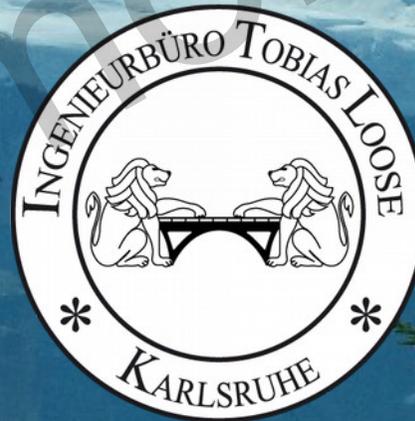




Herdweg 13, D-75045 Wössingen Lkr. Karlsruhe
Courriel: loose@tl-ing.de Web: www.tl-ing.de, www.loose.at
Mobil: +49 (0) 176 6126 8671 Tel: +49 (0) 7203 329 023 Fax: +49 (0) 7203 329 025

Schweißsimulation und Wärmebehandlungssimulation in der Prozeßkettensimulation



Dr.-Ing. Tobias Loose
07.10.2014, Bamberg
LS-DYNA Forum

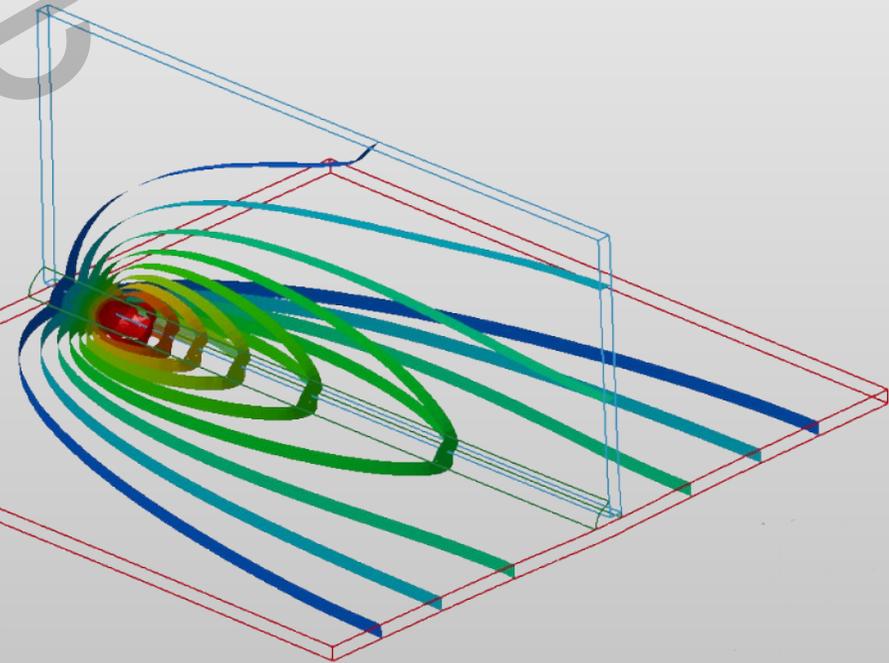
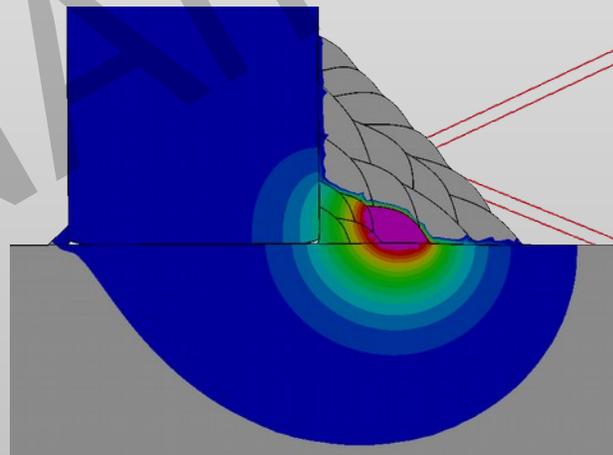


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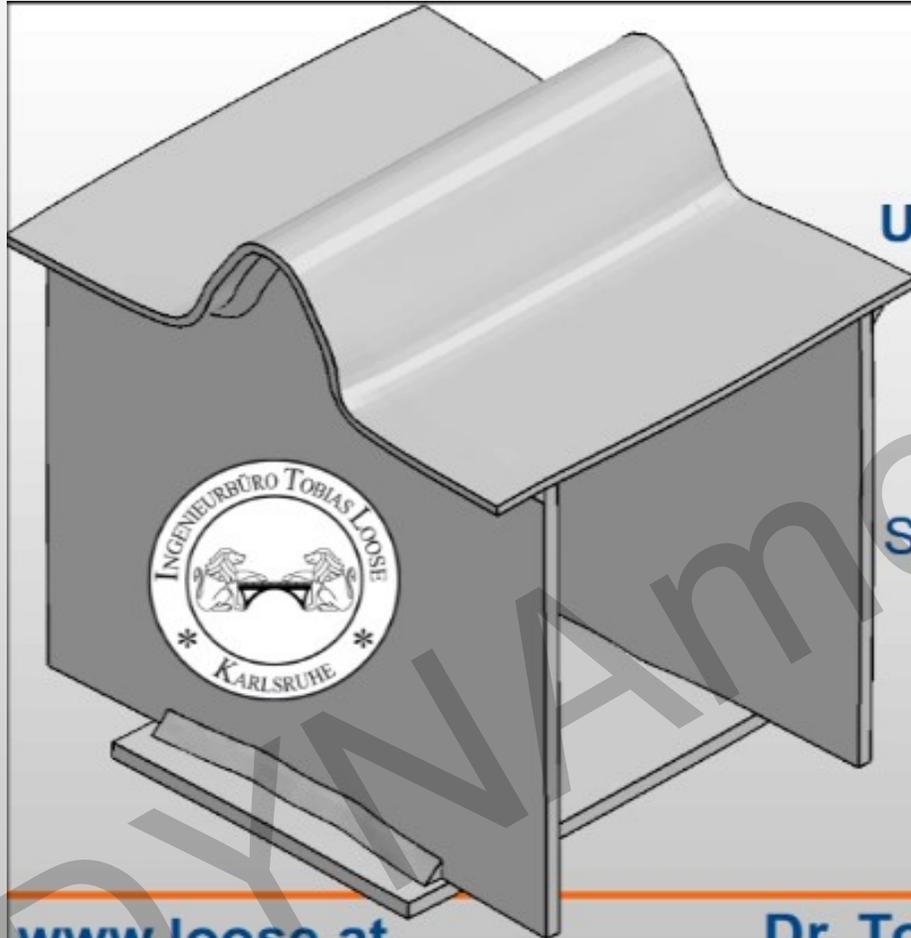
Numerical Simulation for Welding and Heat Treatment since 2004

Consulting - Training - Support
Distribution of software for
Welding and Heat Treatment Simulation



Internet:
DEutsch: www.loose.at
ENglish: www.tl-ing.eu
ESpañol: www.loose.es

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

Manufacturing of a BOX

Forming – Welding – Assembly
Simulation of all process steps

www.loose.at
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Dr. Tobias Loose
17.07.2014

Ingenieurbüro Tobias Loose
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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

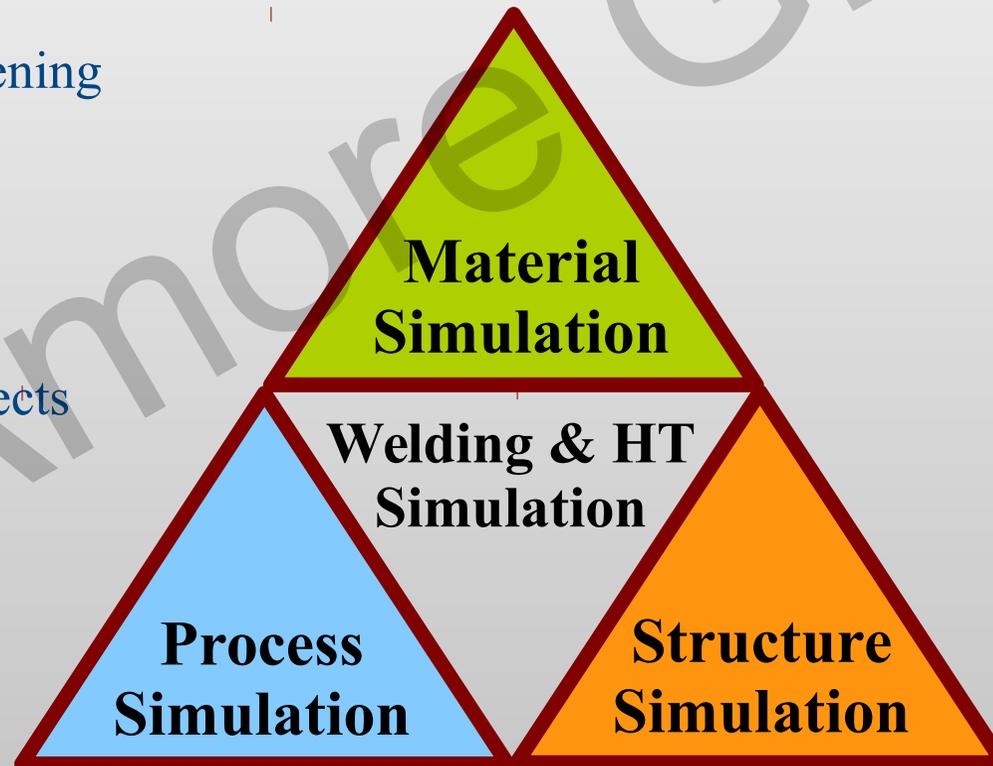
- material properties depend on temperature
- material properties change in thermal loading cycles
→ change of microstructure / phase transformation

History Variables

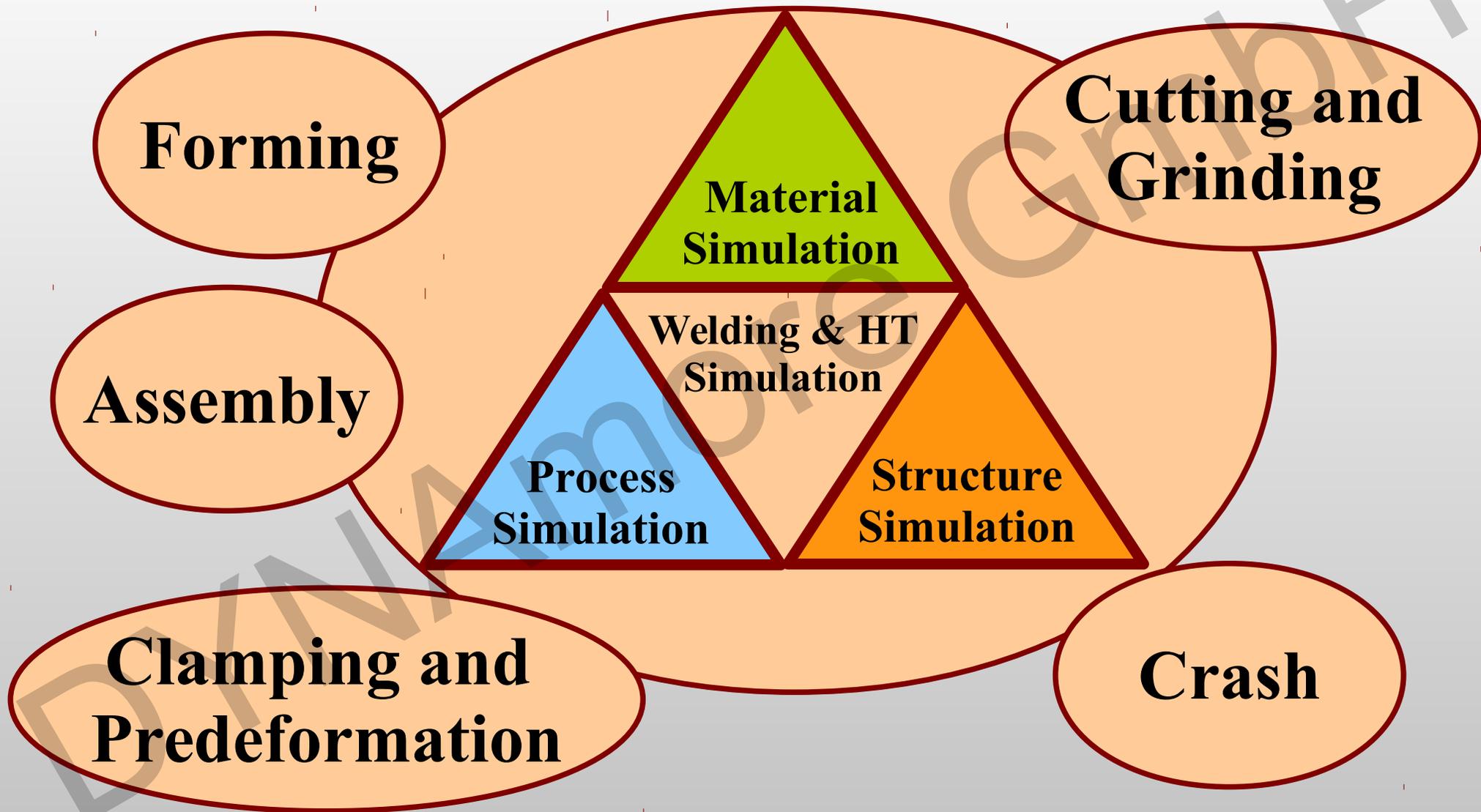
- stress, strain, strain hardening
- phase proportion

Material Model

- 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 model
- Transfer of information 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 model
- Continuous transfer of information within the same code and the same data structure
- Avoid mapping of results

Consequence:

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

Benefit of a Continuous Simulation of Process Chain

- Precalculation of the final state of the assembly:
 - geometry
 - residual stresses
 - microstructure
- Complete simulation of the entire manufacturing process
- Take into account the impact of single manufacturing tasks
- Enables the design of the manufacturing process
- Enables the desing of compensation methods for requested conditions





Process Chain Manufacturing

Manufacturing of a Box

Task and Model

Forming:

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

Assembly:

- Add sidewall

Welding:

- Weld sidewall to the roof

Clamp and predeformation:

- press sidewall on measure

Assembly:

- Add bottom plate

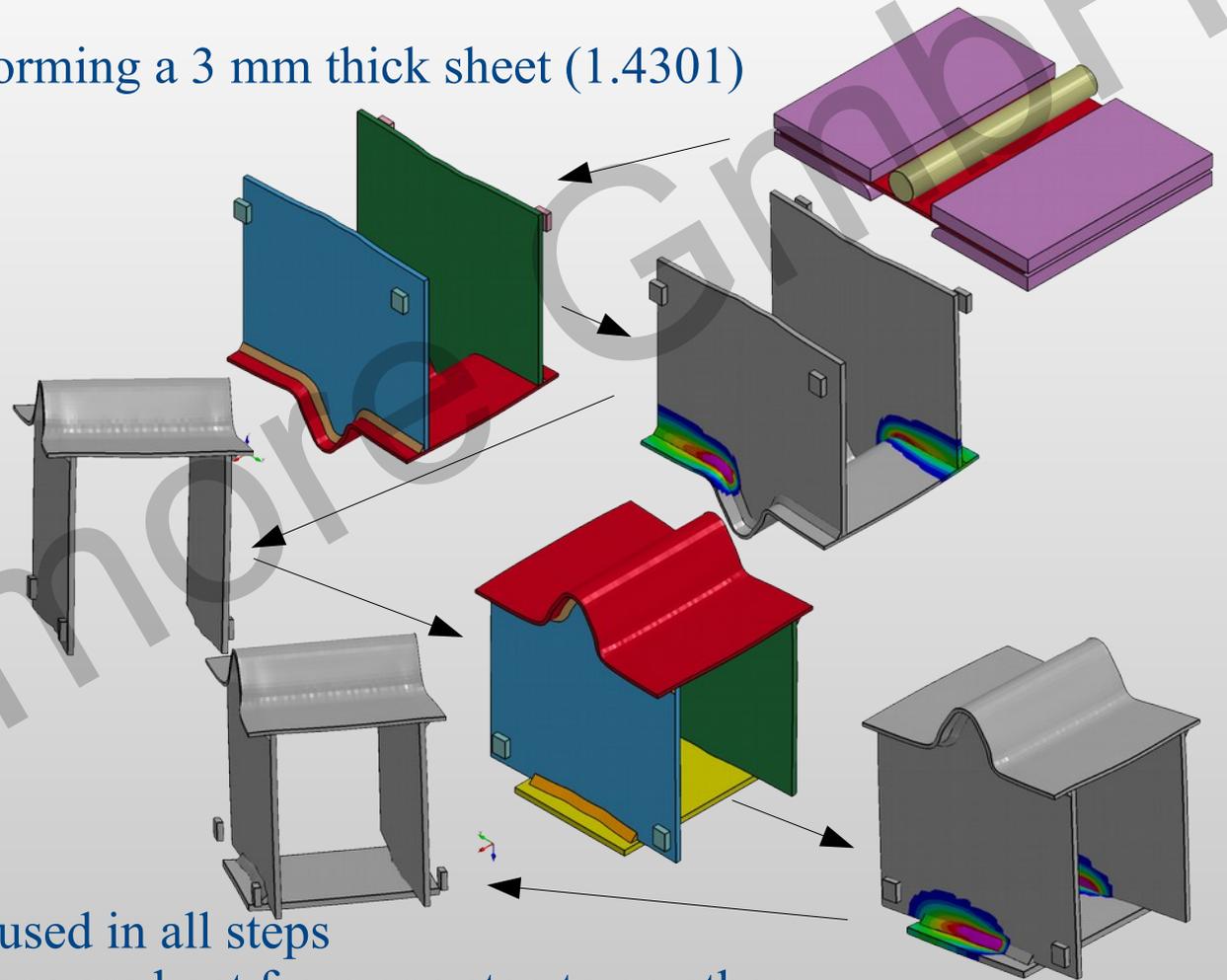
Welding:

- Weld bottom plate to 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 Assemblies

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:

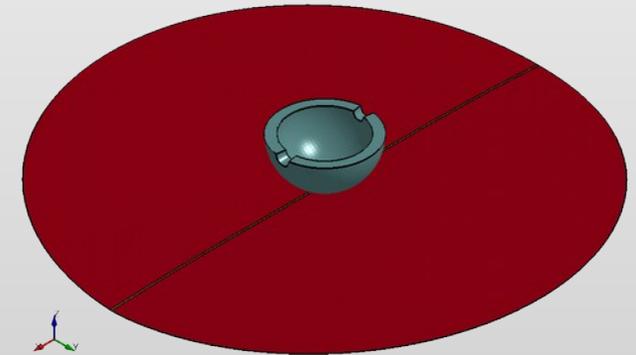
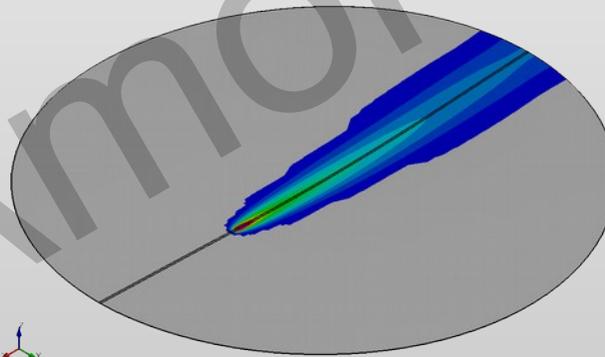
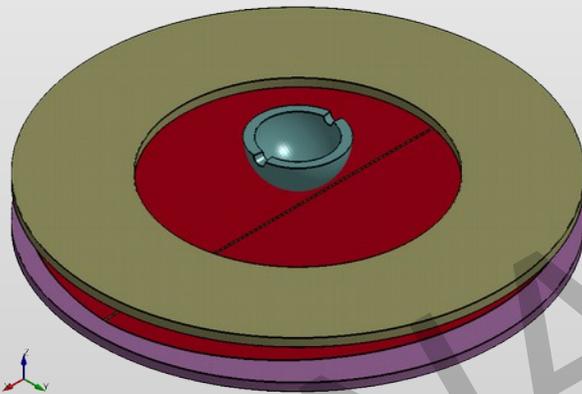
- Two sheets (S355) with 1 mm wall thickness are laser welded

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

Welding

z-displacement 10-times scaled

Laser Welding

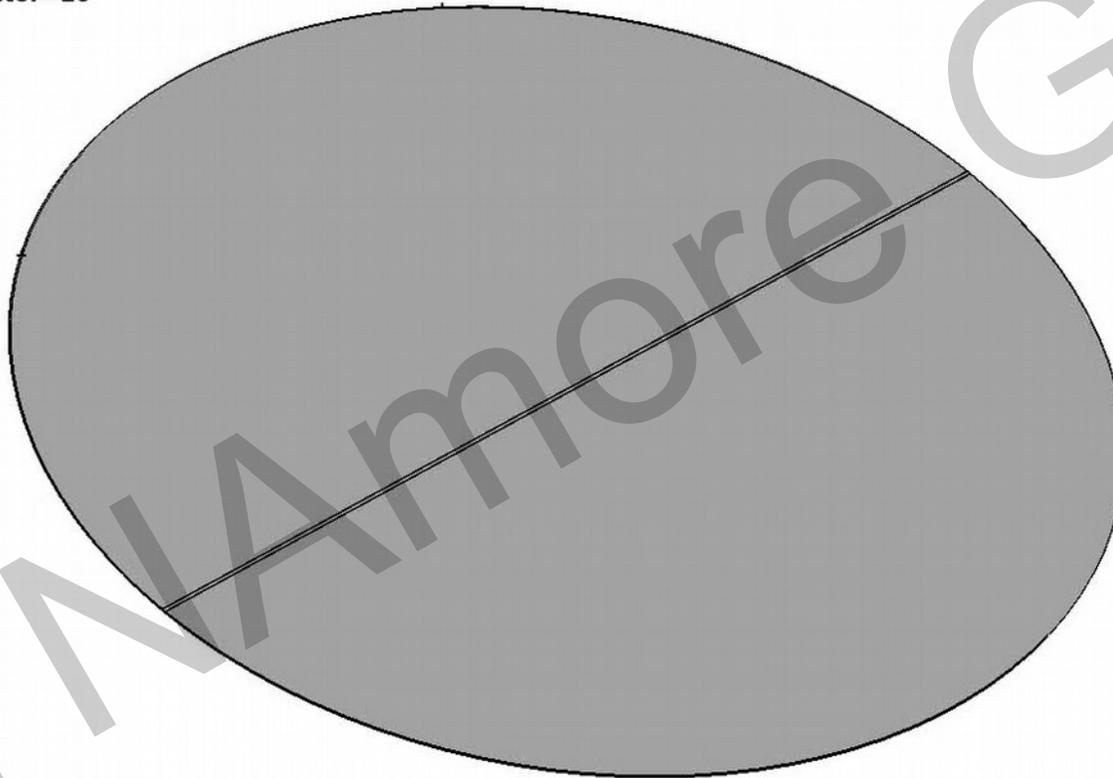
Time = 0

Contours of Temperature

min=293, at node# 1760

max=293, at node# 1760

max displacement factor=10



Fringe Levels



Vertical Distortion

Laser Welding

Time = 1015.1

Contours of Z-displacement

min=-5.77562, at node# 503

max=1.15873, at node# 6212

max displacement factor=5

Fringe Levels

1.159e+00

6.634e-01

1.681e-01

-3.272e-01

-8.225e-01

-1.318e+00

-1.813e+00

-2.308e+00

-2.804e+00

-3.299e+00

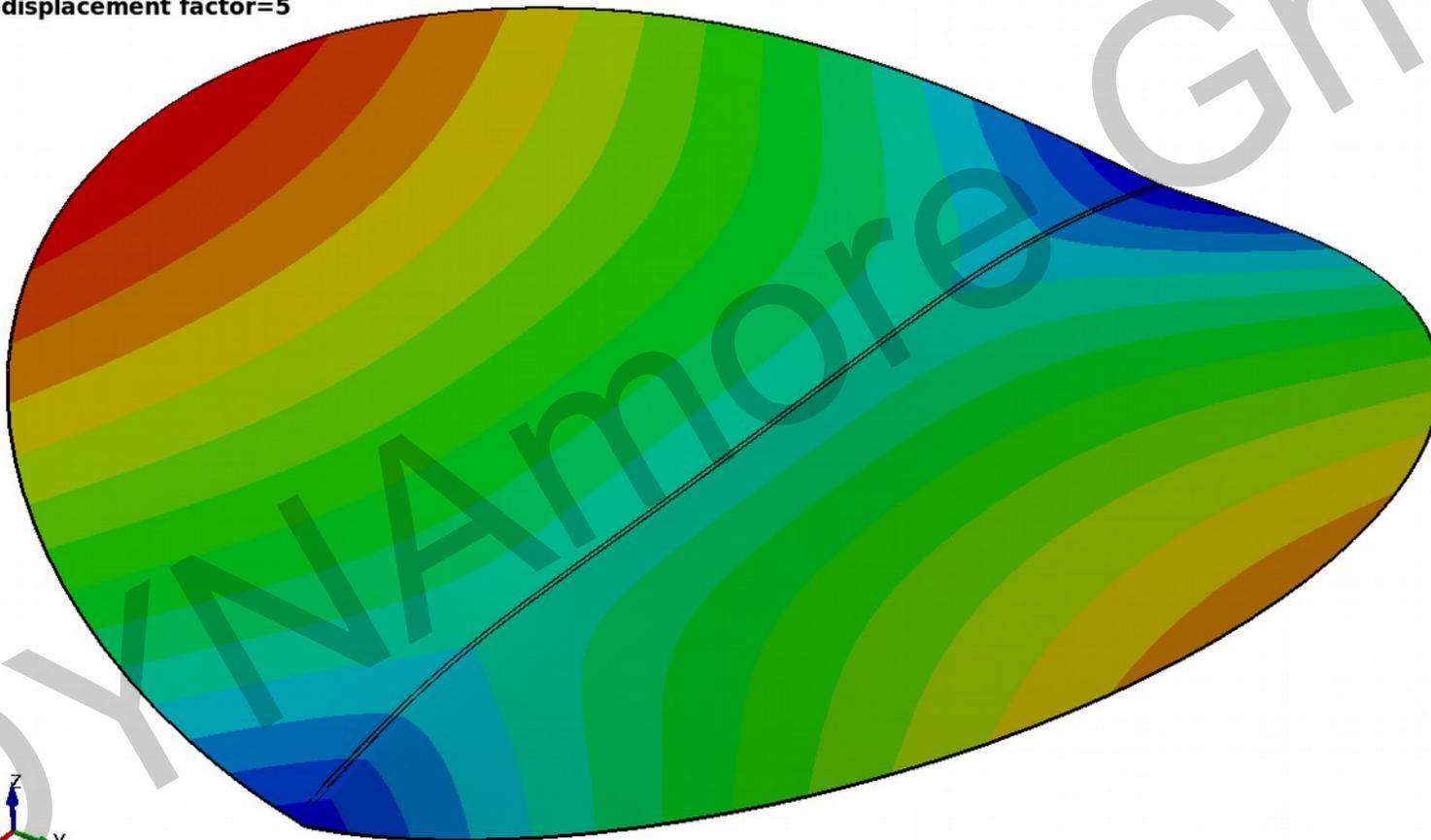
-3.794e+00

-4.290e+00

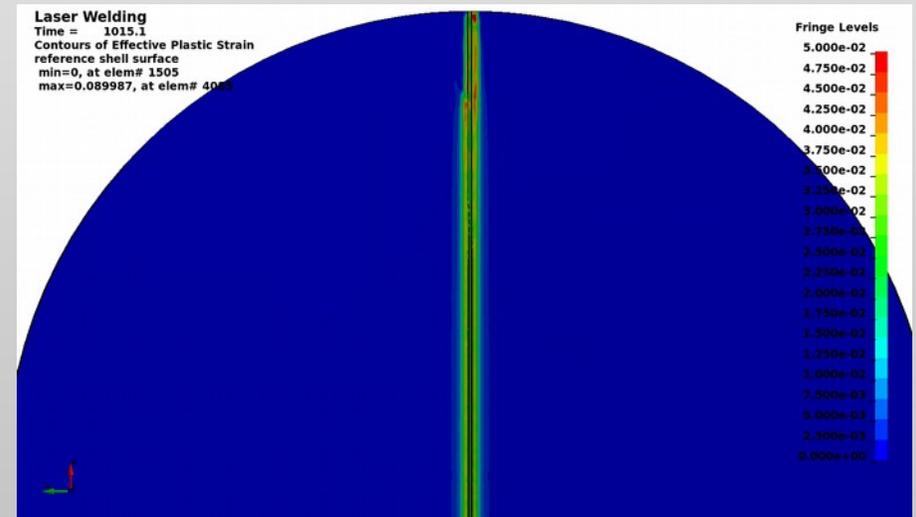
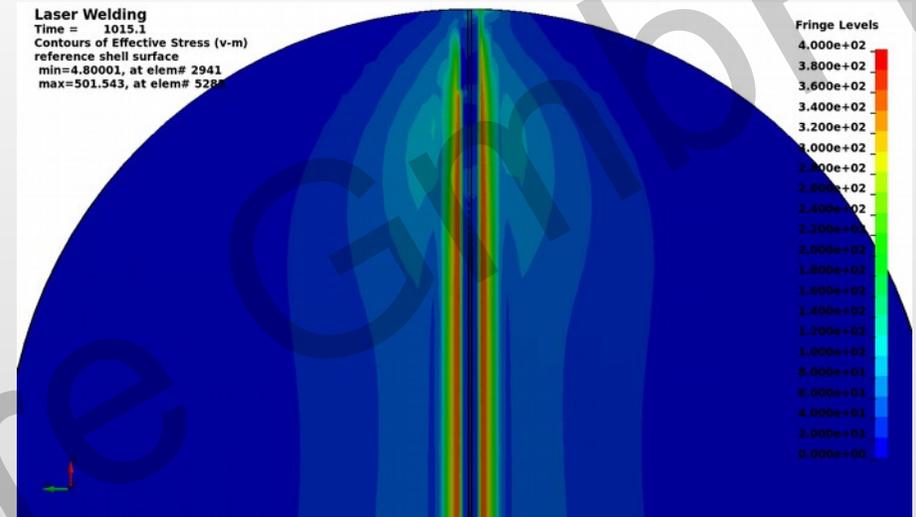
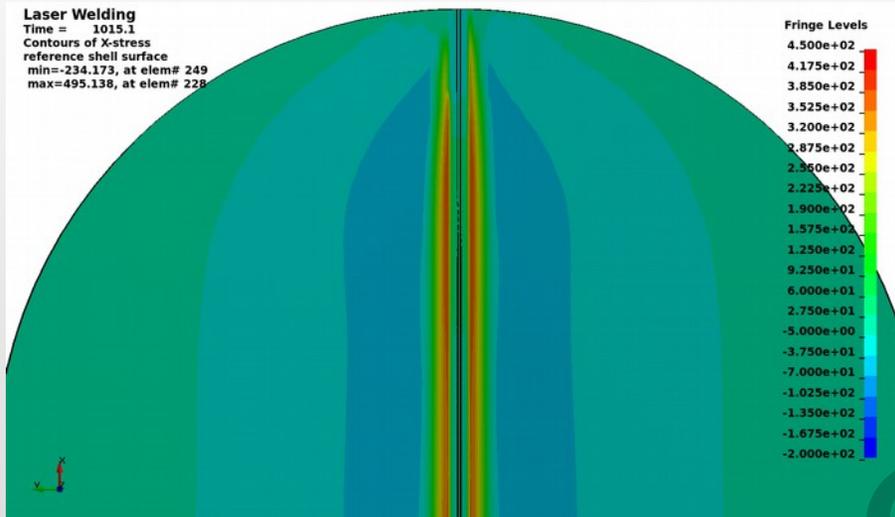
-4.785e+00

-5.280e+00

-5.776e+00

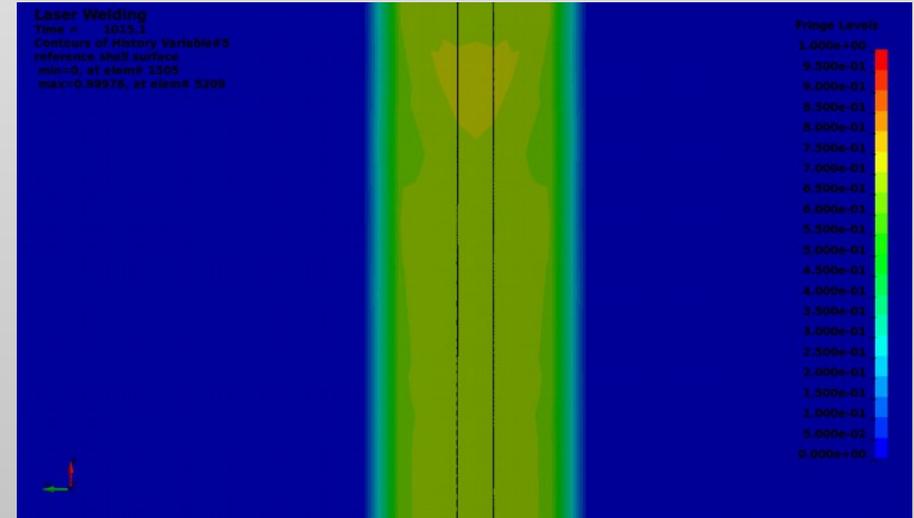
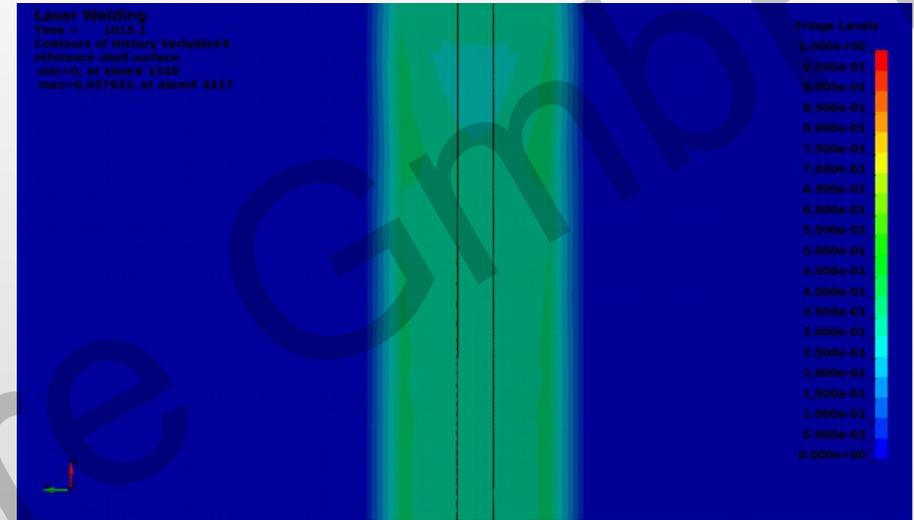
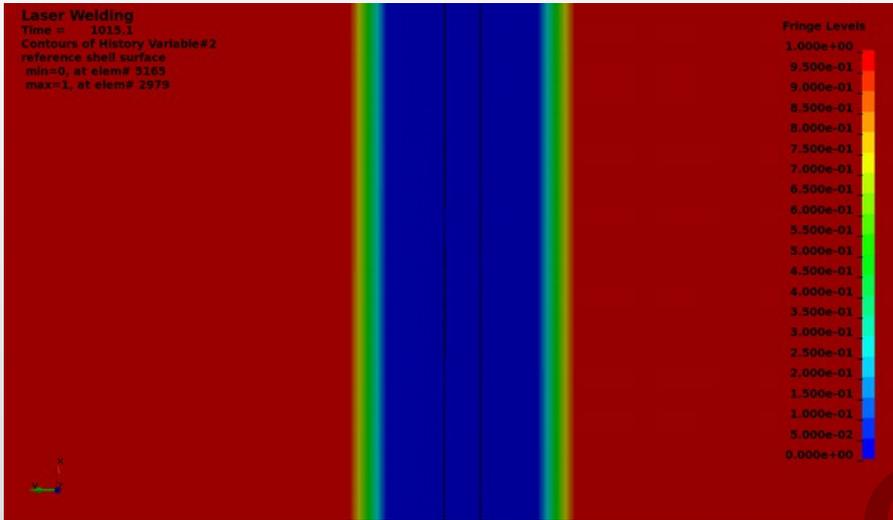


Stresses and Strains in Midsurface of Shell



After welding and cooling
top left:
Longitudinal stress
top right:
Effectiv stress (v. Mises)
bottom right:
plastic strain

Microstructure



After welding and cooling

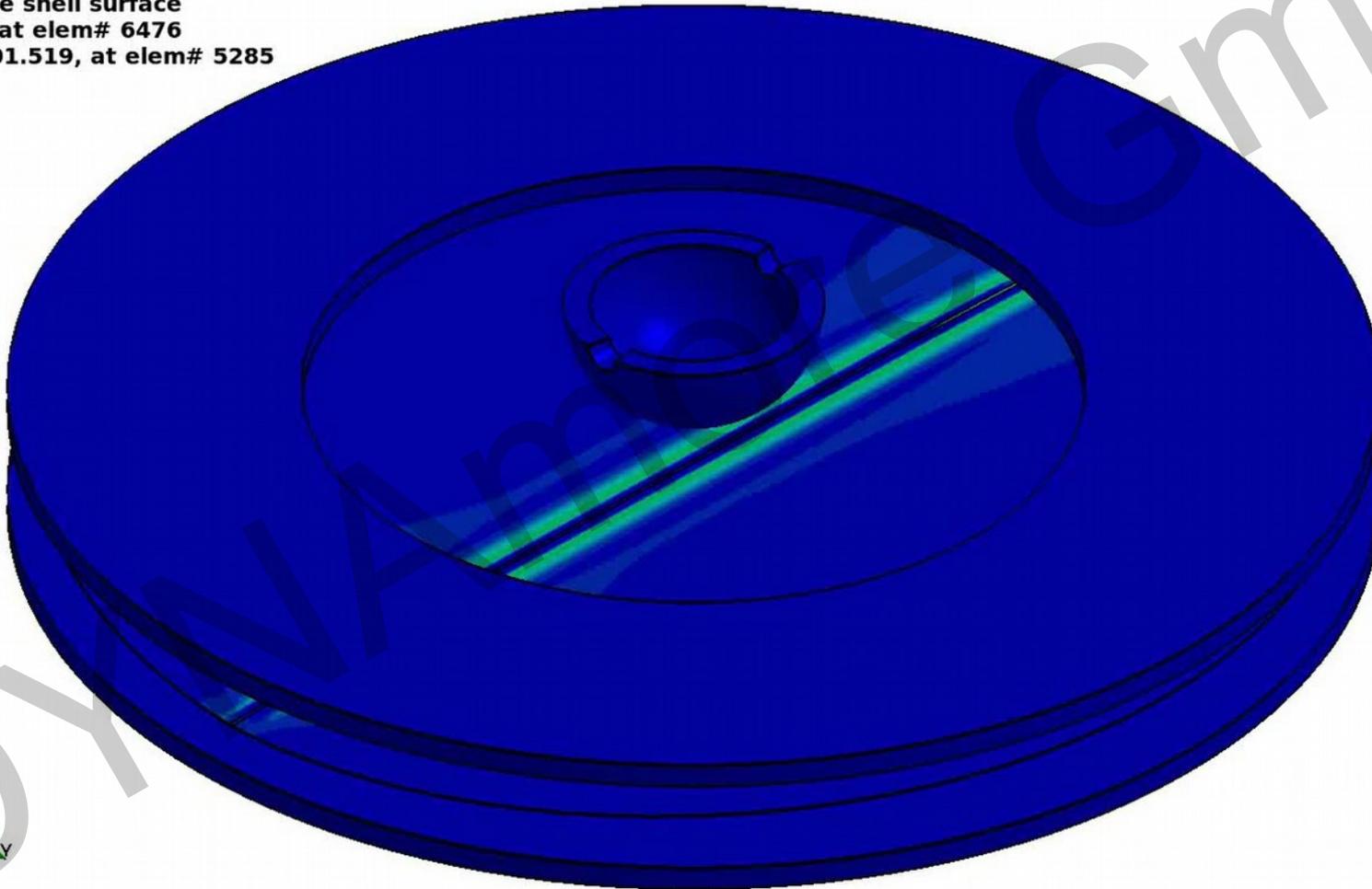
top left:
 Ferrite proportion

top right:
 Bainite proportion

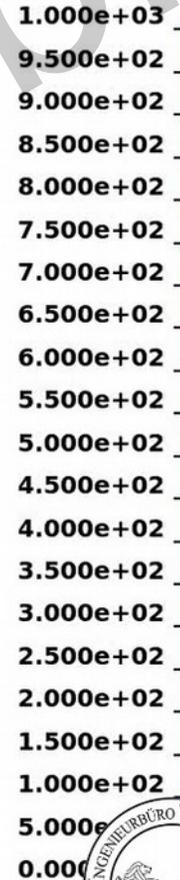
bottom right:
 Martensite proportion

Deep drawing – effective stress

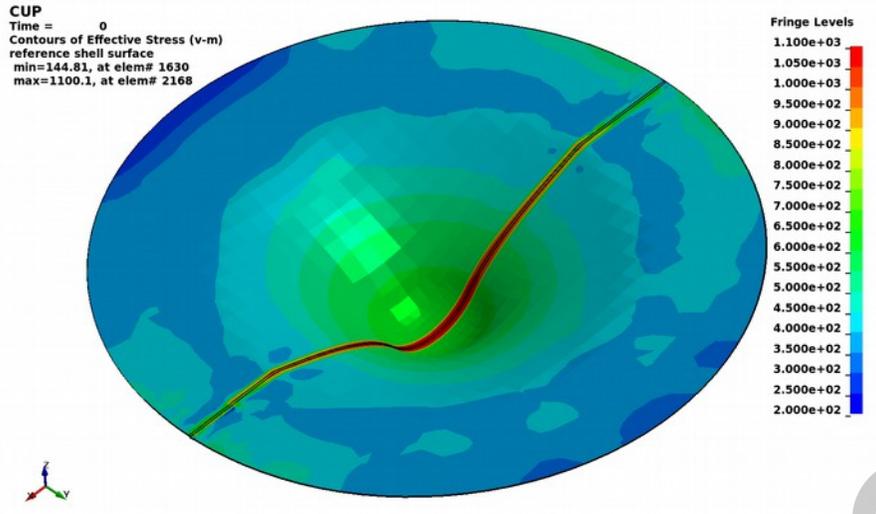
CUP
Time = 0
Contours of Effective Stress (v-m)
reference shell surface
min=0, at elem# 6476
max=501.519, at elem# 5285



Fringe Levels



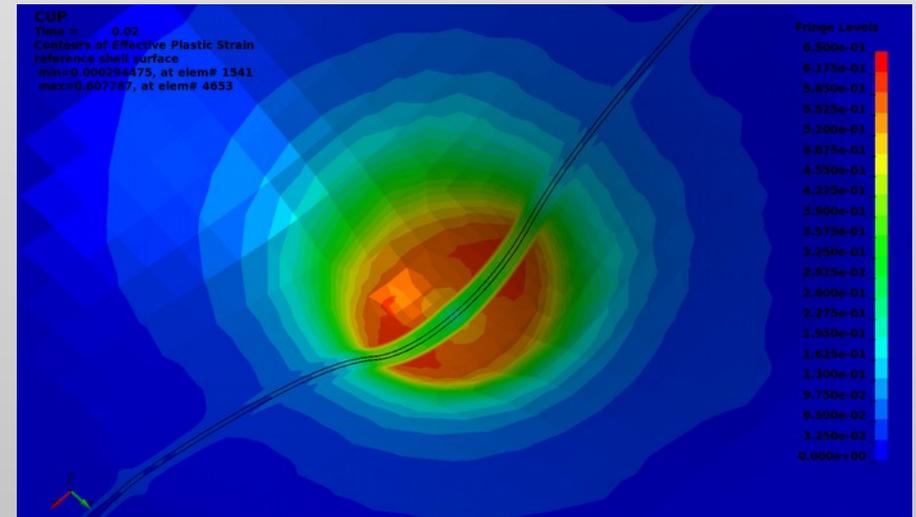
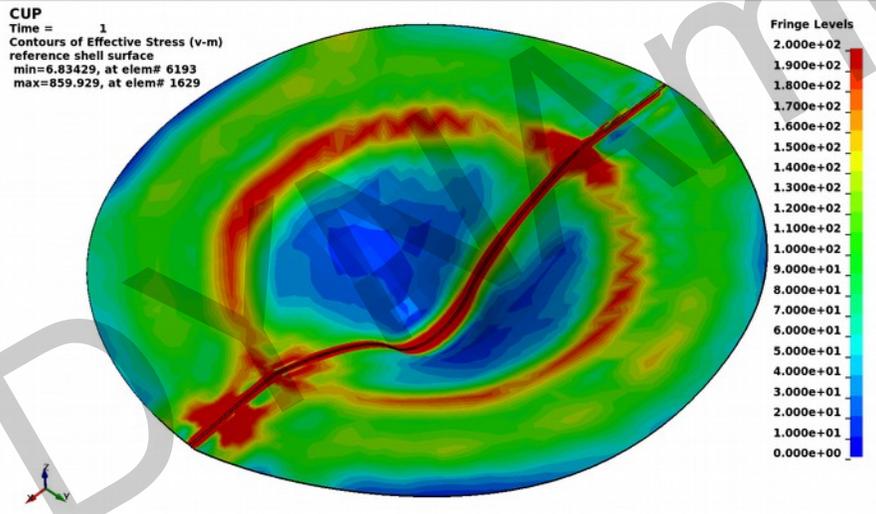
Stresses and Strains in Midsurface of Shell



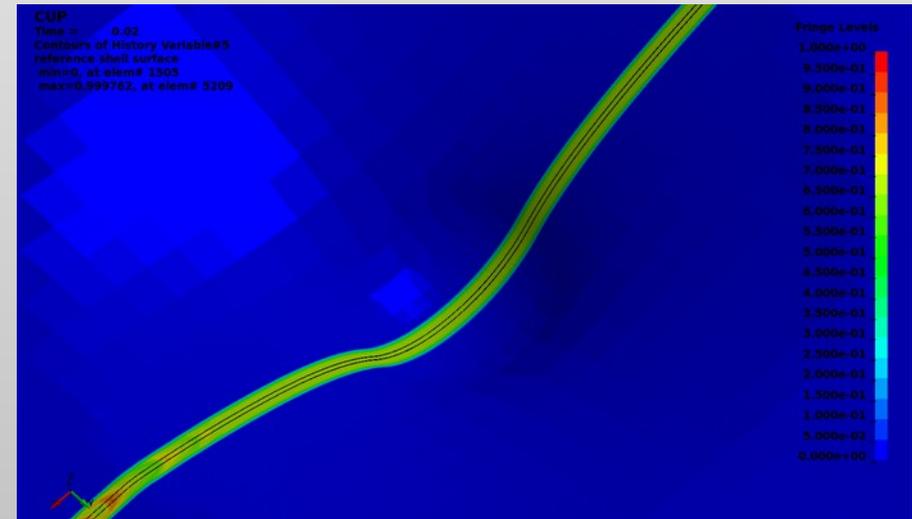
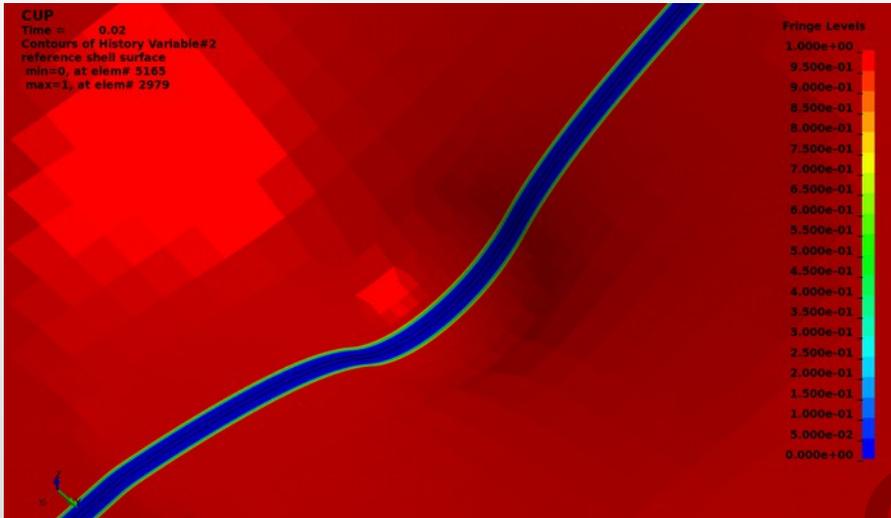
top left:
effectiv stress bevor unclamping
200 .. 1100 N/mm²

bottom left:
effectiv stess after unclamping
0 .. 200 N/mm²

bottom right:
plastic strain after unclamping
0 .. 0.65 m/m



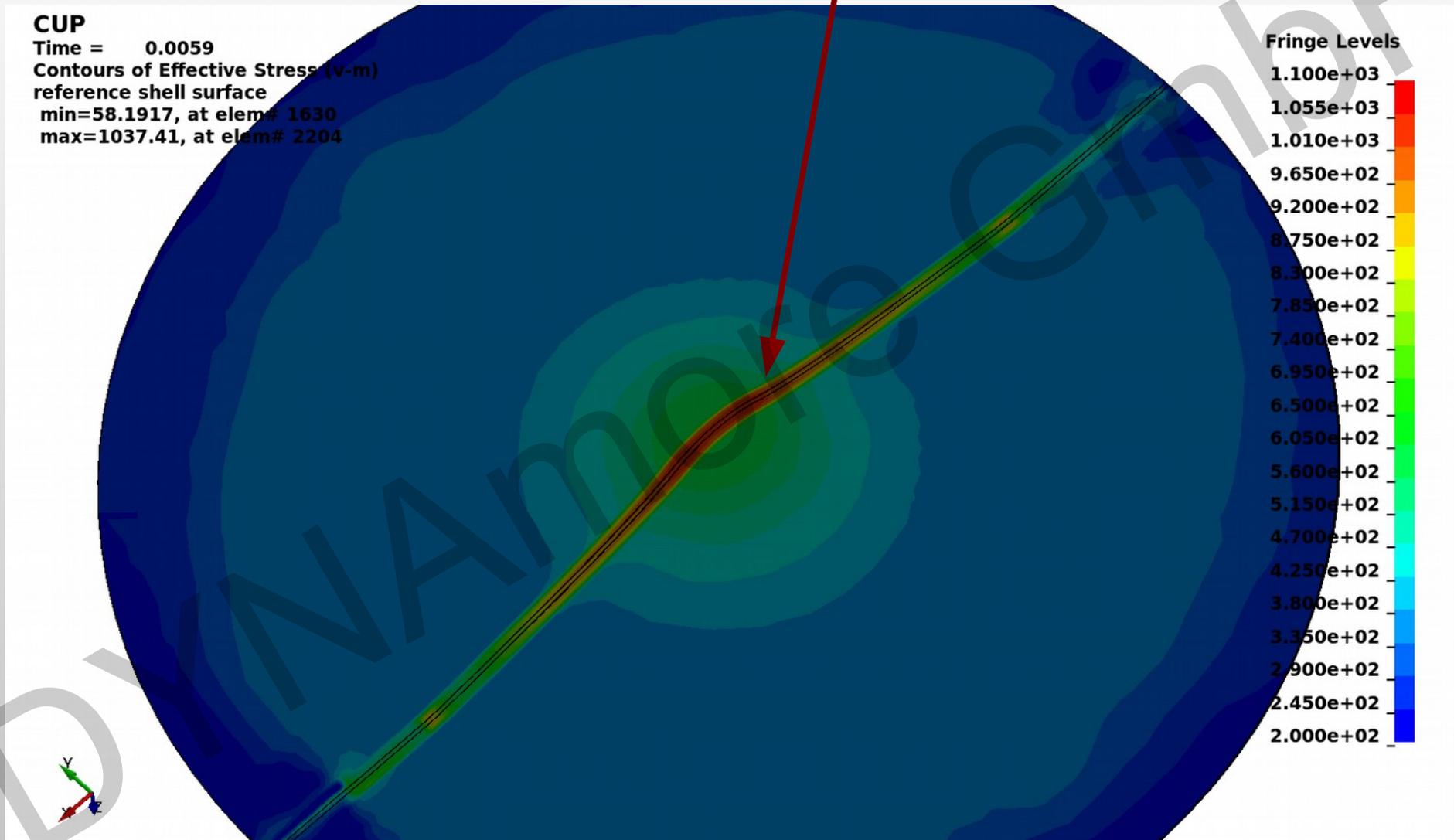
Microstructure during Deep-Drawing



top left:
Ferrite proportion
top right:
Bainite proportion
bottom right:
Martensite proportion

Effective Stress during Forming

Influence of Material Property Change from Welding



Thinning of the Sheet

Influence of Material Property Change from Welding

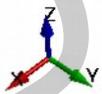
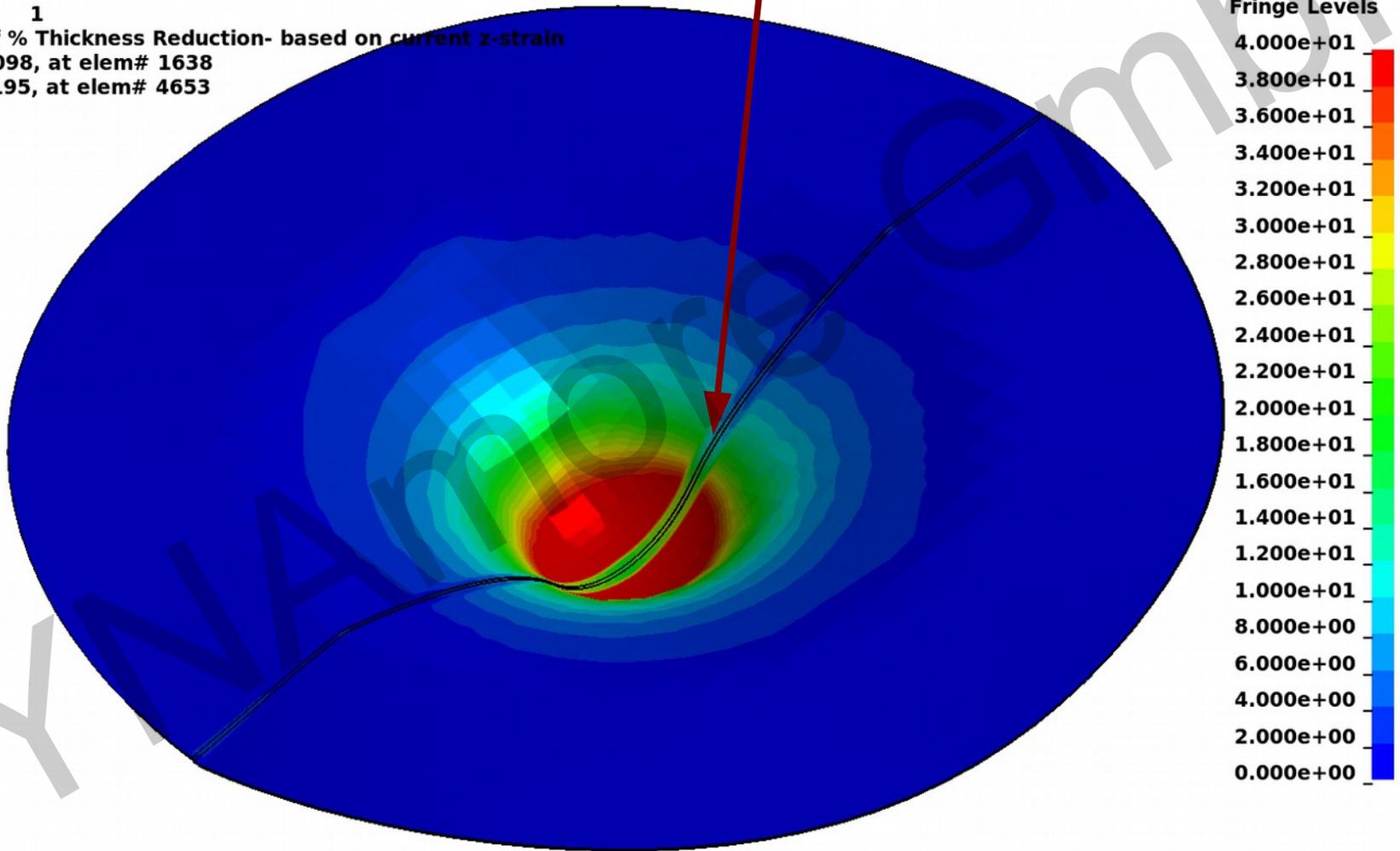
CUP

Time = 1

Contours of % Thickness Reduction- based on current z-strain

min=-21.1098, at elem# 1638

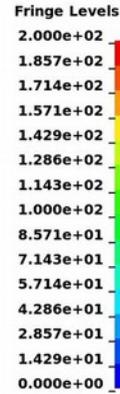
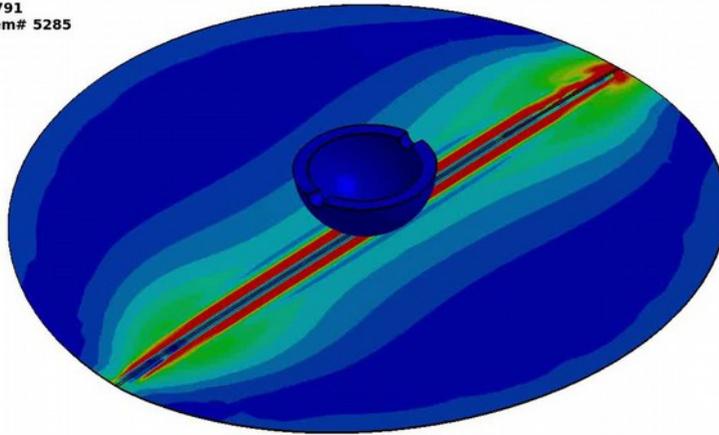
max=44.7195, at elem# 4653



Crash – Effective Stress

Impact Velocity 5000 m/s

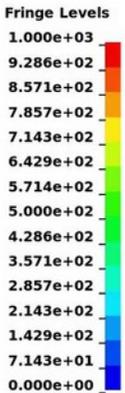
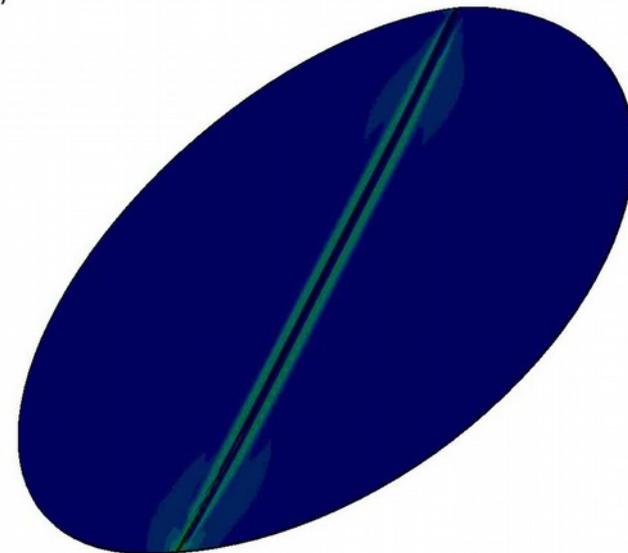
CUP
 Time = 0
 Contours of Effective Stress (v-m)
 reference shell surface
 min=0, at elem# 16791
 max=501.519, at elem# 5285



Fringe Range: 0 .. 200 N/mm²



Stress (v-m)
 ce
 m# 2941
 em# 5285
 www.loose.at

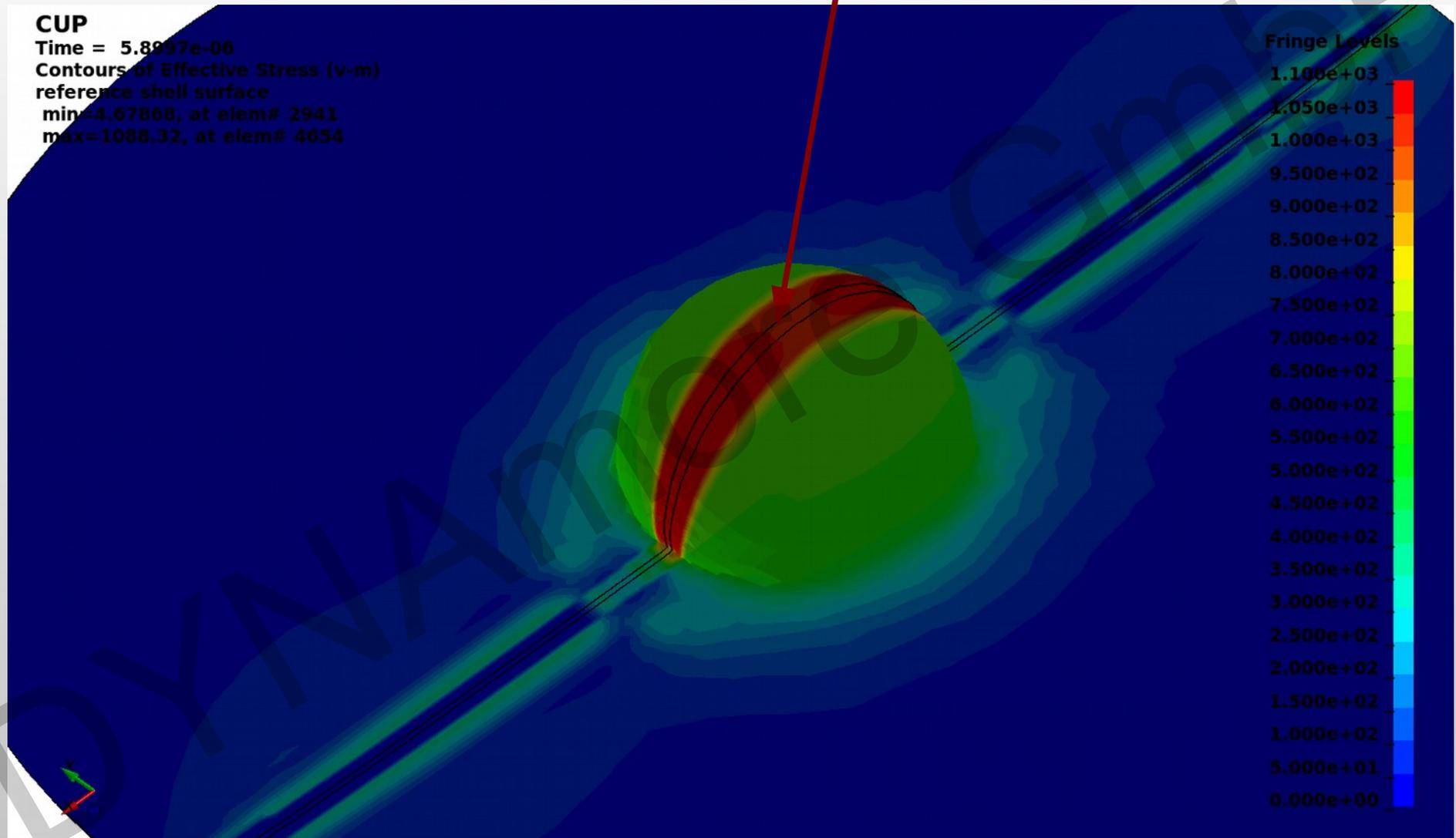


Fringe Range: 0 .. 1000 N/mm²



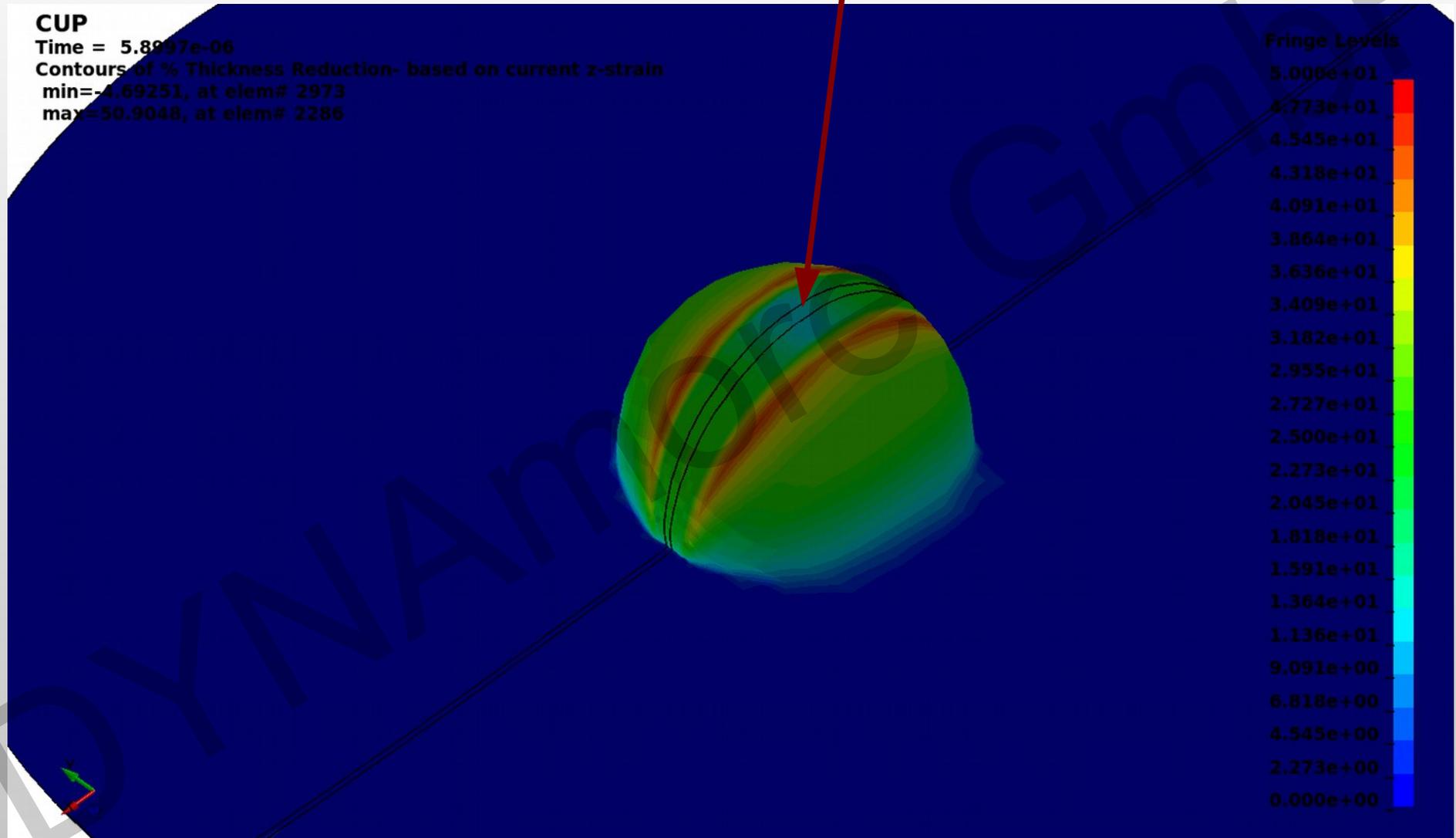
Effective Stress During Crash

Influence of Material Property Change from Welding



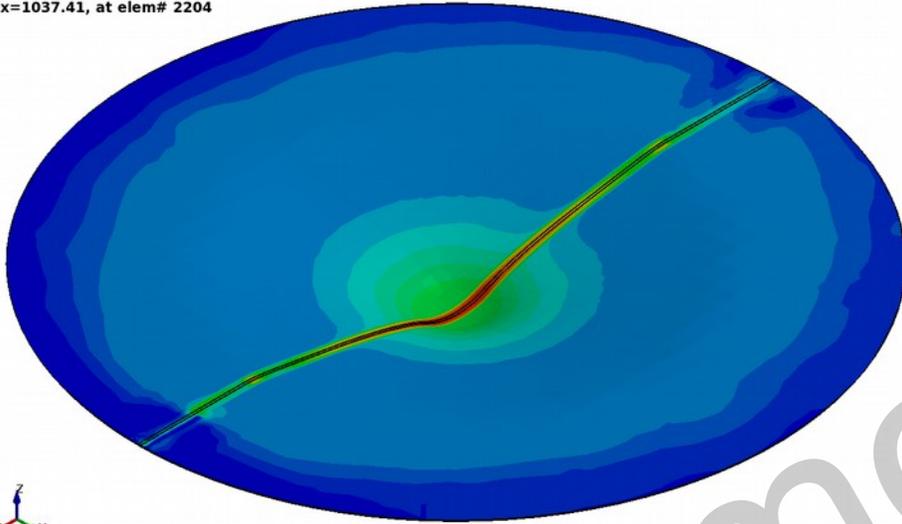
Thinning of the sheet

Influence of Material Property Change from Welding



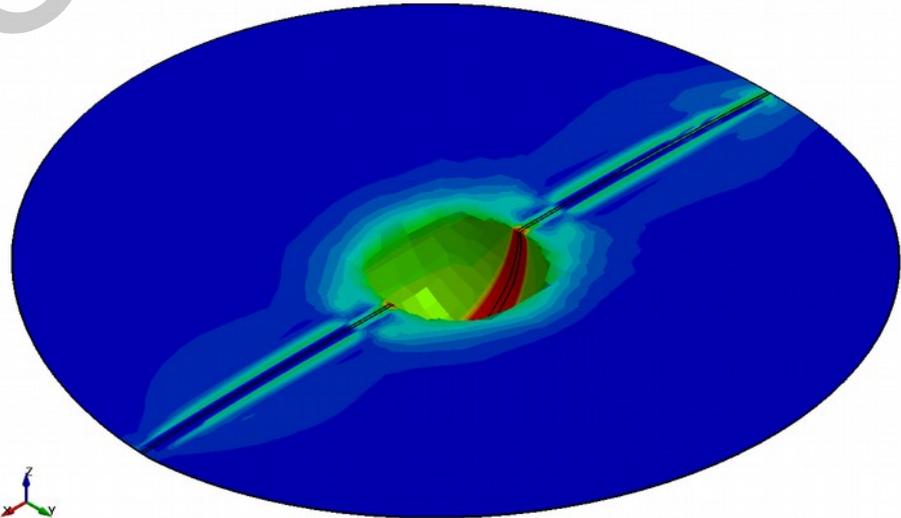
Comparison between Forming and Crash effective Stress at same Penetration Depth

CUP
Time = 0.0059
Contours of Effective Stress (v-m)
reference shell surface
min=58.1917, at elem# 1630
max=1037.41, at elem# 2204



Fringe Levels
1.100e+03
1.055e+03
1.010e+03
9.650e+02
9.200e+02
8.750e+02
8.300e+02
7.850e+02
7.400e+02
6.950e+02
6.500e+02
6.050e+02
5.600e+02
5.150e+02
4.700e+02
4.250e+02
3.800e+02

CUP
Time = 5.8997e-06
Contours of Effective Stress (v-m)
reference shell surface
min=4.67868, at elem# 2941
max=1088.32, at elem# 4654



Fringe Levels
1.000e+03
9.500e+02
9.000e+02
8.500e+02
8.000e+02
7.500e+02
7.000e+02
6.500e+02
6.000e+02
5.500e+02
5.000e+02
4.500e+02
4.000e+02
3.500e+02
3.000e+02
2.500e+02
2.000e+02
1.500e+02
1.000e+02
5.000e+01
0.000e+00

DYNAMISCH



Distortion Compensation

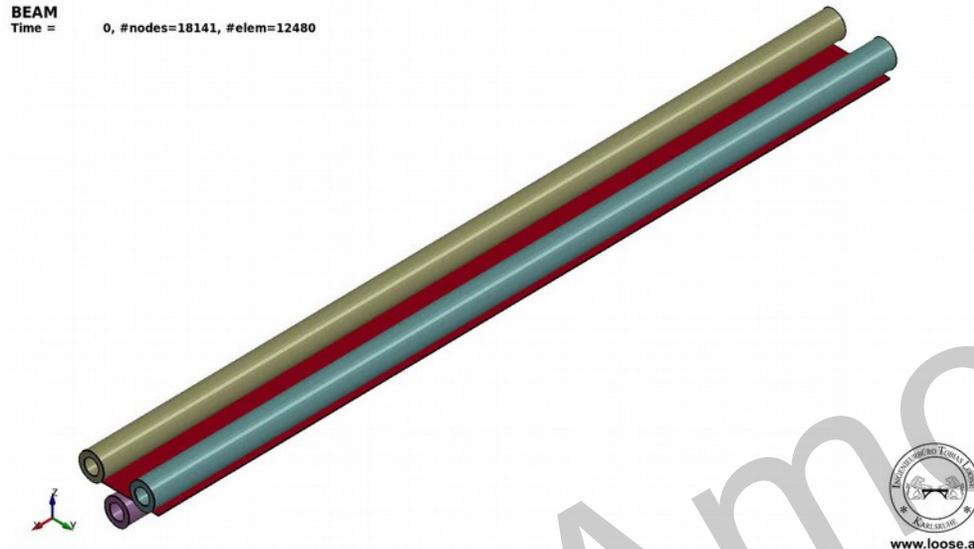
Predeformation

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:

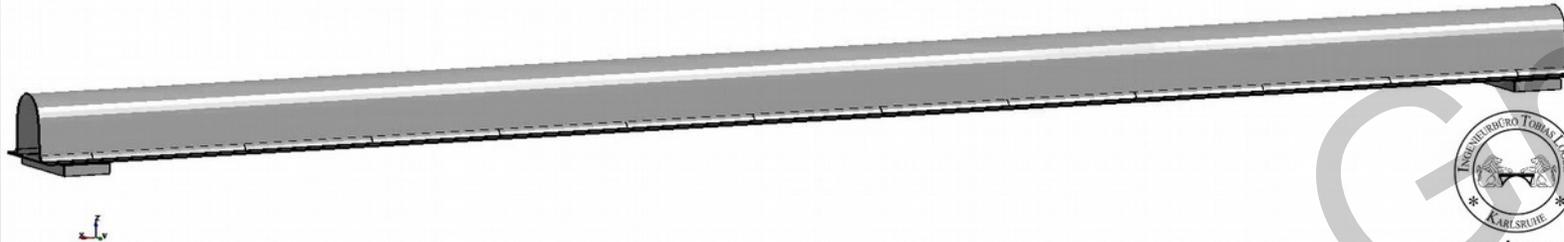
- Shell-elements are used for the sheet and the ground plate
- Solid-elements are used for the filler material and the clamps
- Same material model (*MAT_244) is used in all steps for shells and for solids
- History variables, and deformations are kept from one step to an other

Distortion Evolution during Welding

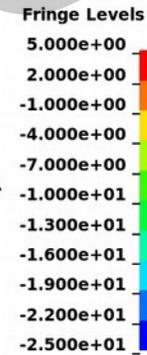
Metatransient Method

Temperature

Beam
Time = 1
Contours of Temperature
min=-293, at node# 16137
max=293, at node# 16132



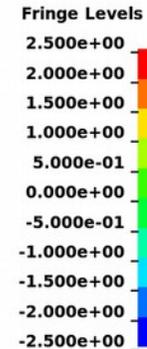
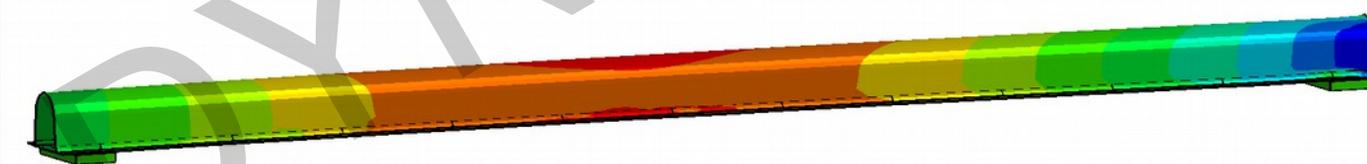
Beam
Time = 70.078
Contours of Z-displacement
min=-21.8152, at node# 18584
max=4.53089, at node# 24244



Distortion

Max vertical distortion during welding:
22 mm down

Beam
Time = 5000
Contours of Z-displacement
min=-3.02258, at node# 19803
max=2.73806, at node# 18586



Max vertical distortion after cooling:
2,7 mm up

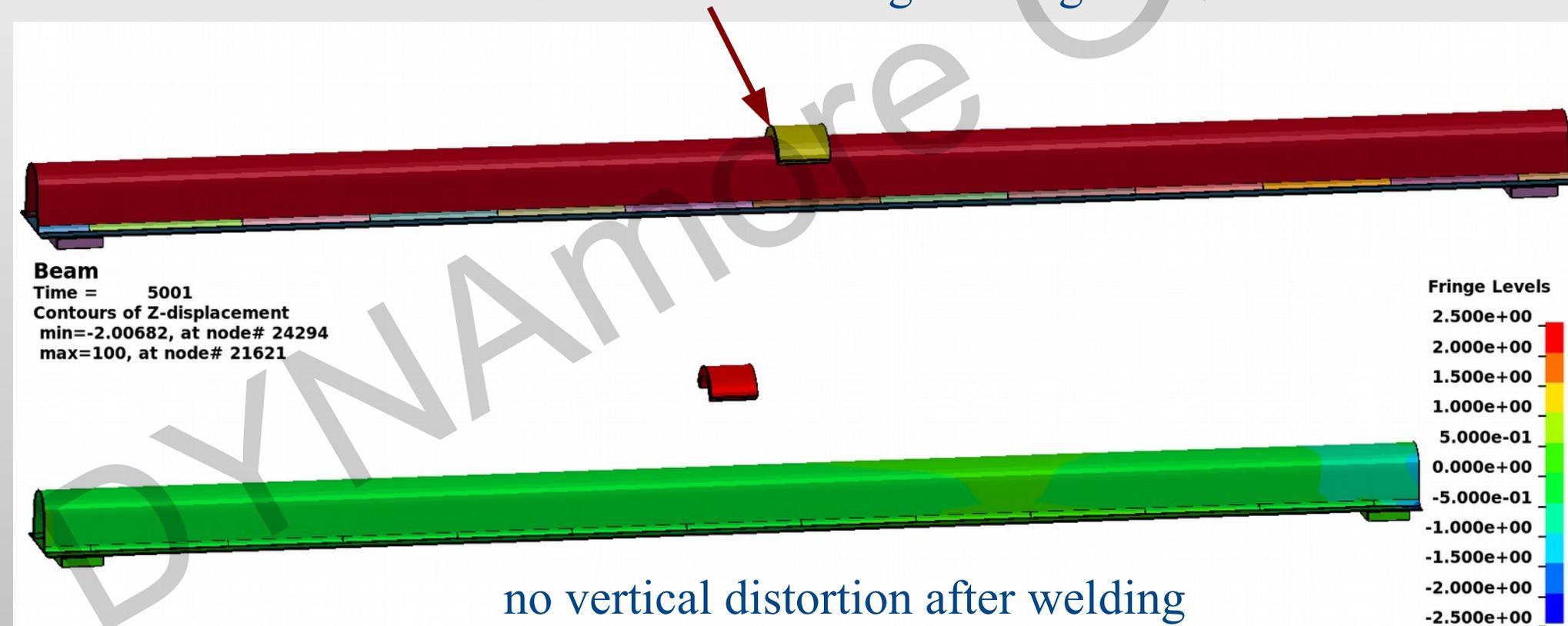
Compensation of distortion

Method A:

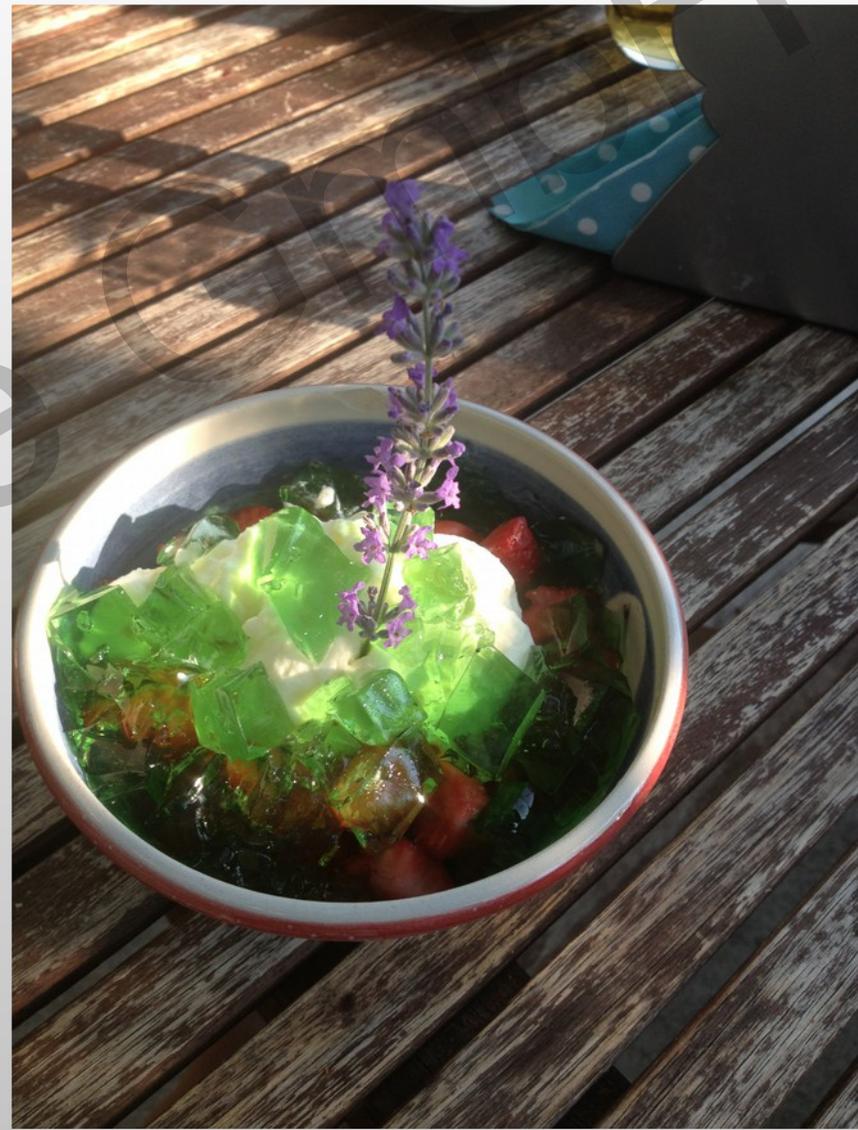
- Stamping of the groove with the inverted final distortion from welding.

Method B:

- Predeformation in vertical direction during welding as shown below:



Summary



Summary

- The manufacturing process comprises several different steps.
- These steps interact and may influence each other.
- For a realistic simulation of the manufacturing process results of previous simulation steps have to be taken as initial conditions.
- The finite element code LS-DYNA provides the feasibility to simulate the manufacturing steps:
forming, assembly, welding, post-weld-heat-treatment, grinding, crash
 - in one code
 - with a continuous data structure
 - with continuous material model and continuous history variables
 - taking into account material property changes
 - 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 processes.

Thanks for your Attention!



DYNAMORE GmbH