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Coupled Simulation of Forming and Welding with LS-DYNA for the design of Distortion-Compensation

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07.10.2014, Bamberg
LS-DYNA Forum

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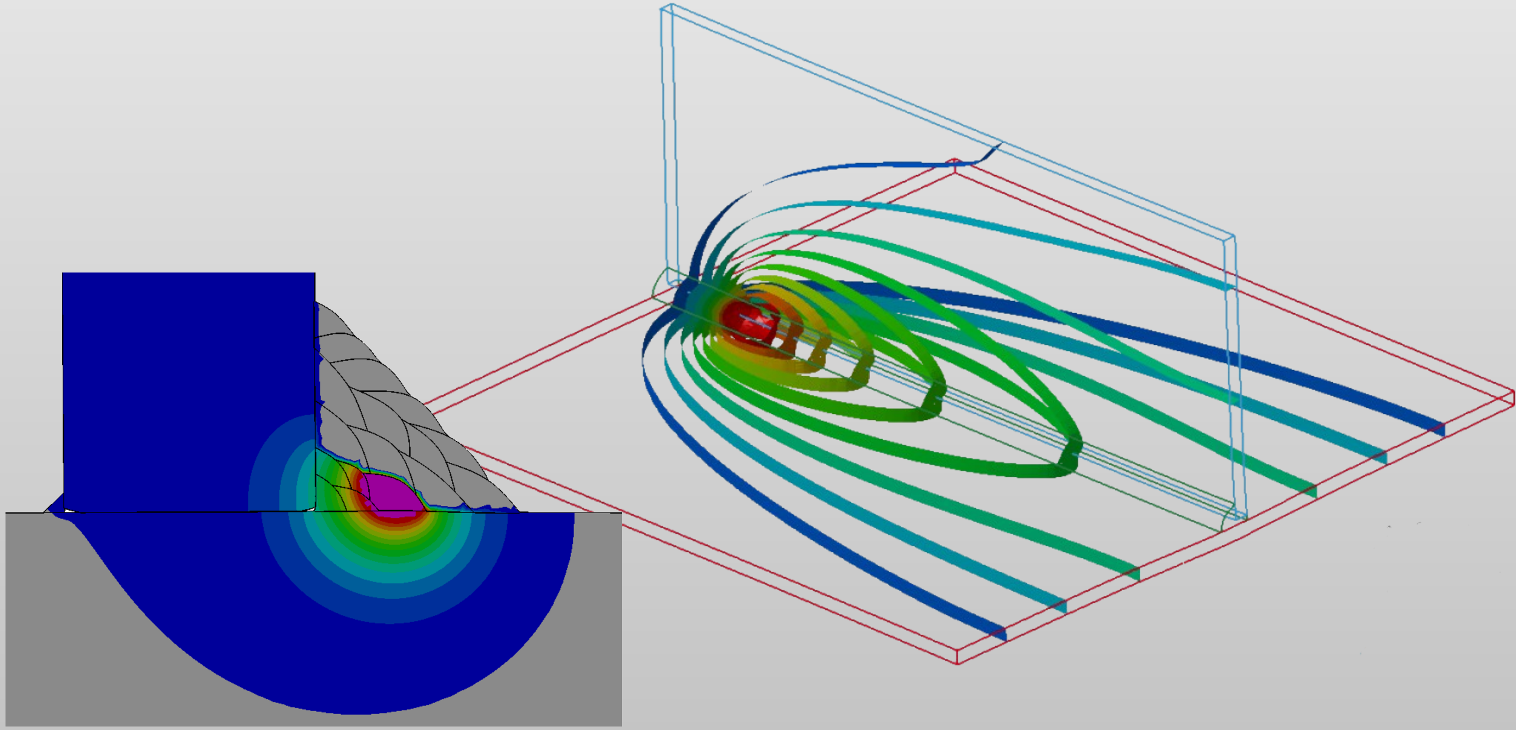
Numerical Simulation for Welding and Heat Treatment since 2004

Consulting - Training - Support

Distribution of software for Welding and Heat Treatment Simulation



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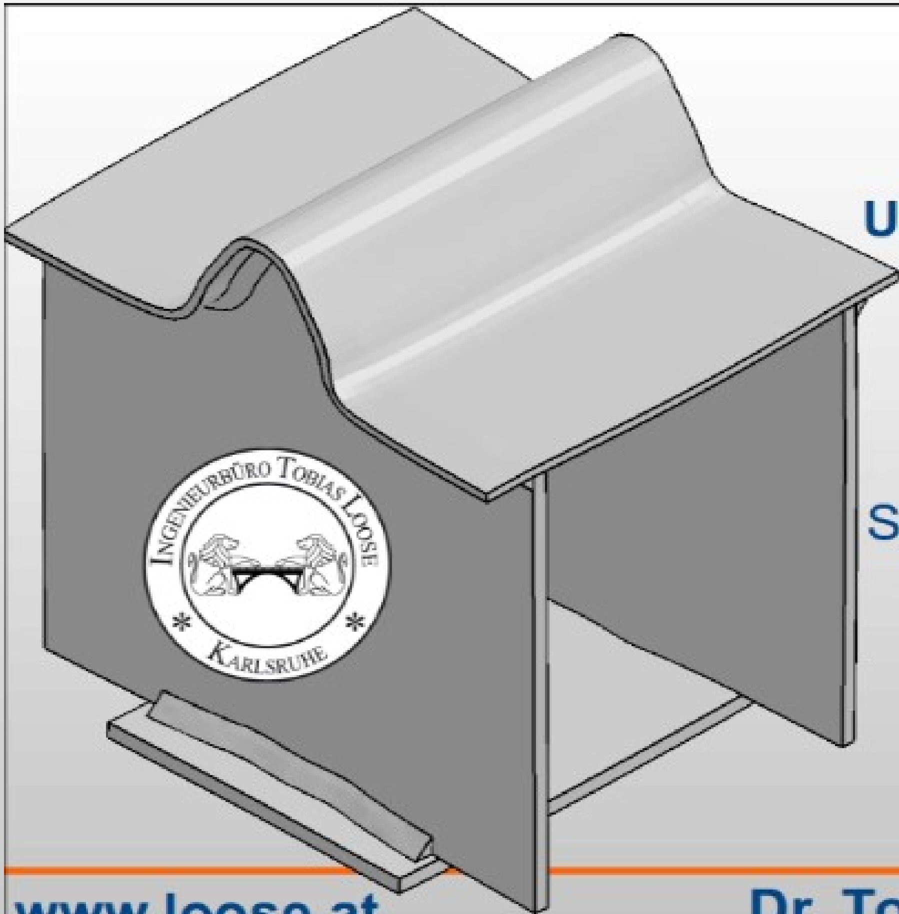
Introduction



LS-DYNA

Herstellung einer BOX

Umformen – Schweißen – Zusammenbau
Simulation aller Prozeßschritte

Fabricación de una CAJA

Deformación – Soldadura – Montaje
Simulación de todas las etapas del proceso

Manufactoring of a BOX

Forming – Welding – Assembley
Simulation of all process steps

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17.07.2014

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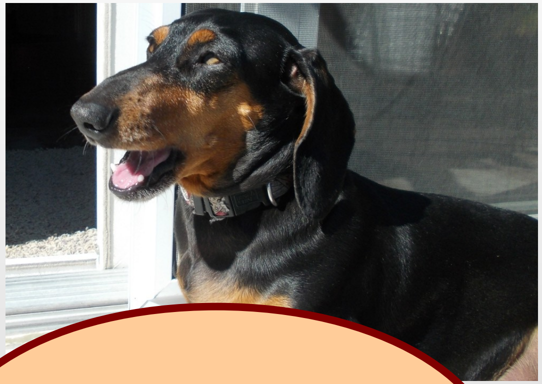
Forming

Heat Treatment

Assembly

Welding

Post Weld Heat Treatment



Simulation of Process Chain

Specific Features of Welding and Heat Treatment Simulation

Material Properties

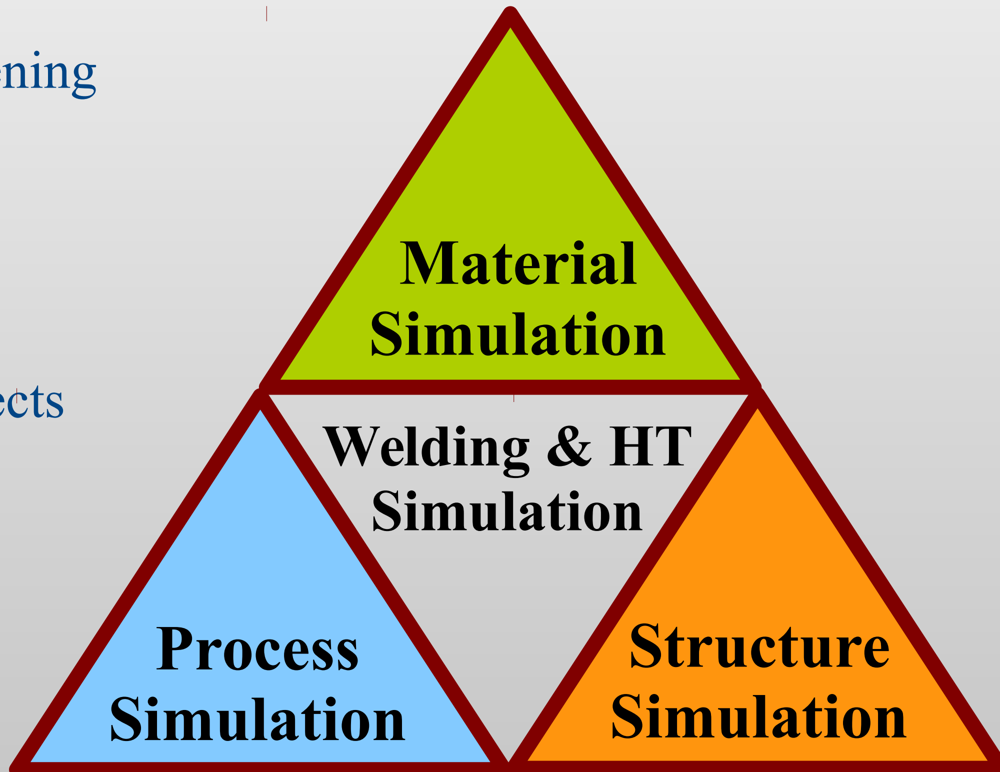
- material properties depend on temperature
- material properties change in thermal loading cycles
  → change of microstructure / phase transformation

History Variables

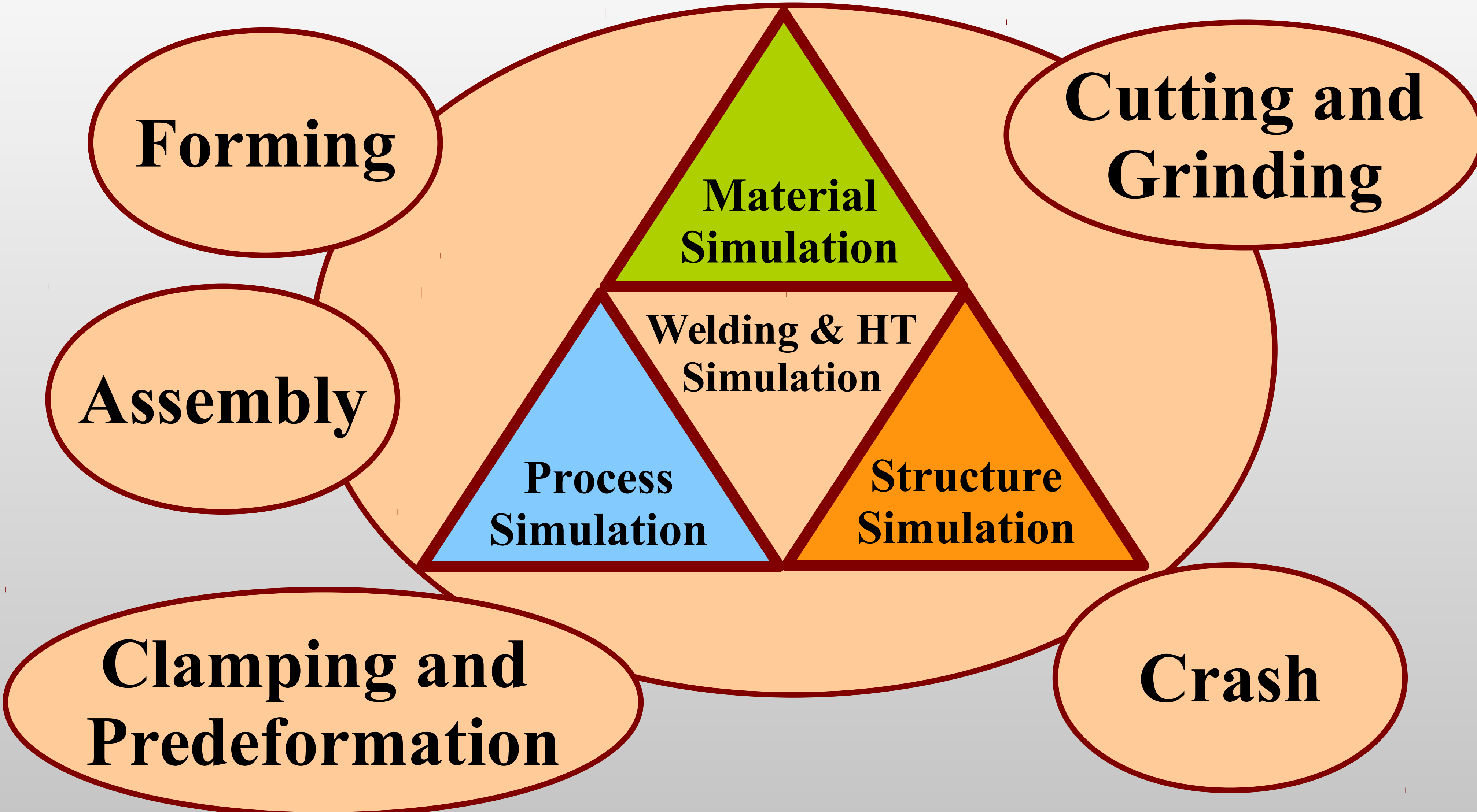
- stress, strain, strain hardening
- phase proportion

Material Modell

- reset of material history
- phase transformation
- phase transformation effects



Simulation of Process Chain



Simulation of Process Chain

Method A:

- Each simulation task with a special simulation tool
- Each simulation task with a specific material modell
- Transfer of informations between two tasks via special interfaces
- Mapping of results

Consequence:

- Information loss from one step to the next step by mapping
- Problem of interface compatibility
- Multiple license costs

Method B:

- As many simulation task as possible in one simulation tool
- Each simulation task with the same material modell
- Continous transfer of information within the same code and the same data structure
- Avoid mapping of results.

Consequence:

- No information loss between single simulation steps
- No trouble with interface compatibility
- Save of license costs

Benefit of a Continous Simulation of Process Chain

- Precalcualtion of the final state of the assembly:
  - geometry
  - residual stresses
  - microstructure
- Complete simulation of the entire manufacturing process
- Take into account the two way impact of single manufacturing tasks

- Enables the design of the manufacturing process
- Enables the desing of compensation methods for requested conditions

Process Chain Manufacturing

Task and Model

Forming:
- The roof geometry is made by forming a 3 mm thick sheet (1.4301)

Assembly:
- Add the sidewall

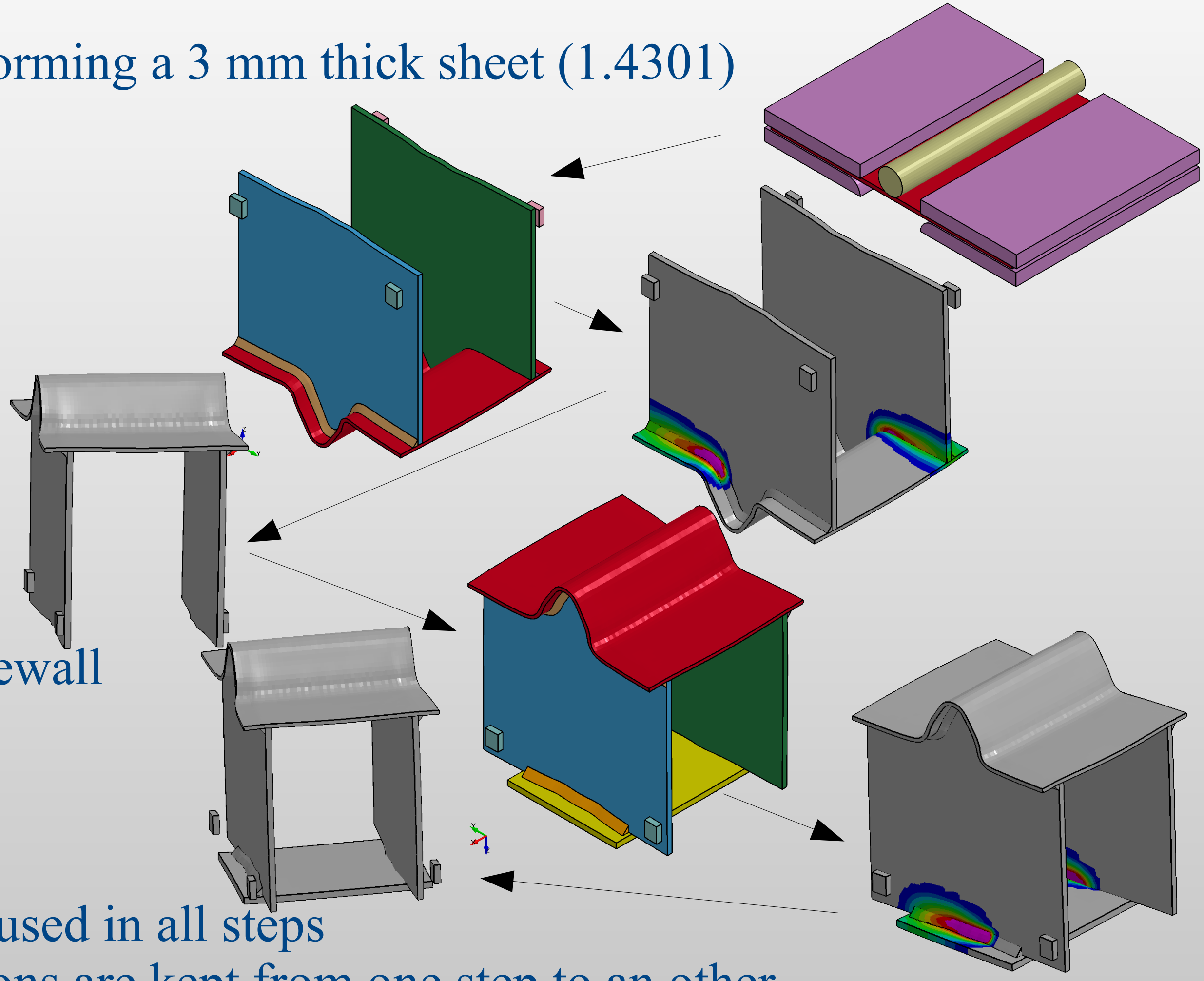
Welding:
- Weld the sidewall to the roof

Clamp and predeformation:
- press the sidewall on measure

Assembly:
- Add the bottom plate

Welding:
- Weld the bottom plate to the sidewall

Unclamping



Model:
- Solid-element model
- Material model (*MAT_270) is used in all steps
- History variables and deformations are kept from one step to an other
- Implicit analysis in all steps

Welded Assemblys

Deep-Drawing of a Cup

Process Chain Welding - Forming

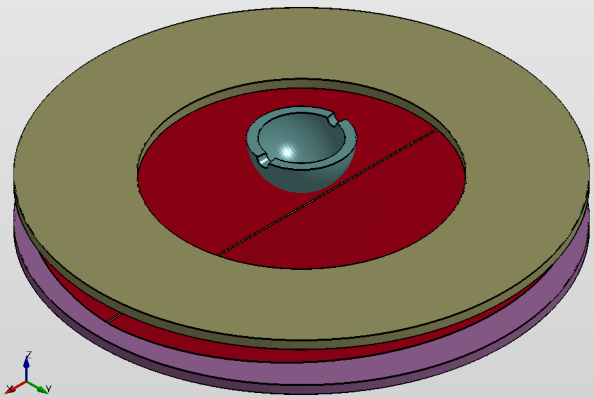
Process Chain Welding - Crash

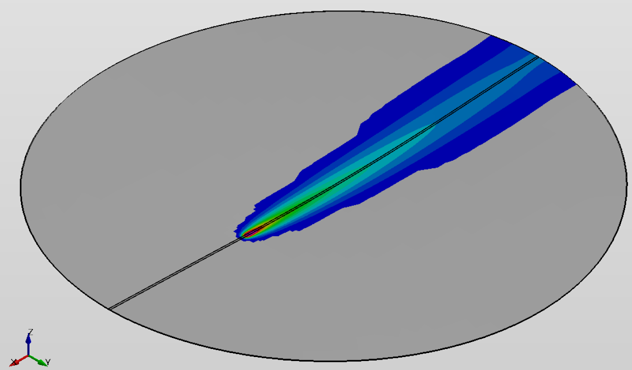
Deep-Drawing of a Cup from a Laser Welded Sheet
Task and Model

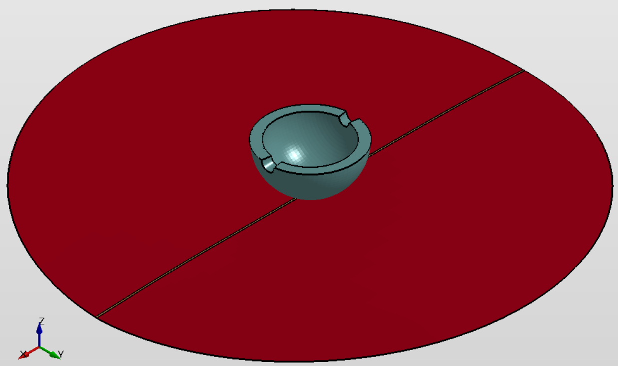
Welding:
- Two sheets (S355) with 1 mm wall thickness are laser welded

Forming:
- The welded and distorted sheet is clamped
- a globular die is pressed slow in the sheet.

Crash:
- The welded and distorted sheet is free
- a bullet impacts the sheet with a speed of 5000 m/s



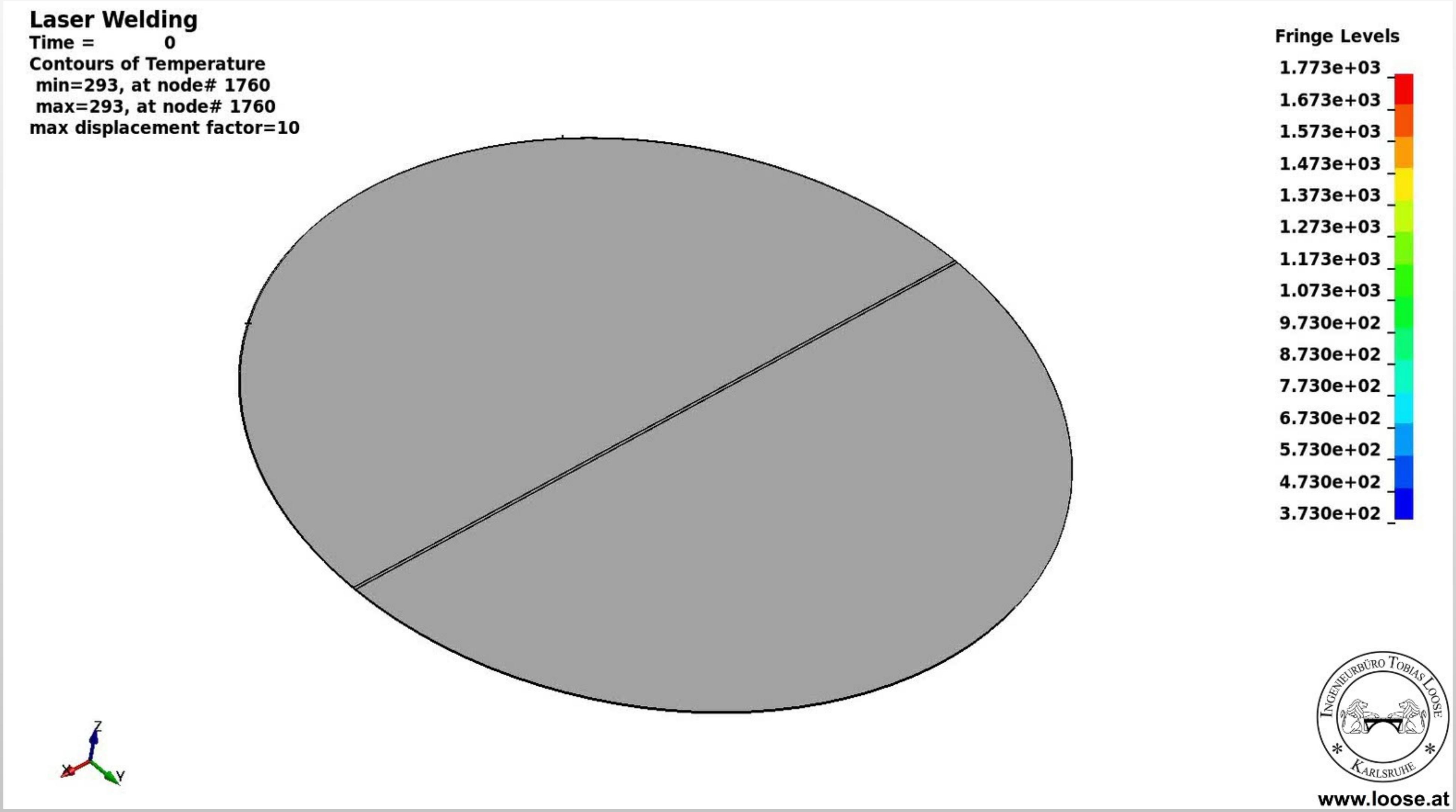




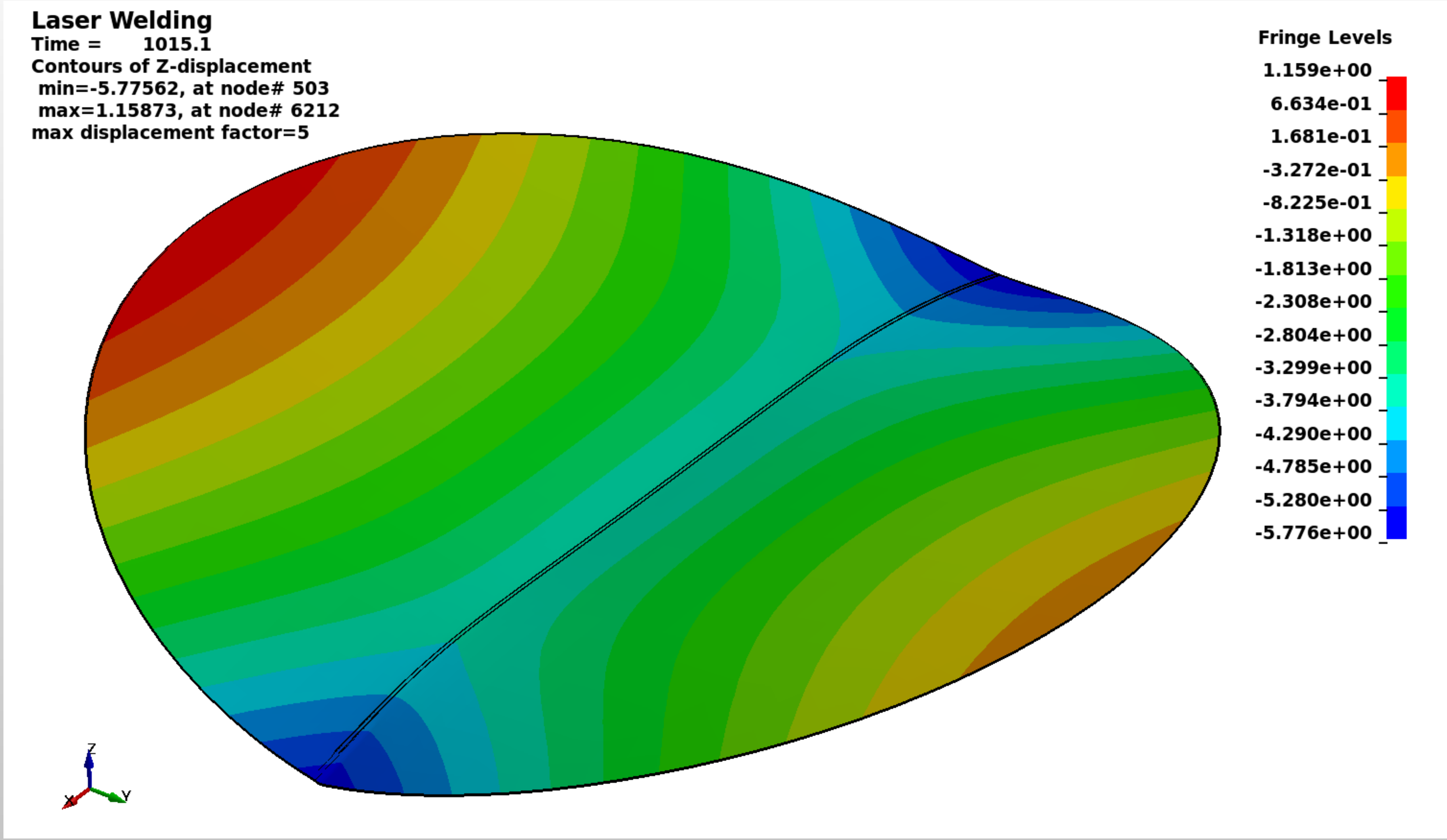
Model:
- Shell-elements are used for the sheet, solid elements are used for the clamps and the die
- Same material model (*MAT_244) is used in all steps
- History variables, phase proportions and deformations are kept from one step to an other
- Welding: implicit analysis, Forming / Crash: explicit analysis

Welding

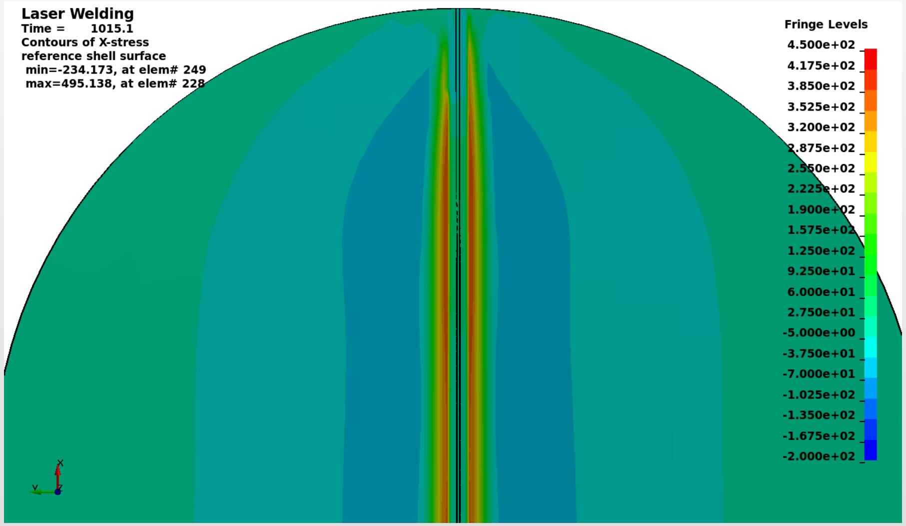
z-displacement 10-times scaled

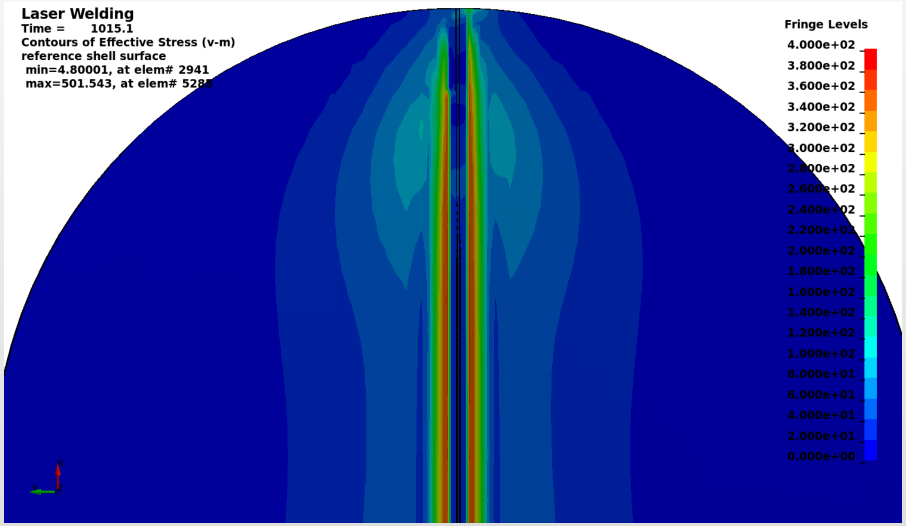


Vertical Distortion



Stresses and Strains in Midsurface of Shell





After welding and cooling

top left:

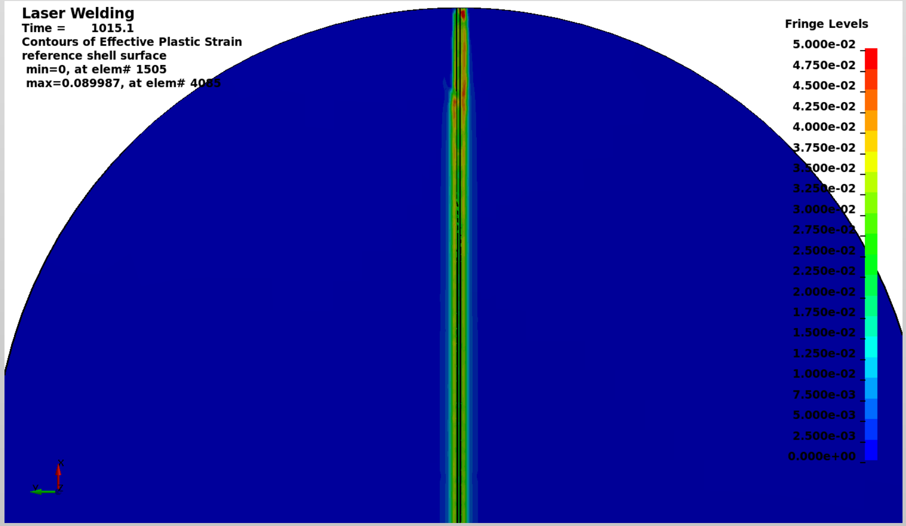
Longitudinal stress

top right:

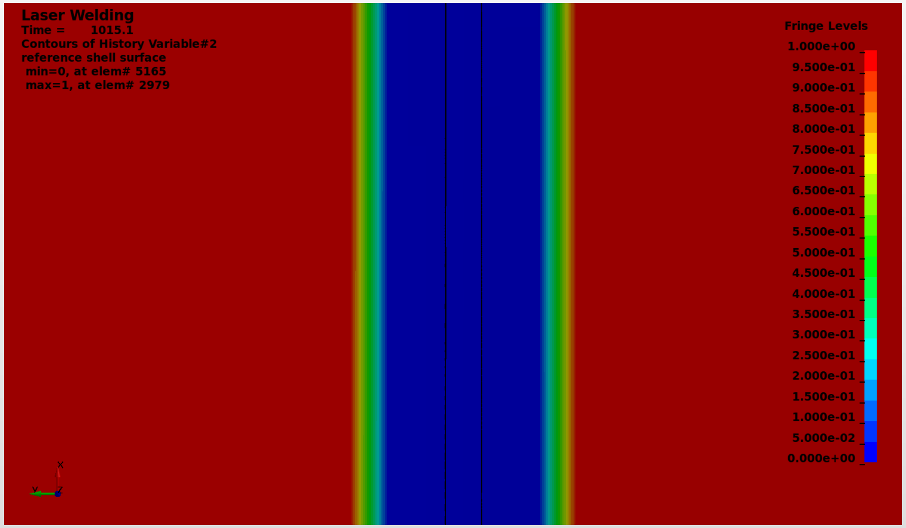
Effectiv stress (v. Mises)

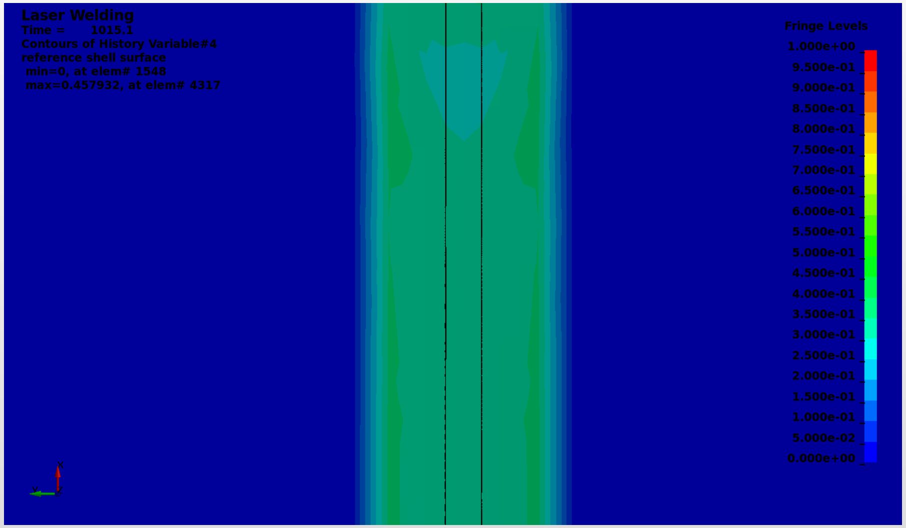
bottom right:

plastic strain



Microstructure





After welding and cooling

top left:

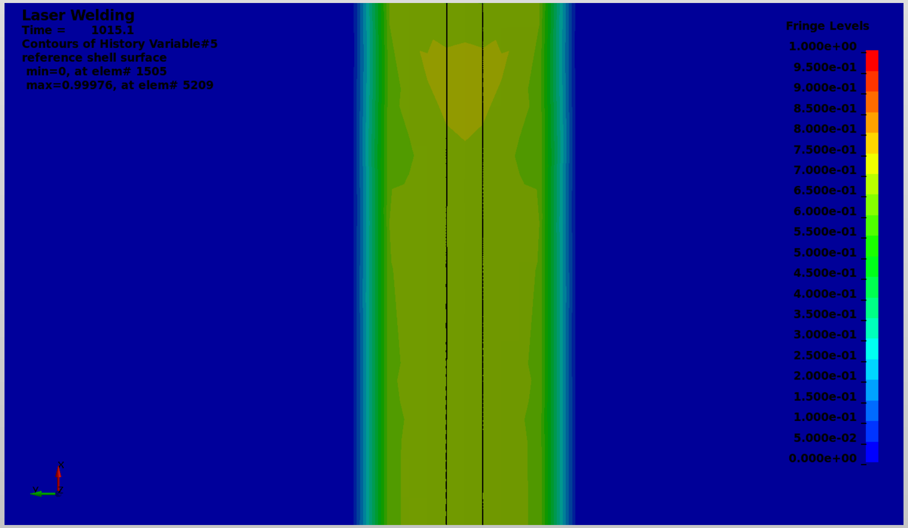
Ferrit proportion

top right:

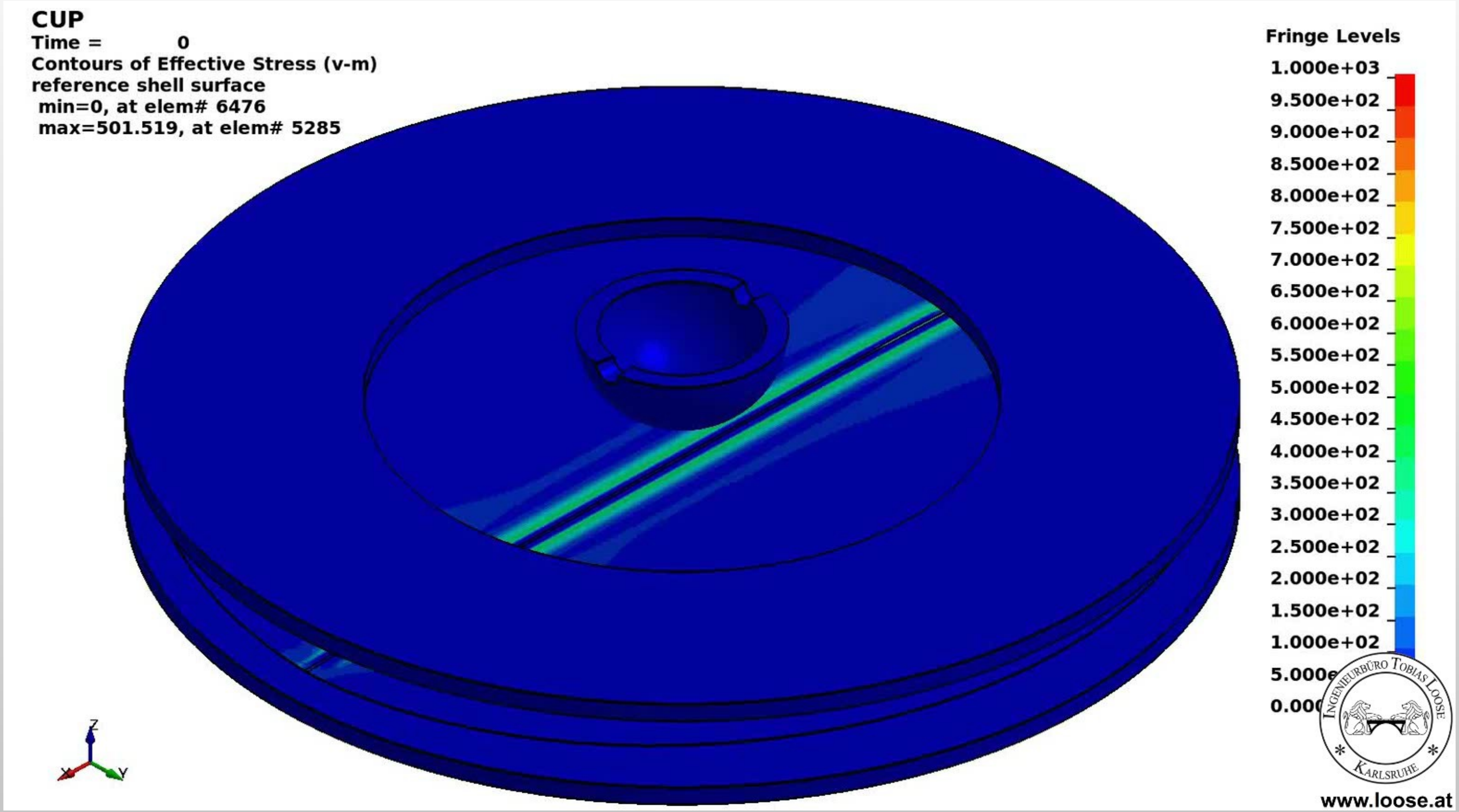
Bainit proportion

bottom right:

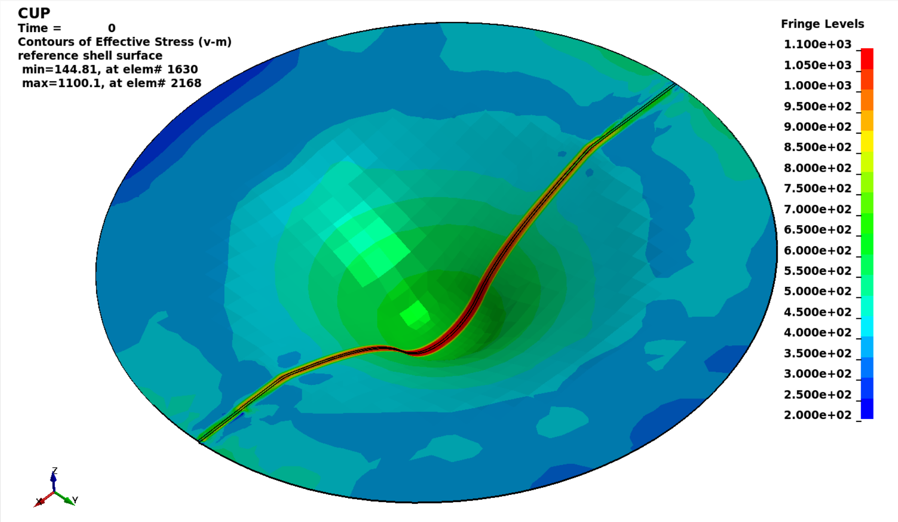
Martensit proportion



Deep drawing – effectiv stress



Stresses and Strains in Midsurface of Shell



top left:

effectiv stress bevor unclamping

200 .. 1100 N/mm²

bottom left:

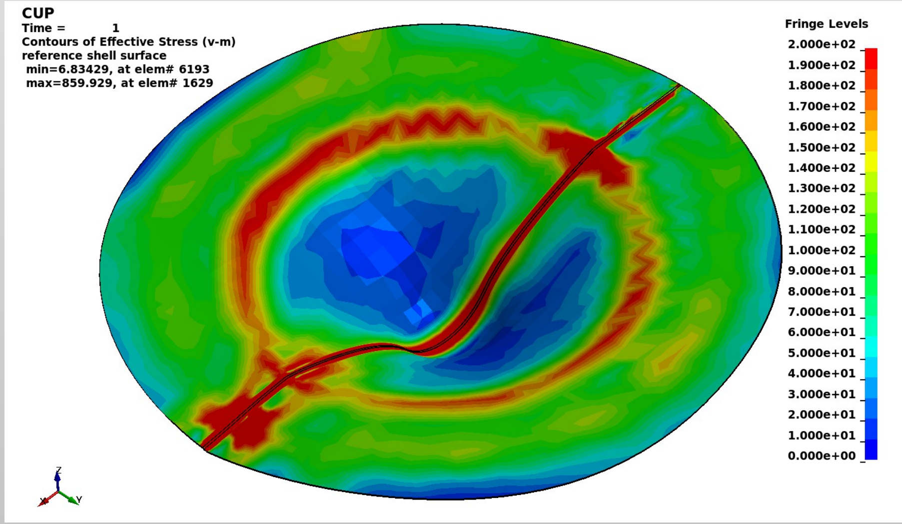
effectiv stess after unclamping

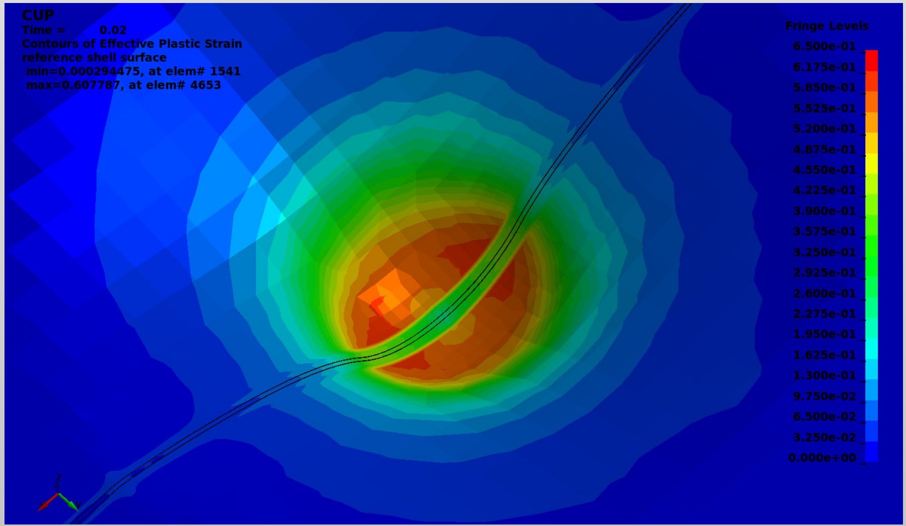
0 .. 200 N/mm²

bottom right:

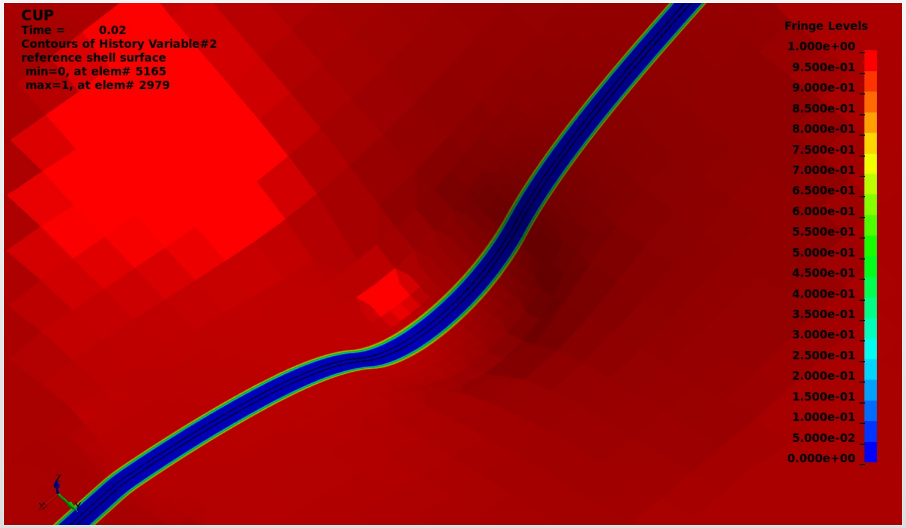
plastic strain after unclamping

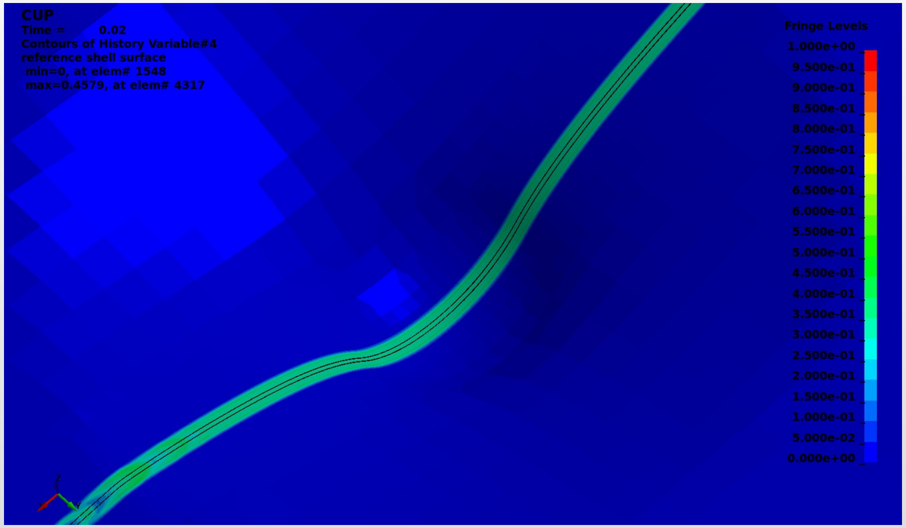
0 .. 0.65 m/m

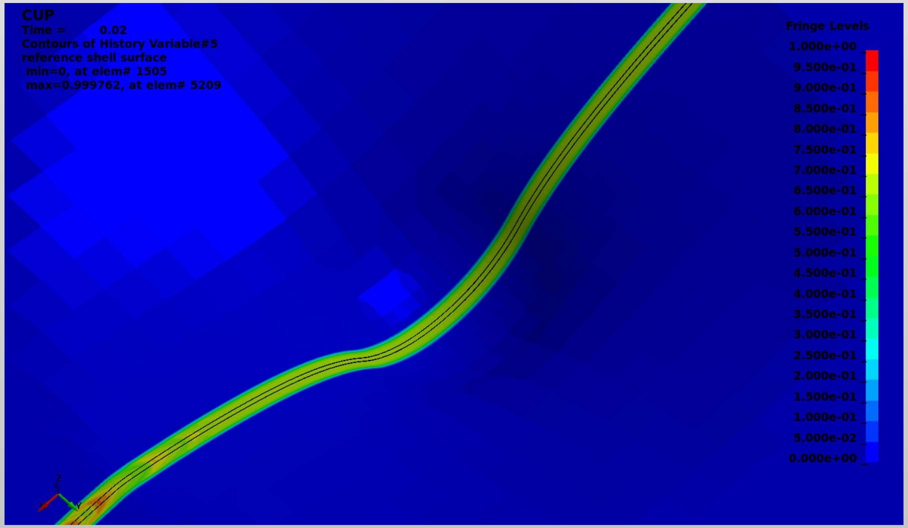




Microstructure during Deep-Drawing







top left:

Ferrit proportion

top right:

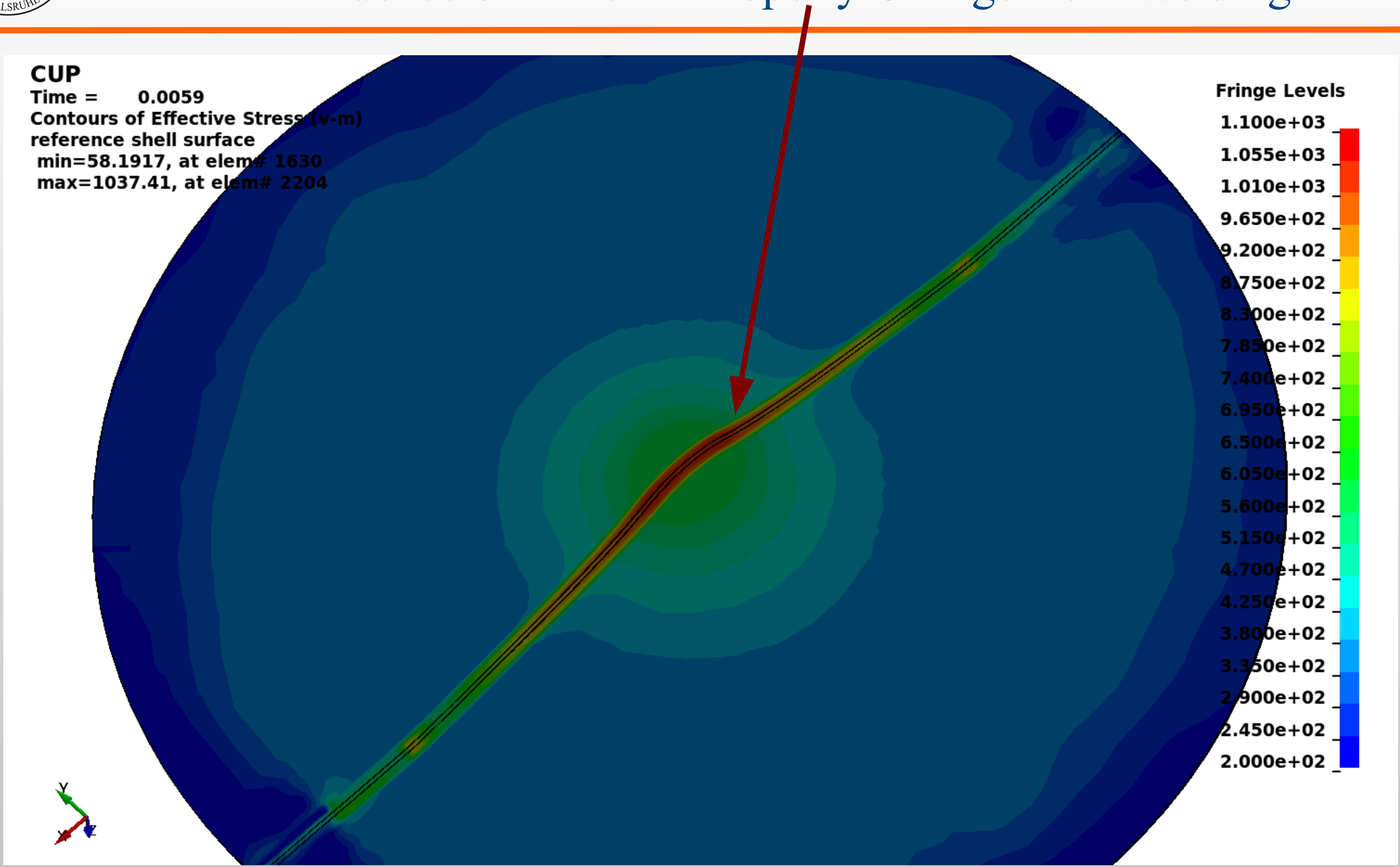
Bainit proportion

bottom right:

Martensit proportion

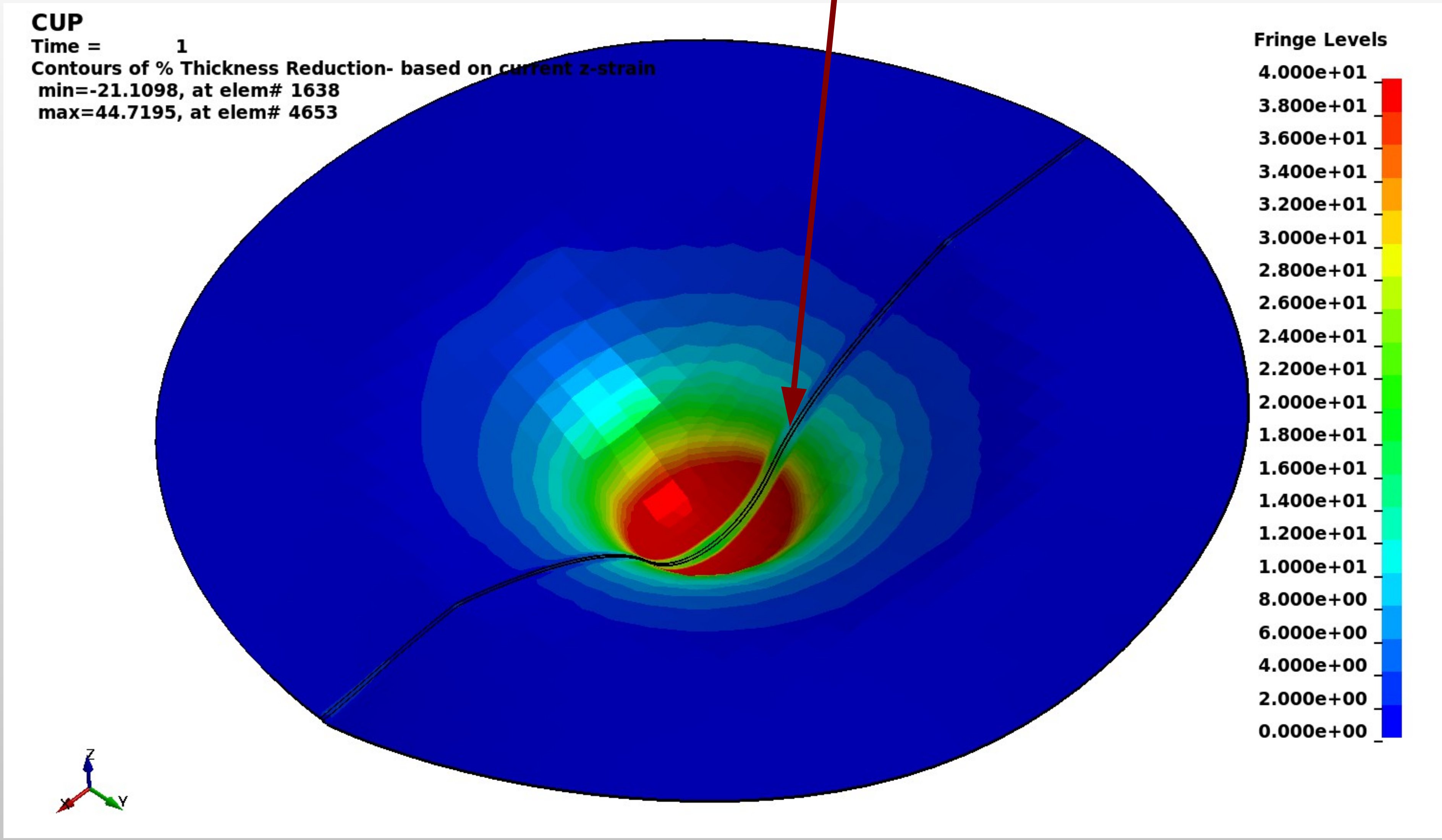
Effective Stress during Forming

Influence of Material Property Change from Welding

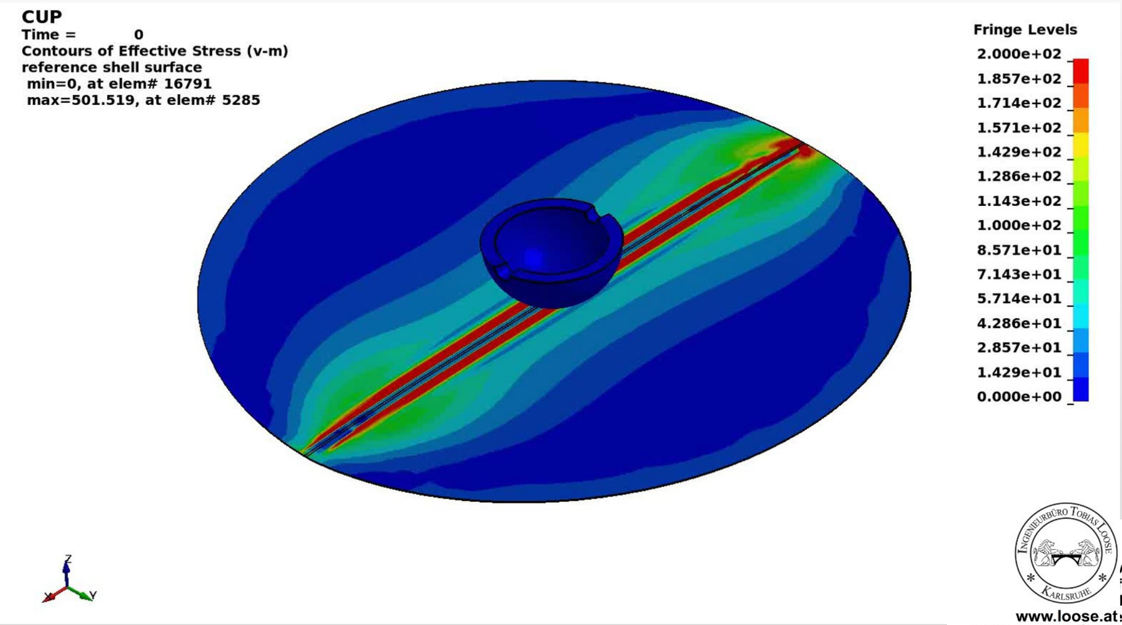


Thinning of the Sheet

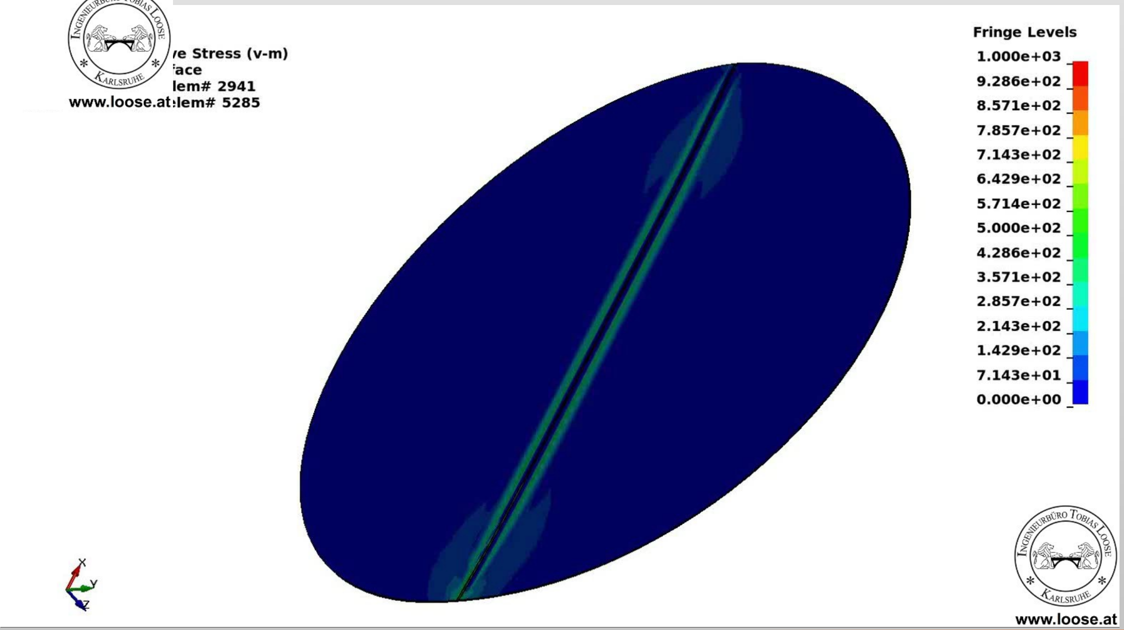
Influence of Material Property Change from Welding



Crash – Effective Stress
Impact Velocity 5000 m/s



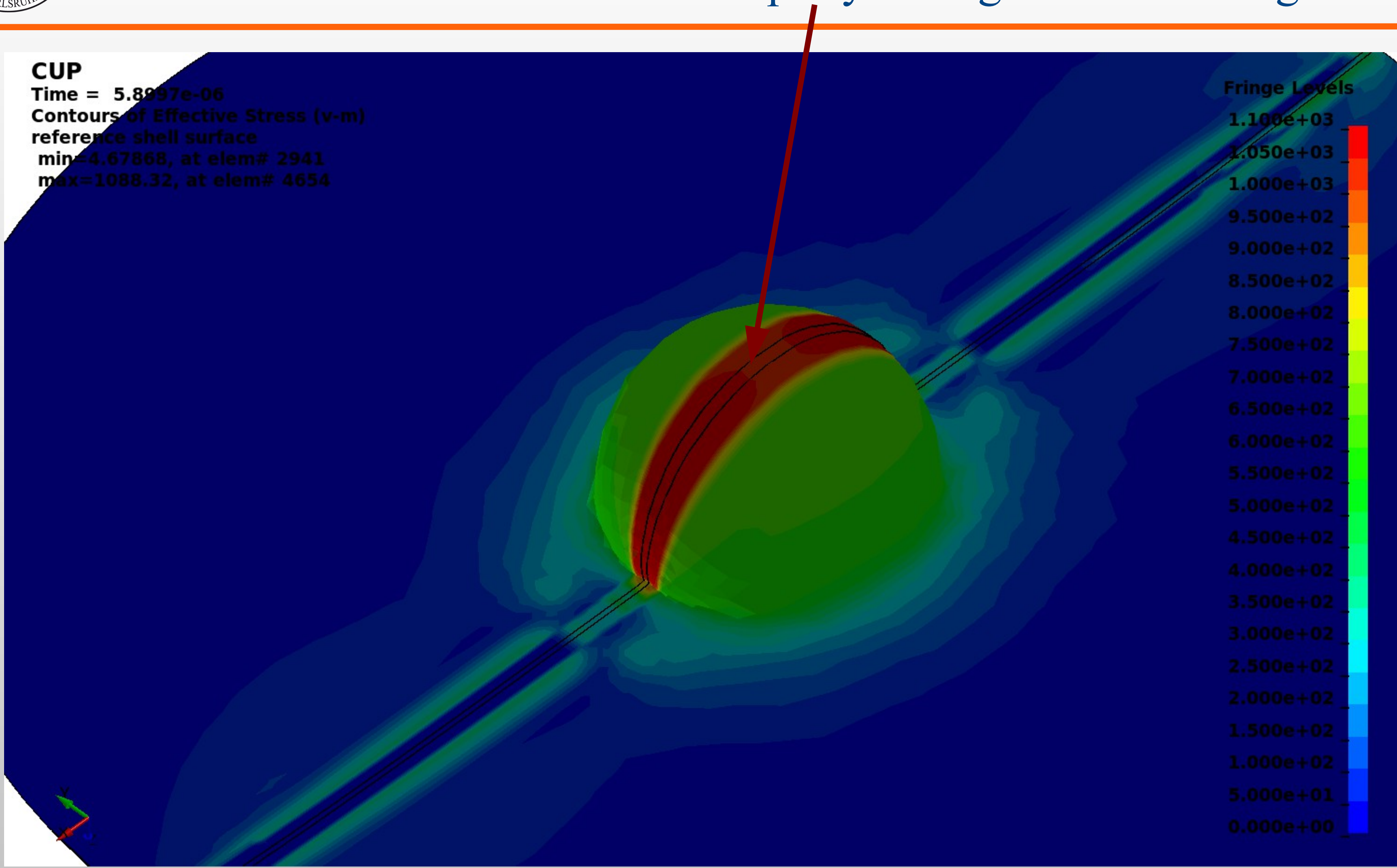
Skala: 0 .. 200 N/mm²



Skala: 0 .. 1000 N/mm²

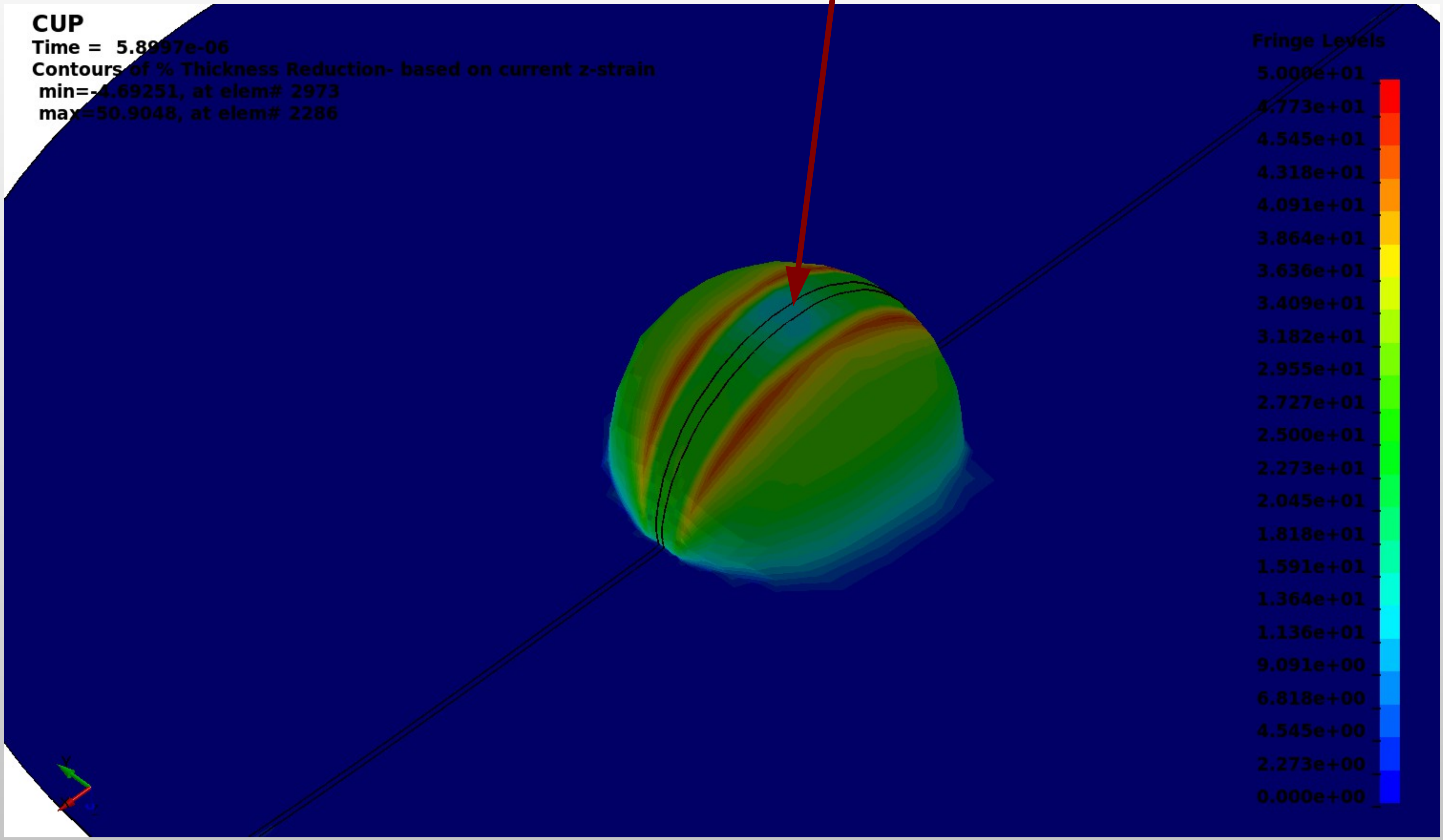
Effective Stress During Crash

Influence of Material Property Change from Welding



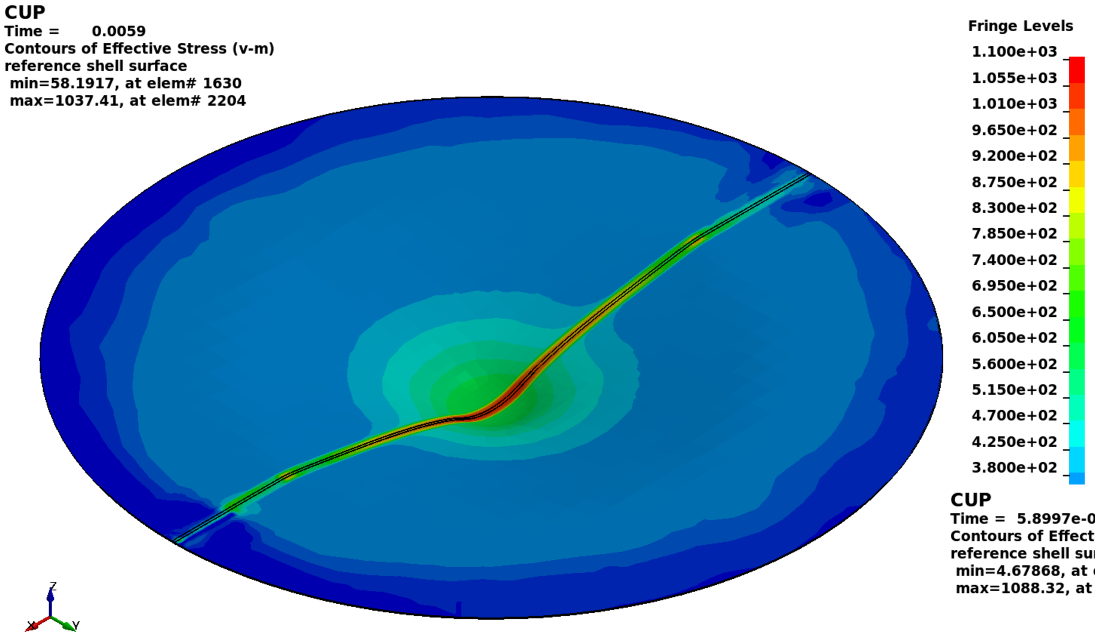
Thinning of the sheet

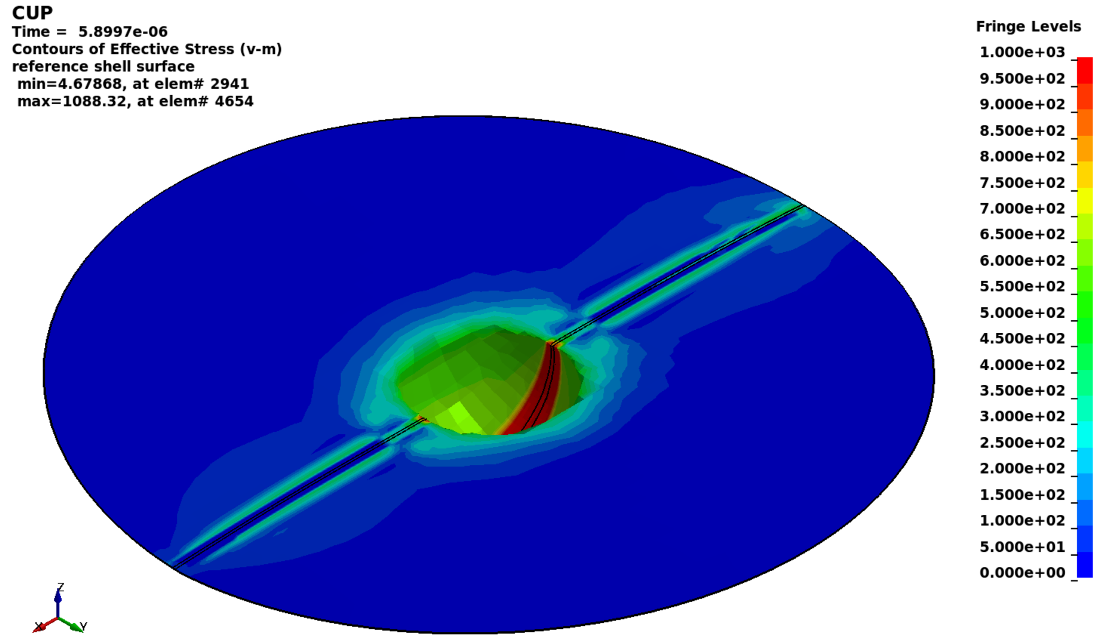
Influence of Material Property Change from Welding



Comparison between Forming and Crash

effective Stress at same Penetration Depth





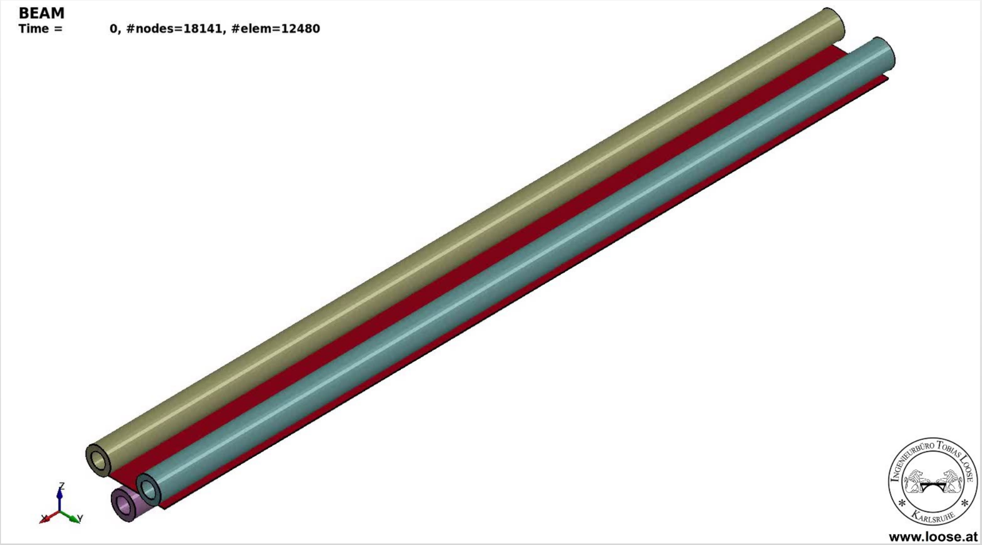
Distortion Compensation

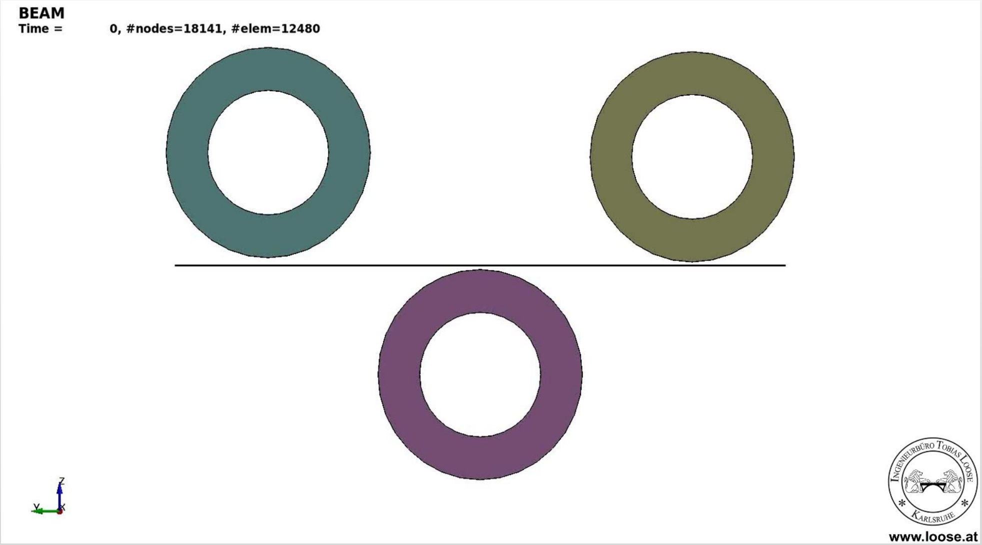
Predeformation

Rolling and Welding of a thin Walled Beam
Task and Model

Rolling:

- A 1500 mm long sheet (S355) with 1 mm wall thickness is rolled to a groove





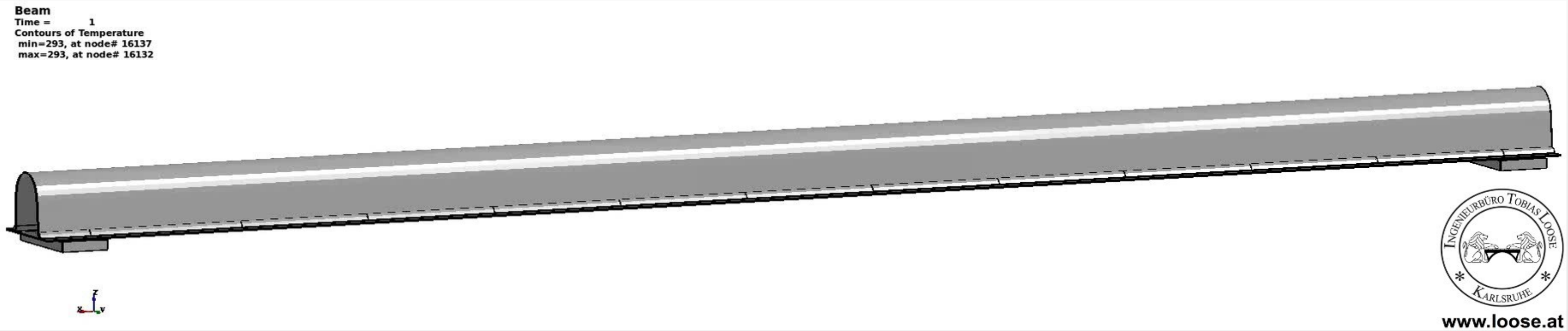
Welding:

- A ground plate is longitudinal welded to the groove

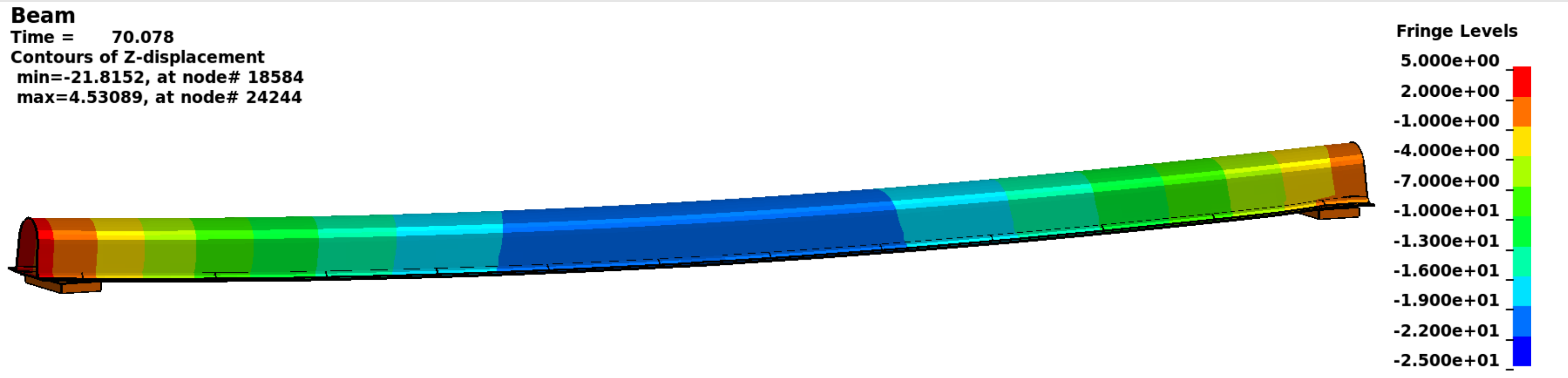
Model:

- Shell-elements are used for the sheet and the ground plate
- Solid-elements are used for the filler material and the clamps
- Same material model (*MAT_244) is used in all steps for shells and for solids
- History variables, and deformations are kept from one step to an other

Distortion Evolution during Welding
Metatransient Method

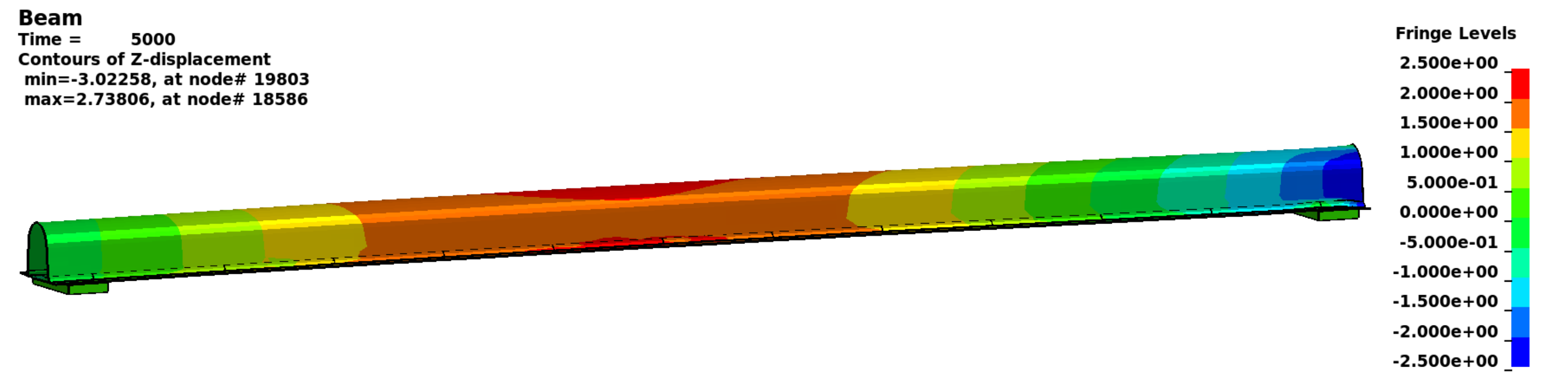


Temperature



Distortion

Max vertical distortion during welding:
22 mm down



Max vertical distortion after cooling:
2,7 mm up

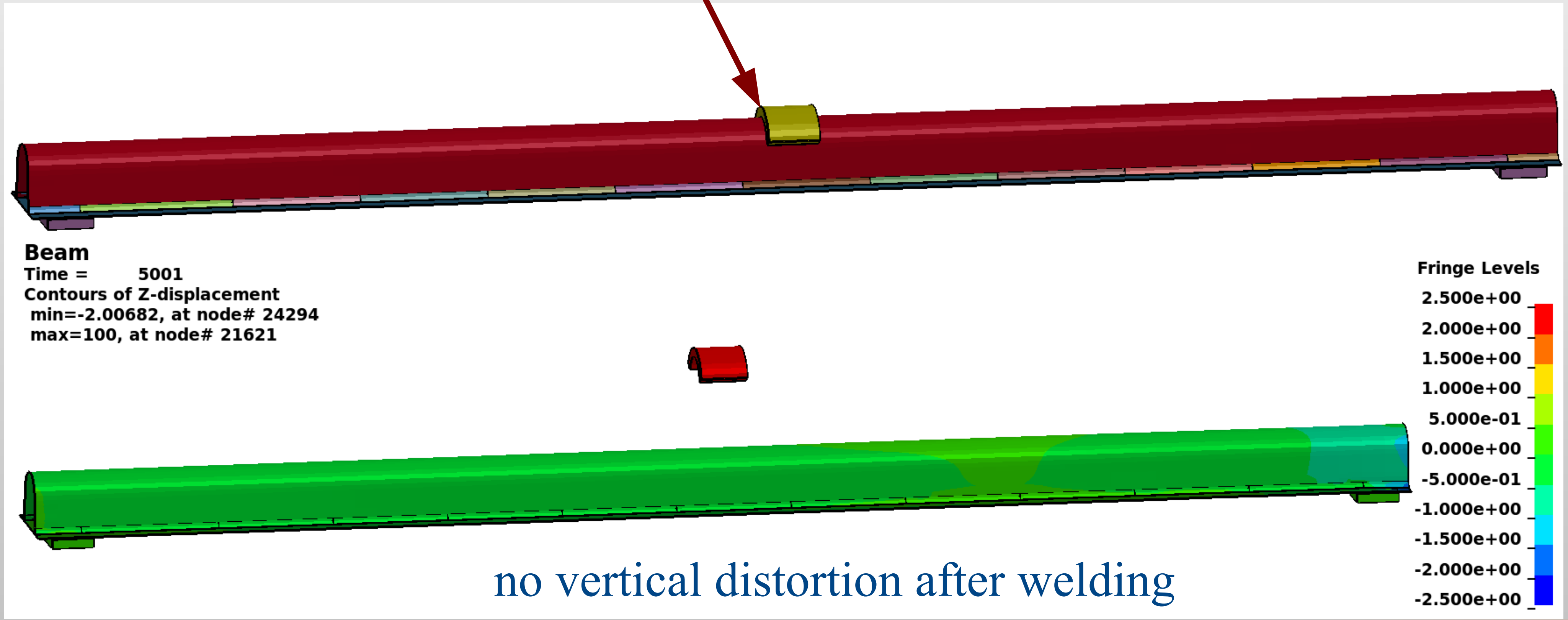
Compensation of distortion

Method A:

- Stamping of the groove with the inverted final distortion from welding.

Method B:

- Predeformation in vertical direction during welding as shown below:



Summary

Summary

- The manufacturing process comprises several different steps.
- These several steps interact and may influence each other.
- For a realistic simulation of the manufacturing process results of previous simulation steps has to be taken as initial conditions.
- The finite element code LS-DYNA provides the feasability to simulate the manufacturing steps:
  forming, assembly, welding, post-weld-heat-treatment, grinding, crash
  - in one code
  - with continuous data structure
  - with continuous material modell and continuous history variables
  - take into account material property change
  - without loss of information by mapping
- Shell-, solid- and mixed shell-solid models can be used
- Thus LS-DYNA is a suitable solution for the simulation of the process chain to simulate complex manufacturing prosesses.

Thanks for your Attention!