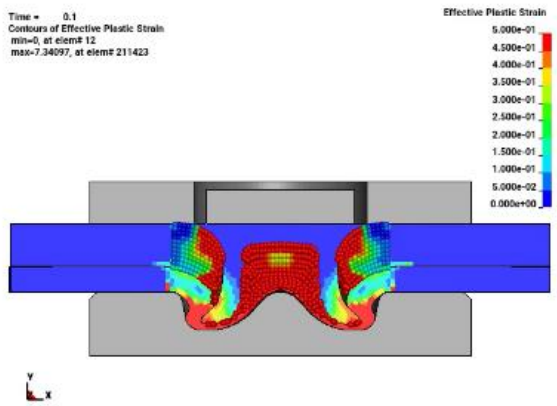
- New in R13: input parameter HOLSHR enables a shear deformation mode in which the bolt shank tears through the plates, enlongating the hole. Cyclic behavior accounts for the enlarging hole.

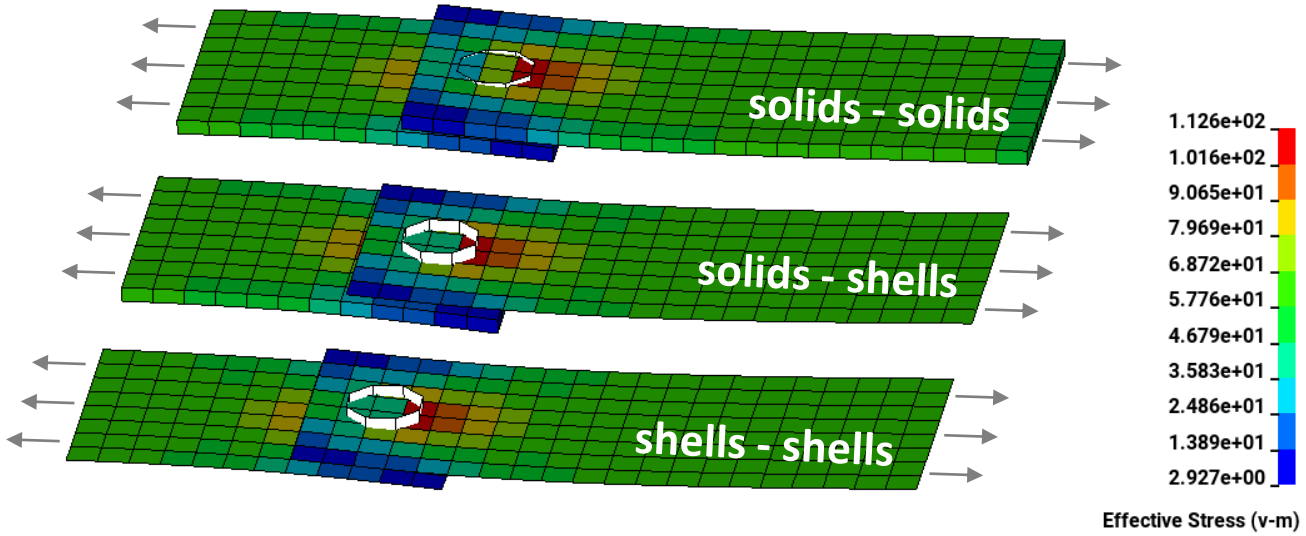


Point wise connection of solid parts

- *CONSTRAINED_SPR2 now supports solid elements
  - Connection model for spotwelds, rivets, screws, etc.
  - SPR2 is an element-free interpolation method frequently used for shells-to-shells connections
  - Thick structures more and more often discretized with solid elements (hexa/tetra/pentahedral)

- Compares well with existing approach
  - Example: lap shear test



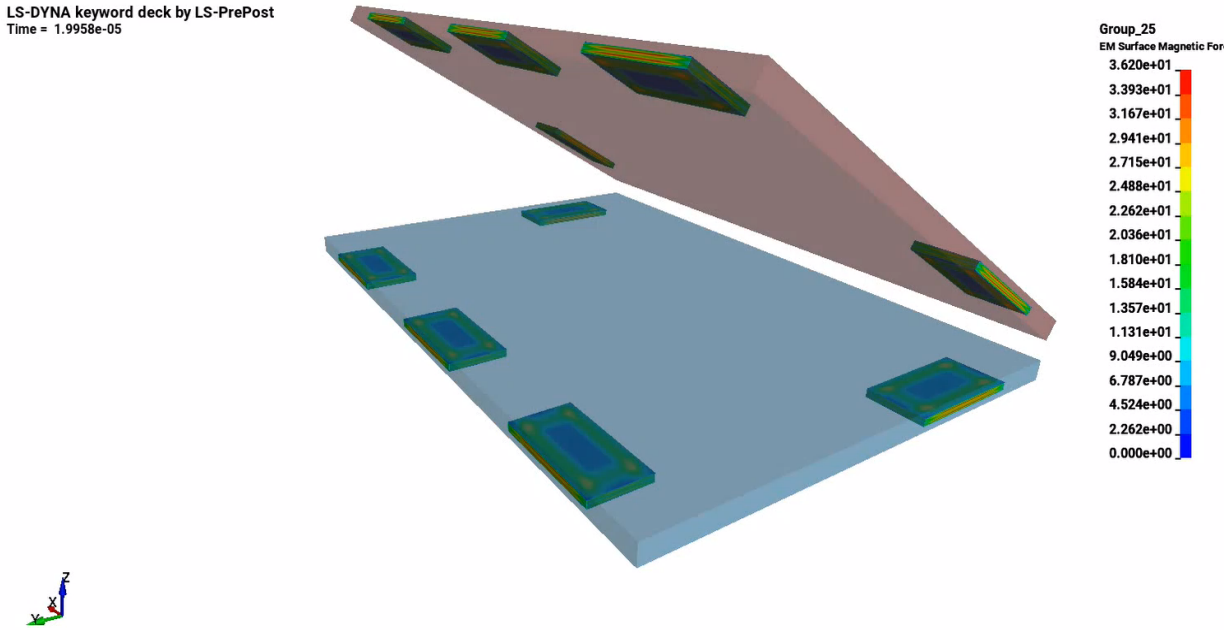


Electro-Magnetic Solver

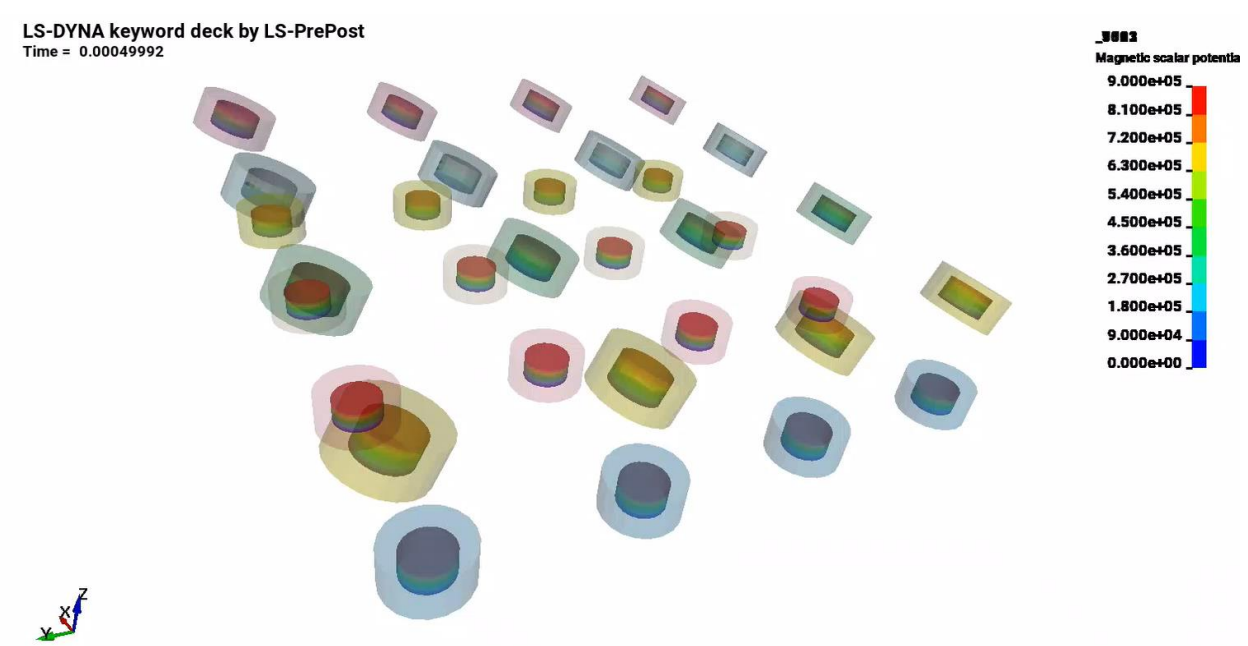
Ansys

Magnet latching

- Thanks to the EM's solver robust FEM/BEM method, no air mesh is needed which means all dofs can be left free for magnet snapping and latching applications.



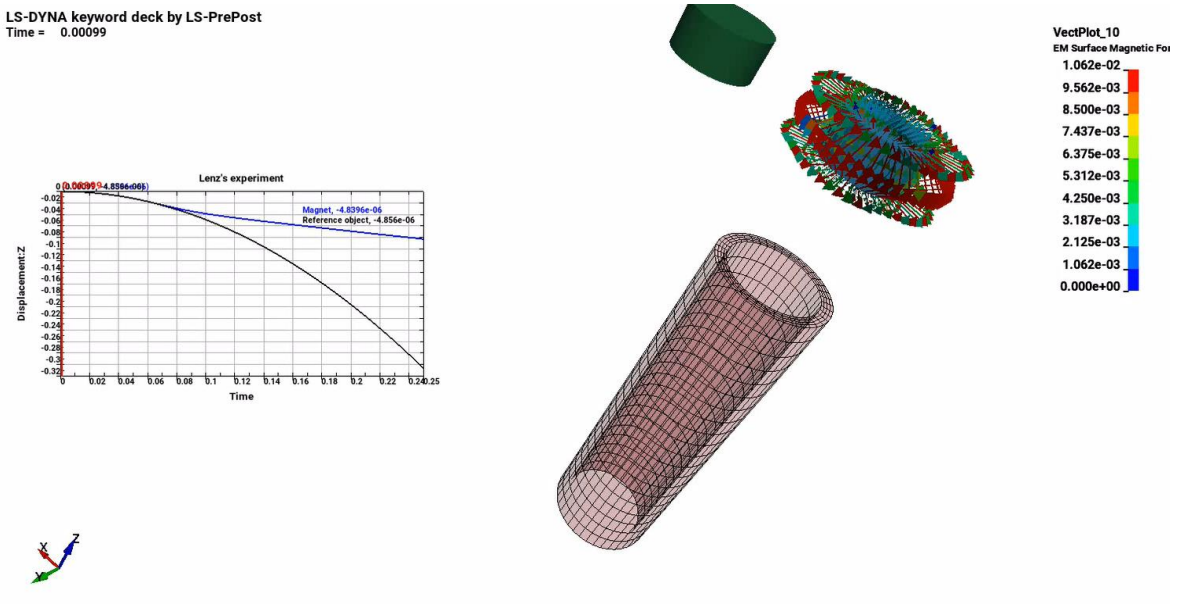
Magnet latching on electronic device



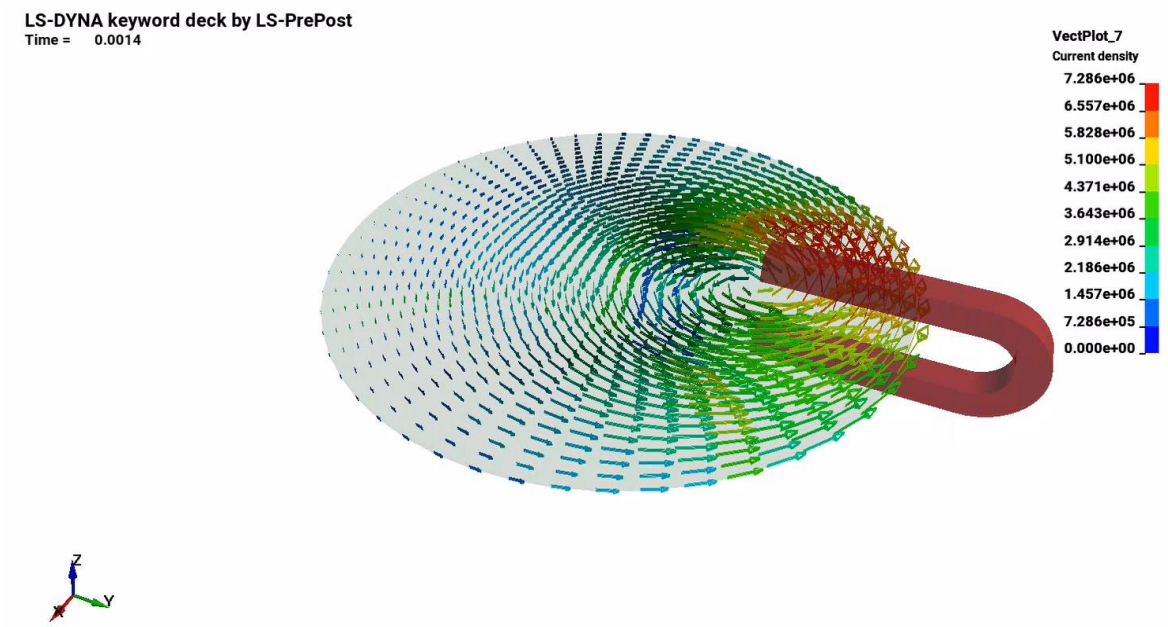
32 magnets snapping

Electromagnetic brakes and motors

- The addition of magnets in LS-DYNA allows the simulation of electromagnetic brakes or motors. Coupling with the structural solver or the thermal solver to consider motion or Joule losses is straightforward.



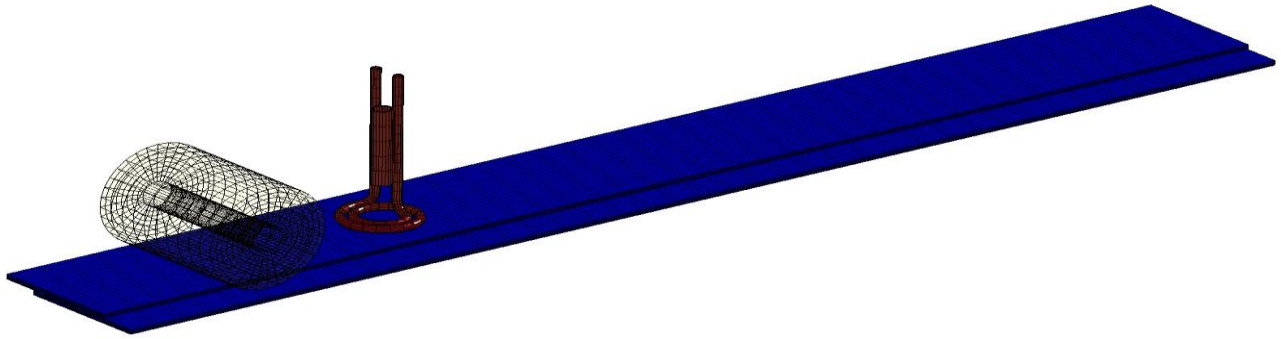
Lenz experiment for eddy current brakes



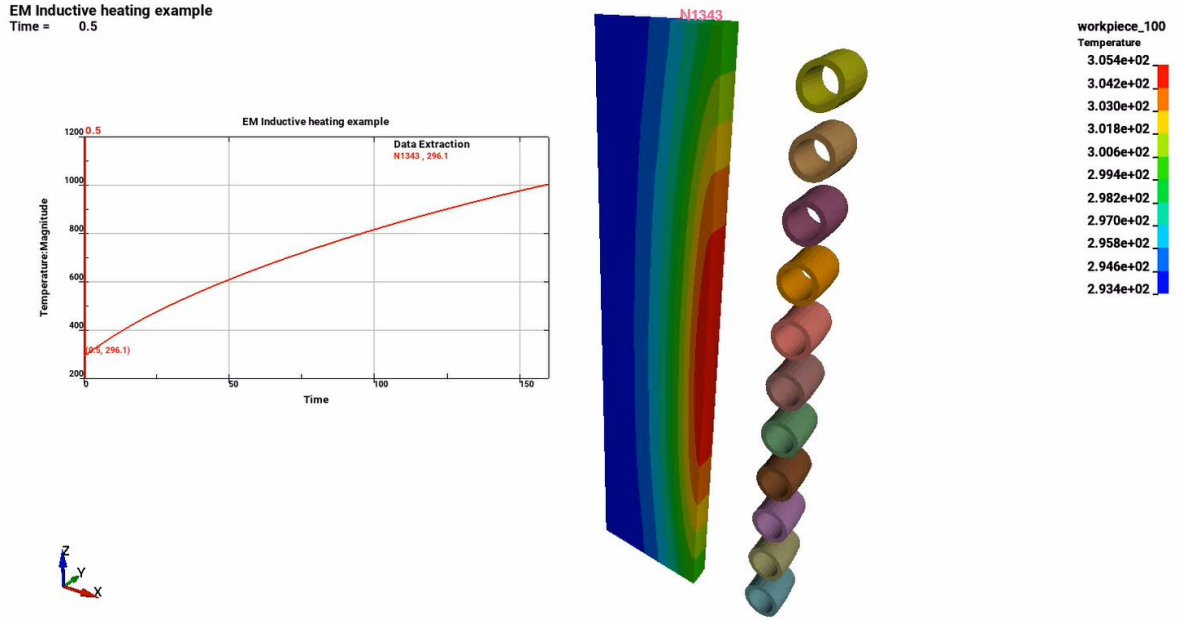
Arago's disk experiment for electromagnetic motor

Inductive heating

- Support of flux concentrators (zero conductivity regions) for more accurate inductive heating simulations thanks to a robust AMS preconditioner.



- Support of features such as 2D axisymmetric solver, or stranded coils to further expand the Inductive heating solver's capabilities.




Ansys