What’s New in Ansys LS-DYNA R16

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UK Users’ Conference, Birmingham, UK

June 2025

Oasys
LS-DYNA Environment

Release management

Every **alternative** year LS-DYNA release will get **long-term support (LTS)** e.g., 14, 16, 18…

Existing versions used in production will continue to get LTS support until discontinued.

Ansys continue to release new version with new features every year.

Upcoming & latest releases		
LS-DYNA 16.0	LTS release	**April 2025**
LS-DYNA 14.2	LTS release	**June 2025**
LS-DYNA 12.2.2*	LTS release	**August 2024**

* Becoming more widely used for production work (explicit)

Ansys LS-DYNA

- Tightly coupled, scalable multi-physics solver
- **One Code, One Model, Multiphysics**

Finite Elements

Meshless

IGA

Multi-scale

DEM/SPH

Ansys LS-DYNA

Solid Mechanics

Fluids

Thermal

Chemistry

NVH/Acoustics

Electro-Magnetism

Industries

- Crash
- Aerospace
- Biomedical
- Electronics
- Defense
- …

R16 highlights

- Major updates and enhancements in the following areas:

Airbags

Contacts

Materials

Implicit

EM

NVH

SPG/ISP

IGA

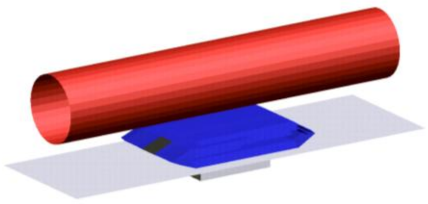
ICFD + CESE

ALE/S-ALE

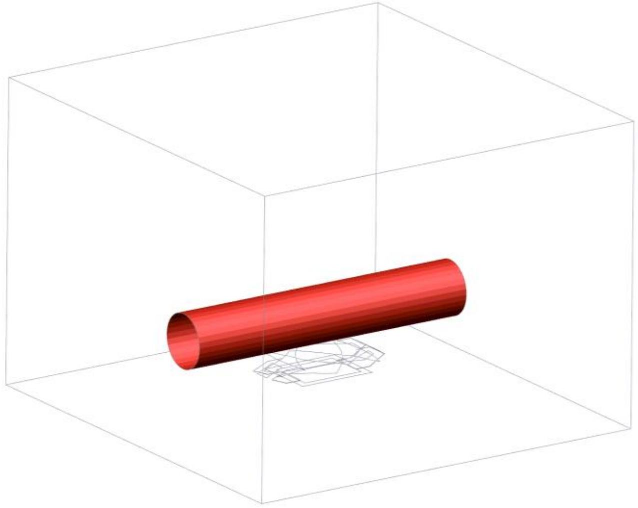
Airbag methods

History of airbag methods

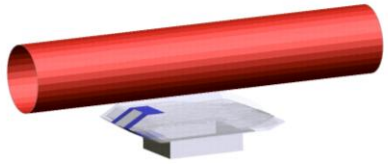
- CV (Control Volume)
  - Simple pressure, too simple for deployment phase



- ALE (Arbitrary Lagrangian Eulerian)
  - Higher accuracy, but CPU intense and difficult to handle



- CPM (Corpuscular Particle Method)
  - Considers the effect of transient gas dynamics and thermodynamics by using a particle to represent a set of finite air or gas molecules
  - Current state-of-the-art: fast and robust
  - Hits accuracy limits for complex gas flows as observed in curtain airbags, for instance



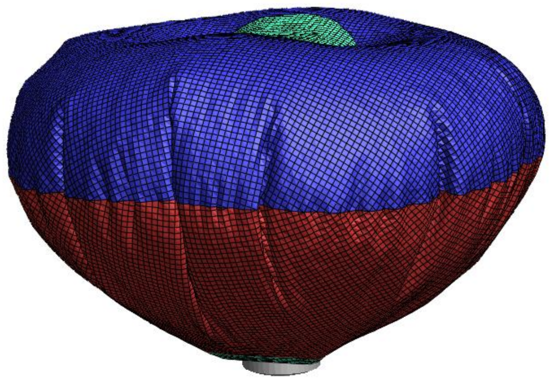
Need for a more sophisticated approach

Introducing CPG: A new CFD approach to airbag deployment

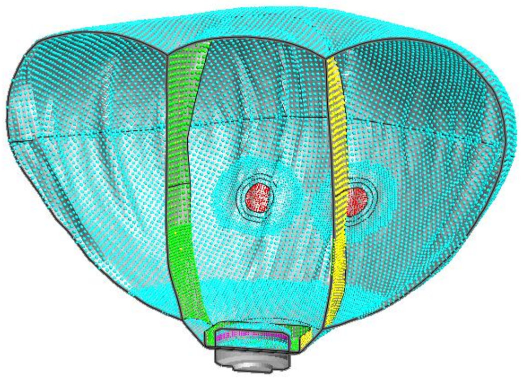
- Continuum-based Particle Gas (CPG): Particle method solving Navier-Stokes equations
- Innovative CFD method particularly well-suited for airbag deployment simulations
- Superior accuracy for complex gas flows, as seen in curtain airbags
- Validation studies with multiple partners
- Brand new solver – first release R16
- New keyword ***AIRBAG_CPG**

PRIMER

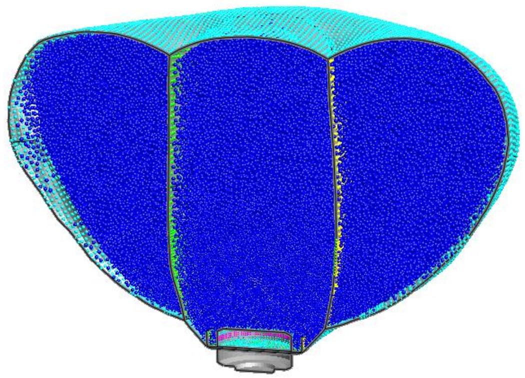
PRIMER v22 supports the new *AIRBAG_CPG keywords



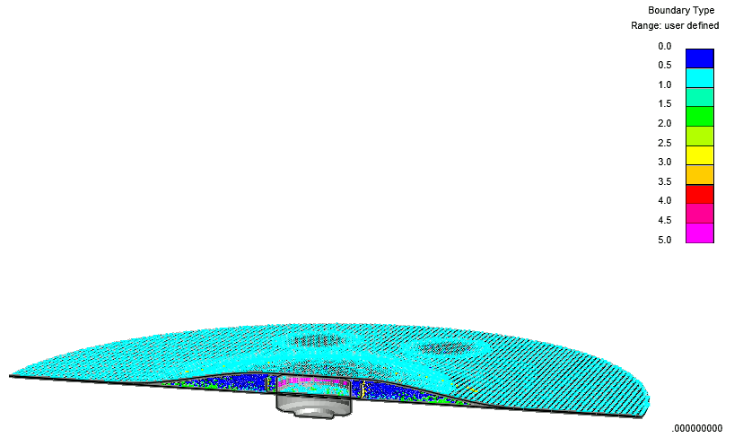
Airbag mesh



Gas boundary particles
Lagrangian displacement



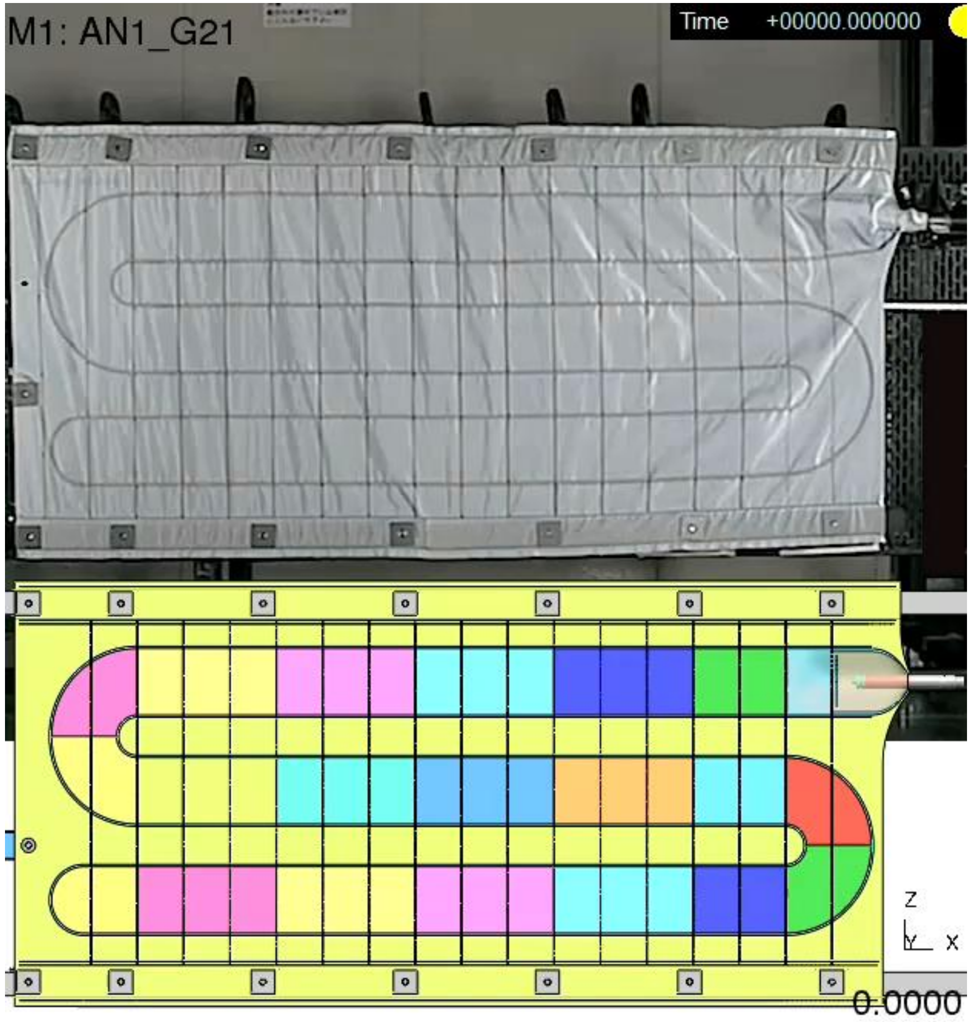
Gas volume particles
Eulerian "grid"



Gas volume gets resampled as the airbag deploys

Introducing CPG: A new CFD approach to airbag deployment

- On-going collaboration with Toyoda Gosei Co. Ltd to validate method and implementation
- Custom-made experimental setup to accelerate development
- The goal is to reduce the need for numerical tuning; this requires:
  - Good fabric material characterisation
  - Good measurement of the inflator characteristics
  - …



Experimental data courtesy of Toyoda Gosei Co., Ltd.
Numerical model courtesy of JSOL Corporation.

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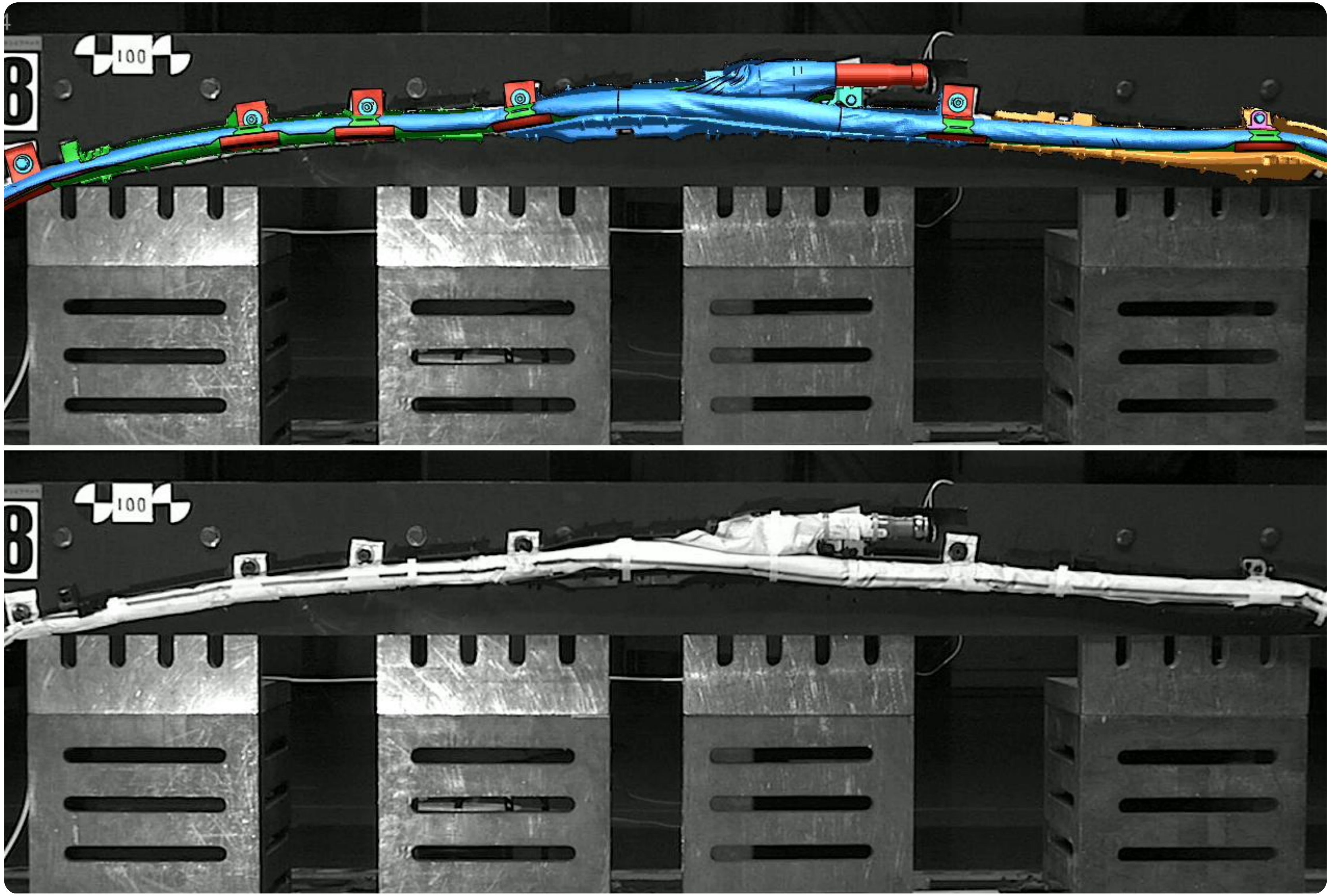
Introducing CPG: real world deployments



Bringing airbag deployment simulations to new levels of predictive accuracy.

D3PLOT

D3PLOT v22 supports the new binary d3dat file, which contains all CPG results data

…CPG applications for battery modelling

Battery abuse simulations: from single cell to EVs

Thermal abuse

Cell failure trigger

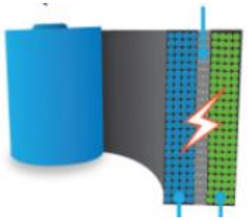
Mechanical abuse

Large current/ Joule Heat/ cell overheating

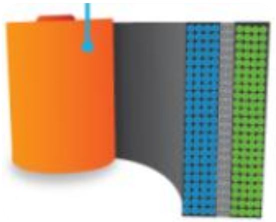
Exothermal Decomposition reactions

Gas release

Combustible mixtures

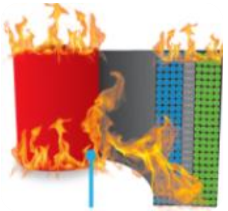


Internal shorting



Temp increase

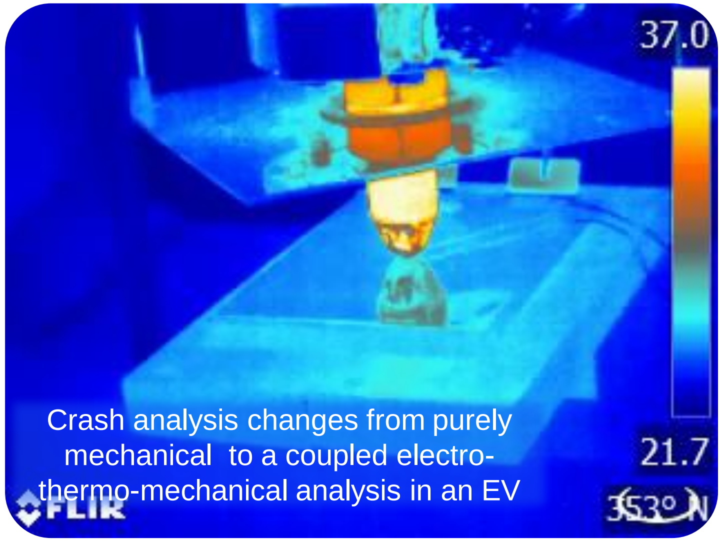
Swelling venting



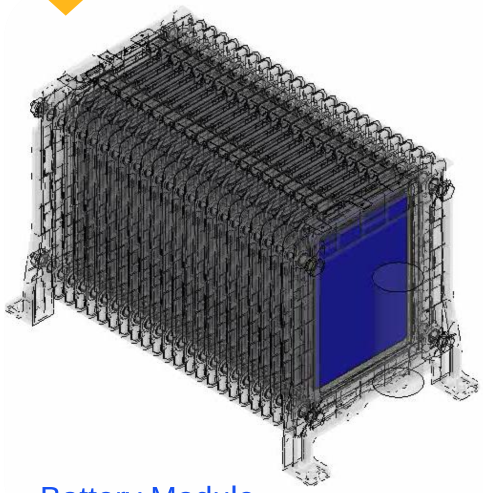
Ignition

Thermal Runway model

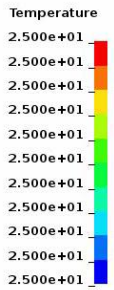
Image adapted from Sinovoltaics



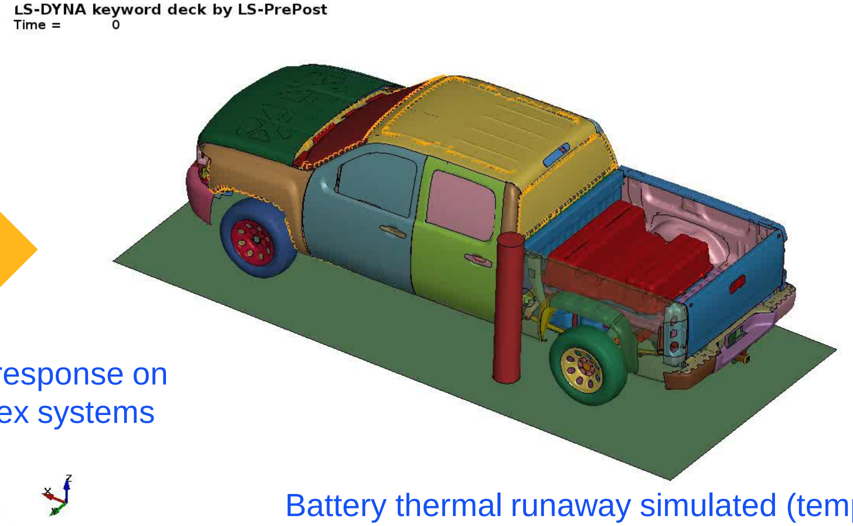
Crash analysis changes from purely mechanical to a coupled electro-thermo-mechanical analysis in an EV



Battery Module under pole impact



Apply cell level response on different complex systems



Battery thermal runaway simulated (temp. > 1000+°C) due to mechanical impact

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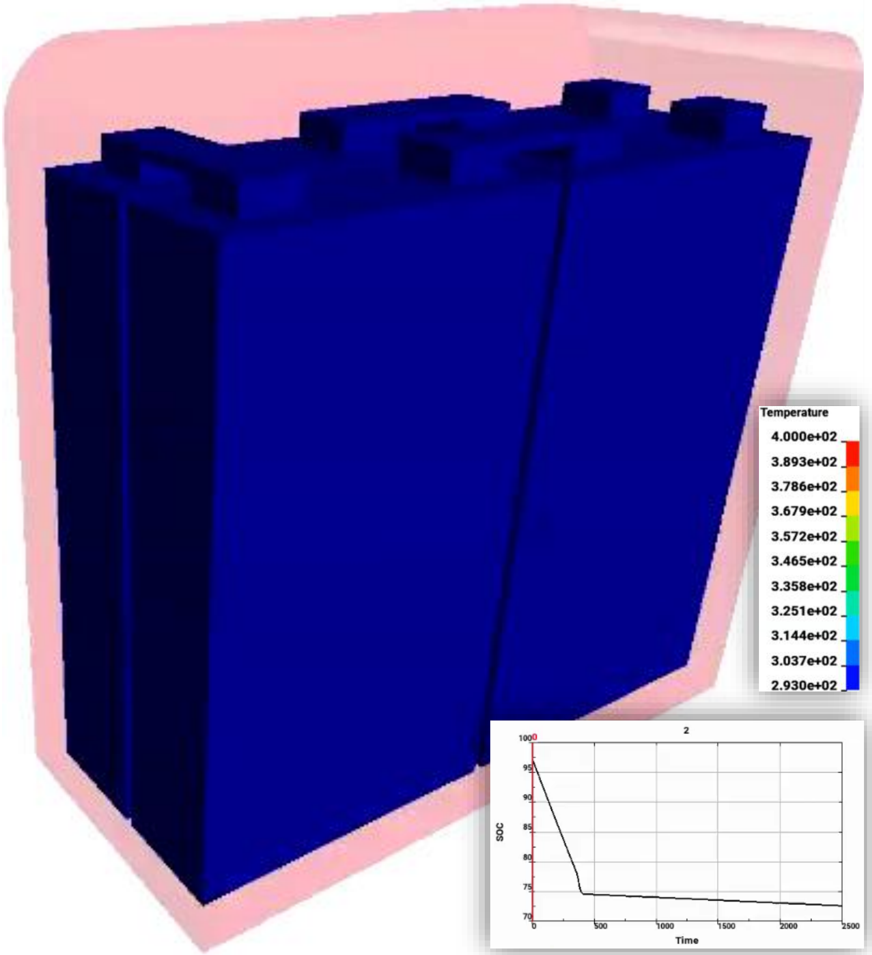
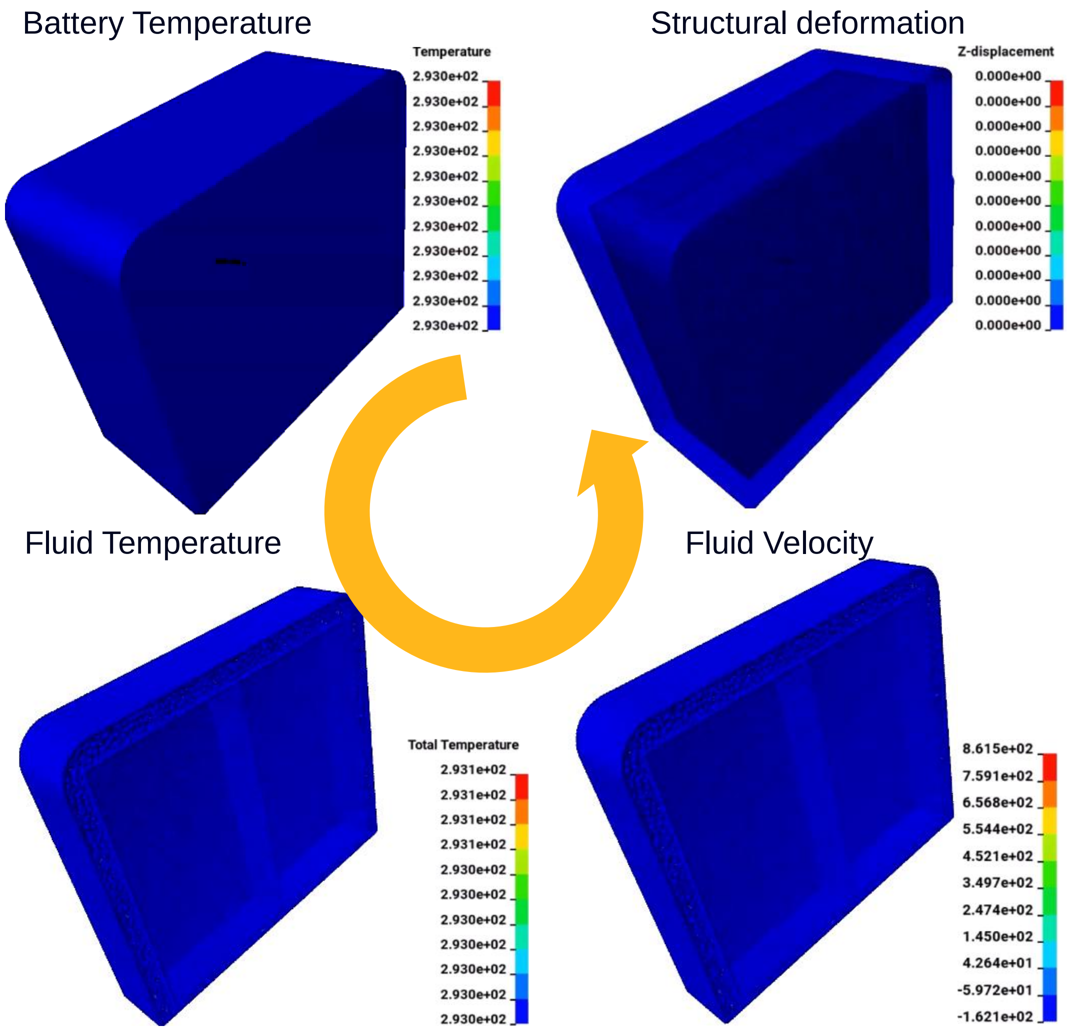
Multi-physics battery modelling – cell short circuit

Classic approach EM+Thermal



Multiphysics approach: EM+Thermal+Structural+CPG/CPM for venting analysis



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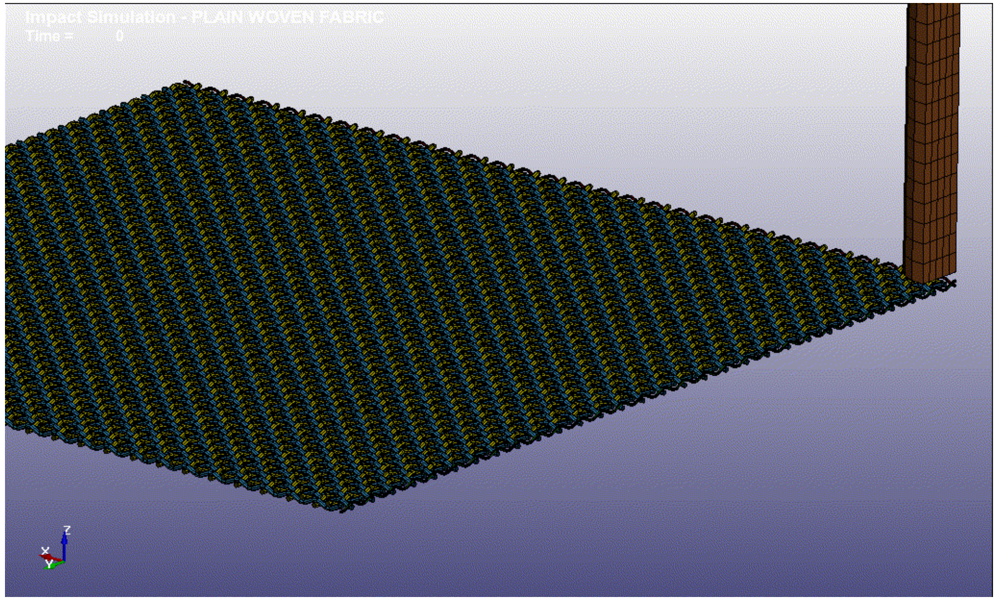
Contacts

Beam elements in segment-to-segment contacts

- **SOFT = 2**
  - Has checked contact between shell, solid and thick shell elements for the past 23 years
- New in R16 is the addition of beam and discrete beam elements
  - Checks beam-to-beam, beam-to-shell, beam-to-solid, and beam-to-thick shell
  - Works with all keyword options that segment-to-segment contact supports
  - The interface must include edge-to-edge checking:

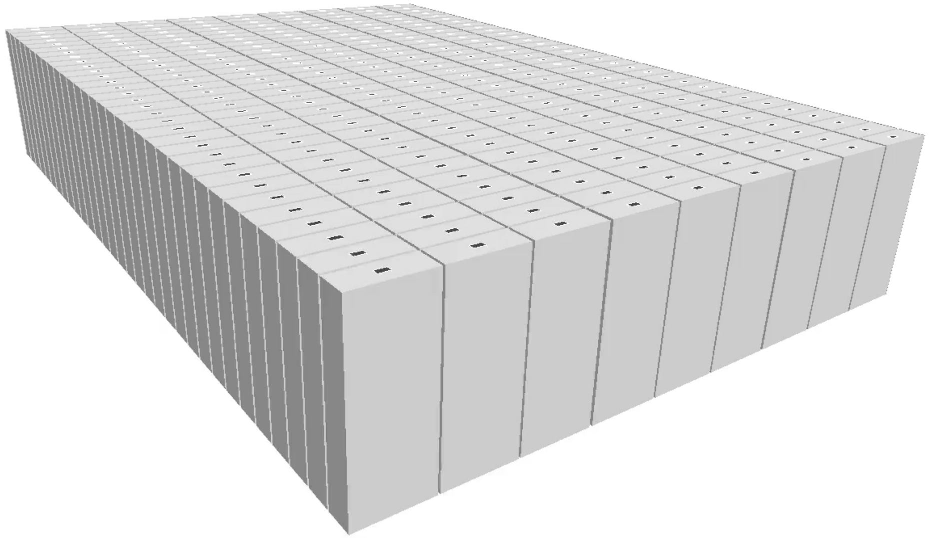
    DEPT = 5, DEPTH = 15, DEPTH = 35, DEPTH = 55
  - Beams are assumed to have rectangular cross-sections



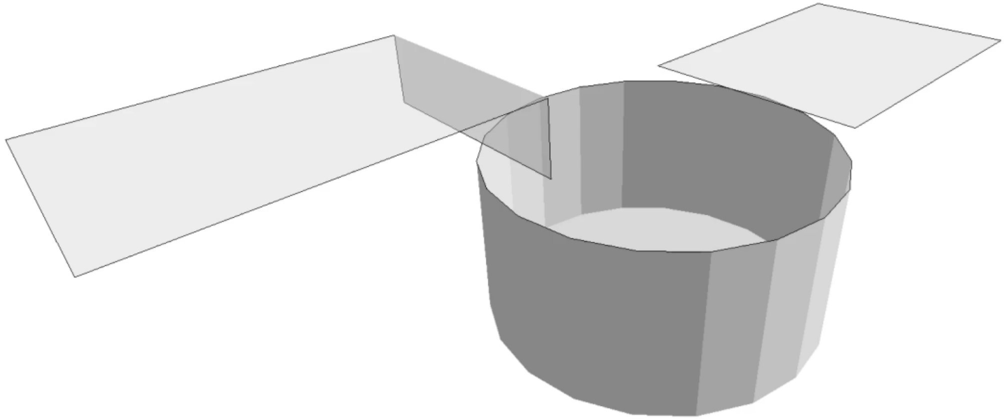
Solid impactor penetrates woven fabric modelled by beam elements

Thermal contact enhancements

- **Single surface** contact definition made available for simplified pre-processing
  - Consider example of thermal runaway in battery packs
  - Instead of ~100 surface-to-surface contacts, one single surface contact will suffice



- Thermal **edge contact** available
  - Works for single surface as well



Material models

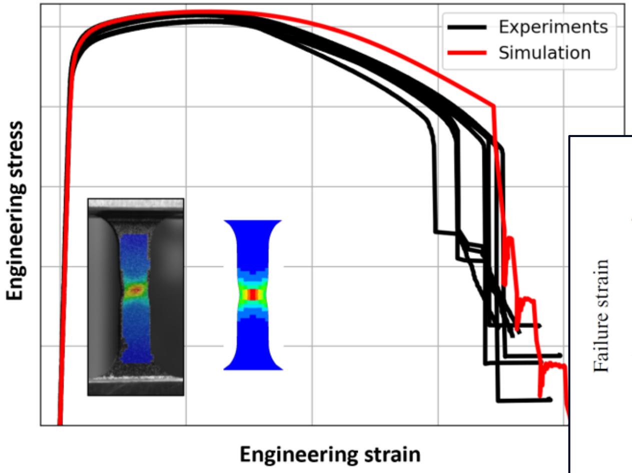
Basic Incremental Failure (BIF)

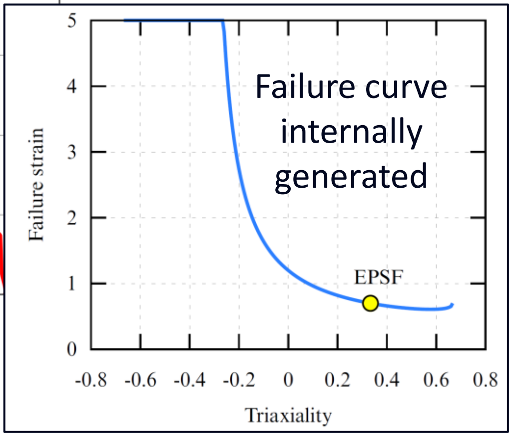
- ***MAT_ADD_BASIC_INCREMENTAL_FAILURE**
- Easy to use incremental failure model
  - Require only tensile test for calibration
  - Can achieve good failure modelling when material data is scarce.
  - It works for shell and solid elements

    (triaxiality and Lode parameter dependence)

True plastic strain at failure
for triaxiality = 1/3, Lode parameter = 1

```
*MAT_ADD_BASIC_INCREMENTAL_FAILURE
$       MID                      NUMFIP  VOLFRAC      NEROD
          1                         -80
$      EPSF      LCSS    LCREGD            LCSRS     DMGEXP
        0.3                                               2
```





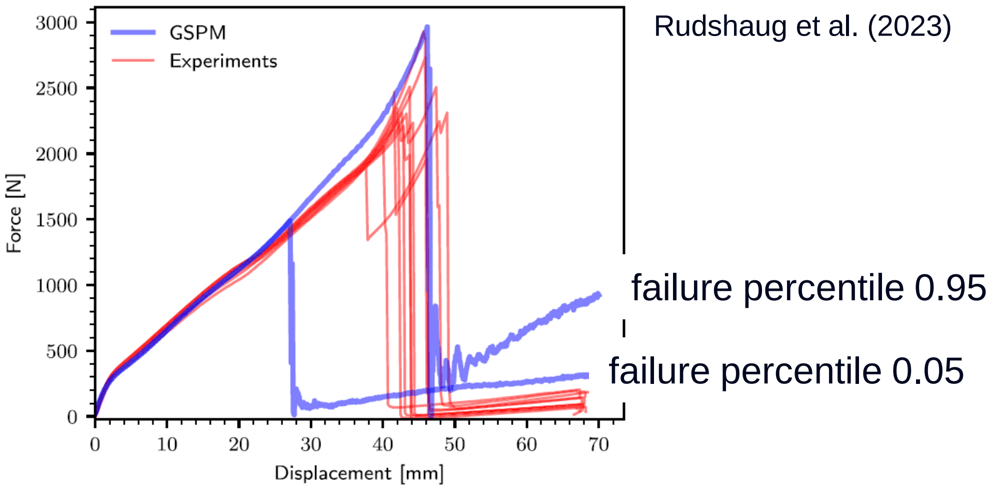
Example:
Complex phase steel

Experiment

FAIL (*MAT_024) BIF

Glass strength prediction model

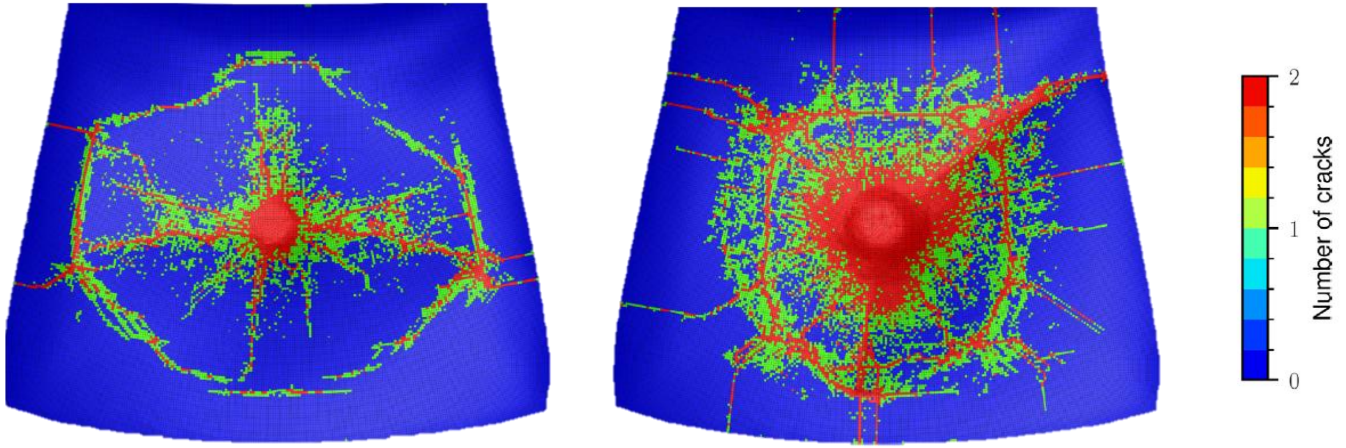
- Available as ***MAT_GLASS_SPM**
- Capabilities of the new method
  - Can describe the probabilistic fracture behaviour of glass via sub-critical crack growth (SCG).
  - Predicts the strength of glass plates of various geometries exposed many different load cases.
  - User can select a representative case of a glass fracture strength simply by altering the failure percentile parameter.
  - Example: windshield impact.



Rudshaug et al. (2023)

failure percentile 0.95 (strong windshield)

failure percentile 0.05 (weak windshield)

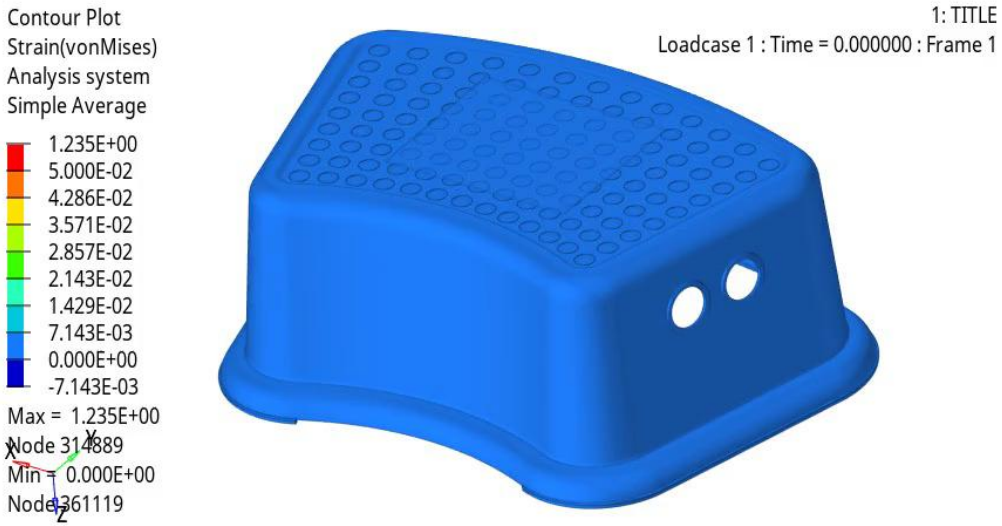


Model details and calibration procedure described in Rudshaug et al., A physically based strength prediction for glass, International LS-DYNA Conference, 2024.

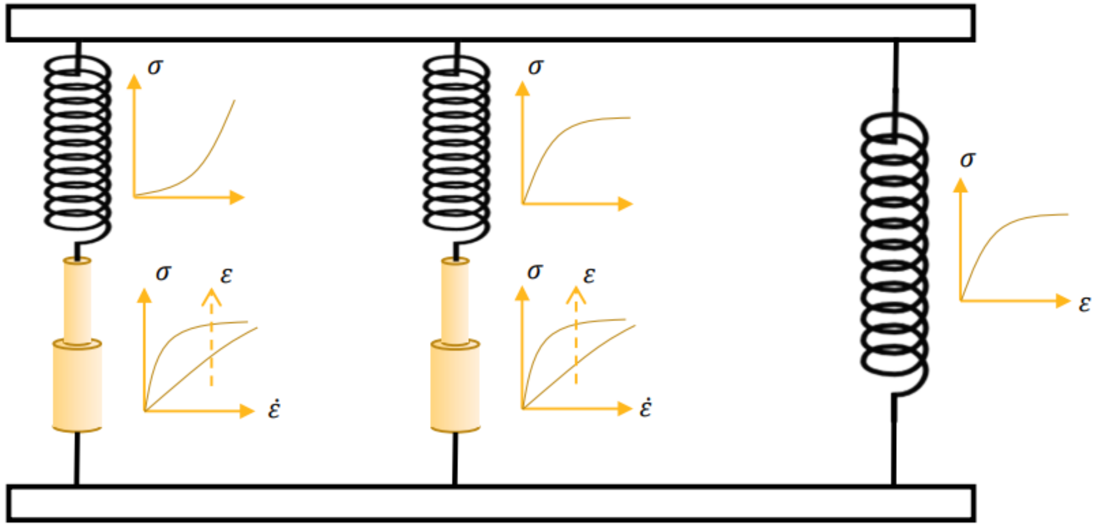
MAT_RRR_POLYMER/*MAT_317

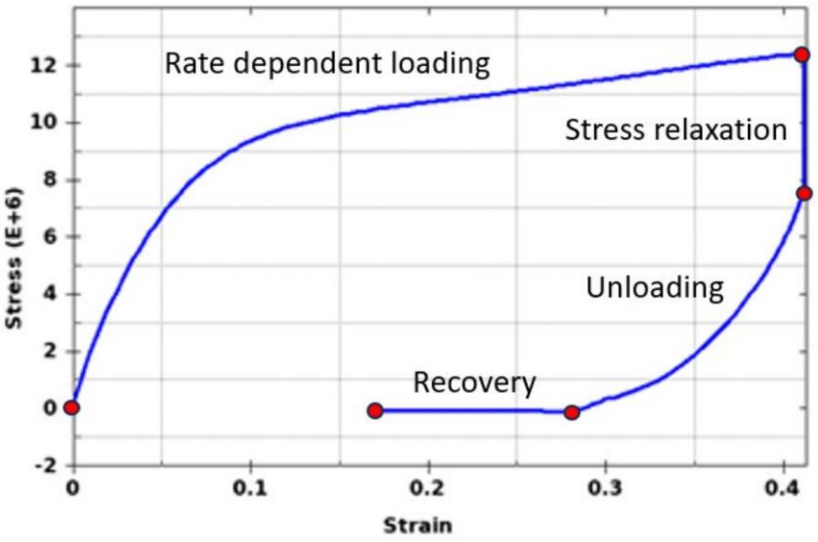
Details: Borrvall et al. A pragmatic approach to modelling of nonlinear rheological networks for polymers, North American LS-DYNA User Forum, 2023

- New material model for thermoplastics
  - Developed in collaboration with IKEA.
  - Handles impact, stress relaxation, and material recovery.
  - Builds on the rheological network framework, containing three links with springs and dampers.
  - Requires 24 material parameters and a sophisticated parameter fit



Both springs and dampers are functions of strain – allows improvements without adding more links

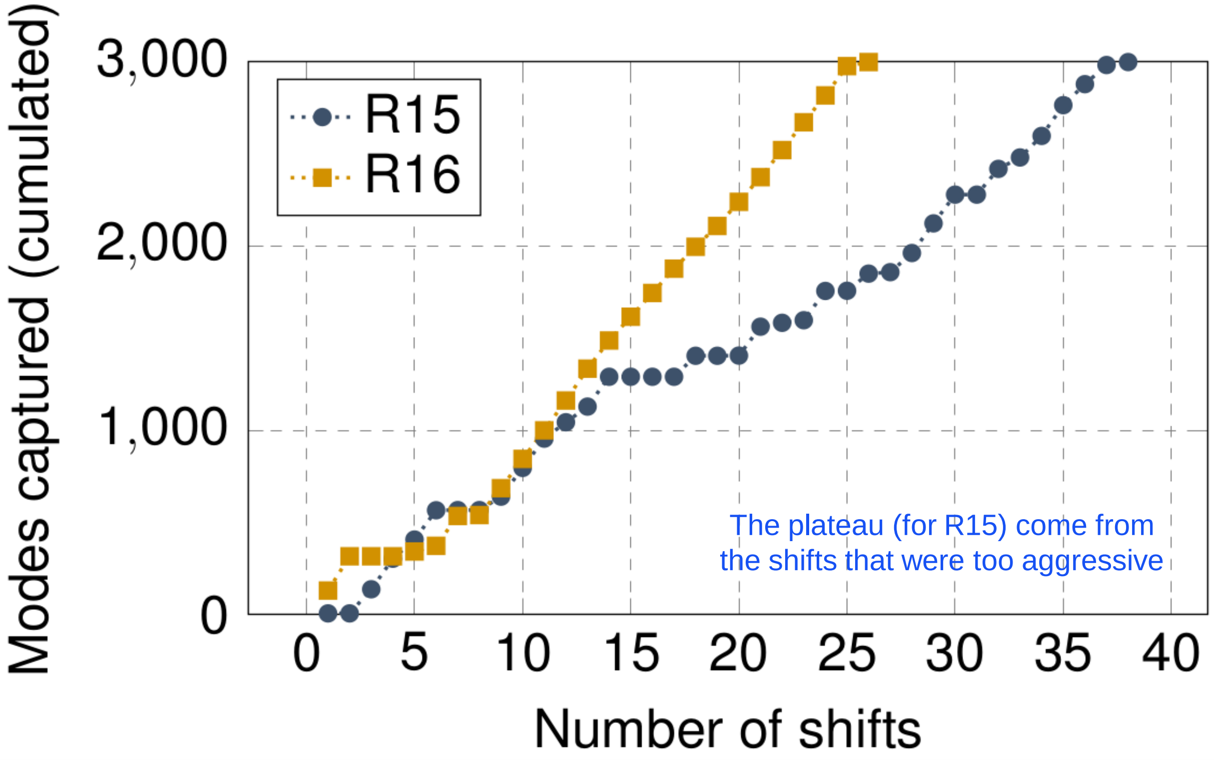


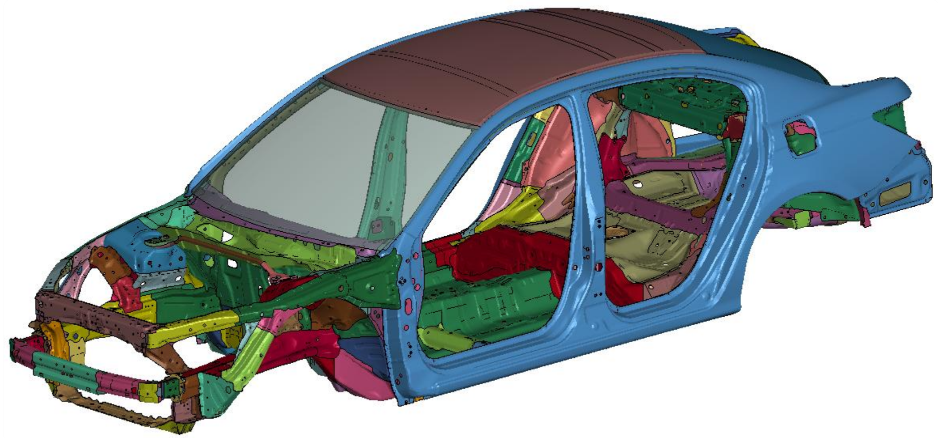


Implicit Solver

Implicit mechanics – Modal analysis I

- Lanczos flagship eigensolver: improved shifting logic.
- More robust and faster when computing thousands of modes.
- Example: Honda Accord model (courtesy Arup and NHTSA), 35M DOFs, 3k modes:

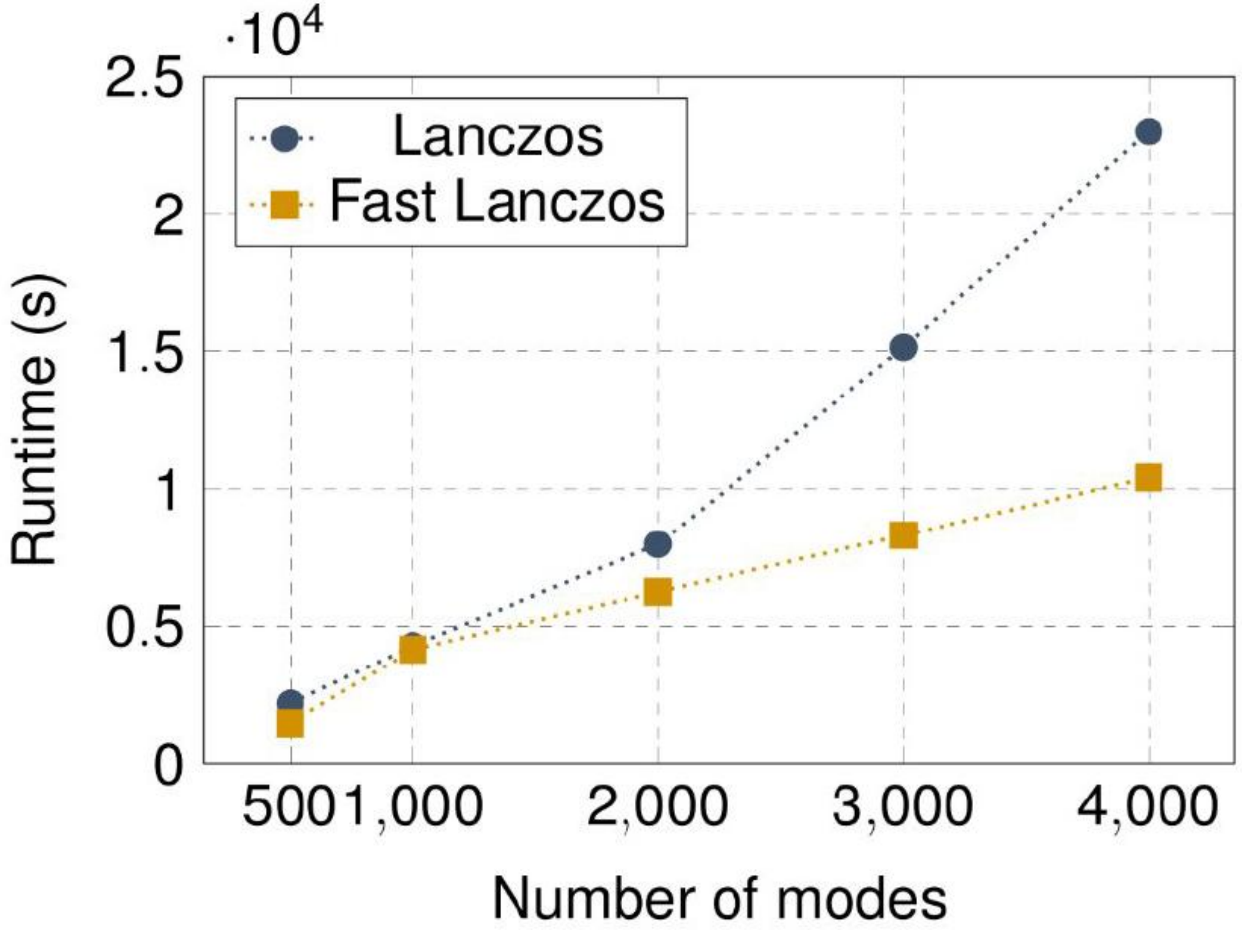




R16 is **34% faster**

Implicit mechanics – Modal analysis II

- New eigensolver called Fast Lanczos released in R15 (**EIGMTH = 103**).
- Approximate eigensolver for computing thousands of eigenmodes for NVH applications.
- R16 → improved shifting logic, and memory management
- Example, 21.9M dof elect sedan model:



Nosie, Vibration, and Hardness (NVH)

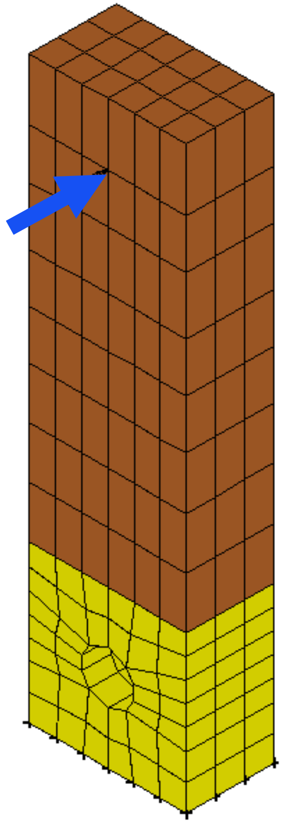
Including residual vectors

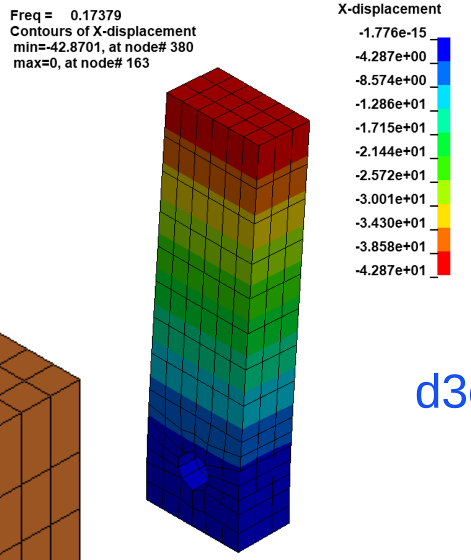
*FREQUENCY_DOMAIN_SSD

- Higher number of mode shapes for higher accuracy, but higher CPU cost
- **Residual mode method** in R16 offers high accuracy with limited eigenmodes
- The method extracts an additional set of modes based on loading conditions
- Residual modes are orthogonal to retained eigenmodes
- **Step 1:** generate eigenmodes and residual vectors
- **Step 2:** run SSD computation with eigenmodes and residual vectors

X-displacement (mm)

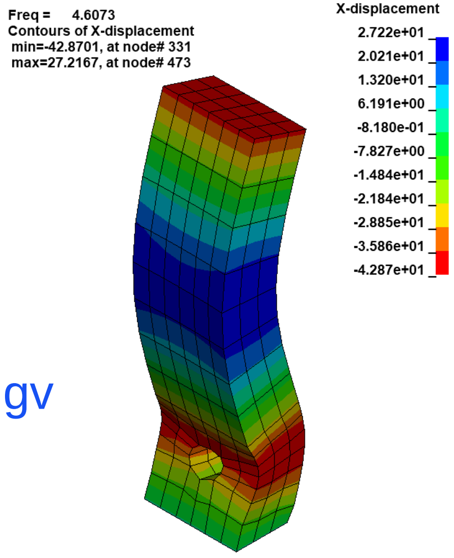
Freq (kHz)	50 modes	1236 modes	50 modes + residual vector
1	1.055	1.068	1.067
10	4.577e-2	6.65e-2	6.517e-2



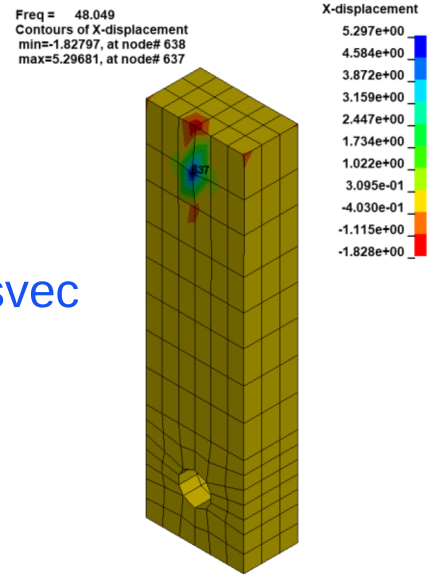


Mode 1

d3eigv



Mode 7



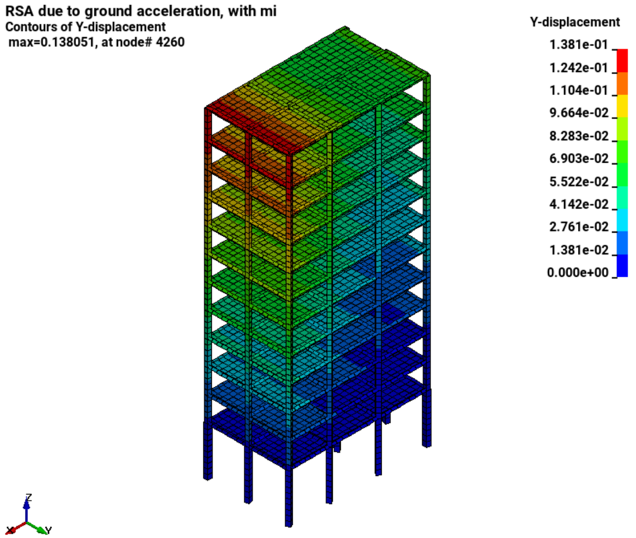
d3resvec

Missing mass correction

- ***FREQUENCY_DOMAIN_RESPONSE_SPECTRUM_MISSING_MASS_CORRECTION**

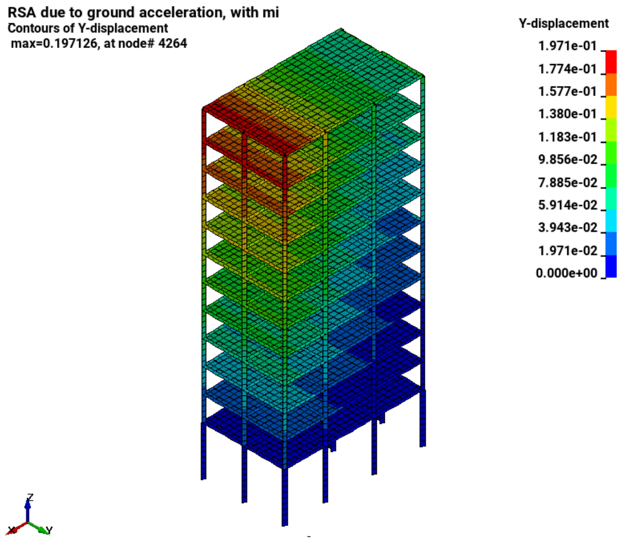
- In general, a mode superposition using a limited number of modes will miss some mass
- For response spectrum analysis, static correction can be made by adding static load response for the missing mass
- Missing mass load is calculated by F(static)-∑(mode load)

Without missing mass correction



Max. Y-displacement = 0.138

With missing mass correction



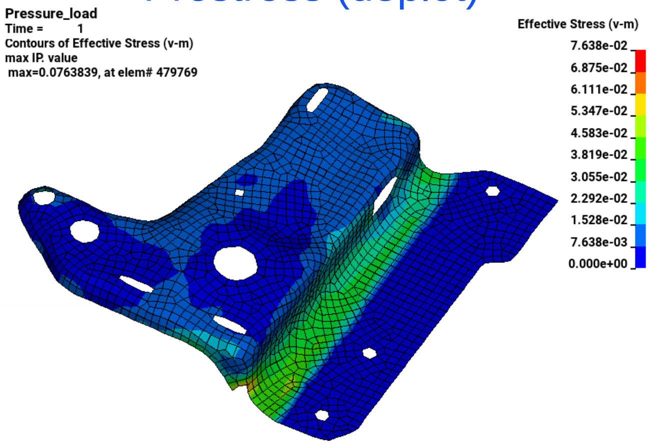
Max. Y-displacement = 0.197

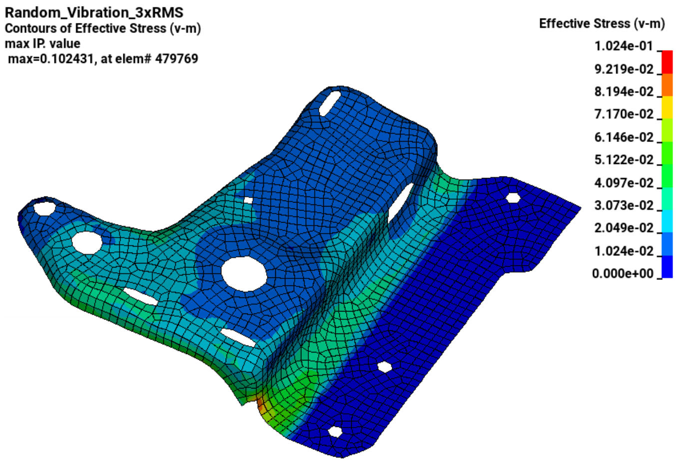
*FREQUENCY_DOMAIN_RANDOM_VIBRATION

New d3rms file

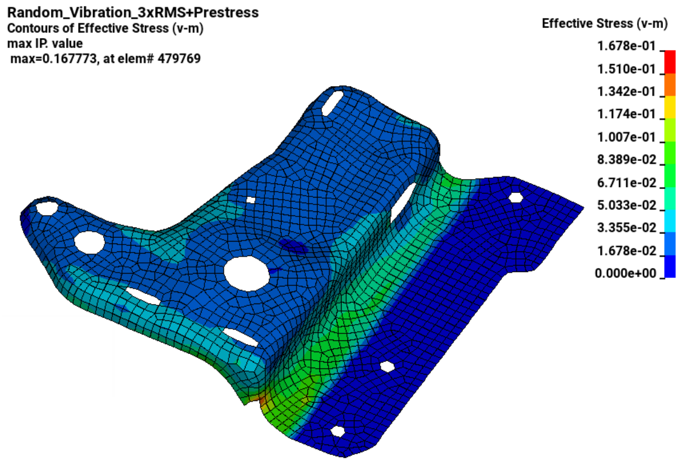
- Users want to do failure analysis using stress in pre-stressed random vibration
- Total stress is the sum of stress in random vibration and pre-stress
- In the past, the 3-sigma (rms) rule was used.
- New d3rms file includes:
  - State 1: RMS response
  - State 2: 3-sigma + pre-stress
  - State 3: 3-sigma + |pre-stress|

Prestress (d3plot)





3-sigma only (max: 102 MPa)



3-sigma + prestress (max: 168 MPa)

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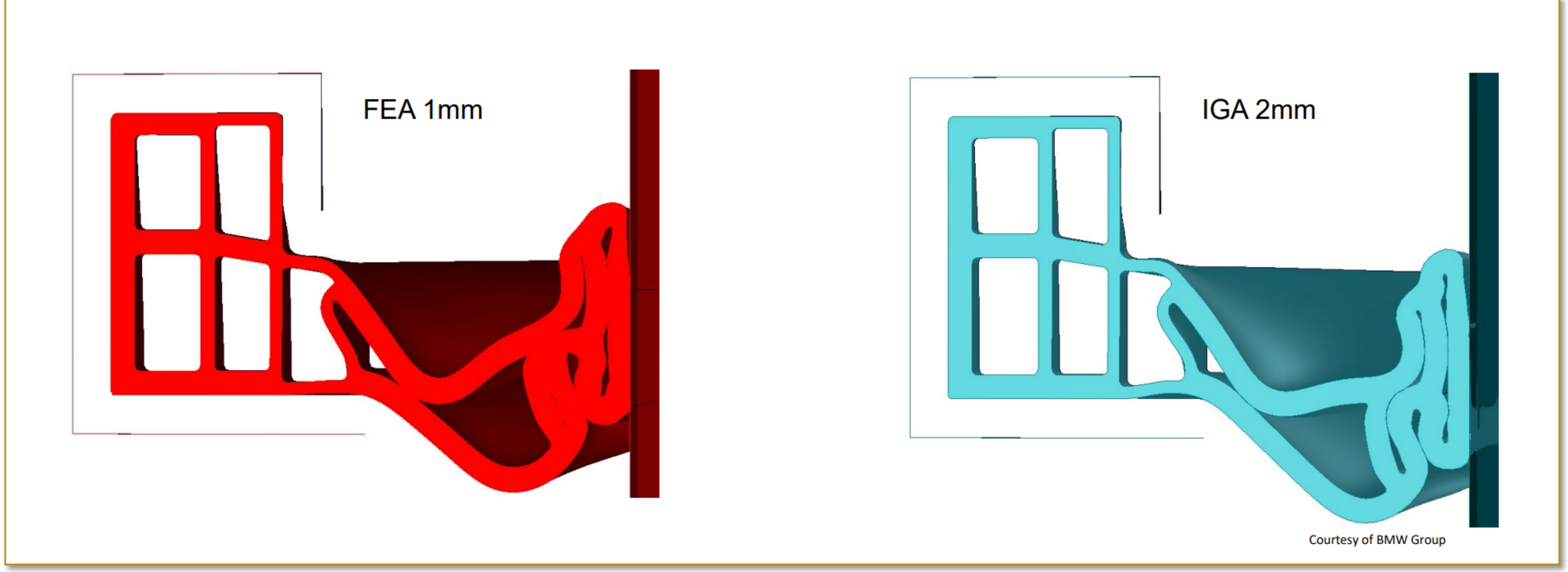
Isogeometric Analysis (IGA)

A note on trimmed solids

Trimmed B-Spline Solids: Examples

- Local buckling pattern of the cross-section in the center of the profile



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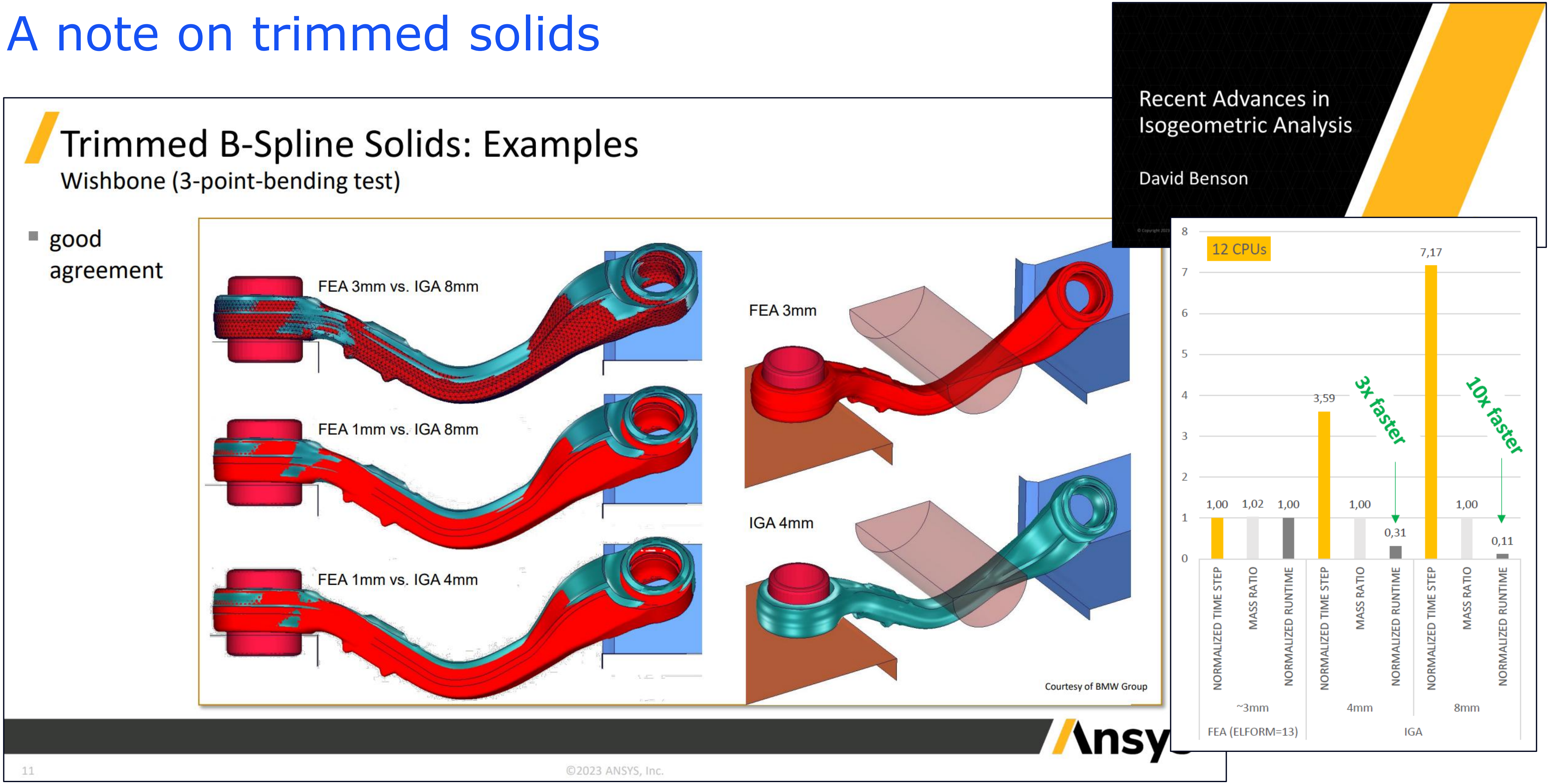
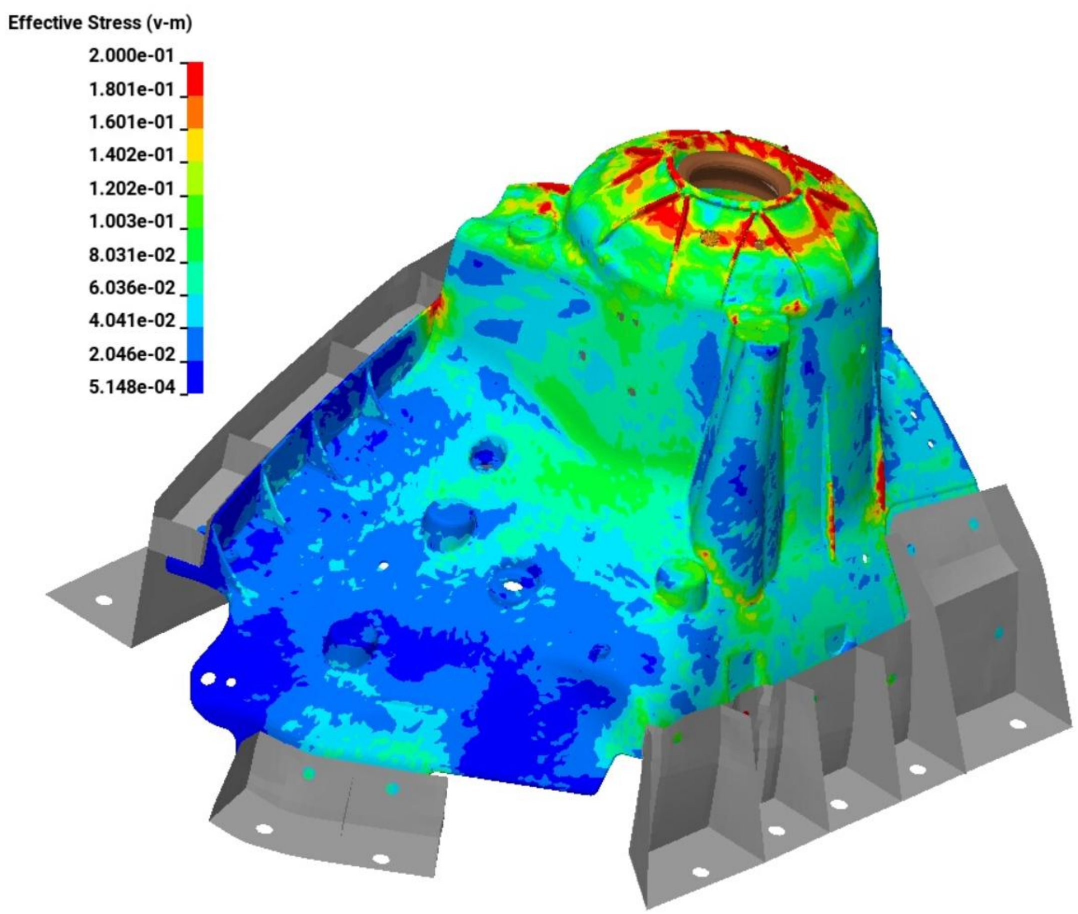
A note on trimmed solids



Included features for trimmed solids



courtesy of General Motors

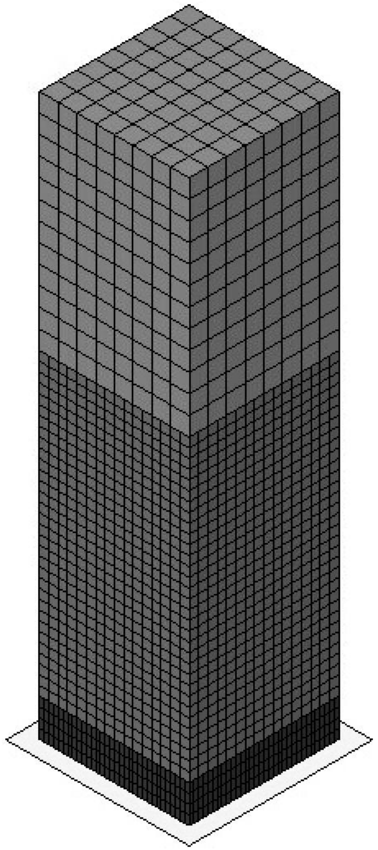
- ***IGA_POINT_UVW**

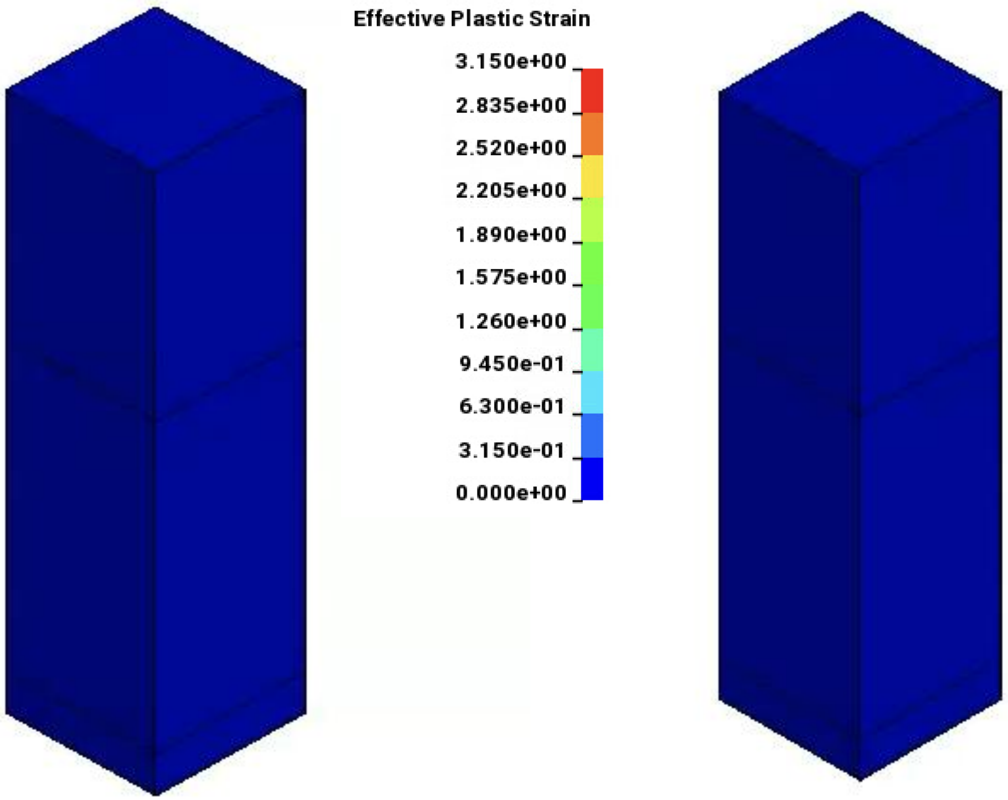
→ Define parametric points on the IGA solid surface such that they can be constrained with the FE nodes.

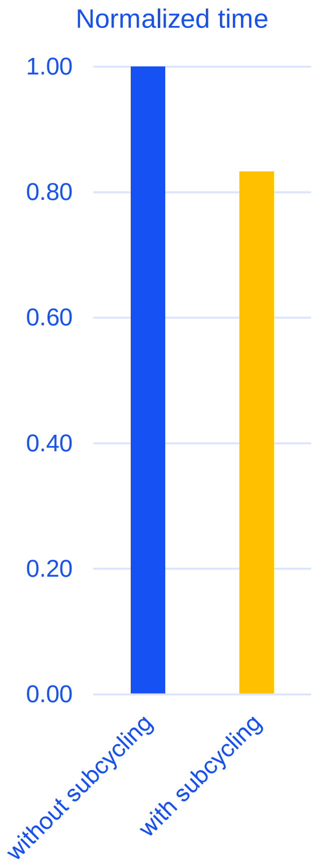
- ***CONSTRAINED_NODAL_RIGID_BODY**
- ***CONSTRAINED_EXTRA_NODES**
- ***CONSTRAINED_SPR2**

IGA: Subcycling

- Enables subcycling for isogeometric solid elements, see ***CONTROL_SUBCYCLE_K_L** and ***CONTROL_SUBCYCLE_MASS_SCALED_PARTS/PART_SET**.





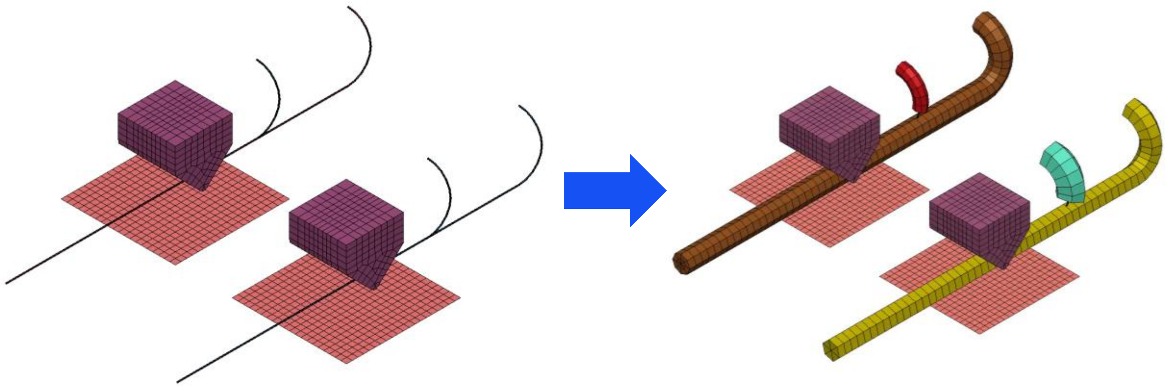


Miscellaneous

Simplified electric cable modelling with *DEFINE_CABLE

- Simplified creation and analysis of electric cables for modelling wire failure in vehicle crash
  - Automatic creation of cables from beam elements
  - Final cables can be a mix of solids/shells/beams
  - Links cross-section data to each original beam element
- Data available in binout (***DATABASE_CABLE**):
  - Compression (contact) force
  - Cross-section area
- Data summary in ASCII-file:
  - Time and location for maximum compression force and minimum cross-section area for each cable and for whole model

Cable generation from beam elements

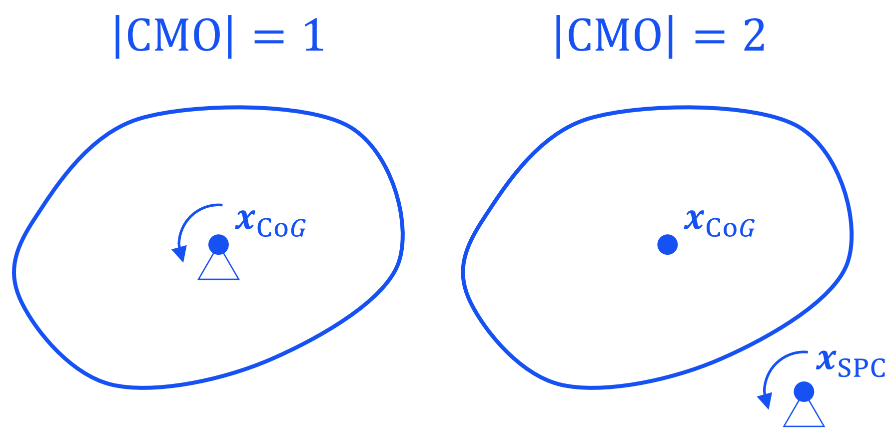


data summary

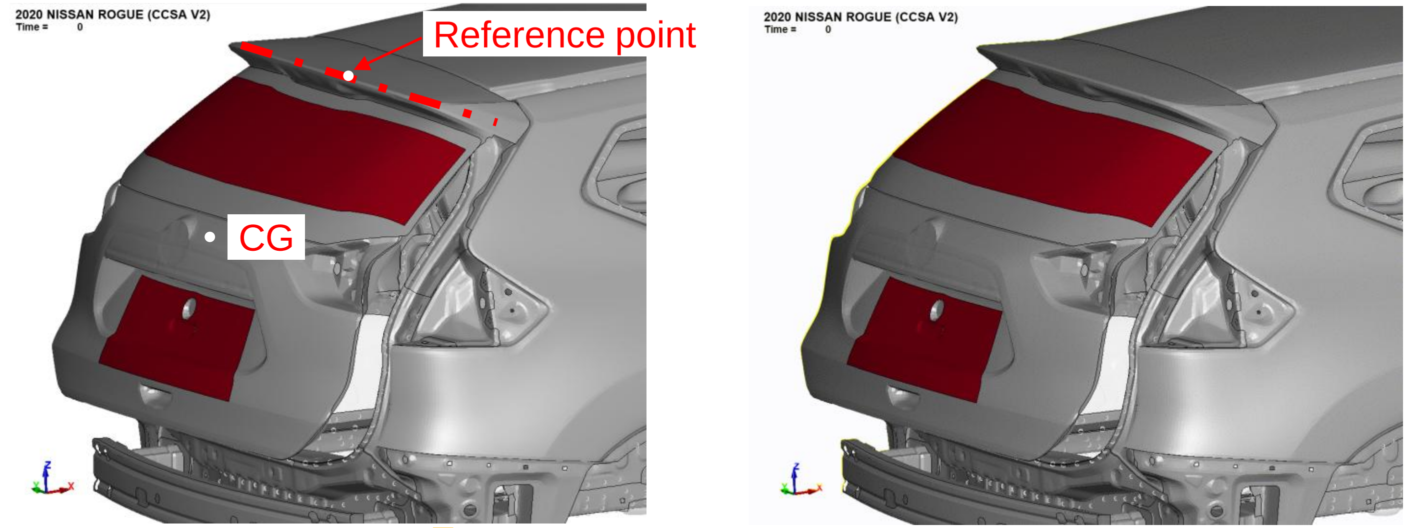
```
PART-WISE DATA:

 Beam part=  83990001, sampling frequency=         1 cycles
 maxstress=    0.4953E-01, time=    0.5000E+01, element=            46
 minarea  =    0.5891E+02, time=    0.5000E+01, element=            48
 maxforce =    0.5590E+01, time=    0.4998E+01, element=            46

 Beam part=  83990002, sampling frequency=        10 cycles
 maxstress=    0.7170E-01, time=    0.4991E+01, element=       6020579
 minarea  =    0.8419E+02, time=    0.4997E+01, element=       6020579
 maxforce =    0.9542E+01, time=    0.4997E+01, element=       6020579

 Beam part=  83990005, sampling frequency=         1 cycles
 maxstress=    0.3333E-03, time=    0.4854E+01, element=       6020613
 minarea  =    0.3247E+03, time=    0.2972E+01, element=       6020613
 maxforce =    0.0000E+00, time=    0.0000E+00, element=             0

 Beam part=  83990006, sampling frequency=         1 cycles
 maxstress=    0.5296E-03, time=    0.2155E+01, element=       6020623
 minarea  =    0.8662E+02, time=    0.2664E+01, element=       6020623
 maxforce =    0.0000E+00, time=    0.0000E+00, element=             0

DATA FOR ALL PARTS:

 maxstress=    0.7170E-01, time=    0.4991E+01, element=       6020579, part=      83990002
 minarea  =    0.5891E+02, time=    0.5000E+01, element=            48, part=      83990001
 maxforce =    0.9542E+01, time=    0.4997E+01, element=       6020579, part=      83990002
```

Rigid body constraint in arbitrary point (CMO = 2)

- Until now, constraints (applied through |CMO| = 1) and prescribed motion have always been translated to act in the centre of gravity of a rigid body.
- By setting |CMO| = 2, the constraints or prescribed motion of the rigid body can be applied in a user specified coordinate.
- This enhancement is available also for nodal rigid bodies.



Simulating the closure of rigid-body truck door



- Simulating the closing of body closures is done with rigid bodies, rotating at the hinges.
- Before R16, the only way to achieve this was using ***PART_INERTIA** to set the centre of gravity at the hinges.
- However, this changes the physical properties and will not lead to accurate results.

Courtesy of CCSA

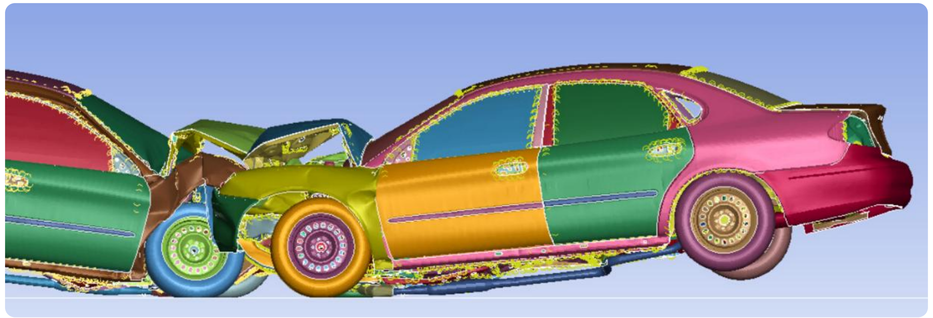
We are coming to the end!

Current development activities

Modular contact

- Still in development (mostly available in DEV, limited in R16).
- Name and input format likely to change
- Looking for early feedback!

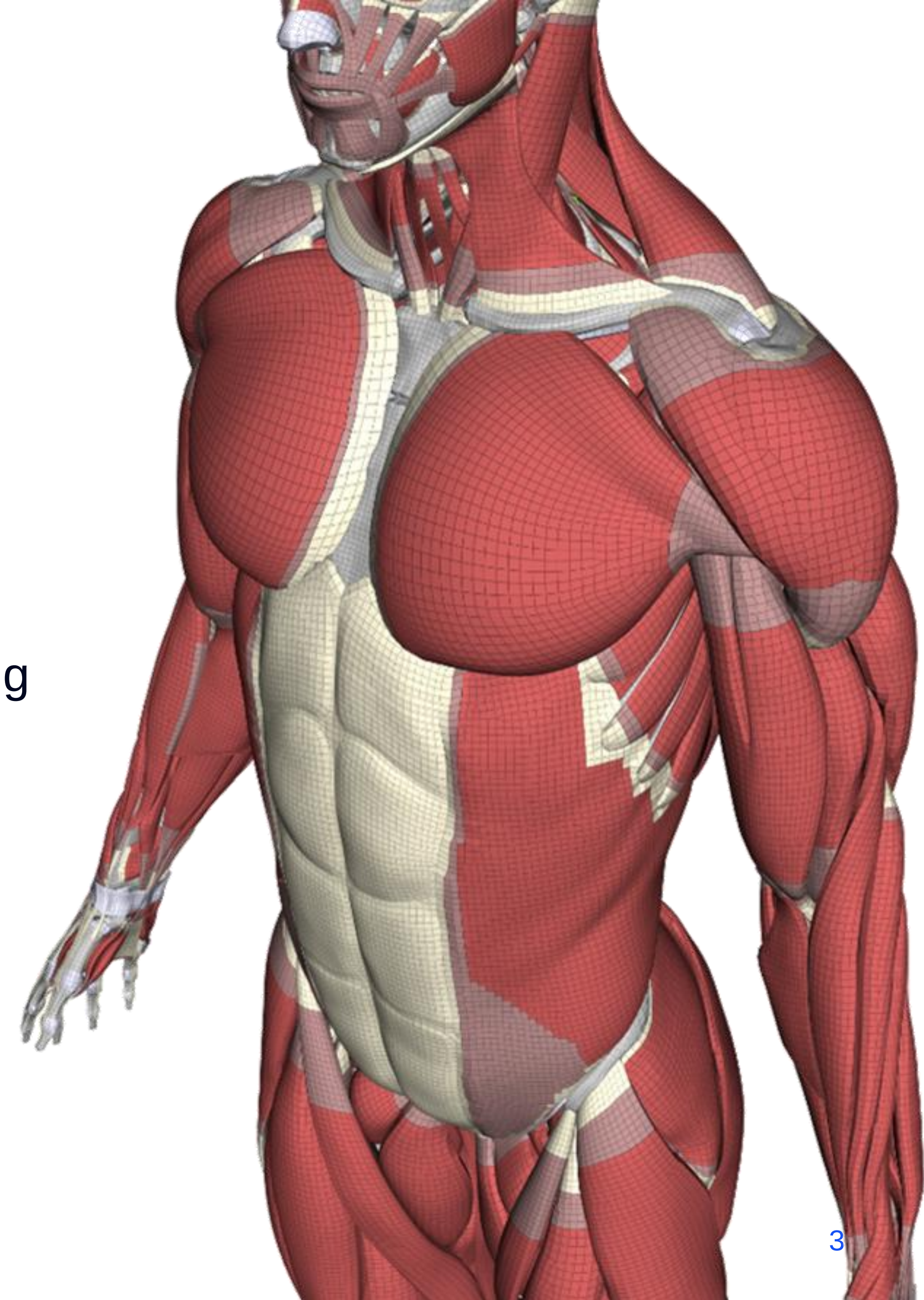
- New modular, generic and universal framework for contacts
- Goal:
  - Unified implementation of contact algorithms
  - Better performance and scalability harnessing modern CPU & GPU architectures
  - Friction, failure and other options will be available across all contact types
- Current status and performance gains so far:
  - New implementation of existing **SOFT = 0/1** contact (**SOFT = 2** in progress)
  - Same keyword-input. Only difference: enabled by setting **SOFT = 10/11**
  - Currently supported ***CONTACT** keywords:
    - **AUTOMATIC_SINGLE_SURFACE**
    - **AUTOMATIC_GENERAL[_INTERIOR][_EDGE_ONLY]**
    - **AUTOMATIC_SURFACE_TO_SURFACE**
    - **AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE**
    - **AUTOMATIC_NODES_TO_SURFACE**



Car-2-car crash. ~10M elements per car
Contact time reduced by **40%**

Introducing Ansys Hans

- High-fidelity human body model
- Exclusively tuned to work with LS-DYNA
- Available now
- Provided with pre-configured PRIMER tree file for positioning



Thank You!