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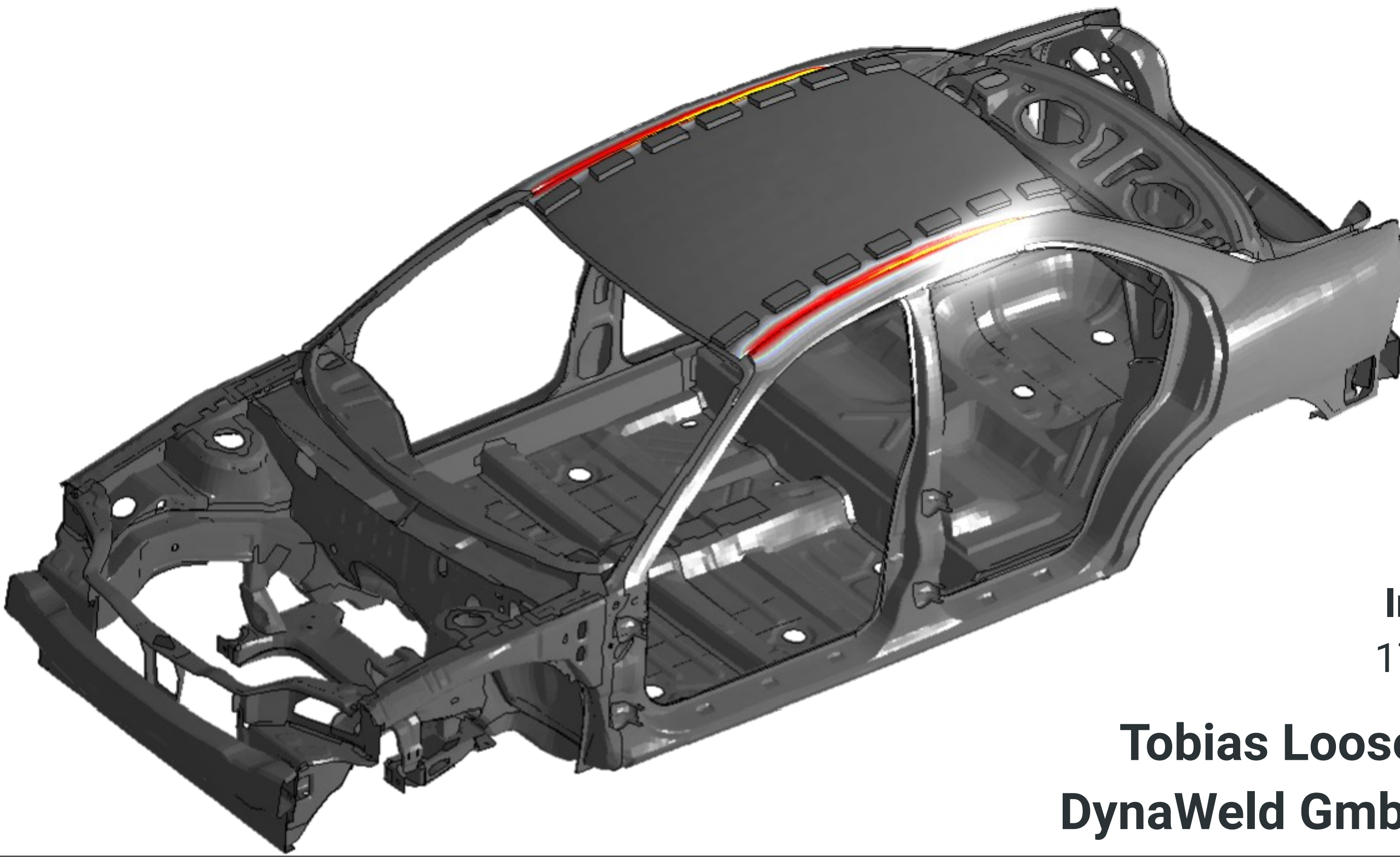
Distortion management
in the Design of the Assembly of Body in White



Insight @ Volkswagen 2019

17.-18.09.2019 Posen, Polen

Tobias Loose and Jens Rohbrecht

DynaWeld GmbH & Co. KG, Germany

No computers
Empirical knowledge and try out by physical tests to achieve best manufacturing processes

Digitalisation in the manufacturing design

Computers and simulation available
The digital try out enables to achieve best manufacturing process in advance!

Introduction

Welding Simulation Process

Welding Simulation Structure

Assembly Analysis Distortion

Welding process analysis

In the welding process analysis,

- the evolution of the heat generation,
- the evolution of melt pool,
- evolution of the weld seam shape,
- the nearby temperature field

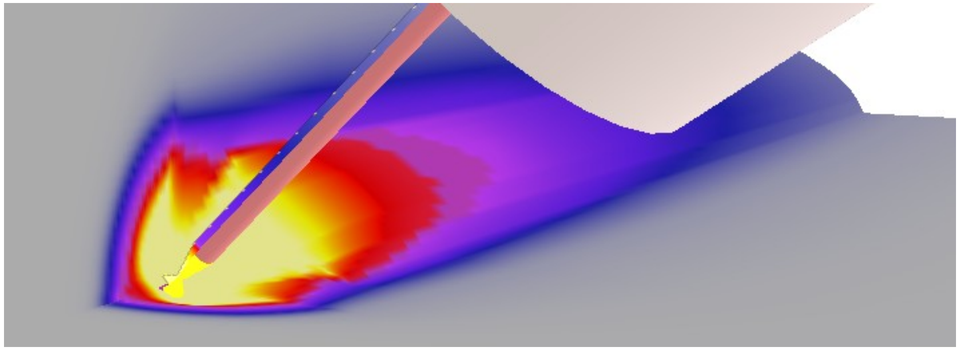
are calculated, with the input of machine settings.

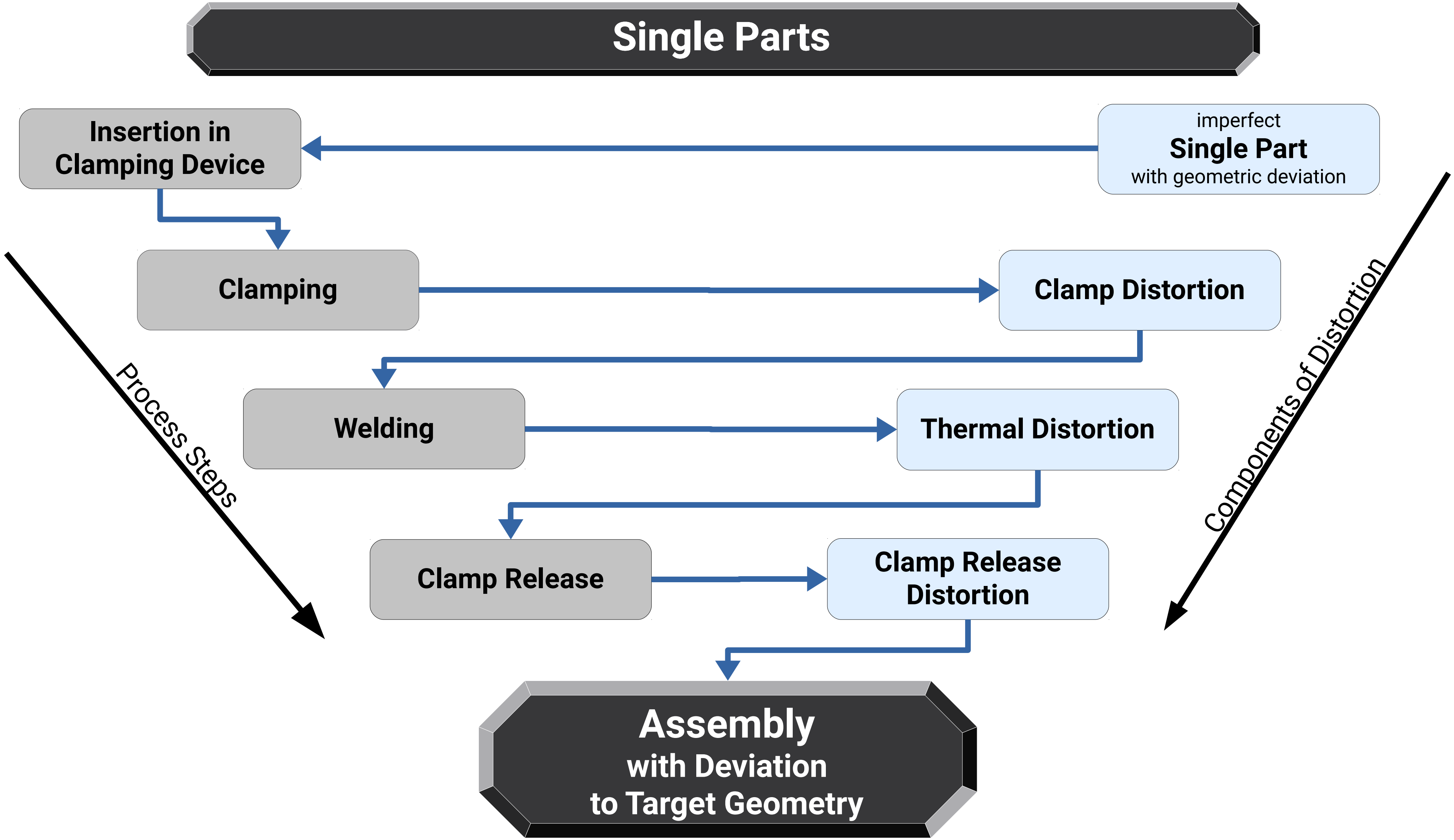
Welding structure analysis

In the welding structure analysis

- the global temperature field,
- the distortion,
- the residual stresses

are calculated with the input of equivalent heat on moving heat sources according the weld plan.




Single Parts
Insertion in Clamping Device
imperfect
Single Part
with geometric deviation
Clamping
Clamp Distortion
Welding
Thermal Distortion
Clamp Release
Clamp Release Distortion
Process Steps
Components of Distortion
Assembly
with Deviation
to Target Geometry

Assembly Analysis Distortion

= **Welding Simulation** (Structure)

\+ **Clamp Kinematic Simulation**

\+ **Imperfect single Parts**

\+ **Imperfect Sub-Assemblys**

\+ **Multi – Stage Simulation** (multi GEO Stations)

Distortion management requires **Assembly Analysis.**

A pure welding simulation
is not sufficient.

DynaWeld's challenge is the development of entire assembly simulation method including welding simulation.

Precise results require precise modeling and consideration of the real physics.

Advanced Simulation Methods

Mechanics at Weld Seams:

DynaWeld developed the „free motion filler technology“, which considers the mechanical details of welding:

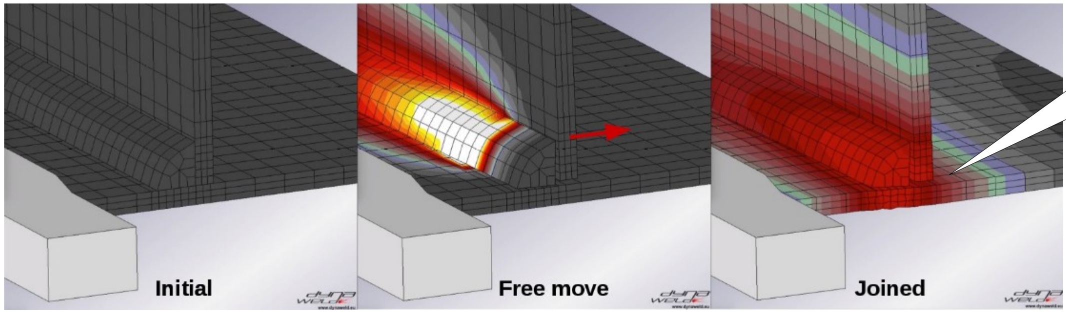
1. Not yet welded seams:

Weld filler elements are present, but should not affect the relative movements of the later connected devices. Therefore a sliding status is remaining, until:

2. Welded seams:

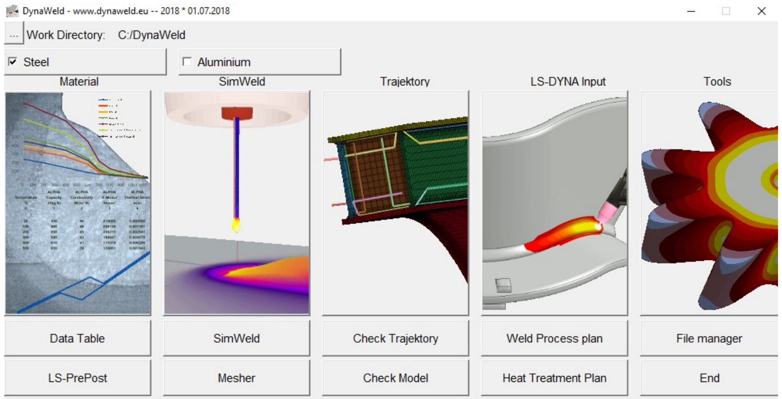
the welding torch heats up materials to the melting point. From the moment of solidification on a permanent connection is kept until the end of the process.

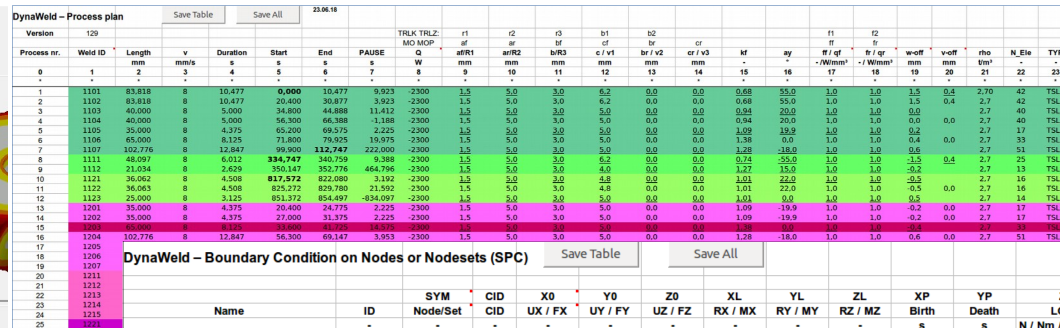
Movements between components, also gap progress where appearing, is kept until heating up and solidification.

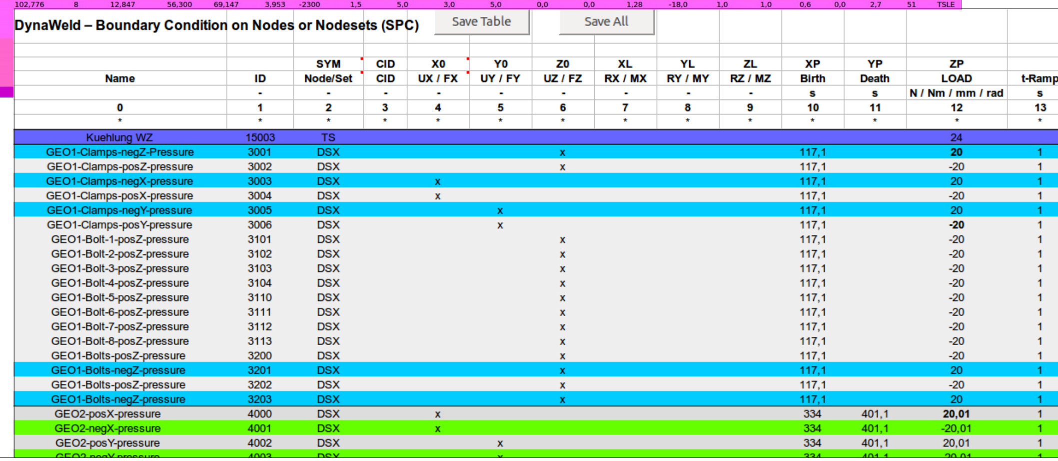


True mechanics are of high importance, as the weld seams, yet welded or not, influence each other and by this the distortions of the entire structure.

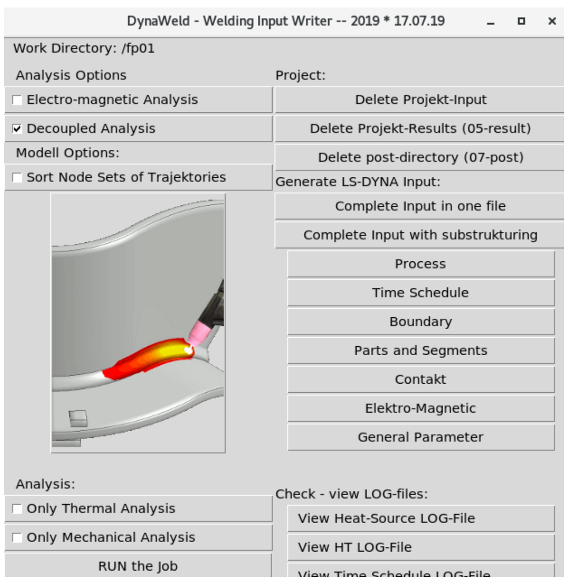
1. **DynaWeld** Preprocessor for complex industrial welding processes over many steps:





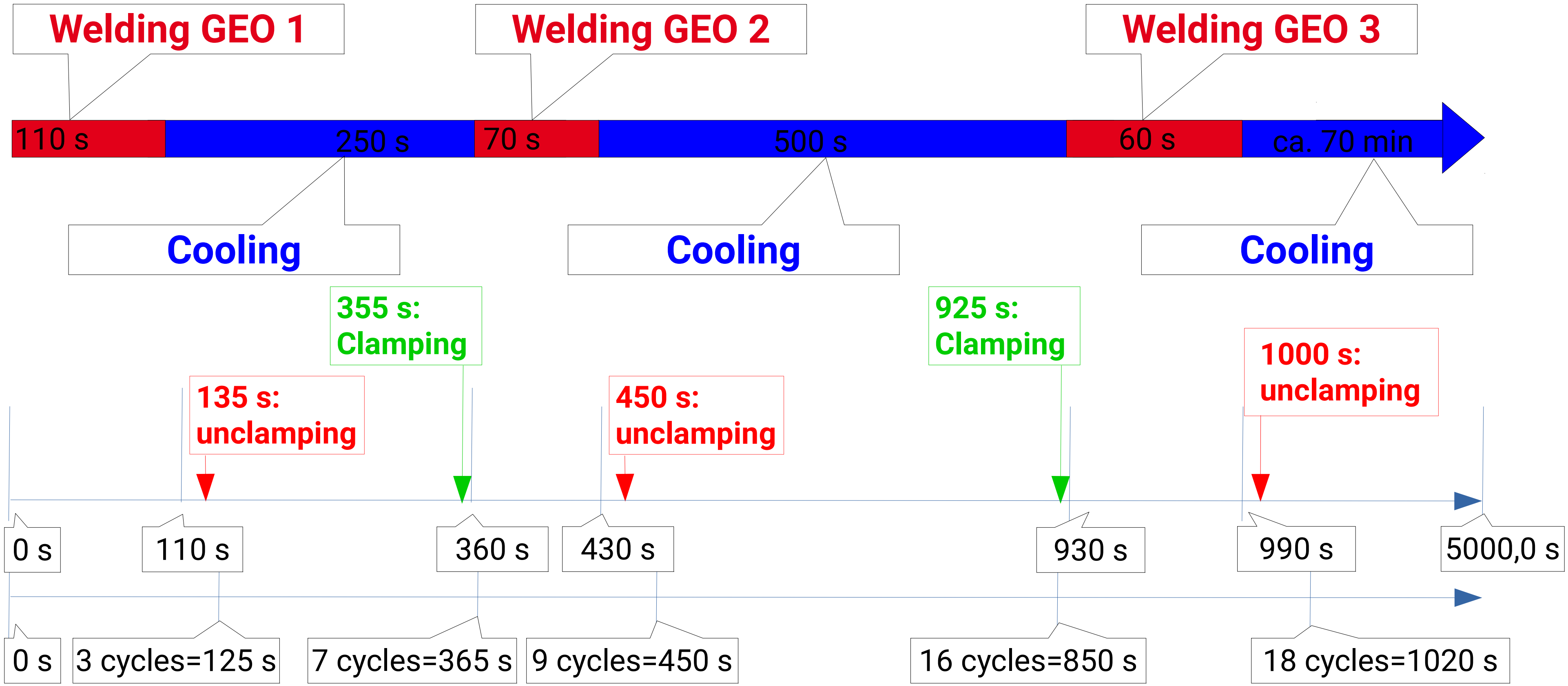


Name	ID	SYM Node/Set	CID CID	X0 UX / FX	Y0 UY / FY	Z0 UZ / FZ	XL RX / MX	YL RY / MY	ZL RZ / MZ	XP Birth	YP Death	ZP LOAD	t-Ramp
	-	-	-	-	-	-	-	-	-	s	s	N / Nm / mm / rad	s
0	1	2	3	4	5	6	7	8	9	10	11	12	13
Kuehlung WZ	15003	TS										24	
GEO1-Clamps-negZ-Pressure	3001	DSX				x				117,1		20	1
GEO1-Clamps-posZ-pressure	3002	DSX				x				117,1		-20	1
GEO1-Clamps-negX-pressure	3003	DSX		x						117,1		20	1
GEO1-Clamps-posX-pressure	3004	DSX		x						117,1		-20	1
GEO1-Clamps-negY-pressure	3005	DSX			x					117,1		20	1
GEO1-Clamps-posY-pressure	3006	DSX			x					117,1		-20	1
GEO1-Bolt-1-posZ-pressure	3101	DSX				x				117,1		-20	1
GEO1-Bolt-2-posZ-pressure	3102	DSX				x				117,1		-20	1
GEO1-Bolt-3-posZ-pressure	3103	DSX				x				117,1		-20	1
GEO1-Bolt-4-posZ-pressure	3104	DSX				x				117,1		-20	1
GEO1-Bolt-5-posZ-pressure	3110	DSX				x				117,1		-20	1
GEO1-Bolt-6-posZ-pressure	3111	DSX				x				117,1		-20	1
GEO1-Bolt-7-posZ-pressure	3112	DSX				x				117,1		-20	1
GEO1-Bolt-8-posZ-pressure	3113	DSX				x				117,1		-20	1
GEO1-Bolts-posZ-pressure	3200	DSX				x				117,1		-20	1
GEO1-Bolts-negZ-pressure	3201	DSX				x				117,1		20	1
GEO1-Bolts-posZ-pressure	3202	DSX				x				117,1		-20	1
GEO1-Bolts-negZ-pressure	3203	DSX				x				117,1		20	1
GEO2-posX-pressure	4000	DSX		x						334	401,1	20,01	1
GEO2-negX-pressure	4001	DSX		x						334	401,1	-20,01	1
GEO2-posY-pressure	4002	DSX			x					334	401,1	20,01	1



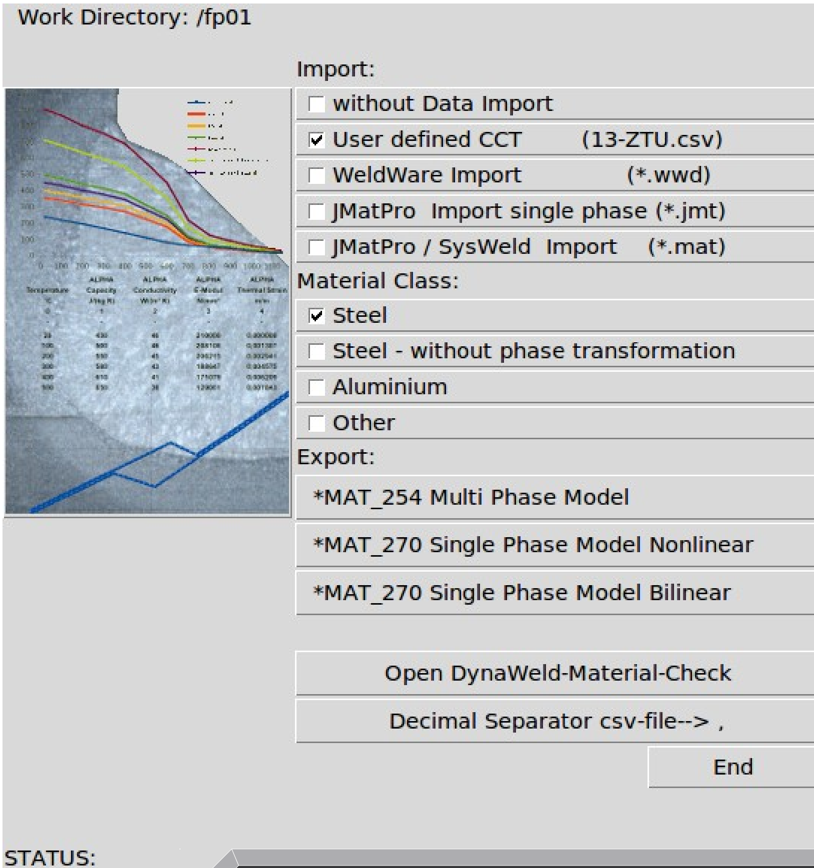
By simple tabular inputs the DynaWeld Preprocessor supports **many weldings** simultanously done by **multiple robots** over different manufacturing steps.
Arbitrary welding procedures and arbitrary clamping tool kinematics are possible.

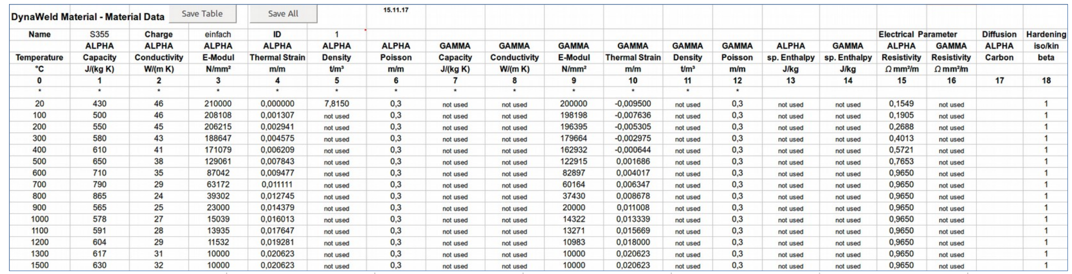
Time schedule of welded assembly over three GEO Stations:
(Welding- and cooling steps, non truly scaled)



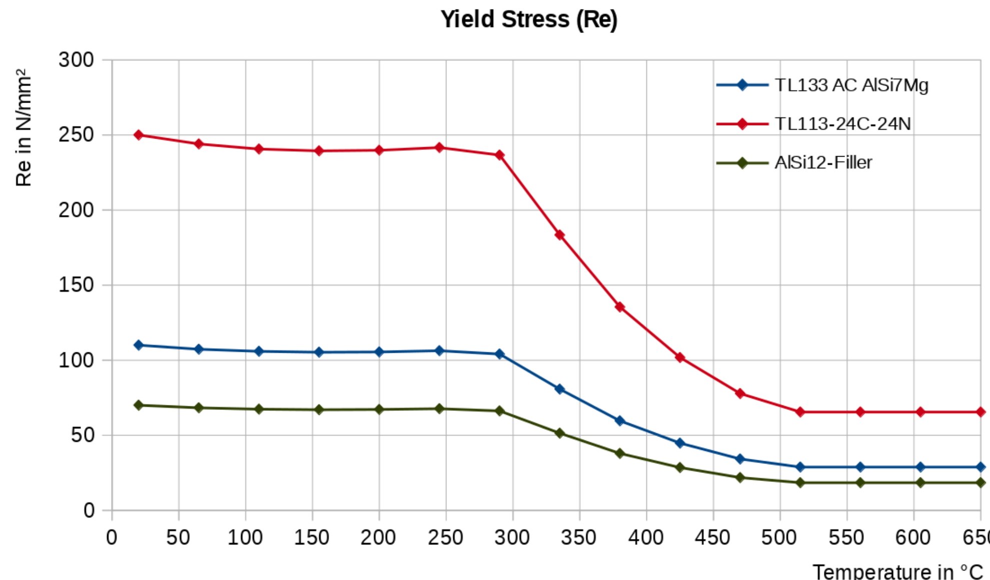
Clamp closing and opening is simulated.
The correct contact conditions are considered.

2. **DynaWeld** Material Data Management:





DynaWeld Material - Material Data		Save Table		Save All		15.11.17												
Name	S355	Charge	einfach	ID	1										Electrical Parameter		Diffusion	Hardening
	ALPHA	ALPHA	ALPHA	ALPHA	ALPHA	ALPHA	GAMMA	GAMMA	GAMMA	GAMMA	GAMMA	GAMMA	ALPHA	GAMMA	ALPHA	GAMMA	ALPHA	iso/kin
Temperature	Capacity	Conductivity	E-Modul	Thermal Strain	Density	Poisson	Capacity	Conductivity	E-Modul	Thermal Strain	Density	Poisson	sp. Enthalpy	sp. Enthalpy	Resistivity	Resistivity	Carbon	beta
°C	J/(kg K)	W/(m K)	N/mm²	m/m	t/m³	m/m	J/(kg K)	W/(m K)	N/mm²	m/m	t/m³	m/m	J/kg	J/kg	Ω mm²/m	Ω mm²/m		
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
*	*	*	*	*	*	*	*	*	*	*	*	*						
20	430	46	210000	0,000000	7,8150	0,3	not used	not used	200000	-0,009500	not used	0,3	not used	not used	0,1549	not used		1
100	500	46	208108	0,001307	not used	0,3	not used	not used	198198	-0,007636	not used	0,3	not used	not used	0,1905	not used		1
200	550	45	206215	0,002941	not used	0,3	not used	not used	196395	-0,005305	not used	0,3	not used	not used	0,2688	not used		1
300	580	43	188647	0,004575	not used	0,3	not used	not used	179664	-0,002975	not used	0,3	not used	not used	0,4013	not used		1
400	610	41	171079	0,006209	not used	0,3	not used	not used	162932	-0,000644	not used	0,3	not used	not used	0,5721	not used		1
500	650	38	129061	0,007843	not used	0,3	not used	not used	122915	0,001686	not used	0,3	not used	not used	0,7653	not used		1
600	710	35	87042	0,009477	not used	0,3	not used	not used	82897	0,004017	not used	0,3	not used	not used	0,9650	not used		1
700	790	29	63172	0,011111	not used	0,3	not used	not used	60164	0,006347	not used	0,3	not used	not used	0,9650	not used		1
800	865	24	39302	0,012745	not used	0,3	not used	not used	37430	0,008678	not used	0,3	not used	not used	0,9650	not used		1
900	565	25	23000	0,014379	not used	0,3	not used	not used	20000	0,011008	not used	0,3	not used	not used	0,9650	not used		1
1000	578	27	15039	0,016013	not used	0,3	not used	not used	14322	0,013339	not used	0,3	not used	not used	0,9650	not used		1
1100	591	28	13935	0,017647	not used	0,3	not used	not used	13271	0,015669	not used	0,3	not used	not used	0,9650	not used		1
1200	604	29	11532	0,019281	not used	0,3	not used	not used	10983	0,018000	not used	0,3	not used	not used	0,9650	not used		1
1300	617	31	10000	0,020623	not used	0,3	not used	not used	10000	0,020623	not used	0,3	not used	not used	0,9650	not used		1
1500	630	32	10000	0,020623	not used	0,3	not used	not used	10000	0,020623	not used	0,3	not used	not used	0,9650	not used		1



Advanced material management to cover thermal related data and quick adjust to applied alloys

Assembly Analysis

Assembly procedure - principle procedure

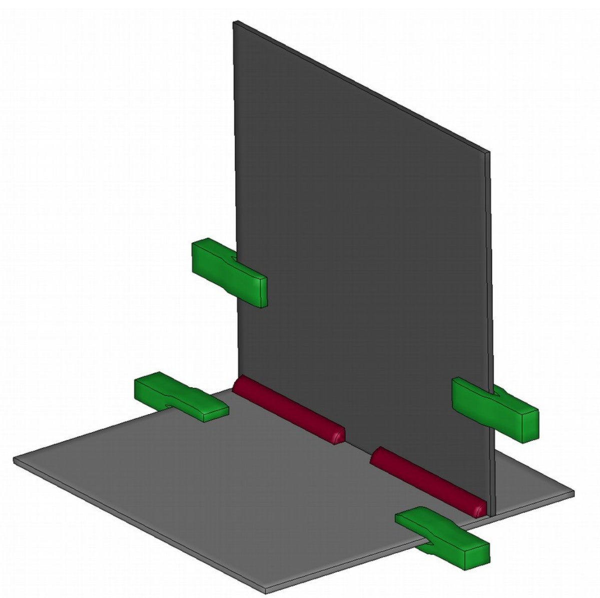
Step 1:
Welding 1 with
2 weld seams

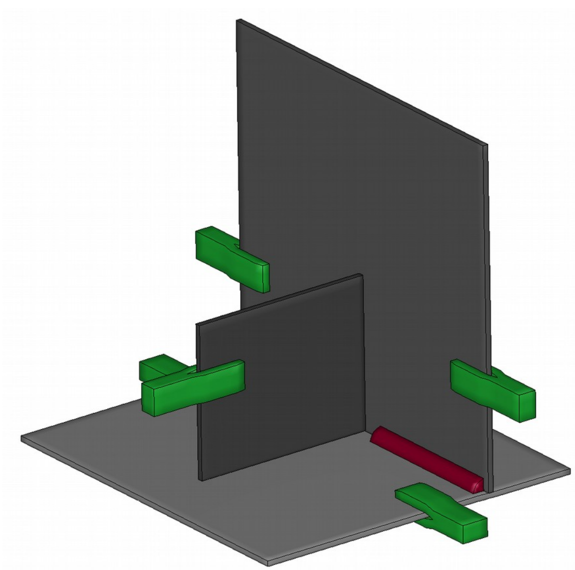
\+

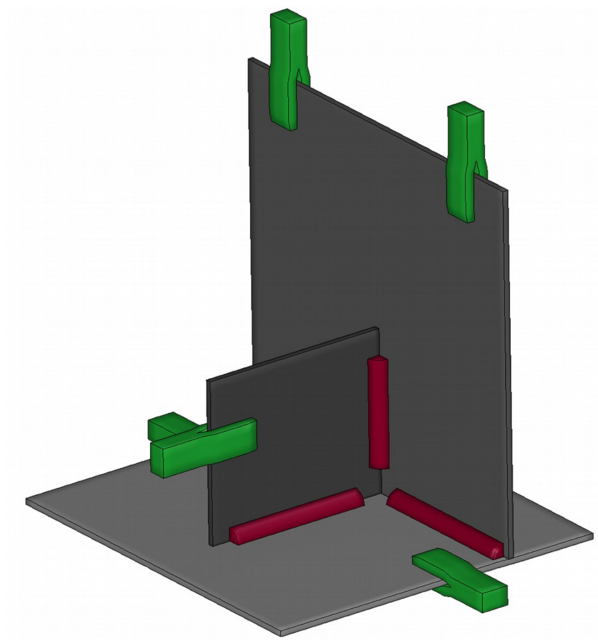
Step 2:
Assembly, adding
further parts

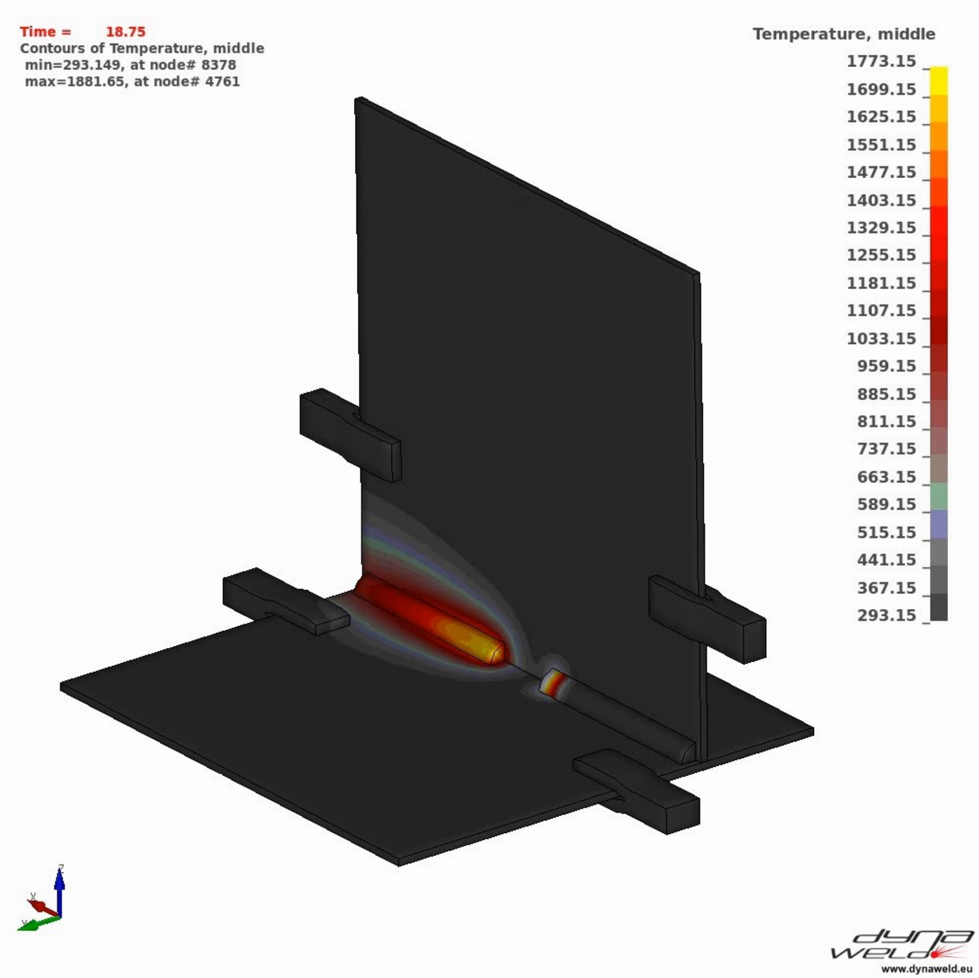
\+

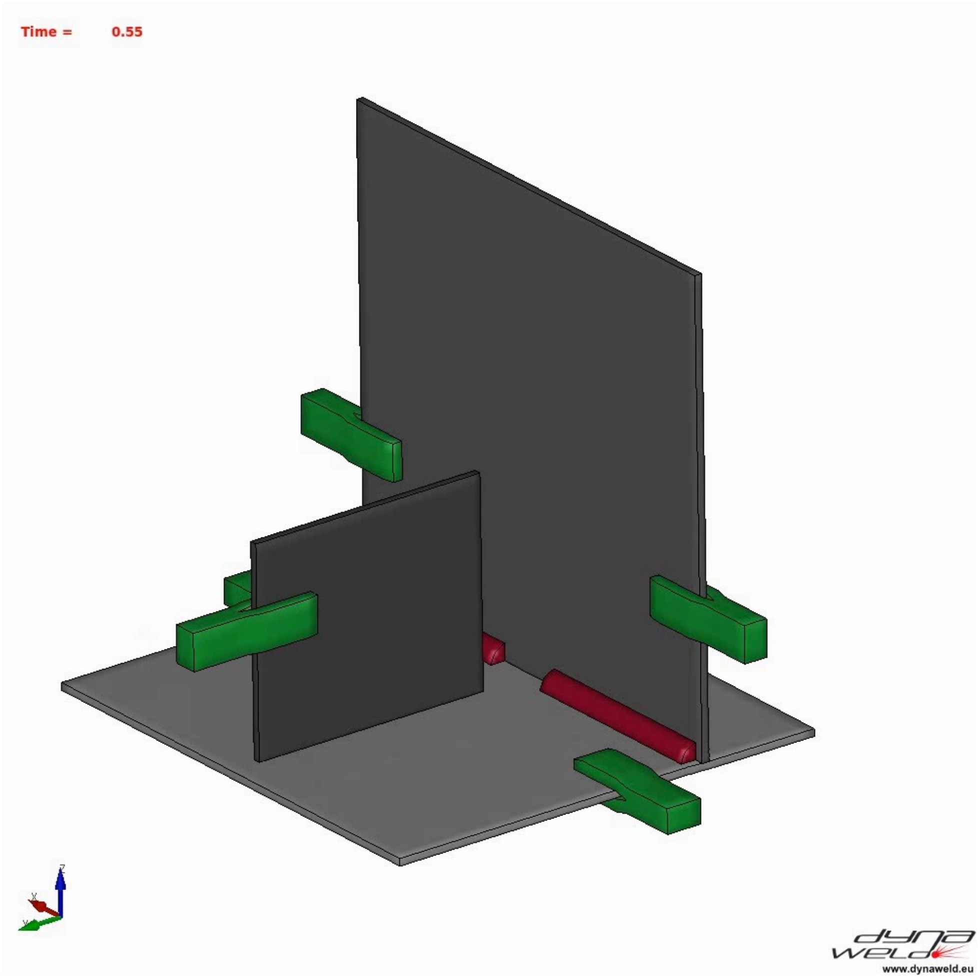
Step 3:
Welding 2, adding
further weld seams








Time = 18.75
Contours of Temperature, middle
min=293.149, at node# 8378
max=1881.65, at node# 4761
Temperature, middle
1773.15
1699.15
1625.15
1551.15
1477.15
1403.15
1329.15
1255.15
1181.15
1107.15
1033.15
959.15
885.15
811.15
737.15
663.15
589.15
515.15
441.15
367.15
293.15
www.dynaweld.eu


Time = 0.55
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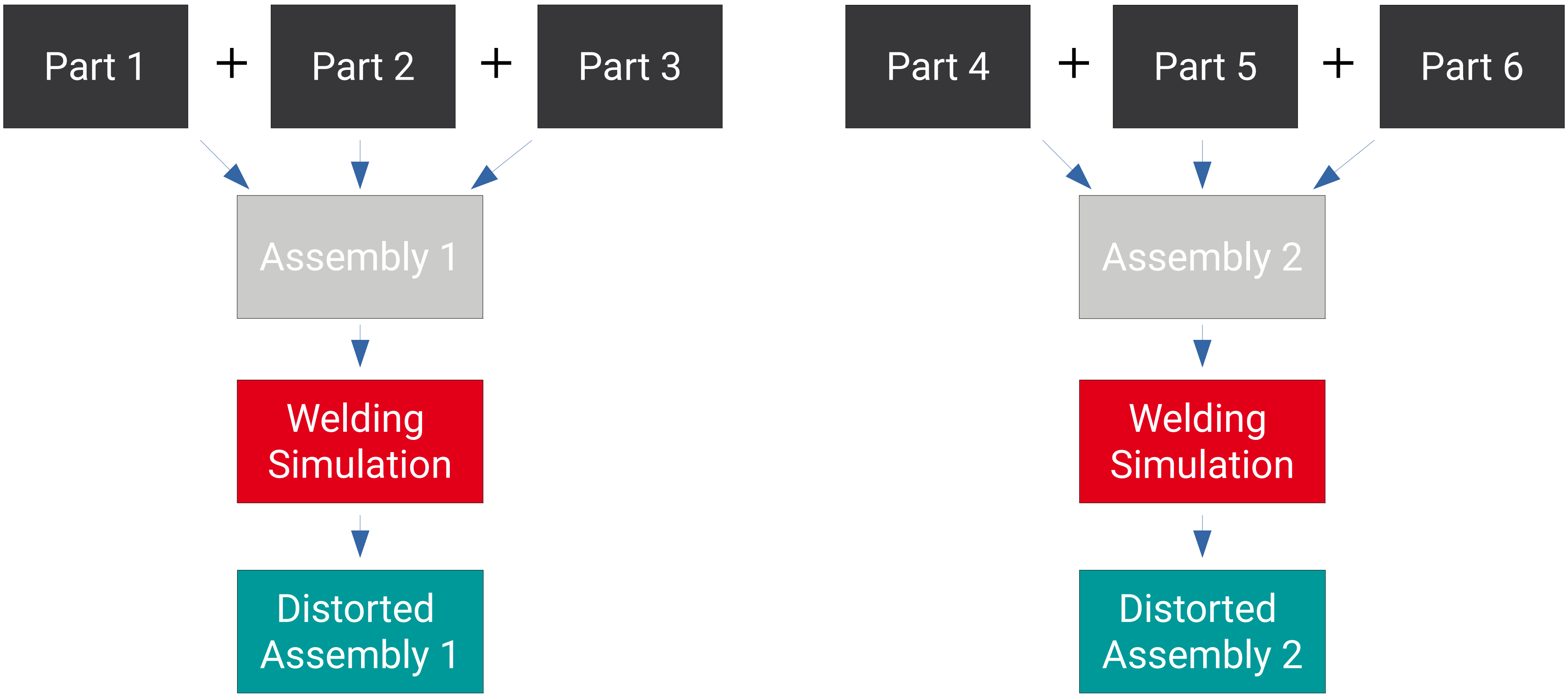
The assembly simulation takes into account prior stages

Assembly procedure - principle procedure



The assembly simulation takes into account prior stages

Assembly procedure - principle procedure

The geometry of single Parts 1 .. 8 may come from CAD or prior manufacturing simulation. They can have perfect geometry or imperfect geometry from prior manufacturing process, for example forming.

Distorted Assembly 1 + Distorted Assembly 2

+

- distorted geometry
- initial strain/stress
- welding contact status
- temperature distribution

+

- distorted geometry
- initial strain/stress
- welding contact status
- temperature distribution

+ Part 7

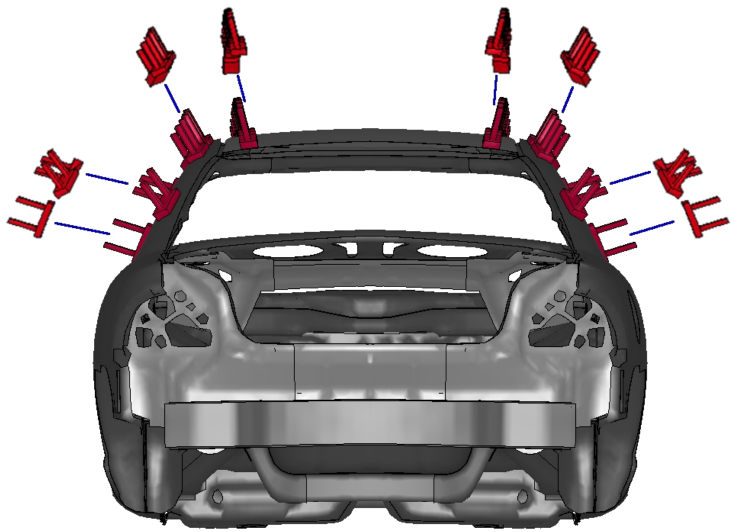
+ Part 8

Welding Simulation

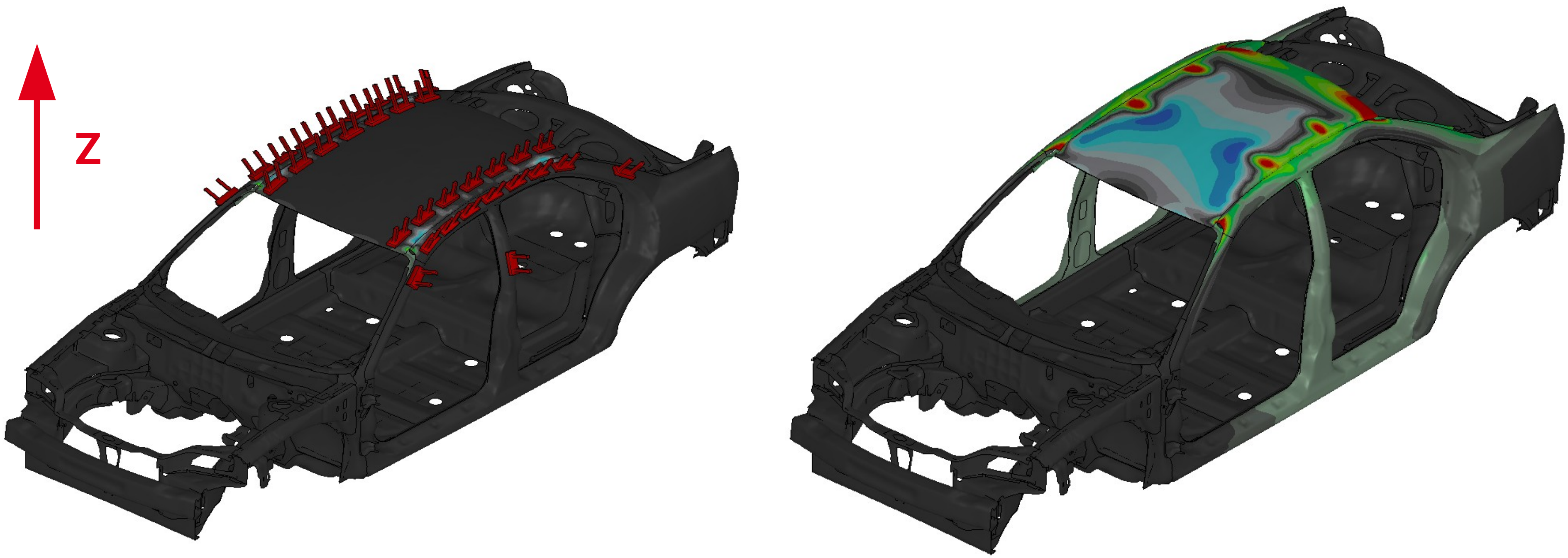
Distorted final Assembly

DynaWeld Car
Welding process of the roof

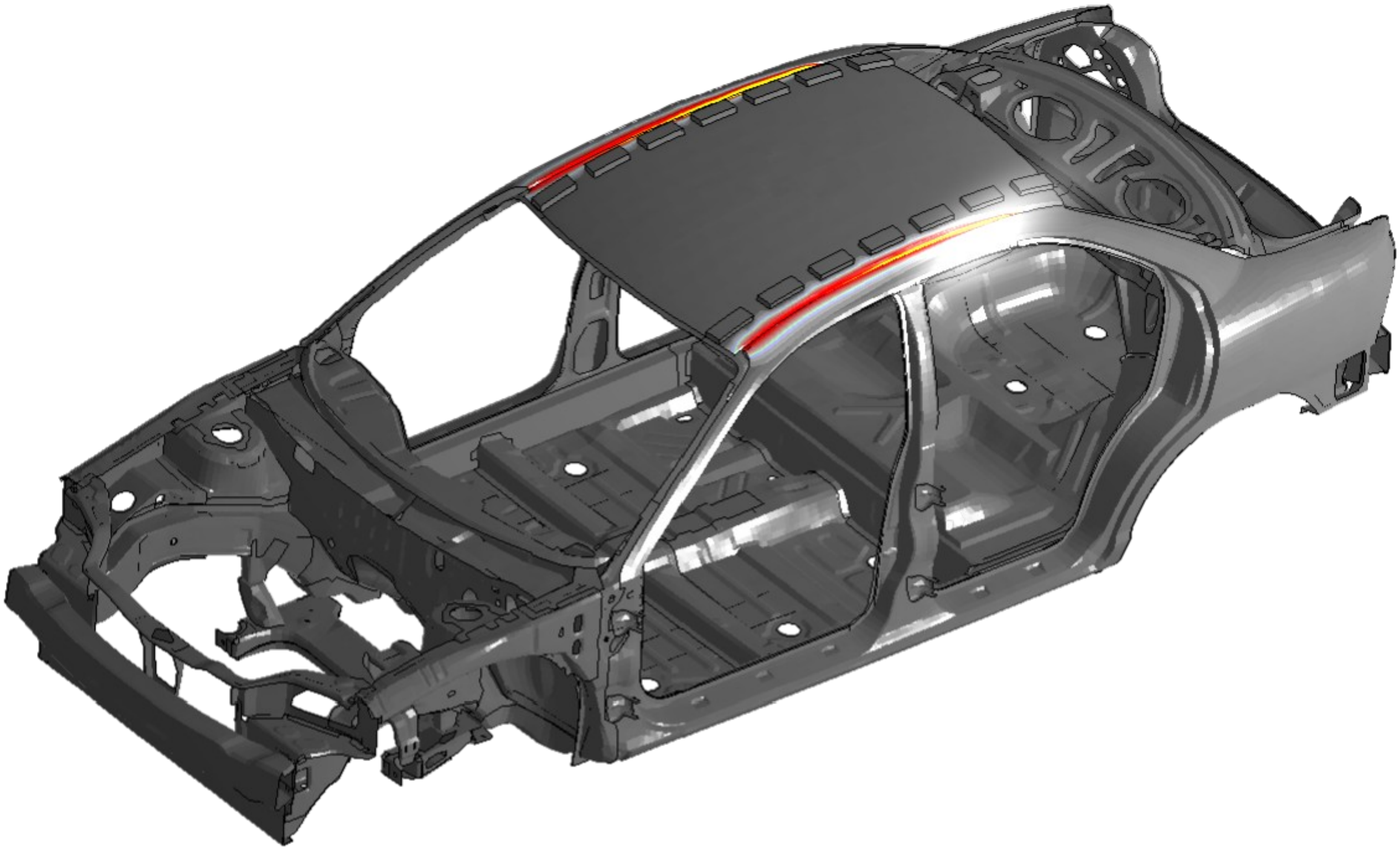
DynaWeld Car
Motion of the clamping tools



DynaWeld Car Z-Distortions before unclamping	DynaWeld Car Z-Distortions after unclamping and cooling

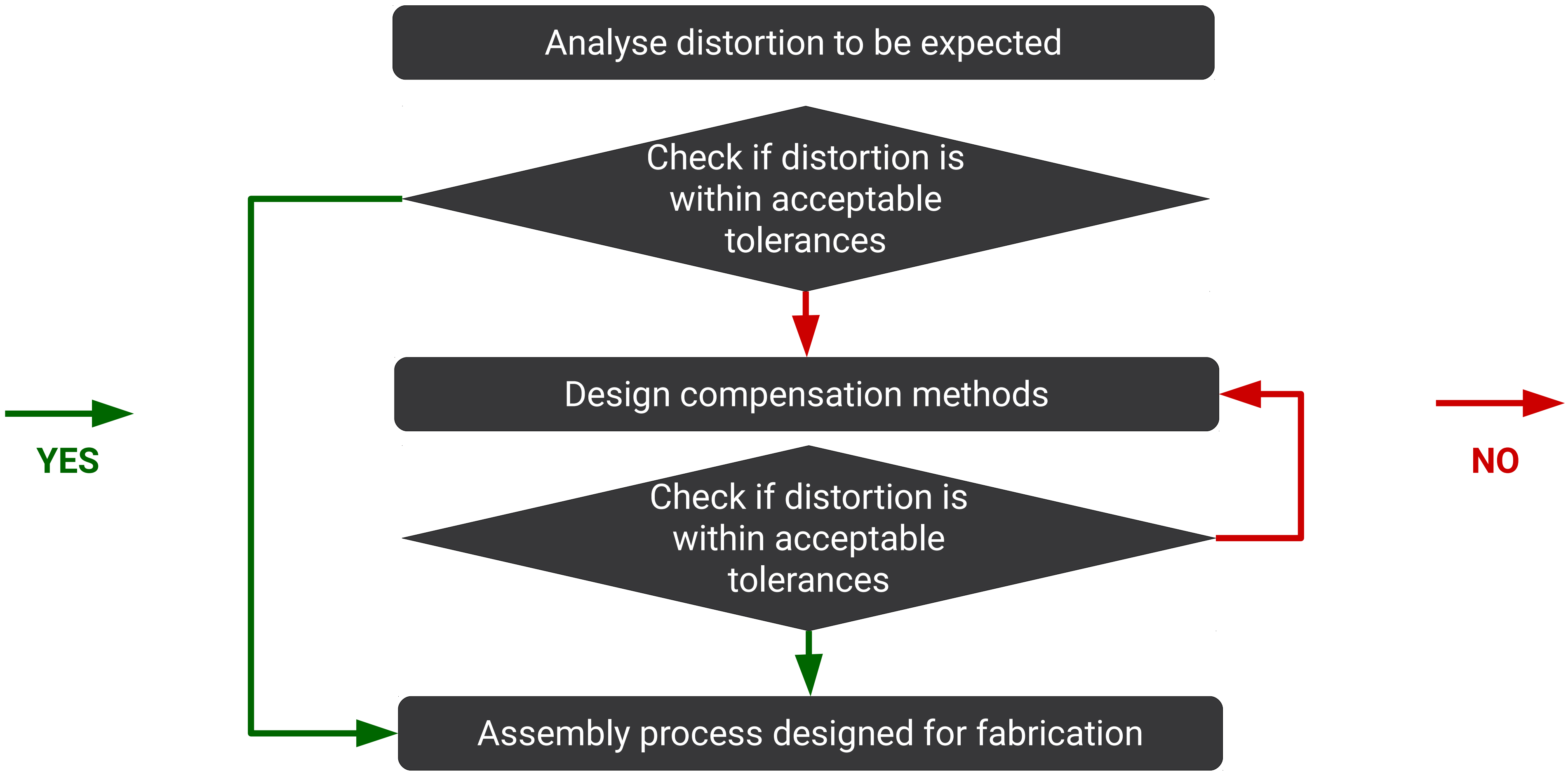


Animation of Roof Welding



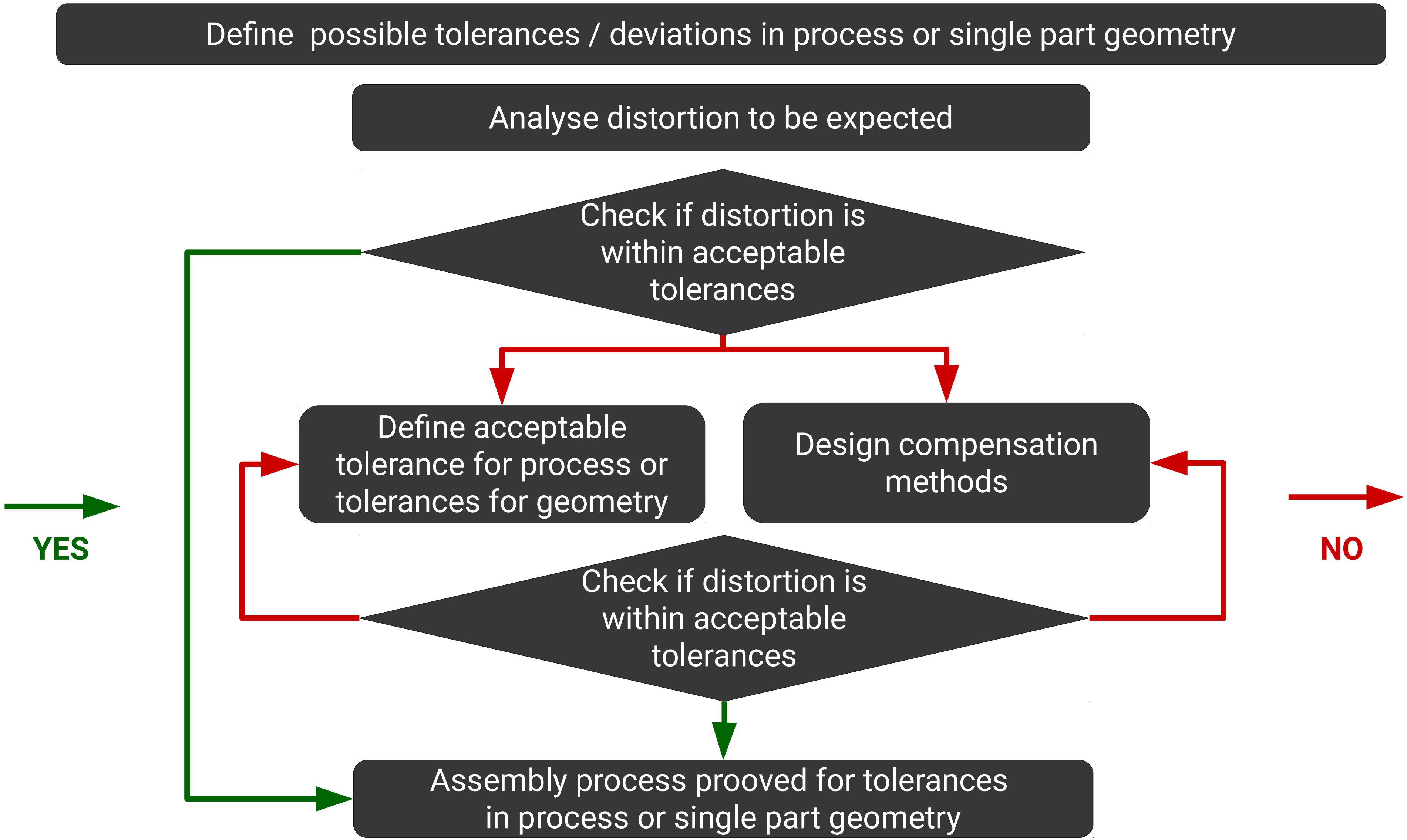
Distortion Management

Numerical calculation of deformation during welding assembly process



Distortion Management

proof of robustness – sensitivity analysis



Manufacturing – straight forward

Proof of design of manufacturing

Sensitivity on tolerances

Sensitivity Weld process - heat input

Sensitivity Clamping device

Sensitivity Imperfect single parts

Results

Proof / Non Proof

„Non Proof“:
requires optimization loop

Small / Moderate / High
Impact on distortion

In case of non acceptable distortions improve the issues with „High Impact“.

How many variants to run for check out best weld sequence?

2 welds = 2 possible weld sequences
3 welds = 6 possible weld sequences
9 welds = 362880 possible weld sequences

It is impossible to check out the best weld sequence due to N!

Is it economic to search for the weld sequence that leads to minimum distortion?

In industrial processes with many welds, rather not!
Apart from the extreme amount of possibilities in industrial processes, any better weld sequence might quickly get in conflict with the given boundary conditions of the manufacturing process.
This can be the cycle time, the amount of robots, their capacity and their interactions, the approachabilities and assembly position during welding.

Only for small weld seam numbers look for the best weld sequence of all possible sequences, else better:

- **Design different weld sequences optimized for production an check which is best**
- **Group welds and check different group orders**
- **Design compensation methods and go ahead with straight forward engineering**

Optimize weld sequence to minimize distortion
is rather a marketing fairy tale than serious engineering

How to Benefit from Distortion Management

Start with Distortion Management in the earliest state as possible:

- Approvement of the prearranged production
- Intervention in early states of development,
  if tolerances are not reached or visible distortions problems appear
- Solutions for distortion issues may be solved by the process design

Assembly analysis and integrated view of manufacturing

- Difference from target geometry by entire process
- Identification of the significant manufacturing steps for distortions and deviations for targeted intervention
- Design of compensation method
- Approval of compensation method or
- Approval of new designed manufacturing process

- Save many try out loops
- Low cost problem solution resolved by geometry design
- Save time to production
- Start production with proved and robust manufacturing processes
- Prevent any expensive emergency situation at production start

Thanks for attention!

Learn more on:
www.dynaweld.info

After more than 40 years of strong research by Pioneers like Goldak, Leblond and other welding distortion analysis by welding structure simulation is a well established and validated method. DynaWeld has entire knowledge on all physics behind and extended experience in application on industrial cases.

Extract of Reference:

- **Loose, T**.: Einfluß des transienten Schweißvorganges auf Verzug, Eigenspannungen und Stabiltiätsverhalten axial gedrückter Kreiszylinderschalen aus Stahl, Universität Karlsruhe, Diss., 2007
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- **Loose, T. ; Sakkiettibutra, J. ; Wohlfahrt, H.** : New 3D-Calculations of residual stresses consistent with measured results of the IIW Round Robin Programme. In: Cherjak, H. (Ed.) ; Enzinger, N. (Ed.) : Mathematical Modelling of Weld Phenomena Bd. 9, Verlag der Technischen Universität Graz, 2010

DynaWeld's full reference: dynaweld.info/en/dynaweld_company/

DynaWeld's research projects: dynaweld.info/en/service/research/