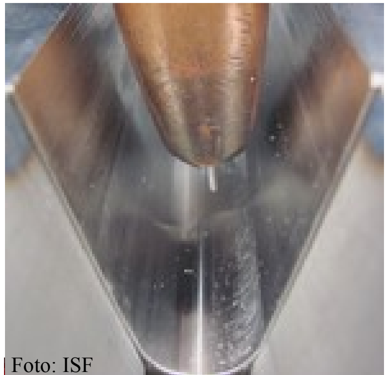
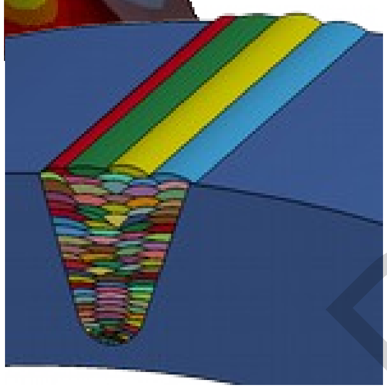


Foto: ISF



Efficient Setup and Documentation

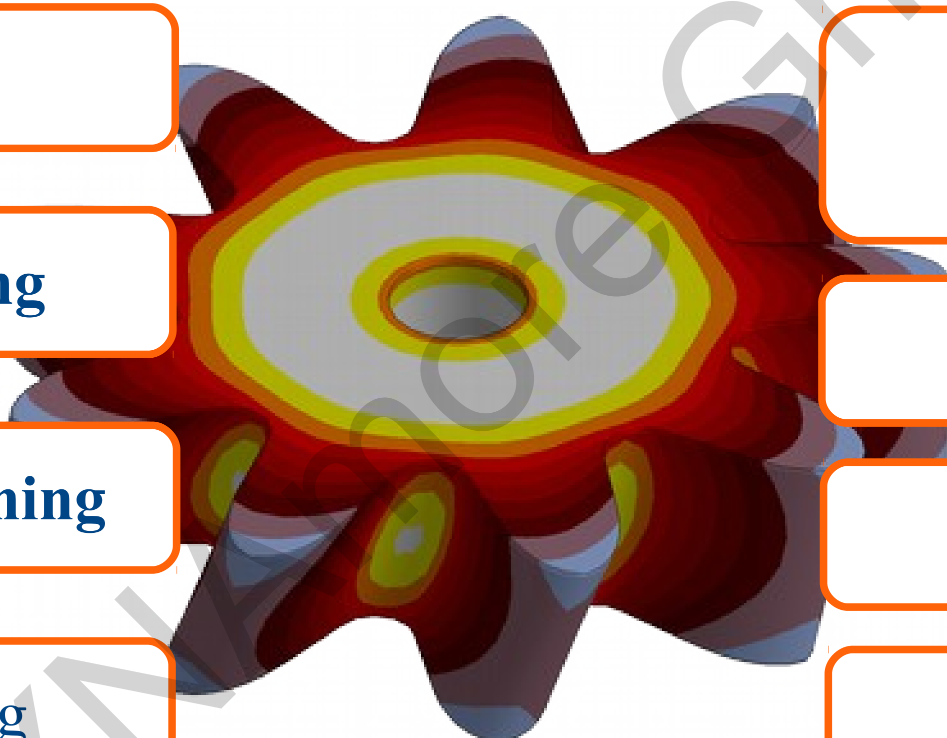
of Simulations for Welding and Heat Treatment with DynaWeld

LS-Dyna Forum Bamberg
10.10.16 till 12.10.16

Tobias Loose
Ingenieurbüro Tobias Loose, Herdweg 13, D- 75045 Wössingen,
loose@tl-ing.de www.tl-ing.eu

Heat treatment overview

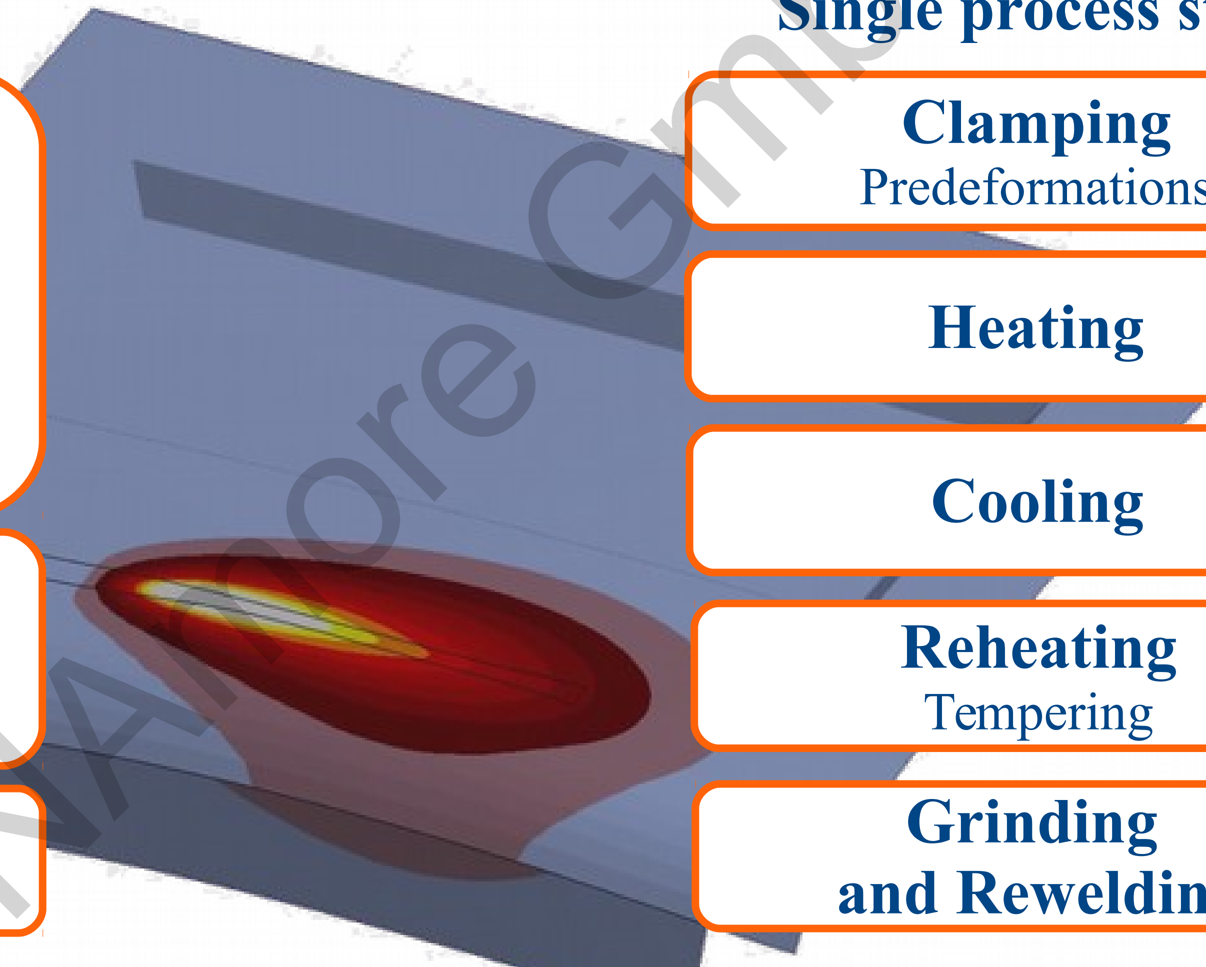
Type of heat treatment	Single process steps
Quenching	**Heating** Thermal Heating Inductive Heating
Case Hardening	**Carburisation**
Inductive hardening	**Quenching**
Press hardening	**Tempering**



Design of properties by local change of material properties and microstructure

Welding overview

welding structure analysis



Type of Welding

Weld Process Type

- Arc Welding
- GMAW, SAW, TIG
- Laser
- Electron Beam
- GMAW-Laser-Hybrid
- Resistive Welding, RSW

single or multi layered welds, tack welds

Dimension
10 µm .. 500 mm

Single process steps

Clamping
Predeformations

Heating

Cooling

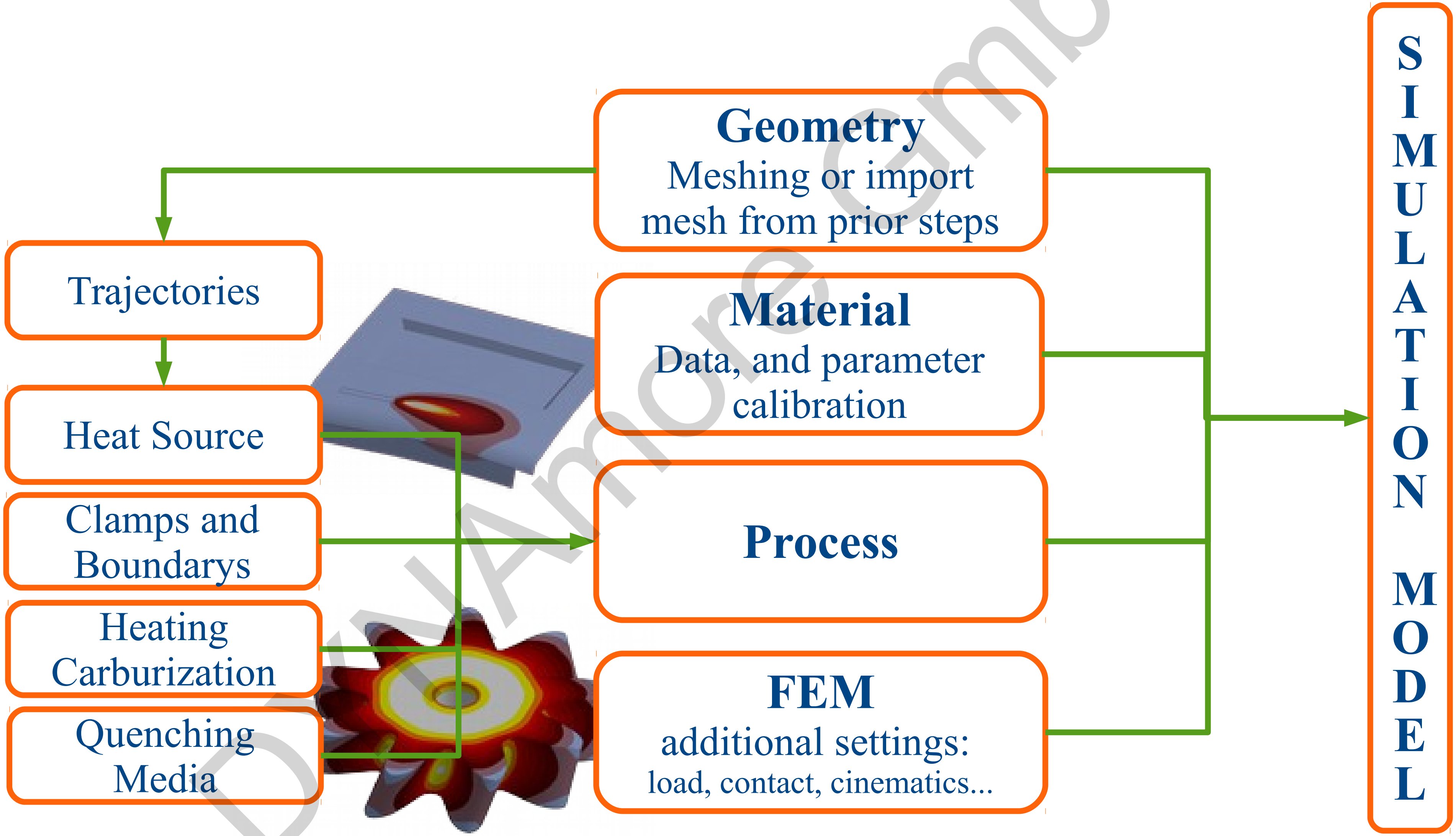
Reheating
Tempering

Grinding and Rewelding

Distortion - Residual Stress - Material Properties after Welding

Substructuring of models

for welding and heat treatment



Benefit of sub structuring

Complex simulation task with many disciplines

easy to mange by task sharing

outsourcing single tasks

Material specialist

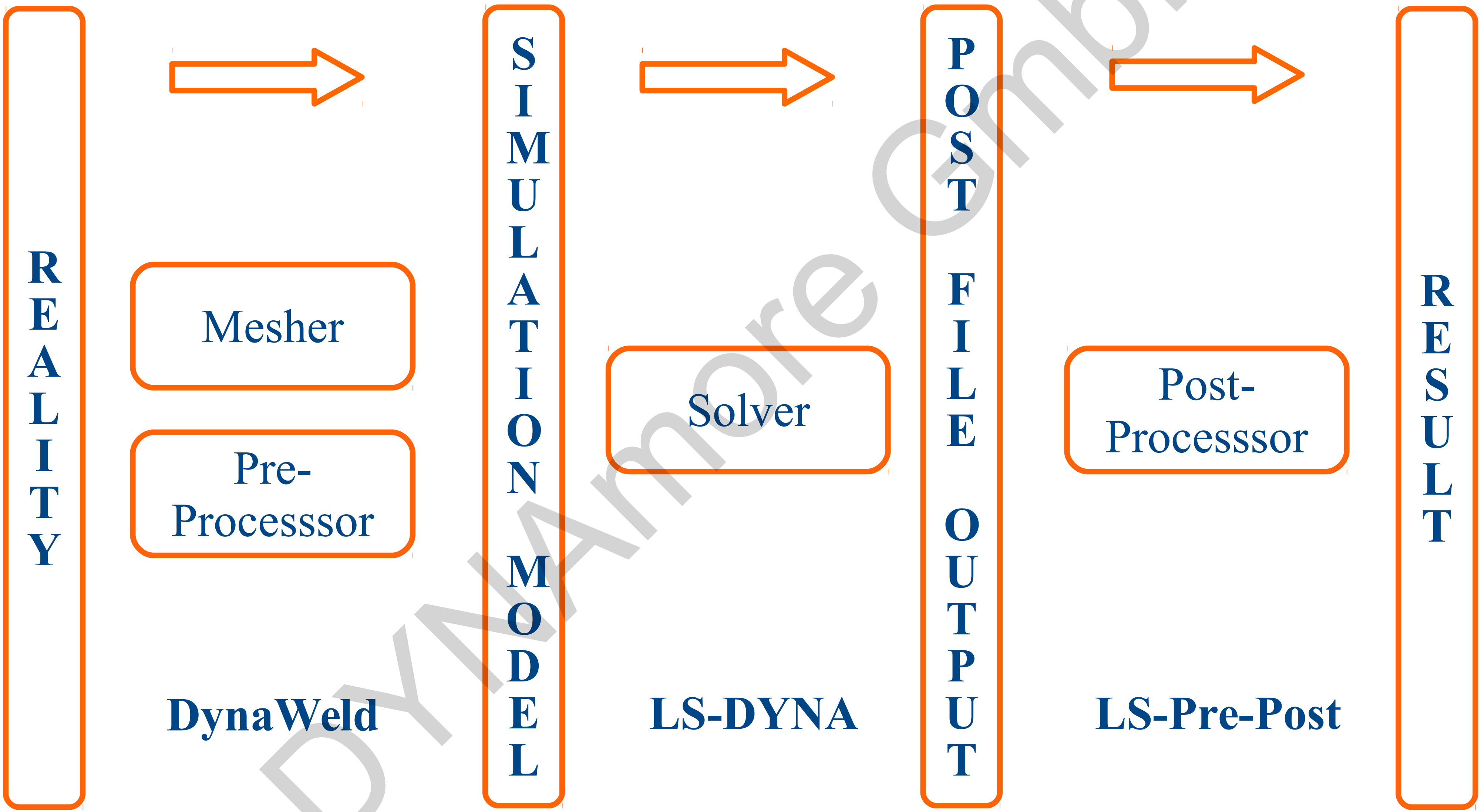
Mesh specialist

FEM specialist

Welding specialist

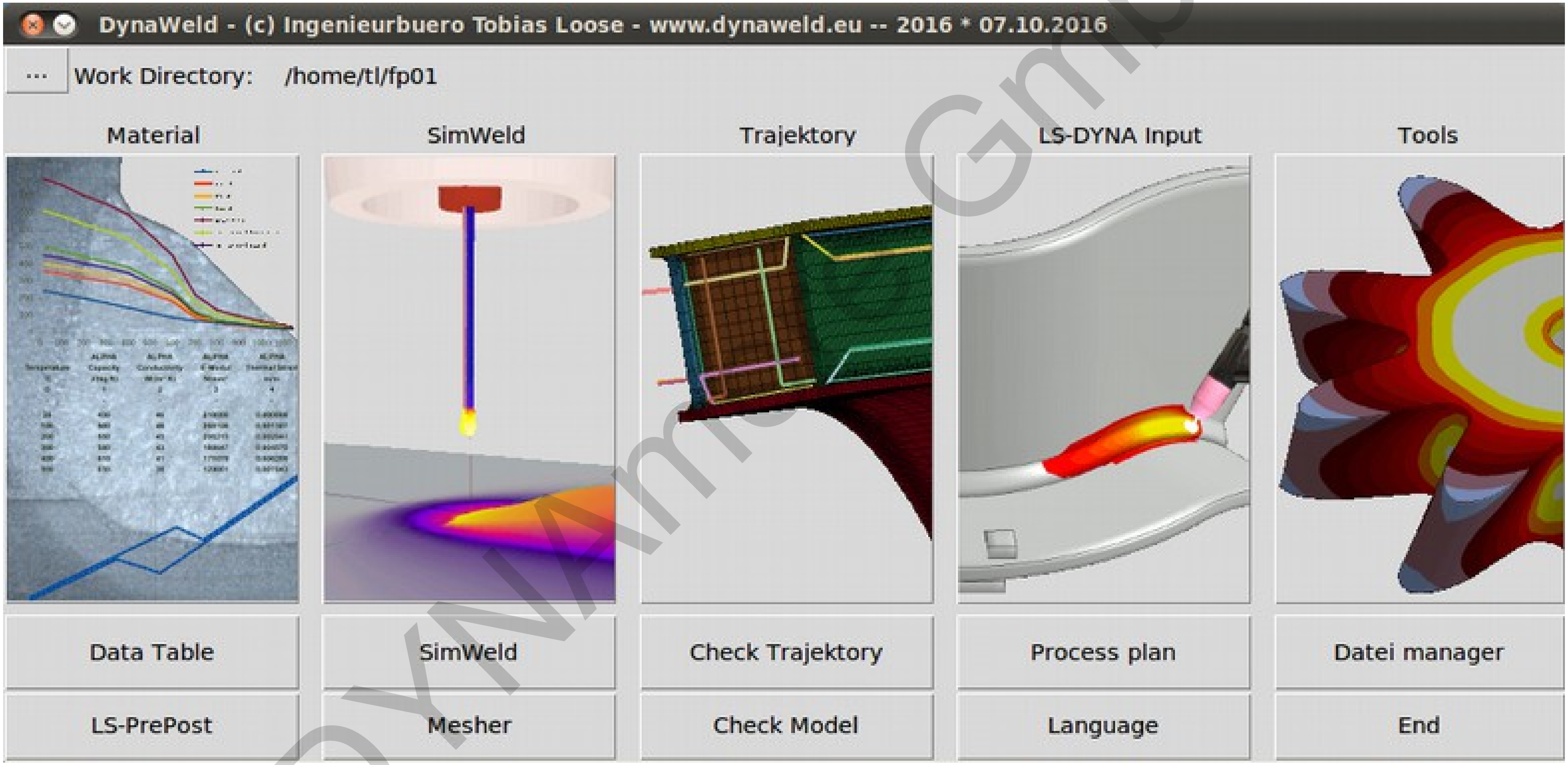
Heat Treatment specialist

Definition of simulation steps



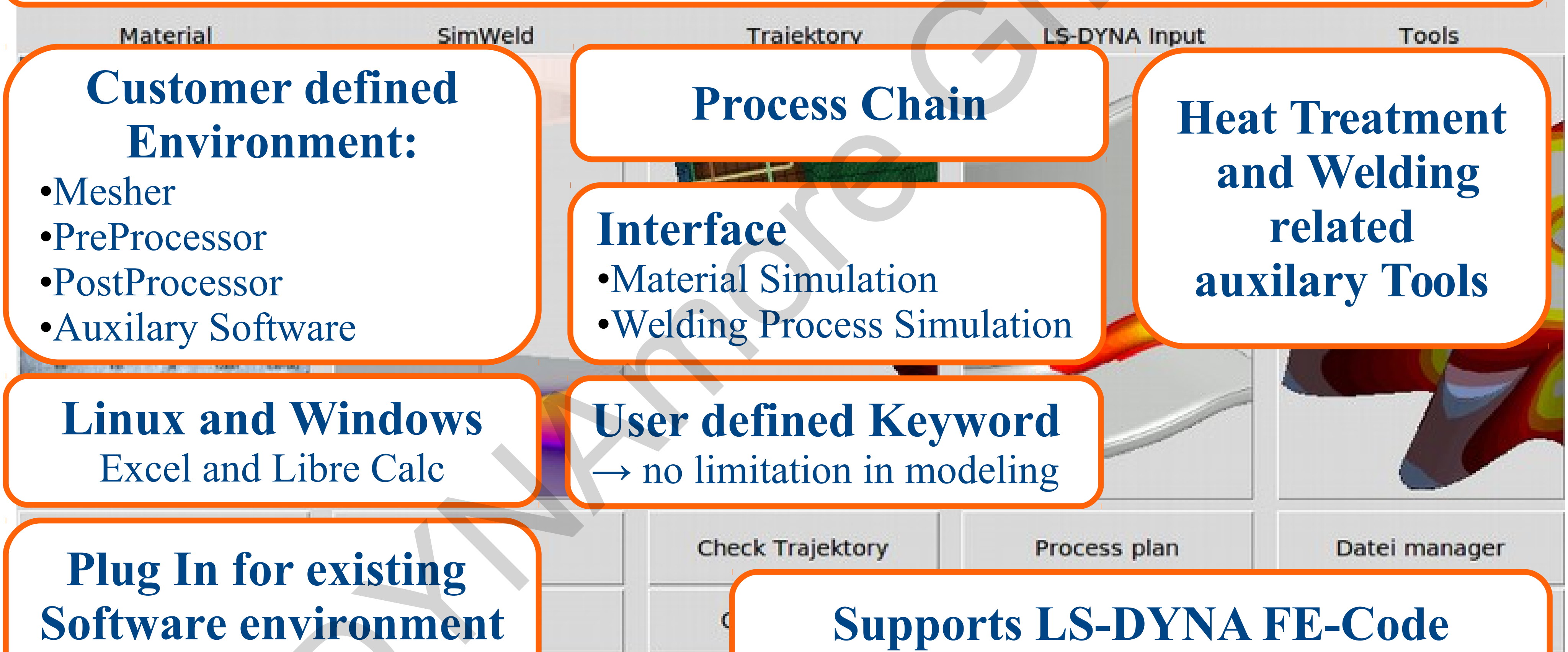
DynaWeld repesents a simulation environment with special preprocessors

DynaWeld
environment and preprocessor



DynaWeld
environment and preprocessor

DynaWeld is not an Island-Solution!



Customer defined Environment:
- Mesher
- PreProcessor
- PostProcessor
- Auxilary Software

Process Chain

Interface
- Material Simulation
- Welding Process Simulation

Heat Treatment and Welding related auxilary Tools

Linux and Windows
Excel and Libre Calc

User defined Keyword
→ no limitation in modeling

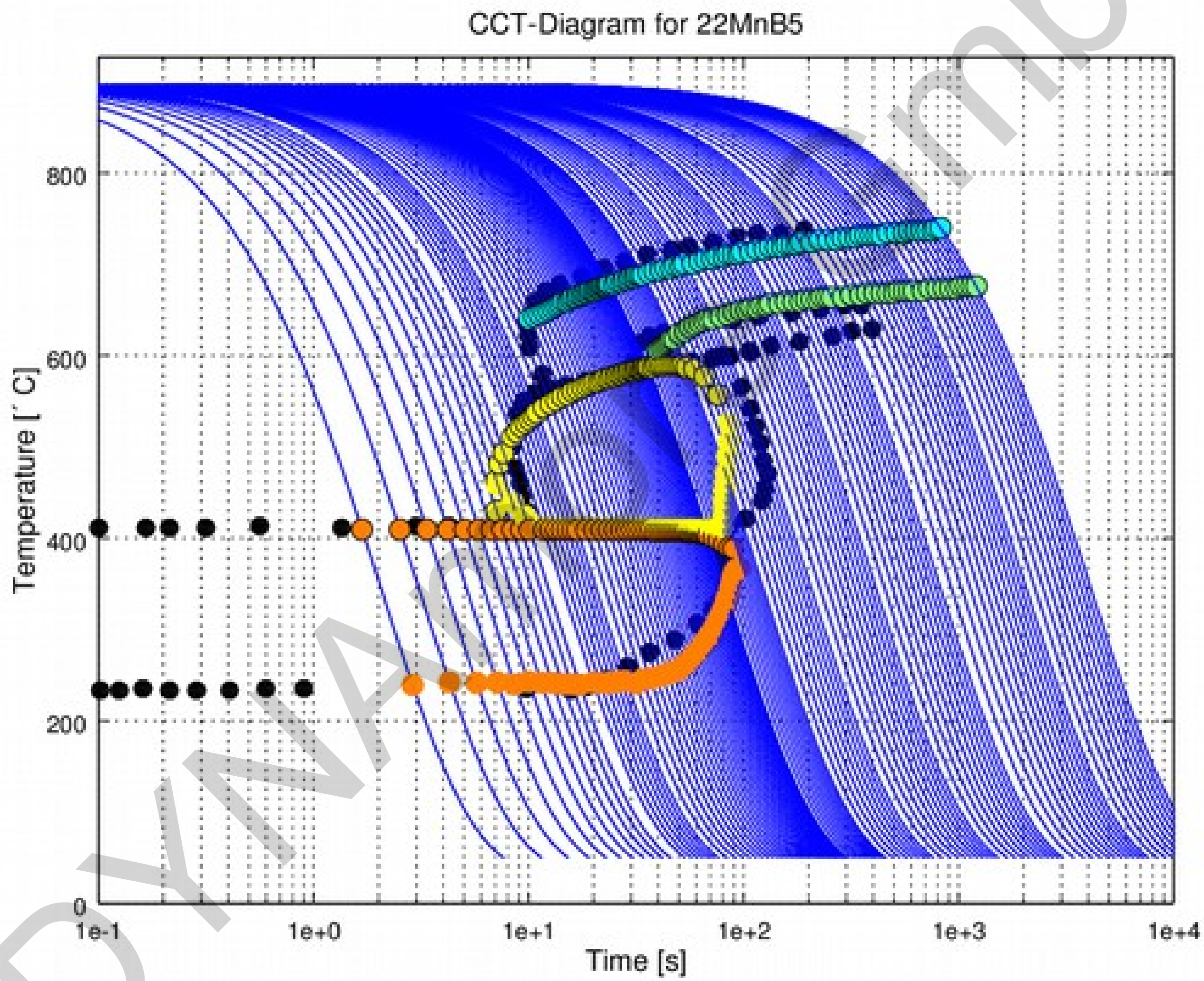
Plug In for existing Software environment as well as stand alone

Supports LS-DYNA FE-Code
one Code - many Solvers - one License Fee

Material

Foto: Edyta Łopatecka

Phase transformation during cooling
CCT-diagram



Quelle: Bernd Hochholdinger, DYNAmore Swiss

Phase kinetic models

Law:
Koinstinen-Marburger

Parameter:

T_{start}:	Start Temperature	MS
α:	kinetic faktor	KM

Use:
f(temperature)
diffusionless transformation

Austenit → Martensit

$$x_b = x_a\left(1.0 - e^{-\alpha(T_{start}-T)}\right)$$

Phase kinetic models

Law:
generalized JMAK
Jonhson-Mehl-Avrami-Kolmogorov

based on Avrami equitation extended by Leblond

Parameter:

x_{eq}:	Proprotion at equilibrium (T)	PEQ
n:	form parameter (T)	N
τ:	kinetic faktor (T)	TAU
f,f':	Leblond factor (dT/dt)	F, F'

Use:
f(temperature, temperture gradient, time)
diffusion-driven transformation
Austinitisation, Tempering
Austenite → Ferite, Perlite, Bainite
phase transformation Aluminium

$$\frac{dx_b}{dt} = n(T)(k_{ab}x_a - k'_{ab}x_b)\left(\ln\left(\frac{k_{ab}(x_a + x_b)}{k_{ab}x_a - k'_{ab}x_b}\right)\right)^{\frac{n(T)-1.0}{n(T)}}, \quad k_{ab} = \frac{x_{eq}(T)}{\tau(T)} f(\dot{T}), k'_{ab} = \frac{1.0 - x_{eq}(T)}{\tau(T)} f'(\dot{T})$$

Advantage:
no limitation on material type nor chemical composition. Fitting according:
temperatur(T) and temperature rate(dT/dt)

Disadvantage:
needs calibration
on existing CCT or TT

Materials with phase kinetic models in LS-DYNA

*MAT_254 / *MAT_GENERALIZED_PHASE_CHANGE

Heat treatment
Welding

all materials

Laws:

Koinstinen Marburger
Oddy
Kirkaldy
generalized JMAK
Time criterium
list might be extended

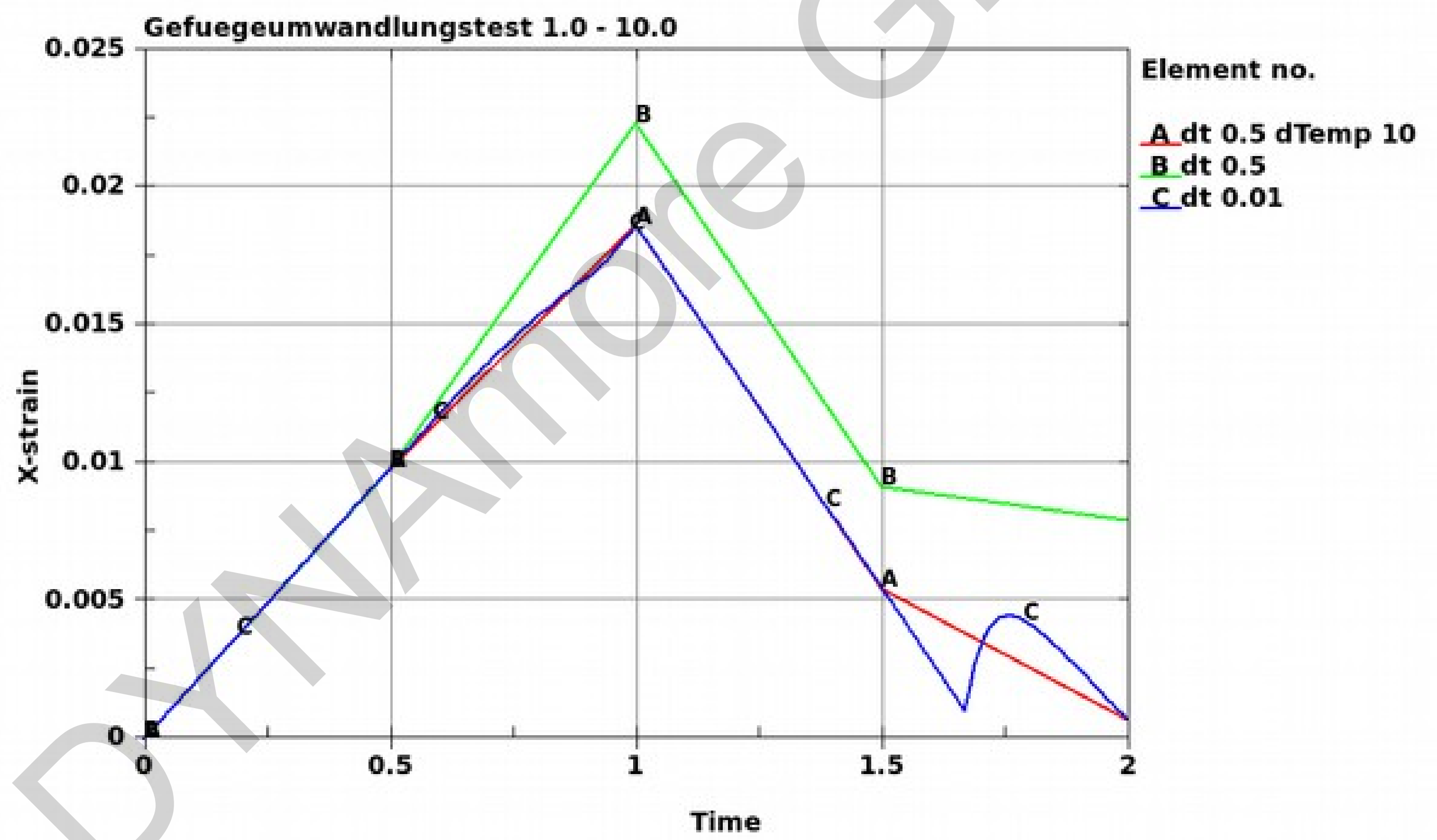
userdefined
assignment of laws

Features:

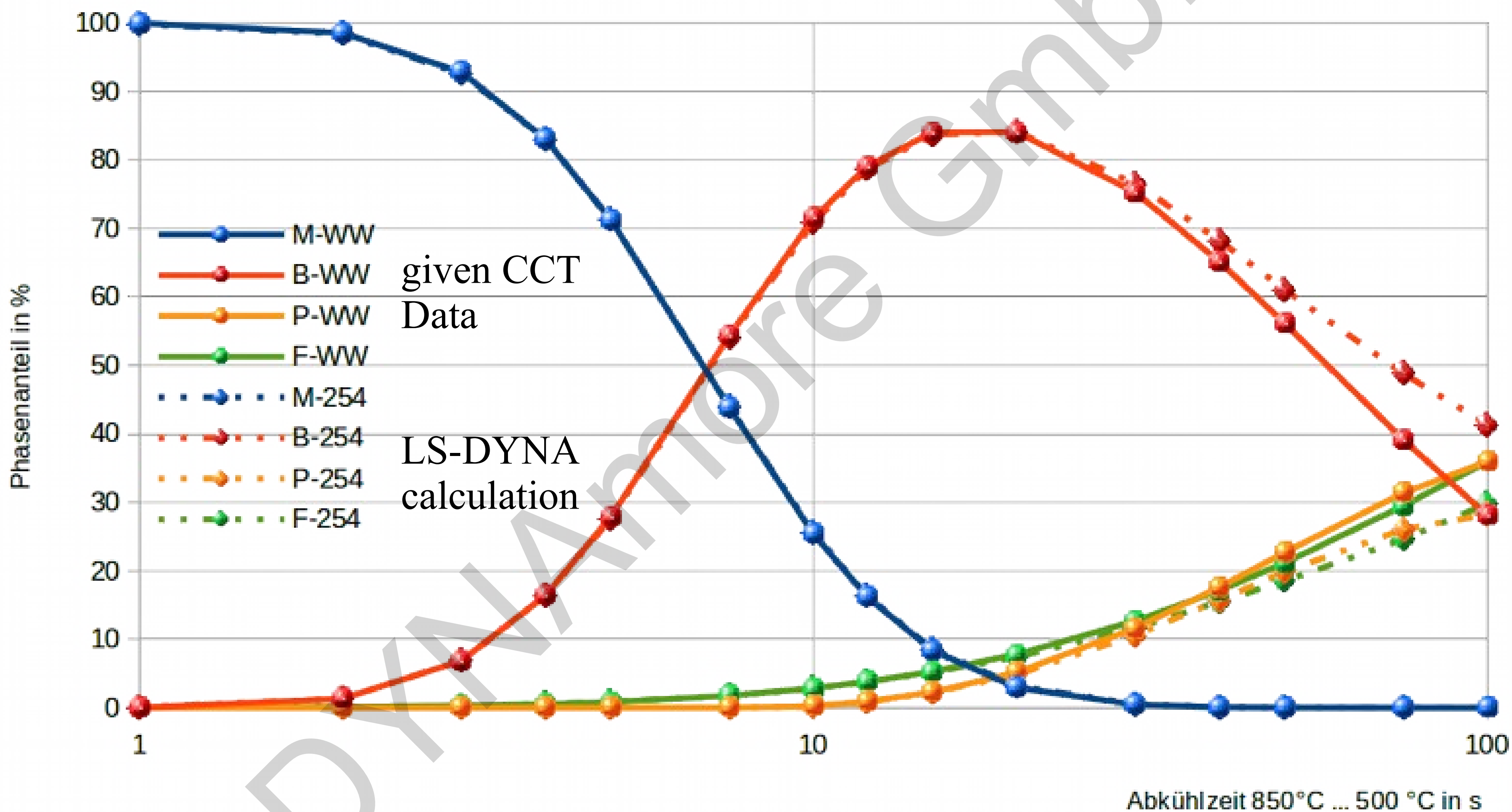
24 Phases
Shells, Solids, 2D-shells
Welding features
Phase transformation strain
Transformation induced plasticity (TRIP)
Subcycling for phase transformation
Tempering
Hardeness computation

Selected features: DTEMP

Phase transformation calculation temperature requires limit on tempearature step
Phase transformation shall not reduce time step of mechanical solver
DTEMP = maximum allowed temperature step drives subcycle for phase transformation:

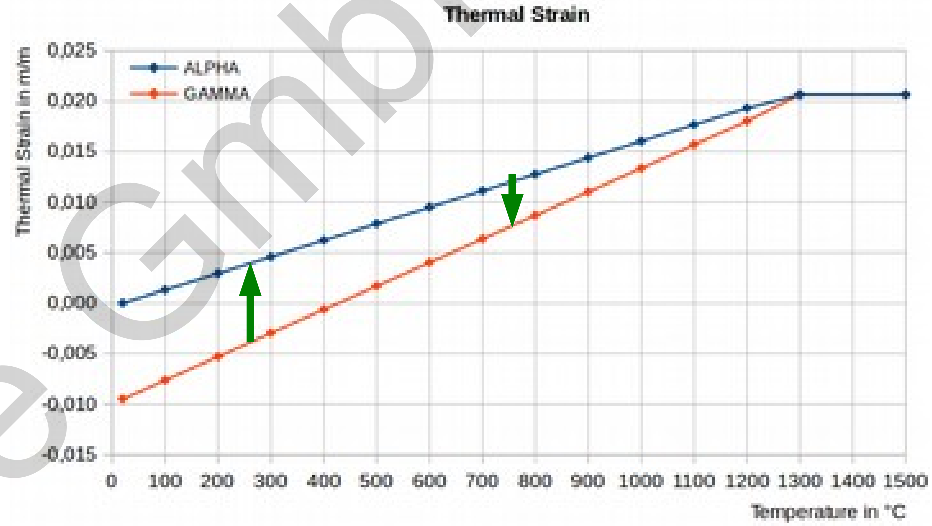


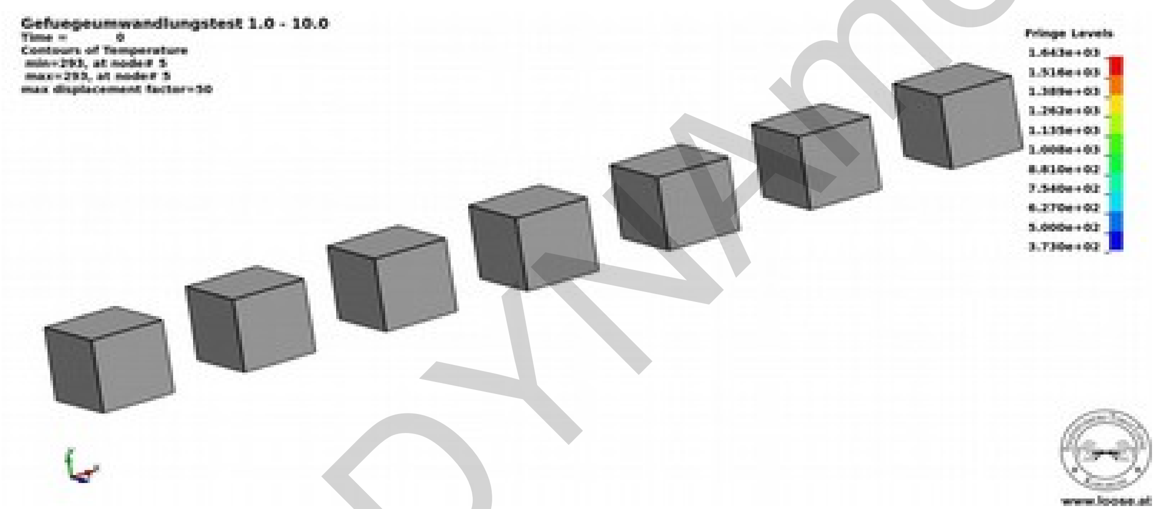
*MAT_254 calibration of phase transformation law



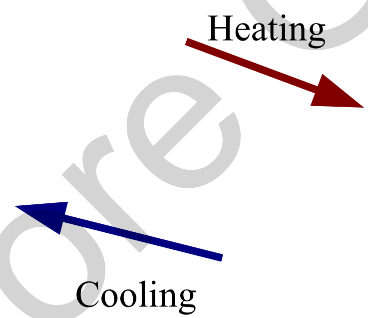
Selected features: phase transformation strain

If Phase A and B have different density
in case of phase transformation
additional strain arises due to volume change:
Phase Transformation Strain.

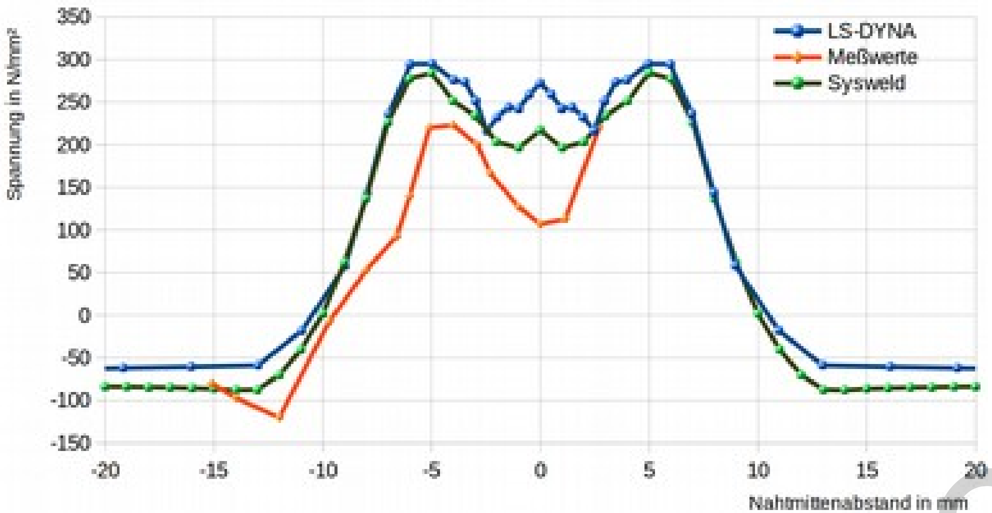


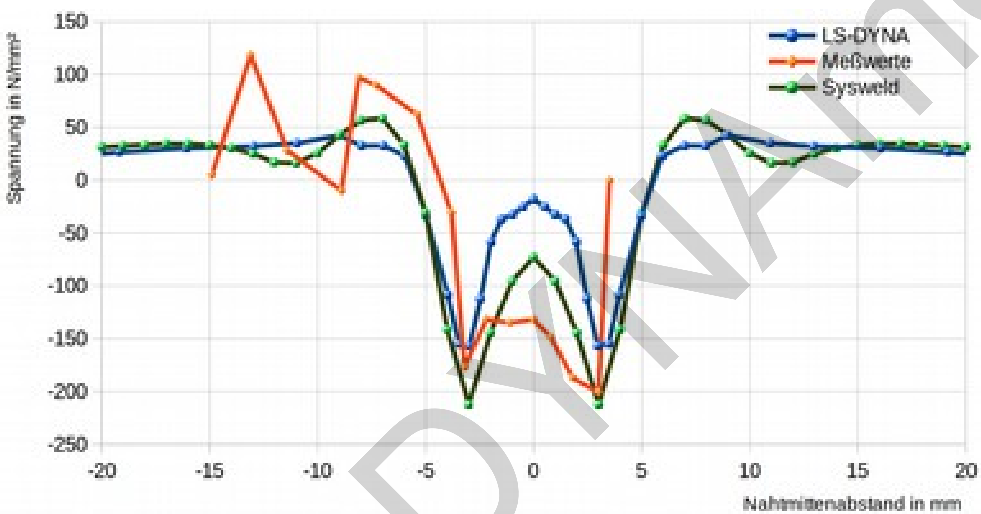


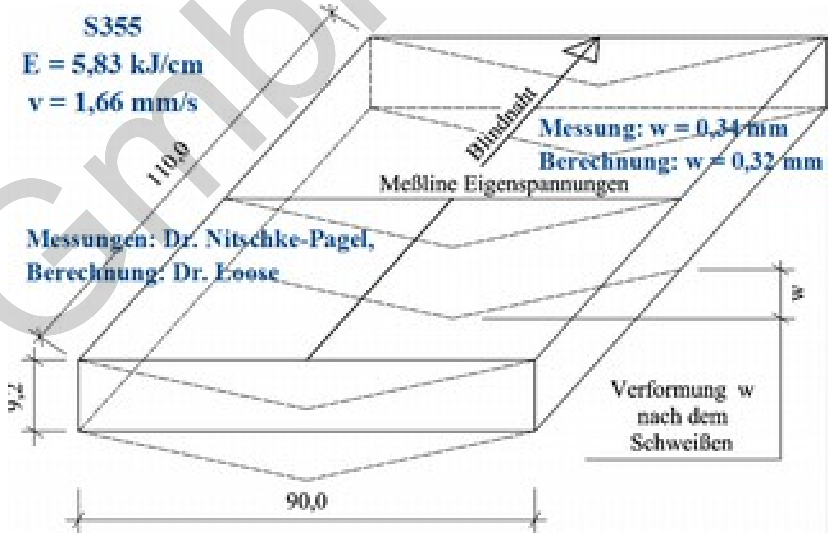
Simplified approach for single phase model *MAT_270



Validation Nitschke-Pagel test



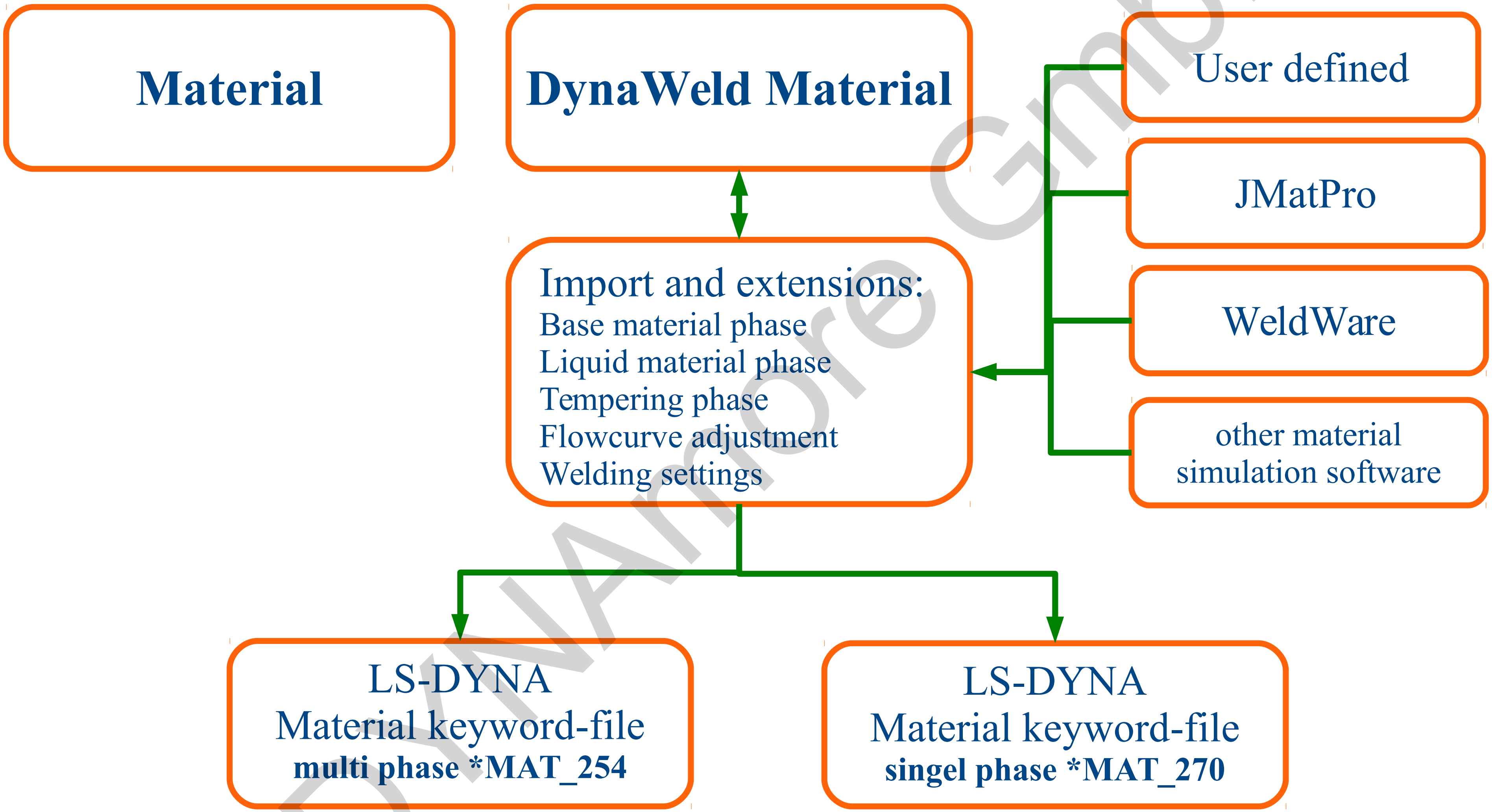




Distortion w:
Experiment: 0,34 mm
Sysweld: 0,32 mm
LS-DYNA: 0,34 mm

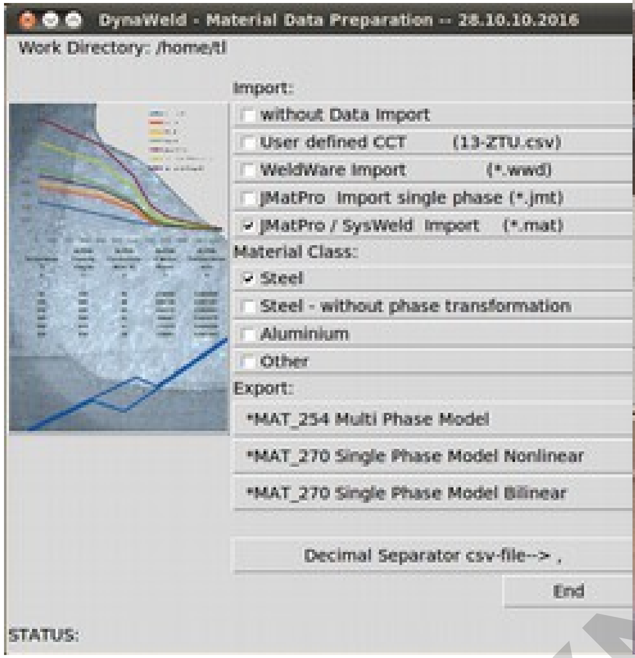
Loose, T.: Einfluß des transienten Schweißvorganges auf Verzug, Eigenspannungen und Stabiltiätsverhalten axial gedrückter Kreiszylinderschalen aus Stahl, Diss, Karlsruhe, 2008

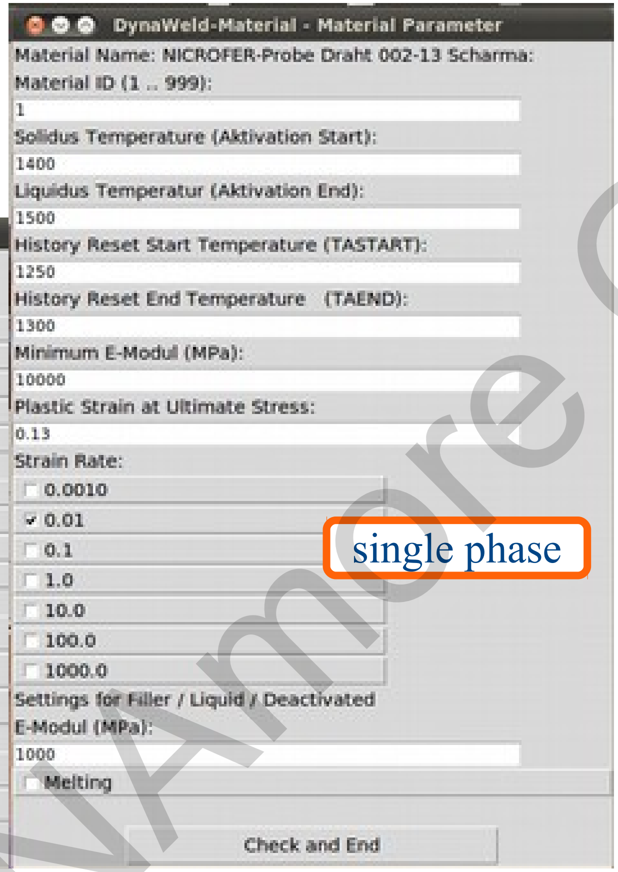
DynaWeld – Management for
high sofisticated welding and heat treatment materials



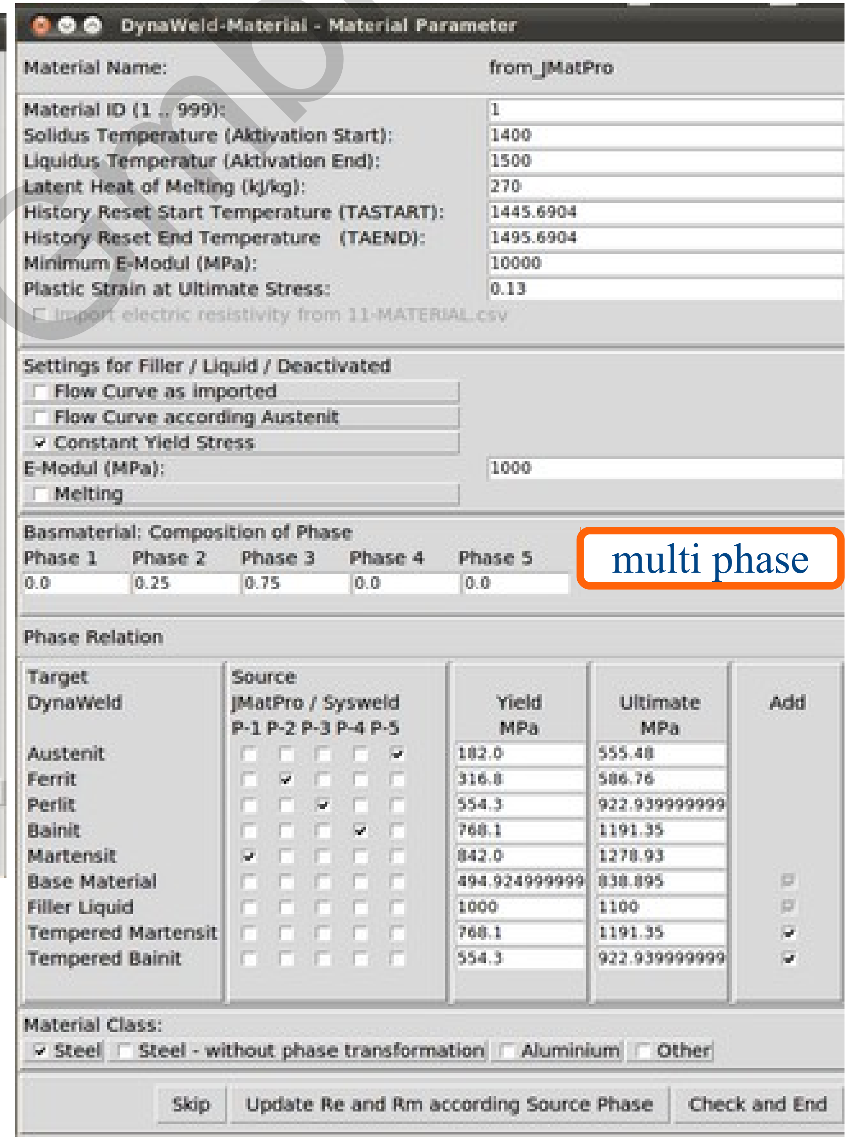
DynaWeld Material - Import

Interfaces





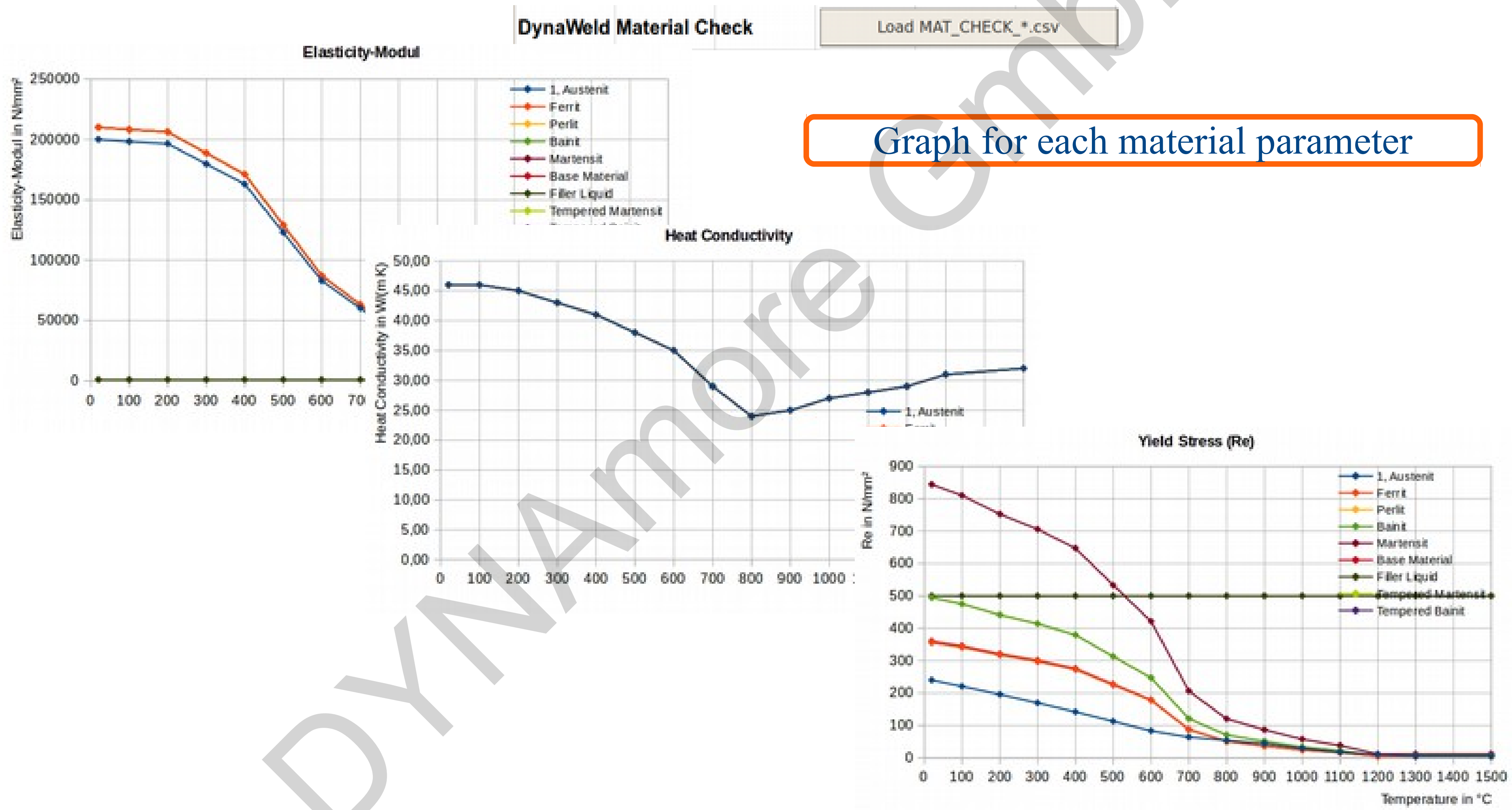
single phase



multi phase

Settings and Extensions

spreadsheet DynaWeld-Material-Check



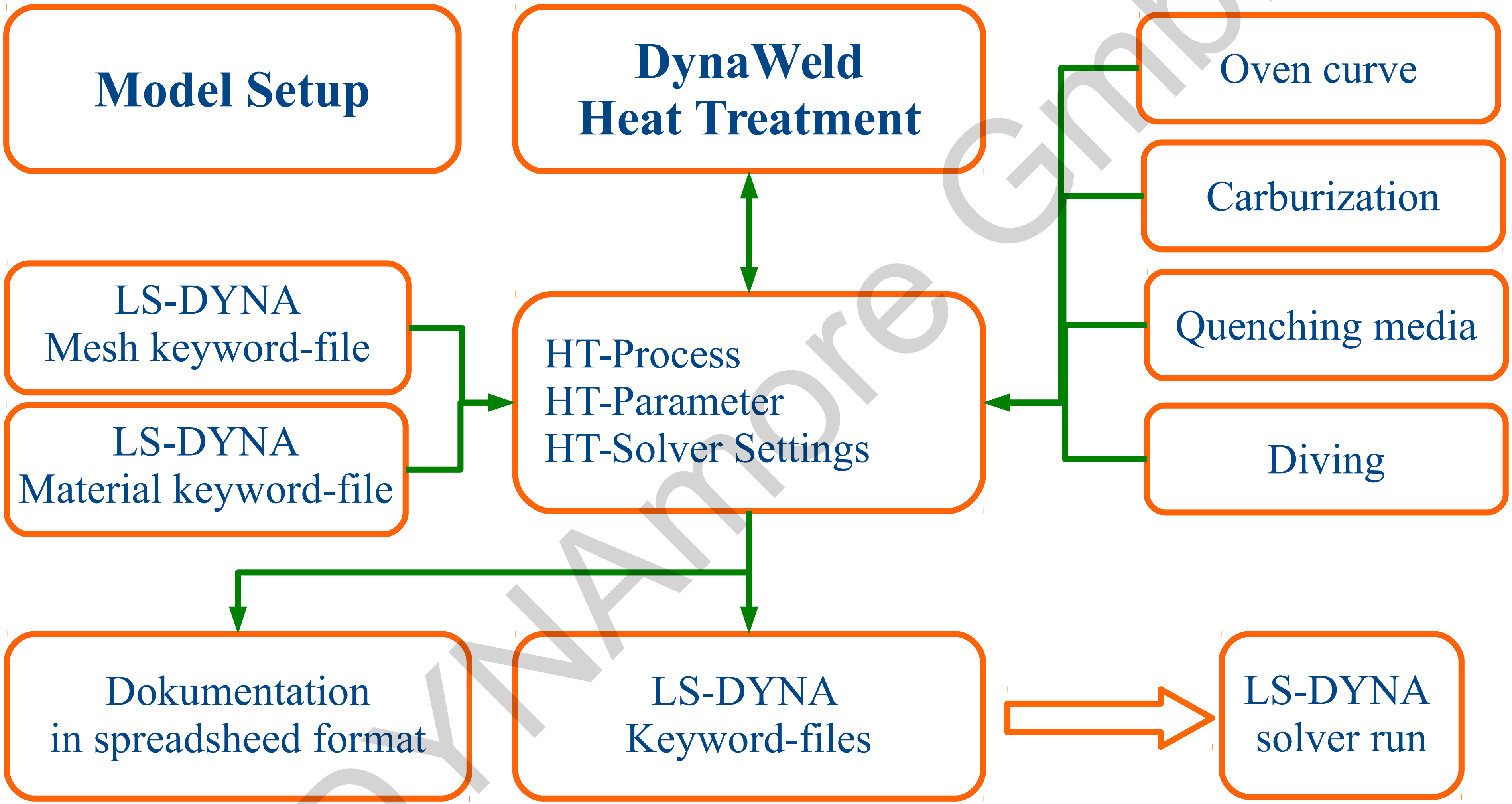
Graph for each material parameter

Foto: Edyta Łopatecka

DynaWeld

Heat Treatment

DynaWeld – Management for
high sofisticated heat treatment simulation setup



DynaWeld Heat Treatment - Process

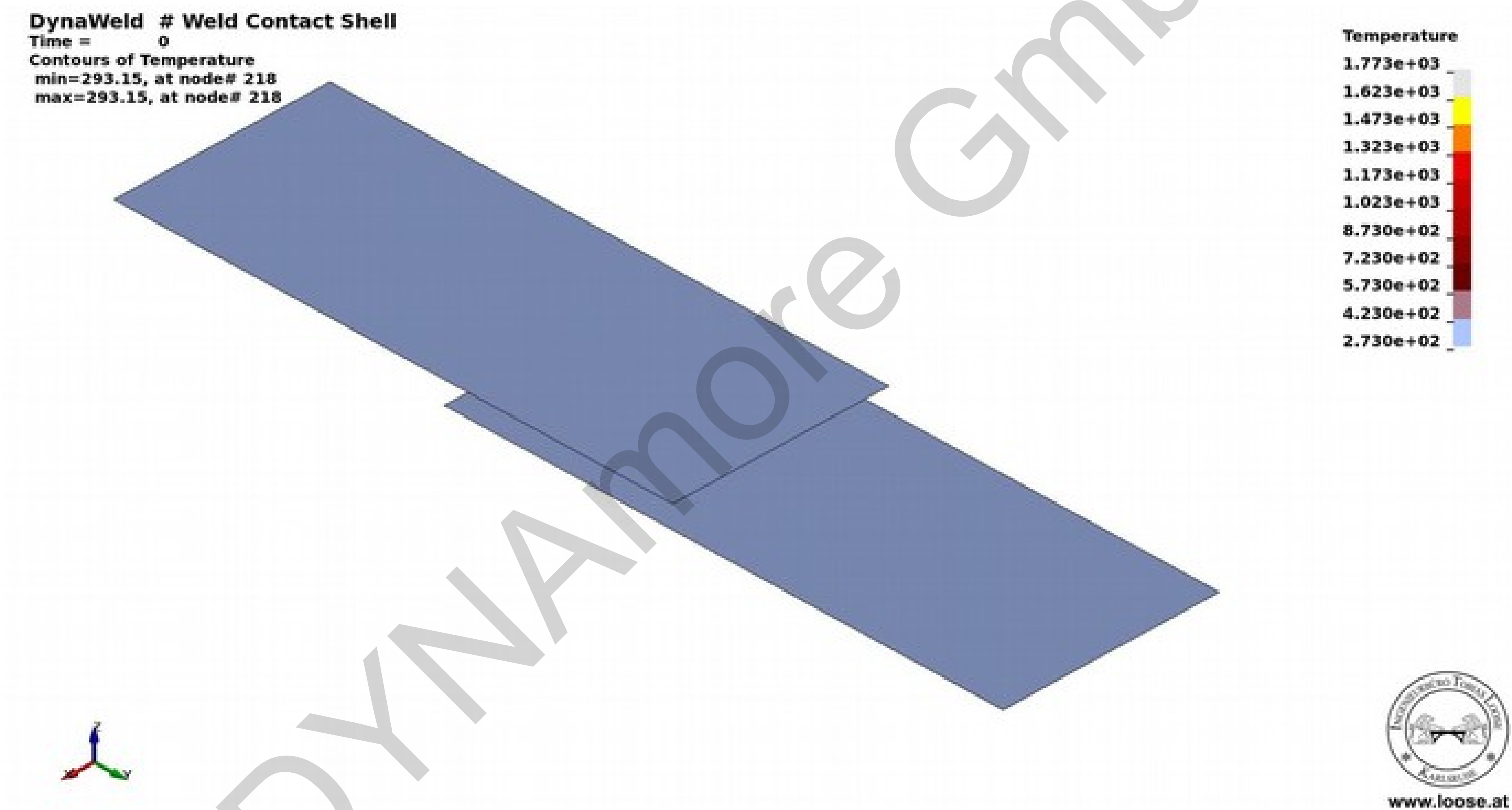
DynaWeld Heat Treatment - Parameter

Foto: Edyta Łopatecka

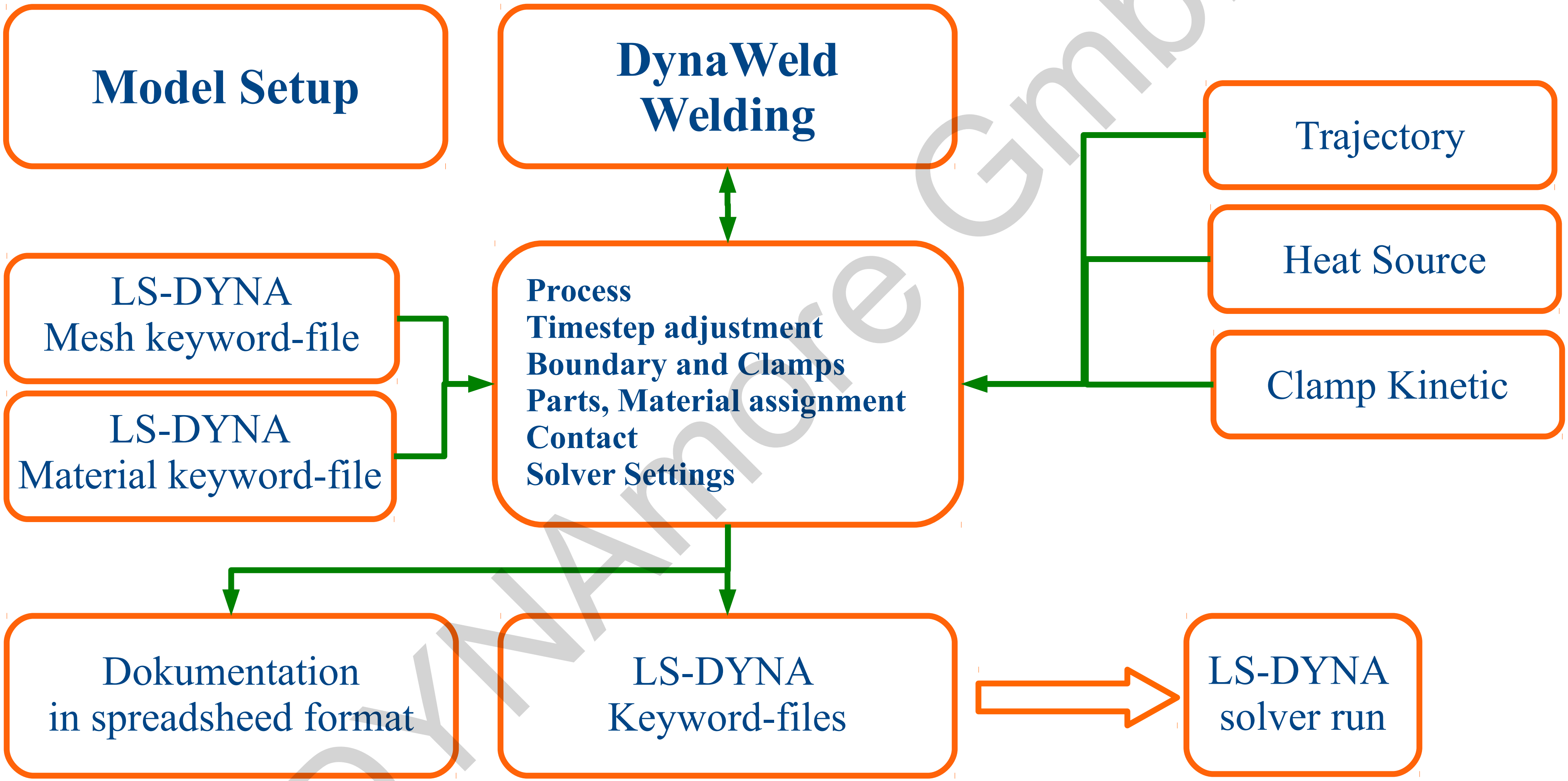
DynaWeld

Welding

Laser welded sheet with tensile test



DynaWeld – Management for
high sofisticated welding simulation setup



DynaWeld Process

DynaWeld – Process plan | Save Table | Save All | 29.04.16

Process nr.	Weld ID	Length mm	v mm/s	Duration s	Start s	End s	PAUSE s	TRLK TRLZ MO MOP Q W	r1 af af/R1 mm	r2 ar ar/R2 mm	r3 bf b/R3 mm	b1 cf c / v1 mm	b2 br br / v2 mm	cr cr / v3 mm	kf -	ay °
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1	1001	58,75208426	7,5	7,8336	0,0000	7,8336	0,0000	7838,4482	3	10,72505	5,07272	4,91363			1,33183878	90
2	1002	64,93651425	7,5	8,6582	7,8336	16,4918	5,0000	7838,4482	3	10,72505	5,07272	4,91363			1,26103721	-90

Types of heat source

surface heat source
volumetric heat source
part heating

Geometric shapes

elipsoid – double elipsoid
cylinder
conus – double conus

Heat input on

shell, shell 2D
solid
segment

Start, end, intermediate time

Multi robots simultaneous

Multiple heat source

auto fill or copy option

Reverse option

Reorder of sequence

Multi layered welds

auto deactivation of
not yet deposit material

SimWeld interface

supports the new LS-DYNA heat source

- on shells and solids
- shell thickness distribution
- engergy input control
- sub cycling
- mesh independent
- time step independent

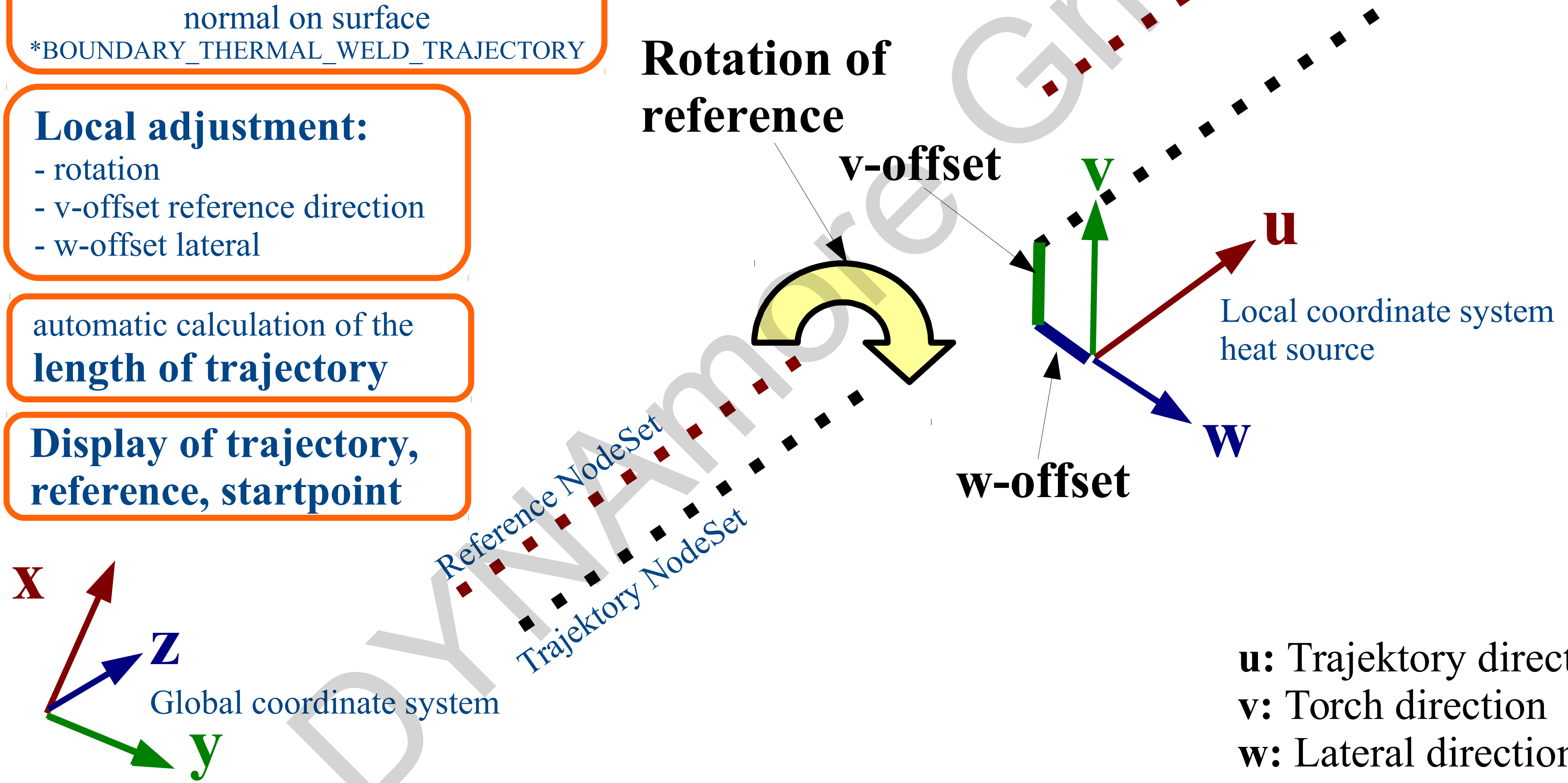
Weldpath definition - trajectory and reference

Definition with one Nodeset
auto detection of reference
normal on surface
*BOUNDARY_THERMAL_WELD_TRAJECTORY

Local adjustment:
- rotation
- v-offset reference direction
- w-offset lateral

automatic calculation of the
length of trajectory

Display of trajectory, reference, startpoint



u: Trajektory direction
v: Torch direction
w: Lateral direction

DynaWeld Boundary

Single point constraints (SPC)

Symetry surfaces

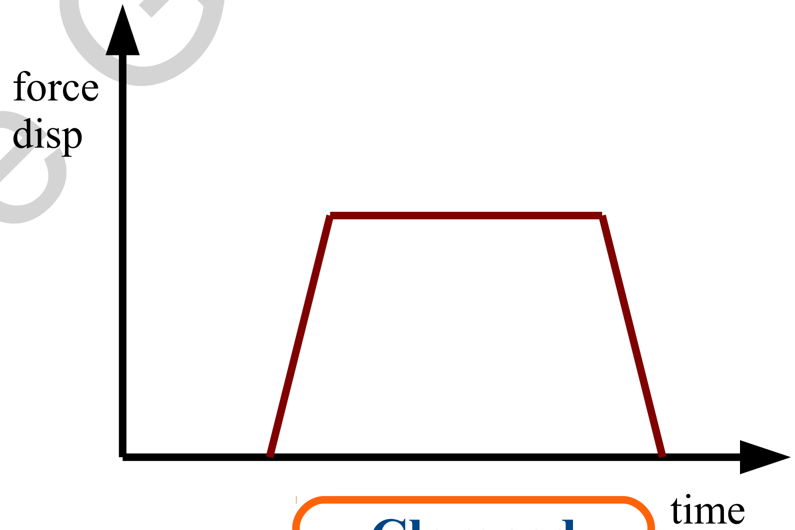
Force on Nodes or Node Sets

Displacement on Nodes or Node Sets

Force or Displacement:

- user defined ramp at start and end
- local coordinate system
- Predeformation
- Prestress

Force or displacement driven clamps



Clamped
force driven or
displacement driven

Clamping

Unclamping

DynaWeld Contact

Standard Contact
R: *_SURFACE_TO_SURFACE_THERMAL
RSH: *_SURFACE_TO_SURFACE_THERMAL in Area of Heat Sources. BC _FLG = 0
RG: *_SURFACE_TO_SURFACE_THERMAL IGAP = 1
RGSH: *_SURFACE_TO_SURFACE_THERMAL IGAP = 1 in Area of Heat Sources. BC _FLG = 0
RO: *_ONE_WAY_SURFACE_TO_SURFACE_THERMAL
ROX: *_ONE_WAY_SURFACE_TO_SURFACE (without Thermal Contact)
RM: *_SURFACE_TO_SURFACE_MORTAR_THERMAL
RS: *_SURFACE_TO_SURFACE_SMOOTH_THERMAL (SOFT = 0)
F: *_TIED_SURFACE_TO_SURFACE
FSH: *_TIED_SURFACE_TO_SURFACE in Area of Heat Sources. BC _FLG = 0
FO: *_TIED_SURFACE_TO_SURFACE_OFFSET
FOSH: *_TIED_SURFACE_TO_SURFACE_OFFSET in Area of Heat Sources. BC _FLG = 0
FCO: *_TIED_SURFACE_TO_SURFACE_CONSTRAINED_OFFSET
FCOSH: *_TIED_SURFACE_TO_SURFACE_CONSTRAINED_OFFSET in Area of Heat Sources. BC
N: *_NODES_TO_SURFACE (without Thermal contact)
NI: *_NODES_TO_SURFACE_INTERFERENCE (without Thermal contact)
SO: SLIDING_ONLY
R2D: *_2D_AUTOMATIC_SURFACE_TO_SURFACE_THERMAL (SSID, MSID := ID of Part Sets)
F2D: *_2D_AUTOMATIC_TIED_THERMAL (SSID, MSID := ID of Part Sets)

Additional Options for Standard Contact to drive MST and SST:
*M0: MST = 0 (M0 0 := zero)
*S0: SST = 0
*M0S0: MST = 0 and SST = 0
Syntax: append after Standard contact R, RSH, RG, RGSH, RO, ROX, RM, F, FSH, FO FO
Example: ROM0, ROS0, ROM0S0

Additional Options for Standard Contact to drive Smooth Option:
S*: SOFT = 0 SBOPT = 3
Symtax: prefix bevor Starndard contact R, RSH, RG, RGSH, RO, ROX, RM
Example: SR SRM SROMO

Welding Contact:
WRnnn: Welding Contact Frition
nnn := Fusion Temperature

mechanical and thermal

Welding contact
change friction → tied by temperature

Friction contact

Tied contact

Shell edge to surface or solid
friction or tied contact

mechanical

Node to surface
auto-correct of large penetration
mechanical only

Special features
smooth option for curved sheets
mortar option for implicit analysis
shell thickness considered automatically

DynaWeld-Welding Input file generator

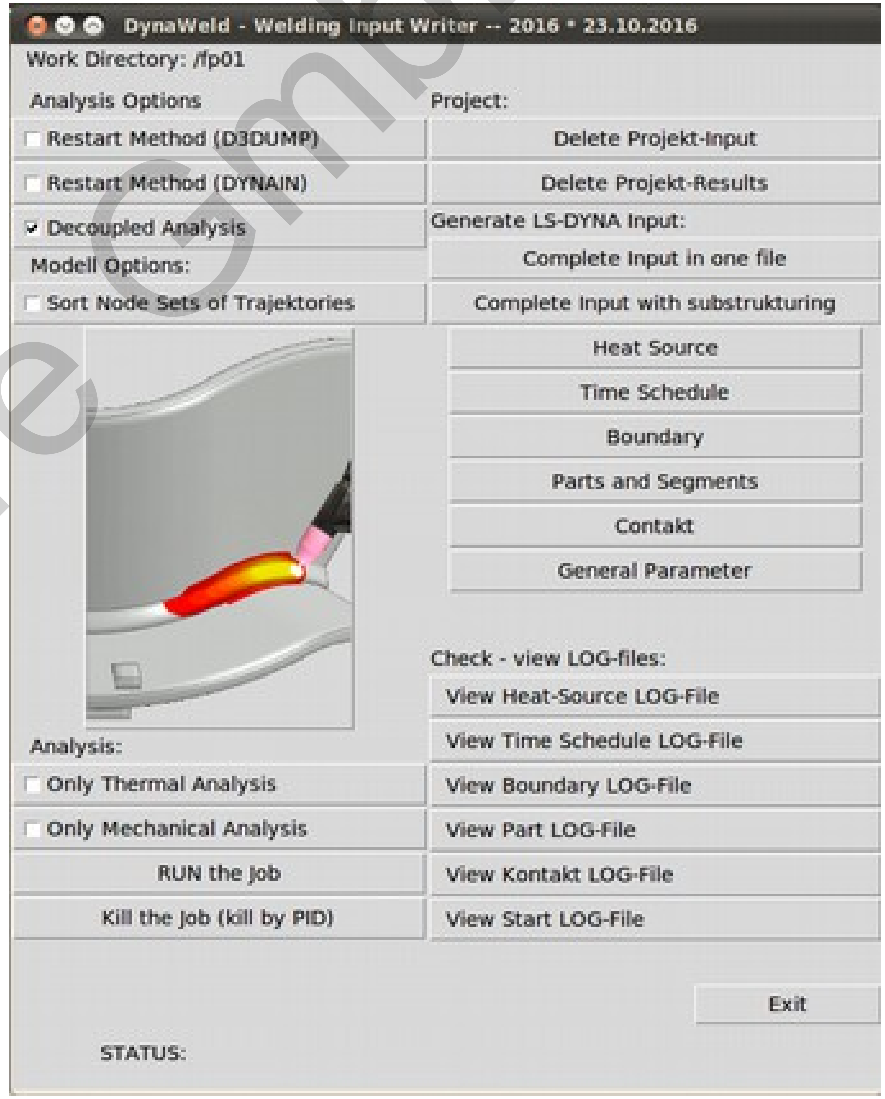
Analysis Options

Clean Work Directory

Generate Input
- one file
- structured input
- single task creation

Check options

Run
and
Kill



DynaWeld Tools

Create Variants

Heat iput check

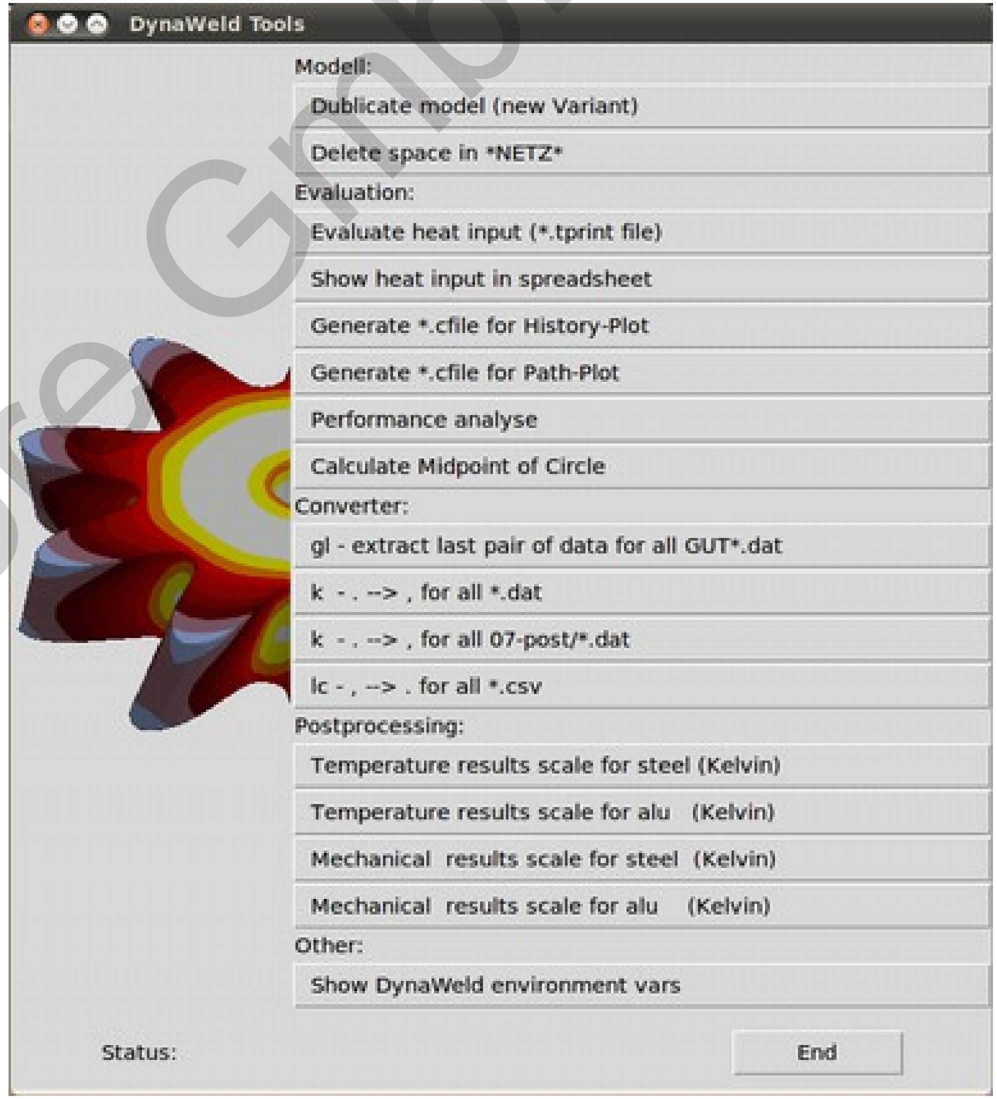
Automatisation
for results along path
or time history at nodes

Performance analyse

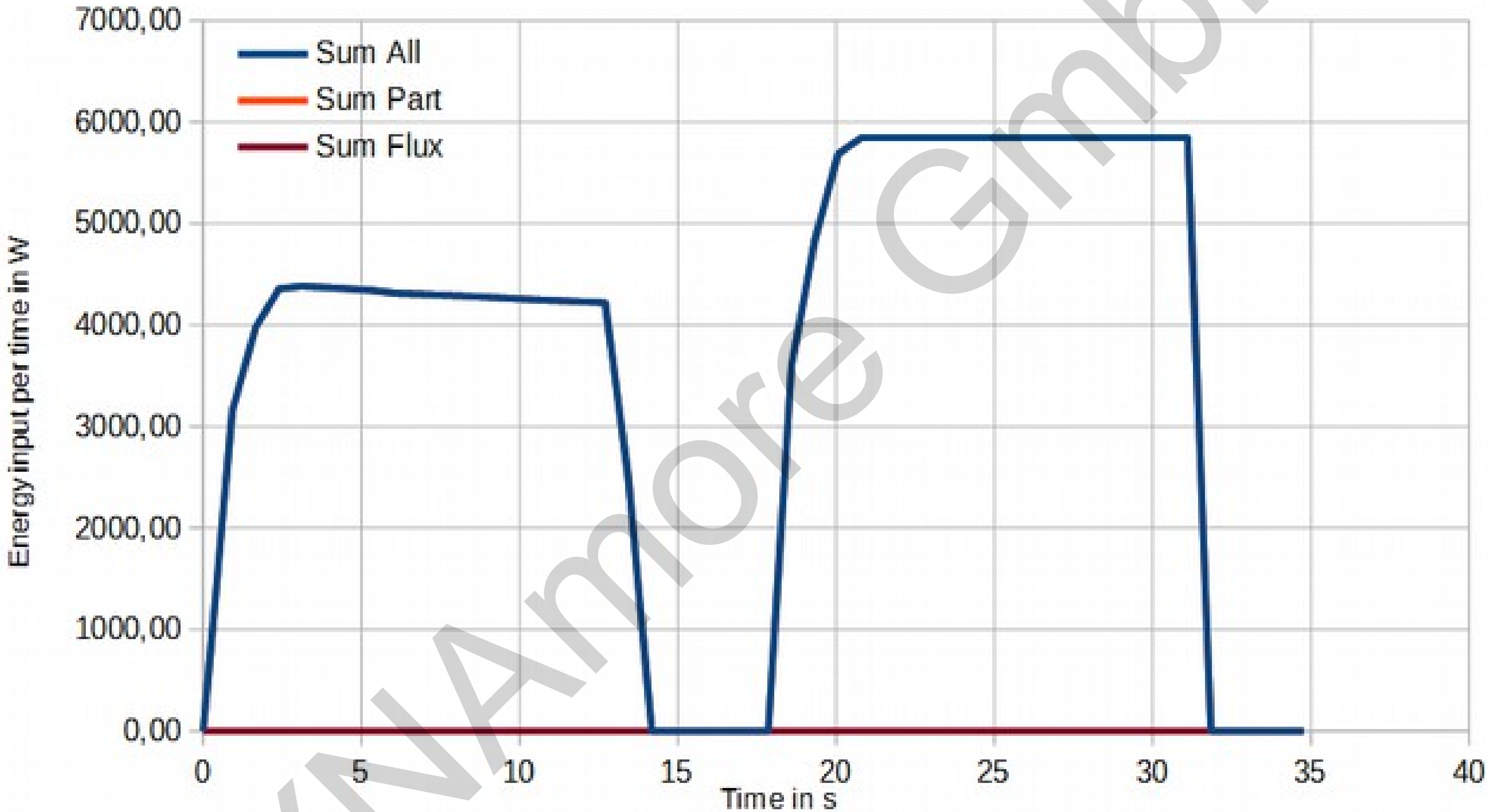
Midpoint by 3 Points

Conversion utilities

Launch postprocessing file
with
DynaWeld temperature scale



Check of heat input and final adjustment



Heat Input Adjustment:

WID	input	target	factor	kf old	kf new
1001	3678	4000	1,09	1,00	1,09
1002	5658	5528	0,98	1,00	0,98

right energy input
right results

Conclusion

LS-DYNA

Material Models representing physics within phase kinetics

from Process parameter to solver keyword input

DynaWeld

Succes
in industrial applied simulation for manufacturing processes with high sophisticated phiysical phenomena like
Heat Treatment and Welding

Foto: Martin Loose