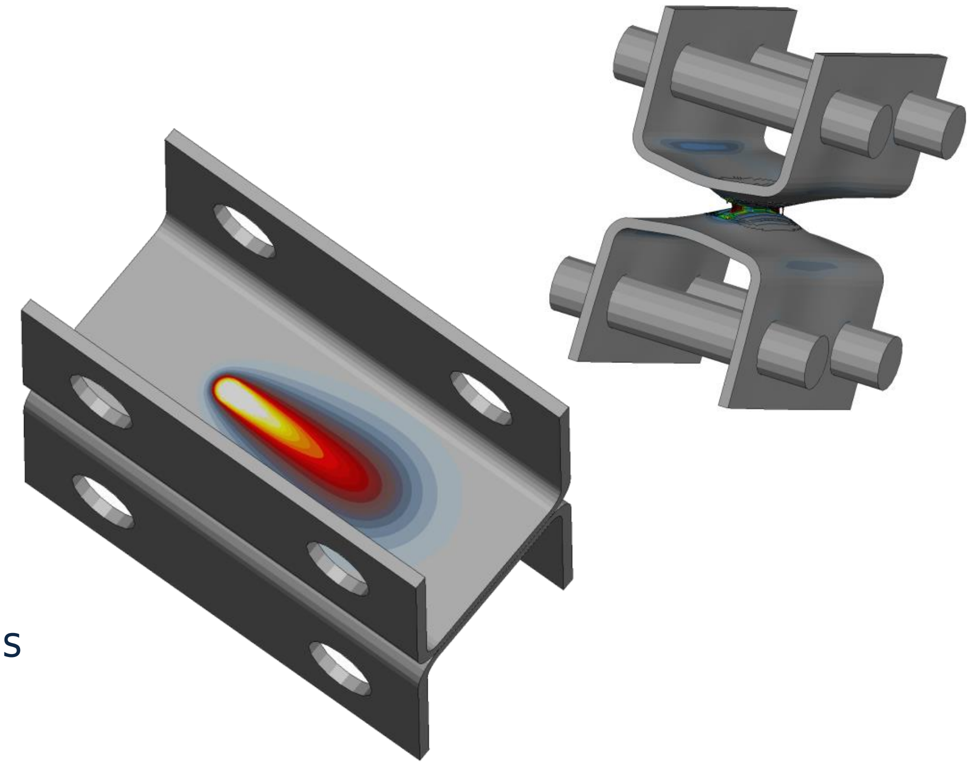
Dr. Loose GmbH
Herdweg 13, D-75045 Walzbachtal
E-Mail: info@Dr-Loose-GmbH.de
Web: www.Dr-Loose-GmbH.de

Determination of Weld Joint Strength by Welding Simulation



Dr.-Ing. Tobias Loose
Dr. Loose GmbH, Germany

31.05. – 01.06.2022 Bad Nauheim
EALA - European Automotive Laser Applications

AUTOMOTIVE CIRCLE

Dr. Loose GmbH

Company

Dr.-Ing. Tobias Loose

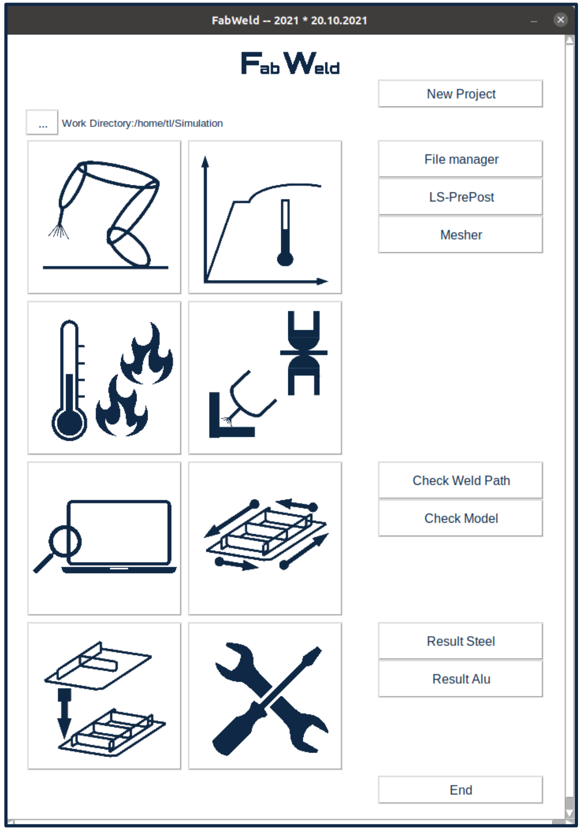
Dr.-Ing. Tobias Loose IWE
President and Shareholder
Dr. Loose GmbH

Numerical Analysis for:

- Welding
- Heat treatment
- Assembly

- Service and Consulting
- Software FabWeld
- Research

Expert for welding simulation since 2004



Advanced **Fab**rication Engineering for **Weld**ed Structures

- designed for advanced simulation models
- supports all fusion welding processes, brazing and heat treatment.
- assembly, clamping, unclamping and mechanical loading.

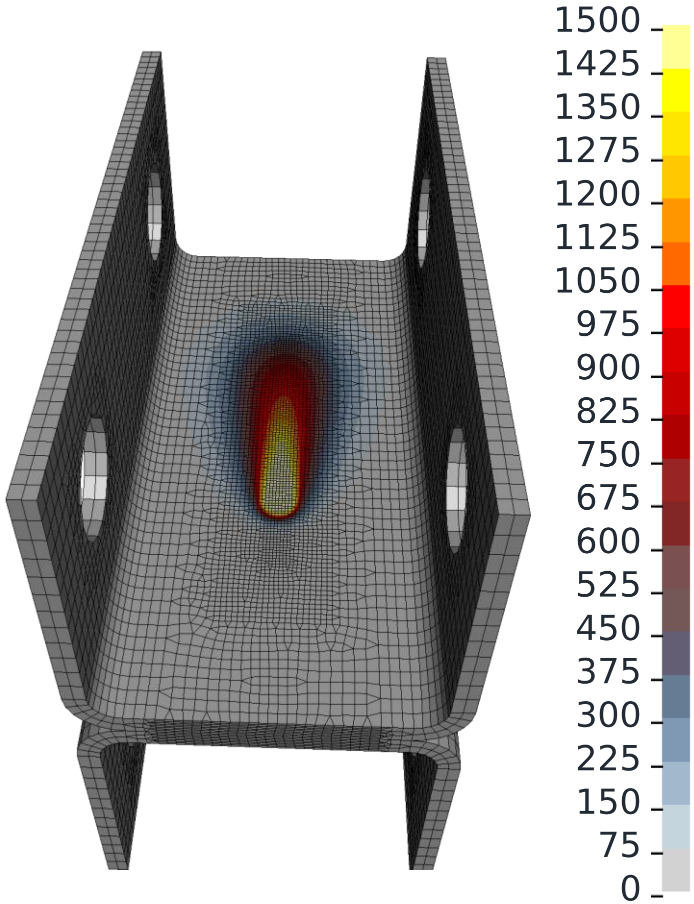
Your benefits from FabWeld:

- high precision simulation and result quality
- ensure and optimize your welding and fabrication design in advance
- get the first time right
- save costs and recources and try out loops before fabrication start

Motivation

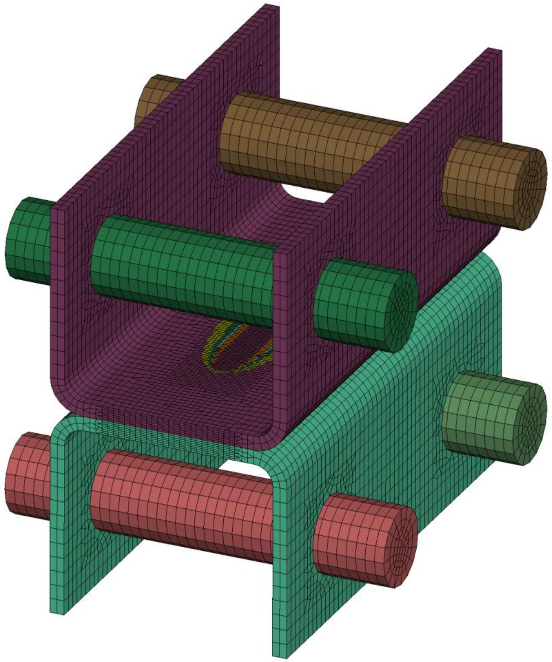
Motivation

- The material properties change during welding in the weld area and the heat affected zone (HAZ).
- This influences prior heat treatment results such as press hardening
- Thus welding also has an impact on the strength and the behavior at ultimate load
- State of the art is:
  The mechanical properties in the weld area are identified by expensive tensile tests



Objective

- The objective is to replace the physical tensile tests by numerical simulation.
- This will be investigated for a KSII specimen made of press hardened boron steel 22MnB5
- The influence of the welding process on the material properties in the HAZ will be determined
- The strength correlates with the hardness
- Discrete material cards are generated based on the hardness profile.



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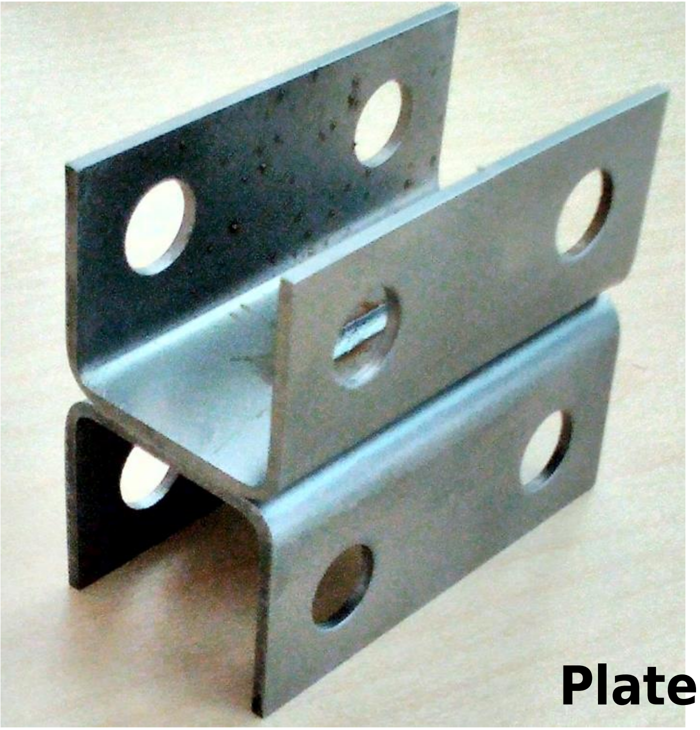
Welding Simulation

Geometry: KSII Probe



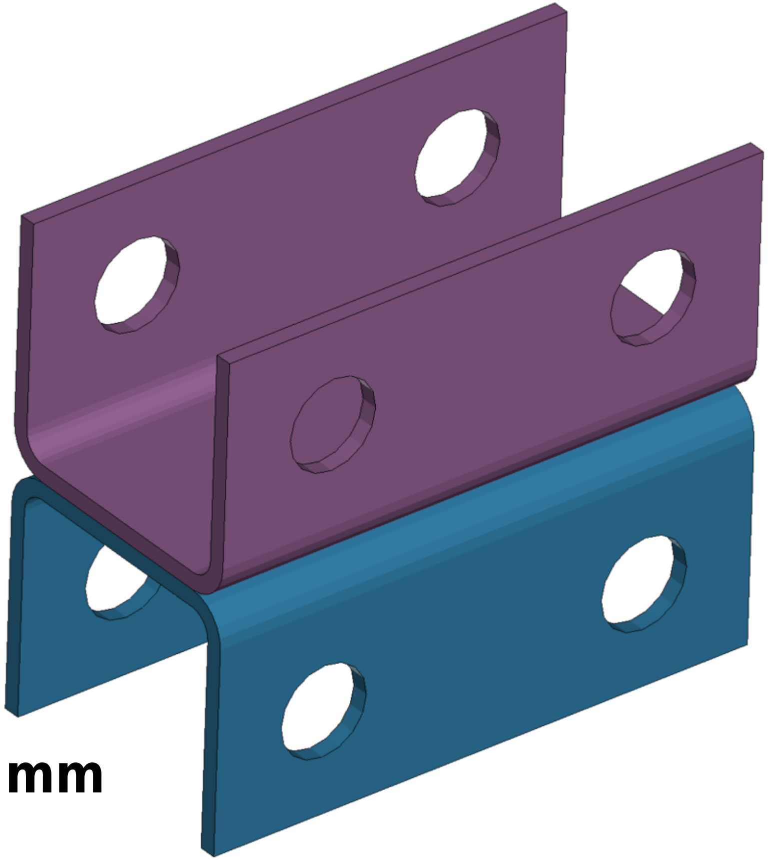
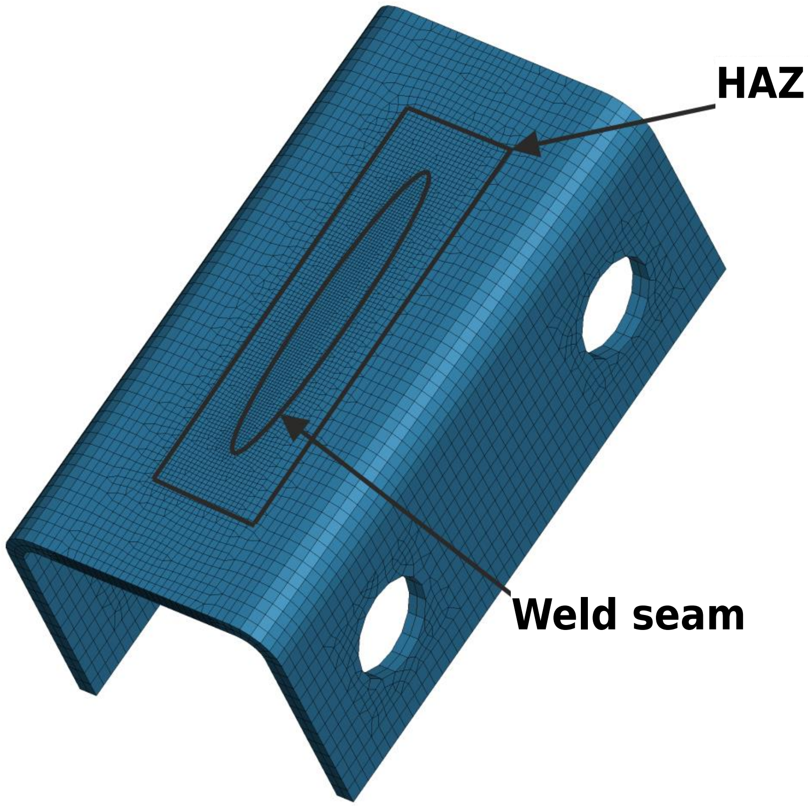


Plate Thickness: 1.5 mm

Mesh for Welding Simulation



Mesh Refinement:

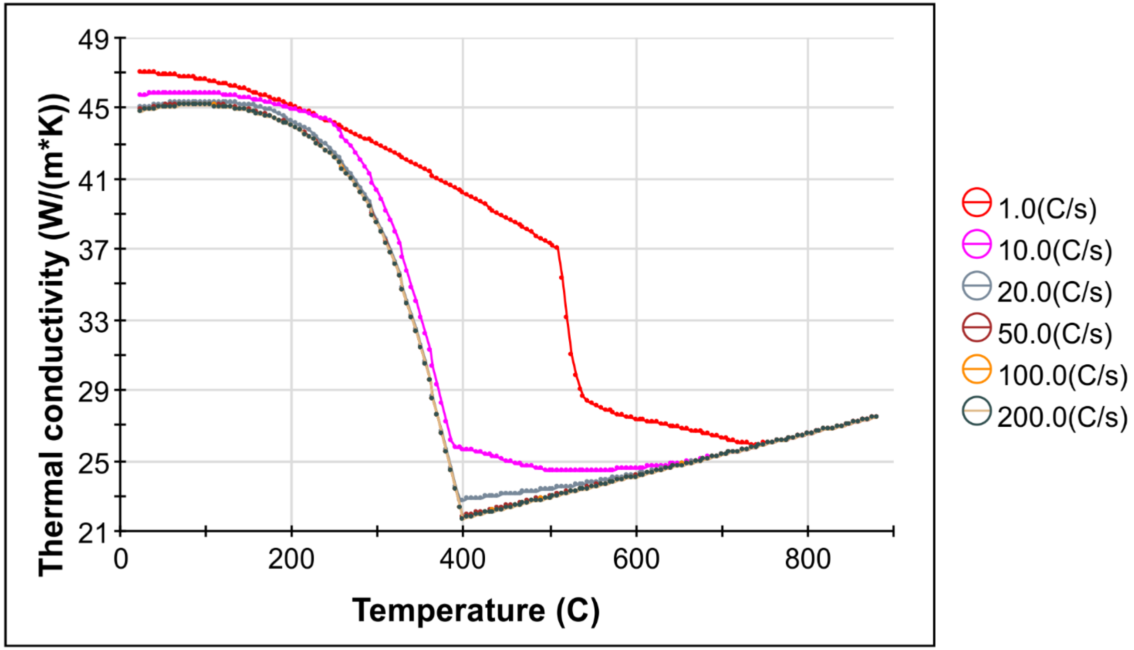
Element length
HAZ ca. 0,4 mm

Element length
Weld seam ca. 0,2 mm

Thermal Material Properties
from JMatPro

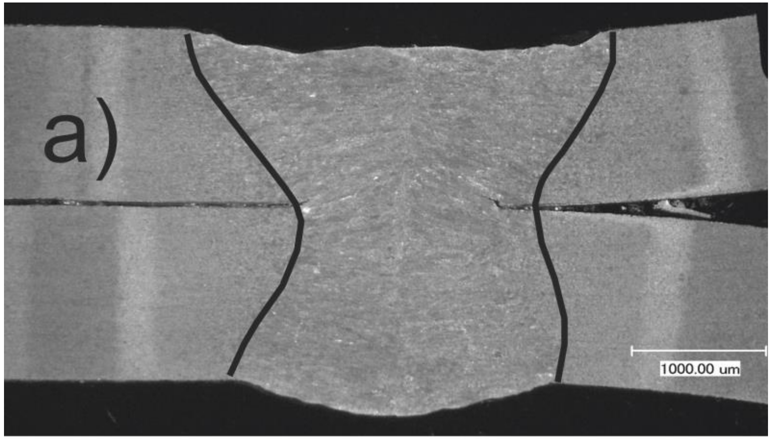
Element	Wt %
Fe	98.088
Al	0.0445
Cr	0.185
Cu	0.0
Co	0.0061
Mn	1.11
Mo	0.0088
Nb	0.0
Ni	0.0279
O	0.0
Si	0.253
Ta	0.0056
Ti	0.021
V	0.0
W	0.0146
B	0.0031
C	0.212
N	0.0
P	0.0163
S	0.0038

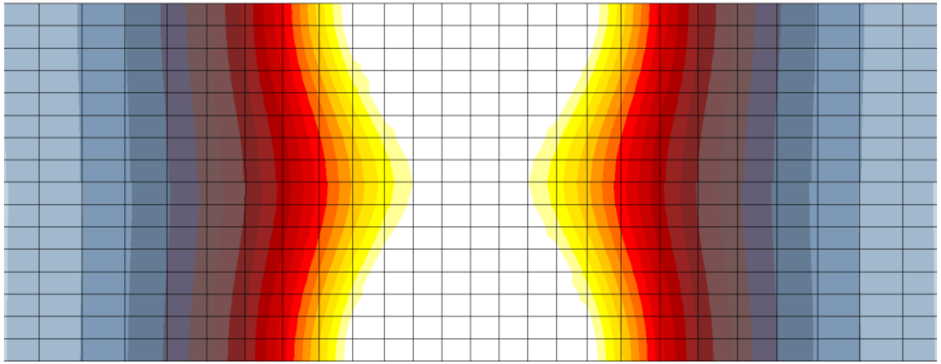
22MnB5_Dyna Properties

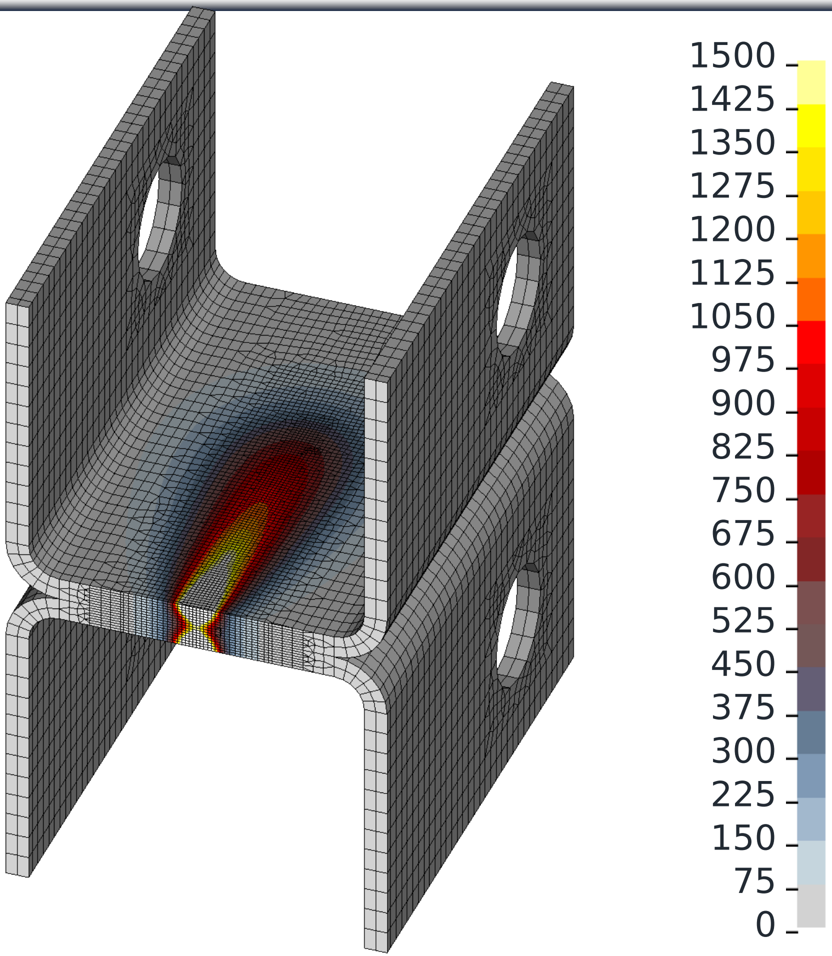


Grain size: 9.0 ASTM

Thermal Analysis
Validation of Equivalent Heat Source







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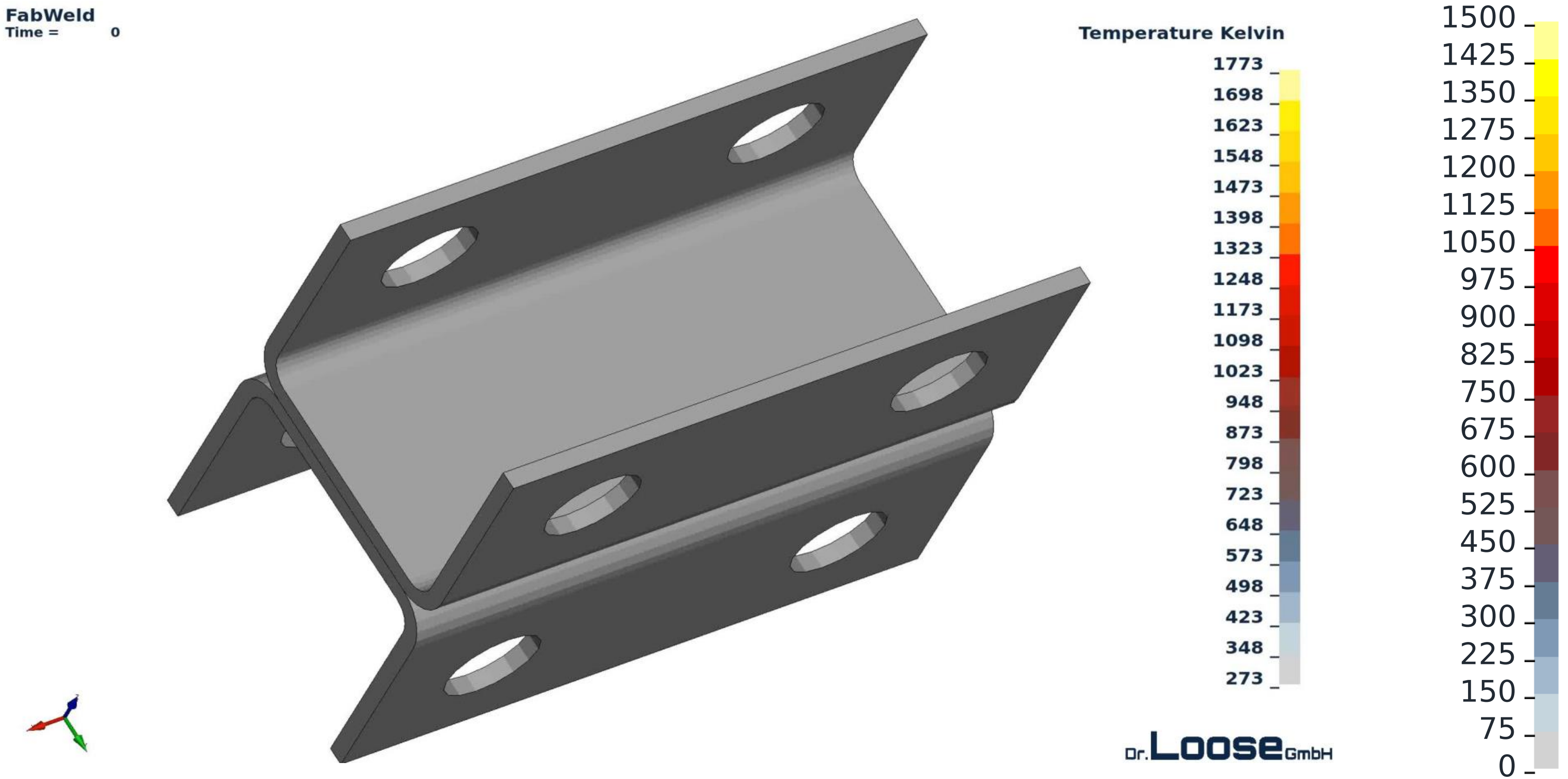
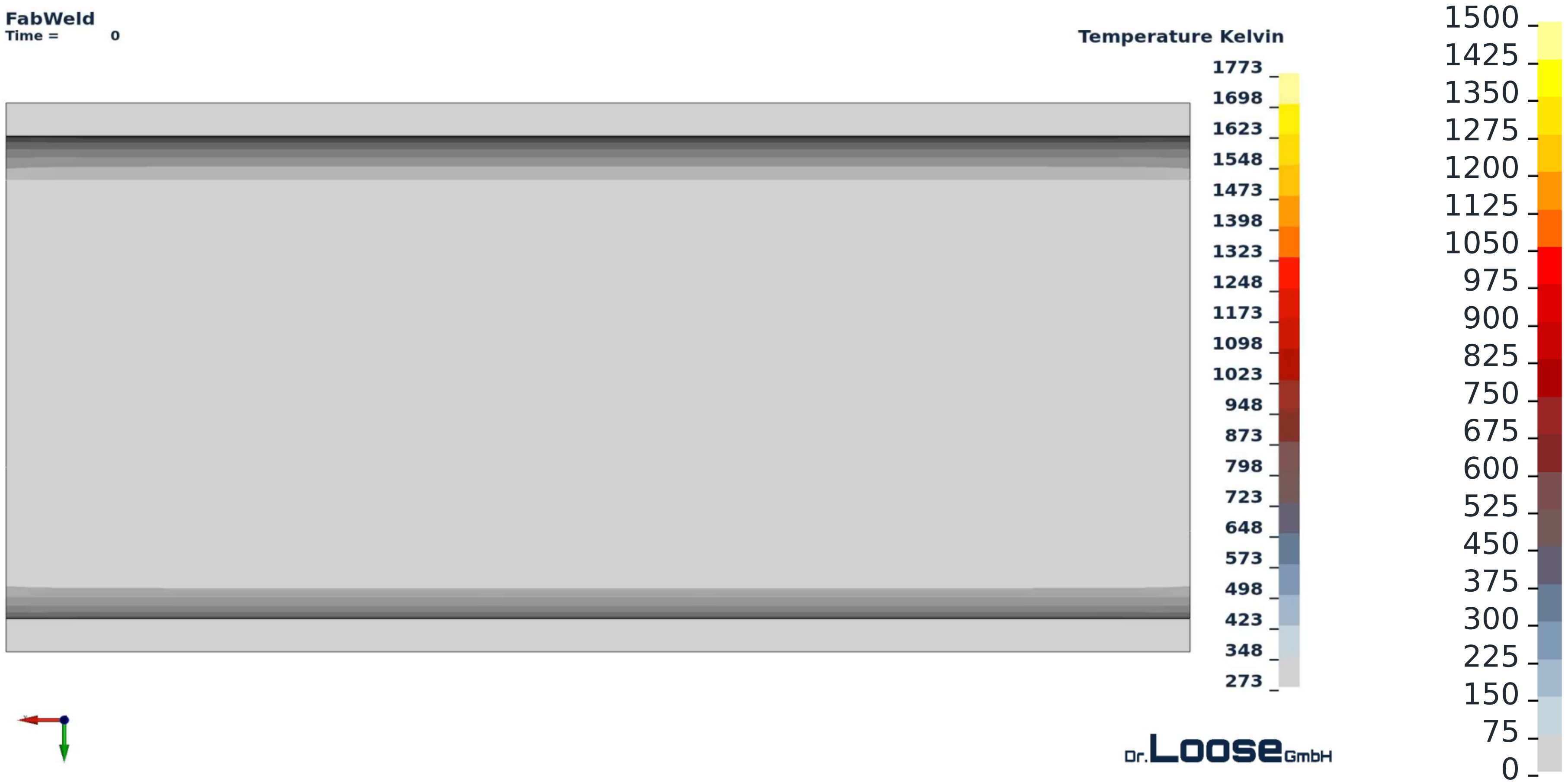
Transient Temperature Field



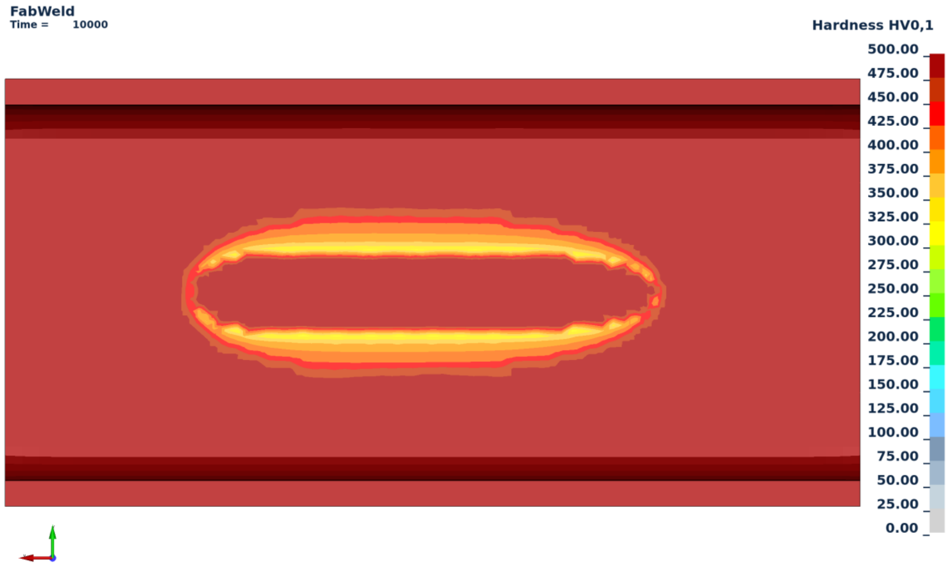
Transient Temperature Field



Microstructure and Strength

Hardness Formula for 22MnB5

- Development of a hardness formula adapted to 22MnB5.
- The formula considers the tempering of martensite.
- The phase transformation from martensite to tempered martensite is realized by a mixture rule from the experimentally identified yield and tensile stresses at different tempering temperature levels.
- The segregation zone at the border of the melt pool is considered too

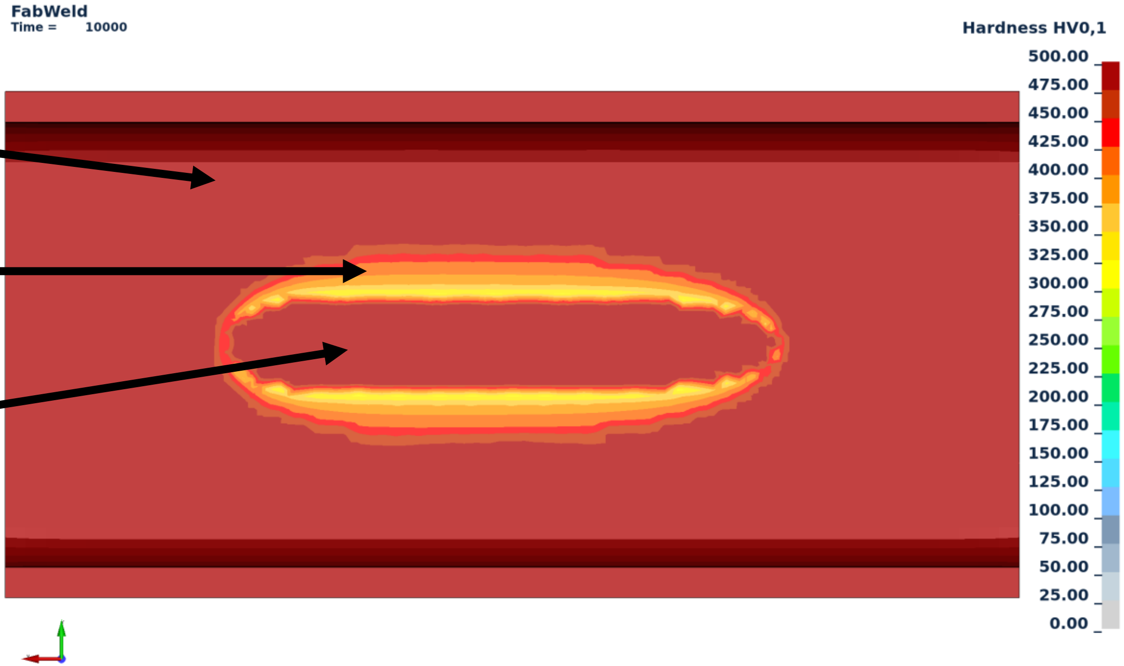


Hardness Formula for 22MnB5

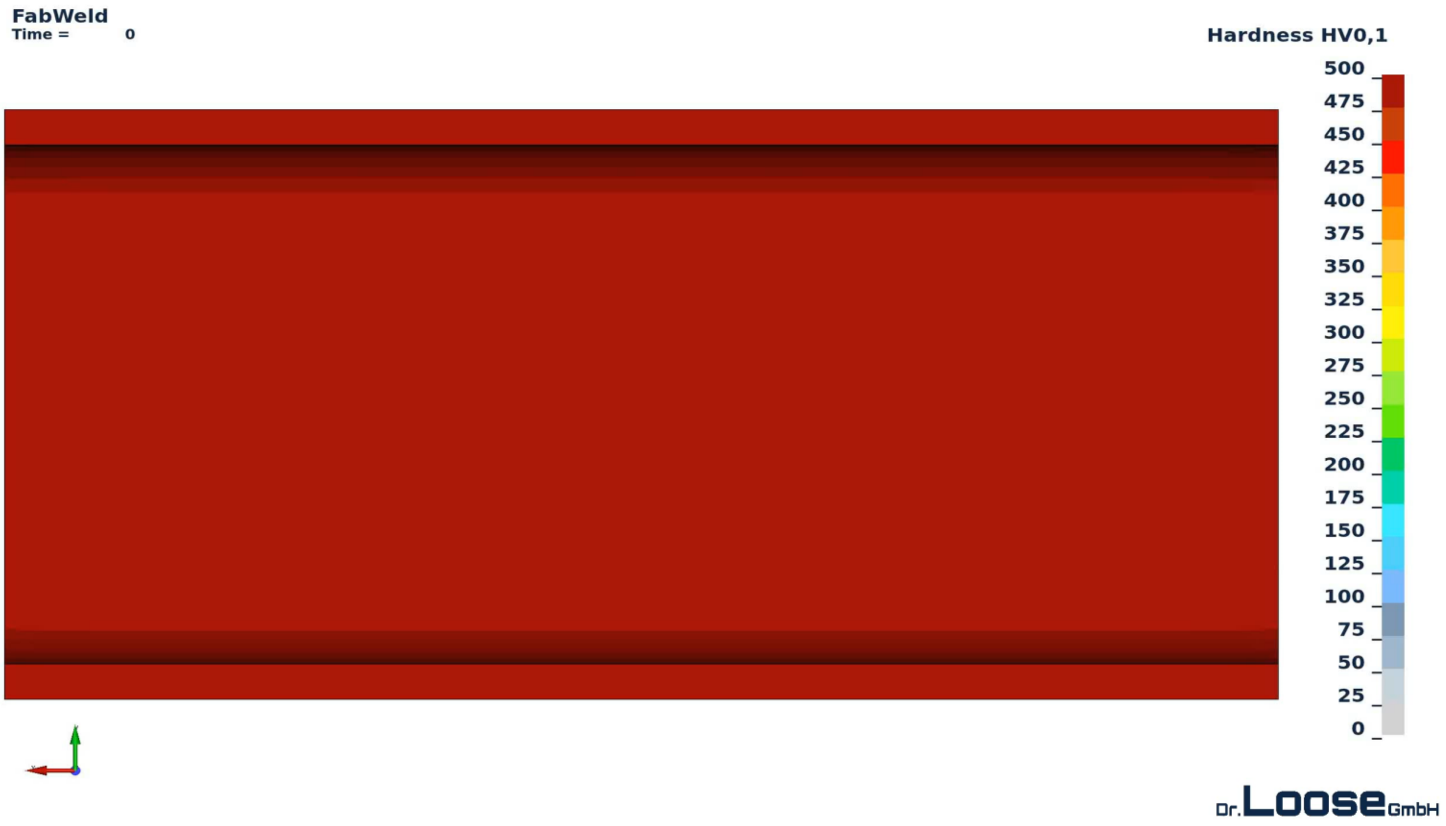
Hardness from press hardening process

Heat affected zone,
tempering effects leads to
reduction of hardness

Molten zone
Hardness from martensite transformed
from austenite after solidification.



Hardness


FabWeld
Time = 0
Hardness HV0,1
500
475
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
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Martensite


FabWeld
Time = 0
Martensite
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
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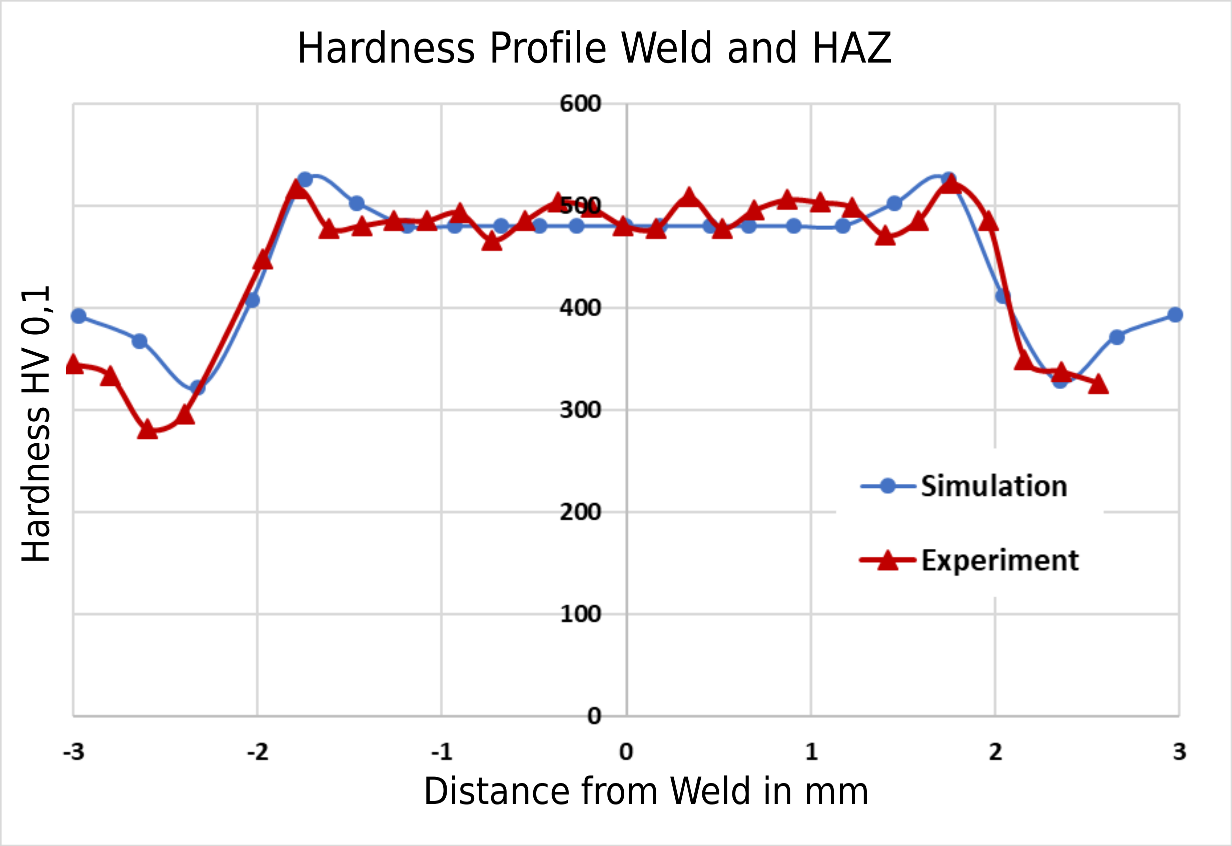
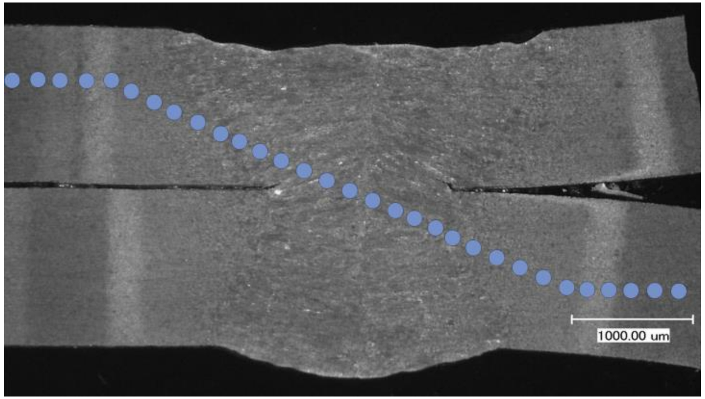
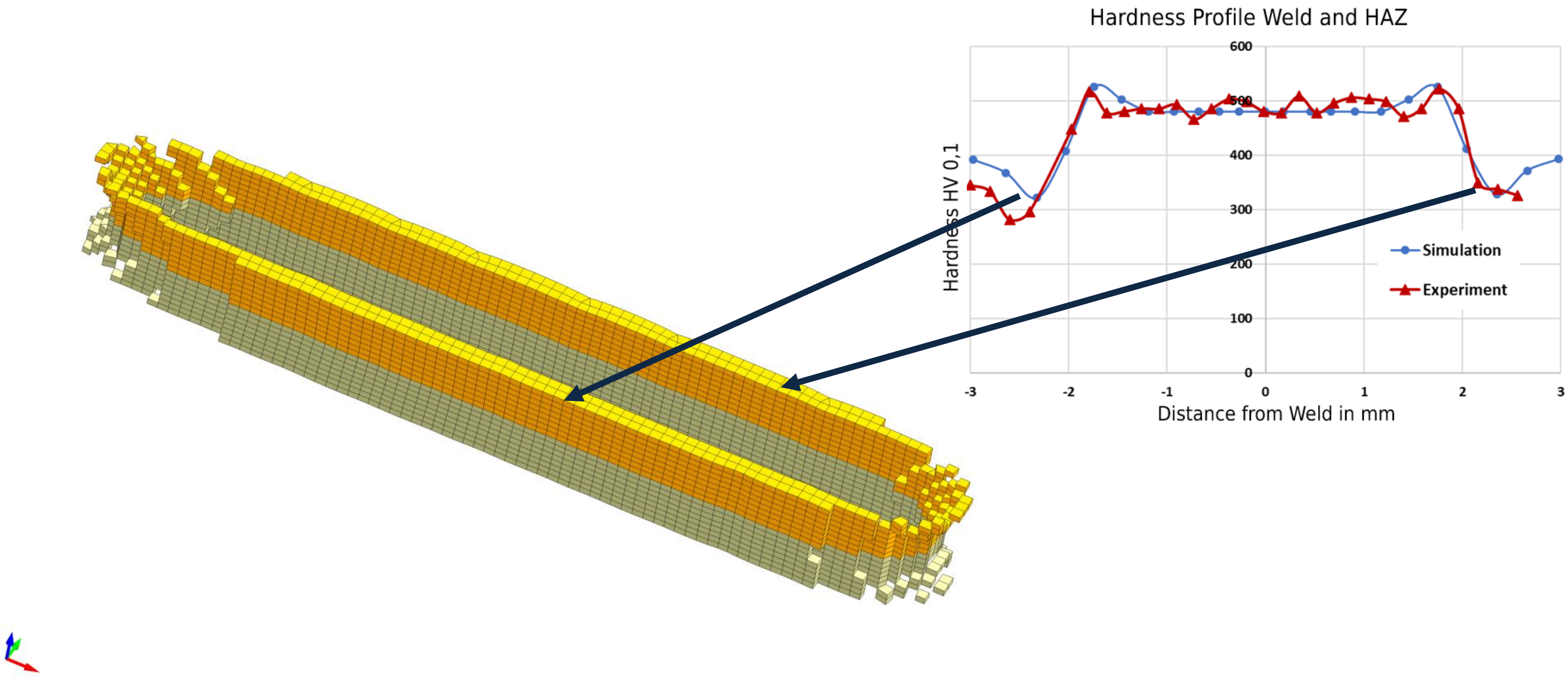
Tempered Martensite

Hardness Profile





Segregation Zone



Discretization of Material Properties
New Part Assignment according Hardness

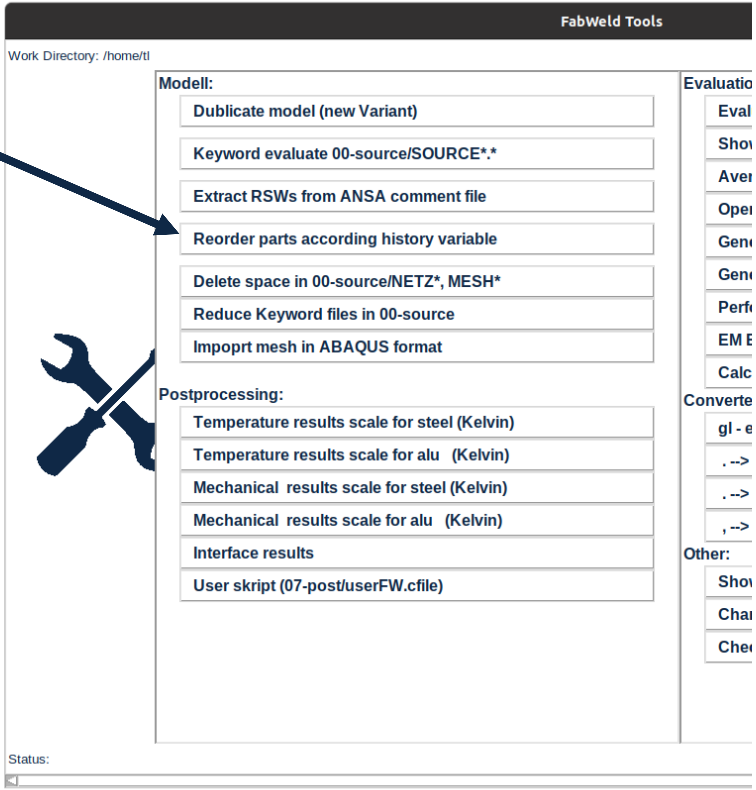
FabWeld Feature „Reorder Part“
Part assignment of elements according history variable

The HAZ contains continous changing material properties.

To perform the analysis of failure, these continuous properties need to be discretisized element wise / part wise. Each zone of similar properties requires its own crash card.

FabWeld has a feature to automate this process:

Input parameters:
- Number of ordinating history variable
- Number of subdivisions
- Limit values of the subdevisions

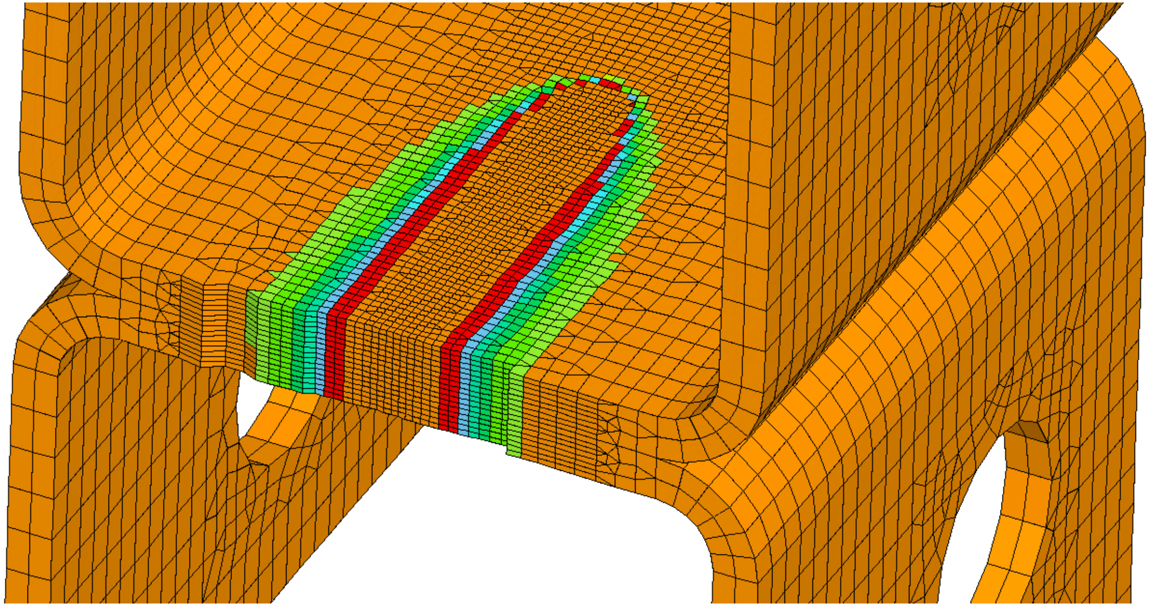


Discretisation of Material Properties
New Part Assignment according to Hardness

Input file for FabWeld

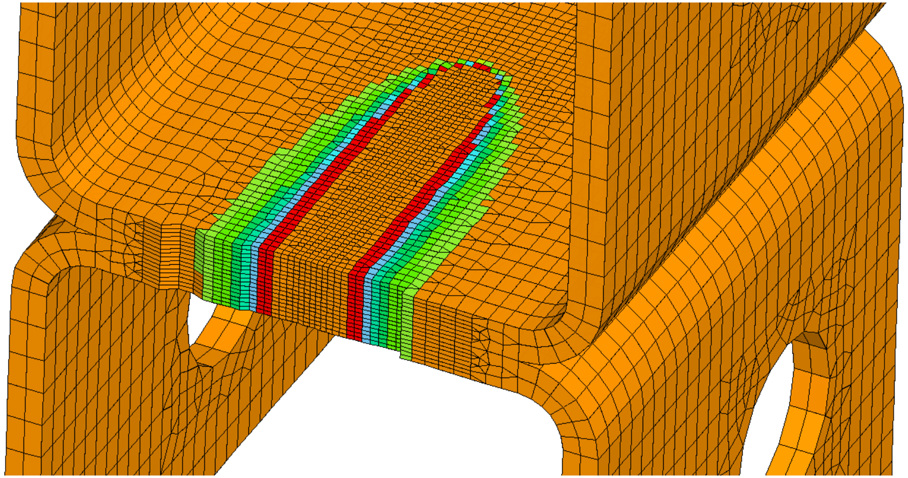
```
# input file name:
56_final_map.inc
# output file name:
56_map.k
# number of parts to be partitioned:
2
# part id's:
12
14
# number of partitions per part:
6
# partitioning:
290
340
390
440
490
# history variable:
36
```

Part assignment according Hardness
this is the history variable #36

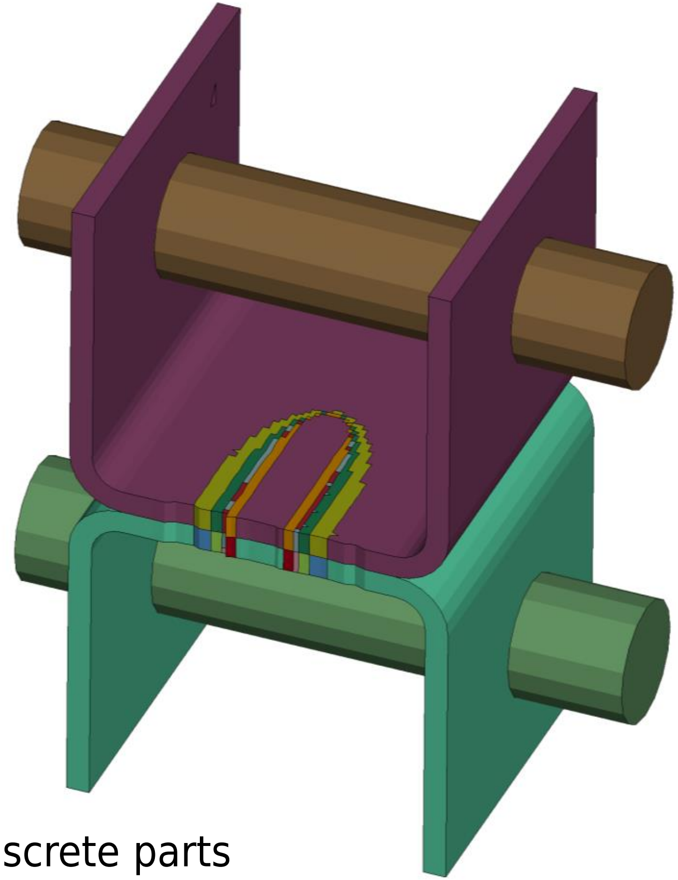


Continuous hardness distribution

FabWeld – Reorder Parts



Continuous hardness distribution

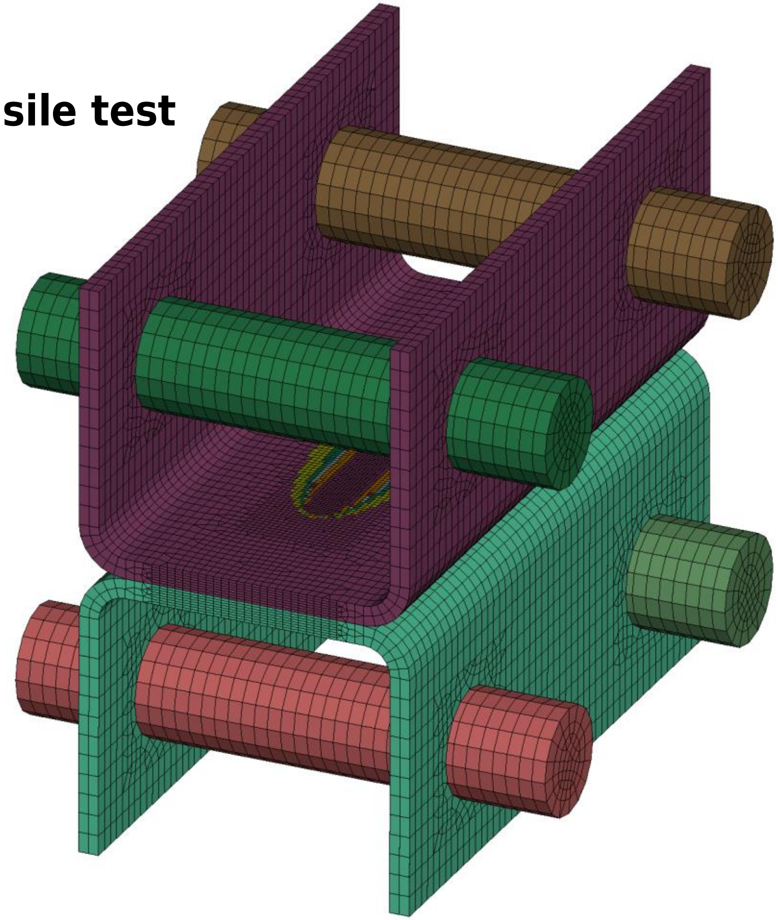


Discrete parts

Numerical Tensile Test

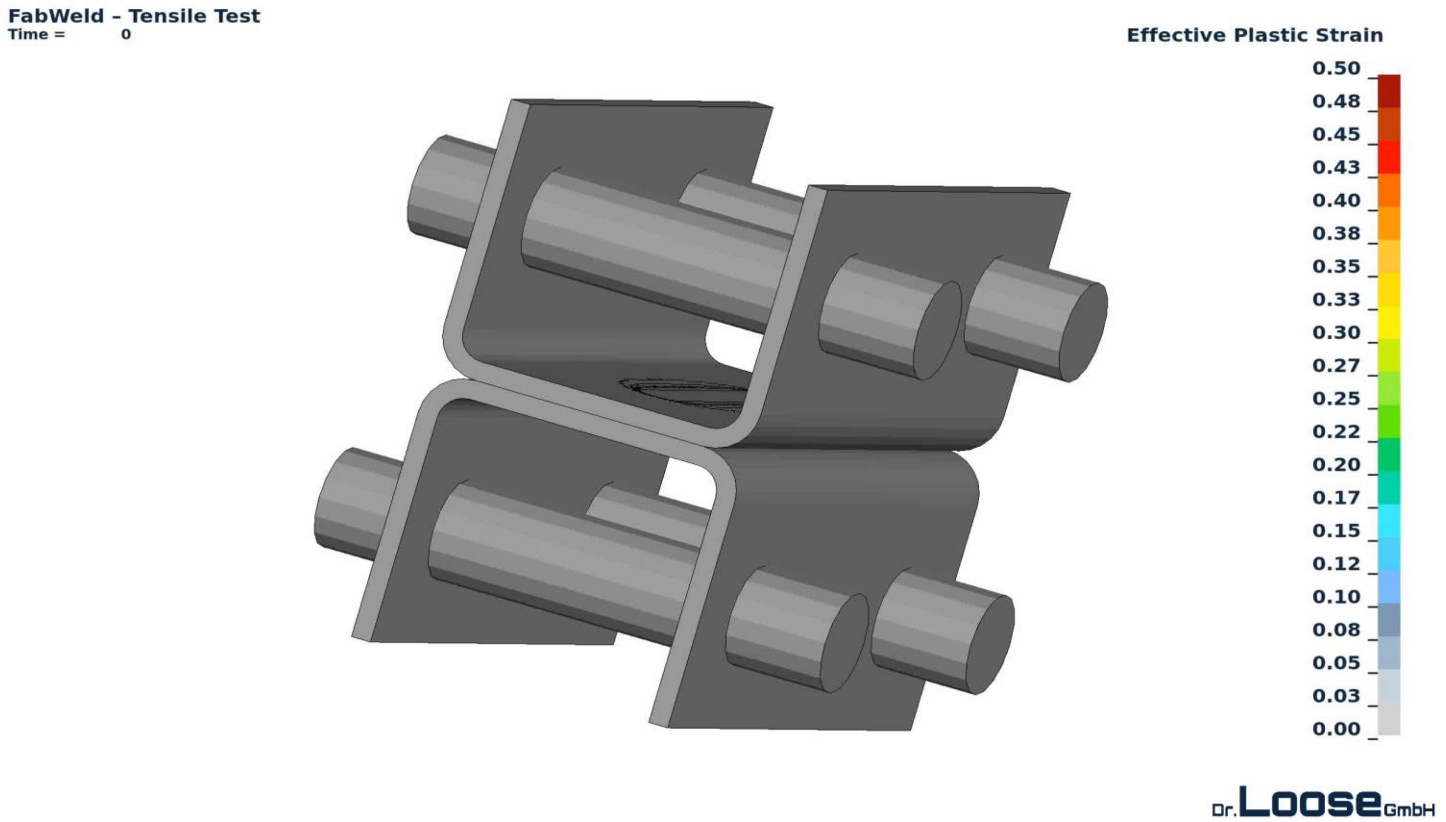
Simulation of Tensile Test

Mesh for tensile test

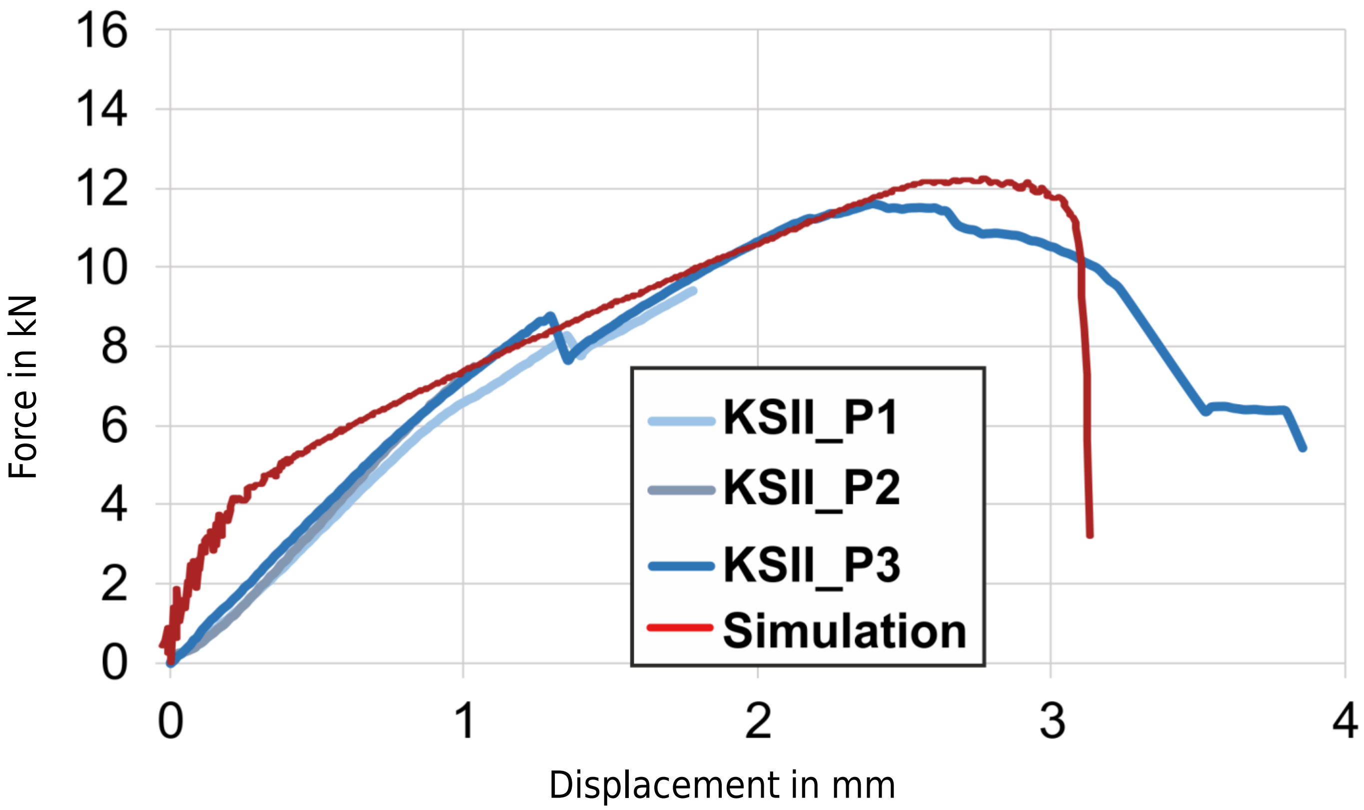


- ca. 85 000
  full integrated solid elements
- Explicit LS-DYNA Analysis
- Simulation time with explicit analysis
  MPP 4 Cores: ca. 8h

Numerical Test

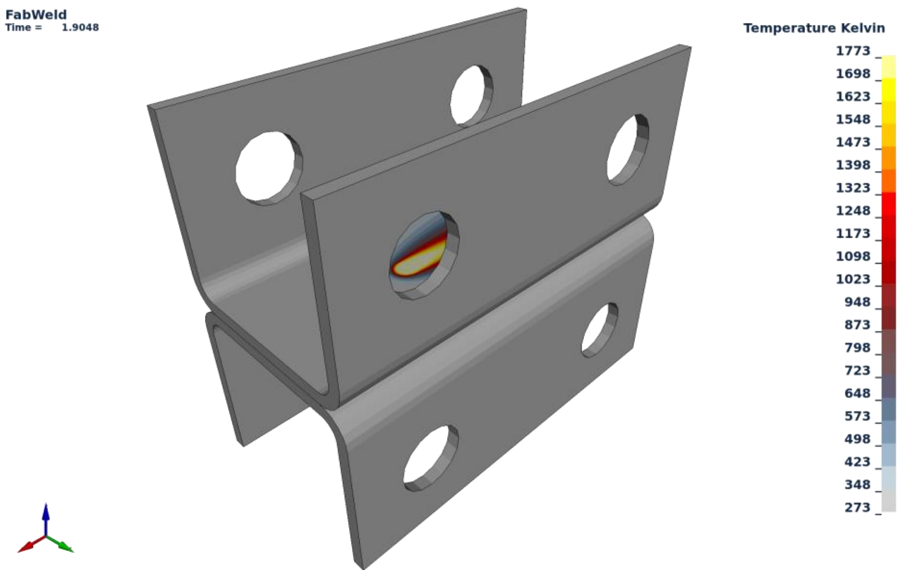


Tensile Test
Virtual Data Versus Experimental Data



Conclusion and Outlook

- The process chain: welding simulation – simulation of limit load-carrying capacity was succesfully performed in the example of press hardened steel.
- The continous material properties in the HAZ were transformed to discrete material cards. FabWeld has a module to automate this procedure.
- The object of further investigations will be the transfer to other welding processes and other materials.



Acknowledgement

Forschungsvereinigung Stahlanwendung e. V.

Laserstrahlschweißen der ultrahochfesten Stähle 22MnB5 und DP1000
-Generierung und Validierung von Materialkennwerten in Wärmeeinflusszonen (WEZ)
für eine geschlossene Simulationskette von der Temperaturfeldsimulation
der Fügetechnik bis zur Belastungssimulation

P 1232/18/2017 / IGF-Nr. 19449 N

All experimental investigations as well as the used crash cards are performed or developed during this project

Thank You!