COMSOL CONFERENCE
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Sicherheit in Technik und Chemie

BAM
Bundesanstalt für Materialforschung und -prüfung

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TRANSIENT PROCESS SIMULATION OF HEAT TRANSFER IN LASER BEAM WELDING WITH AN EQUIVALENT HEAT SOURCE

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Overview

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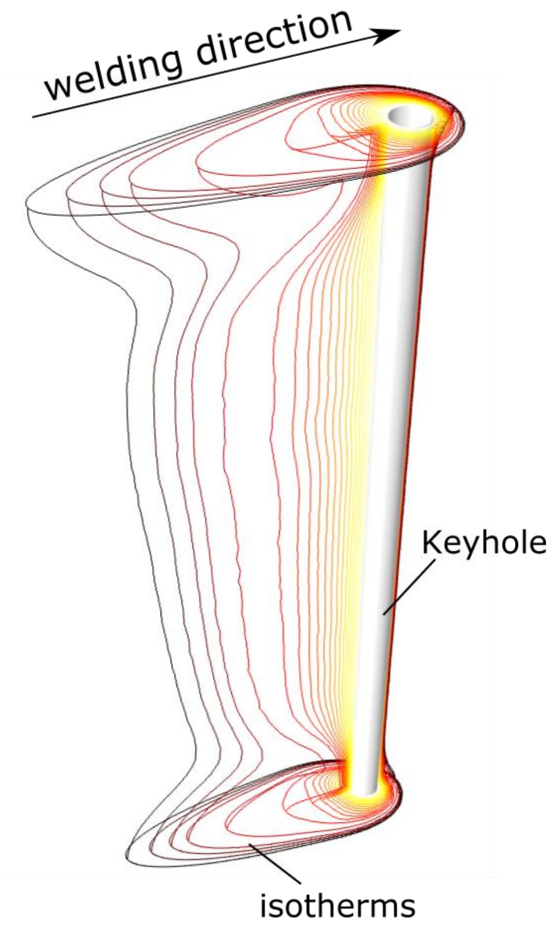
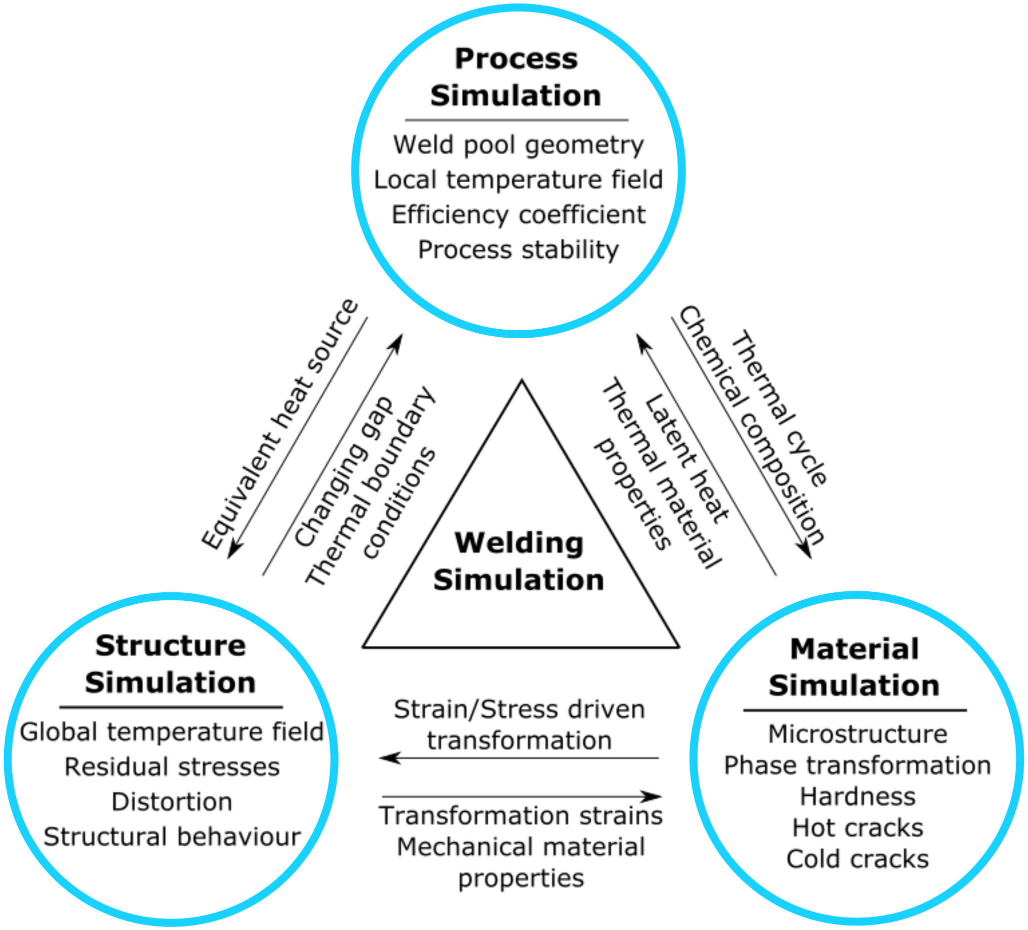
1. Introduction
2. Numerical Modeling & Results
   - CFD
   - Heat Transfer
3. Experimental Observation
4. Conclusions



Temperature field calculation as a part of the welding simulation

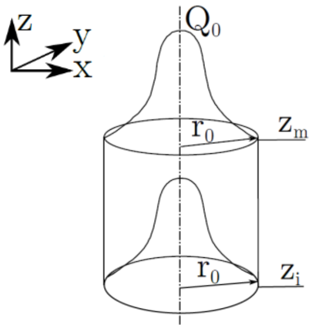


according to Radaj, D: Schweißprozeßsimulation. DVS-Verlag, Düsseldorf, 1999

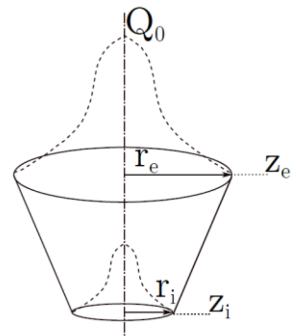
Calculation methods for the transient temperature field

Energy input by a heat source model

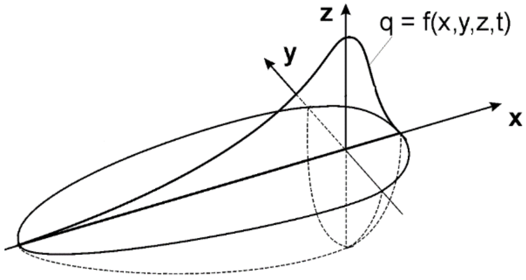
Calibration of the heat source parameters



Cylindrical heat source

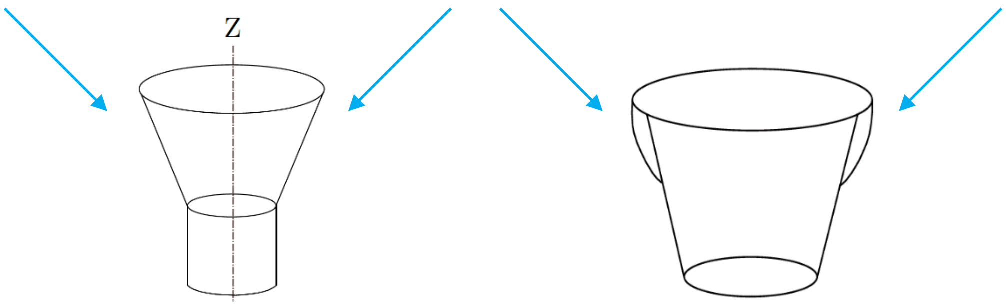


Conical heat source



Goldak's double ellipsoidal heat source

according to Radaj, D.: Fachbuchreihe Schweißtechnik, 2002



according to Chukkan *et al.*, J. Mater. Process. Tech. 219, 2015

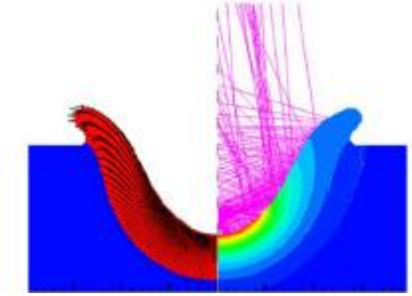
Aim: minimization of the calibration effort

Calculation methods for the transient temperature field

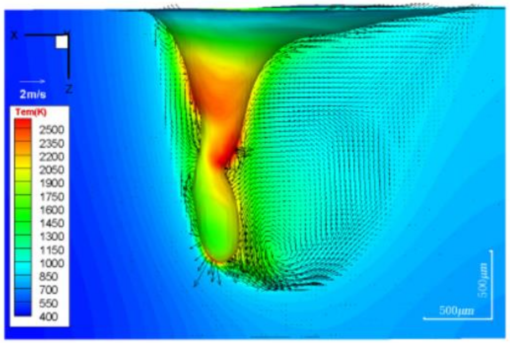
Self-consistent models: multiphysics simulation

Consideration of all important physical effects for the heat transfer

- Optics
- Thermal conduction
- Convection



Gaied *et al.*, Comsol Conference 2015.

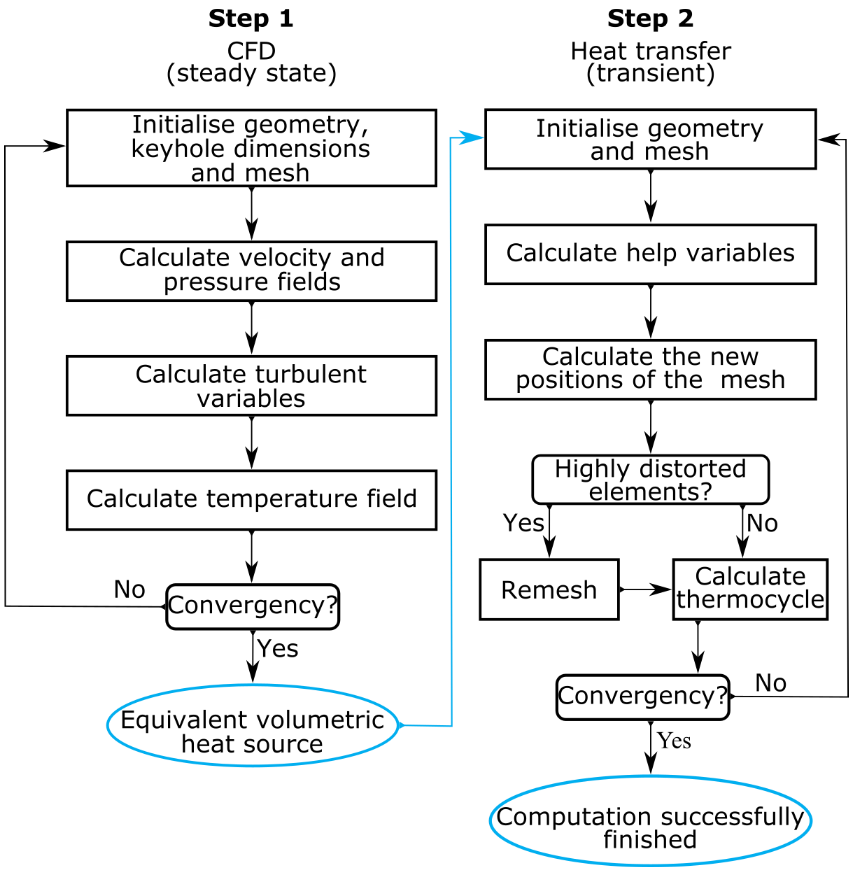


Pang *et al.*, J. Phys. D: Apply. Phys. 44, 2010

Aim: minimization of the calculation time (days/weeks)

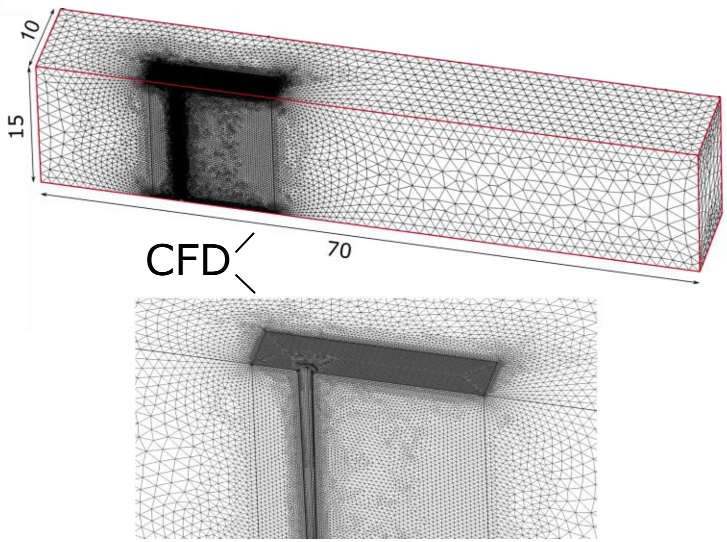
Approach

- Calculation of the local, stationary temperature and velocity fields
- Definition of an equivalent heat source through the isosurface of the melting temperature
- Solve the 3D heat equation considering the calculated equivalent heat source



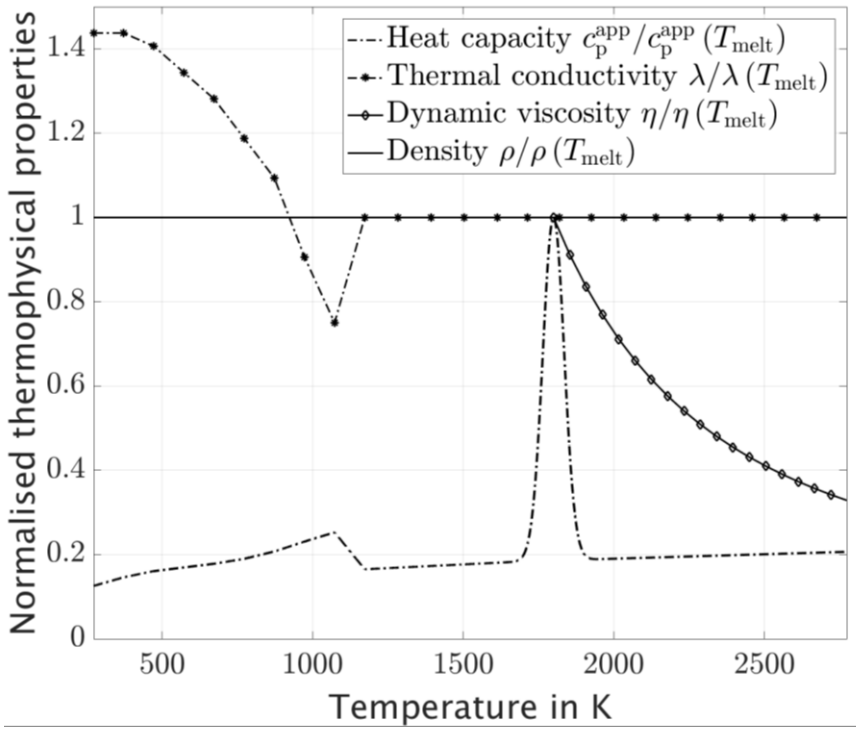
Numerical modeling
Computational domains/meshes/solvers

- Tetrahedral and triangular elements
- Moving mesh
- Pointwise constraints
- CFD – ca. 1.5 x 10^6 elements
- Heat transfer – ca. 9 x 10^4 elements
- Remeshing – ca. 10^5 elements
- Direct solver – PARDISO
- Iterative solver - Multigrid



Numerical modeling
Material model

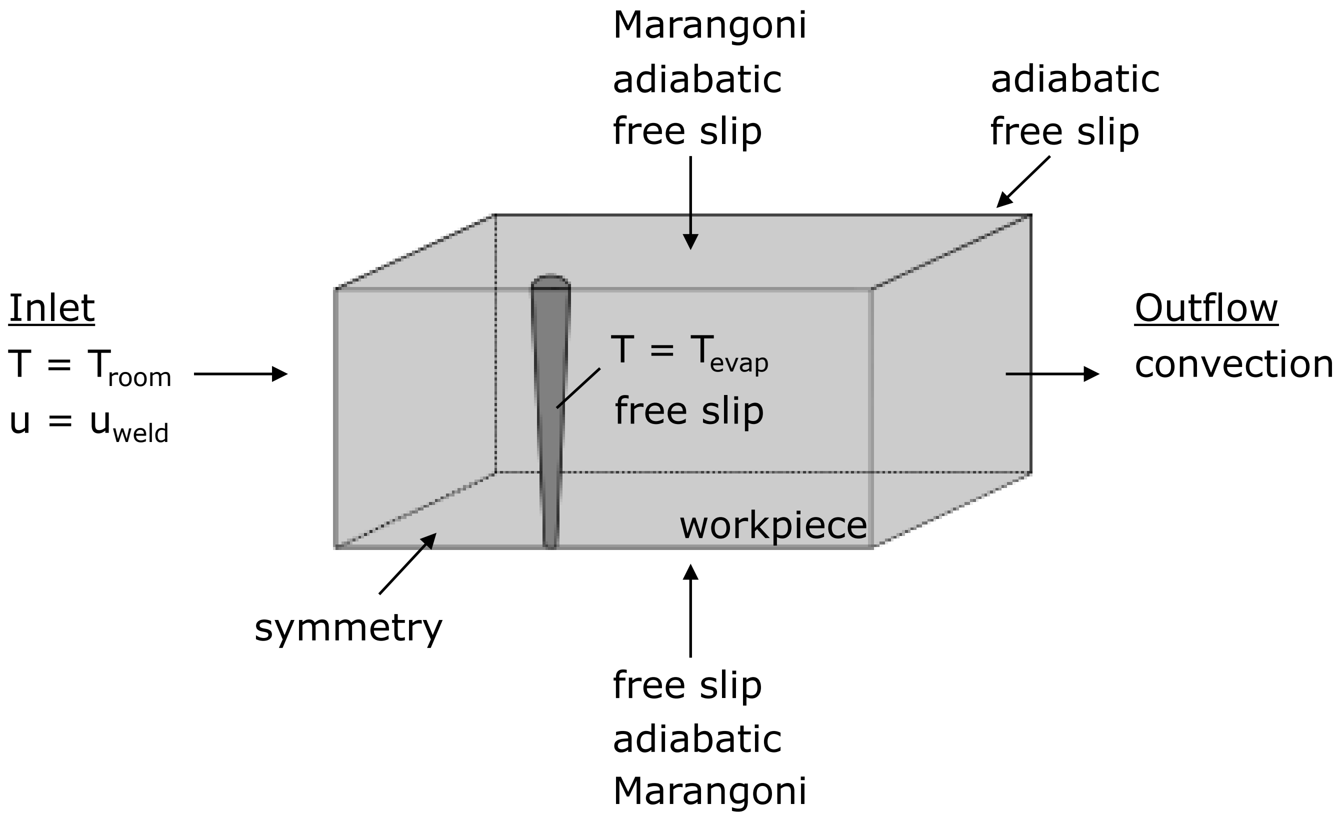
- Low alloyed steel – S355J2G3
- Phase-specific data (ferrite & austenite)
- Constant density through the Boussinesq approximation
- Latent heat considered by the apparent heat capacity method



CFD

Assumptions and boundary conditions

- Steady-state approach
- Fixed geometry of the free surfaces and the keyhole
- Heating due to laser-induced plasma neglected

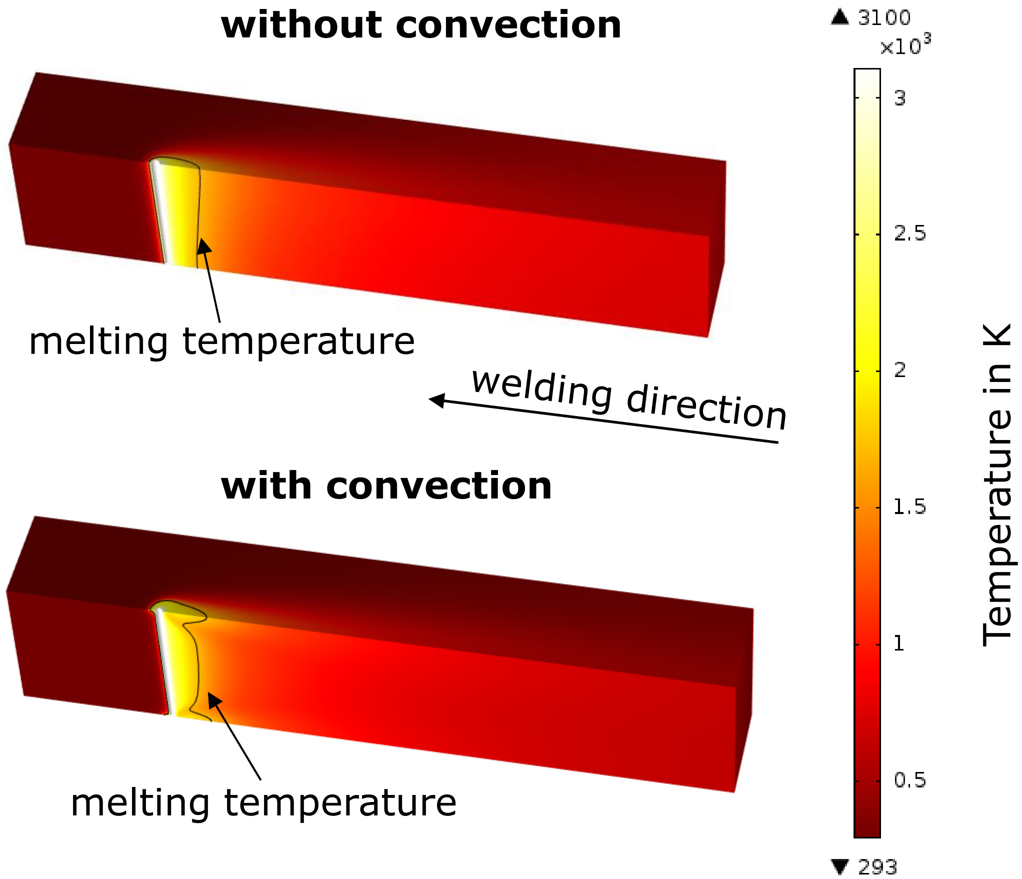


CFD

Weld pool

Computing time < 30 min

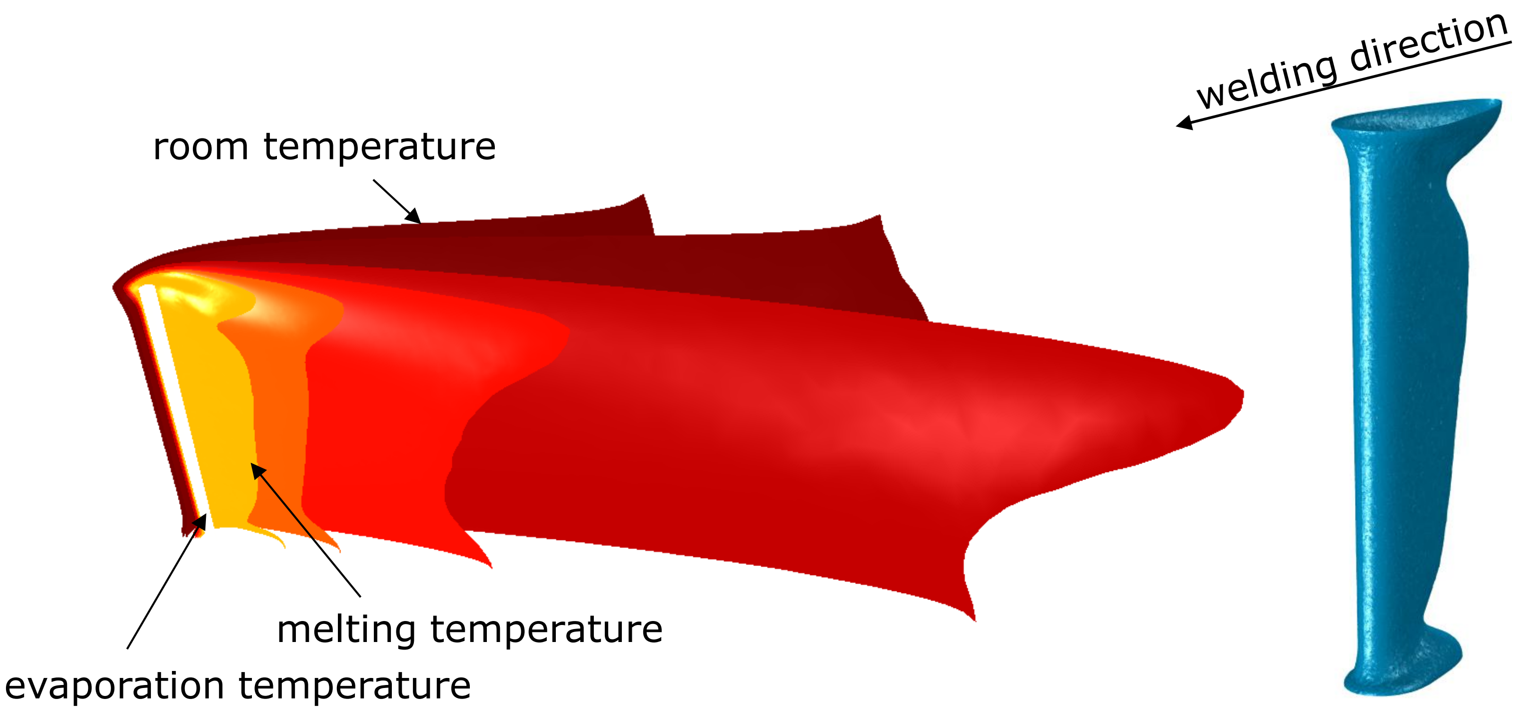
Computing time > 5 h



Strong influence of the fluid flow on the weld pool geometry

CFD

Temperature isosurfaces

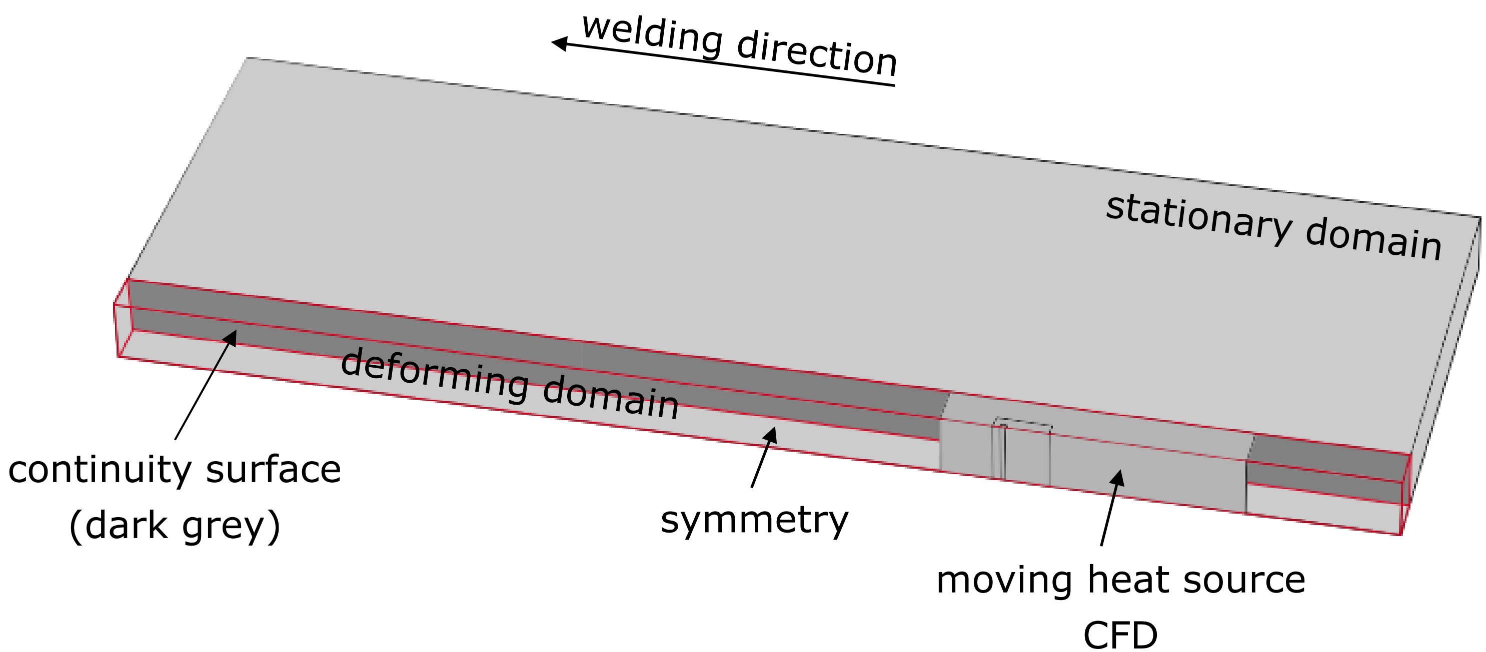


Approximation of the equivalent heat source

Heat transfer

Assumptions and boundary conditions

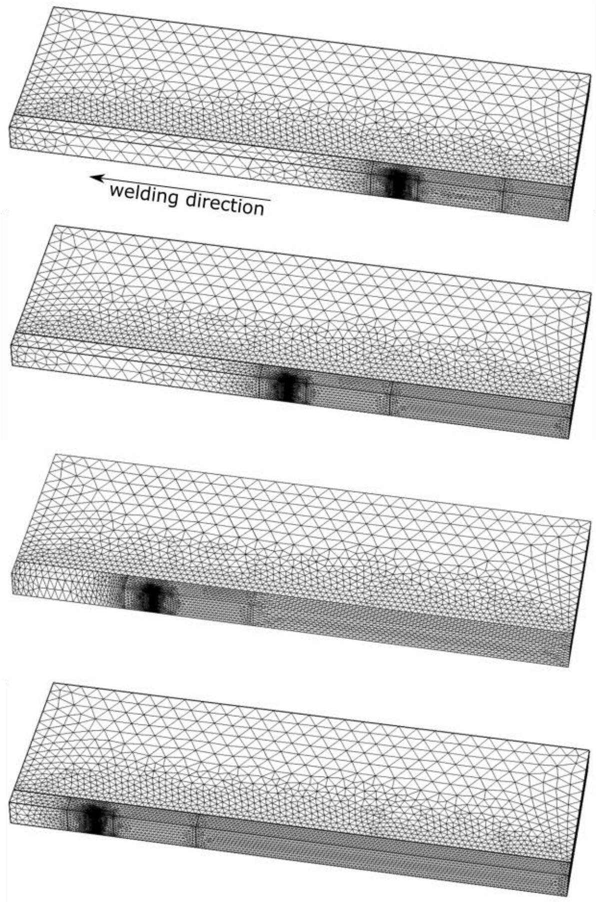
- Heat transfer coefficient (air): 15 W/m²K
- No heat radiation

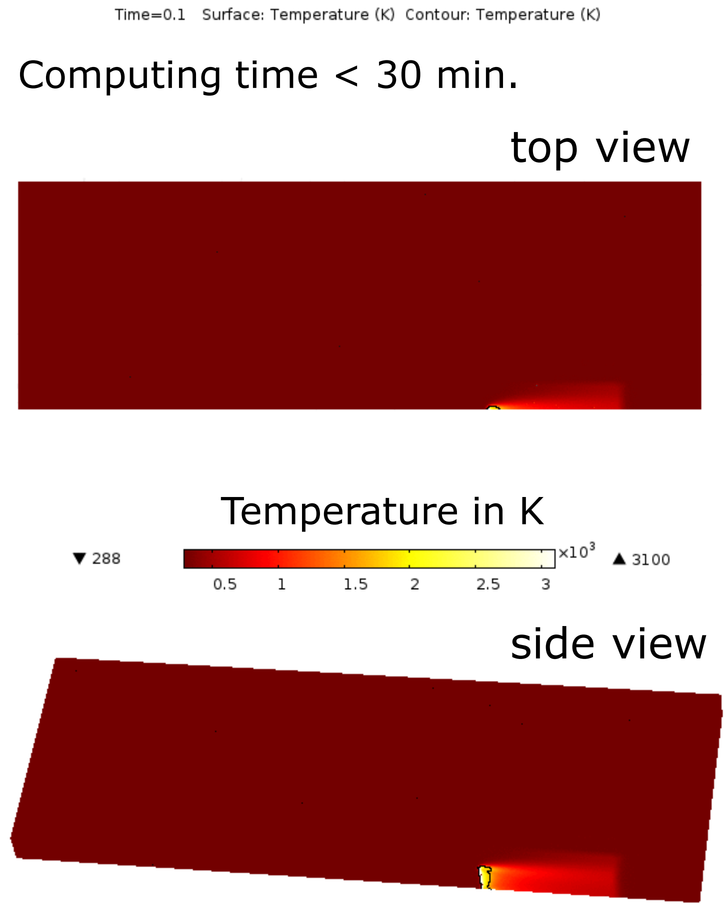


Mesh deformation only within the deforming domain

Heat transfer

Moving mesh

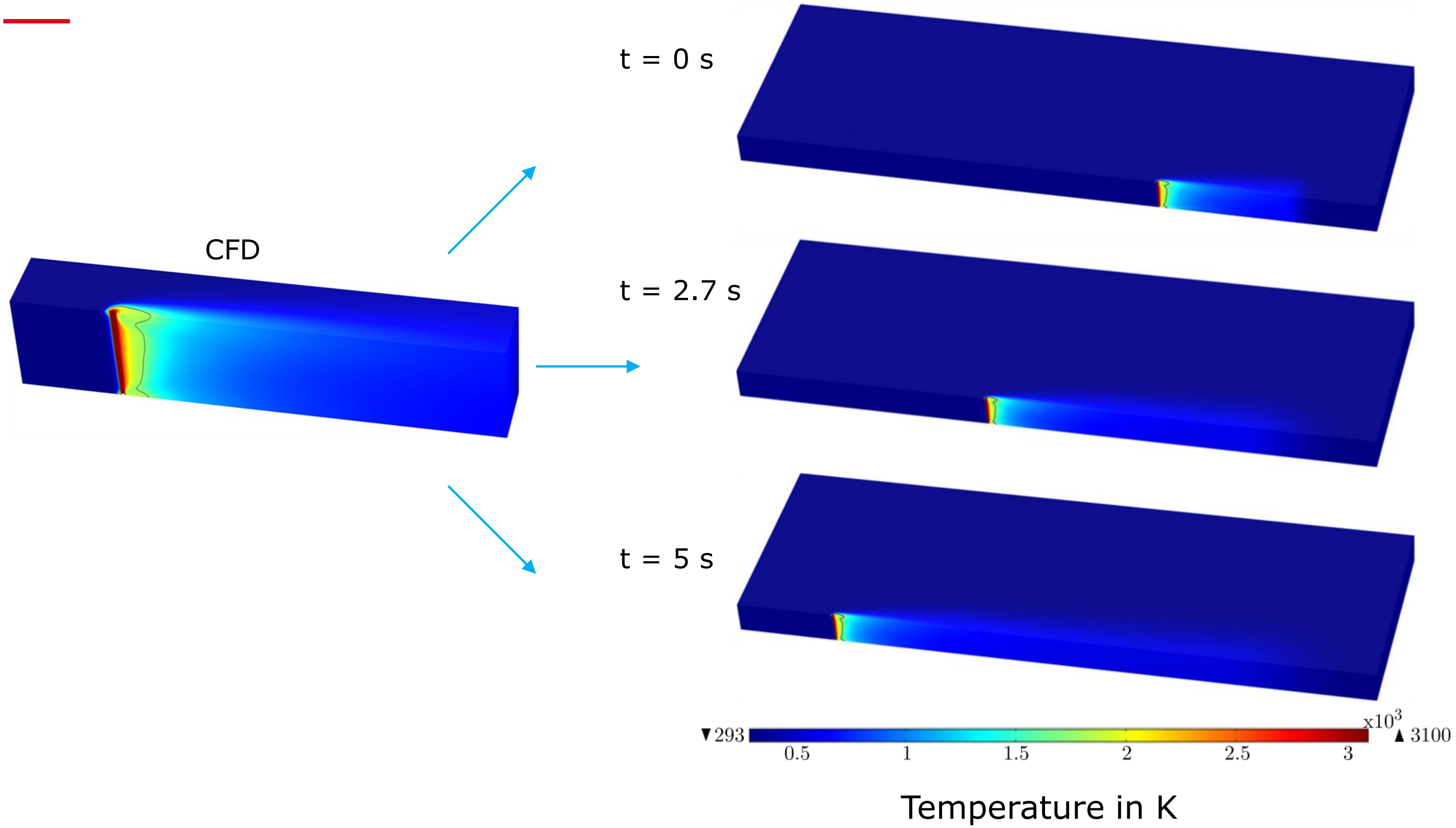




Complete transient 3D computation of the temperature field

Heat transfer

Prescription of the nodes temperature

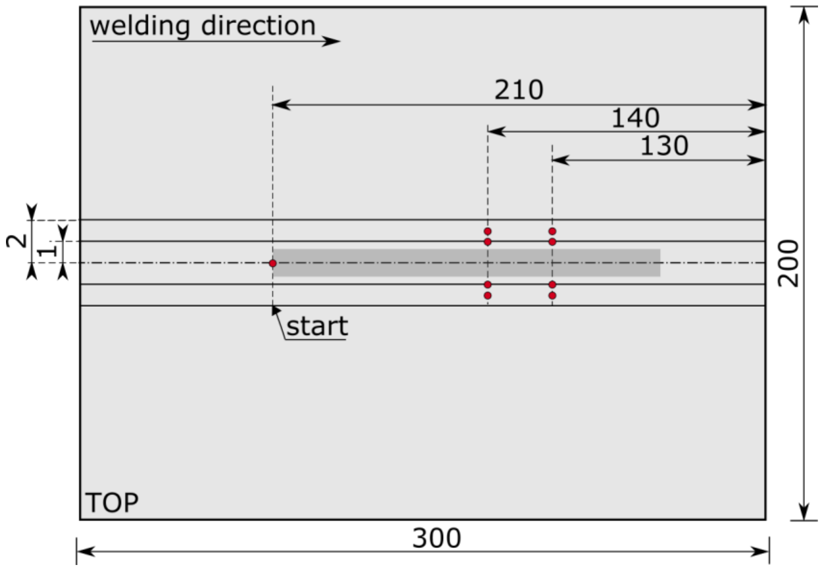


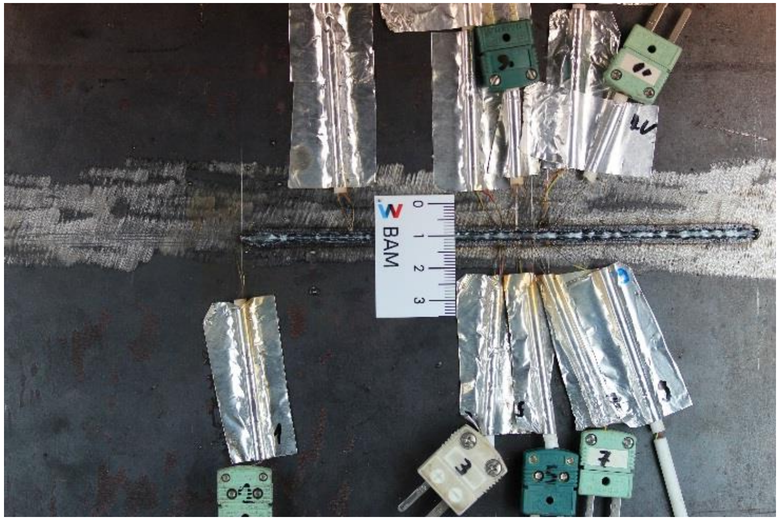
Successful transfer of the CFD results in the heat transfer simulation

Experimental Observation

Experimental setup

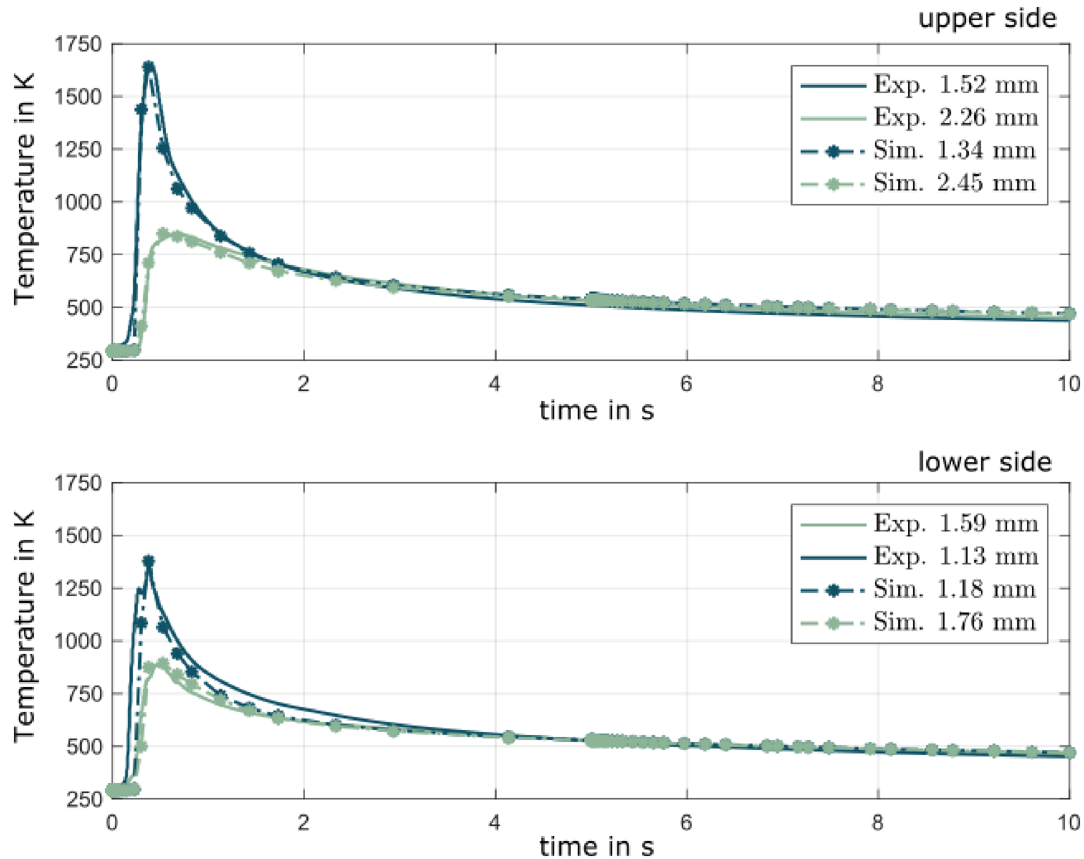
- Temperature measurements with thermocouple elements type K
- Parameters:
  - Material – low alloyed steel S355J2G3
  - Plate thickness 15 mm
  - Laser power 18 kW
  - Welding speed 2 m/min





Results

Comparison between experiment and simulation



Good agreement between simulation and measurements

Conclusions

Outlook

- Combination of advantages of the known modeling methods
- Considered effects of temperature-dependent surface tension, latent heat and free convection
- Reduced number of fitting parameters – Keyhole radii
- Reduced computing time < 24 hours incl. calibration effort
- Good correlation between the numerically calculated and the experimentally observed results
- Investigation of the coupling of process and structural simulation through the calculated equivalent heat source

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Thank you for your attention.