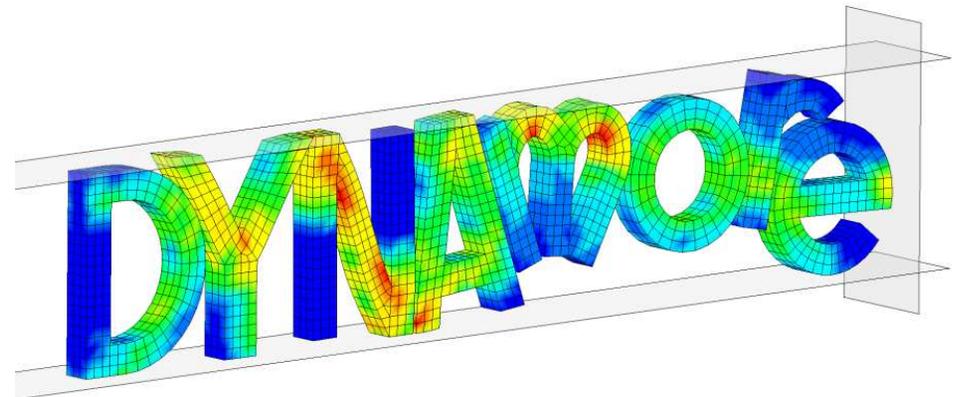# New features in LS-DYNA R8.1

Tobias Erhart, April 13, 2016

- Newest release - published in February 2016
- Robust production version is R7.1.2 (97170)
- This presentation about major changes since R7.1.2
- Comprehensive list of enhancements and corrections in
www.dynasupport.com/news/ls-dyna-r8.0.0-r8.95309-released
www.dynasupport.com/news/ls-dyna-r8.1.0-r8.105896-released

*AIRBAG

- Add RDT option for *AIRBAG_SHELL_REFERENCE_GEOMETRY: time step size based on reference geometry after *MAT_FABRIC birth time

- Several enhancements for *AIRBAG_PARTICLE
  - New blockage (IBLOCK) option for vents
  - Better MPP performance with *DECOMPOSITION_BAGREF/ARRANGE_PARTS
  - External work done by inflator gas to the structure is reported to glstat
  - Support compressing seal vent which acts like flap vent
  - Support Anagonye and Wang porosity equation through *MAT_FABRIC
  - Add keyword option _MOLEFRACTION
  - Calculate heat convection (HCONV) between environment and airbag in consistent fashion when TSW is used to switch from a particle airbag to a control volume
  - Add ENH_V=2 option for vent hole such that two-way flow can occur, i.e., flow with or against the pressure gradient
  - Allow user to exclude surface for initial air particles
  - New option IAIR=4: next slide

*AIRBAG_PARTICLE

- New initial gas option IAIR=4 enables a special logic to treat the region mixed with air and inflator particles.

  - Initial air particles are used in gas front tracking algorithm and do not apply force to the collided segment. Instead, uniform pressure will be applied to it based on the ratio of air and inflator particles.

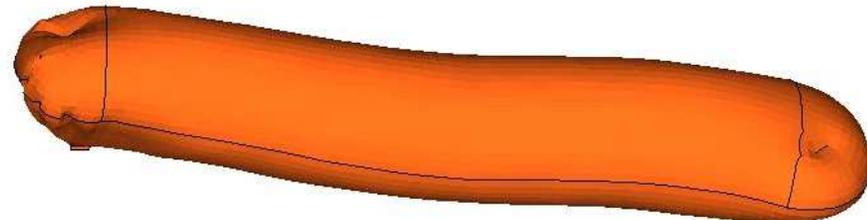- Improves results for tight rolled curtain airbags: fast deployment

"vacuum"
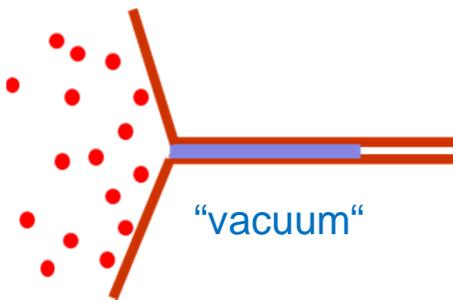
IAIR = 1
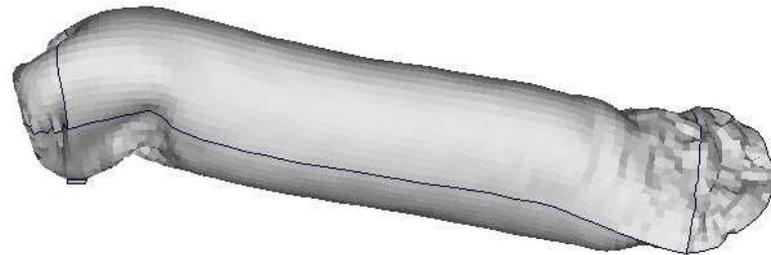
IAIR = 2
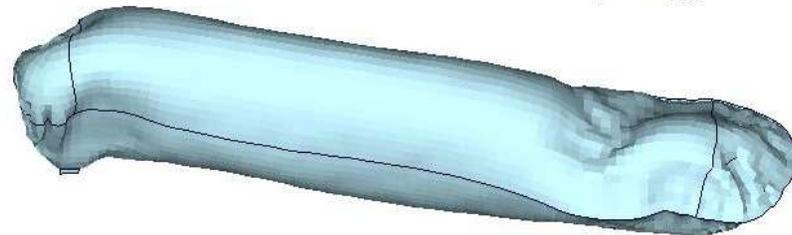
IAIR = 4

Blast simulations

- Solid part or solid part set is now allowed for *PARTICLE_BLAST

- Add ambient pressure boundary condition flag BC_P for *PARTICLE_BLAST

- Activate previously inactive death time BTEND for *PARTICLE_BLAST

- New command *DEFINE_PBLAST_GEOMETRY allows the high explosive domain for *PARTICLE_BLAST
  to be defined by various
  geometric shapes

- Allow multiple
  *PARTICLE_BLAST definitions

- Add *DATABASE_PBSTAT
  to output particle blast statistics

clamped plate subject to the combined
effect of blast and soil impact loading
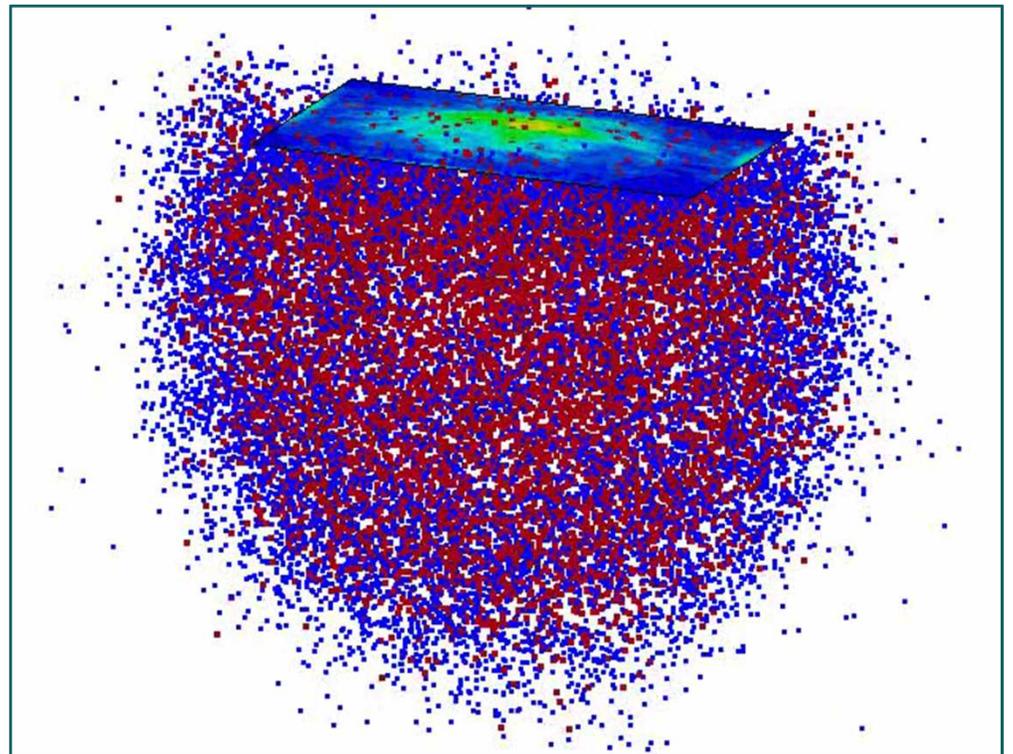
*CONTACT_...

■ Add frictional energy calculation for beams
in *CONTACT_AUTOMATIC_GENERAL

■ Add keyword *DEFINE_CONTACT_EXCLUSION to allow for nodes
tied in some contacts to be ignored in certain other contacts

■ Add EDGEONLY option to *CONTACT_AUTOMATIC_GENERAL to exclude
node-to-segment contact and consider only edge-to-edge and beam-to-beam

■ Enable user defined friction for MPP contact SOFT=4

■ Friction factors are now a function of temperature for
*CONTACT_..._THERMAL_FRICTION

*CONTACT_ERODING_...

■ Major rewrite to improve performance (MPP)

■ The new algorithm uses a completely different approach to determining the contact surface. The old algorithm started from scratch when identifying the exterior of the parts in contact.
The new algorithm is smarter about knowing what has been exposed based on what is eroded, and is faster.

■ Example:
Fan blade out problem $\longrightarrow$

System Configurations:
Cray XC, 12 cores/node
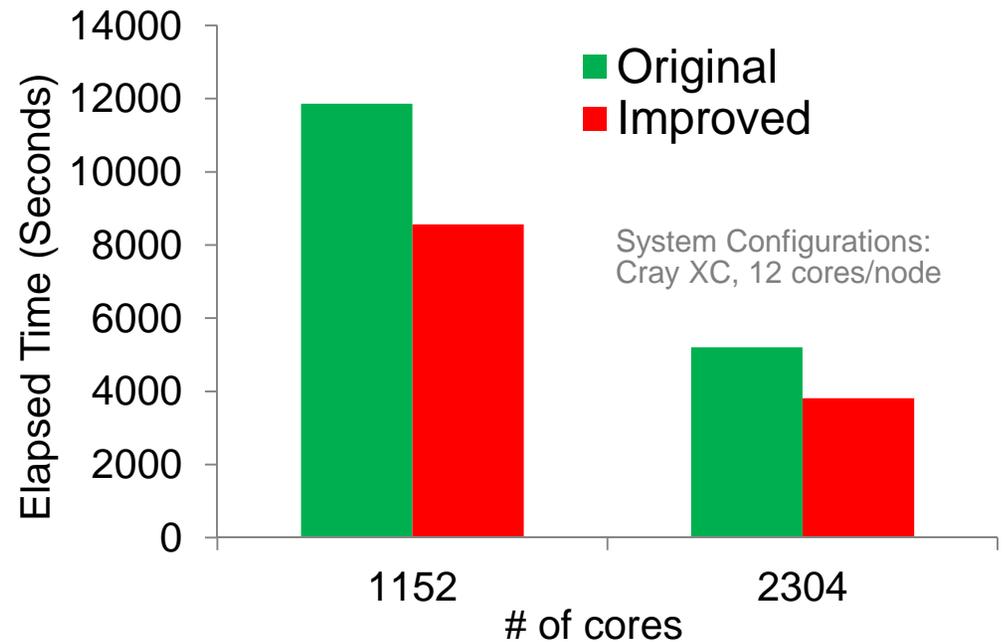
*CONTACT_..._MORTAR

- ■ Efficiency improvements in contact search significantly improves execution

- ■ Supports friction options FS < 0
  - ■ Friction coefficients on *PART_CONTACT
  - ■ Friction table *DEFINE_FRICTION

- ■ Various bug fixes
  - ■ Look ahead adaptivity reintroduced
  - ■ Single surface beam contact
  - ■ Reduce initialization time for forming contact

- ■ Using IGNORE.LT.0 for single surface mortar contact will ignore penetrations of segments that belong to the same part. This will hopefully facilitate removal of initial penetrations in large models

Spurious self-contact
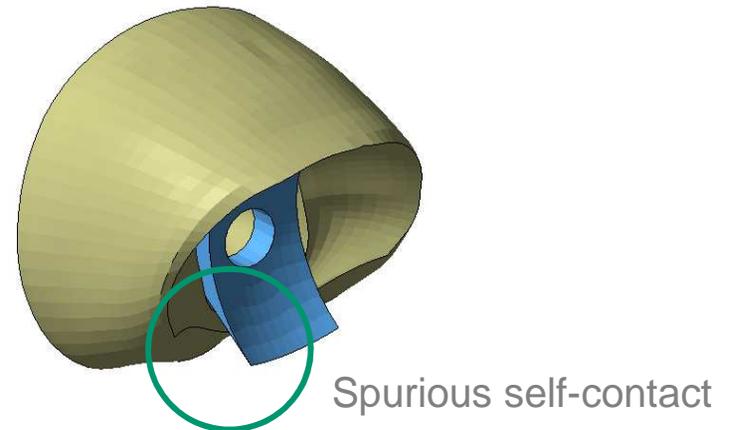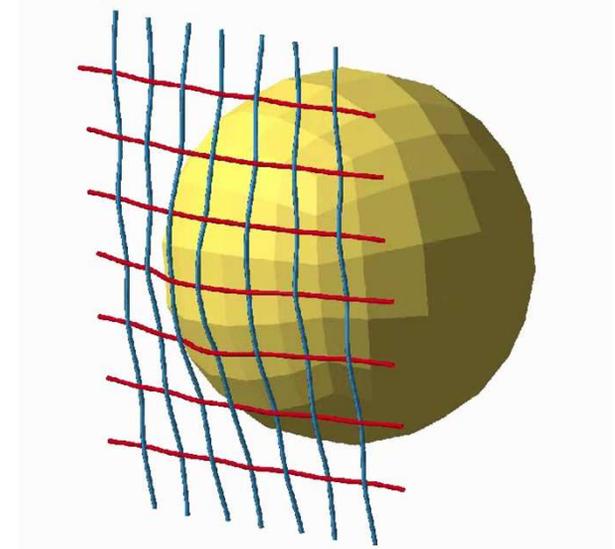
*CONTACT_ADD_WEAR

- ■ Hot forming is hard on tools, wear much higher than in cold forming: Simulating wear is of interest for improving tool design

- ■ New keyword *CONTACT_ADD_WEAR
  - ■ Refer to a forming contact
  - ■ Specify wear law, currently only "Archard"

- ■ Keyword *DATABASE_EXTENT_INTFOR
  - ■ Parameter NWEAR to get wear depth to intfor file for post-processing

- ■ No coupling to simulation, only post processing

- ■ More to come in version R9 ...

untitled
Time =   0.0033998, #nodes=8159, #elem=7605

wrinkling
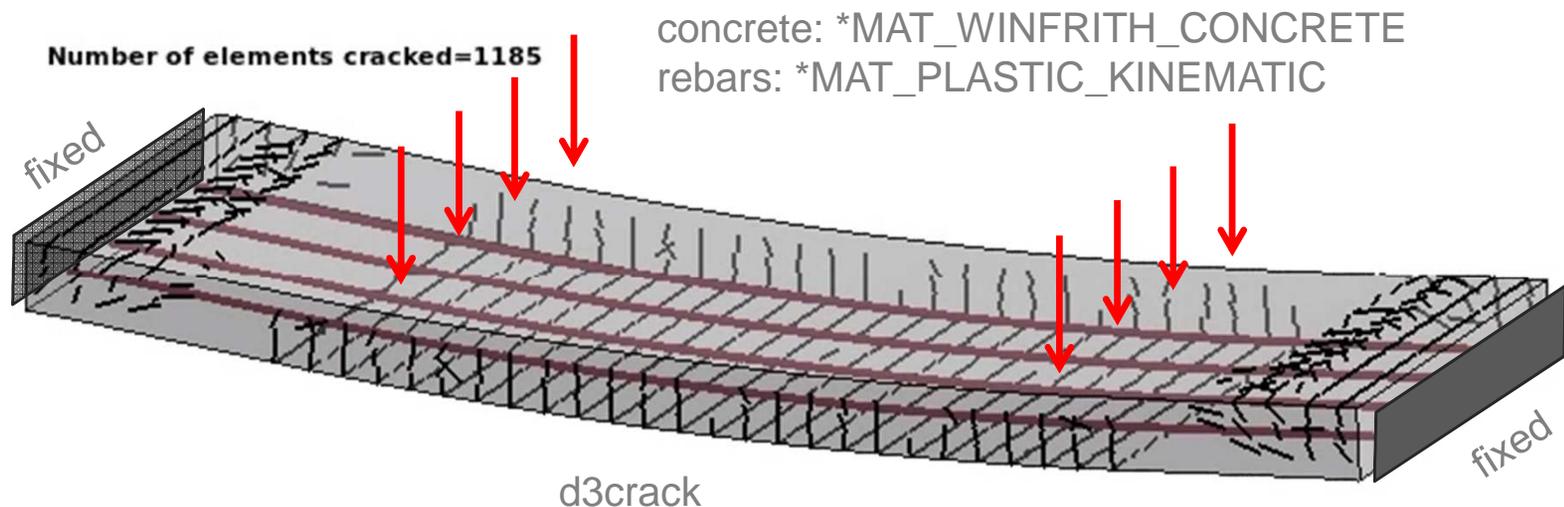tendency influences
wear on binder
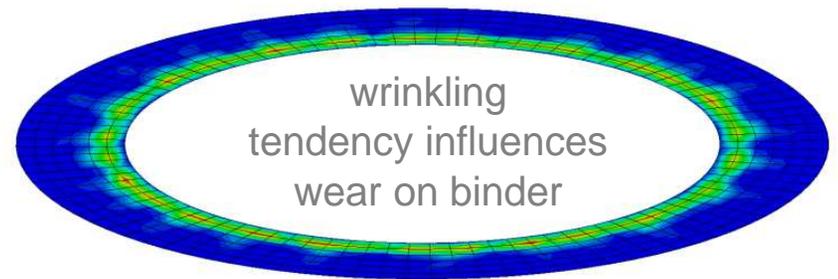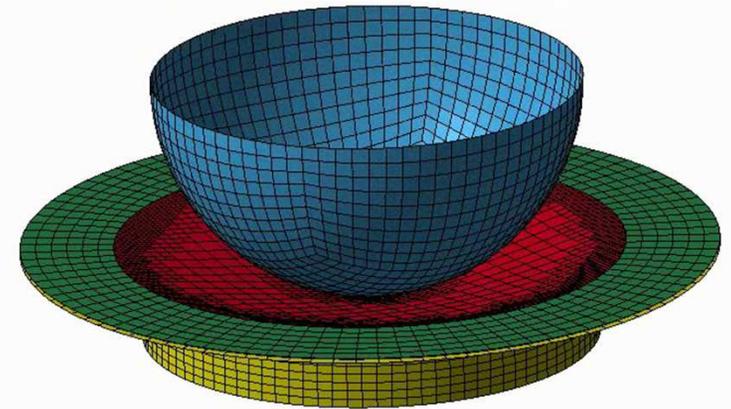
*CONTACT_AUTOMATIC_...

- If ICOR≠0 on Optional Card E, the viscous damping coefficient, VDC, is the coefficient of restitution expressed as percentage of damping

- Coefficient of restitution of two colliding objects represents the ratio of speeds after and before an impact, taken along the line of the impact

- 0.0 (plastic collision) ≤ VDC (COR) ≤ 100.0 (elastic collision)
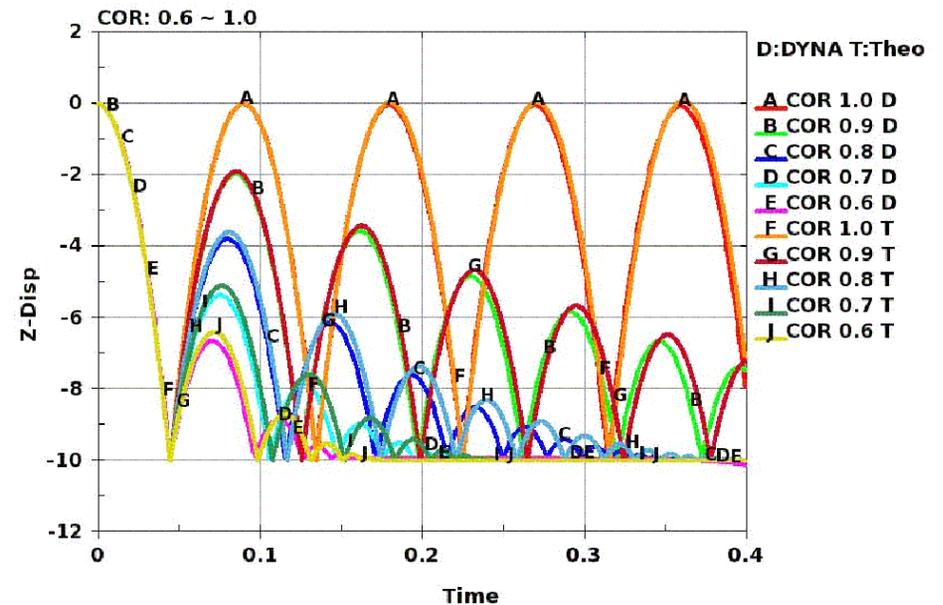
*CONSTRAINED

- **New keyword *CONSTRAINED_BEAM_IN_SOLID:**

  - This feature is basically an overhauled constraint coupling between beams and Lagrangian solids that includes features that make it more attractive in some cases than *CONSTRAINED_LAGRANGE_IN_SOLID, for example, in modeling coupling of rebars in concrete.

  - Allows coupling only in normal directions (optional)

  - De-bonding process via axial coupling force (*DEFINE_FUNCTION: force vs. slip)

  - Correct energy balance

concrete: *MAT_WINFRITH_CONCRETE
rebars: *MAT_PLASTIC_KINEMATIC

Number of elements cracked=1185

fixed

fixed

d3crack

*CONSTRAINED_JOINT

- For penalty-based joints, relative penalty stiffness can now be defined as time dependent value given by load curve (option RPS<0)

  - Nodal points of connected parts must <u>not</u> coincide initially anymore

  - For pre-stressing of joint connections

  - Works for options…
    SPHERICAL,
    REVOLUTE,
    CYLINDRICAL

initial gap gets closed

Time =   0.01

effective stress
[0-120 N/mm²]
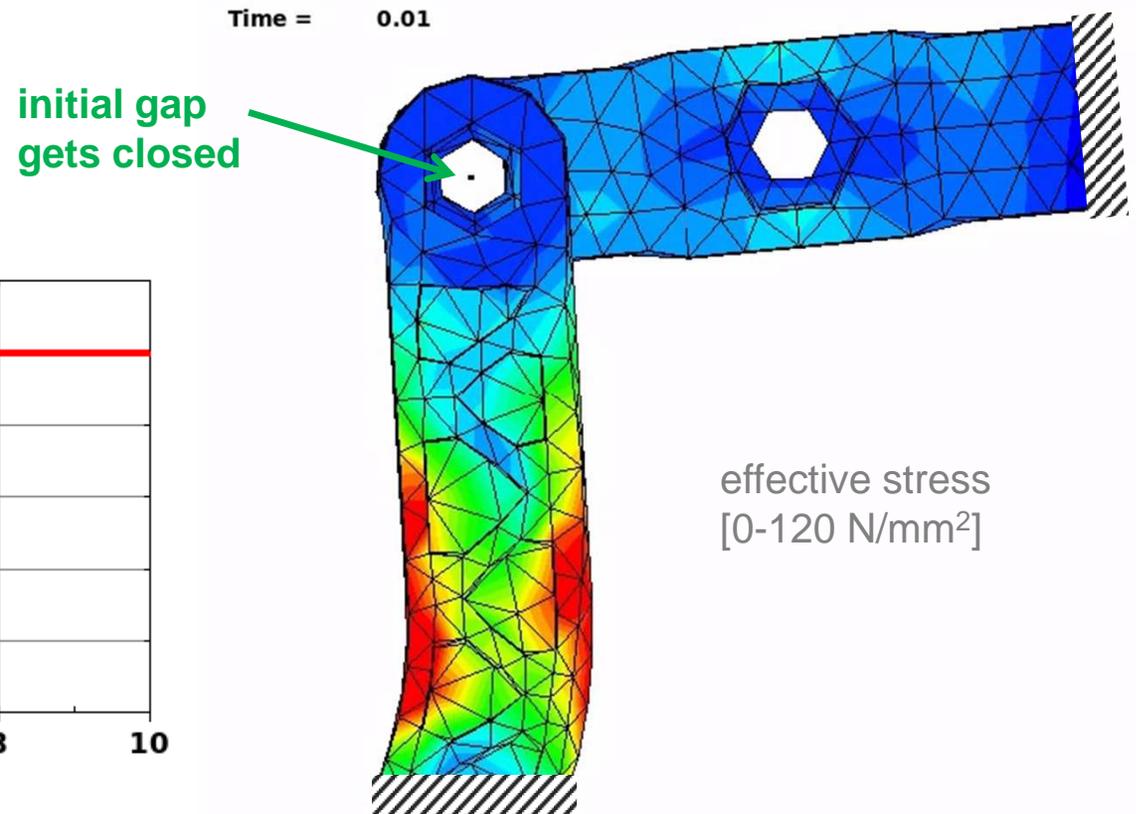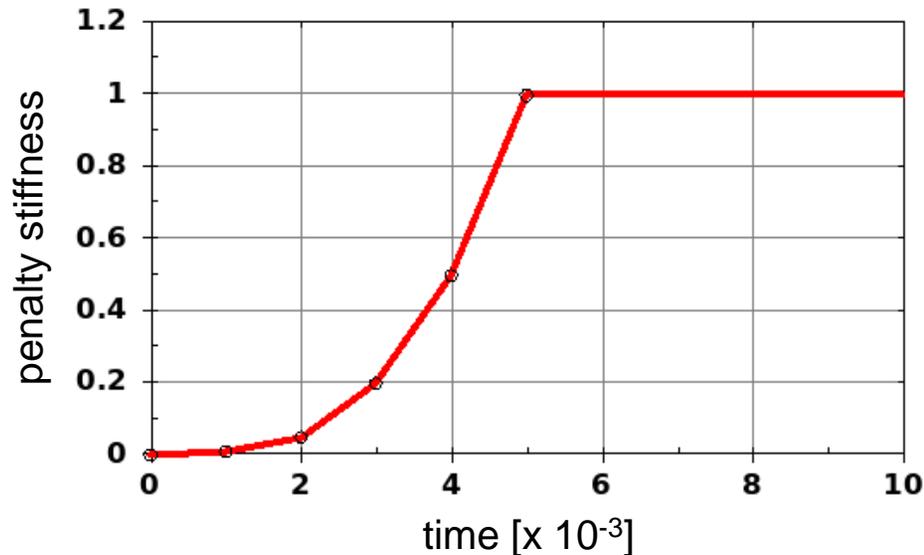
*CONSTRAINED_SPR2/3

- Add failure reports and more d3hsp output

- Add new option to *CONSTRAINED_INTERPOLATION_SPOTWELD: "SPR4"
  - There is a new parameter MODEL to select the new method

- Add new feature MODEL.GE.10 to *CONSTRAINED_SPR3
  - This allows parameters STIFF, ALPHA1, RN, RS, and BETA to be defined as *DEFINE_FUNCTIONs of thicknesses and maximum engineering yield stresses of connected sheets
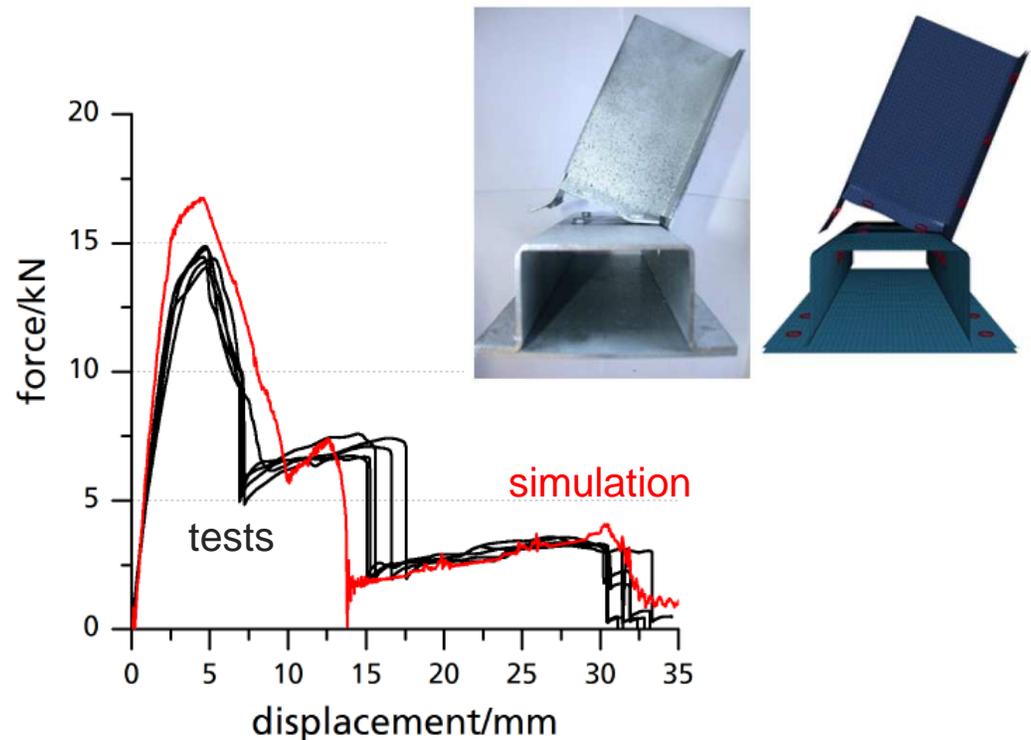
*CONTROL_SUBCYCLE

- New subcycling scheme activated for *CONTROL_SUBCYCLE_K_L (subcycling) and *CONTROL_SUBCYCLE_MASS_SCALED_PART (multi-scale)

  - Simplified input: time step ratios for internal and external force calculations

  - Multi-scale: User may manually designate parts to be integrated at specific time steps

  - Improved robustness and performance

B-pillar refined
DT2MS=-1e-3
DT(B-pillar)=1.3e-4
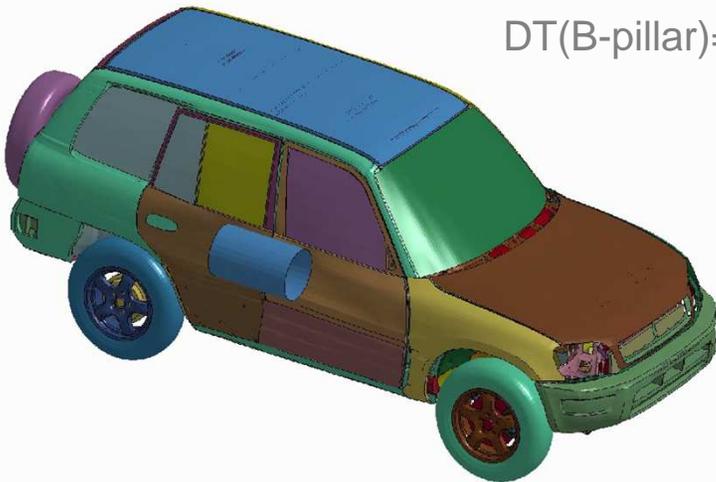
CPU timings (s)	Subcycling, K=64, L=4	Multi-scale, L=4	Default
Contacts	133	133	288
Elements	194	206	636

*CONTROL_REMESHING

■ New method for axisymmetric remeshing (*PART with ADPOPT=3)

■ Works with hexahedral and pentahedral elements (quads and trias in sections)

■ Number of elements can increase and decrease

Contours of Effective Plastic Strain
min=1.53211e-05, at elem# 16821
max=1.70251, at elem# 16022
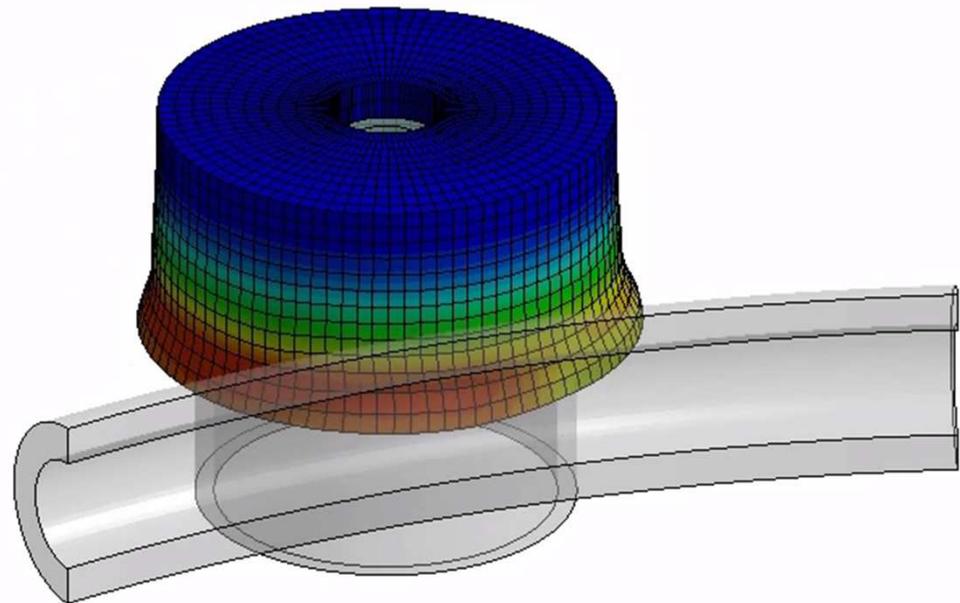
application area:
3-D orbital forming

*DEFINE_ADAPTIVE_SOLID_TO_DES

- Adaptively transform a Lagrangian solid Part or Part Set to DES particles when the Lagrangian solid elements comprising those parts fail.
- One or more DES particles (elements) will be generated for each failed element.
- The DES particles replacing the failed element inherit all of the properties of the failed solid element, e.g. mass, kinematic variables, and constitutive properties.
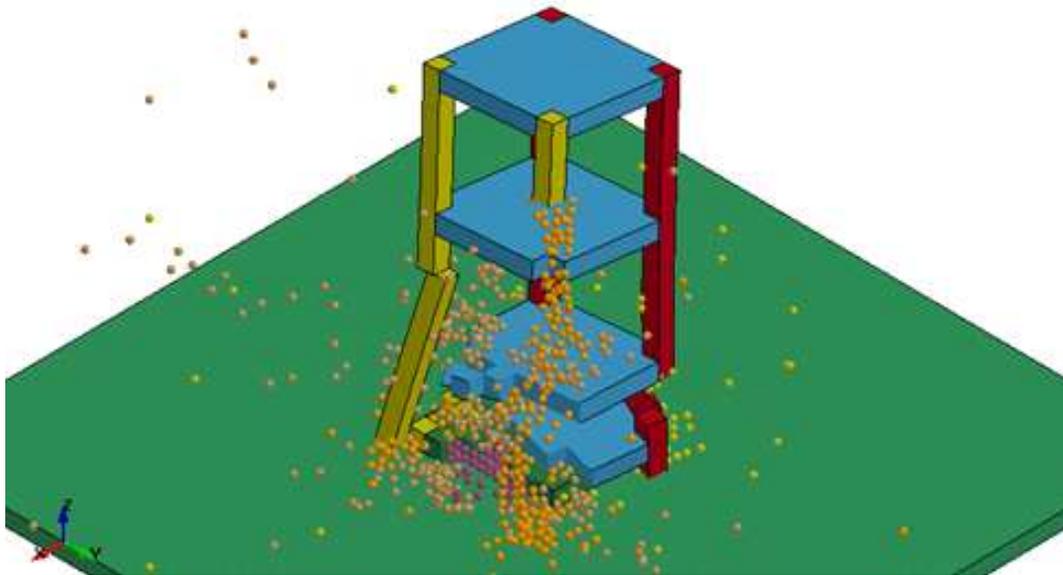
Courtesy of
Institut für Mechanik

Universität Karlsruhe (TH)
Forschungsuniversität · gegründet 1825

*DEFINE_ELEMENT_DEATH

■ New variable IDGRP defines a group id for simultaneous deletion of elements.

■ If one element out of this group is eroded, e.g. due to material failure, all other elements with the same group id will be deleted in the next time step as well.

bolt connection
Time =   0.0016
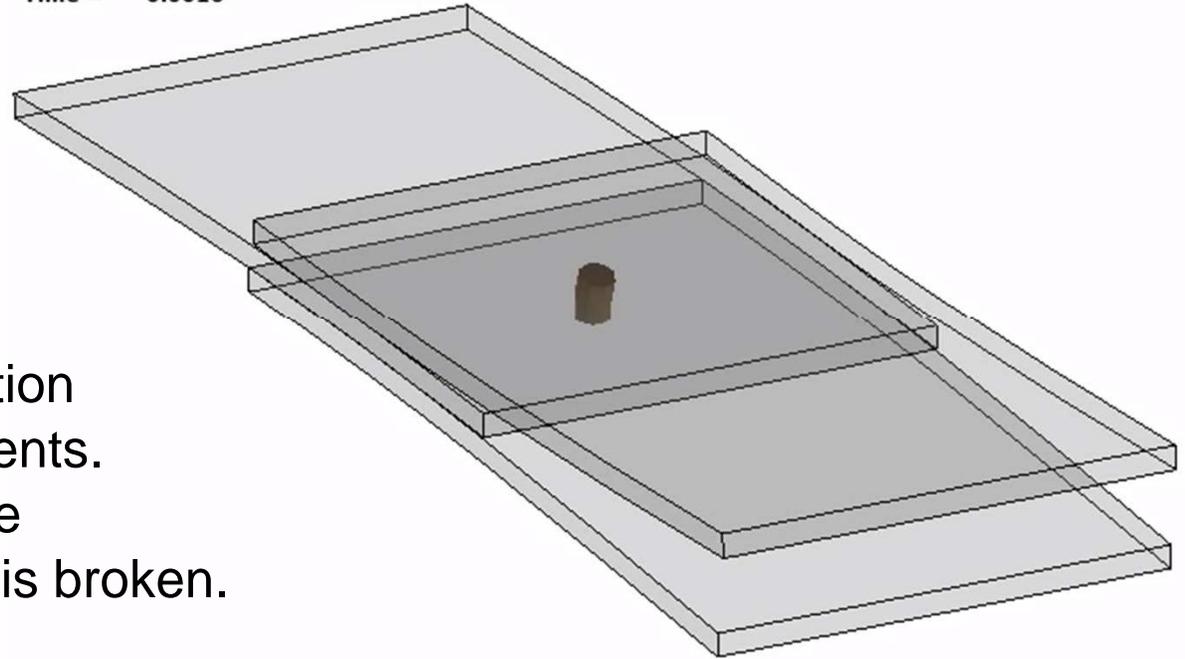
■ Example: 3-sheet bolt connection
modelled with two beam elements.
If one beam fails, the other one
does too → whole connection is broken.

*FREQUENCY_DOMAIN_...

■ Several enhancements and new features in different areas

- ■ acoustic solvers: boundary conditions, output, eigenvalue analysis, incident wave, …
- ■ fatigue solvers: multi-slope S-N curves, multiple damage ratios, new stress index, …
- ■ vibration solvers: random vibration, modal analysis, …

■ New GUI in LS-Prepost 4.2 for frequency domain databases

sound pressure level
of car body with
open windows
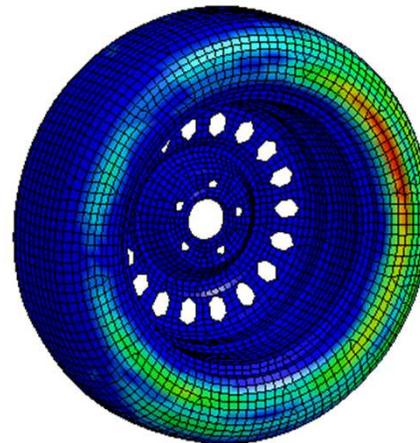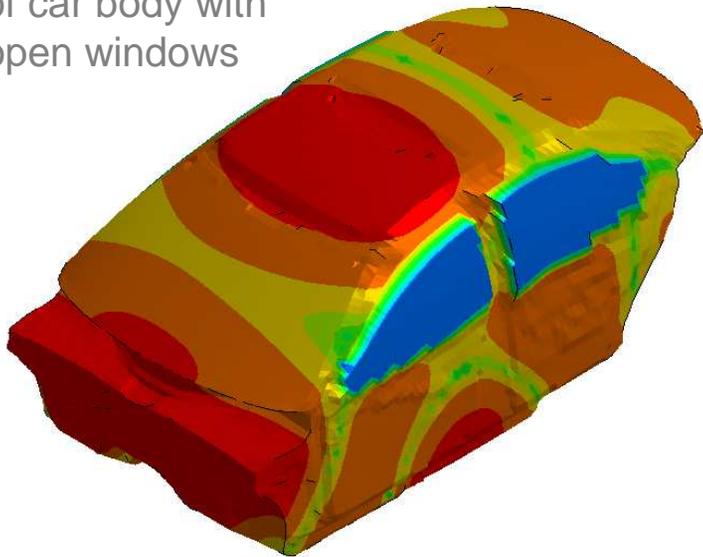
tire noise radiation:
harmonic response

new keyword
*MAT_ADD_FATIGUE:
definition of S-N (Wöhler) curve
for material models

S

$N \cdot S^{b2} = a2$

$N \cdot S^{b1} = a1$

sthres2

sthres1

N
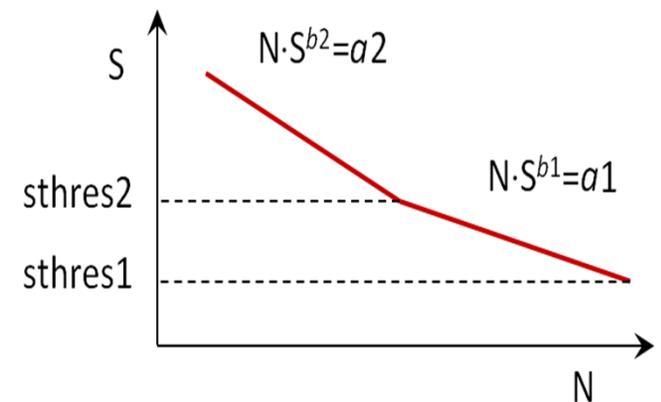
*ELEMENT_BEAM_SOURCE

- New keyword to define a point source (node) where a cable / thread / yarn with pre-defined length can be pulled out

- Input parameters are node id, number of elements to be drawn out, beam element fed length, pull-out force, and minimum beam element length

- Application: e.g. yarn feeders for braiding/weaving processes

moving source

176 moving sources
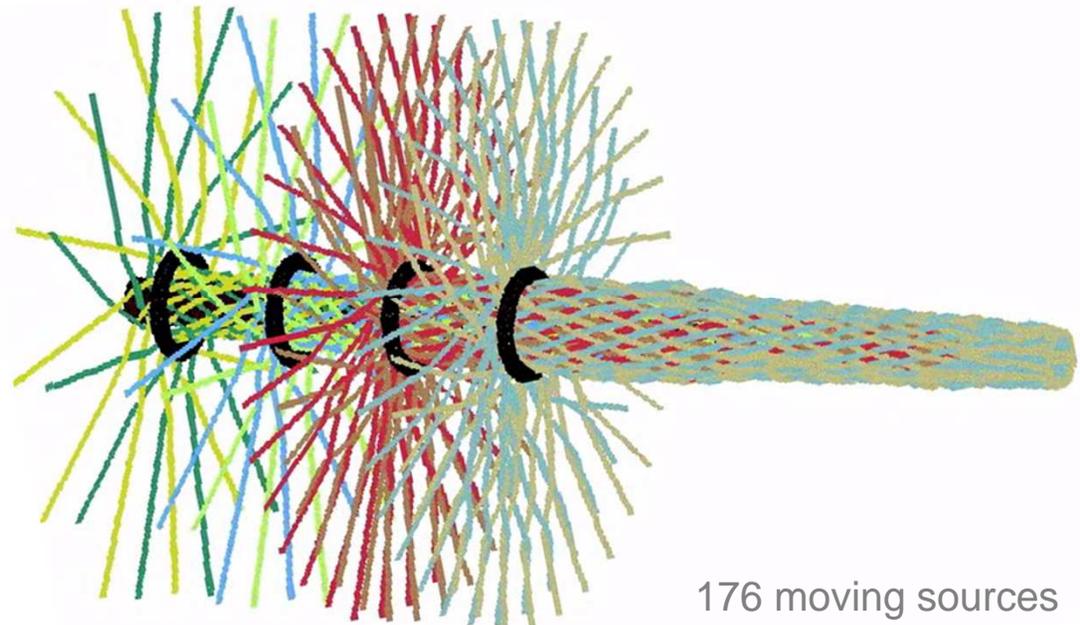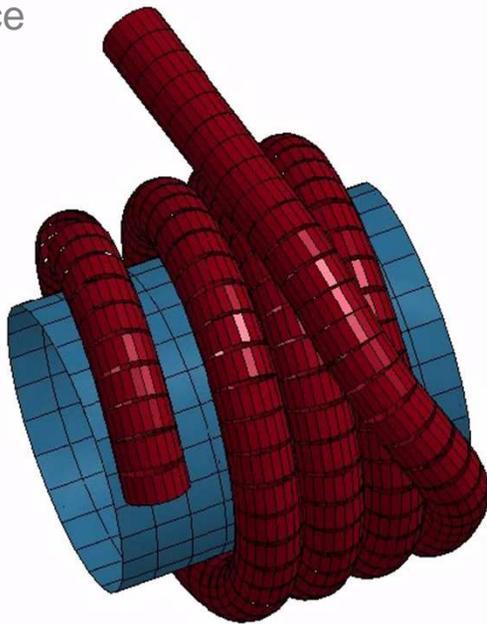
*ELEMENT_TSHELL_BETA

- Works in a similar way like *ELEMENT_SHELL_BETA
- Allows direct thickness extrusion SHELL → TSHELL without loss of material orientation

Cohesive Elements (*SECTION_SOLID, ELFORM=19-22)

- Improve stability for ELFORM=20 (with offsets for use with shells)
  - New incremental formulation to properly handle large rotations
- Add pentahedron elements
  - ELFORM=21 (6-noded pentahedron)
  - ELFORM=22 (6-noded pentahedron with offsets for use with shells)
  - ESORT.gt.0 in *CONTROL_SOLID automatically activates element sorting of pentahedron solid elements
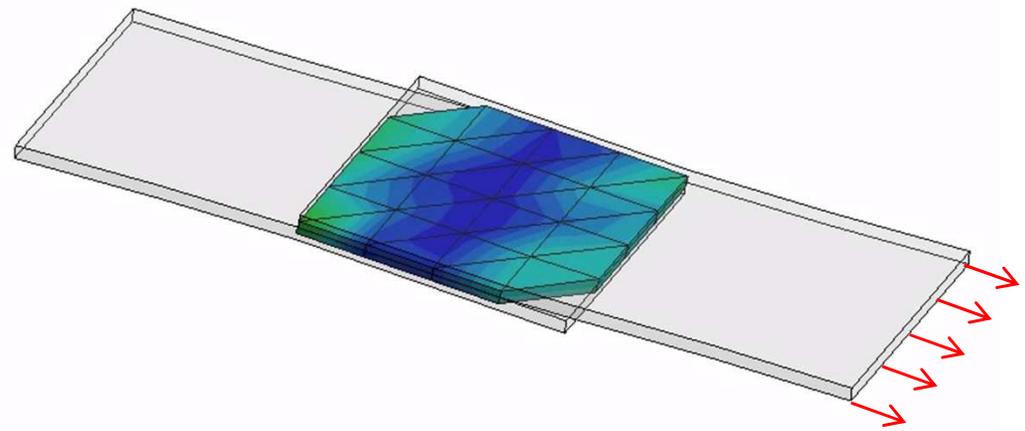
*SECTION_SHELL, new ELFORM=29

- New cohesive <u>shell</u> element for edge-to-edge connectivity between shells
- Takes bending into account, supports MPP and Implicit
- Can be used with usual cohesive material laws (138, 186, 240, 252)
- Presentation was given in Würzburg 2015 by Jesper Karlsson
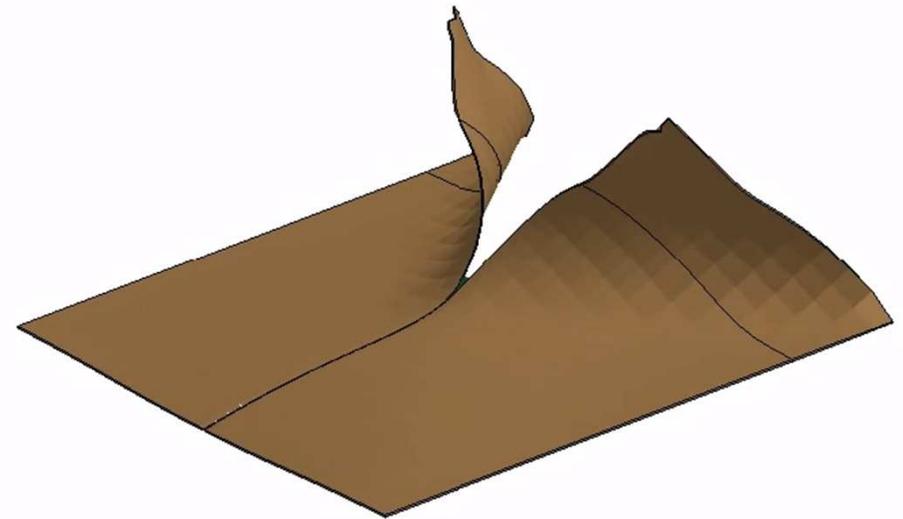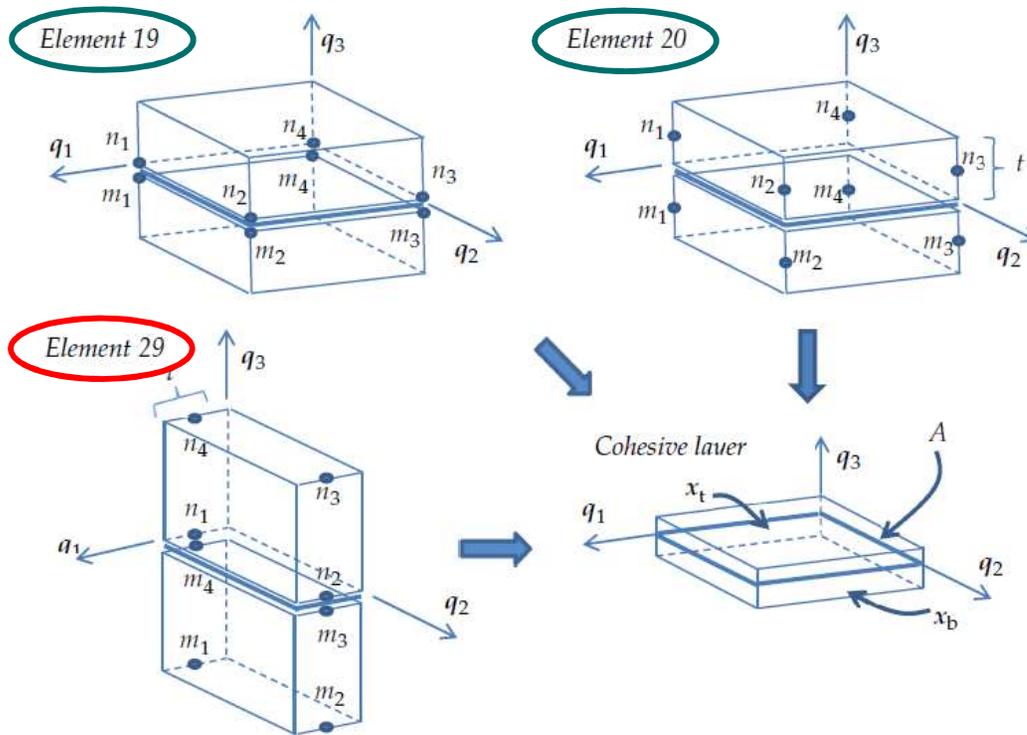
ripping of pre-notched clamped plate

Postprocessing of Solid Element Results

- Add option SOLSIG to *CONTROL_OUTPUT which will permit stresses and other history variables for multi-integration point solids to be extrapolated to nodes.

  - These extrapolated nodal values replace the integration point values normally stored in d3plot. NINTSLD must be set to 8 in *DATABASE_EXTENT_BINARY when a nonzero SOLSIG is specified.

  - Supported solid formulations are: -1, -2, 2, 3, 4, 16, 17, 18, and 23.

  - Warning: Do not use "Setting - Extrapolate" in LS-PrePost when SOLSIG is nonzero.

Example: 3-pont bending, longitudinal stresses

w/o SOLSIG

with SOLSIG

higher resolution in coarse meshes
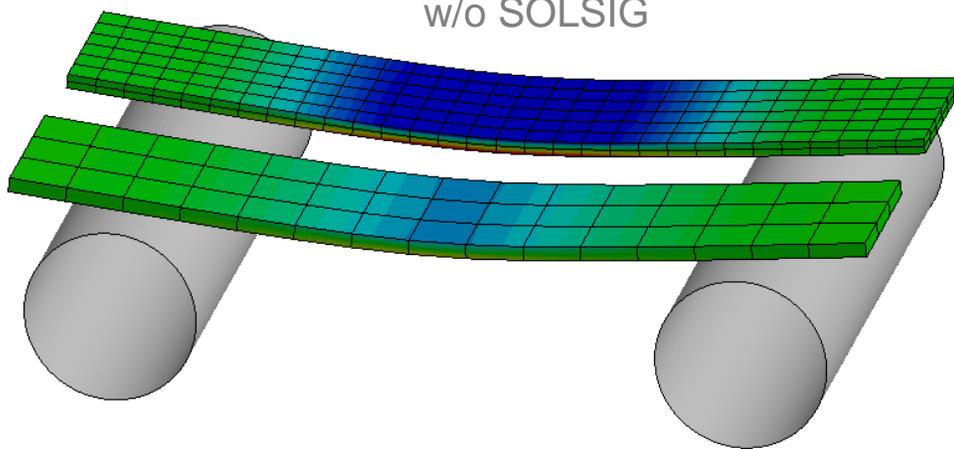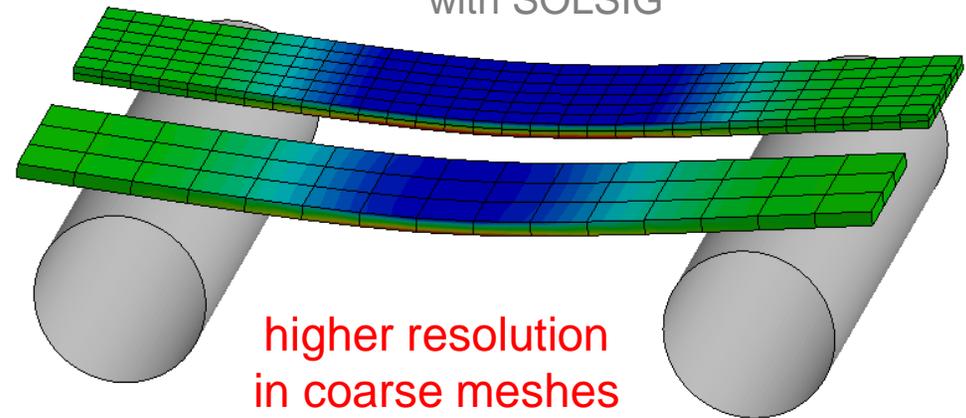
*ELEMENT_SHELL_NURBS_PATCH

■ Several enhancements in the area of Isogeometric Analysis (IGA)

- ■ Add support for dumping of strain tensor (STRFLG.eq.1) for isogeometric shells via interpolation shells

- ■ Add support for dumping of shell internal energy density for isogeometric shells via interpolation shells

- ■ Add conventional mass-scaling for isogeometric shells

- ■ Improved writing of IGAPLOT-file

■ Much more to come
in version R9 …
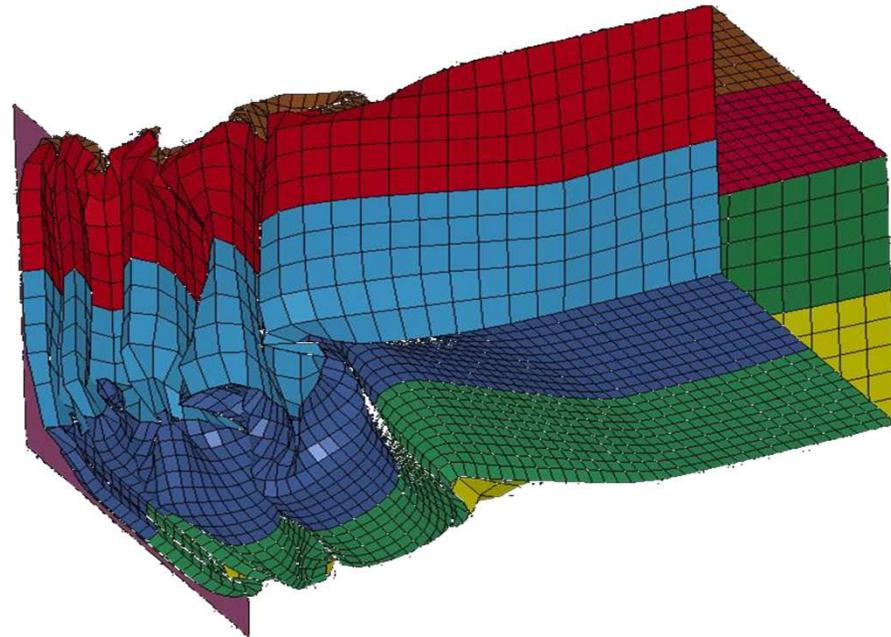
*ELEMENT_DISCRETE

■ ***DEFINE_DE_TO_SURFACE_COUPLING:**
Particle-structure contact with "new" contact definitions

■ Developed especially for discrete element
  to Lagrangian structure interaction

■ Archard's Wear Law to predict surface wear

■ Wear depth is output to the interface force file
  (*DATABASE_BINARY_DEMFOR)

fringe plot of
surface wear
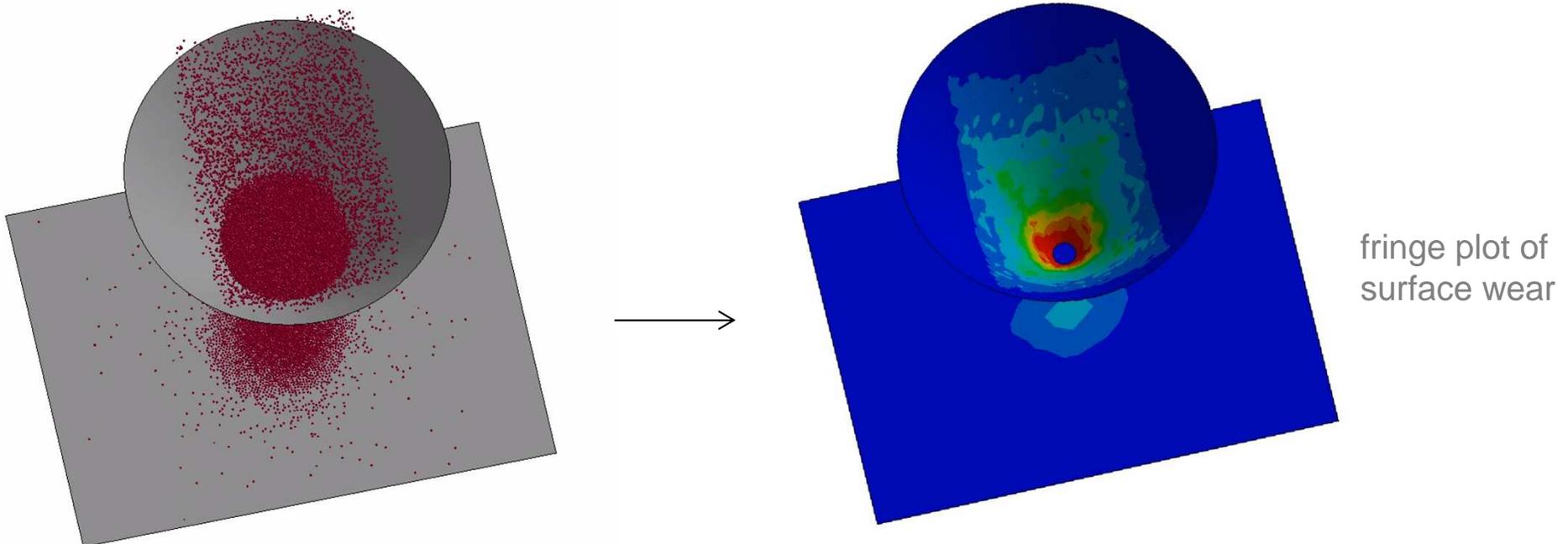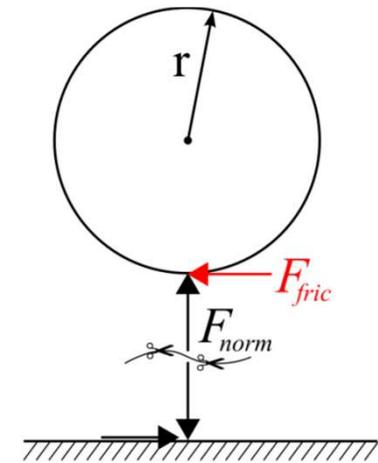
Forming related features

- *CONTROL_FORMING_AUTOCHECK
- *CONTROL_FORMING_MAXID
- *CONTROL_FORMING_ONESTEP
- *CONTROL_FORMING_OUTPUT
- *CONTROL_FORMING_SCRAP_FALL
- *CONTROL_FORMING_TRIM_MERGE
- *CONTROL_FORMING_TRIMMING
- *CONTROL_FORMING_UNFLANGING
- *DEFINE_CURVE_TRIM_3D/NEW
- *ELEMENT_LANCING
- *INTERFACE_COMPENSATION_NEW
- *INTERFACE_BLANKSIZE_DEVELOPMENT
- …
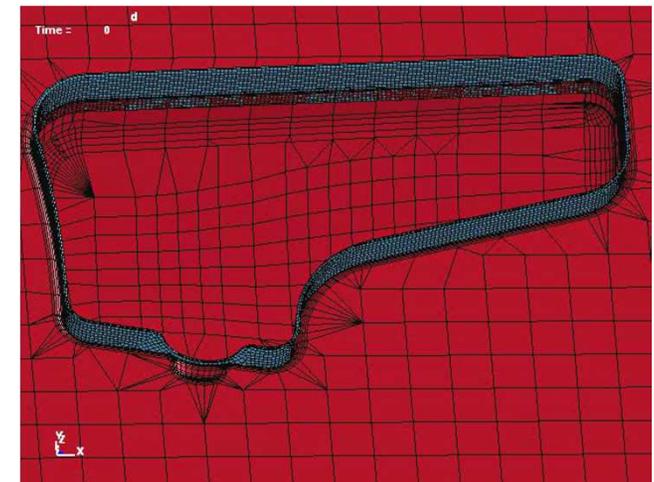
e.g. *CONTROL_FORMING_UNFLANGING

- **Several new features for unflanging**
  - The incoming flange mesh will be automatically checked for mesh quality
  - Allow thickness offset of deformable flange to use the blank thickness from user's input
  - Add a new parameter CHARLEN to limit the search region
  - Allow holes to exist in the flange regions
  - Output a suggested flange part after unflanging simulation, with the failed elements deleted from the unflanged part
  - Add output of forming thickness, effective strain and trim curves after unflanging
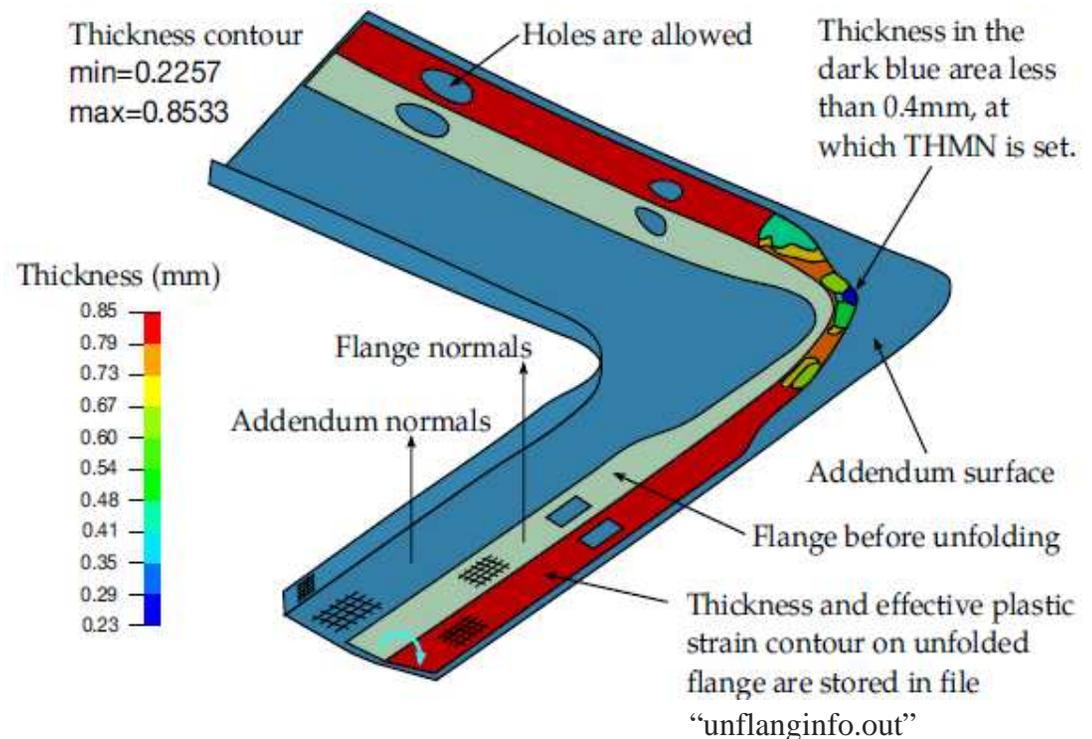
New implicit features

- **Dumping of system matrices, see MTXDMP in *CONTROL_IMPLICIT_SOLVER**
  - Can now dump the damping matrix (in addition to stiffness and mass matrices)
  - Extend matrix dumping capability to MPP
  - MTXDMP<0 will terminate the run after dumping of matrices

- ***CONTROL_IMPLICIT_SOLVER**
  - Nonsymmetric linear solver can be used by specifying LCPACK=3
  - Allow unsymmetric terms to the assembled stiffness matrix from some implicit features (nonuniform follower loads, user elements)

- ***MAT_FABRIC** now available

- ***MAT_SEATBELT** now available
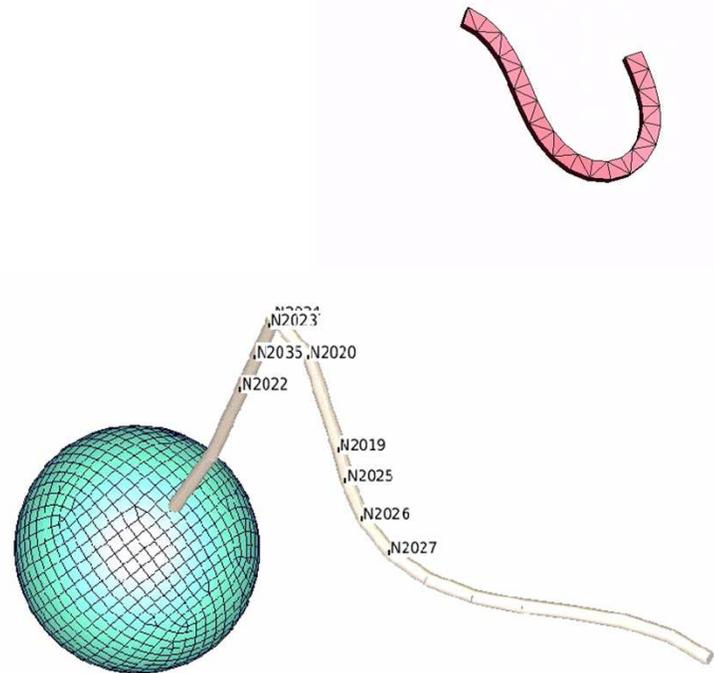
*CONTROL_IMPLICIT_MODAL_DYNAMIC

- Modal Dynamics is used to reduce the cost of analysis. Element and Material computations are replaced by two multiplications by Φ

- This has been in LS-DYNA since LS-DYNA 960 using *CONTROL_IMPLICIT_DYNAMICS with IMASS = 2 or 3

- Now, Modal Dynamics has been enhanced with new features and keywords.
  - *CONTROL_IMPLICIT_MODAL_DYNAMIC
    To activate modal dynamic analysis
  - *CONTROL_IMPLICIT_MODAL_DYNAMIC_MODE
    To select a subset of modes to use in the analysis
  - *CONTROL_IMPLICIT_MODAL_DYNAMIC_DAMPING
    To specify damping coefficients for modal damping.

instrument bracket
with impulse forces

- Talk about that topic given
  by Roger Grimes in Detroit 2014
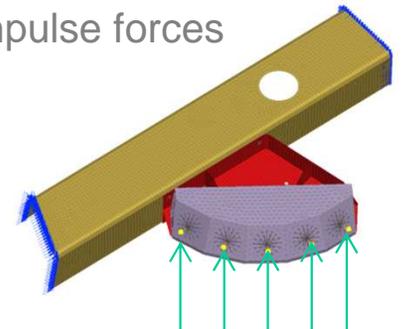
transient explicit: 220 min (single precision)
transient non-linear implicit: 265 min
transient modal dynamics: 4 min

*CONTROL_IMPLICIT_ROTATIONAL_DYNAMICS

- New keyword is added to study Rotordynamics using the implicit time integrator

- Linearized equilibrium equation in the rotating coordinate system includes gyroscopic damping (Coriolis contribution) and centrifugal stiffness

$$\mathbf{Mu} + (\mathbf{D} + 2\Omega\mathbf{C})\dot{\mathbf{u}} + (\mathbf{K} - \Omega^2\mathbf{K}_G)\mathbf{u} = \mathbf{F}$$

- Applications: transient and vibration analysis of rotating parts such as turbine blades, propellers in aircraft, and rotating disks in hard disk drives.

- It is available for beam, shell, solid and thick shell elements.

- Currently only SMP double, MPP under development.

Contours of Effective Stress (v-m)
ipt #2 and ipt #3
min=603.738, at elem# 1884
max=59087, at elem# 832
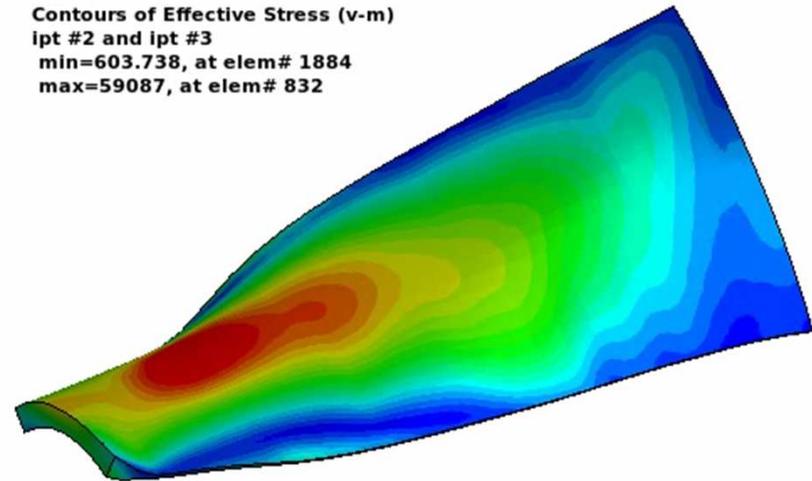
*MAT_FABRIC (*MAT_034)

- Add new formulation FORM = 24 as modified version of FORM = 14
  - The main improvement is that the Poisson's effects work correctly with the nonlinear curves for fiber stress.
  - Also, the output of stress and strain to d3plot are engineering stress and strain instead of 2nd PK stress and Green's strain.

- New material model *MAT_FABRIC_MAP
  - stress response is given exclusively by tables, or maps, and where some obsolete features in *MAT_FABRIC have been deliberately excluded to allow for a clean input and better overview of the model
  - Presentation in Würzburg 2015 by Thomas Borrvall
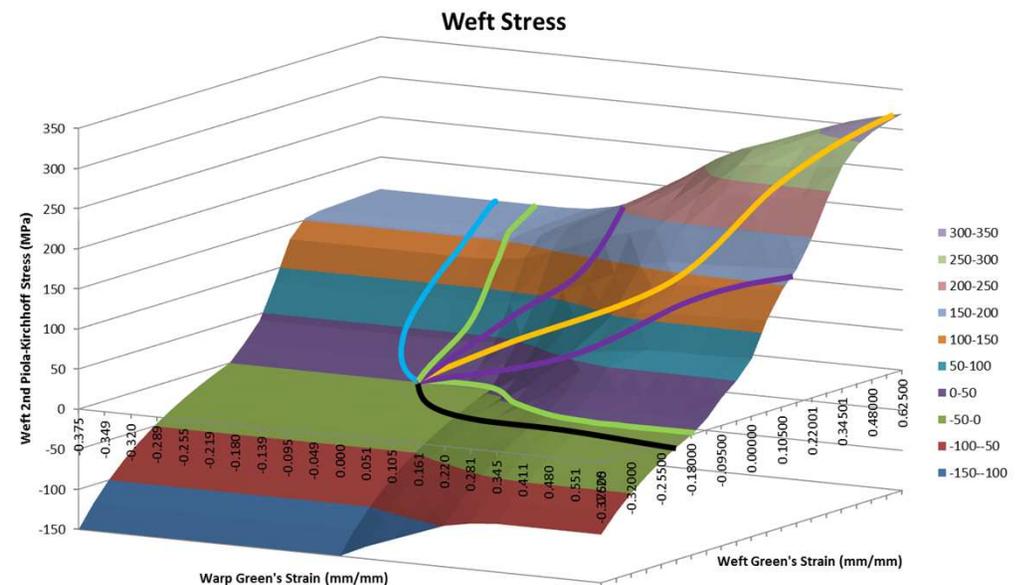
*MAT_LAMINATED_COMPOSITE_FABRIC (*MAT_058)

- Added possibility to define „arbitrary" uniaxial elastic stress vs. strain behavior using curve definitions (valid for EA, EB, GAB)
  - non-linear elastic behavior
  - different stiffness in tension and compression

- Strain rate dependent stiffness using table definition (stress vs. strain vs. strain rate)
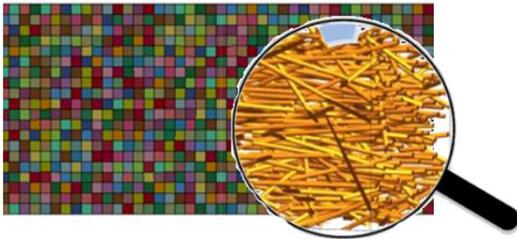
Curve-definition for EA

compression   tension
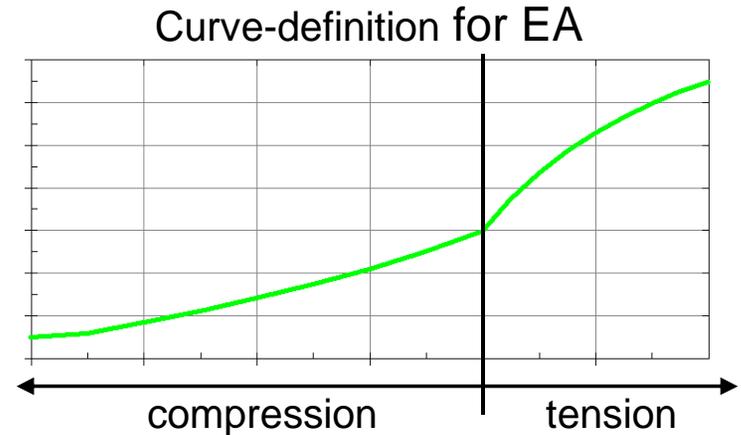
*MAT_SPOTWELD (*MAT_100)

- Add option to use yield curve or table for solid elements (SIGY<0)
- Enable force filtering option NF for solids and solid assemblies
- New "uniaxial option" activated by E<0

*MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)

- Well suited for short-fiber reinforced composites due to anisotropy in elastic and plastic regime

- Added VP=1 (viscoplastic formulation) for shells

- *MAT_157 implemented for solids (including VP=1)

- Possibility to initialize various anisotropic material properties via *INITIAL_STRESS_SHELL/SOLID on a per-element basis (IHIS)

In material card

Drawback: inhomogeneous distribution (e.g. from previous short fiber filling simulation) in component needs individual part definition for every element

With *INITIAL_STRESS_SOLID
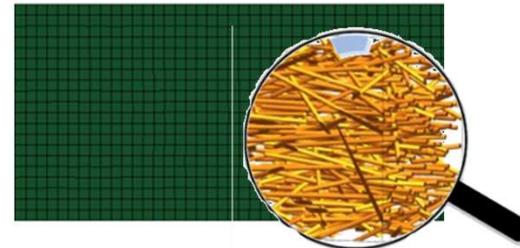
Only one part definition for whole component. Anisotropic coefficients are part of material's history field and can therefore be initialized for each integration point individually

*MAT_UHS_STEEL (*MAT_244)

- By default same start temperatures for phase transitions are assumed for heating and cooling
- Now, advanced reaction kinetics input (`REACT=1`) accepts load curve IDs (input as negative values) for `FS, PS, BS,` and `MS`
- Temperature dependent thermal expansion for austenite and hard phases
- Added load curve for transformation induced strains
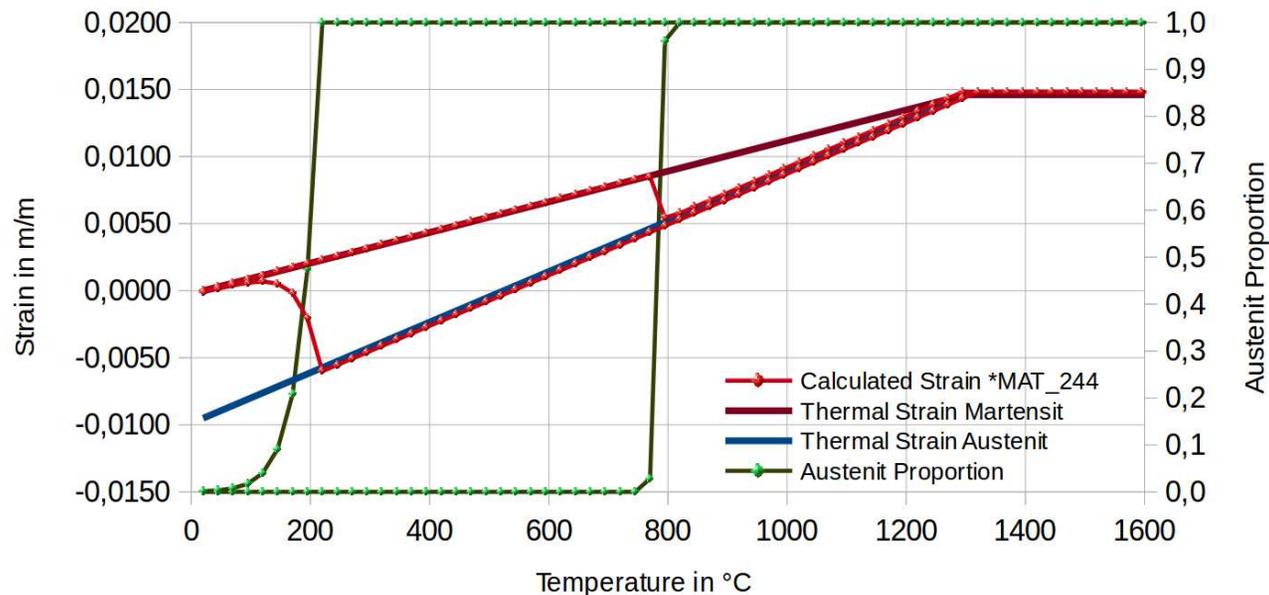
*MAT_UHS_STEEL (*MAT_244)

- New features for welding
- Ghost material approach as in *MAT_270
  - Material is inactive at the beginning, but is activated by temperature
- Annealing is also considered (history variables reset)
- Can be combined with *MAT_THERMAL_CWM

temperature evolution
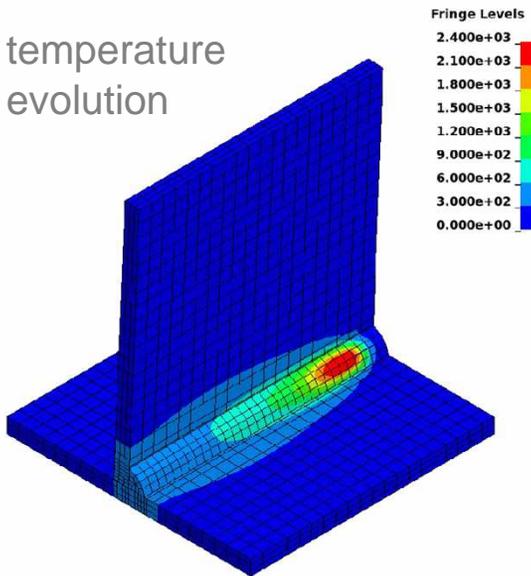
displacement

displacement

w/o ghosting

with ghosting

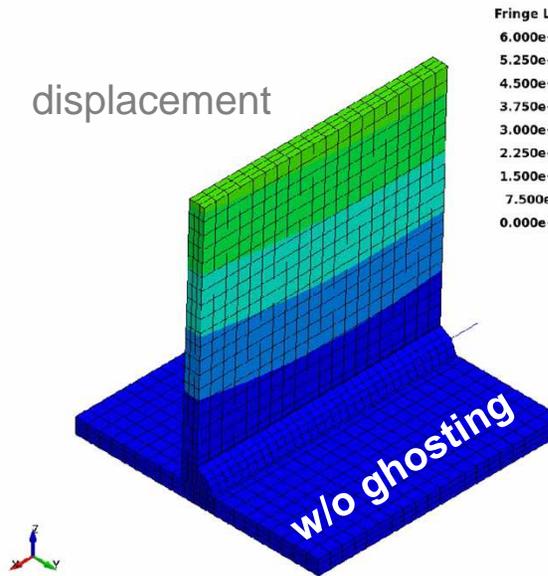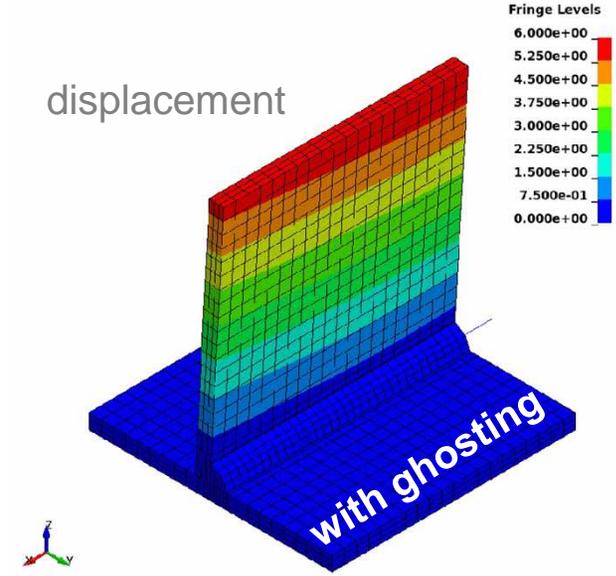# *MAT_REINFORCED_THERMOPLASTIC (*MAT_249)

- Material model for process simulations of fiber reinforced thermoplastics
    - Matrix: temperature and strain rate dependent elastic-plastic material
    - Fiber: anisotropic and hyperelastic formulation
- Material allows to define up to three individual fiber families and keeps track of their elongation and reorientation

geometry: Benteler-SGL
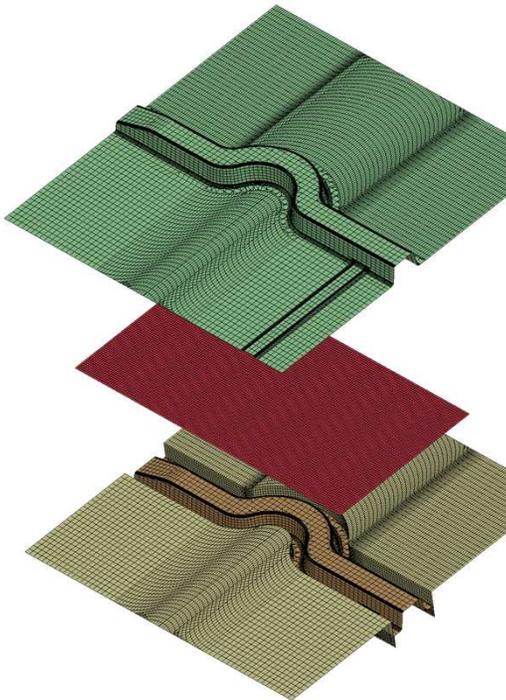
More material model updates

- Add a keyword option called MIDFAIL for *MAT_024
  - failure by plastic strain will only be checked at the mid-plane

- New options for *MAT_224 (TABULATED_JOHNSON_COOK)
  - BETA .LT. 0: strain rate dependent amount given by load curve ID = -BETA
  - Implicit stiffness matrix added

- Add enhanced damage model with crack closure effects to *MAT_104

- Some improvements for *MAT_075 (BILKHU/DUBOIS_FOAM)
  - Rate dependence and manual documentation → good for crushable foams

- Increase robustness of *MAT_CORUS_VEGTER (*MAT_136)

- Several enhancements for *MAT_CWM and *MAT_CONCRETE_EC2

More material model updates

■ New options for *MAT_ARUP_ADHESIVE (*MAT_169)

　　■ Strength values as functions of properties of connection partners

　　■ In-plane failure strain criterion

■ New materials 216, 217, and 218 allow change of material properties on an element-by-element basis upon crossing a plane in space, e.g. *MAT_ELASTIC_PHASE_CHANGE

■ Global deactivation of all *MAT_ADD_EROSION definitions via MAEF=1 on new keyword *CONTROL_MAT

■ New thermal option for *MAT_HYPERELASTIC_RUBBER (*MAT_077) to specify some material properties as functions of temperature

■ New option FLAG=4 for *MAT_103 allows table input w/o interpolation

MPP enhancements

■ For MPP, set a "last known location" flag to give some indication of where the processors were if an error termination happens. Each writes a message to their own message file. Look for a line that says "When error termination was triggered, this processor was".

■ Allow memory2 option in *KEYWORD, for example,
```
*KEYWORD memory=1G memory2=200m
```

■ Tune Xeon 64 AVX2 executable for better performance,
AVX2 is about 10% better than SSE2 exe.

■ Two csv files will be generated after each MPP execution: "load_profile.csv" and "cont_profile.csv". These will give general information about load balancing and cost profile of the job.

■ Many more …

Miscellaneous

- Add a new keyword *BOUNDARY_SPC_SYMMETRY_PLANE
  - Define constraints to enforce planar symmetry for nodes on or near a specified plane. These constraints will be enforced even during adaptivity. This command is similar to *CONSTRAINED_LOCAL but allows selectivity via a part ID.

- *DATABASE_SECFORC, *DATABASE_CROSS_SECTION
  - The secforc data for cross-sections through 2D seatbelt elements is recoded to provide more robust and accurate results.

- *DATABASE_EXTENT_BINARY, *MAT , *SECTION
  - For some materials and elements, thermal and plastic strain tensors can be output to d3plot database, see STRFLG.

- *INCLUDE_UNITCELL
  - New keyword to create an input file containing user-defined unit cell information with periodic boundary conditions

Miscellaneous

- *CONTROL_OUTPUT and command line option "msg=all" or "msg=10087"
  - Add option for detailed warning/error messages to d3msg, parameter MSGFLG
  - Only a few "long" versions of warnings/errors at this time but that list is expected to grow

```
*** Message     10087 (KEY+87)
    in *INCLUDE file name:
    File AAA does not exist
    Keyword read will continue but numerous errors may result

LS-DYNA couldn't read the include file specified in the input deck.

The include file may be improperly specified in the input file.
Please ensure that the path to the include file is specified
correctly. Or, you may use batch queuing system which is allowed to
deal input files only. Please ask your system administrators if the
system considers not only LS-DYNA input file but also include files
you use.
```

Bug fixes

- A wide range of code corrections, inter alia,

    - Fix *BOUNDARY_SPC_SET_BIRTH_DEATH which was not working for MPP when the birth and death time were set to non-zero.

    - Fixes related to contact's intfor database (*DATABASE_BINARY_INTFOR).

    - MPP contact: fix routine that updates segment thicknesses for solid elements (every cycle) so that it honors the OPTT parameter in *PART_CONTACT.

    - Fix MPP adaptivity for very large models: the reading of the adaptive dump file was not working properly for files over 8GB.

    - Update SOFT=2 contact to improve accuracy at points far away from the origin.

    - Correct contact penalty stiffness for cohesive elements.

    - Several fixes pertaining to thick shell elements (*ELEMENT_TSHELL).

    - Fix MPP implicit's output of forces to bndout due to prescribed motion on nodes.

    - Fix rate effects problem in *MAT_ARUP_ADHESIVE.

    - Fix for combination of *MAT_USER with GISSMO.

    - Fix single precision issue in strain calculation of *MAT_FABRIC with FORM = 12, 13, 14.

    - ...

Conclusion: LS-DYNA R8.1

■ Many more developments and enhancements in other areas
(ALE, EFG, SPG, SPH, Thermal, …)
and the multiphysics solvers (ICFD, CESE, EM, Chemistry)

SPH

EFG

SPG
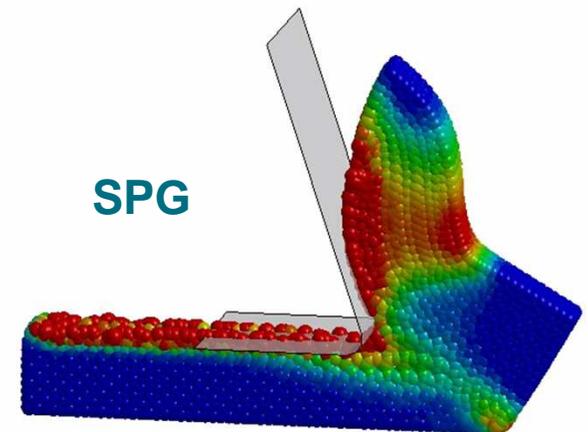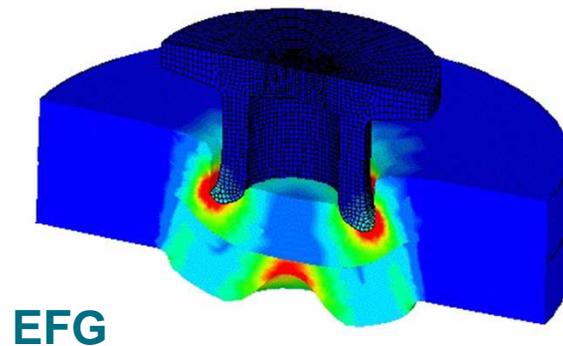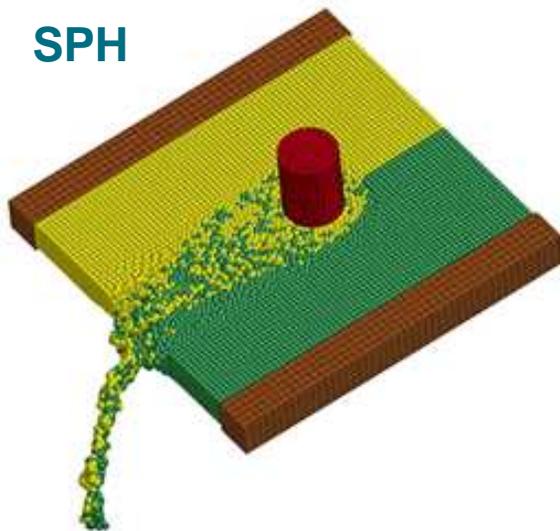
■ R8 Keyword User's Manual can be downloaded from
www.dynamore.de/en/downloads/manuals/