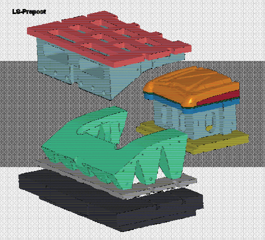
Concepts to Consider Tool Elasticity in Forming Simulations with LS-DYNA

J. Raquet, S. Mandel, D. Lorenz, A. Haufe (DYNA*more* GmbH);

Prof. K. Roll, P. Bogon (Daimler AG)



Concepts to consider Tool Elasticity in Forming Simulations with LS-DYNA

Jeanette Raquet, Silvia Mandel, David Lorenz, Dr. André Haufe
(DYNAmore GmbH)

Prof. Dr. Karl Roll, Dr. Peter Bogon
(Daimler AG)

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Introduction

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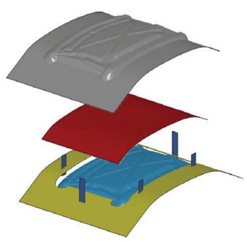
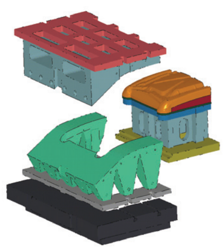
Classical rigid set-up



Algorithmic tools and modeling techniques of classical structural mechanics:

- Submodeling
- Model reduction
- Condensation
- Mode superposition
- …

Classical rigid set-up



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Reduced models in sheet metal forming simulations

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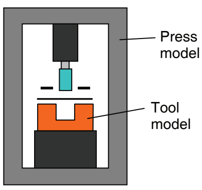
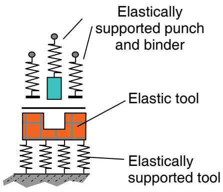
Full model



Discretisation methods:

FEM, BEM, MKS

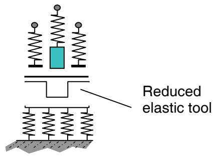
Reduced model



Boundary conditions:

Replacement springs (translational, rotational, non-linear, …)

Reduced tool model



Model reduction of tools?

- Full 3D ✓
- Deformable Rigid Bodies ✓
- Condensed/Super-element ✓
- Weak structure-structure coupling

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1. Methodology: Full 3D discretized

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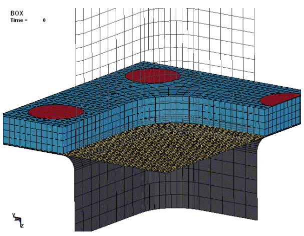
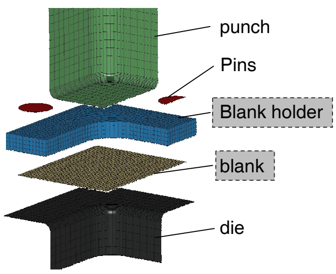
Blank holder is modeled elastically in 3D

- Higher demand for memory
- Higher solution time and model size
- More meshing effort

} Compared to classical rigid set-up



Blank holder: 3130 nodes (3x3130 dof)



[1] Hoffmann, J.: Berücksichtigung der elastischen Werkzeugeigenschaften in der Blechumformsimulation, Diplomarbeit, FH Lausitz in Kooperation mit DaimlerChrysler AG, 2005.

Model set-up uses symmetry condition

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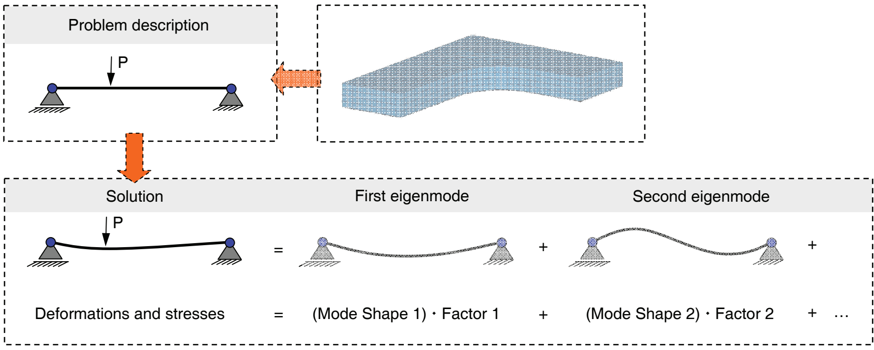
2. Methodology: Deformable Rigid Bodies



- A priori solution of the eigenvalue/eigenmode problem (higher effort) to extract modes.
- Transient dynamic modal analysis (superposition of eigenmodes) to compute actual tool shape.
- Solution in every time step (cycle) is rather simple
- **Advantage:**
  Less memory required – but strongly dependent on number of eigenmodes and problem type
- **Disadvantage**:
  Mode space limits the predictability of the results. If too few modes are chosen dominant (local) deformations may not be captured correctly/sufficiently.

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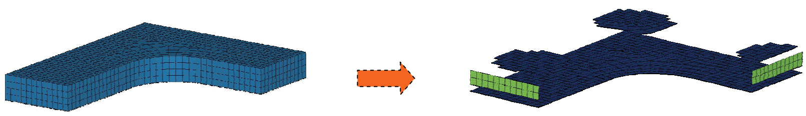
3. Methodology: Condensation

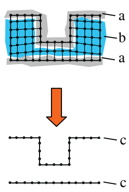


Boundary nodes that define possible nodes of interaction

- Meshing of elastic tool with solid elements
- Definition of boundary nodes that take loads and deformations
- Static condensation within LS-DYNA
- Generation of stiffness and mass matrix (i.e. super-element) in industry compatible NASTRAN file or proprietary binary format:

$$\begin{bmatrix} K_{aa} & K_{ab} \\ K_{ba} & K_{bb} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \end{bmatrix} = \begin{bmatrix} F_a \\ F_b \end{bmatrix}$$

$$\Rightarrow \underbrace{\left(K_{aa} - K_{ab}\, K_{bb}^{-1}\, K_{ba}\right)}_{K_{cc}} u_a = F_a - K_{ab}\, K_{bb}^{-1}\, F_b$$



- Mass matrix is generated analogous

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4. Methodology: Coarse 3D tool meshes combined with fine active tool surface

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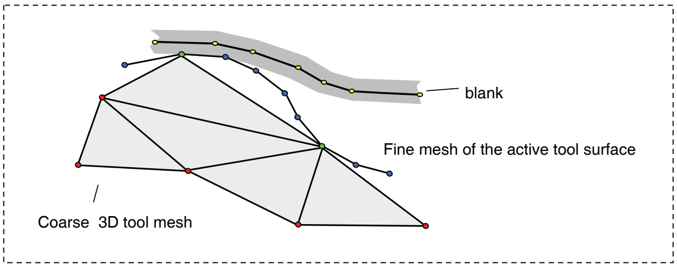
- Coarse 3D tool meshes are applied to take elastic deformation into account
- A fine mesh at the active tool surface takes care of the correct forming geometry



- Active tool surface is modeled by null-material.
- Standard LS-DYNA contact handling allows to tie the surface mesh to the 3D mesh.
- Hence, deformations of the active tool surface are facet-like bound to the solid surface.
- Modeling the active tool surface and the solid tool may take additional efforts.
- Special contact options may be used to tie all nodes to the solid mesh.

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4. Methodology: Coarse 3D tool meshes combined with fine active tool surface

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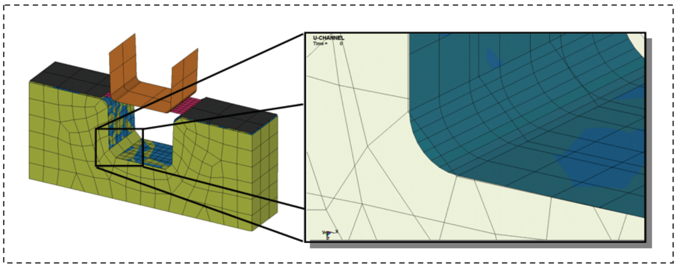

- This methodology allows:
  - Fast modification and replacement of the active tool surface nodes by just writing new CAD-surface meshes.
  - Easy and fast generation of sufficiently fine 3D tetrahedron meshes from CAD software.
  - The user may adjust the mesh size of the tool according to his requirements independent of the active tool surface quality.

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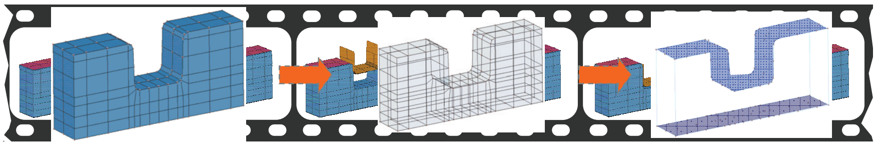
Example 1: 3D Tool

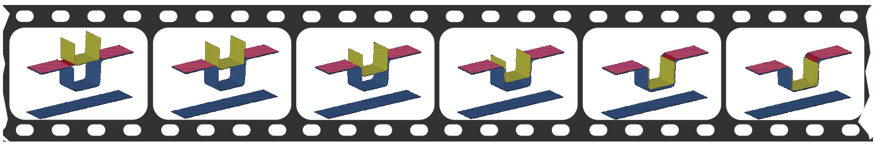
- 3D discretized die
- Internal degrees of freedom are kept
- Forming simulation is done with **standard** stiffness and mass matrix



Contact shells for visualization

Example 1: Condensed tool

- 3D discretized die
- Internal degrees of freedom are released
- Forming simulation is done with **condensed** stiffness and mass matrix



Example 1: Condensed tool

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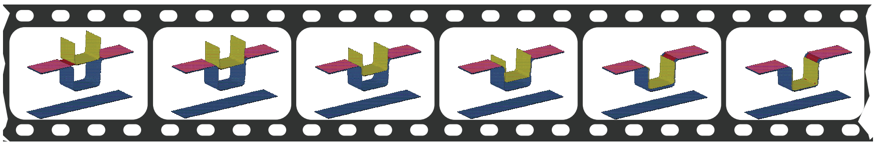
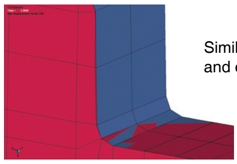
- 3D discretized die
- Internal degrees of freedom are released
- Forming simulation is done with **condensed** stiffness and mass matrix





Similar results between full 3D and condensed simulation run

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Example 2: Demonstrator - SL roof inner

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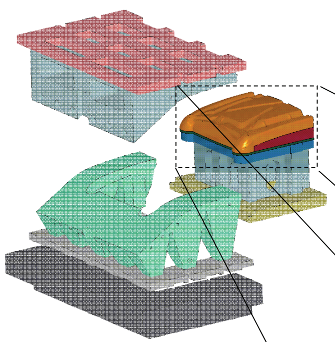
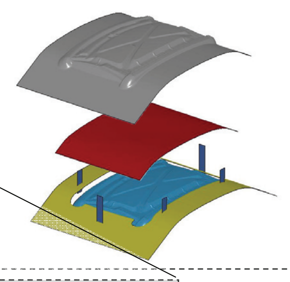
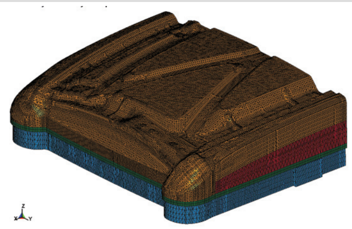


Classical rigid set-up



Detail of model having 900 000 elements



Symmetrical 3D finite element discretized tool set of Mercedes SL roof inner.
> 2 Mio. Elements

Blank: 1.5mm AlMg0.8Si0.9
(Ecodal 608 Novelis)

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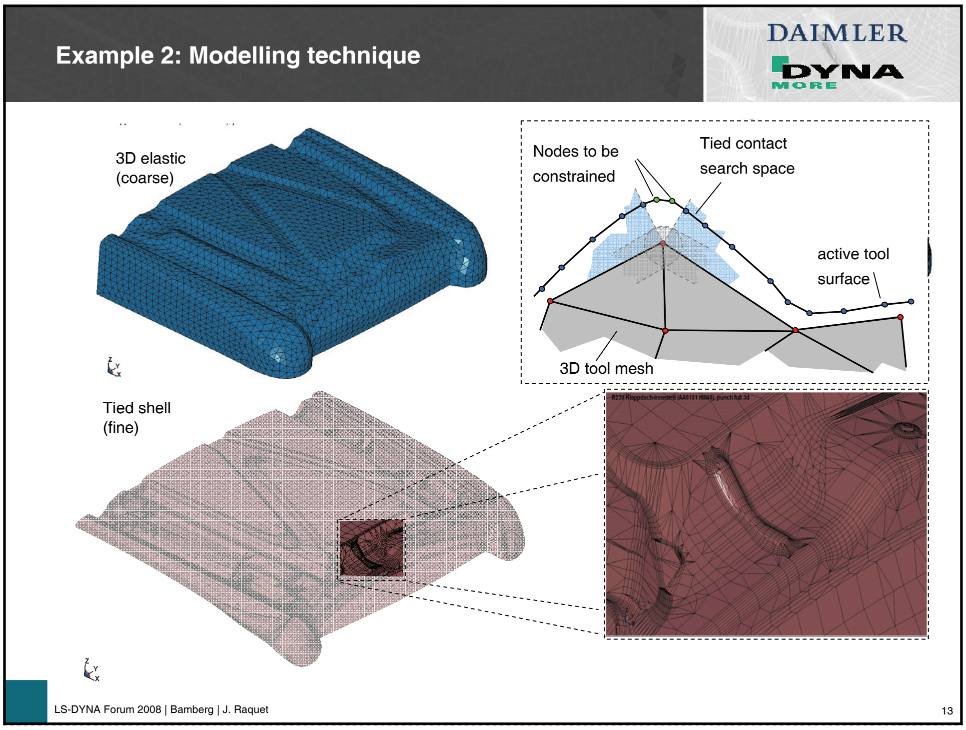
Example 2: Modelling technique
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3D elastic
(coarse)
Tied shell
(fine)
Nodes to be
constrained
Tied contact
search space
active tool
surface
3D tool mesh
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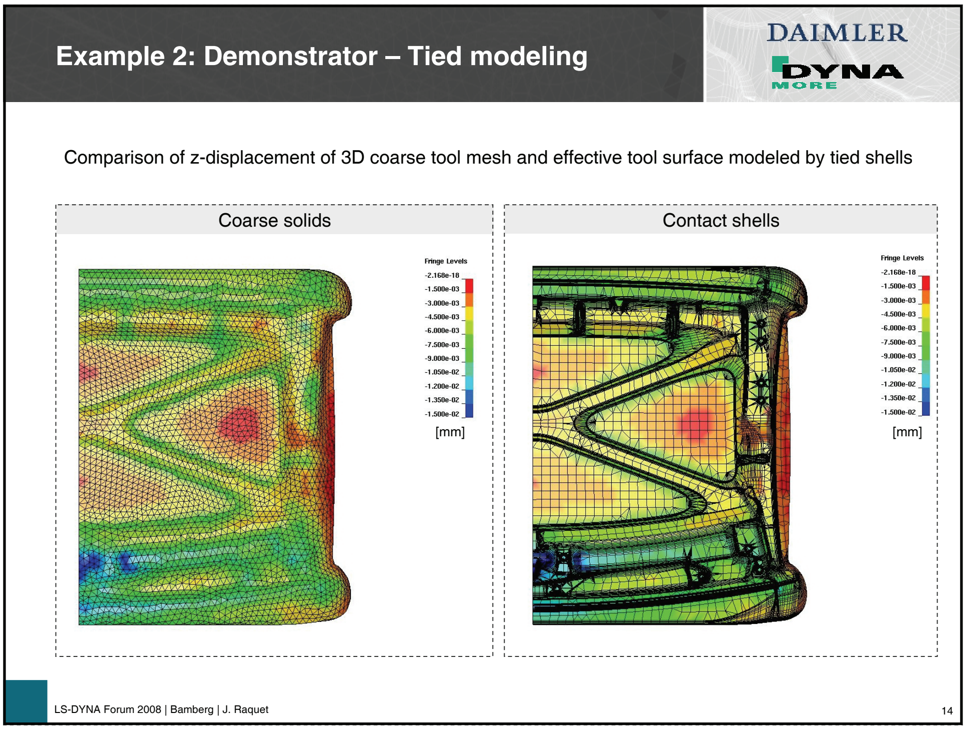
Example 2: Demonstrator – Tied modeling
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Comparison of z-displacement of 3D coarse tool mesh and effective tool surface modeled by tied shells
Coarse solids
Contact shells
Fringe Levels
-2.160e-18
-1.500e-03
-3.000e-03
-4.500e-03
-6.000e-03
-7.500e-03
-9.000e-03
-1.050e-02
-1.200e-02
-1.350e-02
-1.500e-02
[mm]
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Example 2: Demonstrator – Condensation remarks

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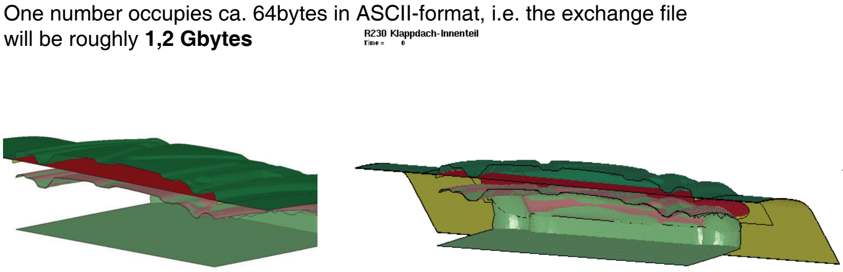
- For the tool having 38400 nodes condensation to 6100 nodes leads to:

  6100 nodes * 3 dof/node = **18300** rows/columns in the matrix
  Number of unique values: 18300 * (18300+1)/2 = **167 mio.** entries**!**
  One number occupies ca. 64bytes in ASCII-format, i.e. the exchange file will be roughly **11 Gbytes** for one information set (i.e. stiffness or mass).

- Storing only the vertical degrees of freedom reduces the amount needed to:

  6100 nodes * 1 dof/node = **6100** rows/columns in the matrix
  Number of unique values: 6100 * (6100+1)/2 = **18 mio. entries**
  One number occupies ca. 64bytes in ASCII-format, i.e. the exchange file will be roughly **1,2 Gbytes**



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Example 2: Demonstrator - rigid vs. 3D elastic

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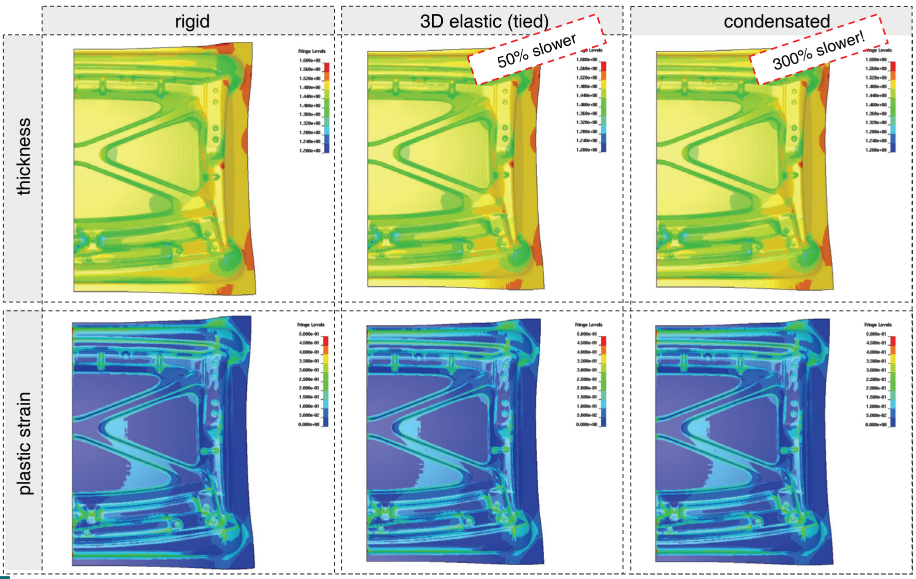

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Summary and outlook

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- Elastic tools and a elastic representation of the press are possible.
- A couple of different approaches have been shown. All need additional effort in meshing and model setup.
- The most easy to use and flexible method may find most users.
- The aforementioned arguments point to the last method presented. Also, seamless transition from rigid tools to deformable tools can be done in the same process environment – even in the same simulation run.
- Additionally to deformable tools users will wish to apply different friction models in different parts of the tool. The latter will eventually lead to models that are capable to estimate the wear of the tools based on locally applied and optimized coatings.
- However, elastic tools also demand more advanced shell models…

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Thank you for your attention.

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