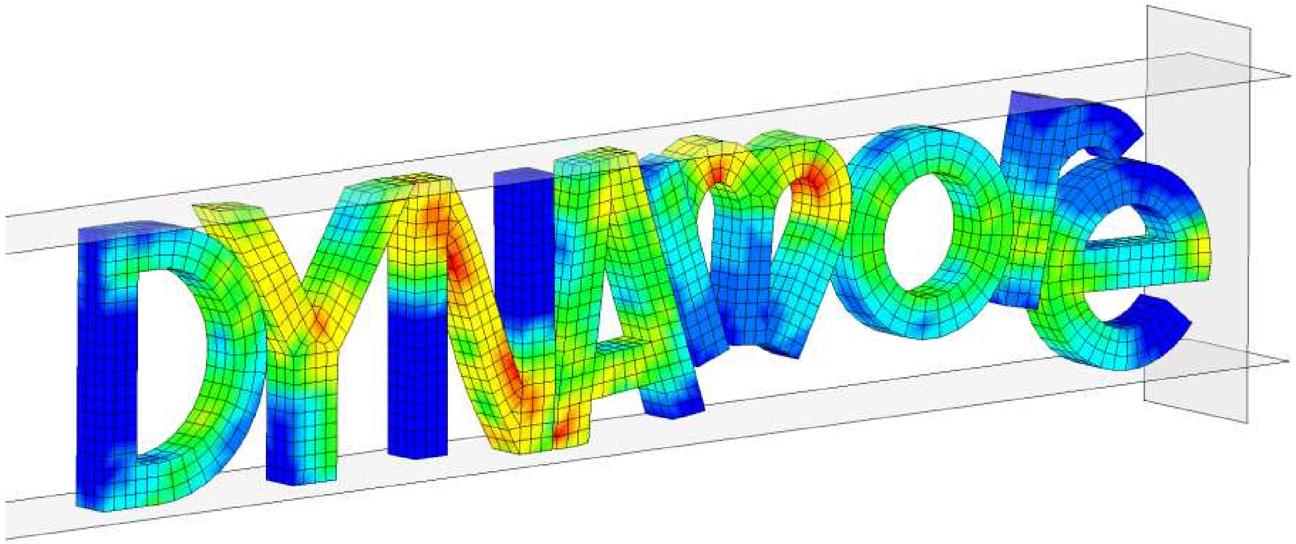
Miscellaneous New Developments in LS-DYNA (2013 - 2014)

- Tobias Erhart

- Stefan Hartmann



Miscellaneous New Developments in LS-DYNA (2013 - 2014)

- **Tobias Erhart**
  - *MAT_ADD_COHESIVE
  - *MAT_TOUGHENED_ADHESIVE_POLYMER (*MAT_252)
  - *MAT_PHS_BMW (*MAT_248)
  - New options for several material models
  - *ELEMENT_BEAM_SOURCE / PULLEY
  - *CONSTRAINED_JOINT with RPS<0
  - *CONSTRAINED_INTERPOLATION_SPOTWELD
  - *DEFINE_ELEMENT_DEATH

- **Stefan Hartmann**

*MAT_ADD_COHESIVE

R7.1.1

- Usually cohesive elements (ELFORM = 19, 20, 21, and 22 of *SECTION_SOLID) can only be used with a small subset of materials (138, 184, 185, 186, 240).
- But with this additional keyword, a bigger amount of standard 3-d material models can be used (e.g. 15, 24, 41-50, 81, 103, 120, 123, 124, 168, 187, 188, 224, 225, 252, …), that would only be available for solid elements in general.
- Therefore, assumptions of inhibited lateral expansion and in-plane shearing are used:

$$\begin{bmatrix}\delta_1\\ \delta_2\\ \delta_3\end{bmatrix} \Rightarrow \begin{bmatrix}\dot{\varepsilon}_{xx}\\ \dot{\varepsilon}_{yy}\\ \dot{\varepsilon}_{zz}\\ \dot{\varepsilon}_{xy}\\ \dot{\varepsilon}_{yz}\\ \dot{\varepsilon}_{zx}\end{bmatrix} = \begin{bmatrix}0\\ 0\\ \dot{\delta}_3/(t+\delta_3)\\ 0\\ \dot{\delta}_2/(t+\delta_3)\\ \dot{\delta}_1/(t+\delta_3)\end{bmatrix} \Rightarrow \begin{bmatrix}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{zz}\\ \sigma_{xy}\\ \sigma_{yz}\\ \sigma_{zx}\end{bmatrix} \Rightarrow \begin{bmatrix}t_1\\ t_2\\ t_3\end{bmatrix} = \begin{bmatrix}\sigma_{zx}\\ \sigma_{yz}\\ \sigma_{zz}\end{bmatrix}$$

e.g. *MAT_024

displacements in cohesive element

3-dim. strain rates

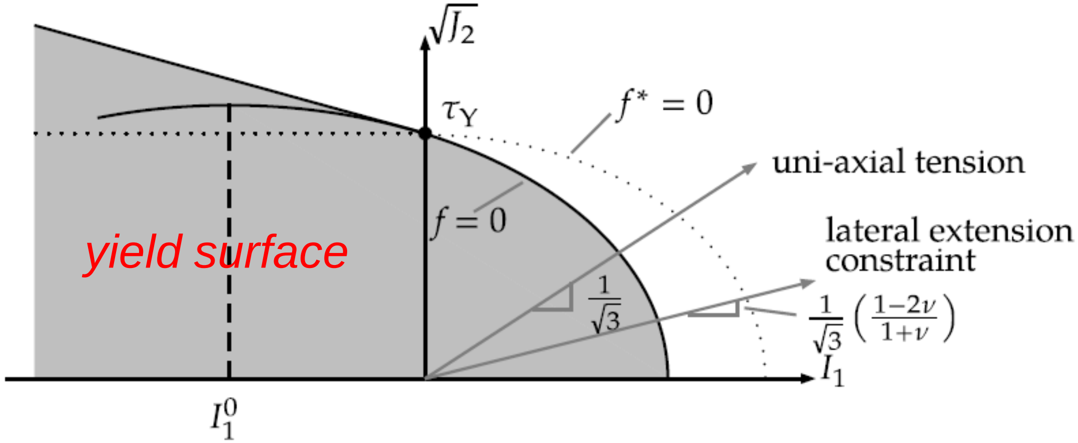
3-dim. stresses

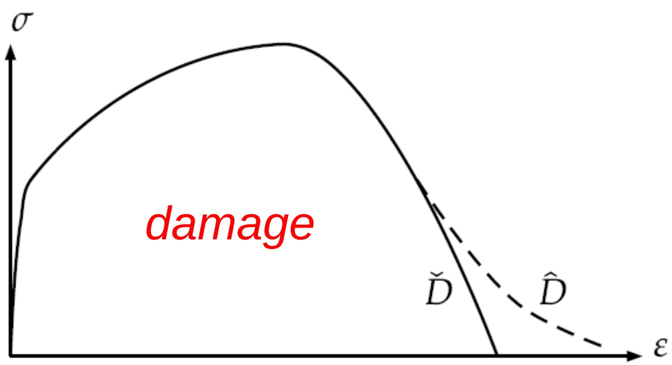
tractions in cohesive element

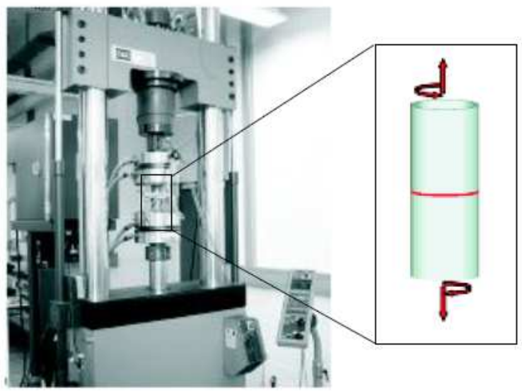
*MAT_TOUGHENED_ADHESIVE_POLYMER (*MAT_252)

R7.1.1

- New material model for crash optimized high-strength adhesives under combined shear and tensile loading
  - Drucker-Prager-Cap type plasticity + rate dependence + damage + failure
  - well suited for combination with *MAT_ADD_COHESIVE

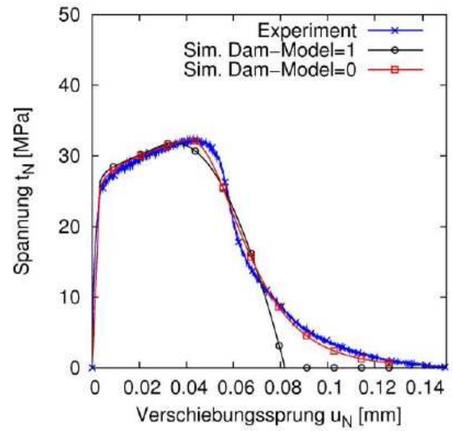






Model developed in German FAT* project: good agreement between experiments and simulation

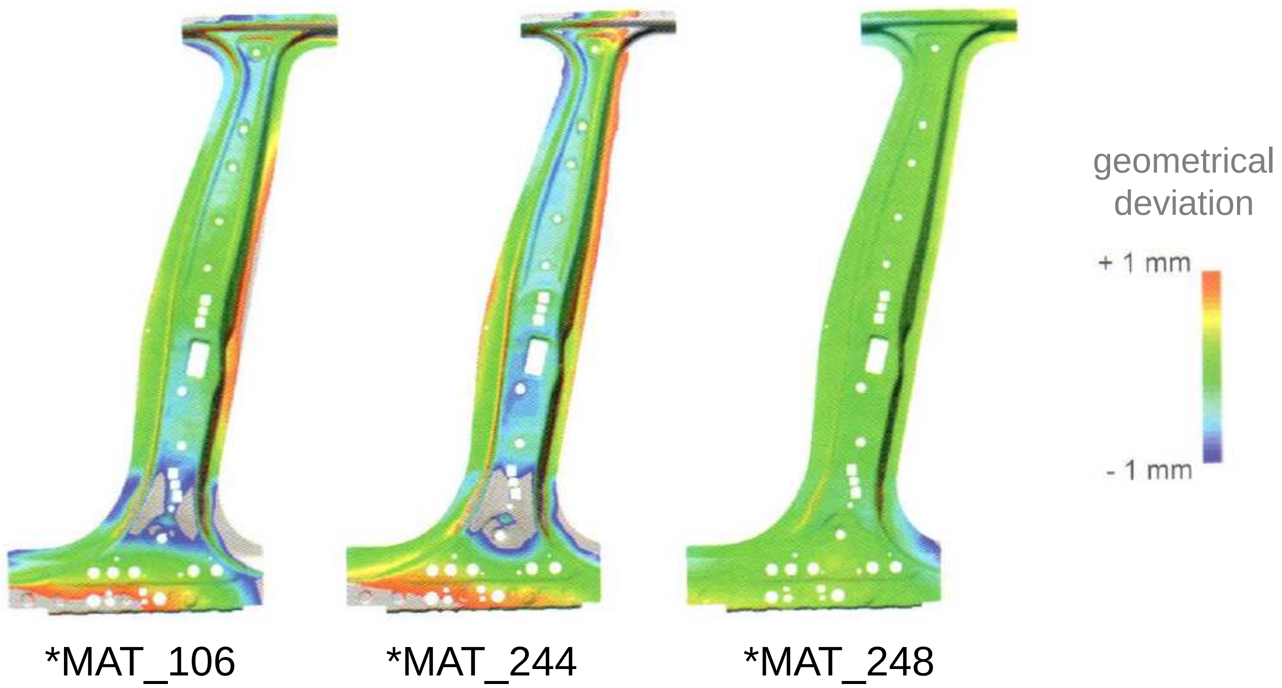
*Research Association for Automotive Technology



*MAT_PHS_BMW (*MAT_248)

R8.0

- New material model for press-hardening steel applications
- Result of a collaboration with BMW (Ph.D. of Paul Hippchen 2014)
- Intended for hot stamping processes with phase transformation effects
- Based on *MAT_UHS_STEEL (*MAT_244) with improved phase change kinetics model, more flexibility in material parameter definitions, and an approach for transformation induced strains



More Material Model Updates

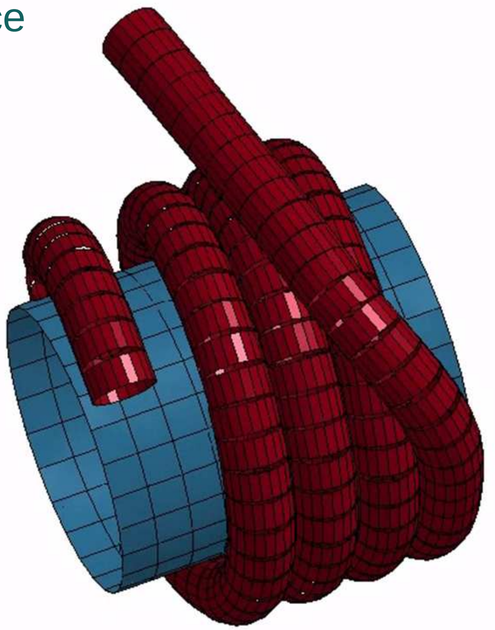
- Improved robustness of plasticity algorithm in *MAT_JOHNSON_COOK (*MAT_015) — R7.1.1
- New option IHIS for *MAT_ANISOTROPIC_ELASTIC (*MAT_002) to define directional stiffness terms via *INITIAL_STRESS_SOLID on a per-element basis — R8.0
- *MAT_TABULATED_JOHNSON_COOK (*MAT_224) available for implicit analysis — R8.0
- Enhanced damage model with crack-closure effect and more flexibility in *MAT_DAMAGE_1 (*MAT_104) — R8.0
- New features in *MAT_ADD_EROSION: Arbitrary history variable can be used for GISSMO damage model (instead of plastic strain), memory requirements reduced, global flag to switch off all *MAT_ADD_EROSION cards — R8.0

*ELEMENT_BEAM_SOURCE

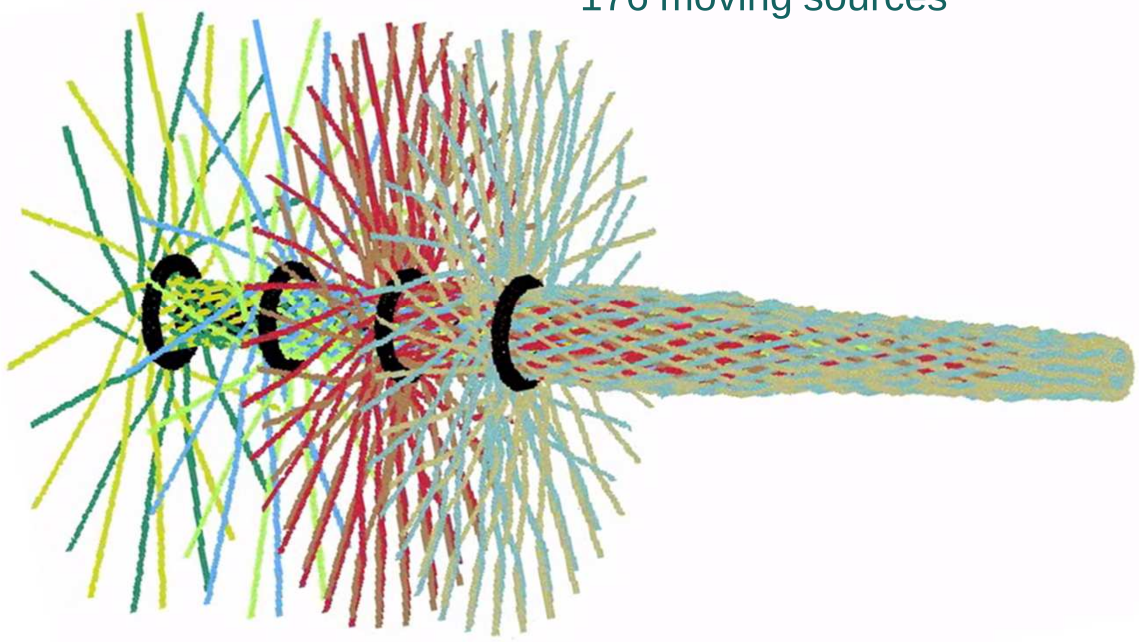
R8.0

- 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



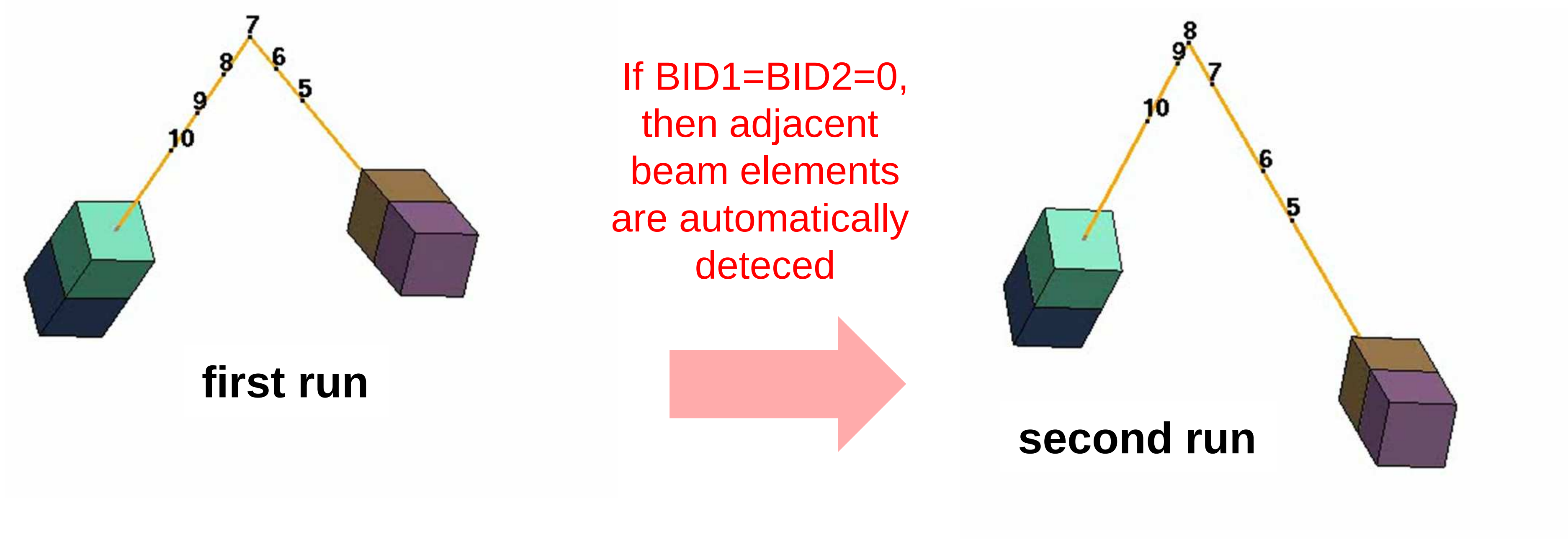
176 moving sources



*ELEMENT_BEAM_PULLEY

R7.1.1

- New option for automatic detection of adjacent beam elements (useful for process chain, where pulley connectivity changes)

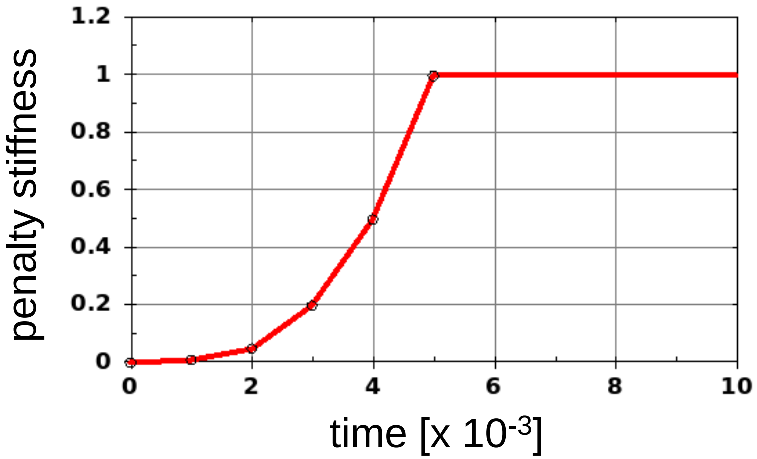


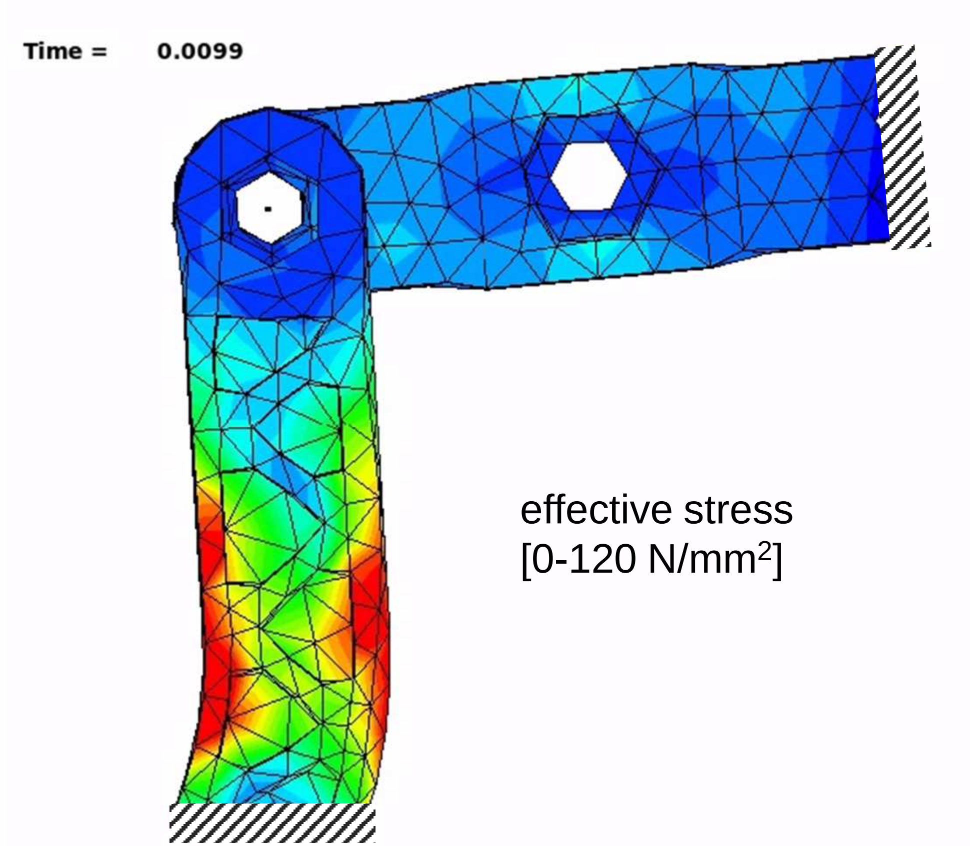
- Increase accuracy for slipping and swapping by tightening slip condition tolerances, correcting velocity of swapped node, and changing internal precision from single to double for selected pulley variables
- Improve implicit capabilities:
  Slipping – better convergence, more accurate results

*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 (implicit still missing)
- Works for options…
  SPHERICAL,
  REVOLUTE,
  CYLINDRICAL

R8.0

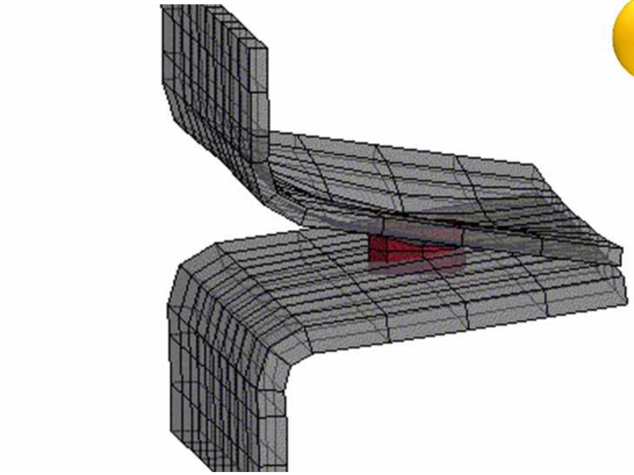




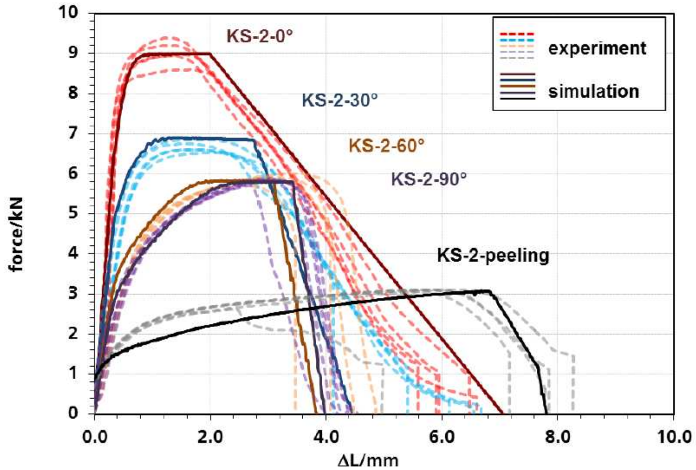
*CONSTRAINED_INTERPOLATION_SPOTWELD

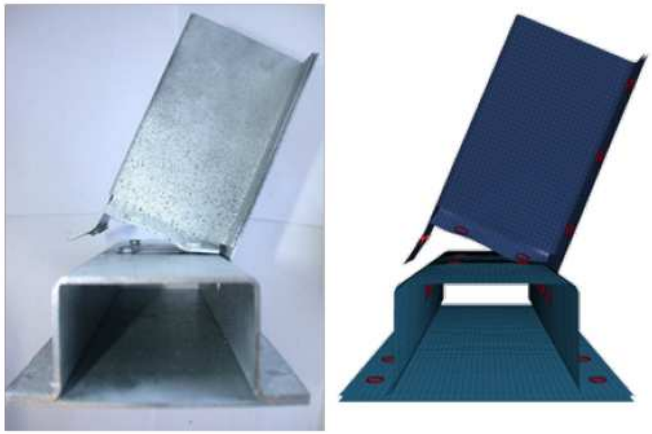
- New model for self-piercing rivets, based on paper by M. Bier (Manchester 2013)
- Improved behavior for peeling load case conditions

R8.0

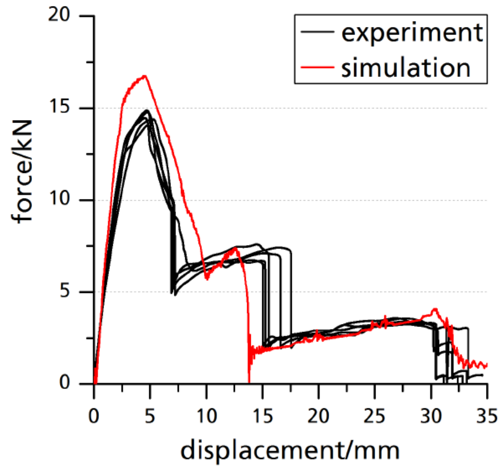


peel test





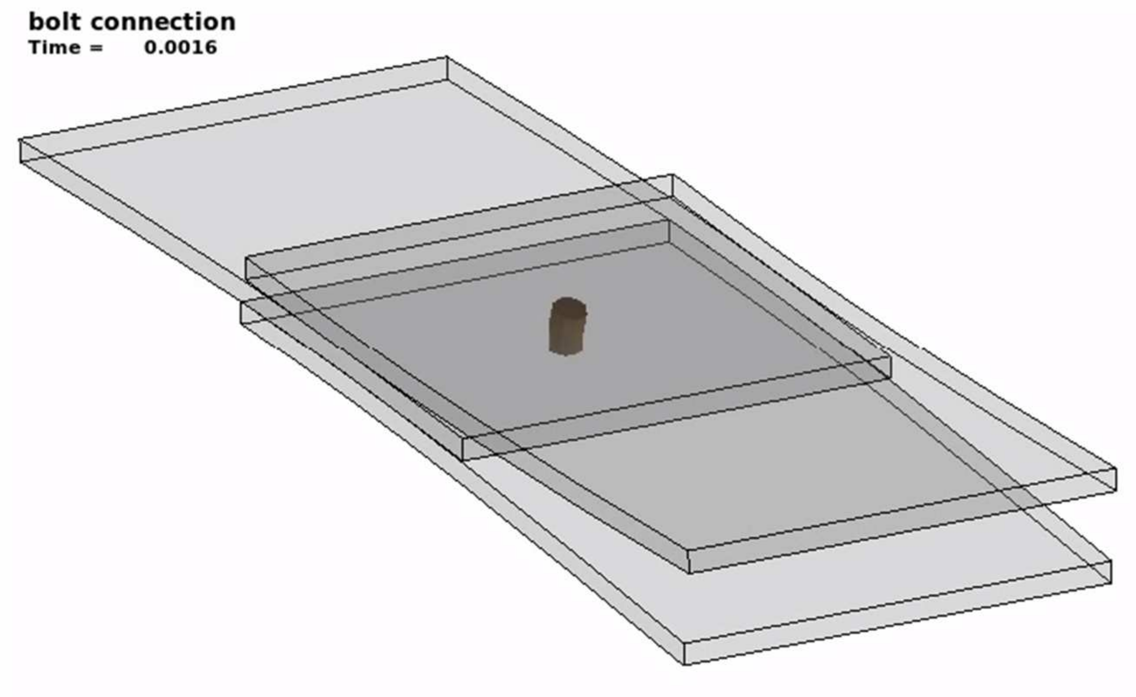
T-joint impact analysis



*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 too.

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



R8.0

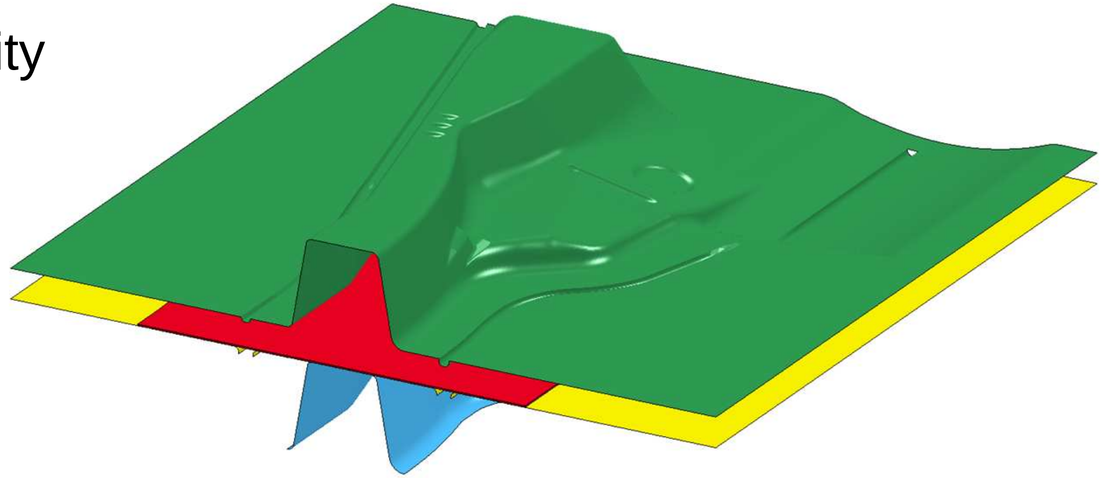
Miscellaneous New Developments in LS-DYNA (2013 - 2014)

- **Tobias Erhart**

- **Stefan Hartmann**
  - Isogeometric Analysis (IGA) - *ELEMENT_SHELL_NURBS_PATCH
  - *MAT_LAMINATED_COMPOSITE_FABRIC (*MAT_058)
  - *MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)
  - *MAT_PIECEWISE_LINEAR_PLASTICITY (*MAT_024) – VP=2
  - *ELEMENT_TSHELL_BETA
  - Pentahedron - Cohesive elements

Isogeometric Analysis (IGA) *ELEMENT_SHELL_NURBS_PATCH

- Isogeometric analysis (IGA) is the fastest growing area of computational mechanics research.
- It will take years to reach the maturity of current FEA in LS-DYNA



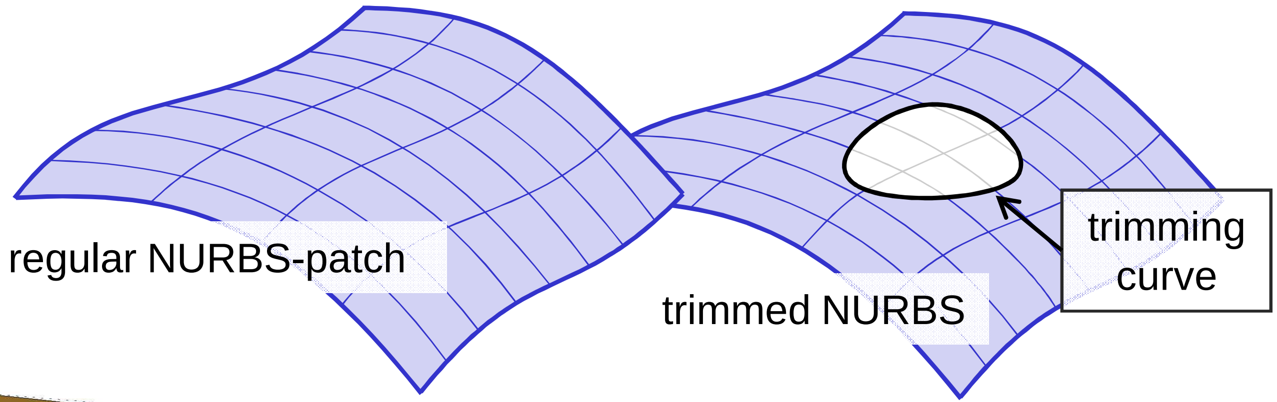
Current status (SMP & MPP)

- Standard NURBS for shells (with and without rotationals DOFs, blended shell)
- Contact with NURBS (IGACTC=1 on *CONTROL_CONTACT, optional card 6)
- All penalty based contacts via interpolation elements
- Implicit and explicit time integration R7.1.1
- Improve critical timestep estimation, add conventional mass scaling R8.0

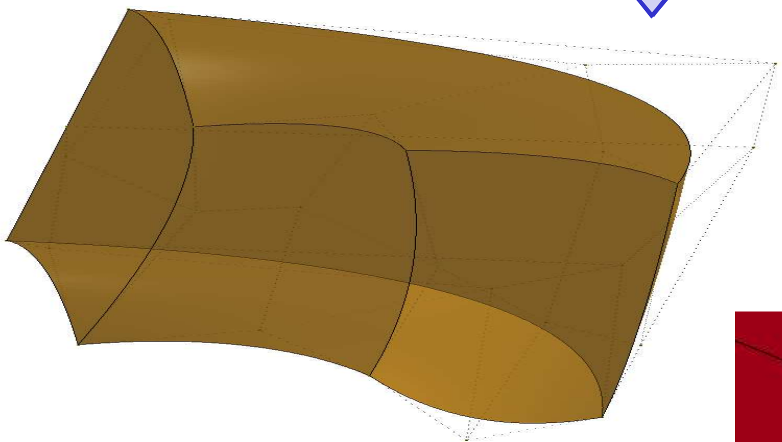
Isogeometric Analysis (IGA) *ELEMENT_SHELL_NURBS_PATCH

Near Future plans

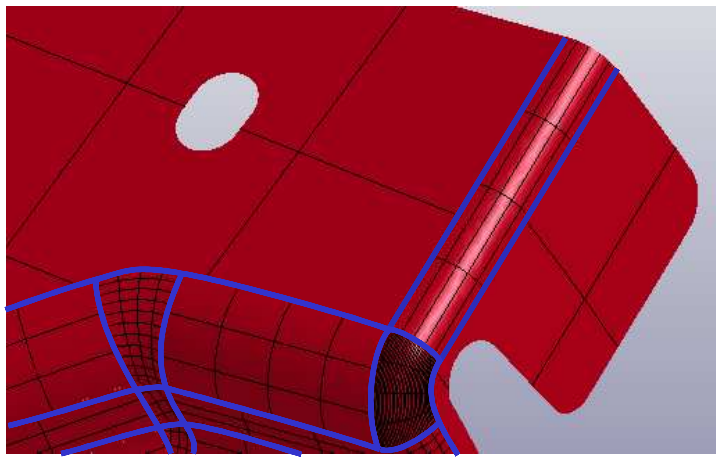
- Trimmed NURBS for shells



- NURBS for solids



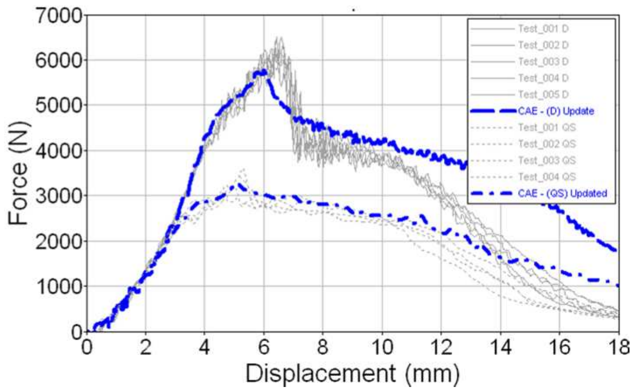
- Coupling of non-matching (or trimmed) NURBS-patches maintaining the order of continuity

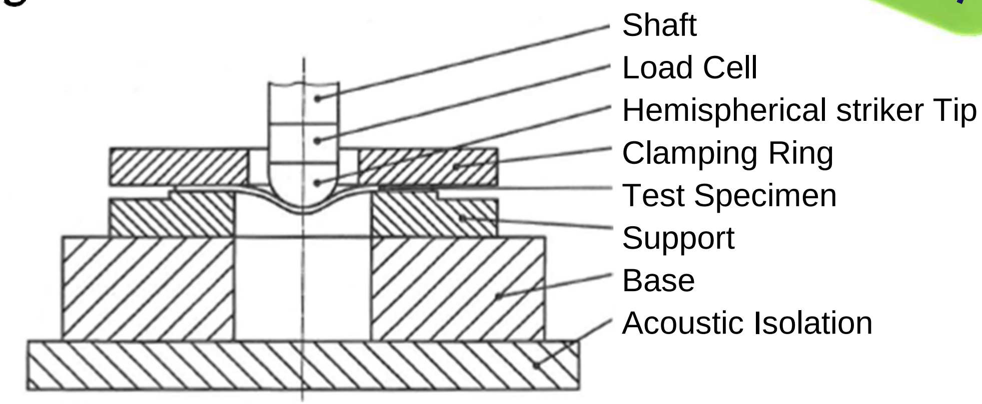


*MAT_LAMINATED_COMPOSITE_FABRIC (*MAT_058)

- Added optional card 8 & 9 to define strain rate dependent strengths (XC, XT, YC, YT, SC) limit strains (E11C, E11T, E22C, E22T, GMS)
- Specify various load curves (*DEFINE_CURVE) defining strengths and strains vs. strain rate

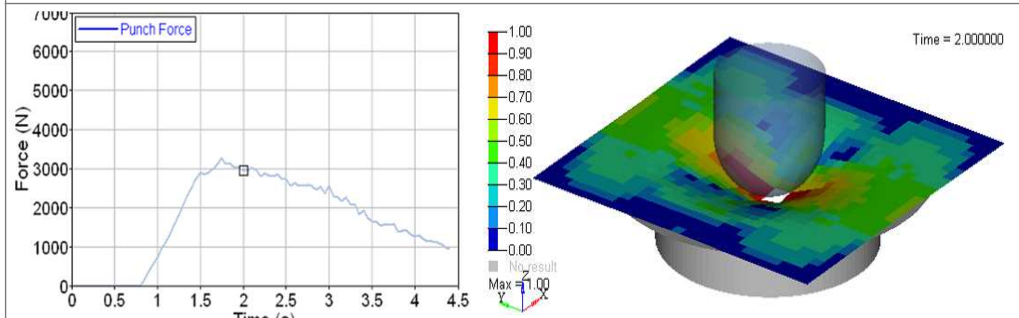
R7.1.1





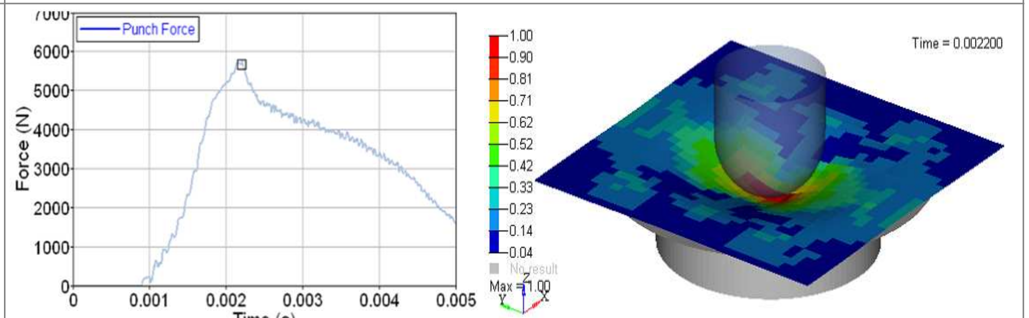
Disc Punch Test Configuration

Quasi-Static Response



Damage in 0°

Dynamic Response



Damage in 0°

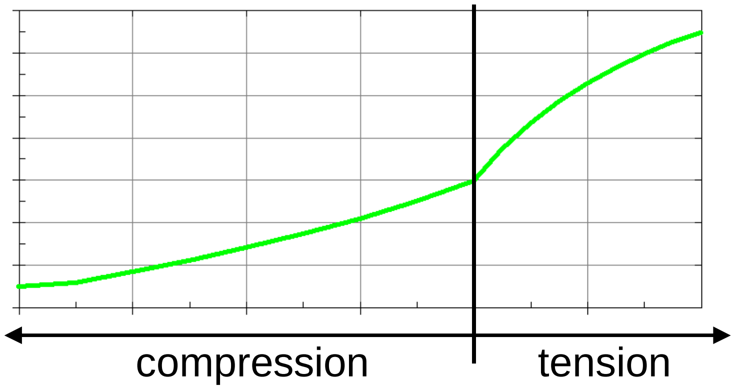
from: Jerome Coulton (HYUNDAI Motor Group), *Improvements to material 58*, LS-DYNA Forum, 2013

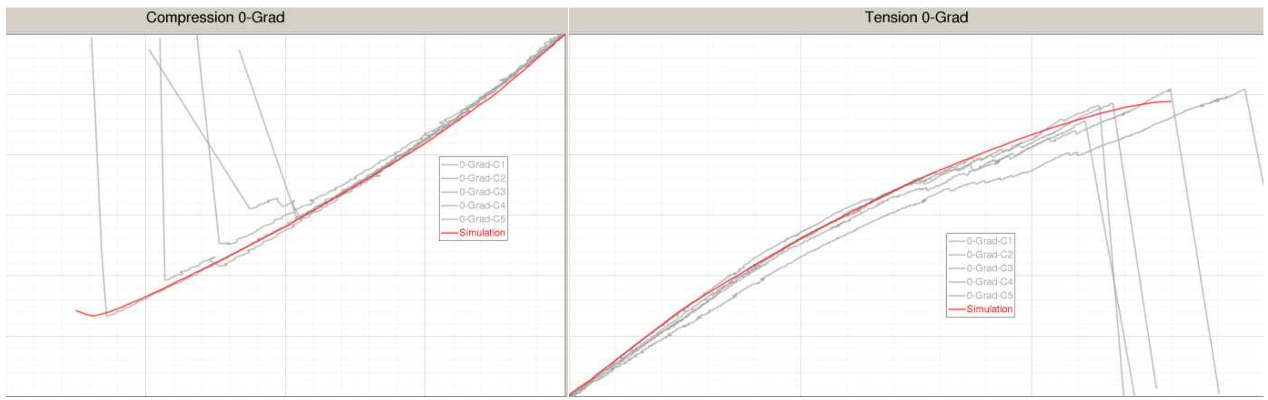
*MAT_LAMINATED_COMPOSITE_FABRIC (*MAT_058)

- 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

GT.0.0:	Young’s modulus – longitudinal direction
LT.0.0:	Load curve ID or Table ID = (-EA) **Load Curve.** When (-EA) is equal to a Load curve ID, it is taken as defining the uniaxial elastic stress vs. strain behavior in longitudinal direction **Tabular Data.** When (-EA) is equal to a Table ID, id defines for each strain rate value a Load curve ID giving the uniaxial elastic stress vs. strain behavior in longitudinal direction.

Curve-definition for EA





*MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)

- 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)

R8.0

$$\text{IHIS} = a_3 \times 8 + a_2 \times 4 + a_1 \times 2 + a_0$$

- Solids:

Flag	Description	Variables	#
a_0	Material directions	$q_{11}, q_{12}, q_{13}, q_{31}, q_{32}, q_{33}$	6
a_1	Anisotropic stiffness	Cij	21
a_2	Anisotropic constants	F, G, H, L, M, N	6
a_3	Stress-strain Curve	LCSS	1

$$\text{NHISV} = 6a_0 + 21a_1 + 6a_2 + a_3$$

- Shells:

Flag	Description	Variables	#
a_0	Material directions	q_1, q_2	2
a_1	Anisotropic stiffness	Cij	21
a_2	Anisotropic constants	r_{00}, r_{45}, r_{90}	3
a_3	Stress-strain Curve	LCSS	1

$$\text{NHISV} = 2a_0 + 21a_1 + 3a_2 + a_3$$

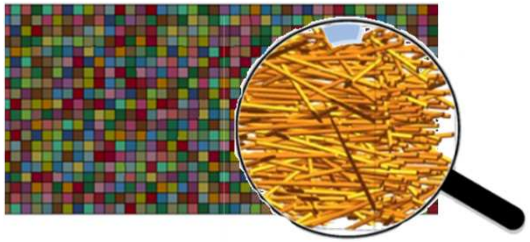
*MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)

- Example for shells, IHIS=3 ($a_1 = 1$, $a_0 = 1$) → NHISV=2+21=23
- *INITIAL_STRESS_SHELL

R8.0

CARD 1	eid	nplane	nthick	nhisv	ntensor	large	nthint	nthhsv
CARD 2	t	sigxx	sigyy	sigzz	sigxy	sigyz	sigzx	eps
CARD 3	hisv1=q_1	hisv2=q_2	#3=C_{11}	#4=C_{12}	#5=C_{13}	#6=C_{14}	#7=C_{15}	#8=C_{16}
CARD 4	#9=C_{22}	#10=C_{23}	#11=C_{24}	#12=C_{25}	#13=C_{26}	#14=C_{33}	#15=C_{34}	#16=C_{35}
CARD 5	#17=C_{36}	#18=C_{44}	#19=C_{45}	#20=C_{46}	#21=C_{55}	#22=C_{56}	#23=C_{66}	

In material card



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

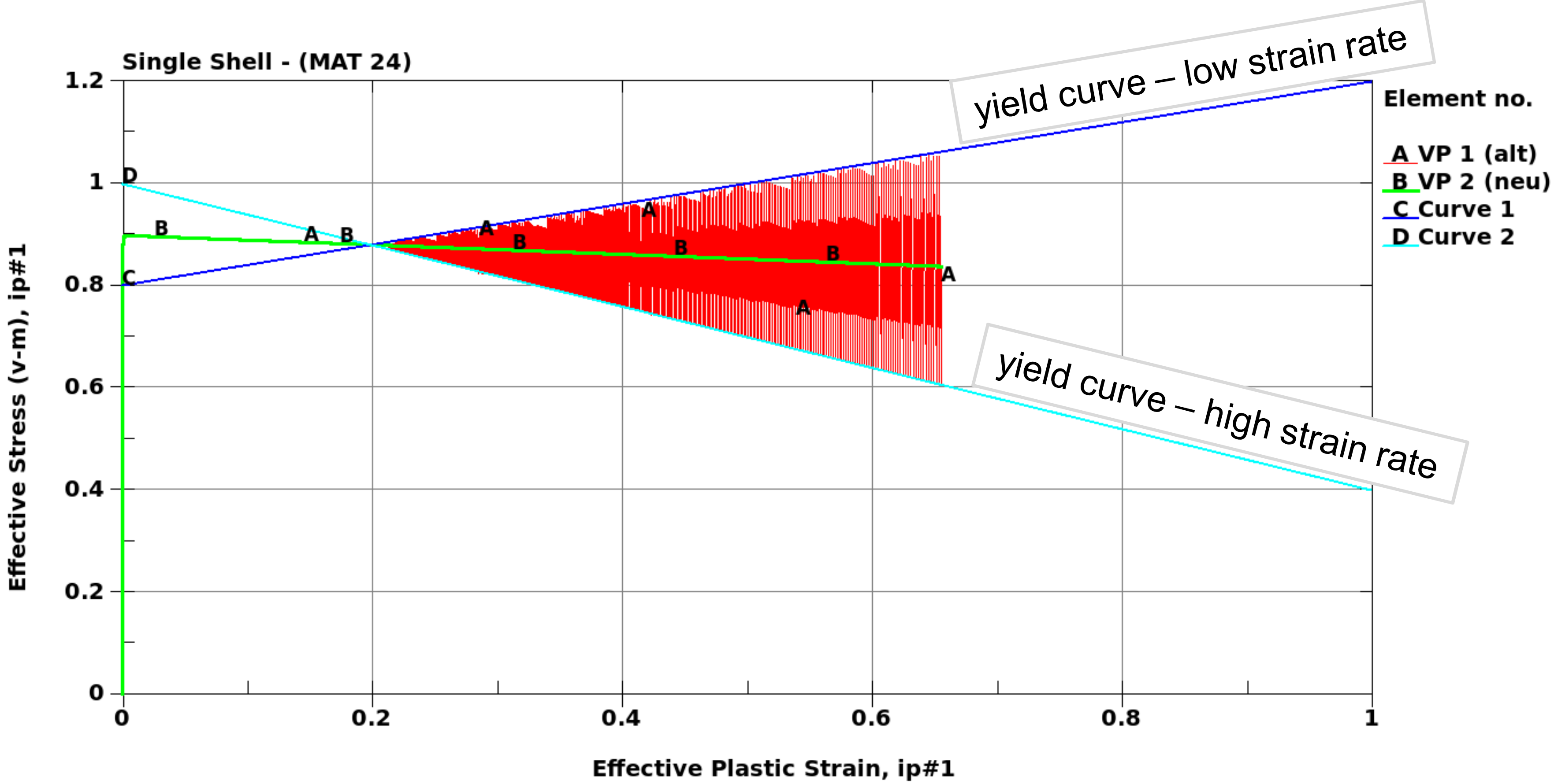
With *INITIAL_STRESS_SOLID

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_PIECEWISE_LINEAR_PLASTICITY (*MAT_024)

- Added VP=2 (viscoplastic formulation) for shells
  - Possibility to use table-definition for strain rate dependent yield curves where the yield curves may cross each other at higher strain-rates

R8.0



*ELEMENT_TSHELL_BETA

R8.0

- 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)

R8.0

- Improve stability for ELFORM=20 (with offsets for use with shells)
- Add pentahedron elements
  - ELFORM=21 (6-noded pentahedron)
  - ELFORM=22 (6-noded pentahedron with offsets for use with shells)
  - *ELEMENT_SOLID: **N2, N1, N5, N5, N3, N4, N6, N6**
  - ESORT.gt.1 in *CONTROL_SOLID automatically activates element sorting of pentahedron solid elements