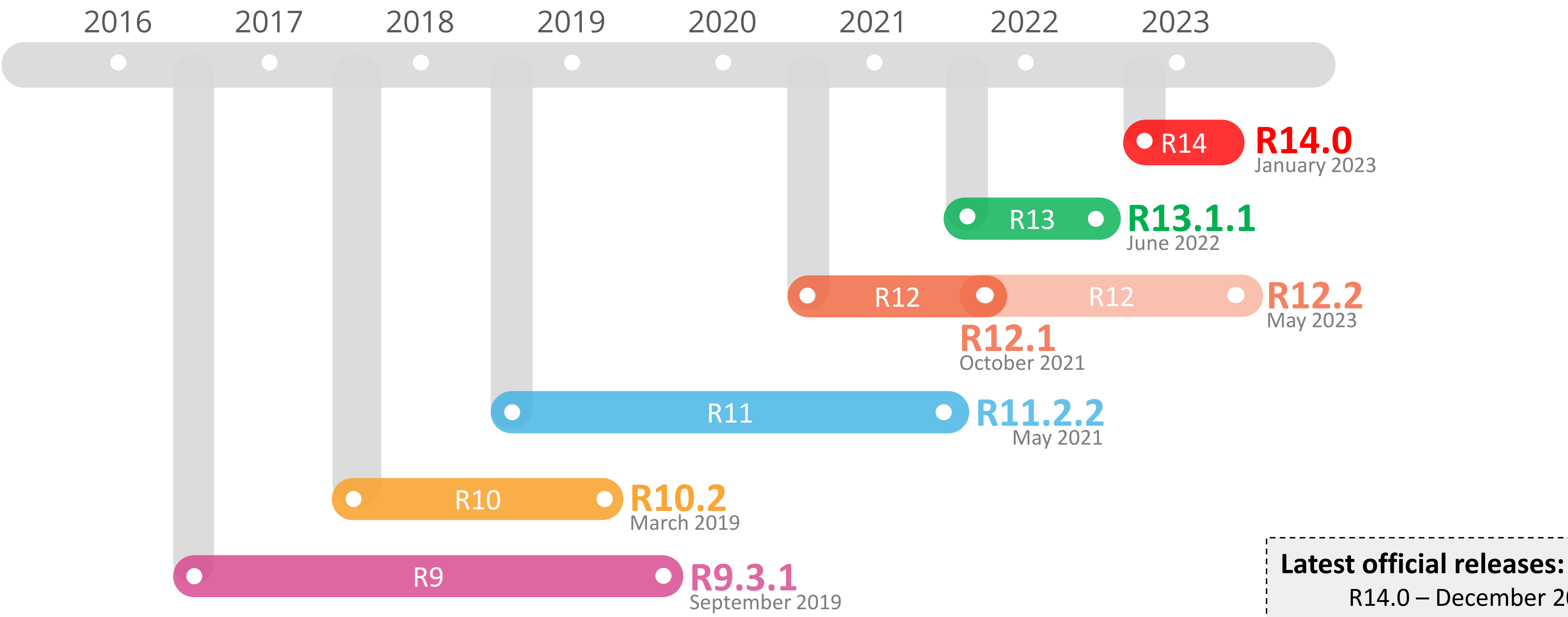
LS-DYNA R14 Highlights

Richard Sturt

LS-DYNA Releases



Latest official releases:

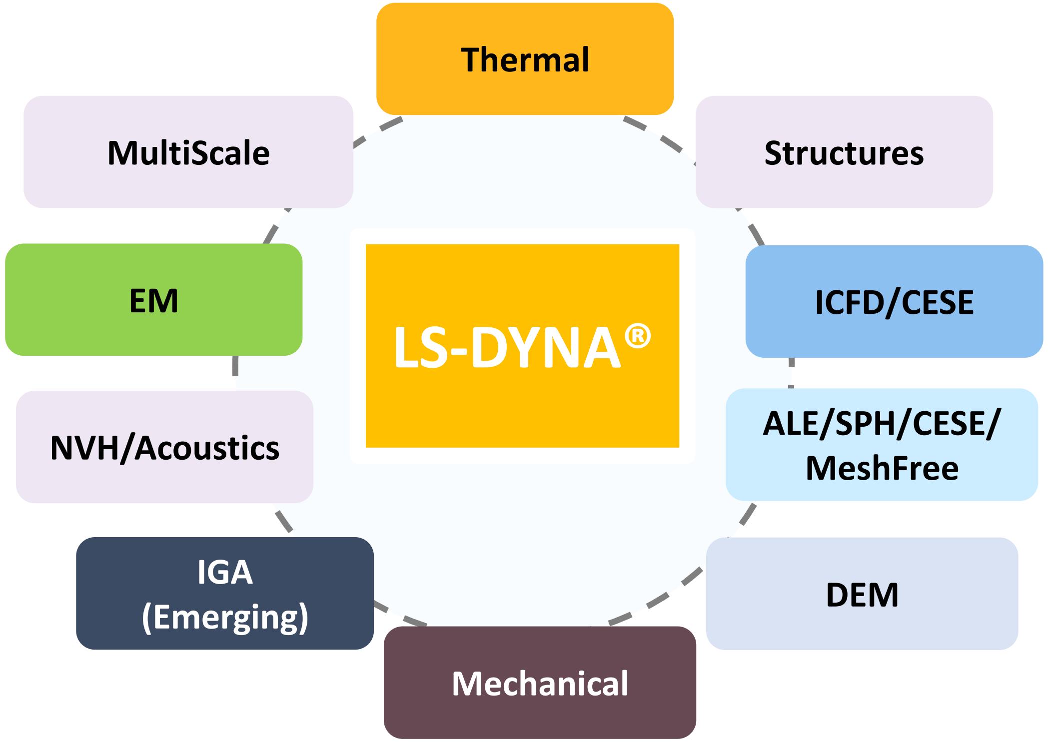
R14.0 – December 2022
R13.1.1 – June 2022
R12.1 – October 2021
R11.2.2 – May 2021

Widely used versions

Ansys

2023R1 (R14) Release features

- Many new capabilities
- All integrated in One Code strategy
  - Tightly Coupled, Scalable Multi-Physics Solver
- R14.0 available since January 2023
  - Minor release 2023R2 (14.1) approx. July 2023
  - All other tools are released at the same time: ANSYS Forming, LS-OPT Pro, LS-TaSC, …
- Detailed documentation in User’s Manuals, release notes



MPI support

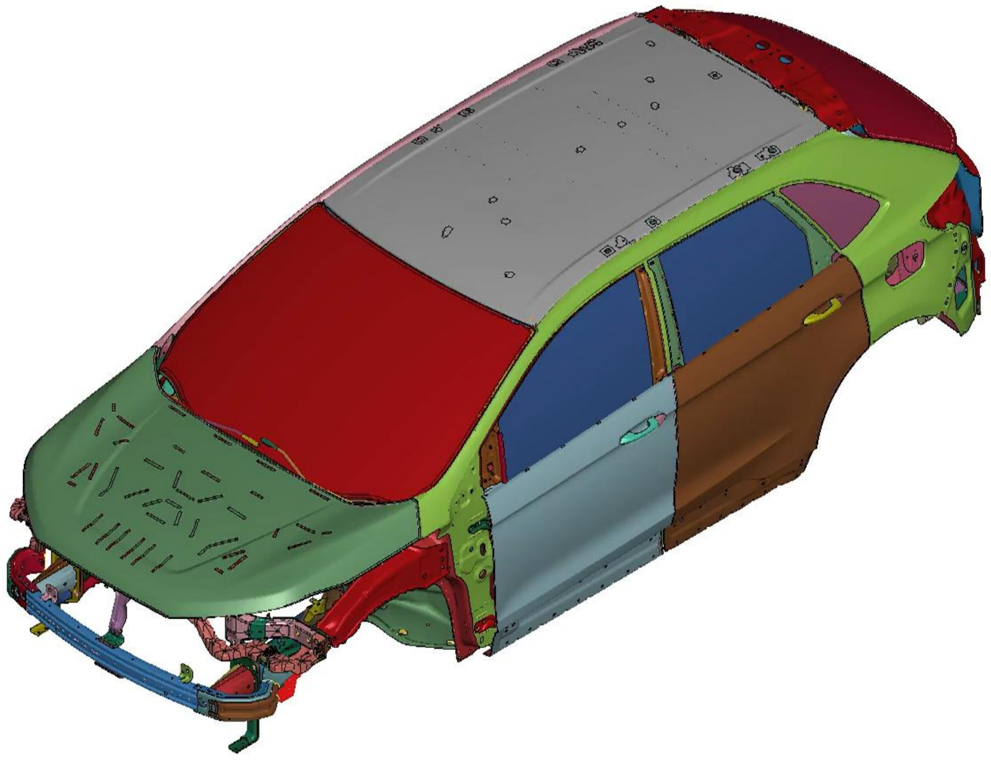
- R14 supports these MPIs:
  - Linux: Intel-MPI, Platform MPI, Open-MPI
  - Windows: MS-MPI, Intel-MPI
- Intel-MPI and Open-MPI are “the future”
- Other MPIs will be dropped in future but timeframe not fixed yet
- Aim to reduce number of executables (QA effort etc)
- OneMPI: the same LS-DYNA executable to support different MPIs via environment variable setting.
- R14: the LS-DYNA Intel-MPI executables have OneMPI capability (instructions available from support team); separate executables for other MPIs will also be provided.

Isogeometric Analysis (IGA)

Ansys

IGA aims and status

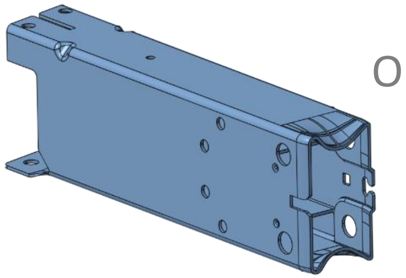
- Use the CAD geometry definition directly in the analysis without an FE mesh
- Aim: accuracy of geometry definition; maintain connection with CAD
- 5-6 OEMs actively pushing this in research mode
- R14 ready for testing (but keep in touch with support team)



courtesy of Ford Motor Company

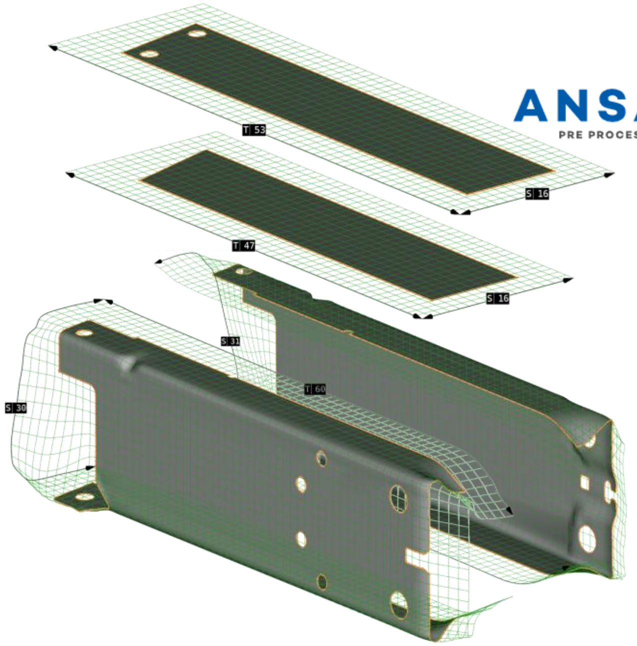
IGA process

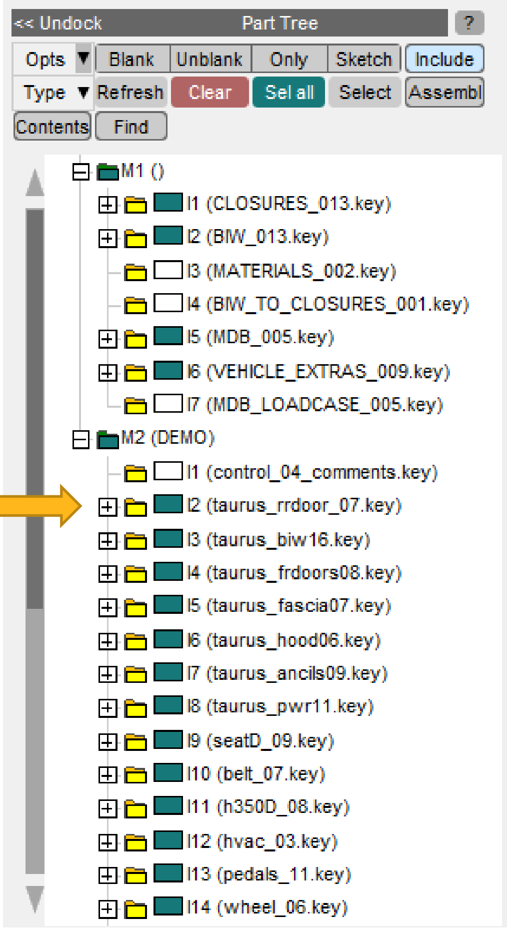
- Pre-processing to clean up the CAD
  - Avoid having a patchwork of small surfaces within one continuous part
  - Eliminating this step would require change of approach by CAD team…
- Export surface translated to *IGA format into an INCLUDE file
- Incorporate within crash model using existing connections, contacts, etc.
- CPU time:
  - For same accuracy at same timestep, IGA is slower
  - IGA can potentially run at a bigger timestep, could then be faster



Original CAD design

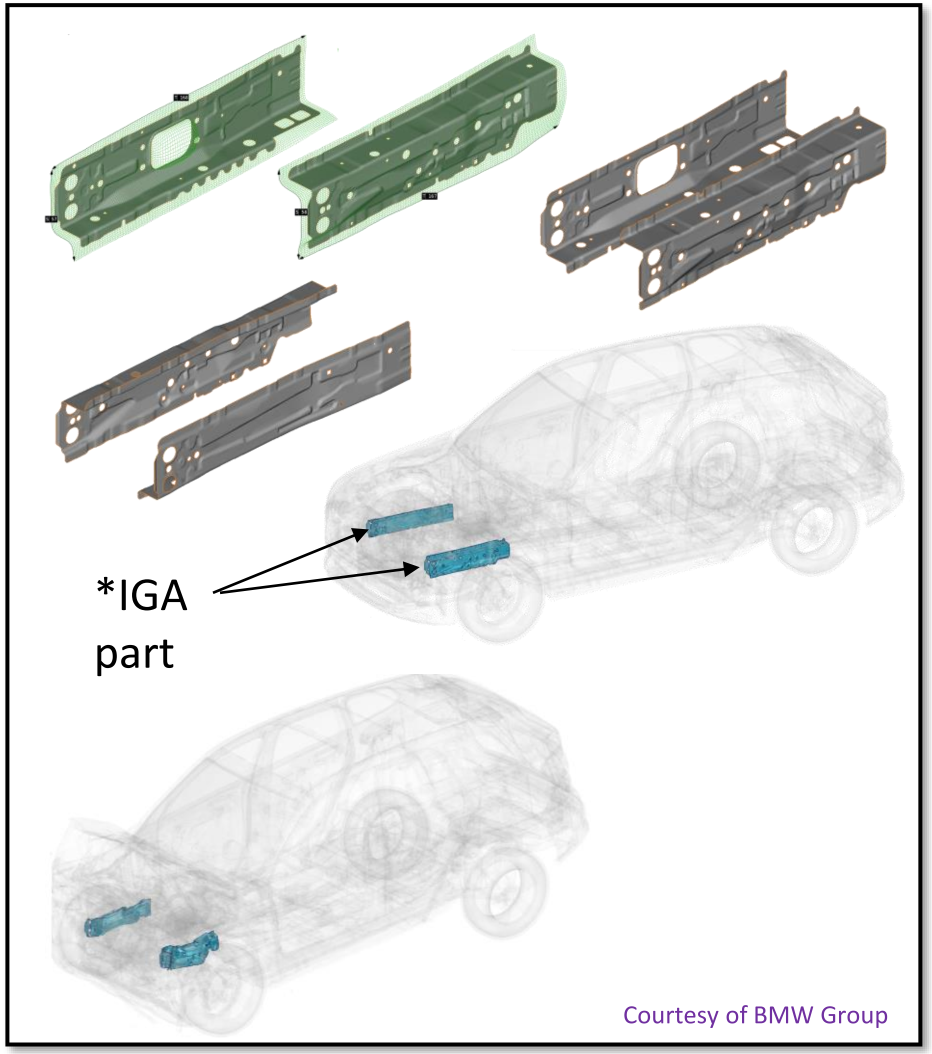
Courtesy of BMW Group





IGA process

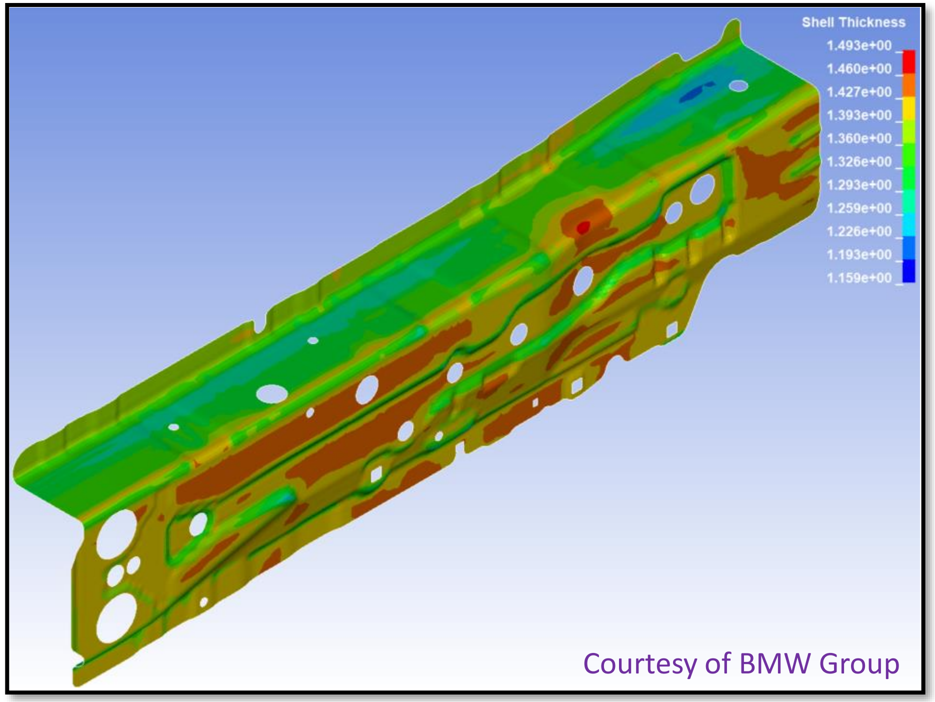
- With R14, parts modelled with *IGA can be included in a typical full crash model successfully
- Contacts, connections, boundary conditions all work, as for FE parts
- No need to change control cards or other crash model settings



Hybrid assembly – Full vehicle front crash

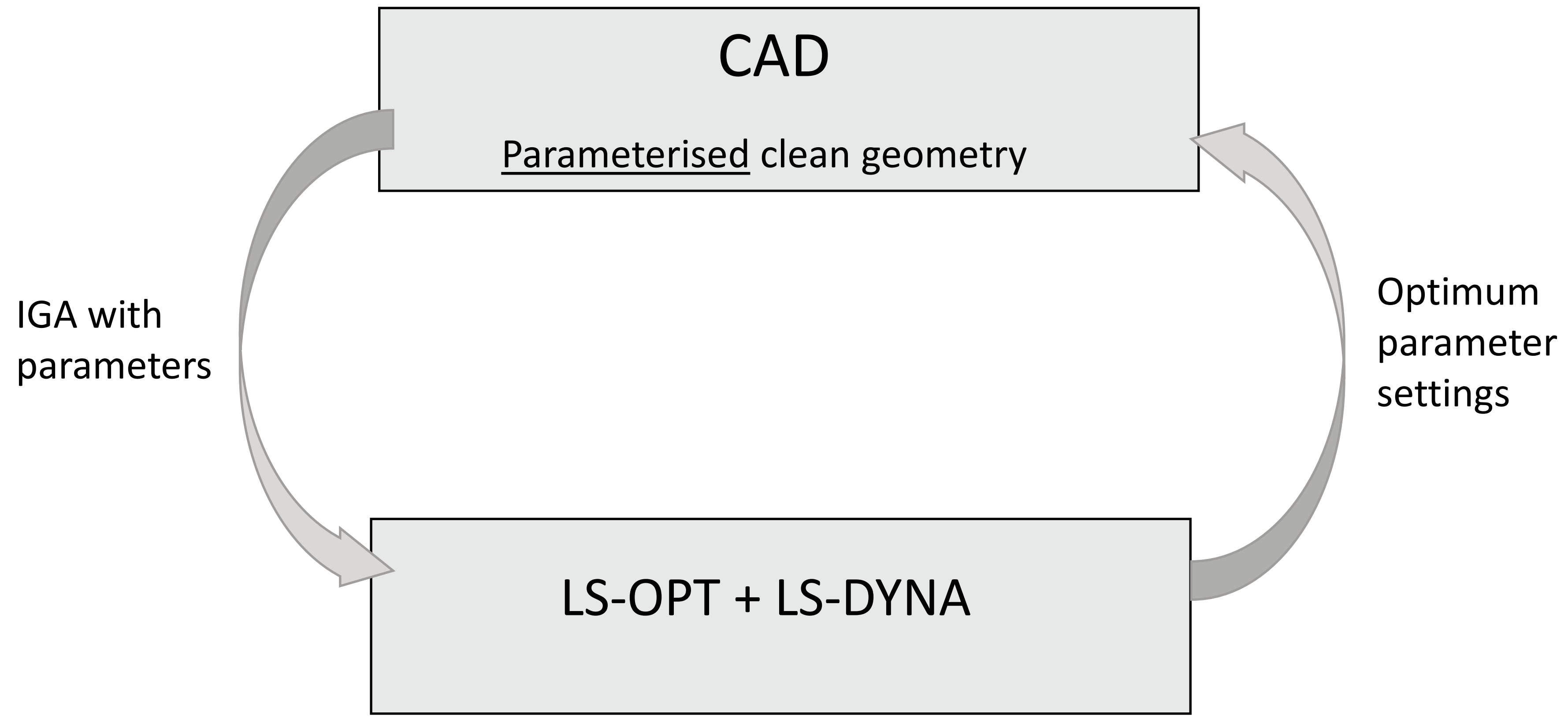
Mapping/Initializing

- Support multistage analysis (i.e. stamping) via dynain-file
- Keyword *INITIAL_STRESS/STRAIN_IGA_SHELL
- Allows the initialization of the following quantities at integration points:
  - Shell thickness
  - Initial stresses
  - Initial strains
  - Initial plastic strains
  - History variables



Shell thickness mapped via dynain-file using ENVYO

IGA process


CAD
Parameterised clean geometry
IGA with parameters
Optimum parameter settings
LS-OPT + LS-DYNA

IGA current development: solids

16th LS-DYNA Forum 2022 | Bamberg, Germany

Analysis of 3D structures using IGA solids: Current status and future directions

Stefan Hartmann, Lukas Leidinger
DYNAmore GmbH, Germany

Manuel Meßmer
Technical University of Munich, Germany

Liping Li, Marco Pigazzini, Lam Nguyen, Attila Nagy, Dave Benson
Ansys/LST, Livermore, CA, USA

1st eigenmode

M. Meßmer, 13th European LS-DYNA Conference 2021, Ulm, Germany.

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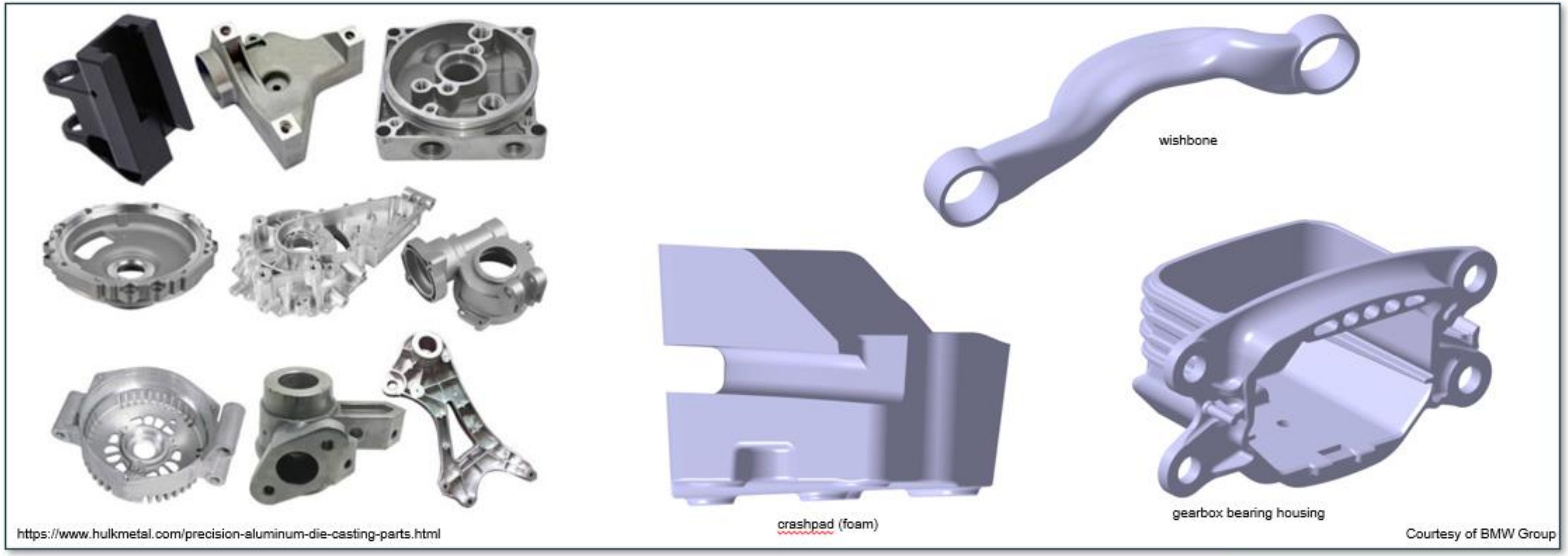
IGA current development: solids

Motivation

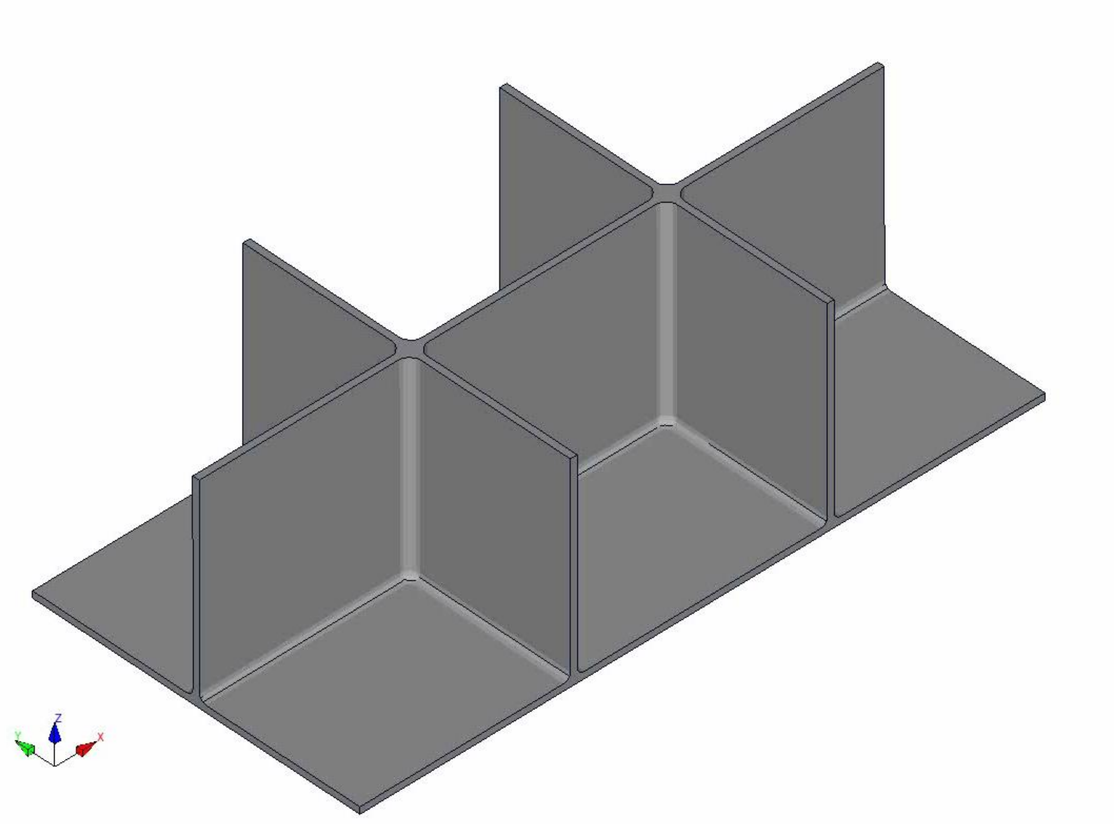
Volume components in engineering

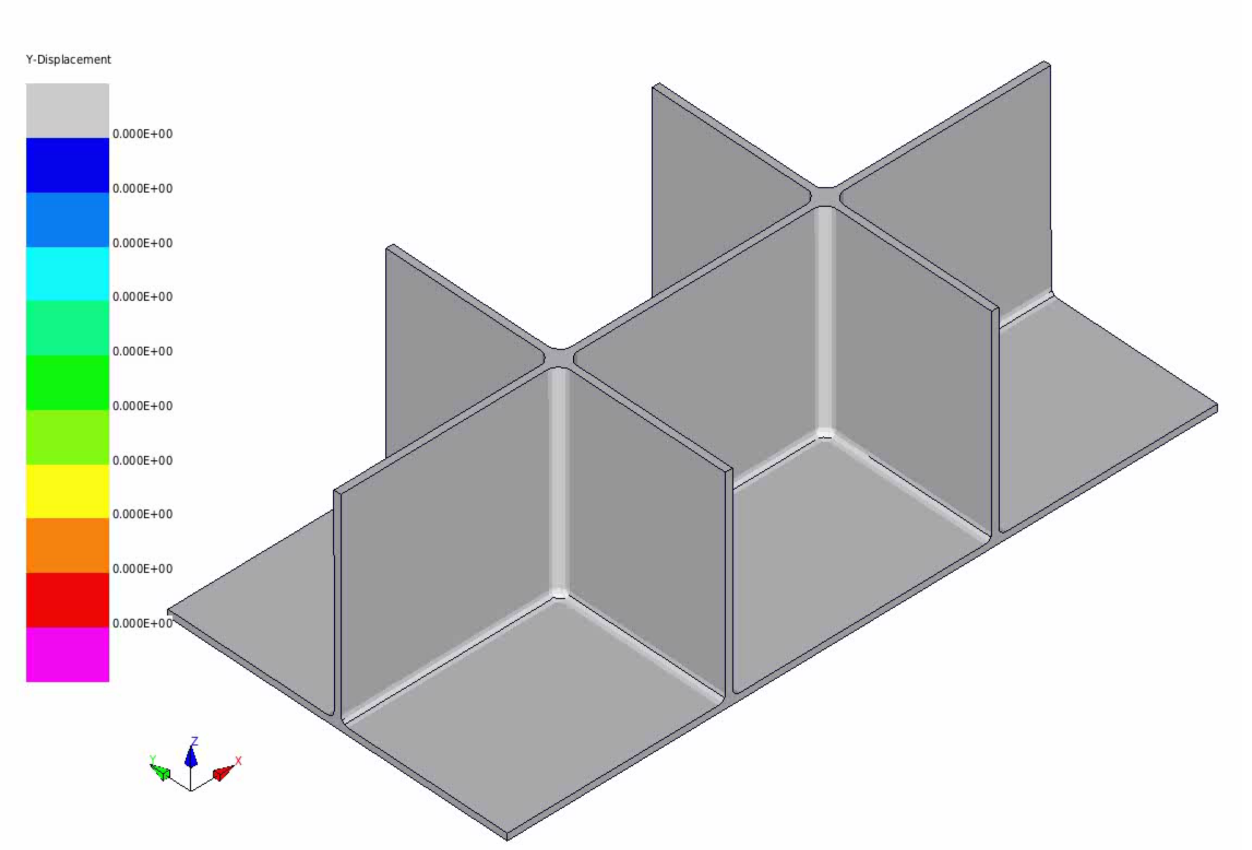
- Cast parts in car
  - Not practically feasible to model them with finite shell elements



IGA current development: solids

IGA 2mm





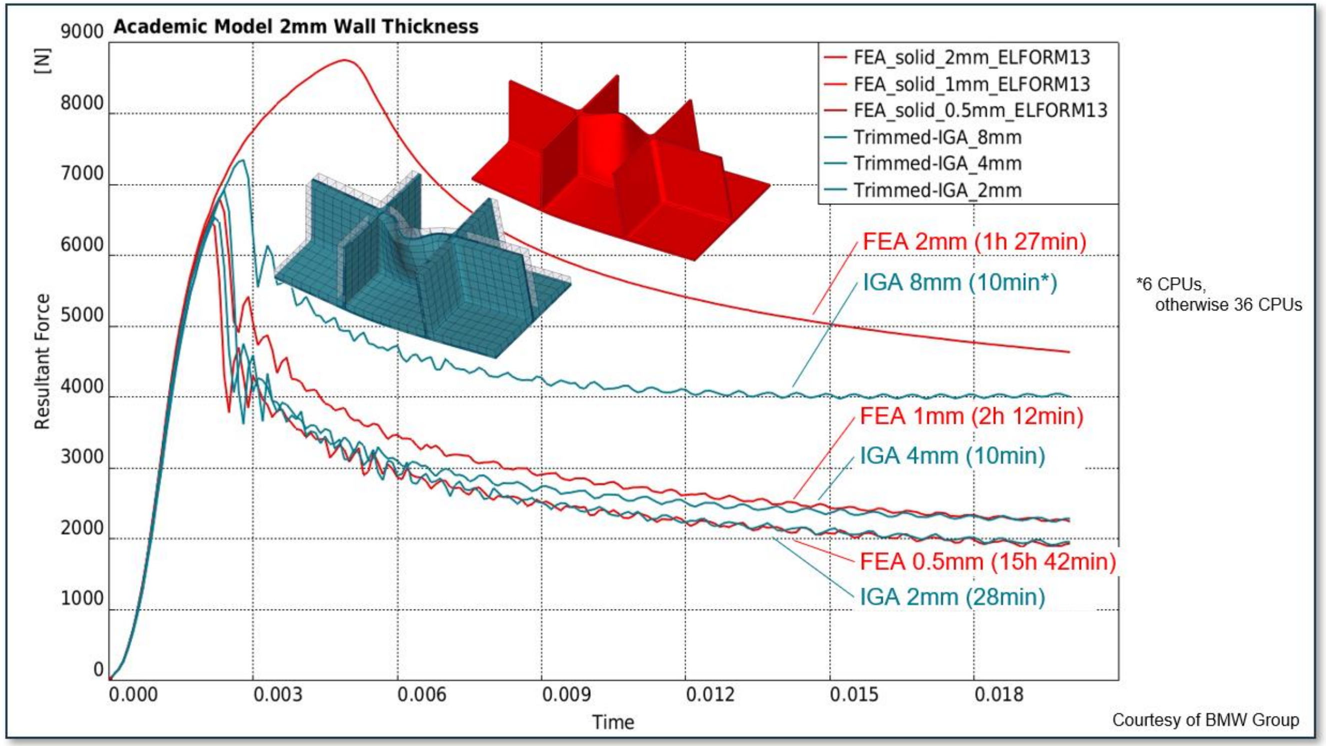
Courtesy of BMW Group

IGA current development: solids

Examples

Academic Cast Component: FEA vs. IGA

- Resultant Force and computational time
- Comparable accuracy:
  - FEA_1mm – IGA_4mm
  - FEA_0.5mm – IGA_2mm
- Finest trimmed IGA model is 3x faster than coarsest FE model!
- Larger time step for trimmed IGA (at least 4x higher here)
  - Feasible time step for full vehicle simulations could be achieved with 4mm trimmed IGA solids



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Battery modelling

Modeling Options

- Randle circuit models on different scales & level of detail

Micro scale (*EM_RANDLES_SOLID)

- Detailed modeling of battery layers.

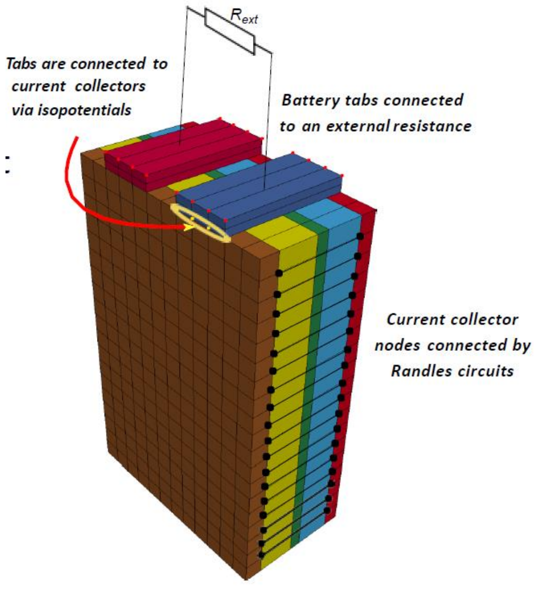
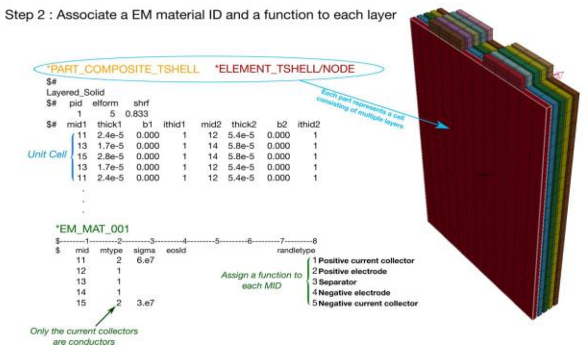


*Figure scaled in thickness direction

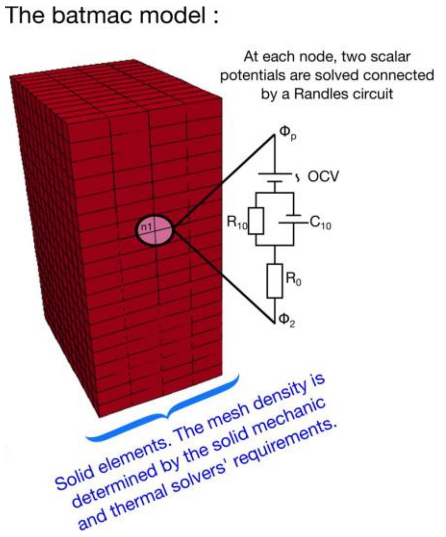
Meso scale (*EM_RANDLES_TSHELL)

- Modeled using thick shell to allow faster run.
- Layer definition is still required.



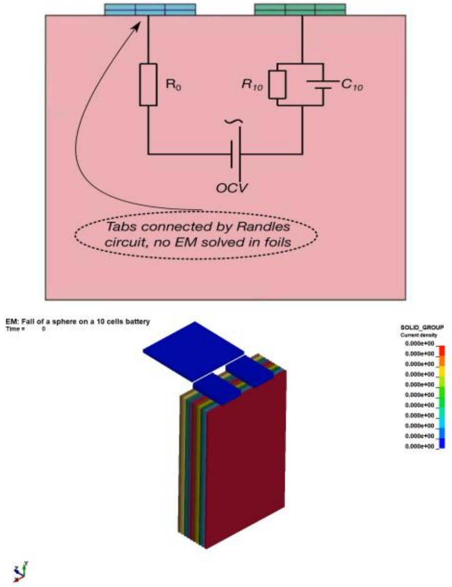
Macro scale (*EM_RANDLES_BATMAC)

- Modeling at nodal level to allow fastest run.
- Suitable candidate when considering Multiphysics work.



Meshless model (*EM_RANDLES_MESHLESS)

- Battery internal layers are not modeled.
- Suitable for external shorts modeling.



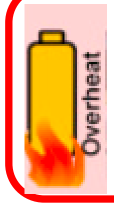
Testing Matrix

Physics	Test Required	Test Outcome

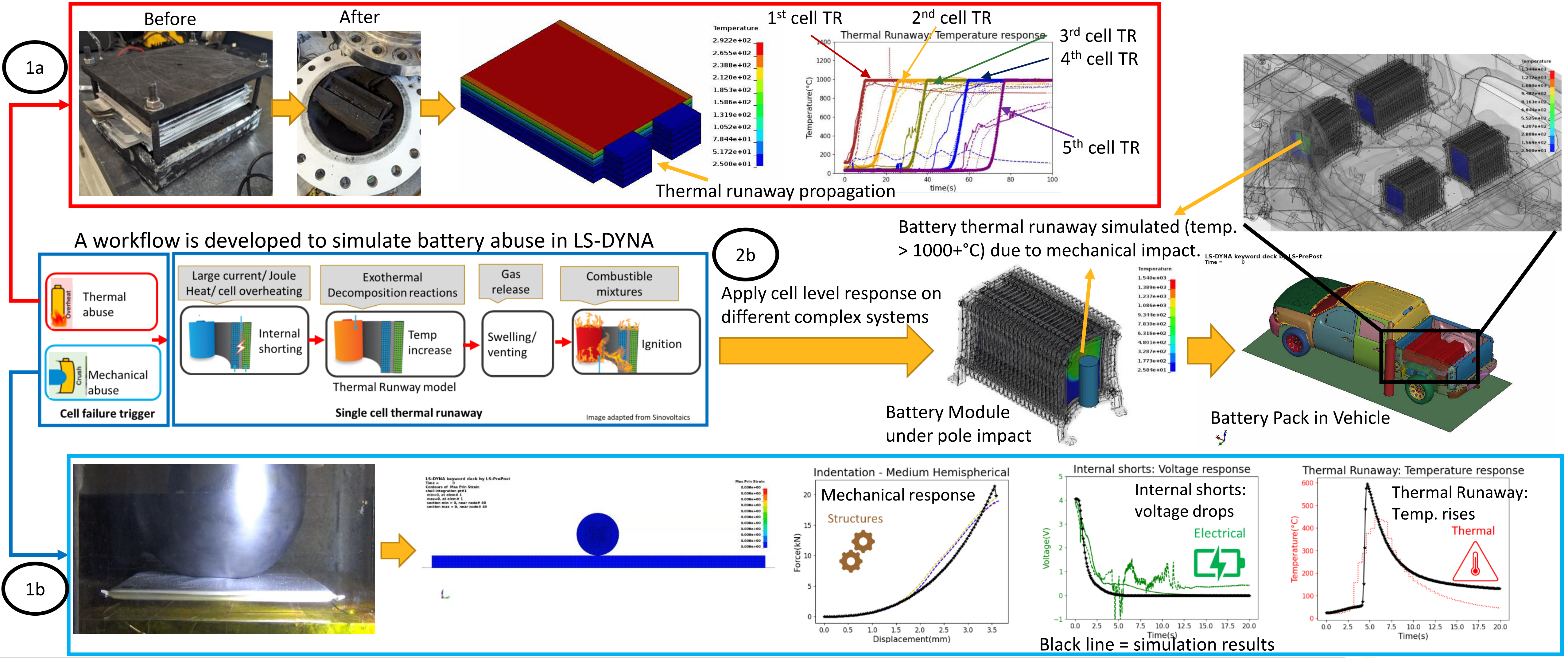
Electrical	HPPC/Capacity Test	• Voltage vs. SOC
		• Voltage vs. current
		  • SOC
		  • temperature

Mechanical abuse	Mechanical Tests • Compression Test (Calibration) • Indentation Test (Validation)	• Force vs. Displacement • Voltage drop profile • Temperature rise profile

Thermal abuse	Thermal Tests
	• Thermal Runaway Test
		• Thermal properties
		  • Heat Capacity
		  • Thermal conductivities
		• Voltage drop profile
		• Temperature rise profile
		• Gas release information



LS-DYNA Battery Abuse Simulation: From Single Cell to EVs



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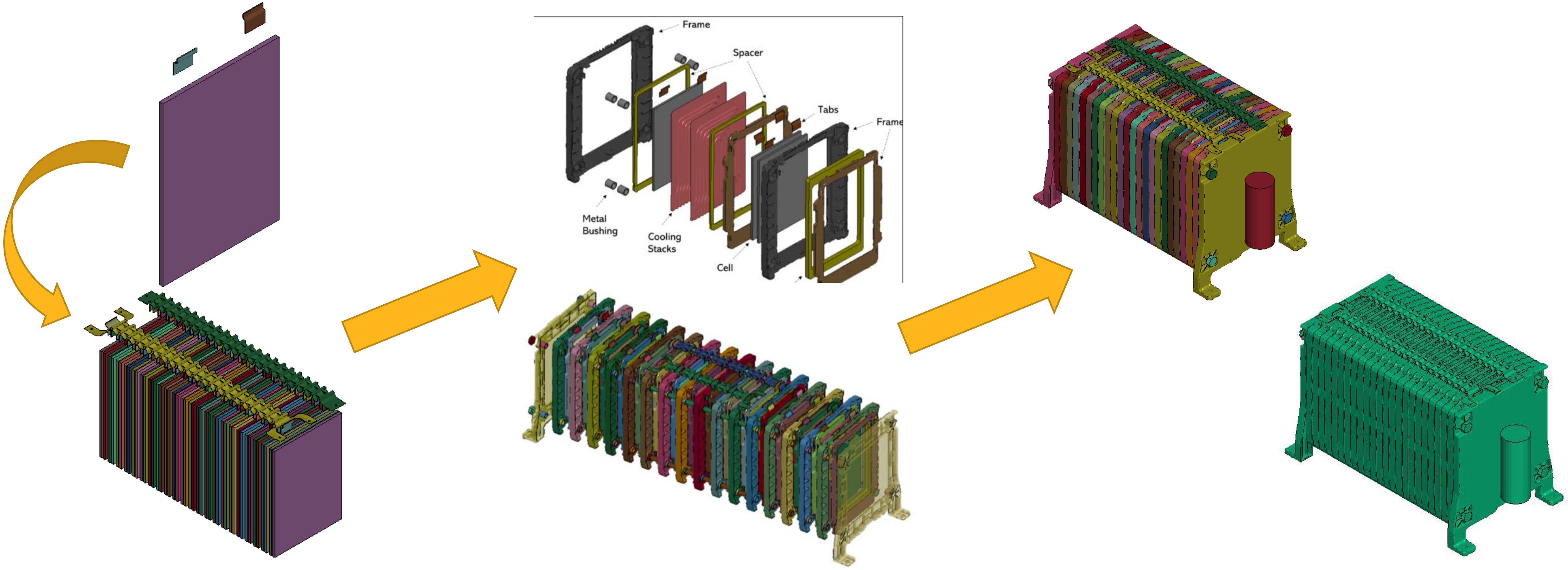
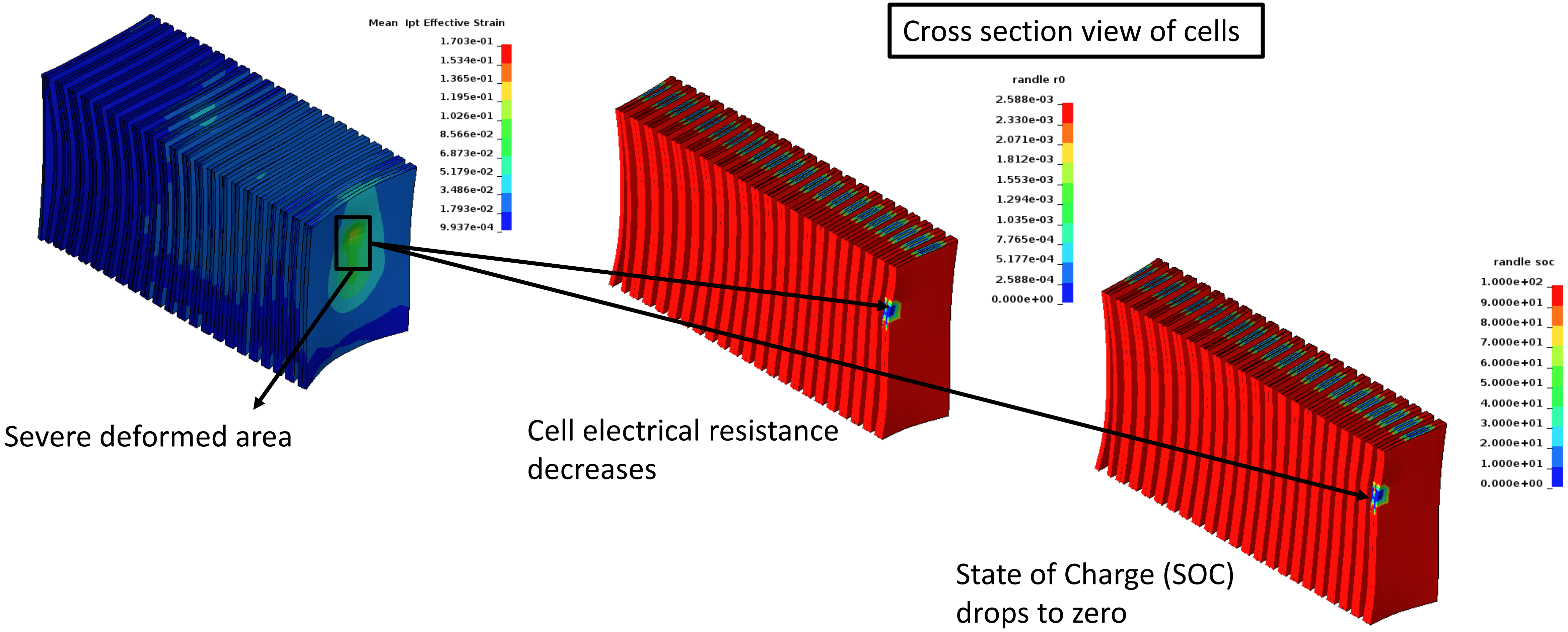
Single Cell to Module

- The single cell model developed previously is scaled to a battery module.
- The battery module is subjected to pole impact to investigate thermal runaway event.



Single Cell to Module

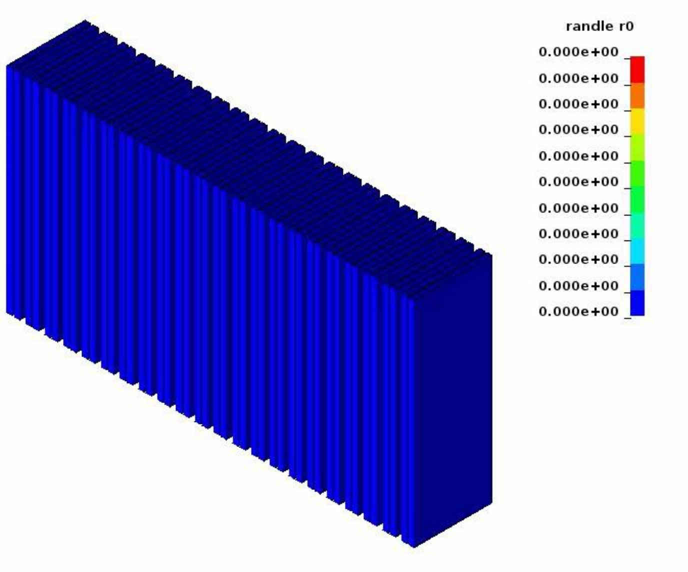
- Internal shorts and exothermic reaction criteria is met under mechanical loading



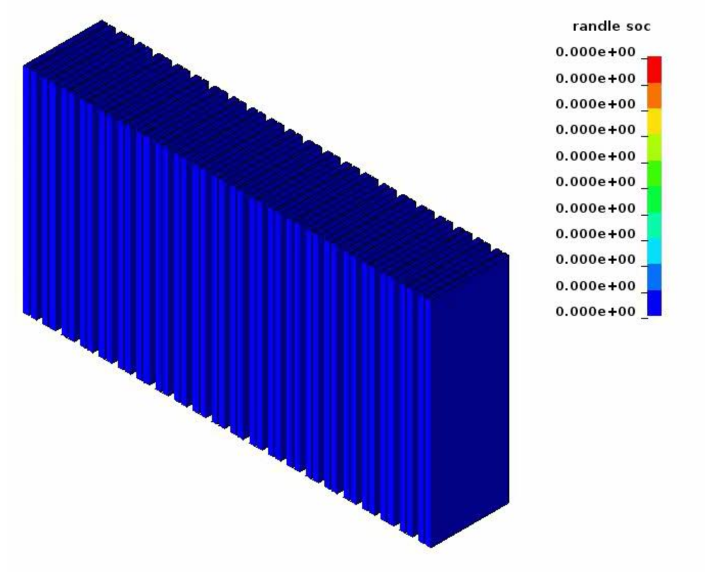
Single Cell to Module

- Internal shorts and exothermic reaction criteria is met under mechanical loading
- Resistance/SOC decreases and propagates as temperature rises.
- Additional simulation including cell-cell temperature propagation can also be modeled.

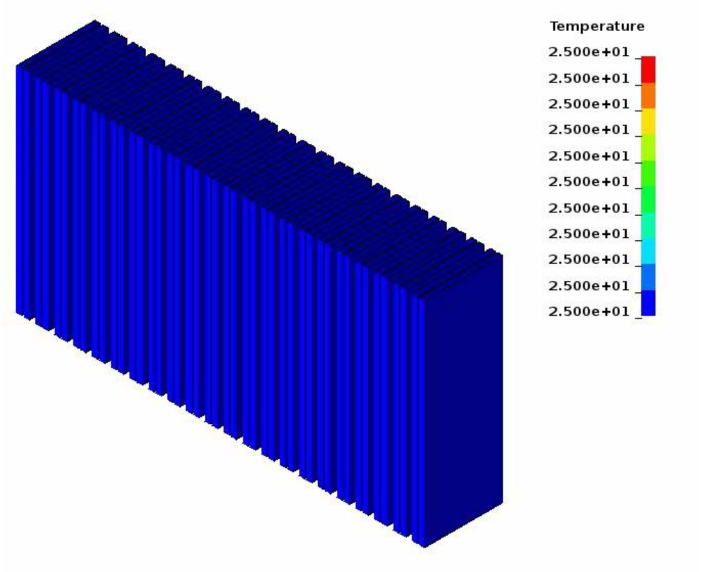
Resistance



State of Charge (SOC)



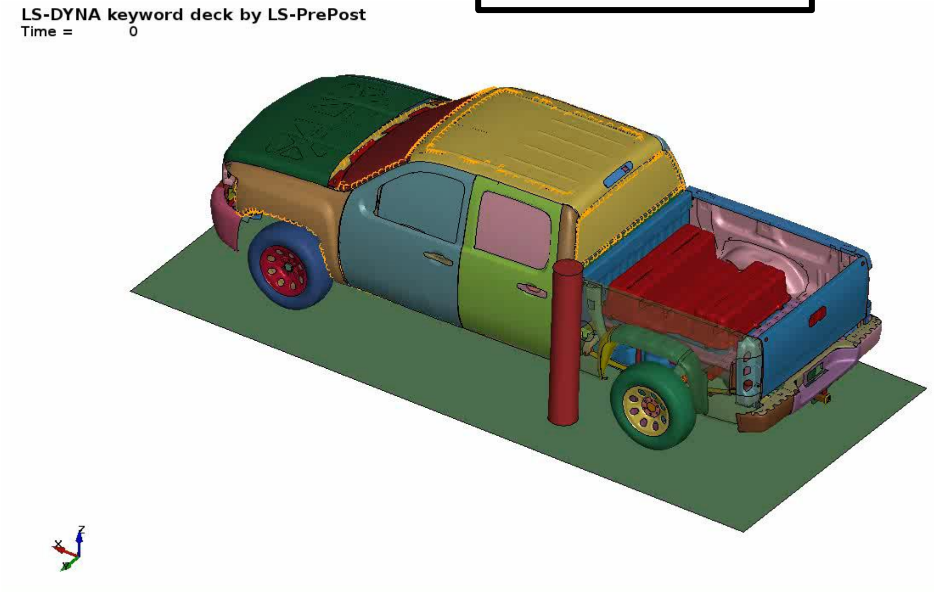
Temperature



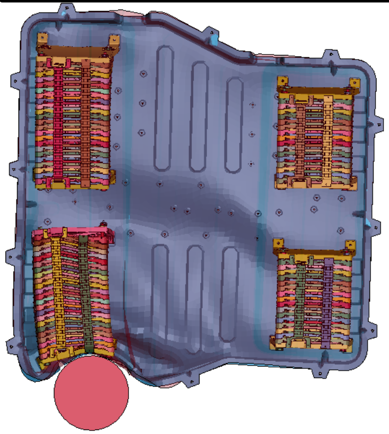
Module to Full Vehicle

- A battery pack is modeled and mounted on a truck vehicle while side impact simulation is performed.

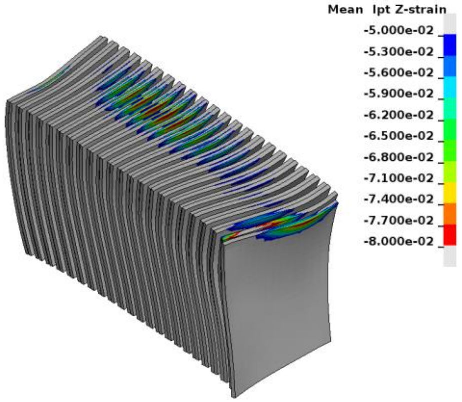
Vehicle impact

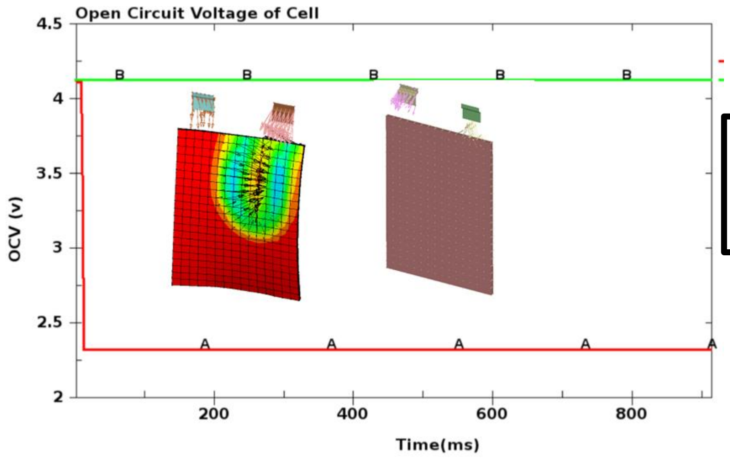


Pack deformation



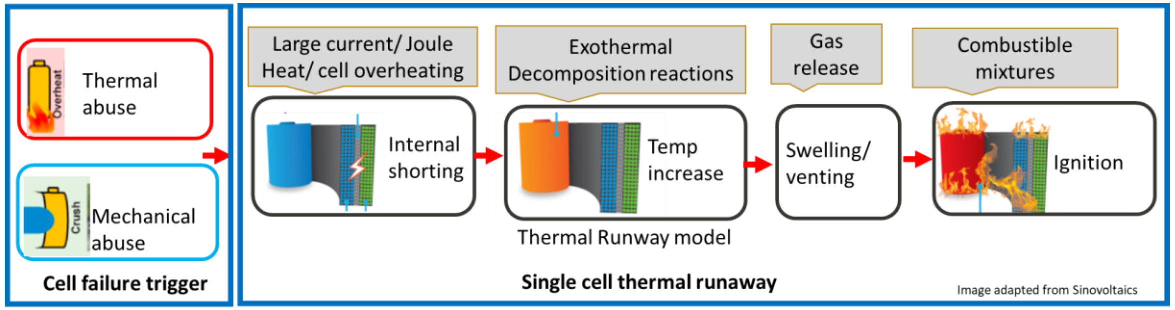
Some cells are shorted





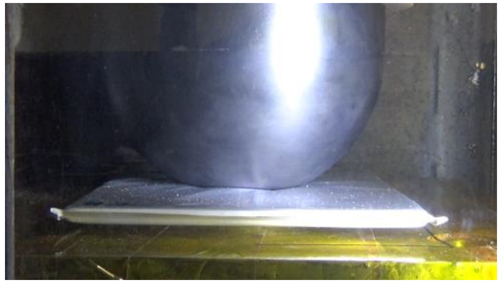
Cell's voltage drop due to shorts

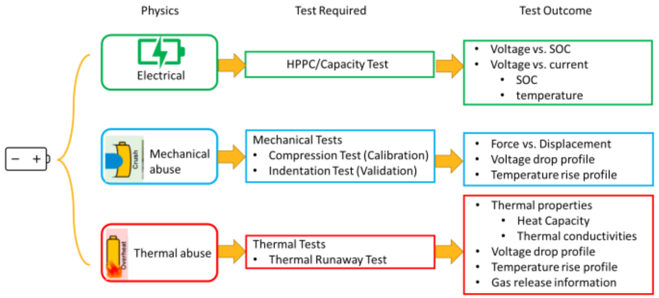
Battery Abuse Simulation - Overview

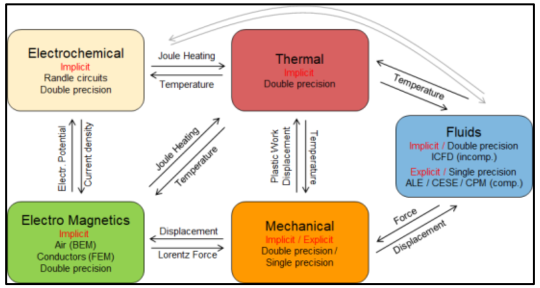


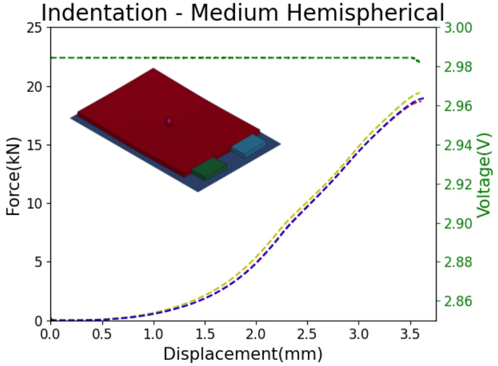
A workflow is developed to simulate battery abuse

Experimental tests performed to collect cell's characteristics

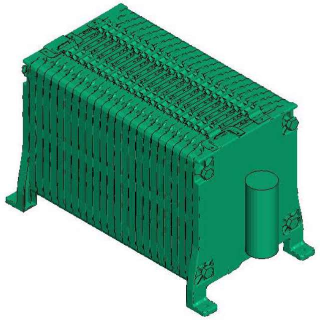


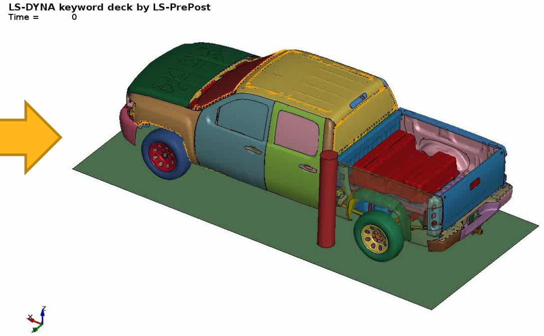






'Digitize' and simulate cell's properties numerically (FEM)





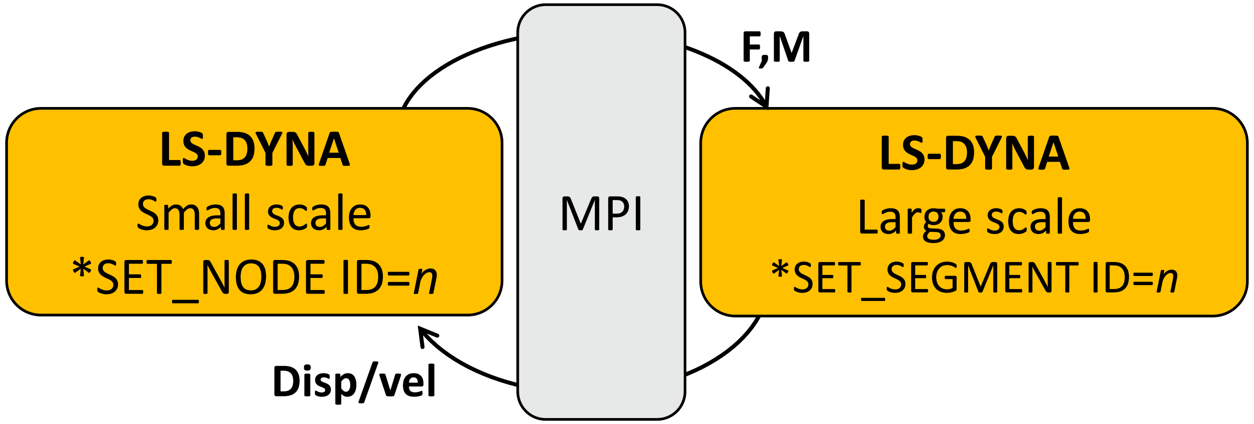
Ability to scale single cell response to complex systems

Multiscale & Mesh-free

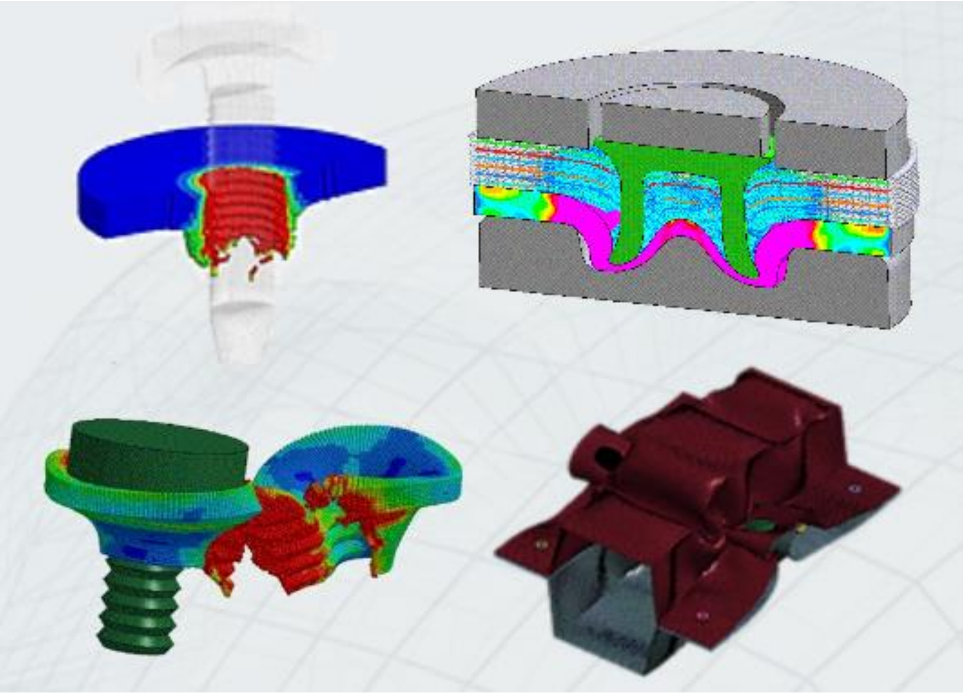
Ansys

Two-scale co-simulation

- *INCLUDE_COSIM
  - 2-way interaction of LS-DYNA models, e.g. structure model + detailed joint model
  - The two models run quasi-independently but talk to each other via MPI
  - Tied contact approach to connect the two models



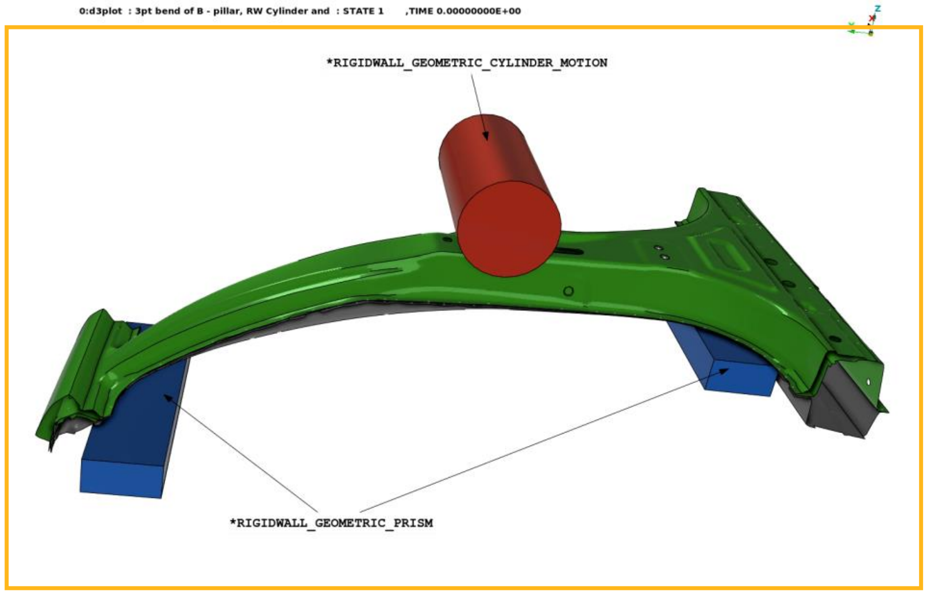
From www.lstc-cmmg.org



Implicit

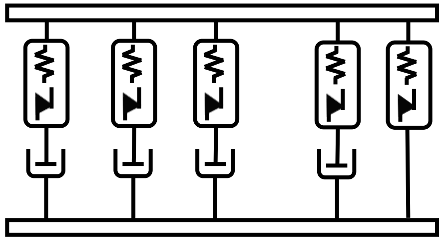
Implicit Developments

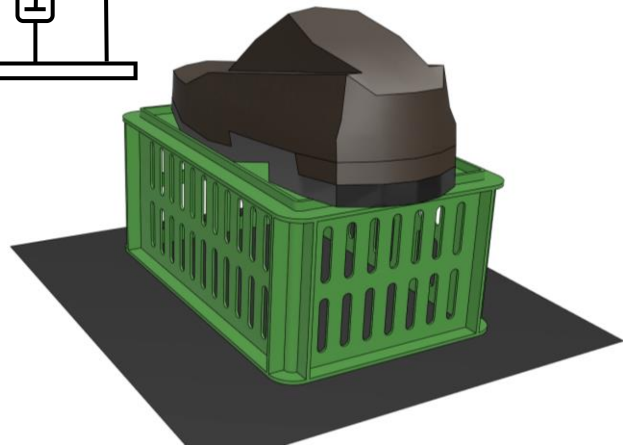
- Ongoing efforts to improve solution speed and memory management
- Faster output of FRF "subcases" with different input points (not R14)
- The option IACC=2 on *CONTROL_ACCURACY is introduced for explicit analysis
  - For making implicit and explicit more compatible when switching between the two
  - For instance, this will invoke the strongly objective tied contacts even for explicit analysis
- Various inequality constraints are now supported by way of Lagrangian Multipliers
  - Rigid body stoppers, rigid walls, contact entity
  - Improves convergence for these features



Materials

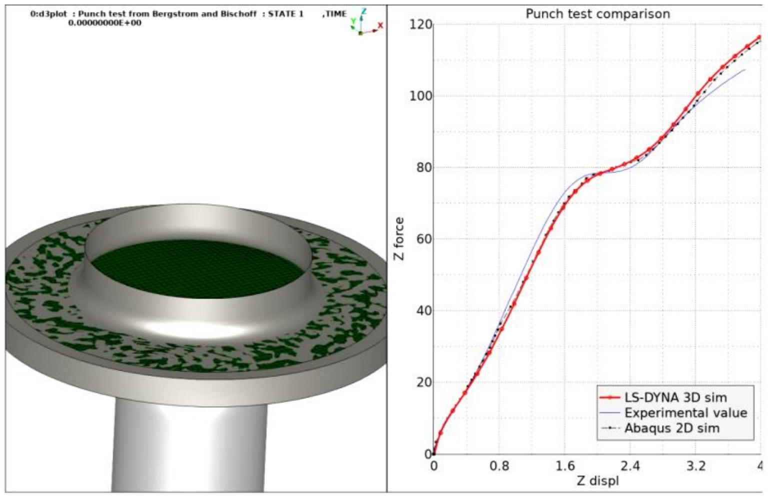
Nonlinear Viscoelasticity (Creep)





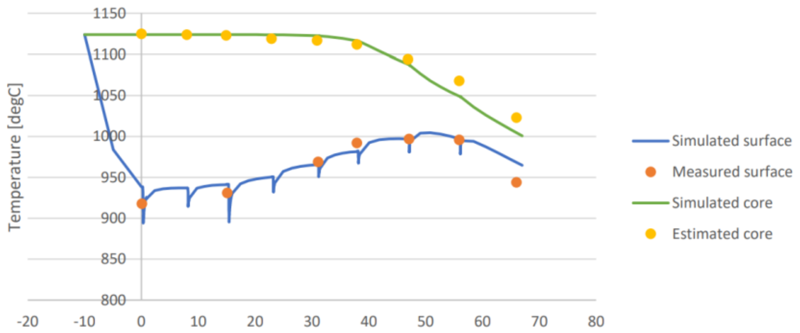
- Enhancements for *MAT_ADD_INELASTICITY
  - supplemented with nonlinear viscoelastic laws, efficient variants of the creep laws
  - The relaxation coefficients in Prony series can depend on stress and strain to effectively support the Norton-Bailey and Bergström-Boyce creep laws
  - Paper by Bengzon et al. (2021), see www.dynalook.com

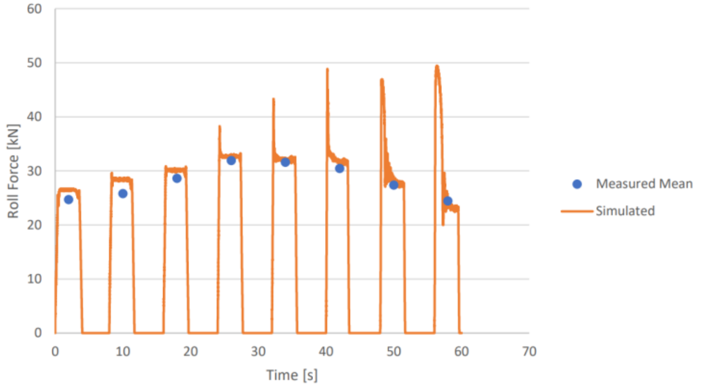
- New *MAT_318 aka *MAT_TNM_POLYMER
  - Model for forming of thermoplastics including temperature effects
  - E.g. UHMWPE used in medical devices
  - Paper by Bergström and Bischoff (2010)
  - https://polymerfem.com/three-network-model

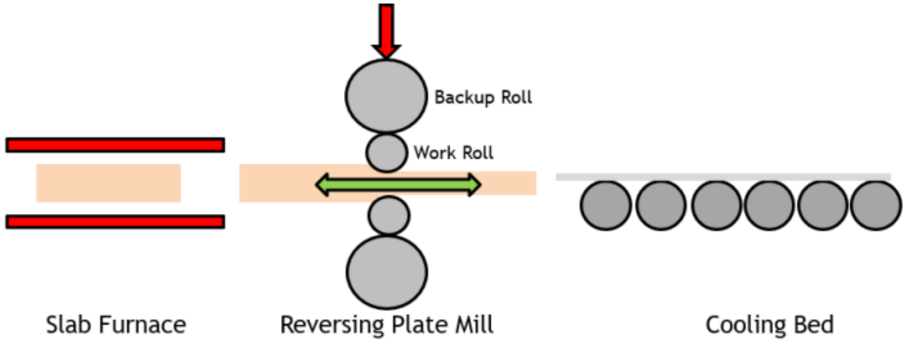


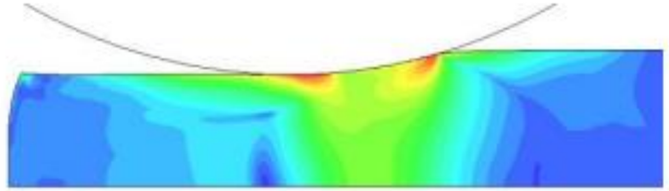
Hot Forming and Thermoplasticity

- New *MAT_HOT_PLATE_ROLLING (*MAT_305)
- Thermoelastoplastic material for hot rolling
  - Features: work hardening, dynamic softening, static recovery, and static recrystallization
  - Input parameters: calibrated from Gleeble tests at various deformation rates and temperatures
  - Developed in cooperation with Swedish steel industry to create virtual process lines for working and heat treatment processes
  - Paper by Schill et al. (2021), see www.dynalook.com



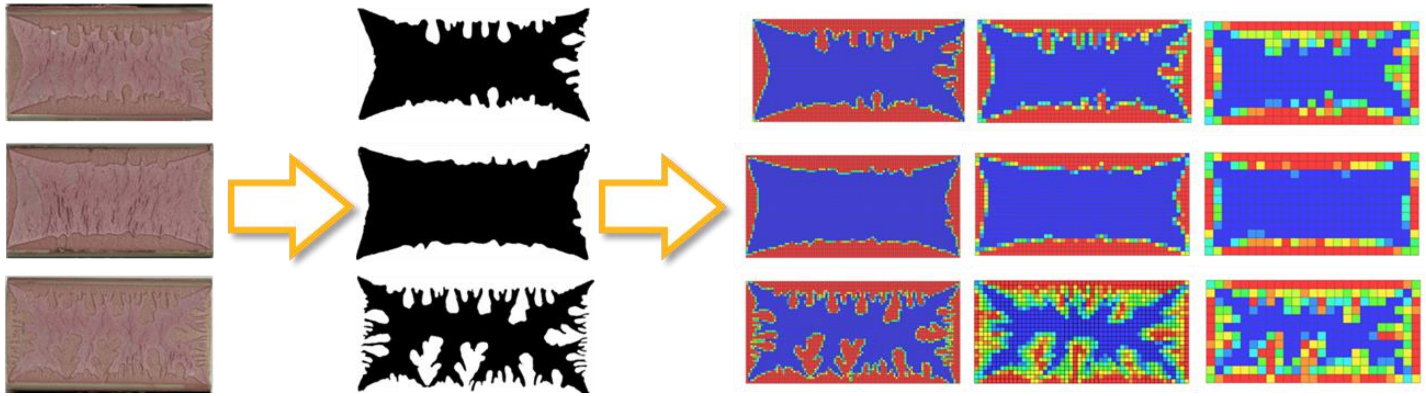


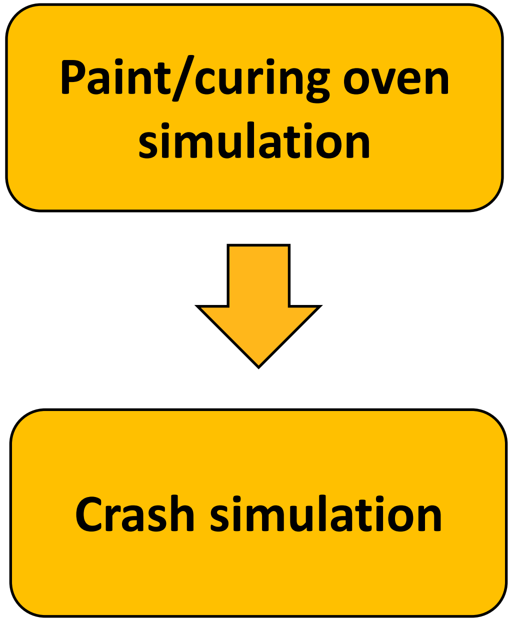




New options in *MAT_307 for thermoset adhesives

- Distortional hardening with respect to temperature variations
  - Temperature dependence for shape of yield surface (non associated $I_1 - J_2$ plasticity of TAPO model)
  - Yield strength depends on temperature and degree of cure
- Differentiation of damage mechanisms
  - Material damage mechanism based on TAPO model
  - Phenomenological approach for (pre-)damage due to viscous fingering in the liquid phase of the adhesive

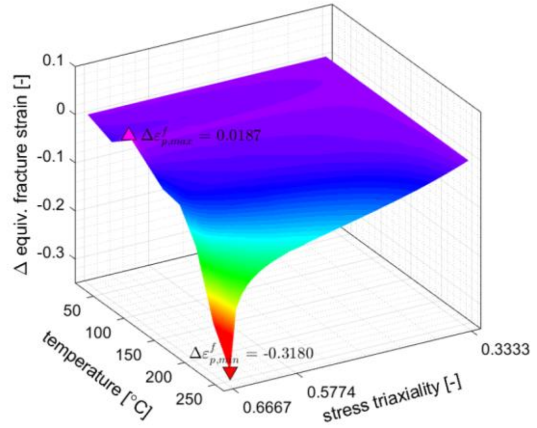




Updates for *MAT_ADD_DAMAGE_GISSMO

- Properties depending on more and more variables
  - Failure/critical strain as function of plastic strain rate, temperature, Lode parameter, and triaxiality
  - Regularization factor as function of Lode parameter, triaxiality, and element size
  - Fading exponent as function of element size, triaxiality, and Lode parameter
  - Analytical failure strain, i.e. LCSDG<0 refers to *DEFINE_FUNCTION,
    got new arguments: plastic strain rate, temperature, history, element size.

  ⟶ **Improved failure prediction for large variety of applications**

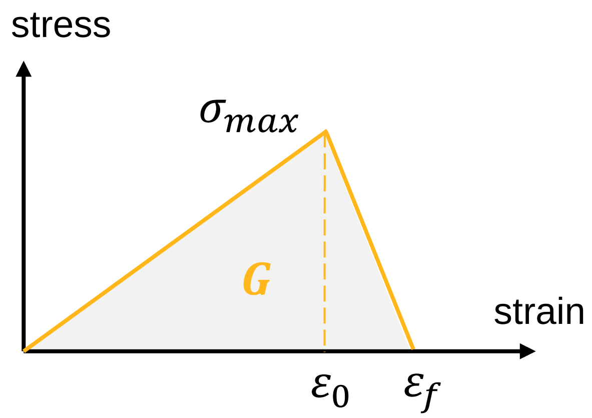


- Added new flag INSTF for instability treatment
  - This flag governs the behavior of instability measure, F , and fading exponent, FADEXP

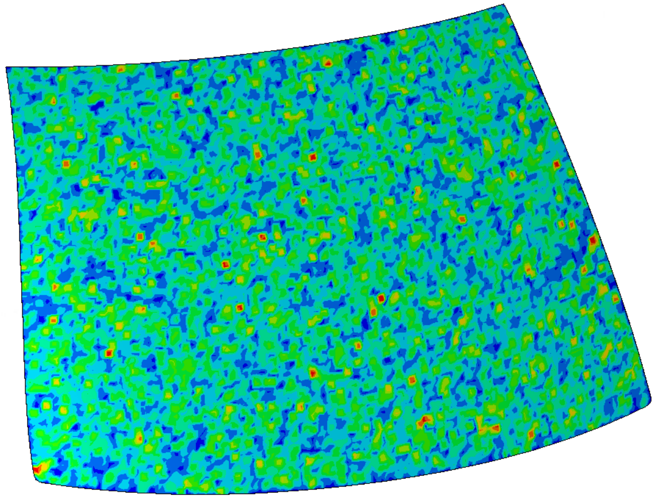
  ⟶ **Better agreement with experimental data in post-necking behavior under various stress states**

Glass model enhancements (*MAT_280)

- Optional damage model invoked by input of fracture energy
  - Orthotropic damage model with linear softening governed by crack opening strain
  - This can replace the existing approach of stress reduction over a few cycles



- Spatially varying distribution of properties
  - Scale factor for FT (tensile strength) on history variable #13 can be defined per element with *INITIAL_STRESS_SHELL
  - … or as automatically generated distribution by the new keyword option _STOCHASTIC (needs *DEFINE_STOCHASTIC_VARIATION)



e.g. windshield with inhomogeneous defects

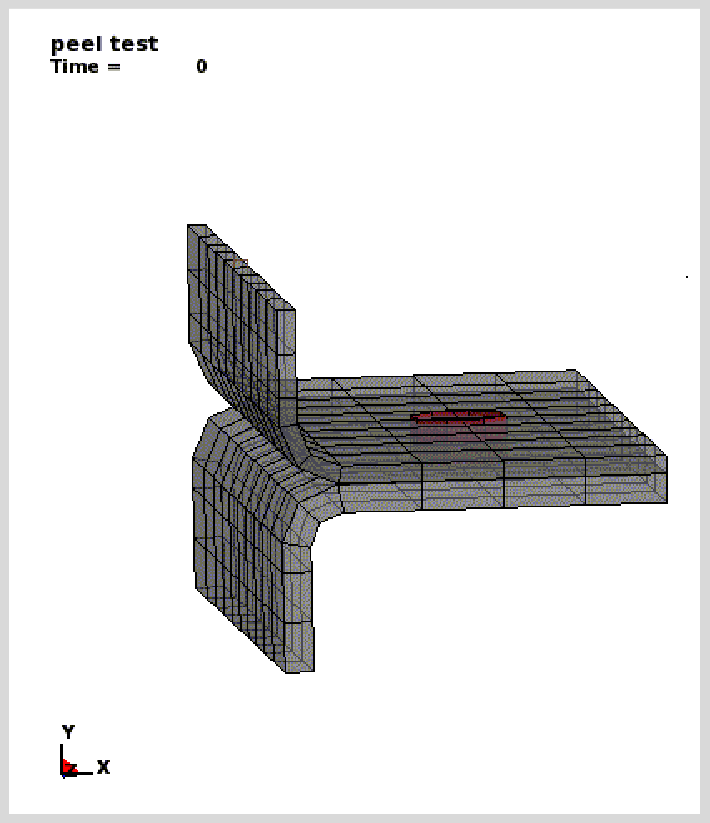
Connections

Ansys

Updates for SPR3 connectors

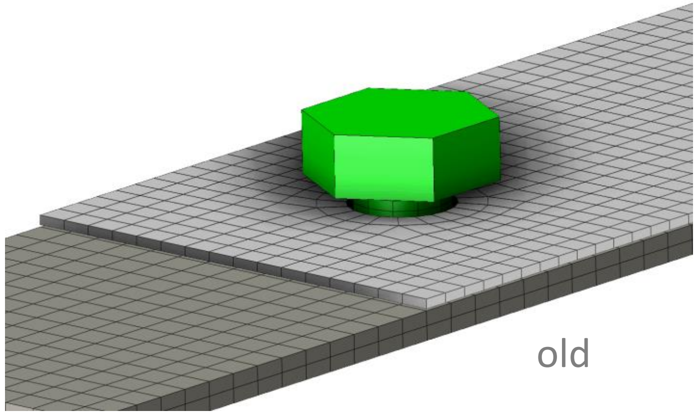
New options for *CONSTRAINED_INTERPOLATION_SPOTWELD aka “SPR3”

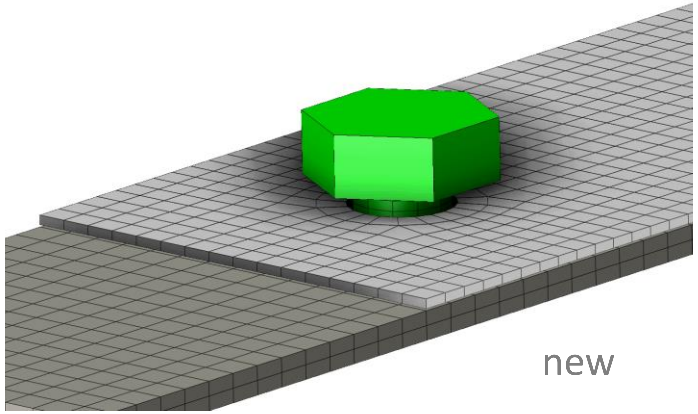
- Connection to thick sheets or volume components
  - Meets increased demand for using hex and tet elements
- Connection to in-plane composed parts, i.e., part sets
  - E.g. tailor welded blanks or other areas with different properties
- Introduction of “peel ratio”
  - Better load and failure prediction in bending-dominated cases
- Simplified scaling of properties
  - Modify strengths, but keep shape of load-displacement curve



Preloading Bolts

- IZSHEAR=2 for solid element bolts has been extended to KBEND=2 for beam bolts
  - Bending resistance invoked to protect the structural integrity of the bolt
    → **more robust and realistic**
  - The prescribed force is distributed over all specified beams to avoid special purpose modelling
    → **more robust and easier to handle**
  - The contraction rate of beams has an upper limit to avoid dynamic effects as bolt heads may otherwise impact plates with arbitrary velocity. This applies to both solid (IZSHEAR=2) and beam (KBEND=2) element bolts. → **noise reduction in bolts with play**



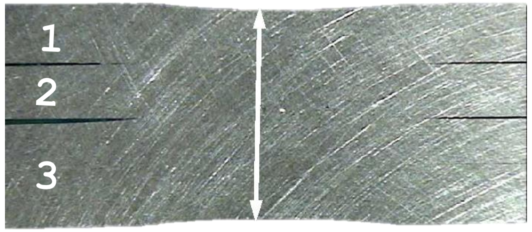


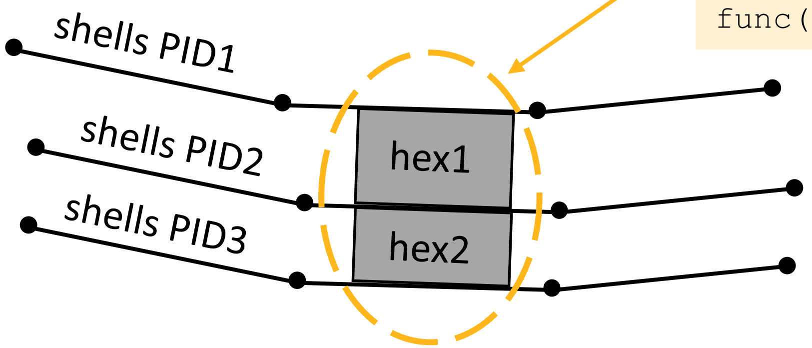
Spot welds or rivets joining more than 2 flanges

- Existing capability: *MAT_SPOTWELD with *DEFINE_SPOTWELD_FAILURE sets the failure forces for each pair of Part IDs.
- New keyword *DEFINE_MULTI_SHEET_CONNECTORS
  - *n* sheets/panels connected by *n*-1 joining elements (current max. *n*=4)
  - Material and failure behavior of joining elements can be described based on geometric and material properties (thicknesses, yield stresses, etc.) of all *n* sheets involved
  - Better failure prediction through this information exchange
  - Currently available for single hex elements with *MAT_100_DA

```
$                D_SIGY
                    100
*DEFINE_FUNCTION
       100
func(t1,t2,t3,t4,sy1,sy2,sy3,sy4,...)=...
```

3-sheet SW





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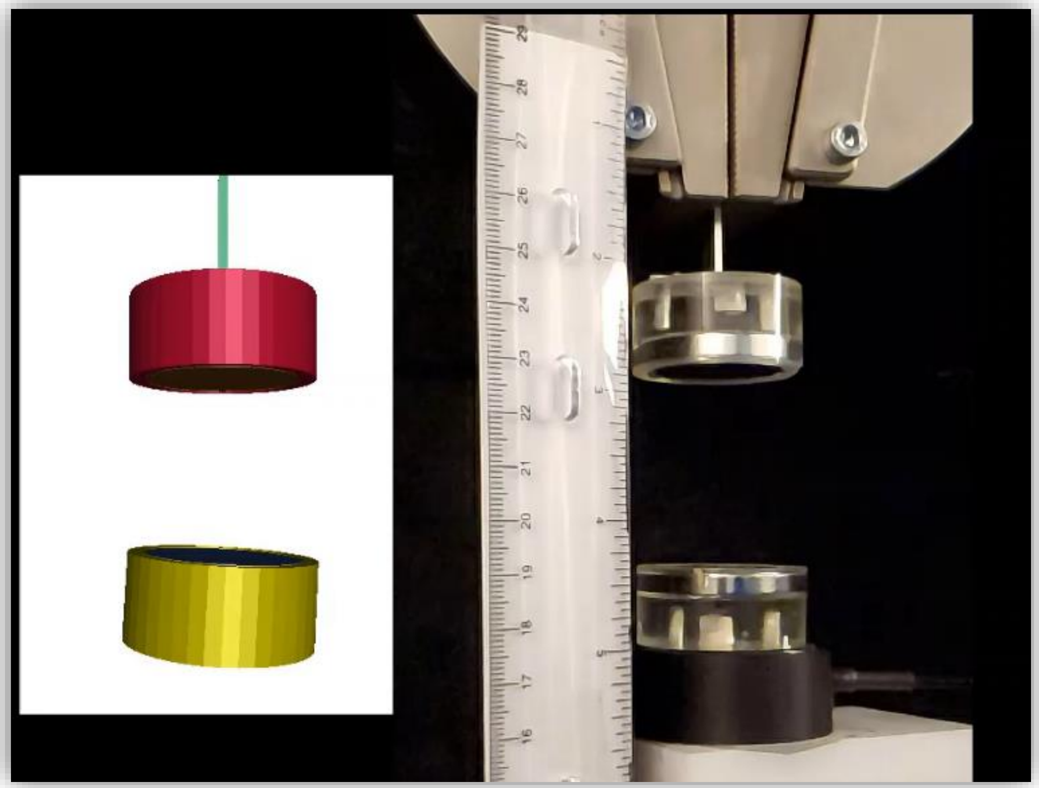
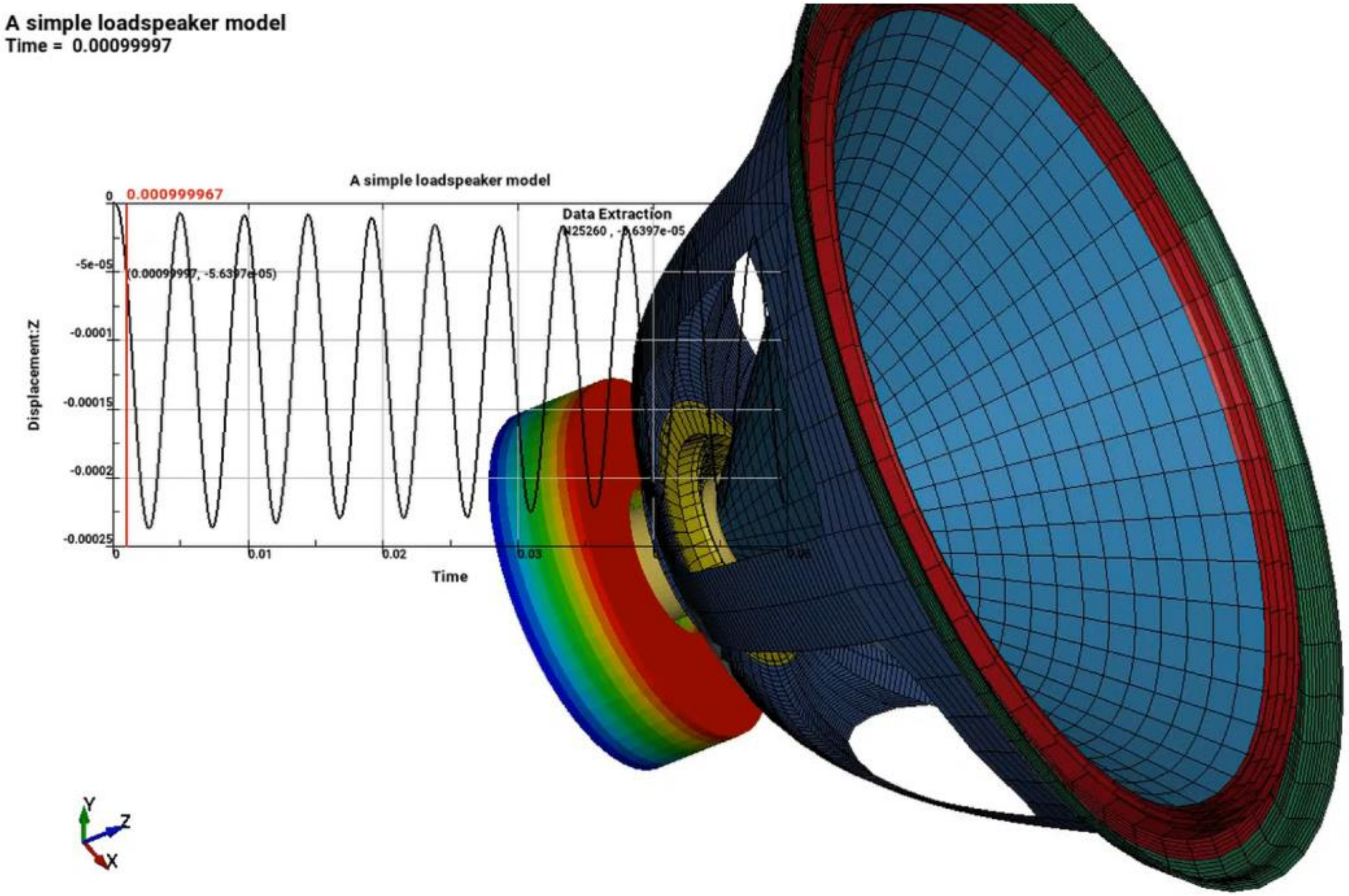
Miscellaneous

Magnets and electromagnetic simulations

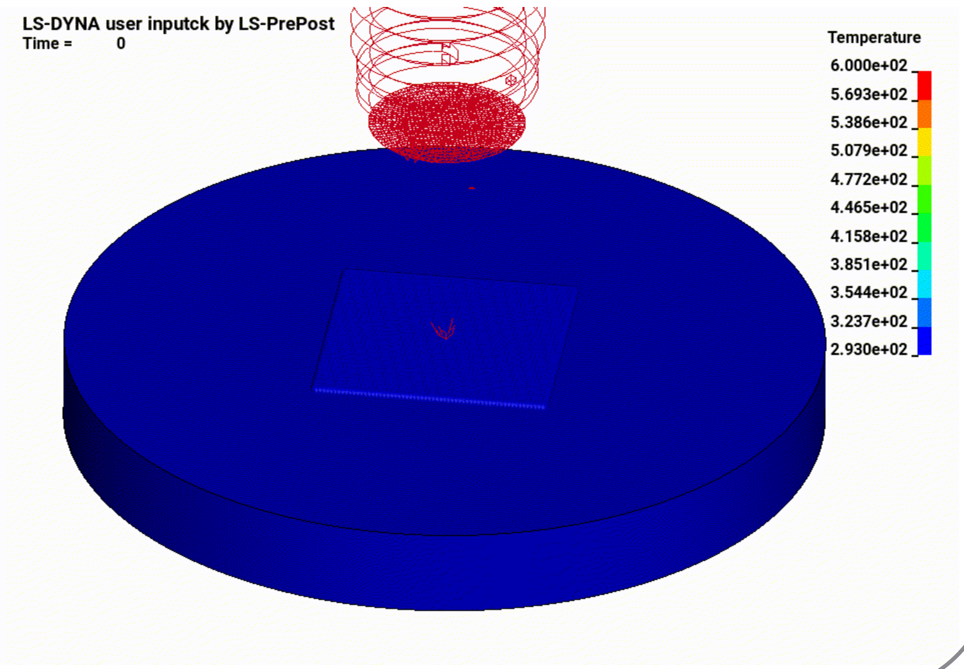




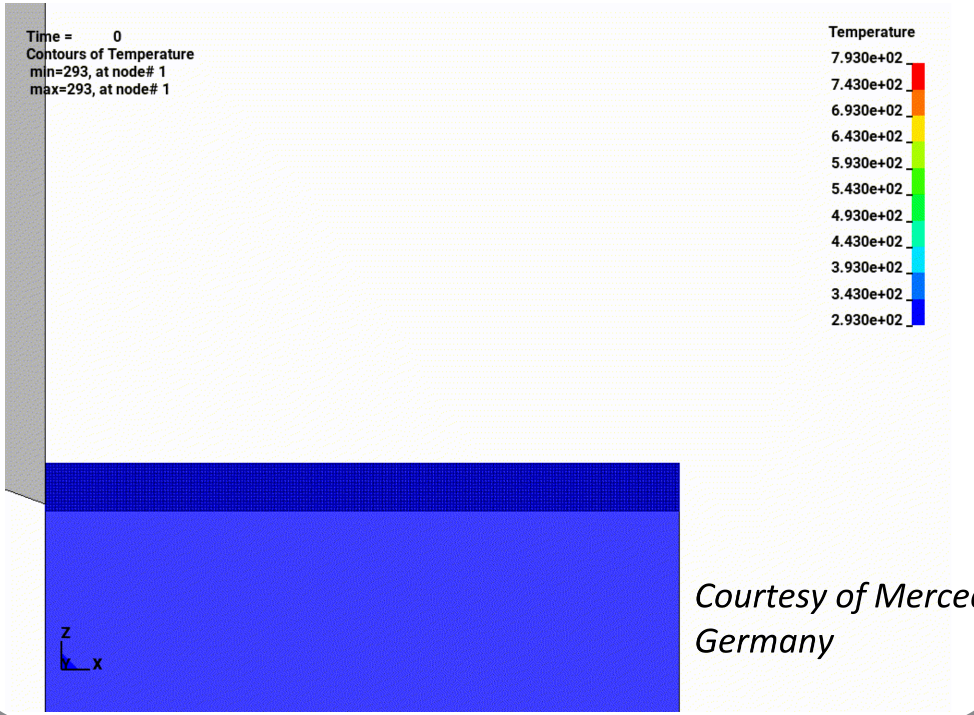
SPG: Thermal-mechanical Coupling Analysis (SMP and MPP)

✓ **Thermal effects in SPG parts can now be effectively modeled in metal fabrication simulations**

- Temperature dependent material properties
- Thermal expansion, thermal conductivity, heat generation due to friction and plastic material work
- Collaboration with major OEMs for experimental validation



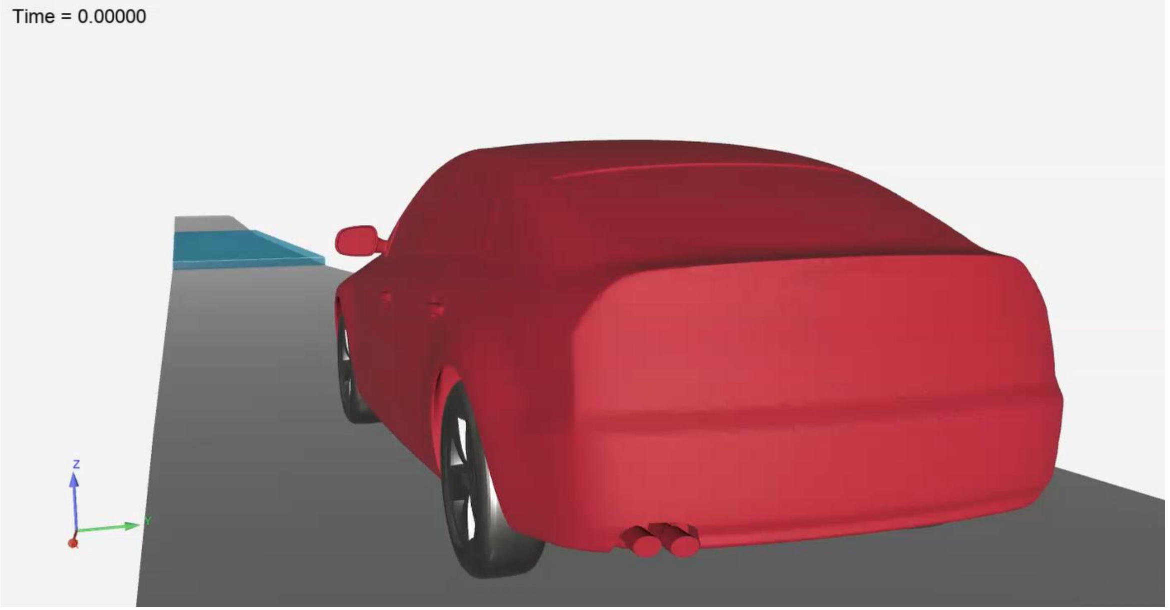
Temperature distribution

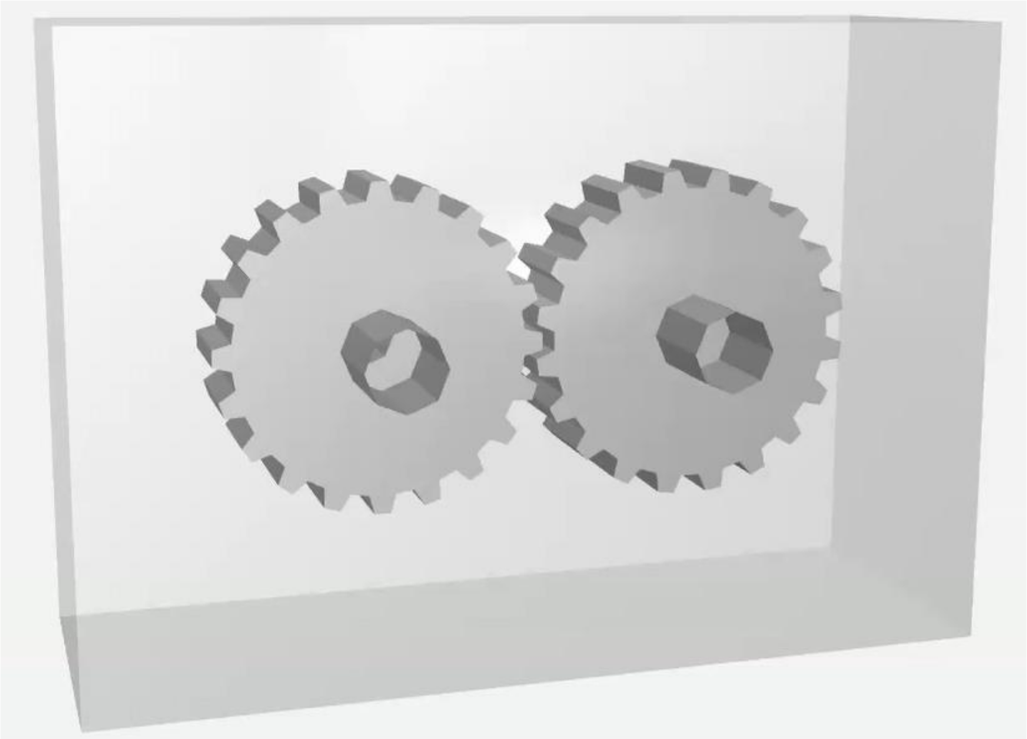


Courtesy of Mercedes, Germany

SPH applications

Wading Analysis, ISPH solver

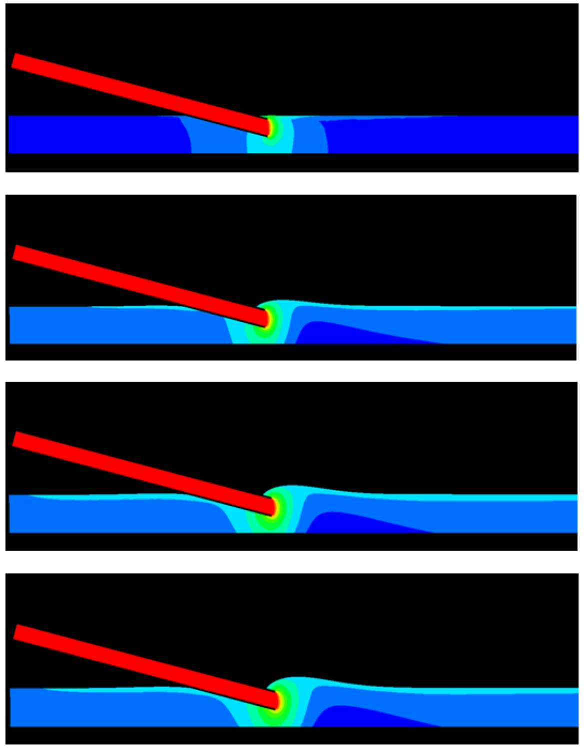


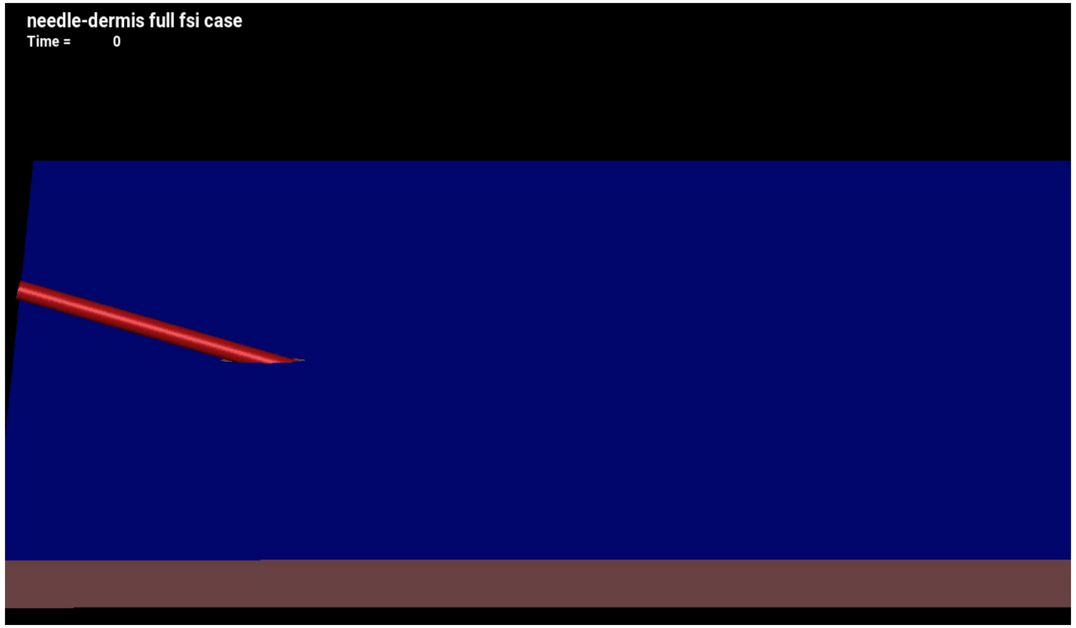


ICFD/FSI and Species Transport Phenomena.

Intradermal injections and drug delivery

With the increase in vaccination campaigns during the COVID-19 outbreak, the med Industry started using numerical models for coupled physics to study the drug delivery through the human tissue as well as for the delivery on other devices like the one used by patients with other conditions like diabetes.





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