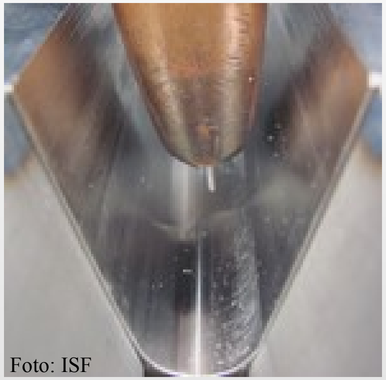
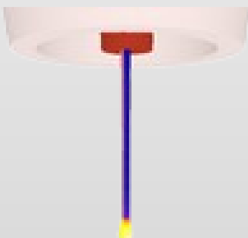
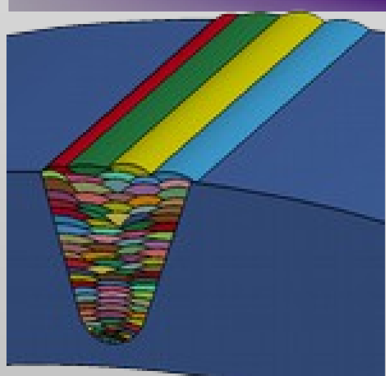






SimWeld und DynaWeld

Infotag Schweißen und Wärmebehandlung

20.10.2015 Aachen

Dr.-Ing. Tobias Loose

Ingenieurbüro Tobias Loose, Herdweg 13, D- 75045 Wössingen

loose@tl-ing.de www.tl-ing.eu

Dr.-Ing. Oleg Mokrov

Institut für Schweißtechnik und Fügetechnik der RWTH Aachen (ISF),

Pontstraße 49, D-52062 Aachen,

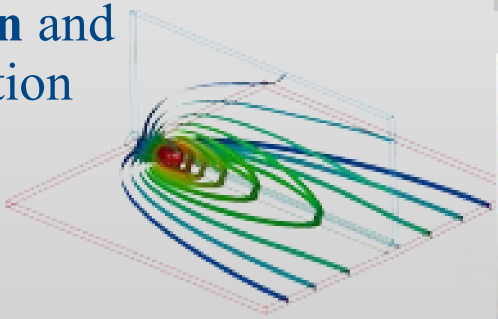
mokrov@isf.rwth-aachen.de, www.isf.rwth-aachen.de

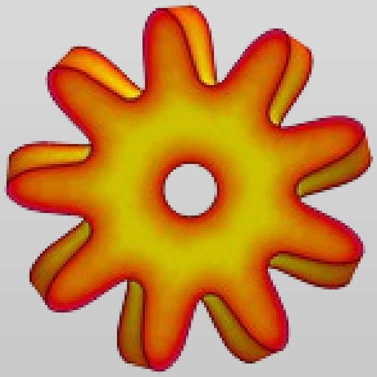
Herdweg 13, D-75045 Wössingen Lkr. Karlsruhe
E-Post: loose@tl-ing.de Web: **www.tl-ing.eu www.loose.at**
Mobil: +49 (0) 176 6126 8671 Tel: +49 (0) 7203 329 023 Fax: +49 (0) 7203 329 025

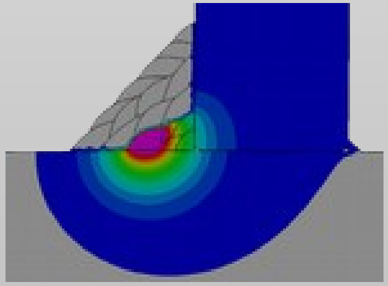
Numerical Simulation for Welding and Heat Treatment since 2004

- Consulting
- Training
- Support
- Software Development
- Software Distribution

for **Welding Simulation** and Heat Treatment Simulation







www.WeldWare.eu

www.SimWeld.eu

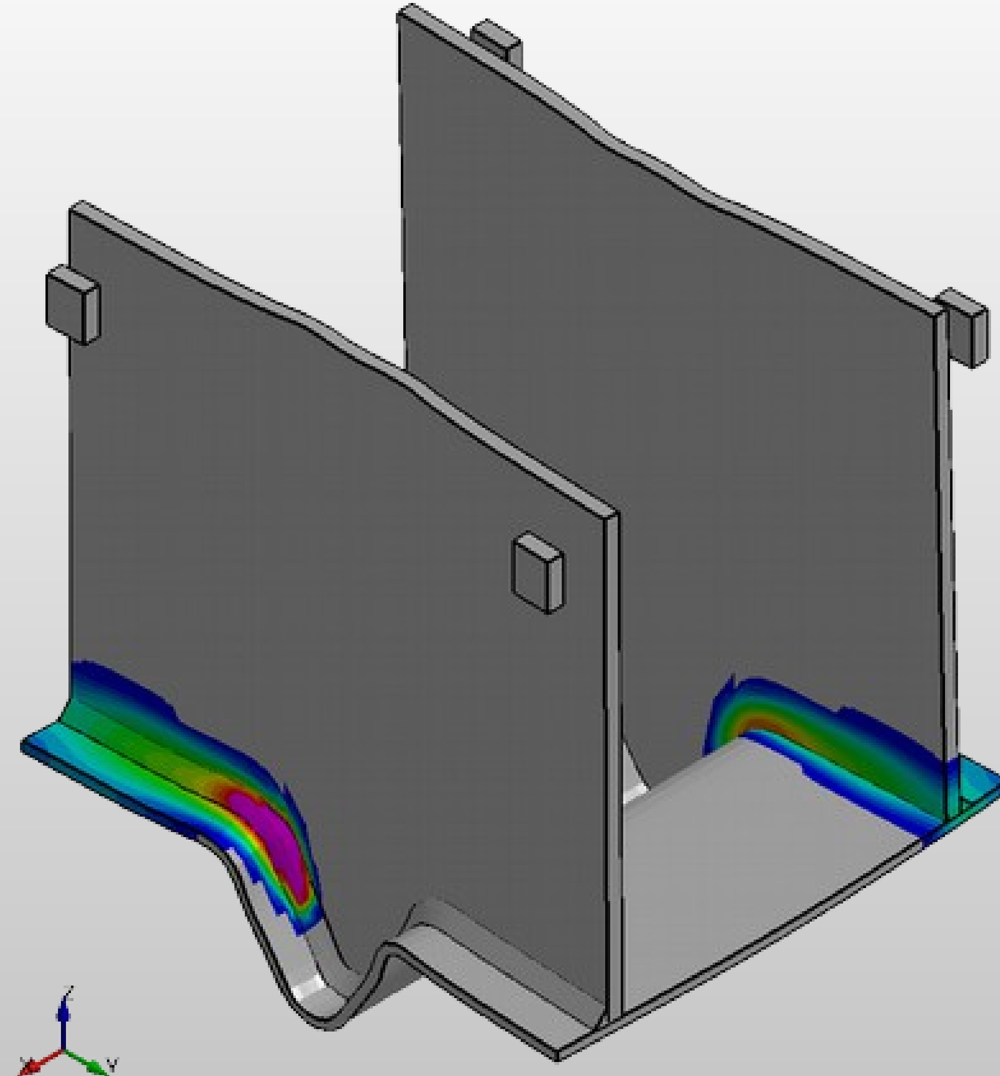
www.DynaWeld.eu

Internet:

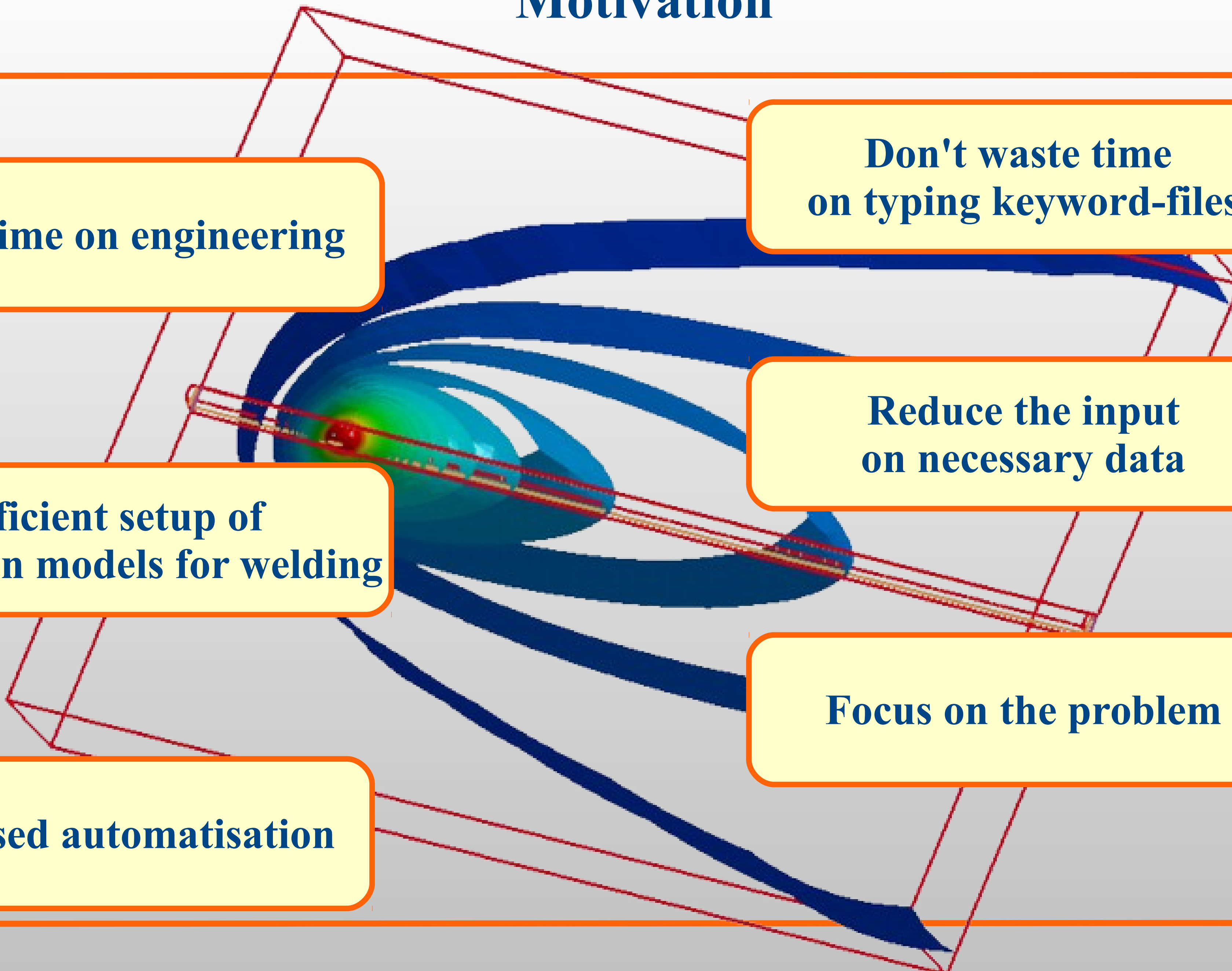
DEeutsch: **www.loose.at**
ENglisch: **www.tl-ing.eu**
ESpañol: **www.loose.es**

Motivation

and Introduction



Motivation



Spend time on engineering

Don't waste time on typing keyword-files

Reduce the input on necessary data

Efficient setup of simulation models for welding

Focus on the problem

Maximised automatisation

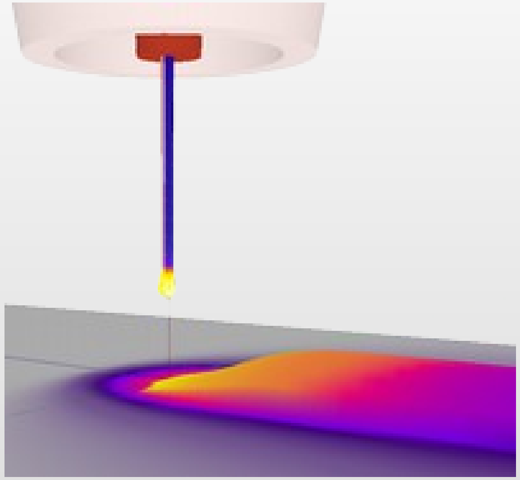
Workflow of a welding project with SimWeld and DynaWeld

Meshing

Trajectories

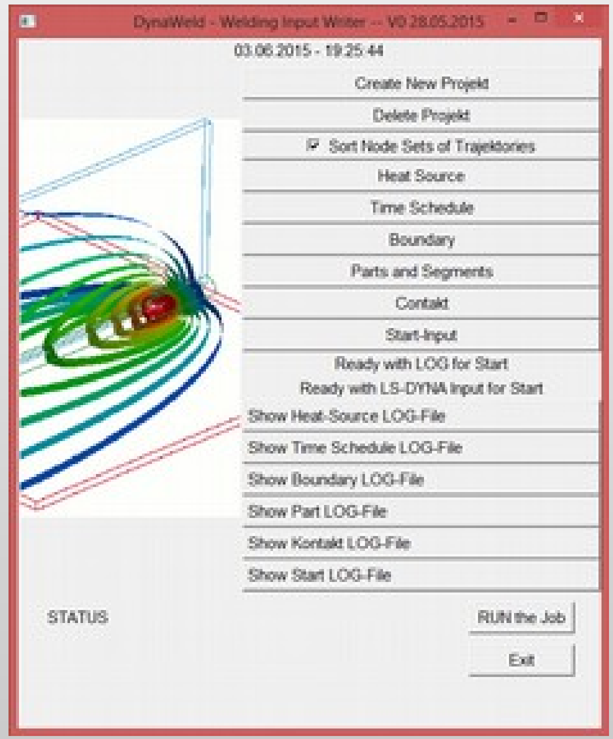
WPS
Heat Source

Process Plan



SimWeld

DynaWeld



New Project

Create

Check

R U N

N o r m a l   t e r m i n a t i o n

Process Simulation – Structure Simulation

Welding Process Simulation

- **SimWeld**
- for GMA Welding

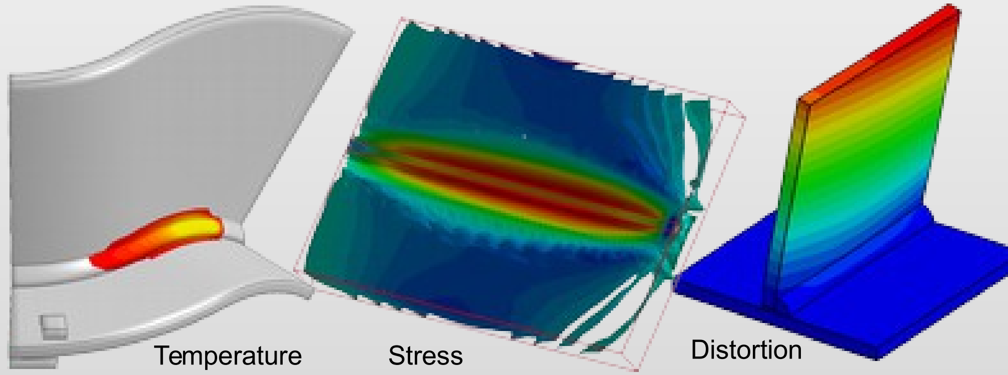
Foto: ISF

- Prediction of
  - Heat Input
  - Weld Pool
  - local Temperature Field
- Input:
  - Process Parameter

For beam welding (Laser, Electron Beam) exist no tool for industrial use like SimWeld. The prediction of the equivalent heat source requires the method of adjustment by mircosection.

Welding Structure Simulation

- **DynaWeld / LS-DYNA**
- for all types of welding



- Prediction of
  - Deformation
  - Residual Stress
  - global Temperature Field
- Input:
  - Equivalent Heat Source
  - Trajectories and Process Plan

WPS and Process Plan

The

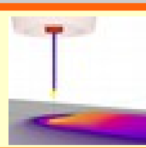
Welding Procedure Specification (WPS)

is a document that describes

- weld process type
- machine settings (U, I, Puls)
- weld preparation
- work position

Input for
welding process simulation

SimWeld



The

Process Plan

is a document that describes

- the order of the welds
- start time of welds
- intermediate time between welds
- weld type

Input for
welding structure simulation

DynaWeld

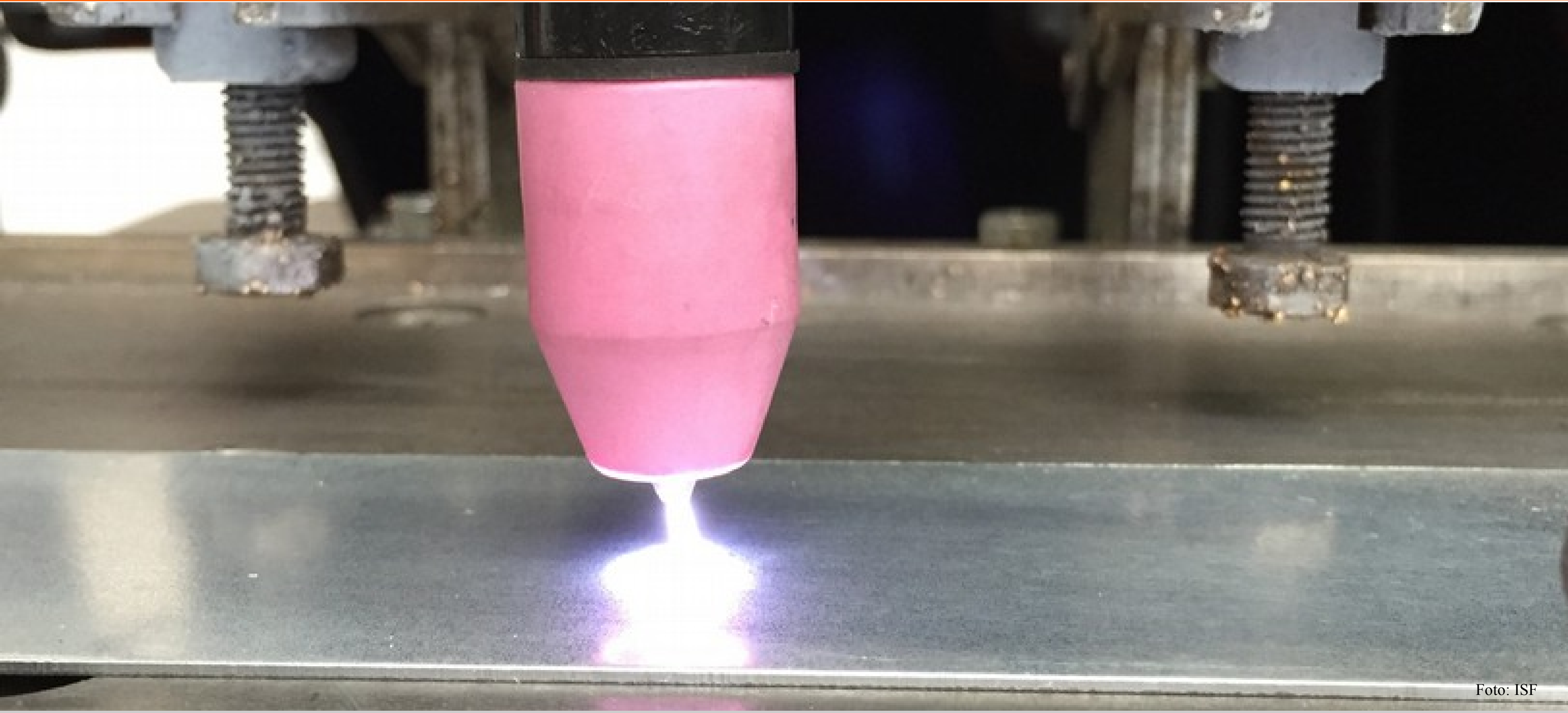
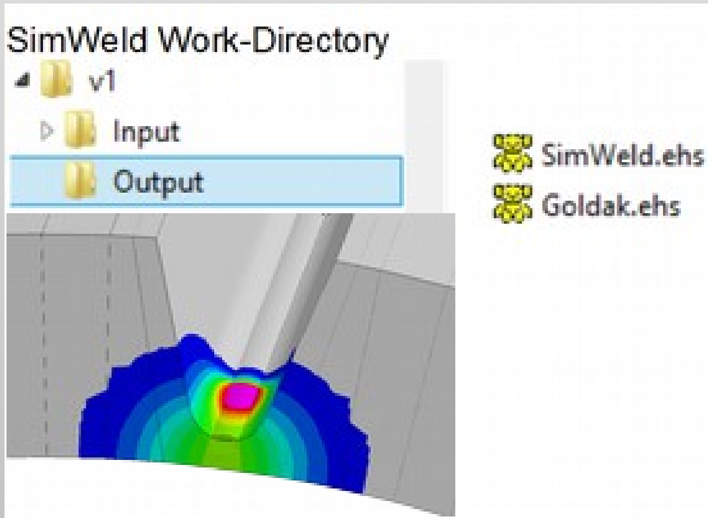


Foto: ISF

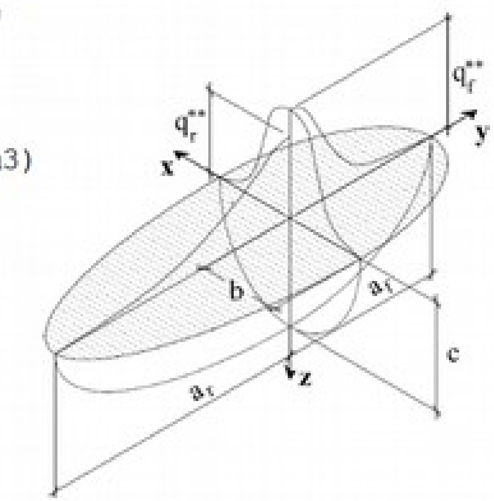
Equivalent Heat Source

Equivalent Heat Source

- The Equivalent Heat Source is a coupled function of geometry and intension of the heat generation density.
- It describes the thermal loading of a welding structure simulation.
- Its aproach is to generate the same heat input as the real proccess.
- It is an engineering aproach and not real physics.
- It covers fluid dynamic effects like convection in the weld pool.
- Any funktion is allowed.
- To find the heat source parameter is the challenge but **SimWeld** predict them.




```
3D double ellipsoid source
3756,71510  //Q (W)
2532,43120  //Qf (W)
1224,28390  //Qr (W)
86,38137  //q0_front (W/mm3)
2,61212  //q0_rear (W/mm3)
2,88001  //af (mm)
18,54003  //ar (mm)
7,76000  //b (mm)
6,08000  //c (mm)
3,24000  //x0 (mm)
3,32000  //z0 (mm)
0,00000  //ay (degree)
51,00000  //vy (cm/min)
```



SimWeld Heat Source
a new Equivalent Heat Source aproach for GMAW

Goldak - Gauss

SimWeld - SuperGauss

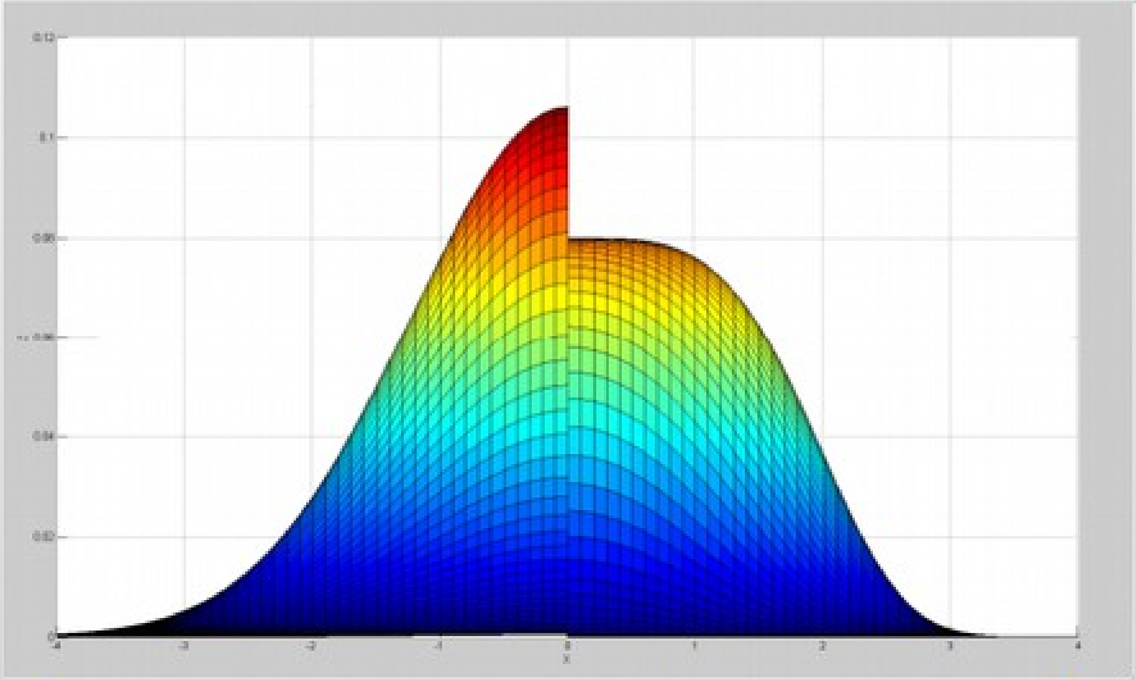
- Konstanten:

$r_x = r_y = 3;$

$c = 3;$

$k = \frac{c}{r_x \cdot r_y};$

$b = \pi;$



- Konstanten:

$r_x = r_y = 3;$

$c = 2;$

$k = \frac{c}{r_x \cdot r_y};$

$b = \frac{\pi^{1.5}}{2};$

$$f_{Ryk}(x, y) = \frac{k}{b}\exp\left(-k\left(x^2 + y^2\right)\right)$$

$$f_{MR4}(x, y) = \frac{k}{b}\exp\left(-\left(k\left(x^2 + y^2\right)\right)^2\right)$$

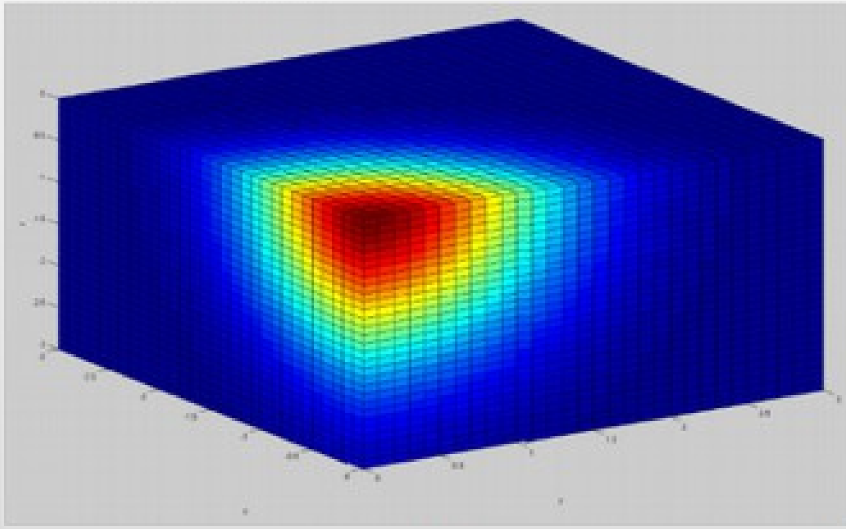
$$\iint f_{Ryk}(x, y)dxdy = \iint f_{MR4}(x, y)dxdy = 1$$

improved threshold of heat density outside the elipsoid
same parameter as Goldak heat source

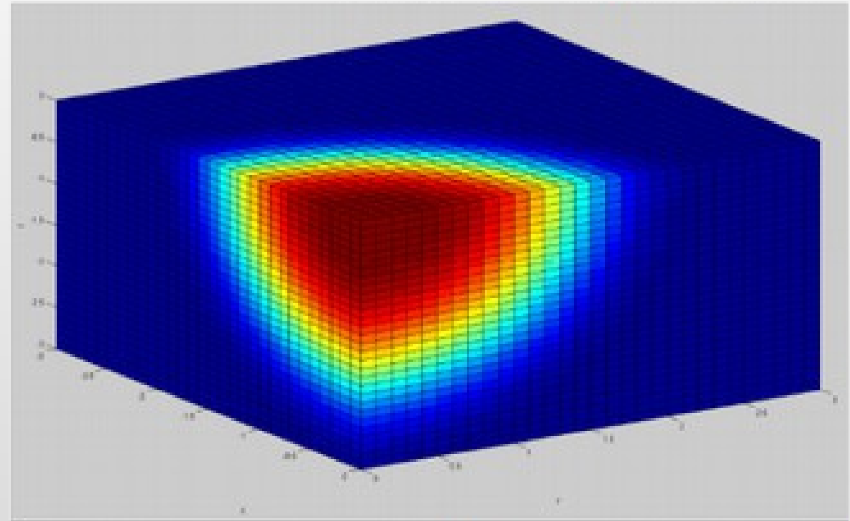
SimWeld Heat Source

a new Equivalent Heat Source aproach for GMAW

Goldak - Gauss



SimWeld - SuperGauss



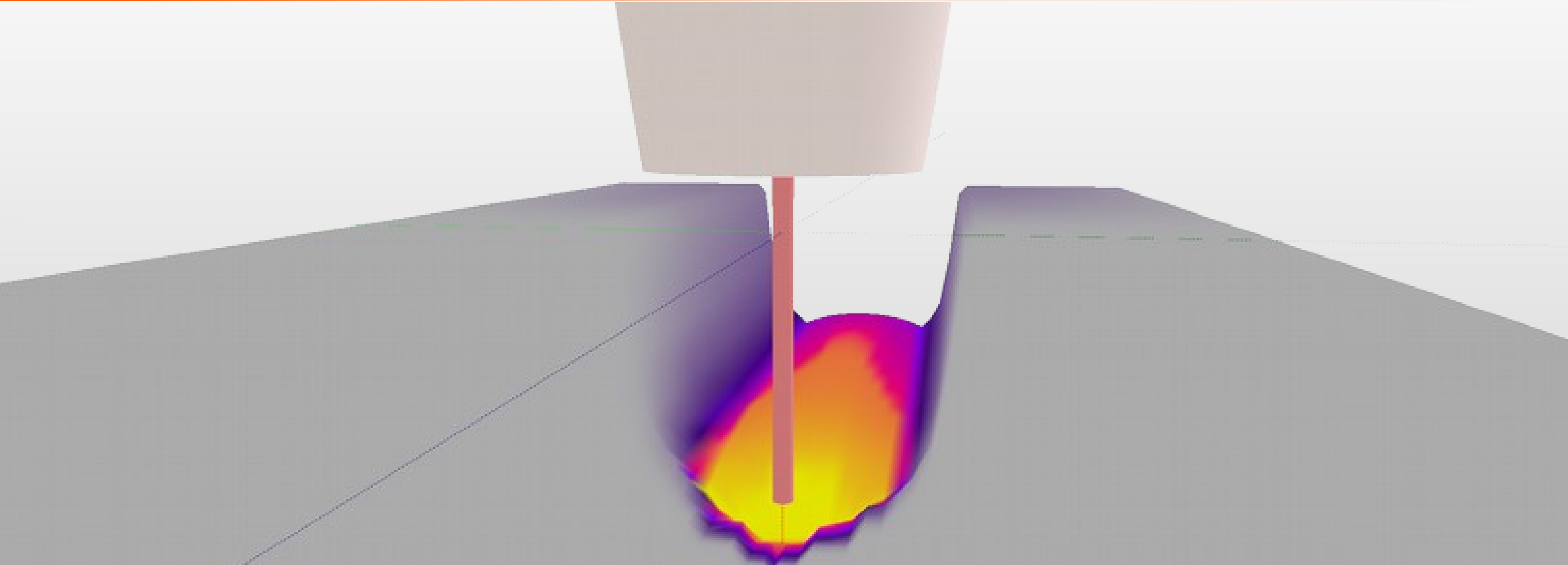
$$f_{Gol}(x, y, z) = KG \exp\left(-\left(x^2k_x + y^2k_y + z^2k_z\right)\right)$$

$$f_{MR4}(x, y, z) = KM \exp\left(-\left(x^2k_x + y^2k_y + z^2k_z\right)^2\right)$$

$$r_x = r_y = 2; r_z = 3; \quad c = 3; \quad k_x = \frac{c}{r_x^{\,2}}; \; k_y = \frac{c}{r_y^{\,2}}; \; k_z = \frac{c}{r_z^{\,2}};$$

$$b = (r_x \cdot r_y \cdot r_z)\pi^{1.5}; \quad KG = \frac{2c^{1.5}}{b}; \quad KM = \frac{2c^{1.5}}{b \cdot 0.691368};$$

improved aproach for the effect of fluid heat convection in the weld pool



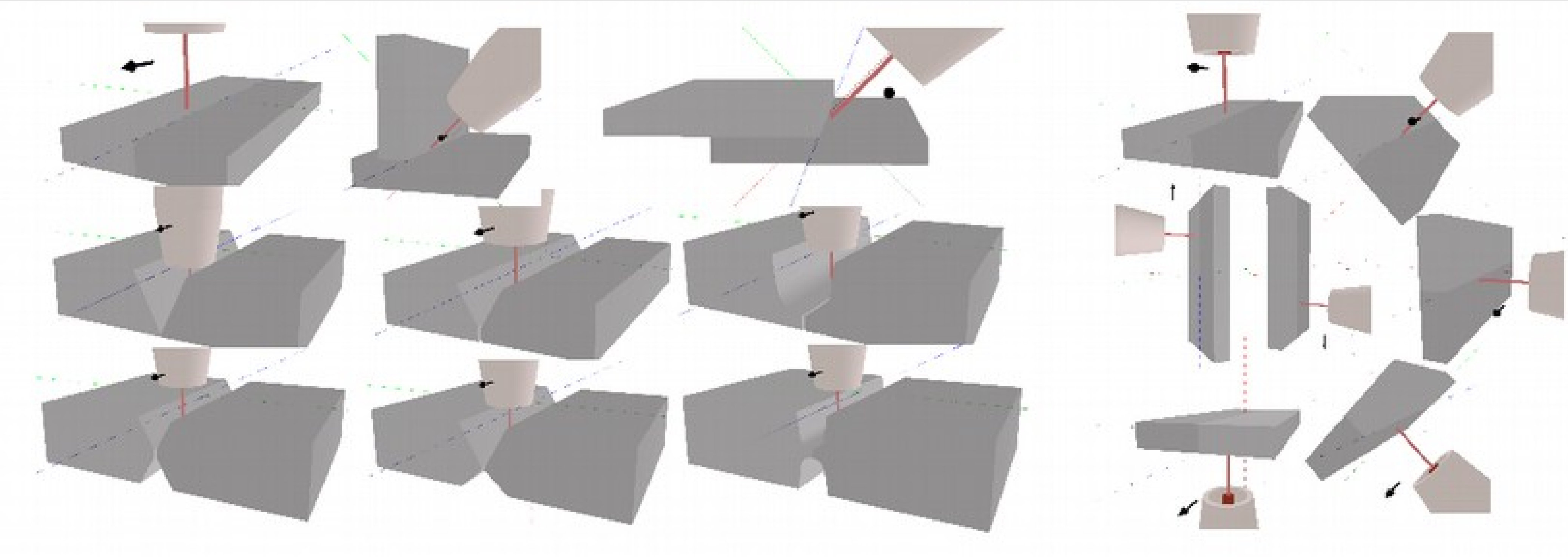
SimWeld

Process Simulation GMAW

Numerical Prediction of Equivalent Heat Source

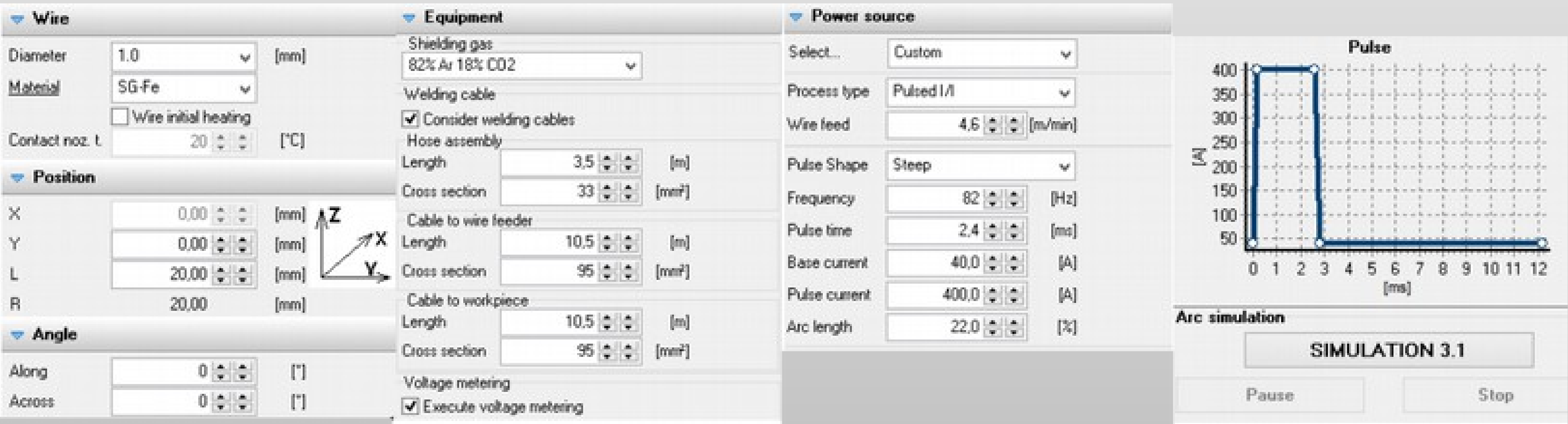
SimWeld Preprocessing

- Definition of:
  - weld preparation
  - geometry and geometric parameter
  - work position
  - material



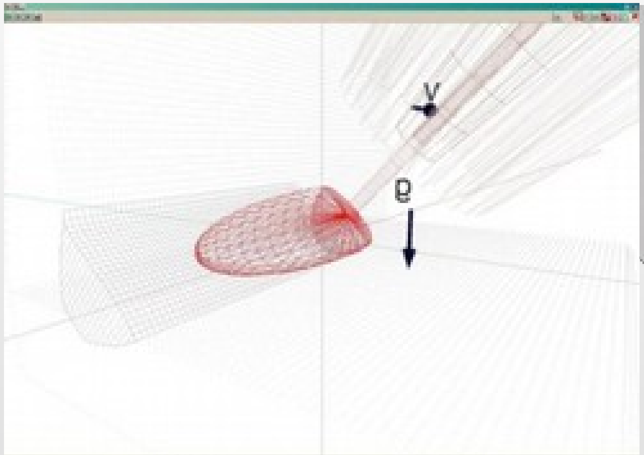
SimWeld Preprocessing

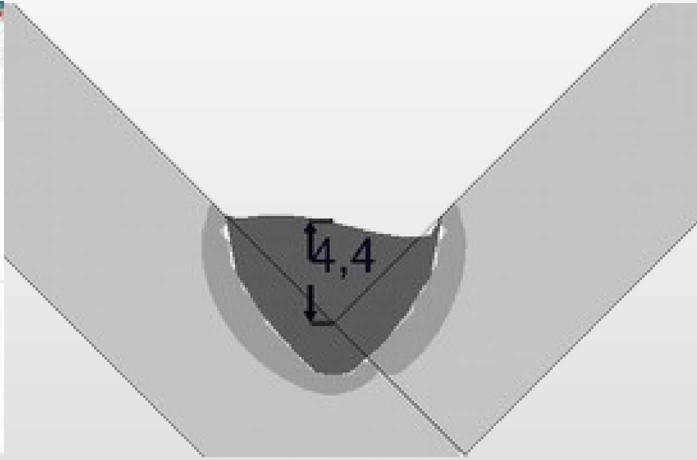
- Definition of:
  - wire: feed, diameter, material,
  - stick out
  - travel speed
  - angle of torch, stabbing, slabbing, skew
  - shielding gas
  - machine settings U, I
  - process type normal, pulsed U/I, pulsed I/I
  - pulse parameter

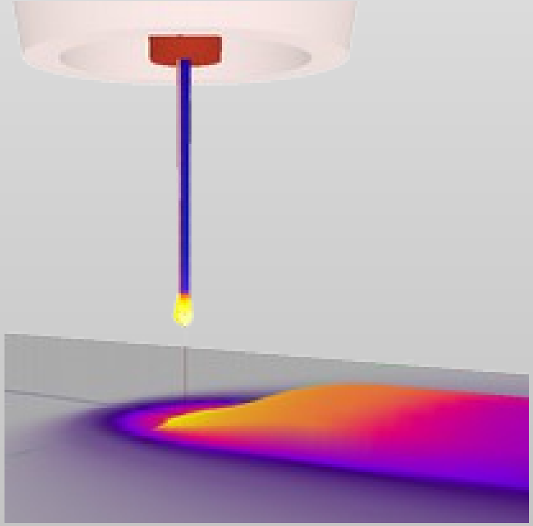


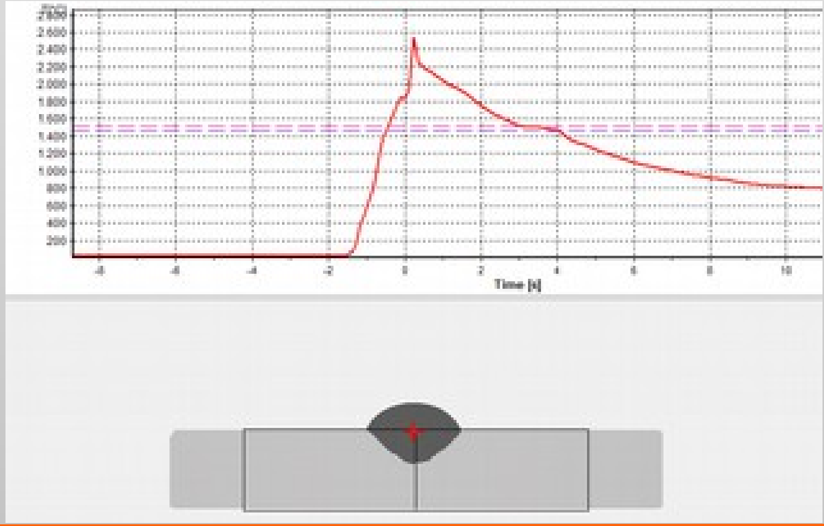
SimWeld Results

- **Equivalent Heat Source**
- Weld Pool Geometry
- Droplet
- Wire Temperature
- Energy, Voltage, Currency
- Temperature Curve

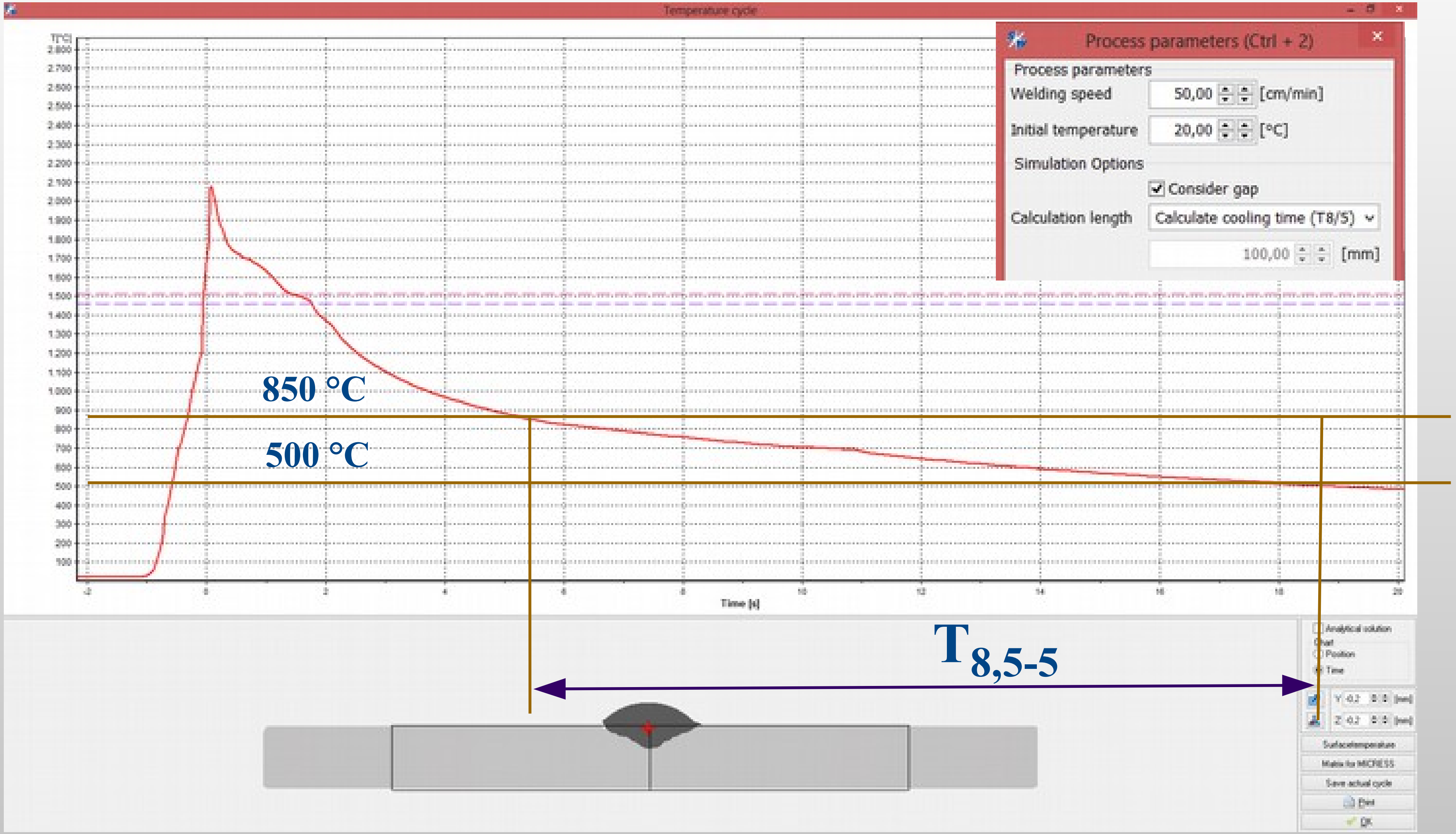


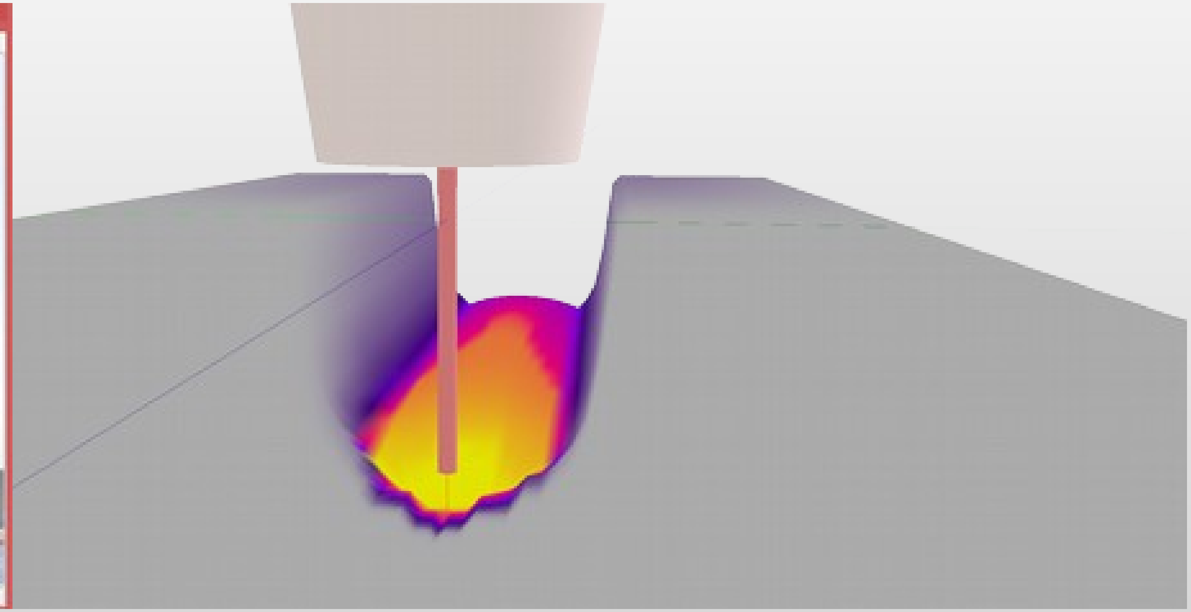






Simulation Time till end of $T_{8,5-5}$





Interface

WeldWare - SimWeld

Prediction of Weld Quality

extended Quality Assurance

Material Specification
Chemical Composition

↓

WeldWare®

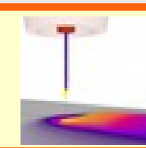
↓

Material Analysis
***wwd-File**

WPS
Welding Procedure Specification

↓

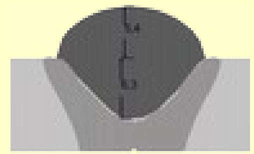
SimWeld

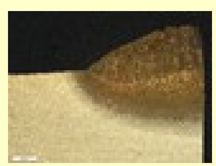


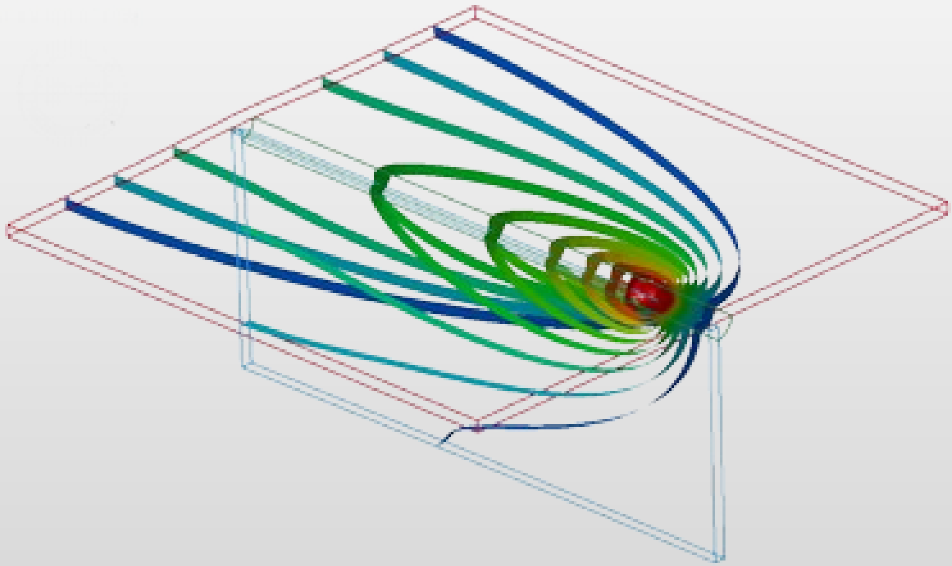
↓

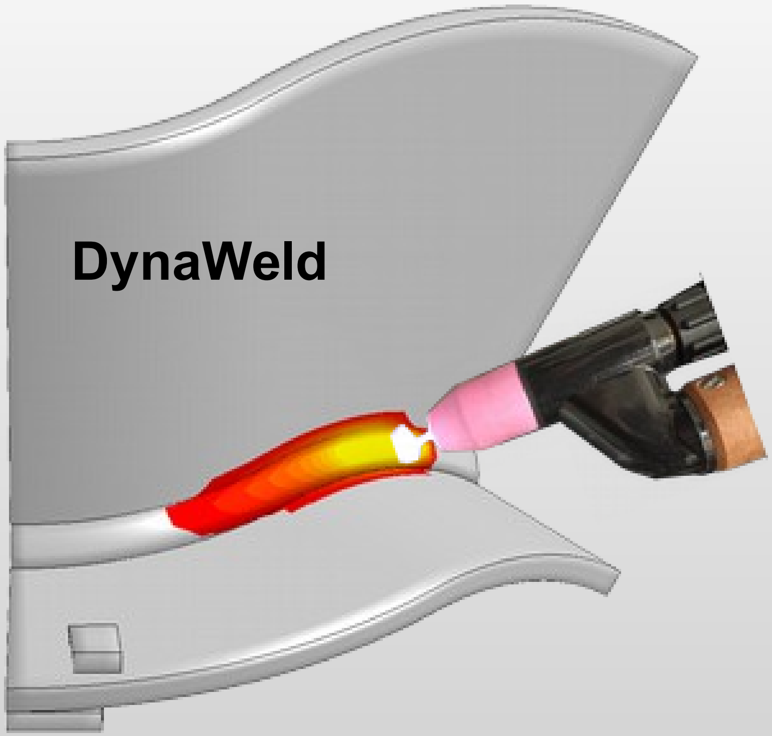
Thermal Analysis
Temperature Rate

- **Weld-Pool**
- **HAZ**
- **Microstructure**
- **Yield Strength**
- **Ultimate Strength**
- **Hardness**
- **Ultimate Elongation**









DynaWeld

Welding and Heat-Treatment with LS-DYNA

Distortion – Restidual Stress - Microstructure

DynaWeld

The Idea for an efficient Preprocessor for Welding tasks

Add On and compatible to existing Pre-Processor

Define trajectory quick and easy

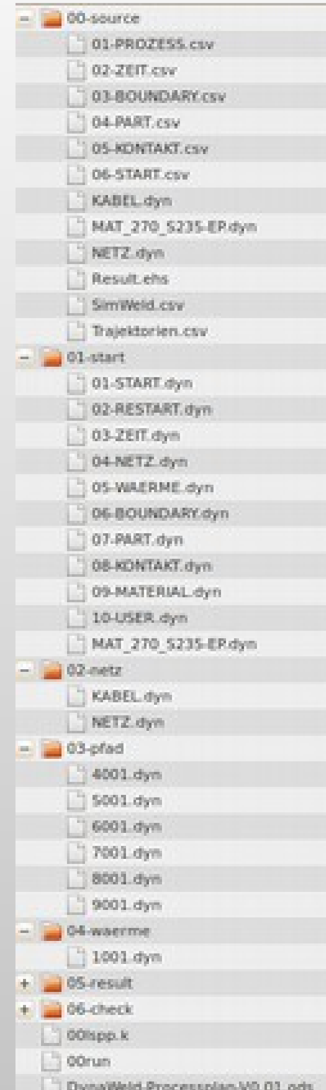
Definition and Dokumentation of the simulation Model in one spreadsheet-file

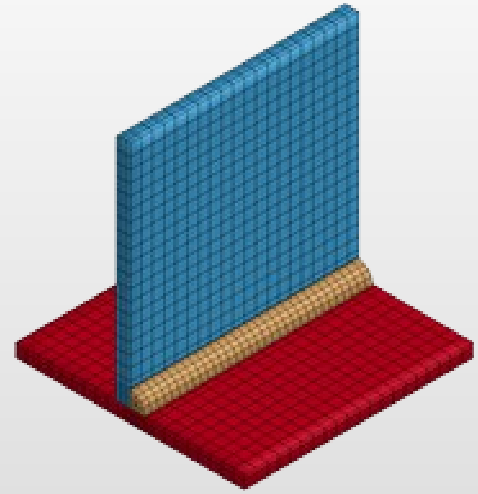
Every data in readable and editable ascii- / csv-format

Editable keyword-files with the ability of user extentions

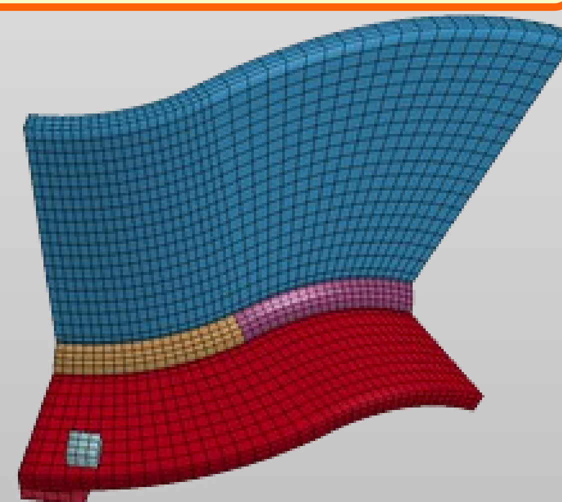
Strong name convention for files and IDs but minimised clicks

Setup-Tool for Engineers to minimise work time



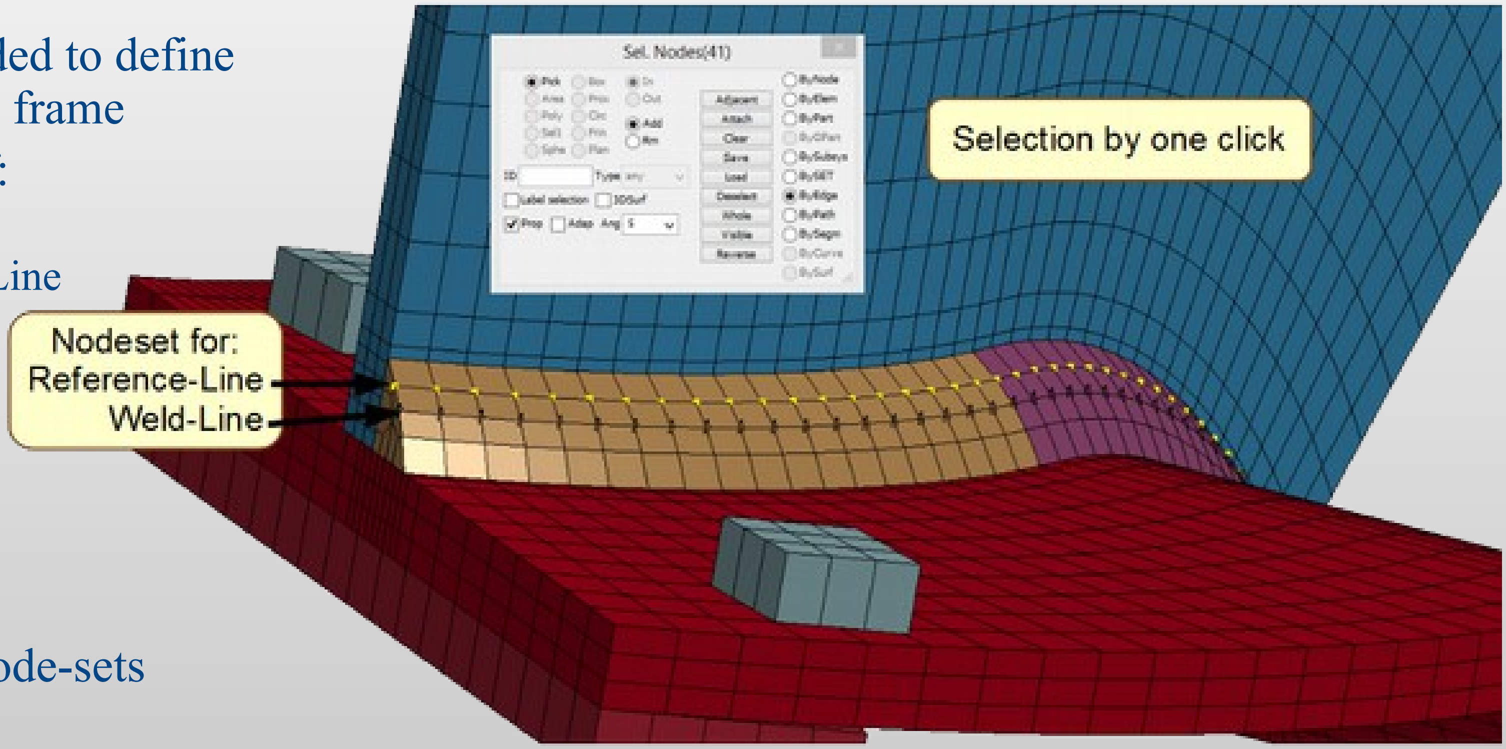


Structured input deck with quick acess



Weld Path

- The definition of welding heat input consist of:
  - Location: Weld Path
  - Energy: Heat Source
- Two trajectories are needed to define a local moving reference frame
- The weld path consist of:
  - Trajektory Weld-Line
  - Trajectory Reference-Line
  - Time information:
    - start
    - velocity

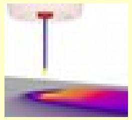


- DynaWeld uses sorted node-sets to define the trajectories
- DynaWeld sorts unsorted node-sets
- Definiton of node-sets in LSPrePost with option „By PATH“ or „By EDGE“
- DynaWeld calculates the length of the trajectory and its number of Elements

Process Plan

with import of SimWelds equivalent heat source

SimWeld
heat source import



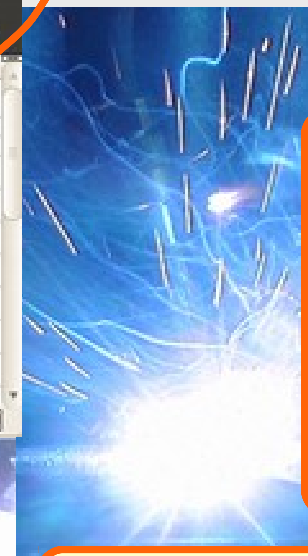
Process	v	Q	af	ar	b	c	ff	fr
	mm/s	W	mm	mm	mm	mm	-	-
0	3	8	9	10	11	12	13	14
*	*	*	*	*	*	*	*	*
SimWeld.ehs	4,167	5525,822	3,455	23,547	5,455	8,848	1,113	0,887

DynaWeld-Processplan-V0.01.ods - LibreOffice Calc

DynaWeld – Process plan

Process nr.	Weld ID	Length	v	Duration	Start	End	PAUSE	Q
		mm	mm/s	s	s	s	s	W
0	1	2	3	4	5	6	7	8
*	*	*	*	*	*	*	*	*
1	1001	55,65987	4,16666667	13,3584	1000,0000	1013,3584	5,0000	5525,8223
2	1002	74,21316	4,16666667	17,8112	1018,3584	1036,1695	5,0000	5525,8223

01-PROZESS / 02-ZEIT / 03-BOUNDARY / 04-PART / 05-KONTAKT / 06-START



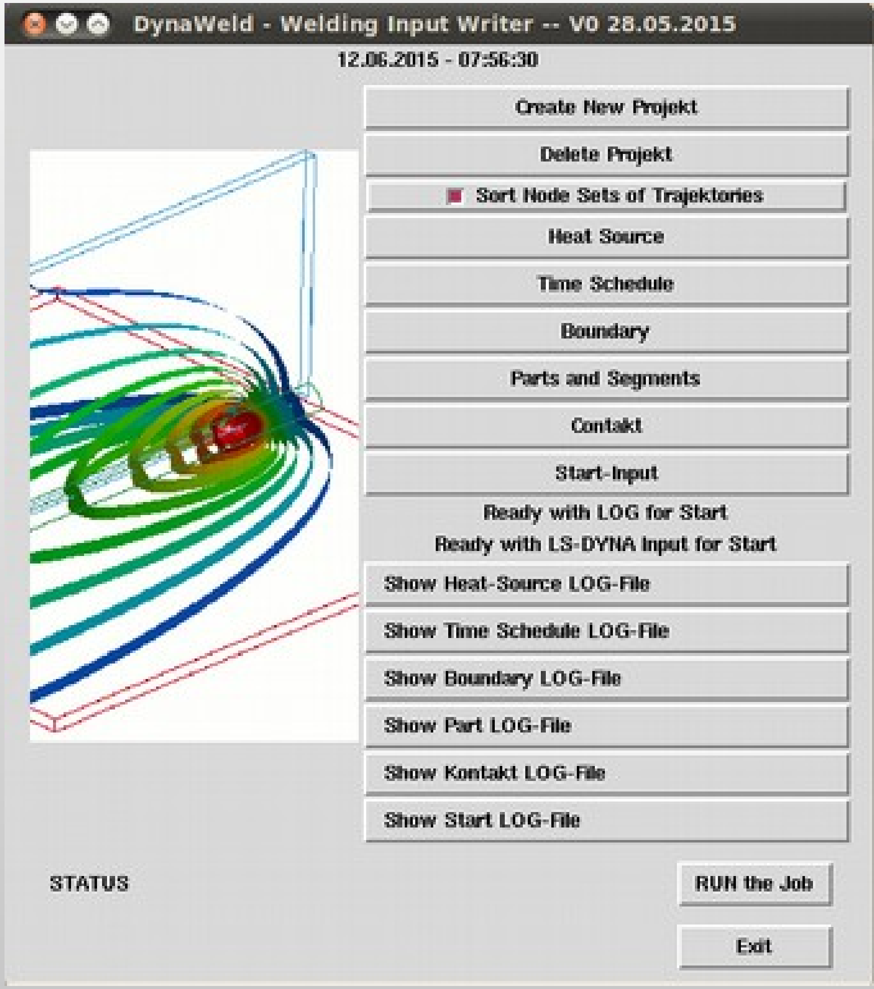
Components

Welds

Clamps

- ProcessPlan
  - Complete Information of Welding Tasks
  - Complete Information of Clamps
  - Documentation of the Simulation

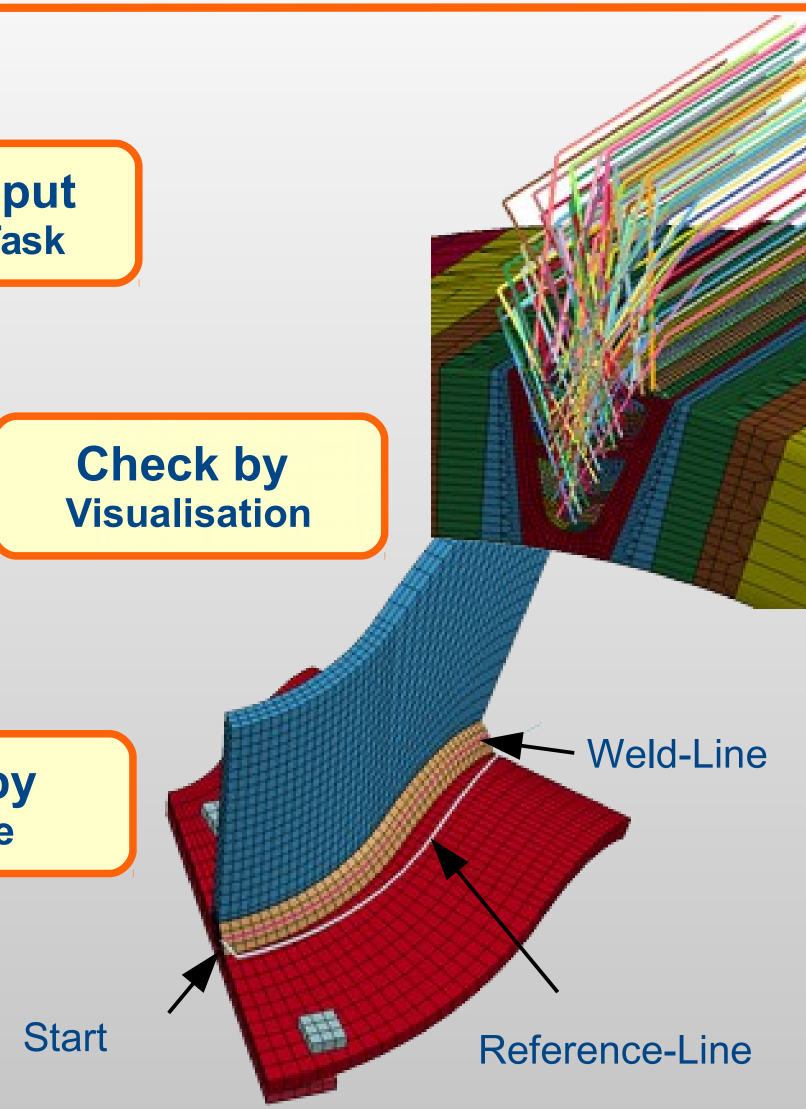
Input Deck Creation and Check Options



Create Input Task by Task

Check by Visualisation

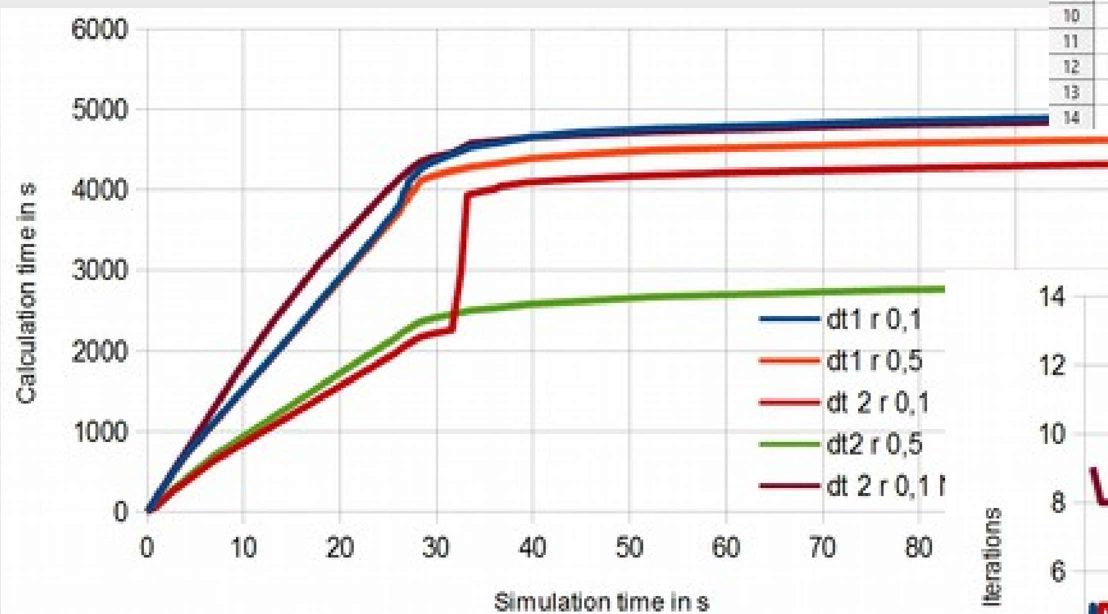
Check by Log-File



DynaWeld - Performance Analyse

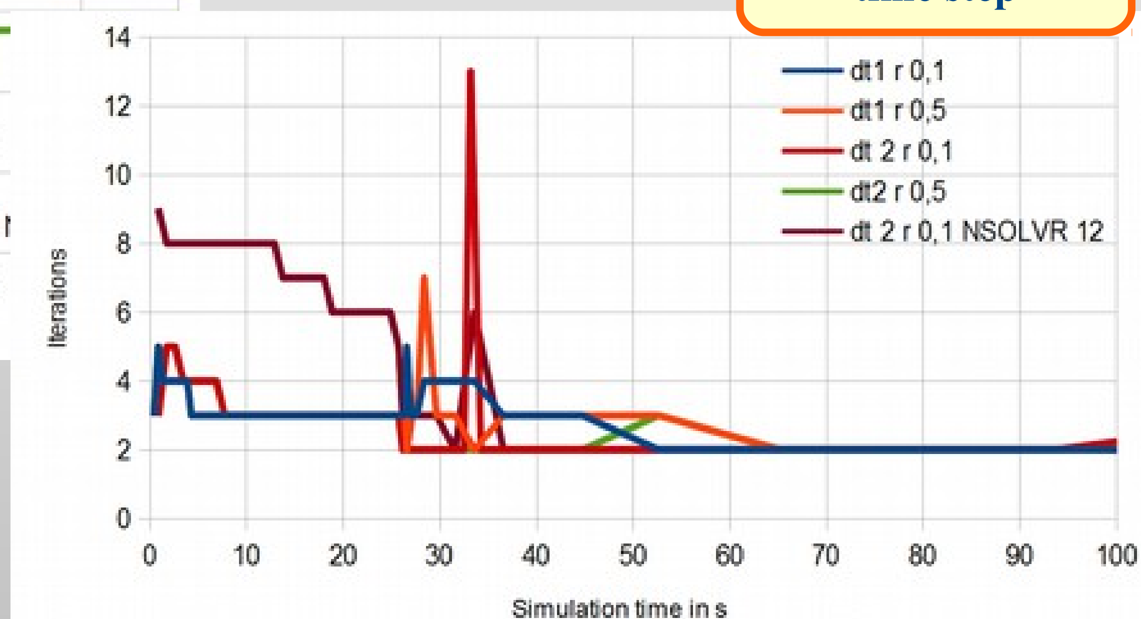
Performance Analysis Sheet

	A	B	C	D	E	F	G
1		#===#					
2		(c) Ingenieurbuero Tobias Loose # www.loose.at - www.tl-ing.eu					
3		Datum: 12.05.2015 - 11:02:14					
4		#===#					
5	Step ID	real time	time since start	simulation time	time step	iteration	retry steps
6	-	TT:MM:JJJJ HH:MM:SS	s	s	s	-	-
7							
8	0	11:05:2015 18:35:55	0	0,00			
9	1	11:05:2015 18:36:44	49	0,43	0,43	3	0
10	2	11:05:2015 18:38:26	151	0,86	0,43	5	0
11	3	11:05:2015 18:39:44	229	1,29	0,43	4	0
12	4	11:05:2015 18:41:01	306	1,71	0,43	4	0
13	5	11:05:2015 18:42:18	383	2,14	0,43	4	0
14	6	11:05:2015 18:43:36	461	2,57	0,43	4	0



Simulation Performance

Iterations per time step



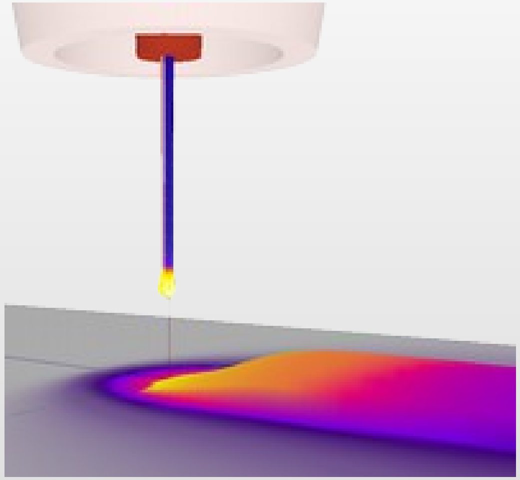
Workflow of a welding project with SimWeld and DynaWeld

Meshing

Trajectories

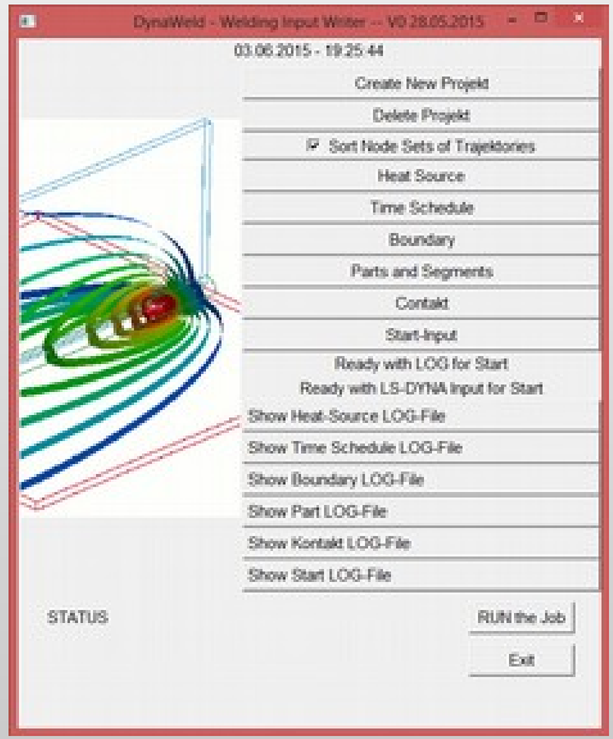
WPS Heat Source

Process Plan



SimWeld

DynaWeld



New Project

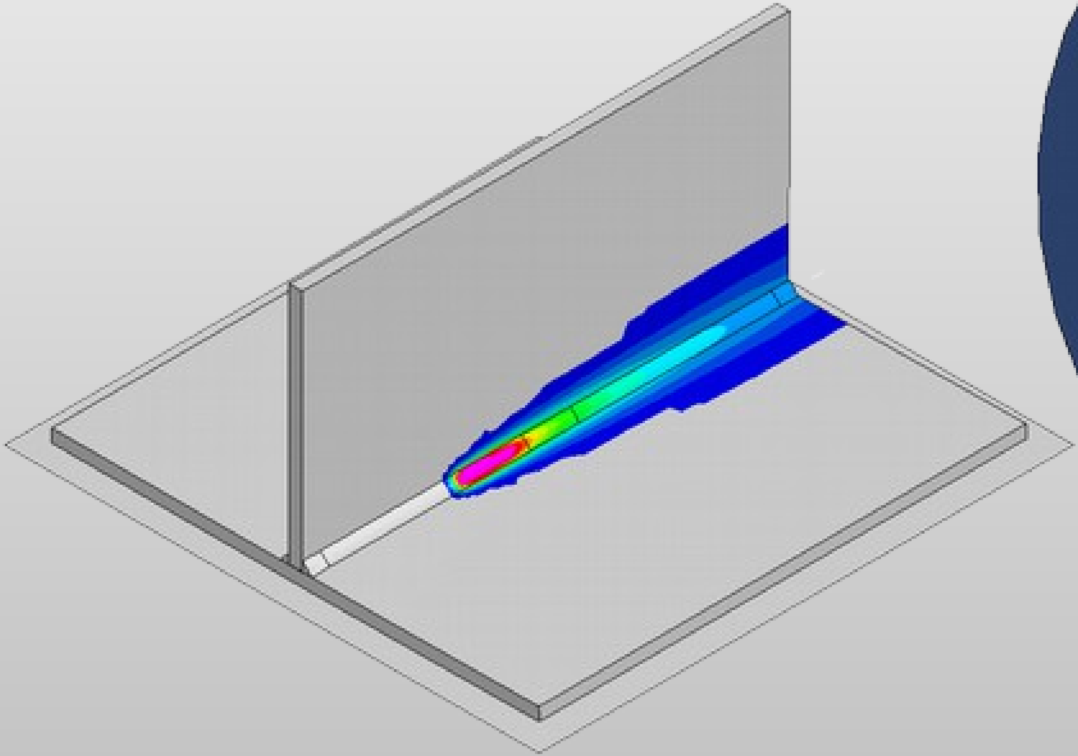
Create

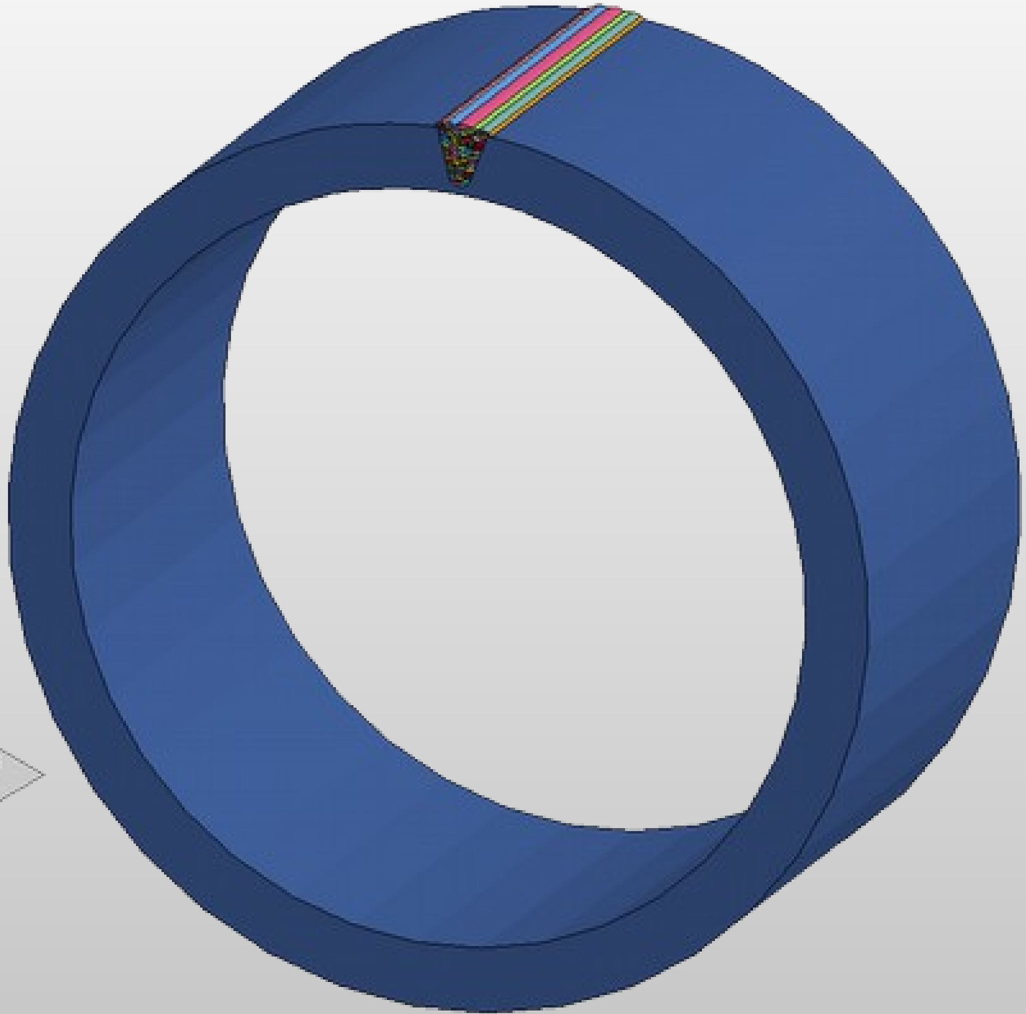
Check

R U N

N o r m a l   t e r m i n a t i o n

Examples

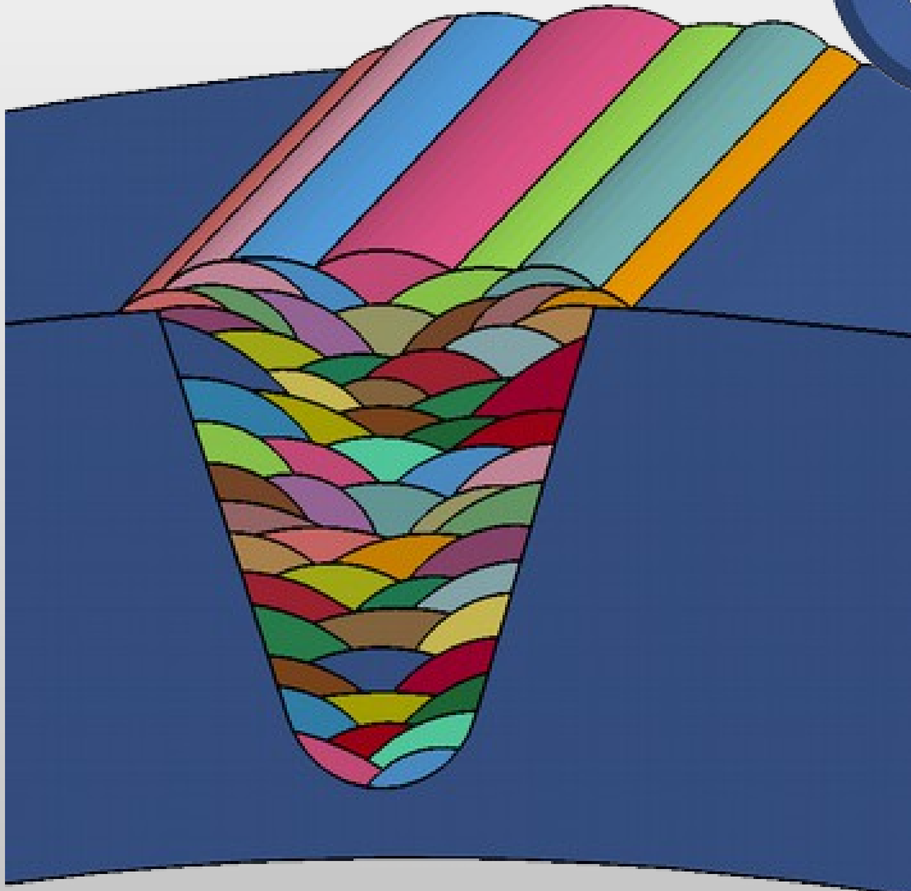


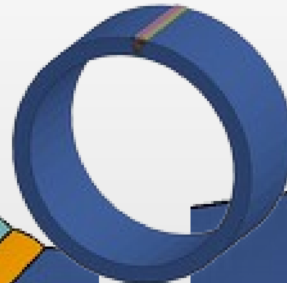


Weld of a Pipe with 40 mm Wall Thickness

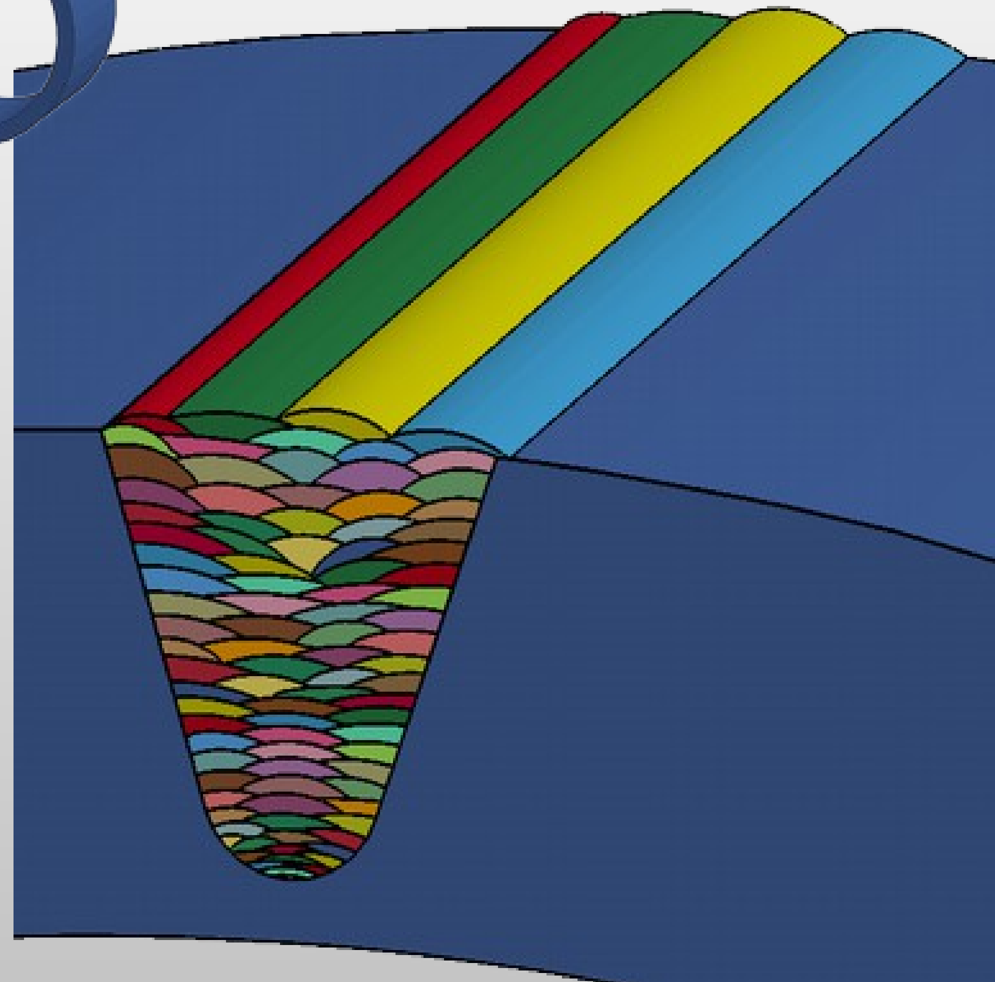
made of Alloy 625

60 Layer - GMAW



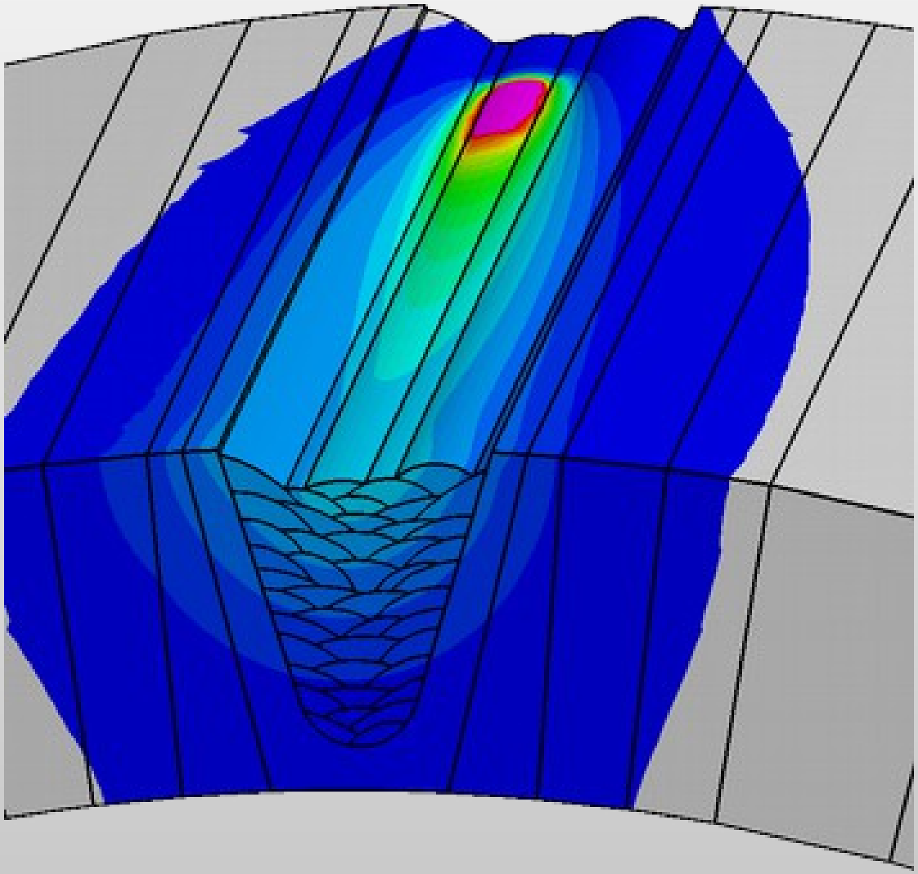


93 Layer - TIG

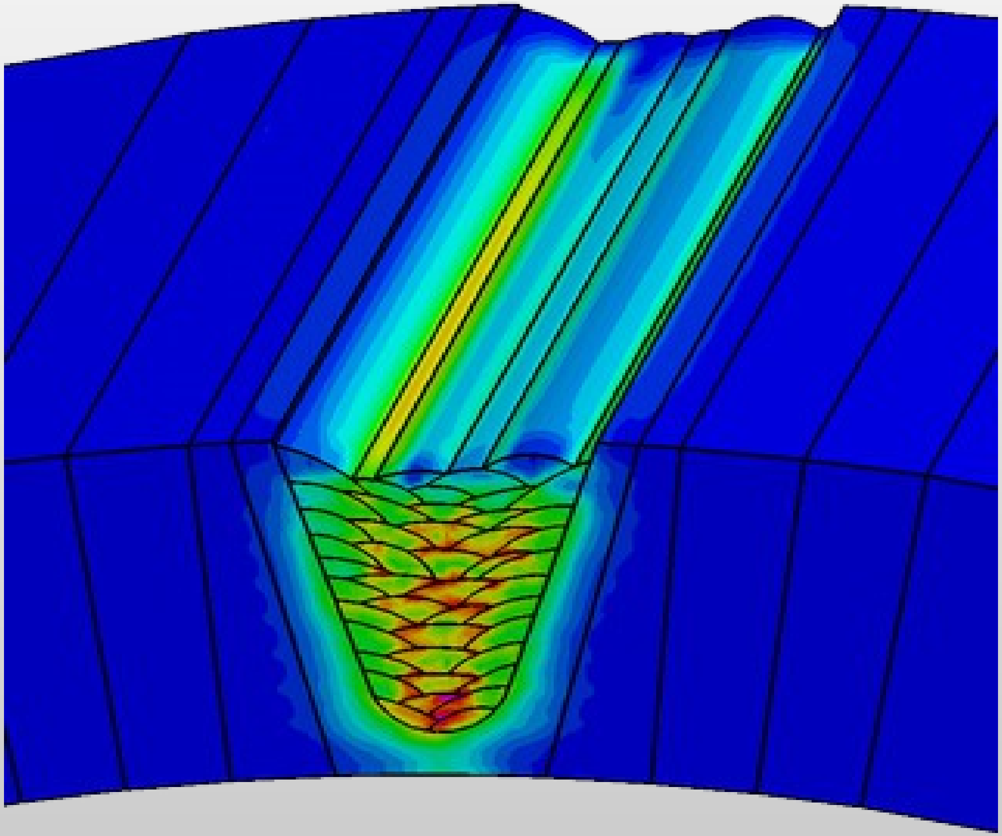


Weld of a Pipe with 40 mm Wall Thickness
made of Alloy 625 - 60 Layer GMAW

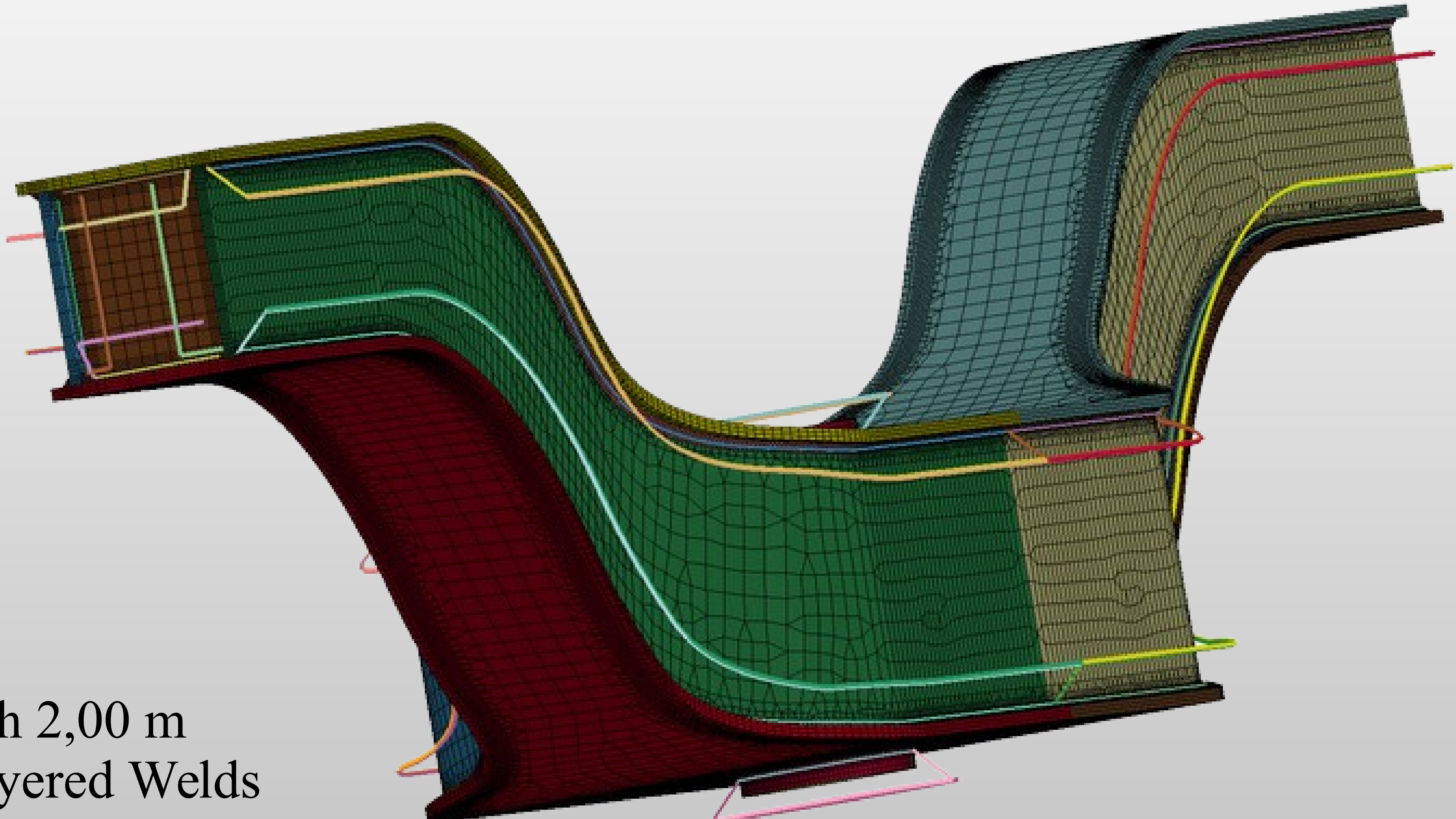
Temperature Layer 44



Equivalent Plastic Strain

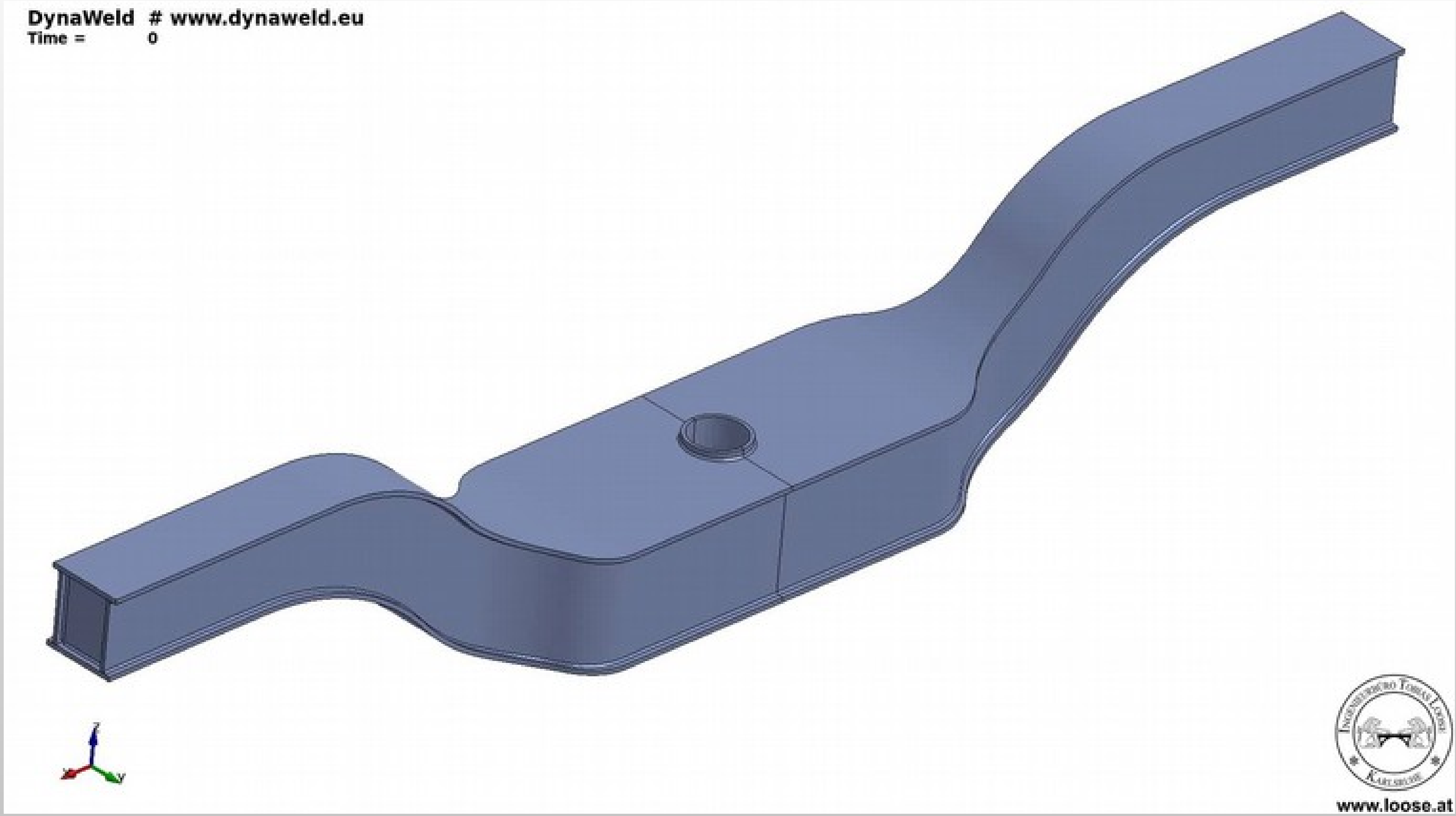


Curved Hollow Section Beam



Length 2,00 m
8 2-layered Welds
12 single layered Welds

Animation of Welding




Thanks
for your
Attention!