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Nord: Hermann-Löns-Straße 3A, D-21382 Brietlingen
Kamen: Herbert-Wehner-Straße 2, D-59174 Kamen
E-Post: info@dynaweld.de Web: www.dynaweld.eu

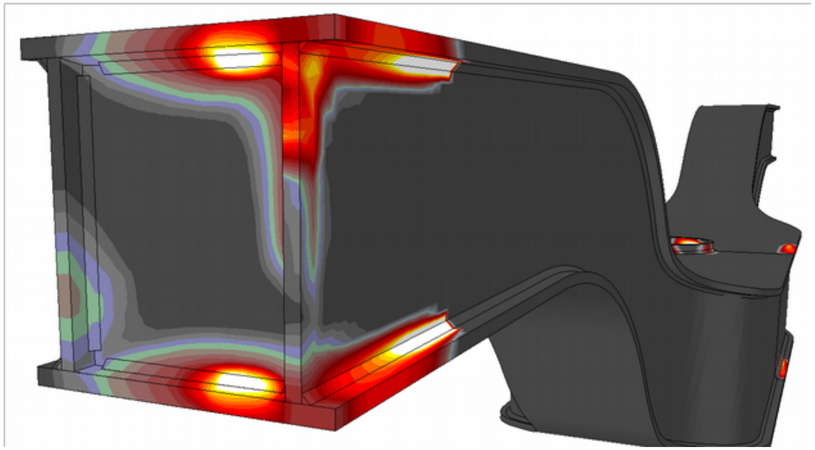
Can simulation speed up your manufacturing time

Tobias Loose, **DynaWeld - Germany**
John Goldak, **Goldak Technologies Inc. - Canada**

28.03.2019

Studienamiddag 3 AUTOLAS:
Lasmallen, vervorming en lasparameters

Expo Brussel



12th international Seminar
Numerical Analysis of Weldability

2018 Seggau - Austria

John Goldak in discussion with Tobias Loose


9th International Seminar
Numerical Analysis of Weldability
Graz – Seggau, Austria

Kenneth Easterling
Best Paper Award

Given to the paper

New 3D-calculations of residual stresses consistent with measured results of the IIW round robin programme

T. Loose, J. Sakkiettibutra, H. Wohlfahrt

This paper has been valued by an international committee as the best contribution made over the three years proceeding on the advancement of knowledge or practice in respect of mathematical modeling of weld phenomena.

Graz Seggau, September 2009

Awardings

- 2018 John Goldak - Lifetime Award for his work in welding computional mechanics
- 2009 Tobias Loose - Best Paper Award

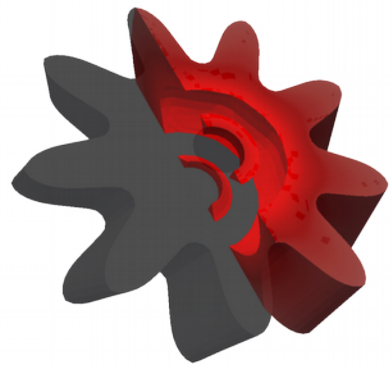
About DynaWeld's Business

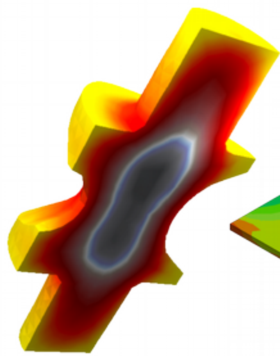
- Process Optimization
- Distortion Compensation
- Quality Optimization

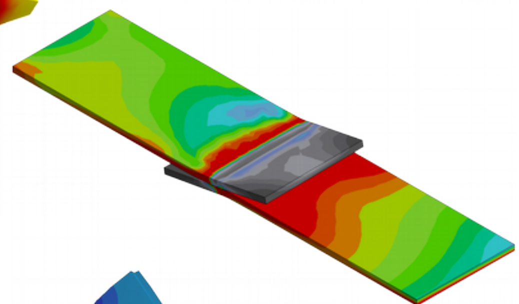
- Heat Tratment
- Welding
- Hotforming

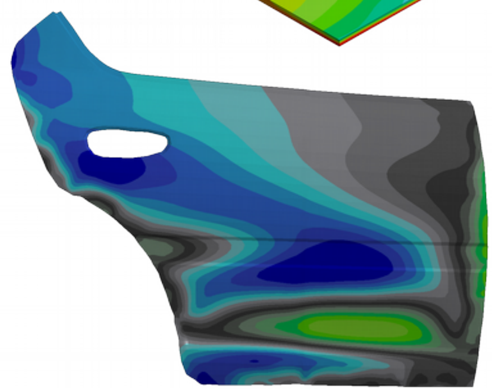
- Distortion
- Residual Stress
- Metallurgy
- Crack And Strength

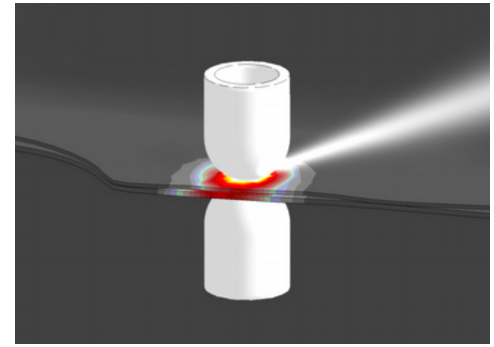
- Material Management





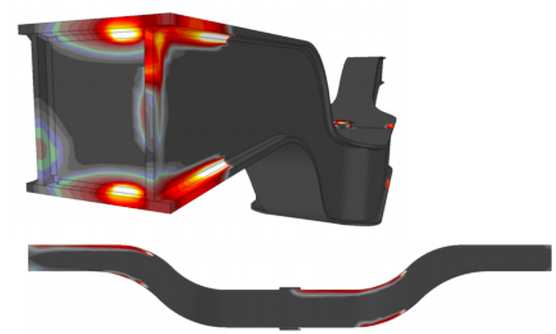






DynaWeld is more than 20 Years of experience in

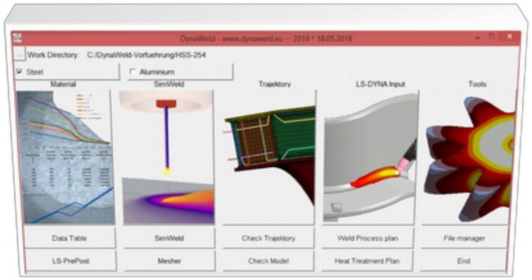
simulation of all kinds of thermal related manufacturing and material processes



Consulting And Research

DynaWeld's Development

DynaWeld®



- Preprocessor
- Environment And Material Data Manager
- Welding, Heat Treatment, Forming
- High Sofisticated Simulations

- **Simulation of Assembly**

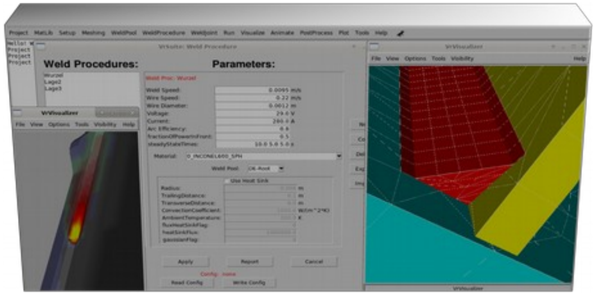
MatplusHQ

- Simulation Tool
- Pre- Postprocessor And Solver
- Heating And Quenching
- Very Easy Usage For Everyone

Development - Training - Support - Customer related software solutions

DynaWeld's Distribution

Goldak VrSuite from Goldak Tecnologies Inc.



- Entire Simulation Tool
- Meshing, Automesh of Single / Multipass Filler
- Pre- And Postprocessor
- Solvers designed for Welding / Heat-Treatment
- Material Database
- Material Simulation
- Microstructure Macroscale Analysis
- Microstructure Microscale Analysis, Solidification and Graingrowth Simulation

Goldak Technologies

- Welding
- Heat-Treatment
- Casting

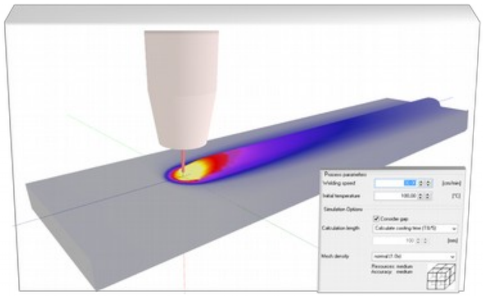
- Deformation
- Residual Stress
- Microstructrure

- Optimisation Tool for
  - Zero Distortion
  - Stess Minimisation
- Fatigue Analysis and crack propagation

Development - Training - Support - Customer related software solutions

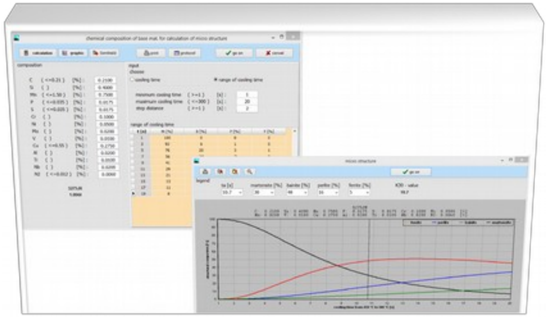
DynaWeld's Distribution

SimWeld® from ISF



- Pre- And Postprocessor
- Welding Process Simulation
- Environment And Material Data Manager
- Direct Input Of Power Source Process Data

WeldWare® from SLV



- Welding Advisory Tool
- Simple and Fast Estimations
- Material and CCT Data For Steel
- Easy To Use

Development - Training - Support - Customer related software solutions

Benefits and Applications

Benefits

Prematurely detection of possible manufacturing problems

- **causal research**
- **testing alternatives**
- **all before finalize the production facilities**

Virtual design of process, manufacturing and state of assembly
in early stage without physical experiments and trials

- **enables straight forward engineering**
- **save resources**
- **save cost**

Optimisation of process by simulation

- **saves time**
- **saves cost**
- **increase productiveness**

Process chain simulation

- **enables design from material up to final product**

Simulation accompanied manufacturing monitoring the state of workpart

- **guarantees high level of quality**

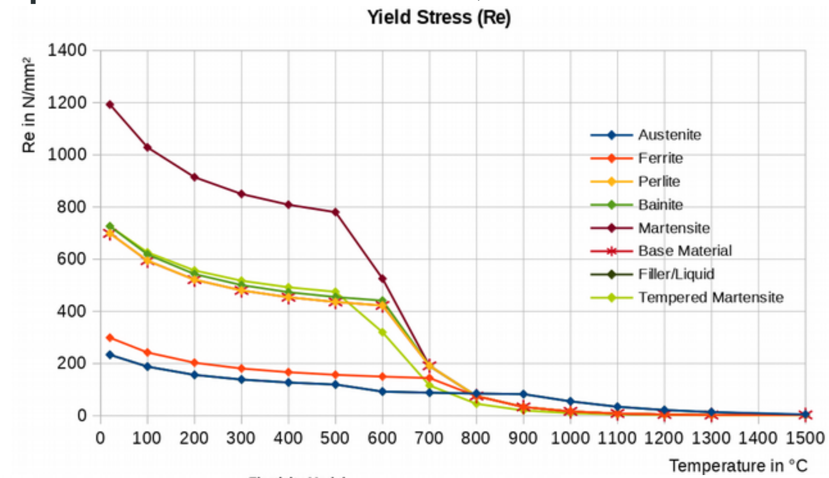
Applications

- **Distortion**
  - Optimization, compensation
- **Mechanical and metalurgical properties**
  - Microstructure
  - Stress, strain, strain hardening
- **Heat engineering**
  - Analysis and evaluation of temperature field
- **Process, process parameter**
  - Melt pool evolution
  - Weld nugget size
  - Window of acceptable process parameter
- **State of assembly as initial state for further analysises**
  - Strenght analysis
  - Ultimate load analyis
  - Forming, crash, coating…
- **Process chain analysis of many manufacturing steps**
  - Heat treatment, welding, forming, cutting, grinding

Simulation Background and Validation

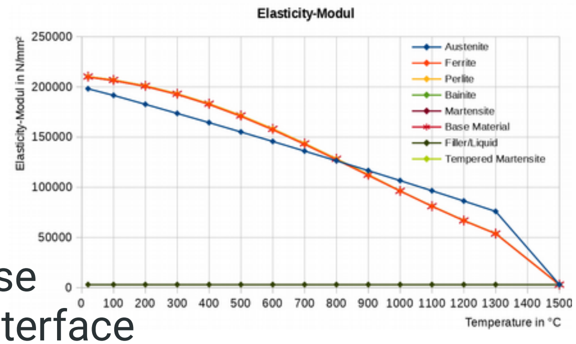
Material Properties for Welding Analysis

Material properties and material model for welding analysis needs to take into acount thermal dependend behaviour,



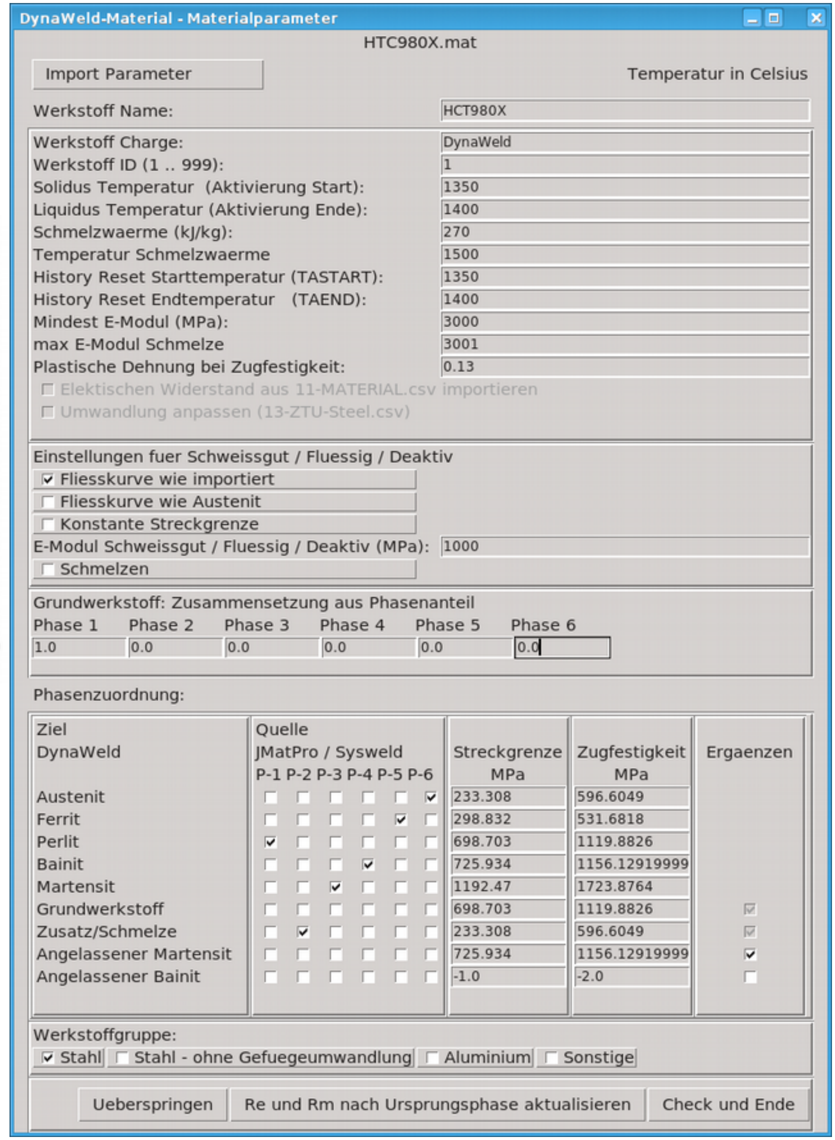
in certain cases the metalurgical behaviour too.

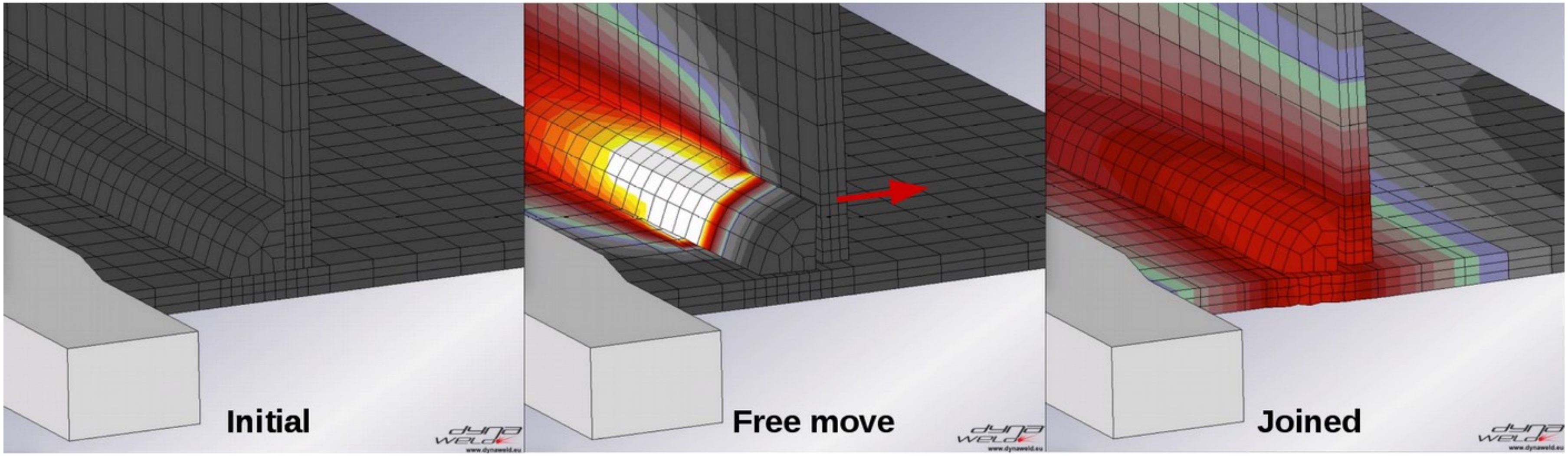
Apart from expensive measurements a material simulation can provide the necessary data too.



Solutions:

- Material Database
- Material Data Interface
- Material Simulation
- User defined Data

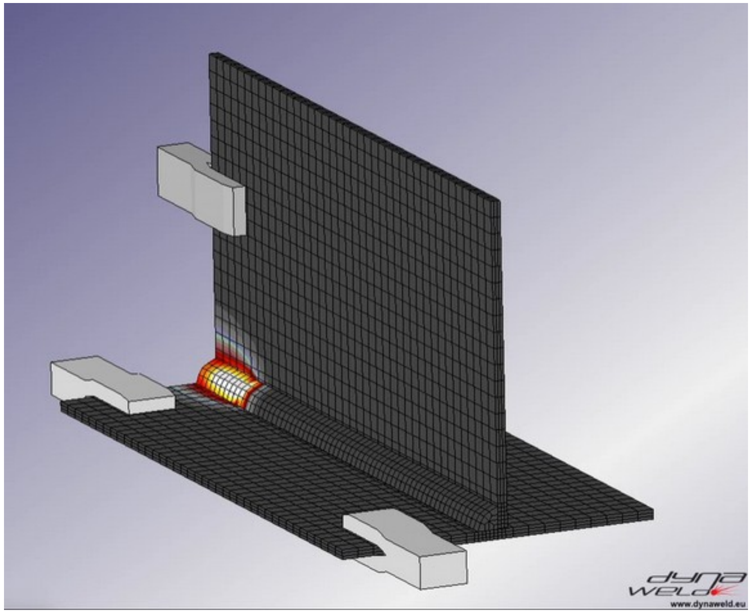


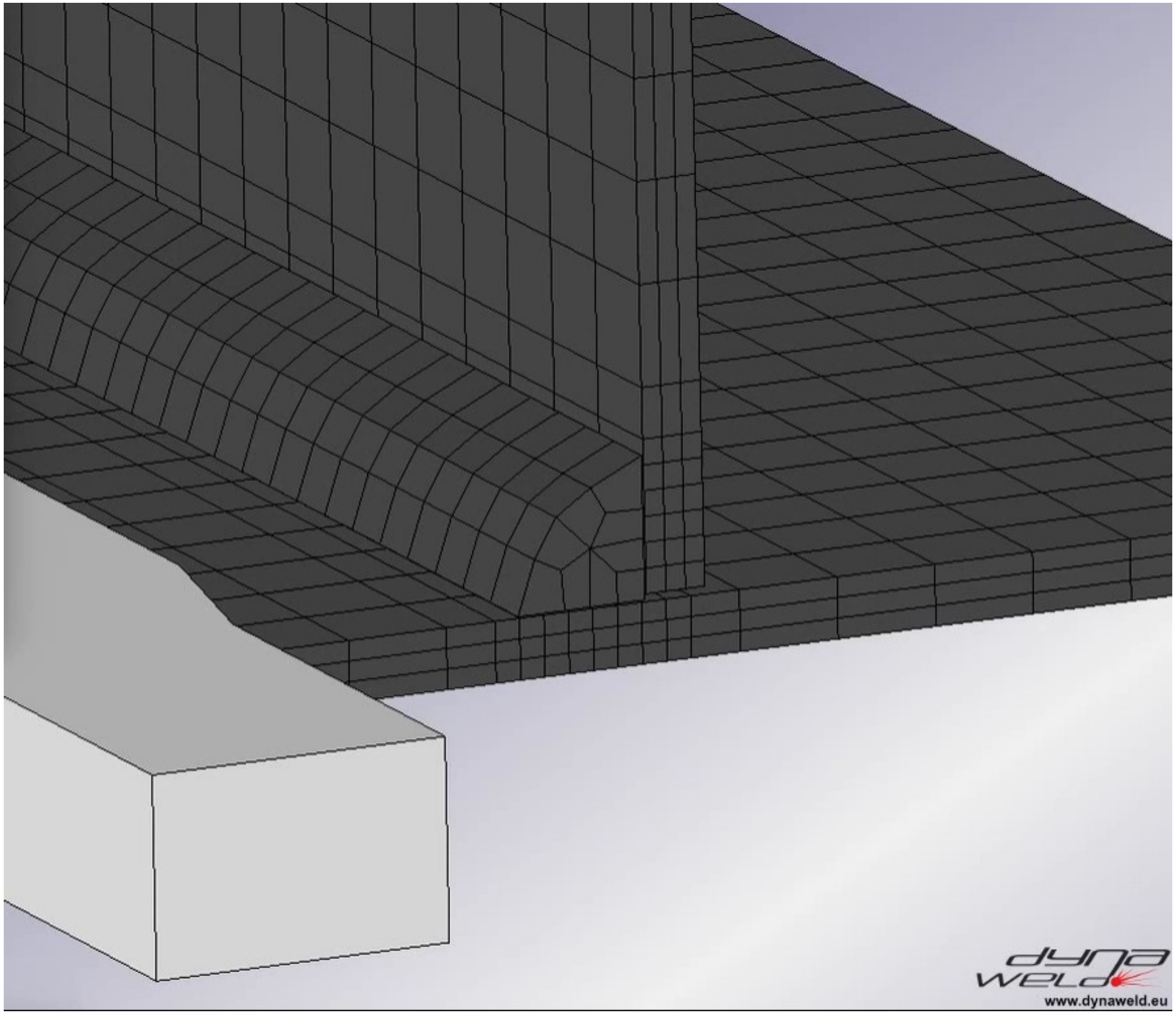


- Tack welding
- Clamps and clamp closing
  - distortion by clamp closing
- Predeformation
  - distortion compensation
- Grinding and cutting
  - distortion by residual stress release

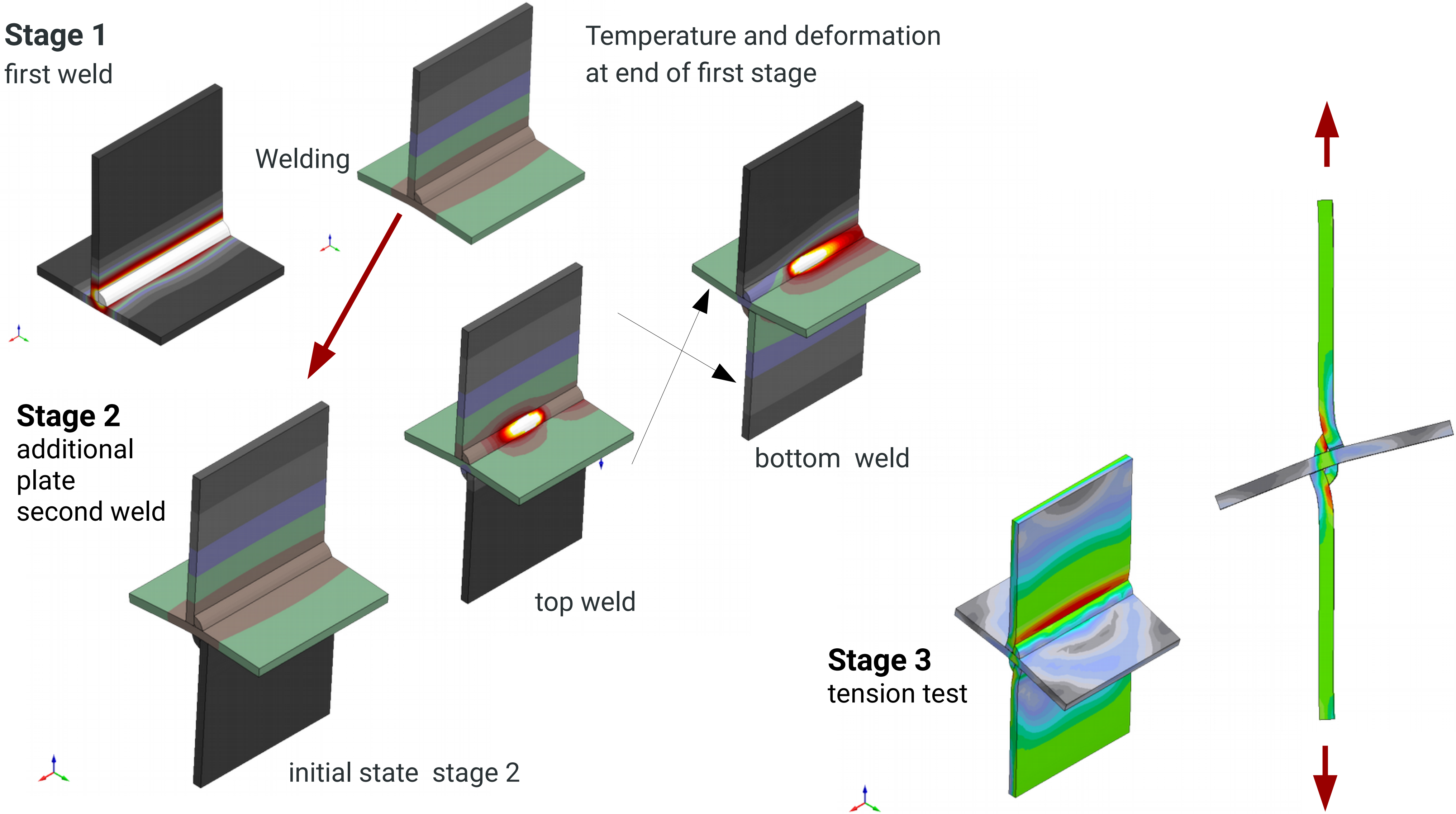
Free Motion Filler Technology

and other important issues for distortion engineering

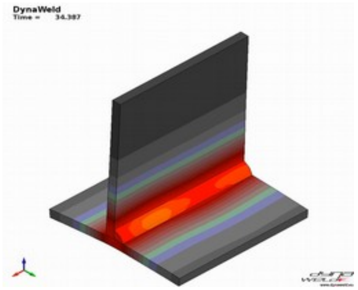




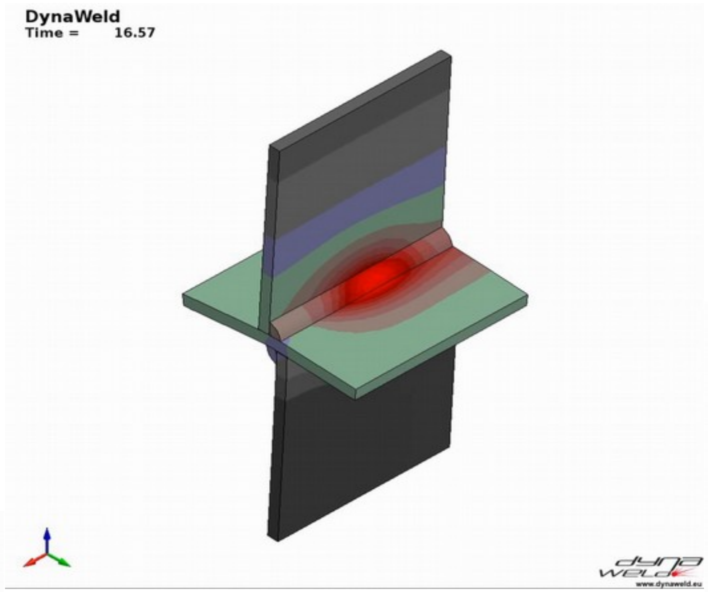
Multi stage simulations



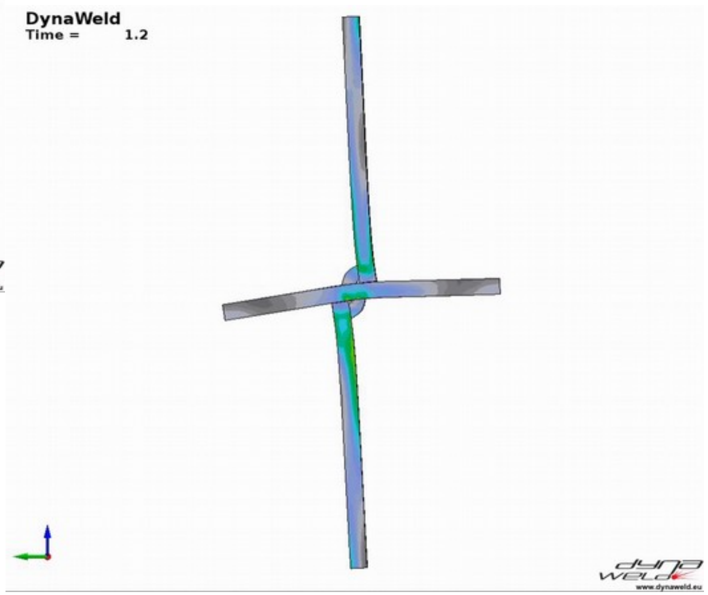
Stage 1

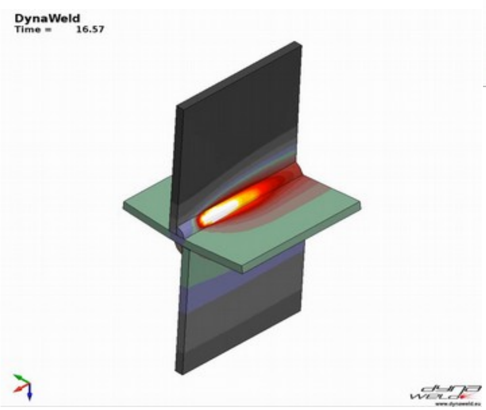


Stage 2



Stage 3 - Tension test





Stage 2 upside down

Virtual Weld Test validated with Real Weld Experiment

Goldak Technologies

Experimental Setup

The experimental setup consisted:

- Two 1018 to 1018 plates
  - (300 by 140 by 6.35 mm)
- Digital Image Correlation (VIC 3D)
- Luna ODISI B Fiber Optic System
- 2 Thermocouples
- 1 iPhone X, FLIR Pro One Camera
- 4 Clamps
- 1 Tig Welder

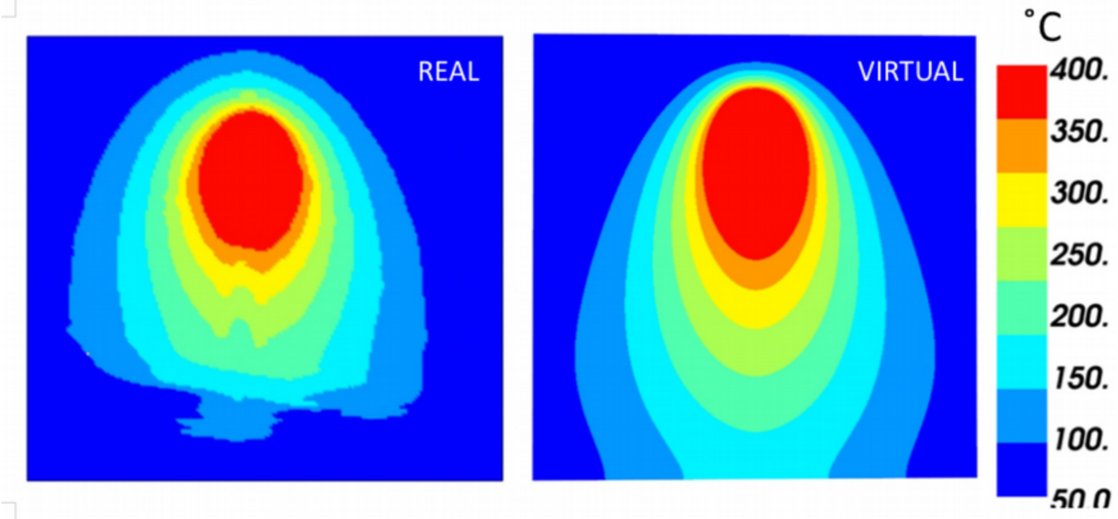
Vr Software Suite

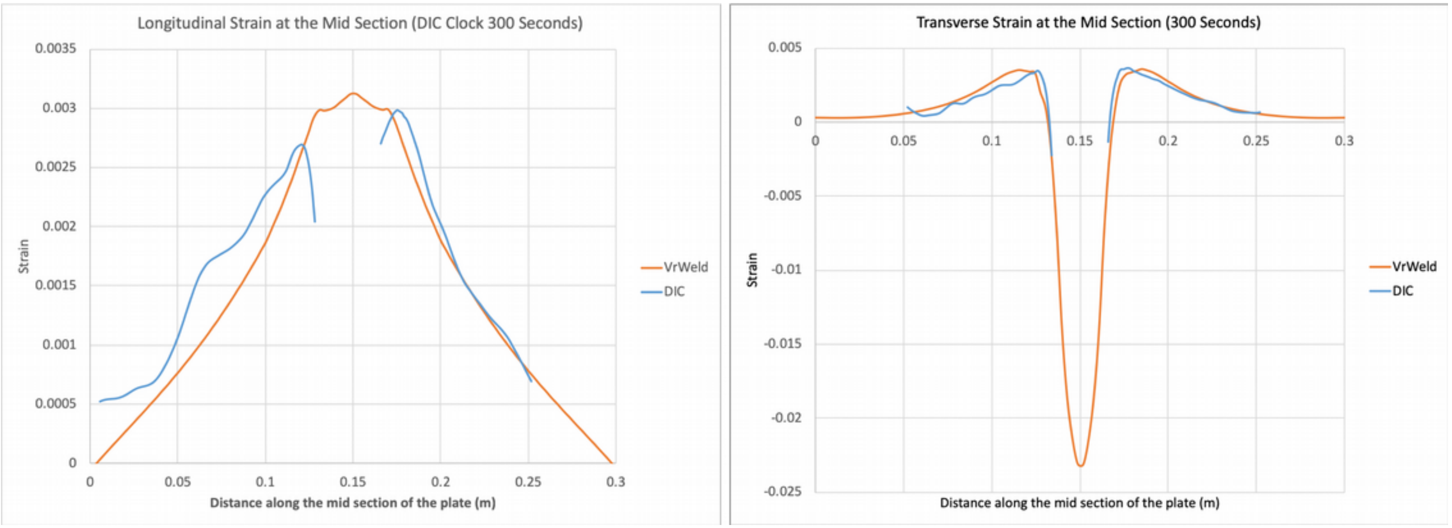
Goldak Technologies Inc.

Goldak, J. et. al.:
Correlation Large Sets of Experimental Data With High Resolution Computational Weld Mechanics Models.
In: Proceedings of 12th International Seminar Numerical Analysis of Weldability, 23.-26.9.2018, Seggau, Austria

Comparison of Temperature and Strain

Goldak Technologies



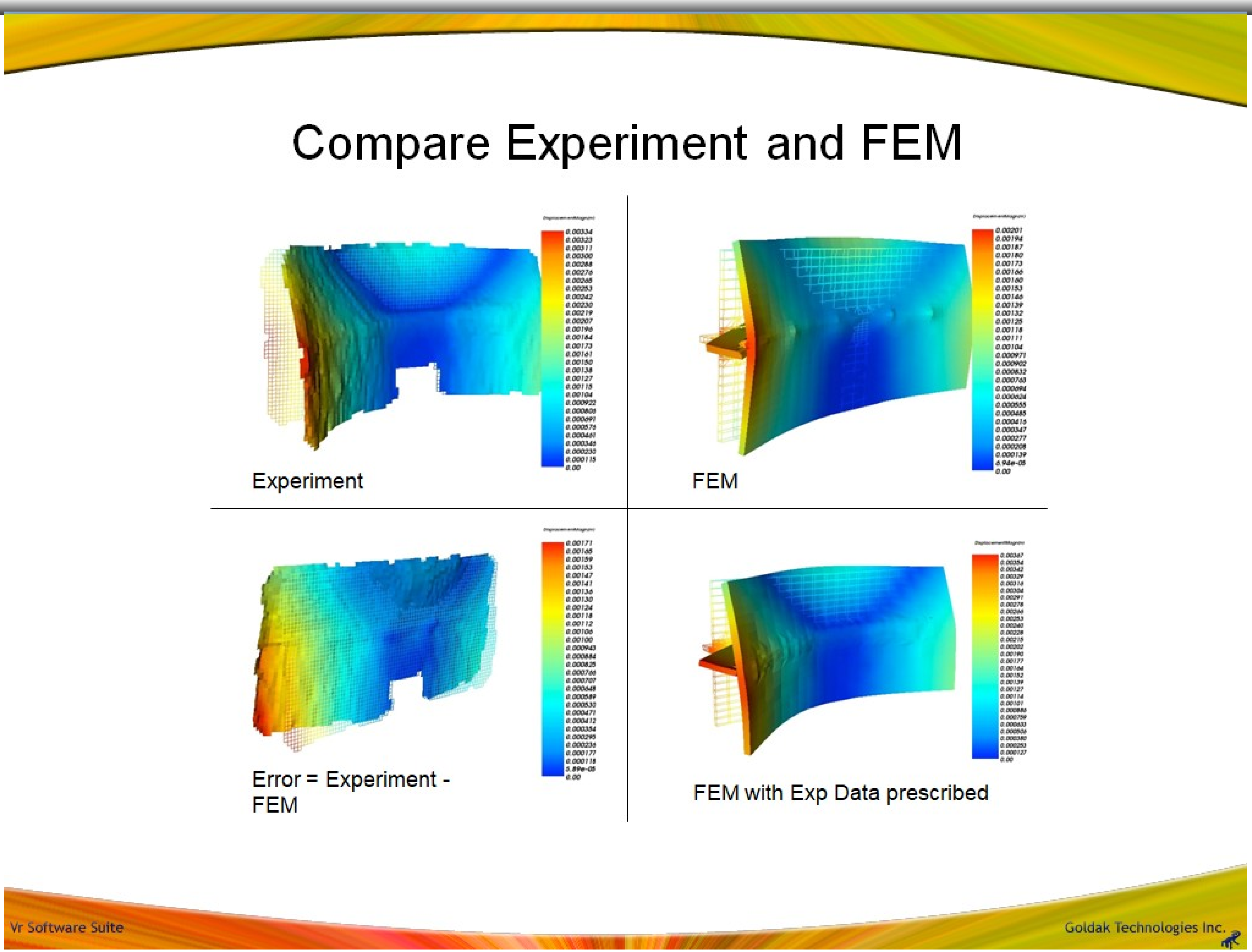


Validation at Fillet welded T-Joint with Tack Welds

Goldak Technologies

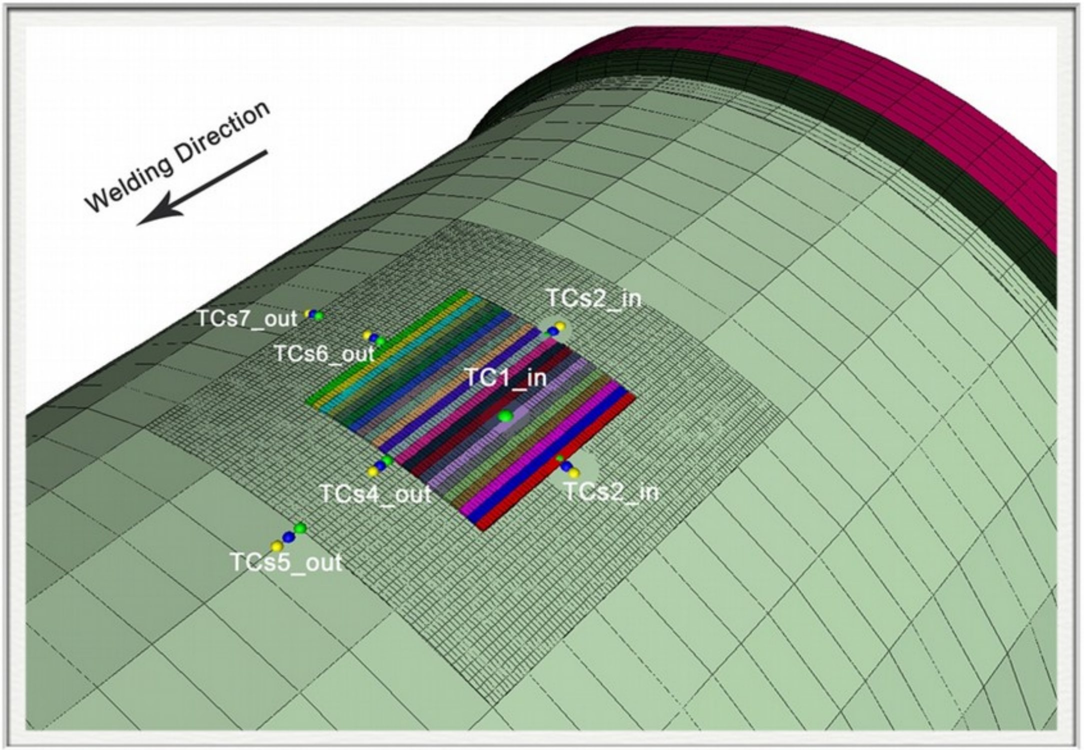
3D optical measurement with Aramis

Numerical analysis (FEM) with VrWeld



Goldak Technologies

Thermocouple Locations



Vr Software Suite

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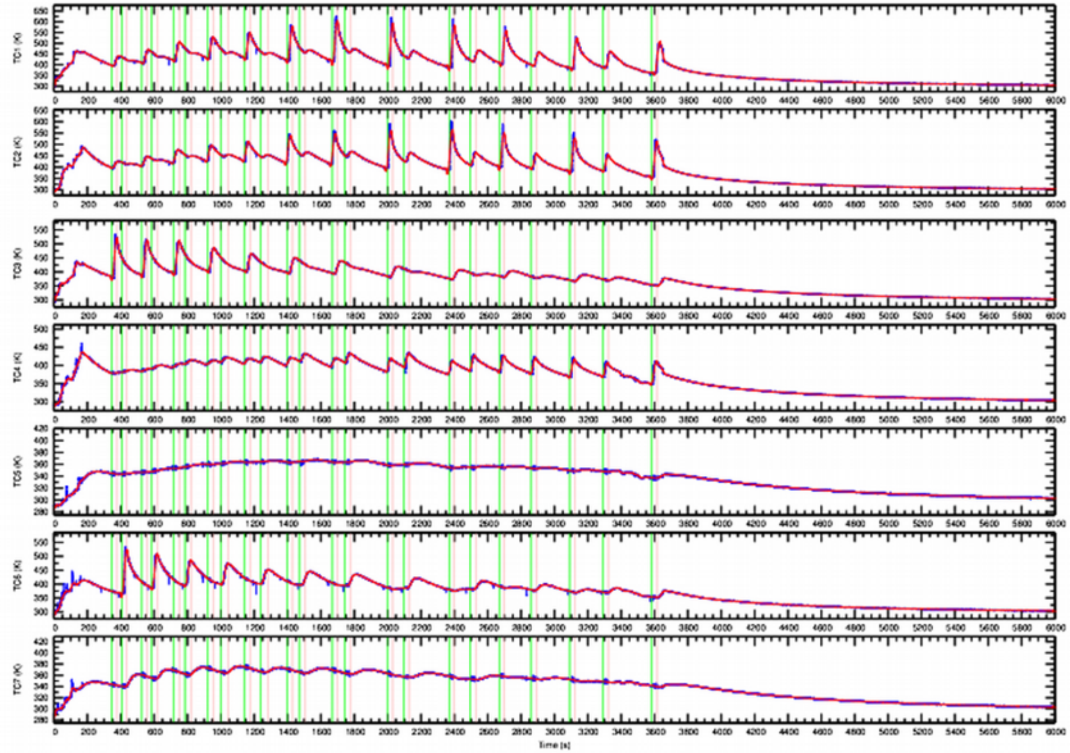
Validation of Temperature
multipass Overlay Weld on Cylinder

Goldak Technologies

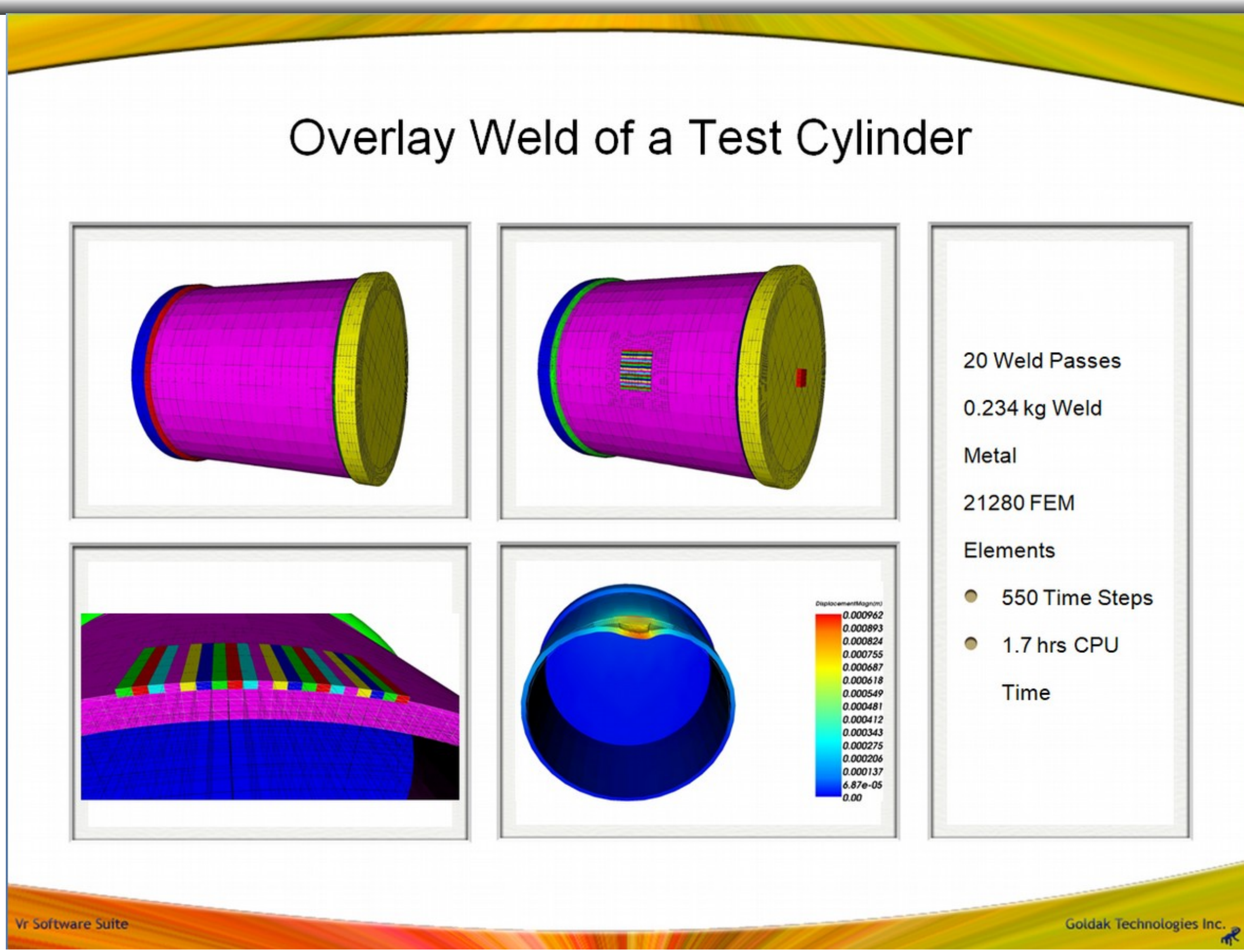
Real (Blue) & Virtual (Red) Temperatures in an Overlay Weld



Vr Software Suite

Goldak Technologies Inc.

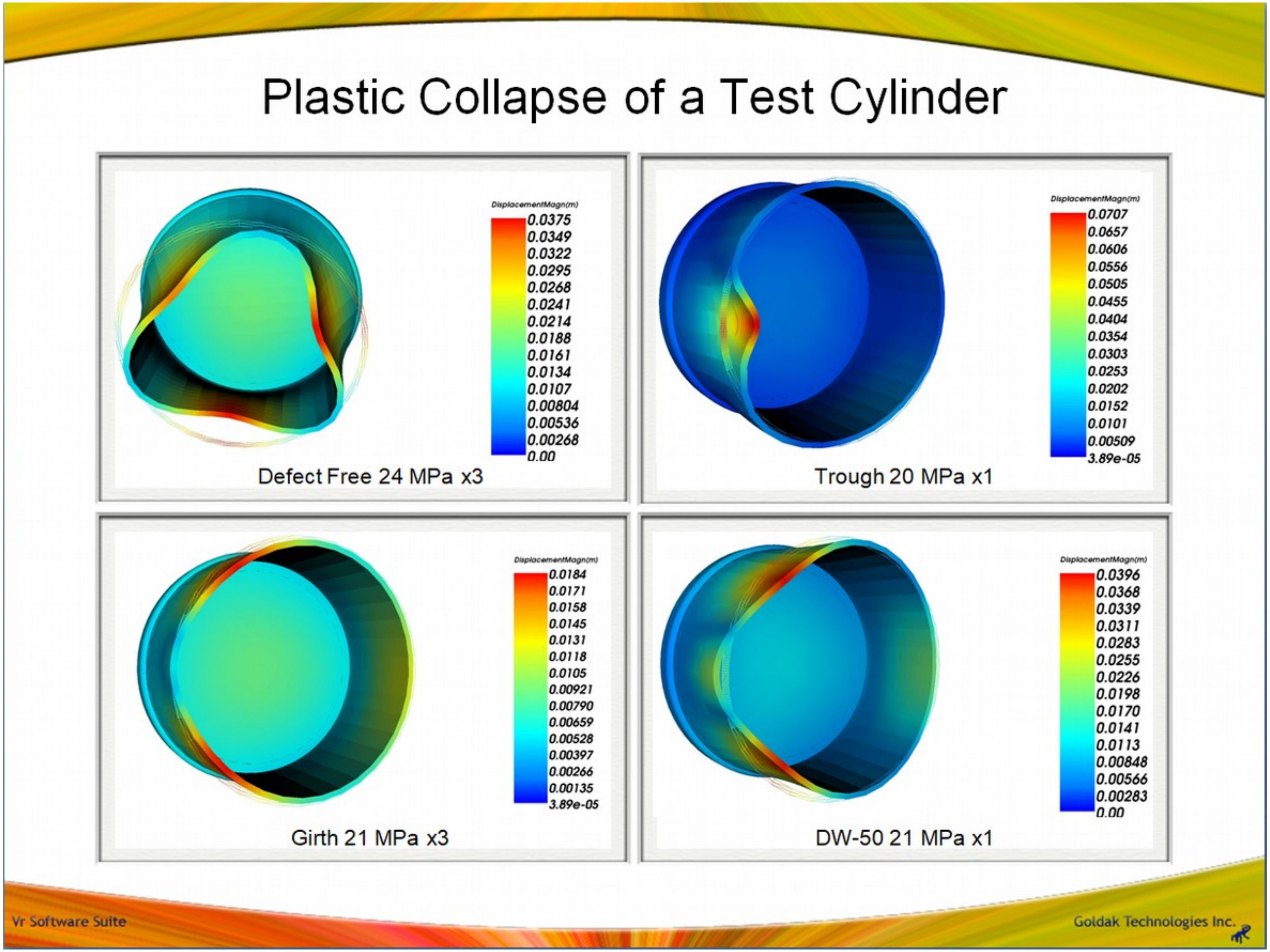
Goldak Technologies



Determine Ultimate Load of Repair Weld

multipass Overlay Weld on Cylinder

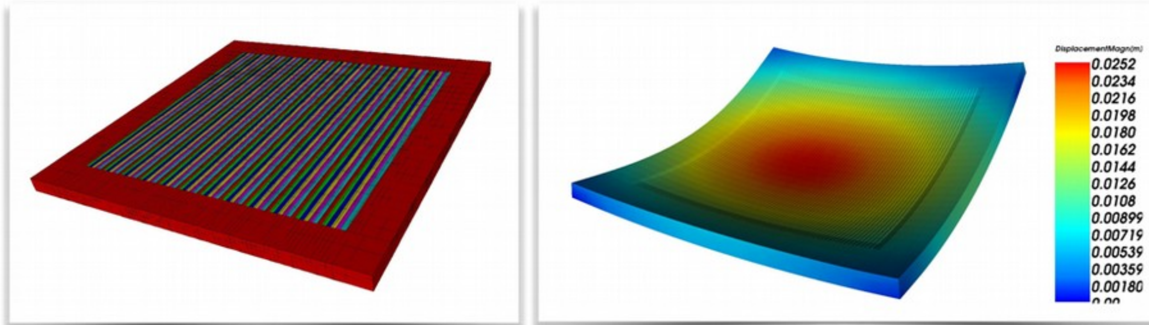
Goldak Technologies

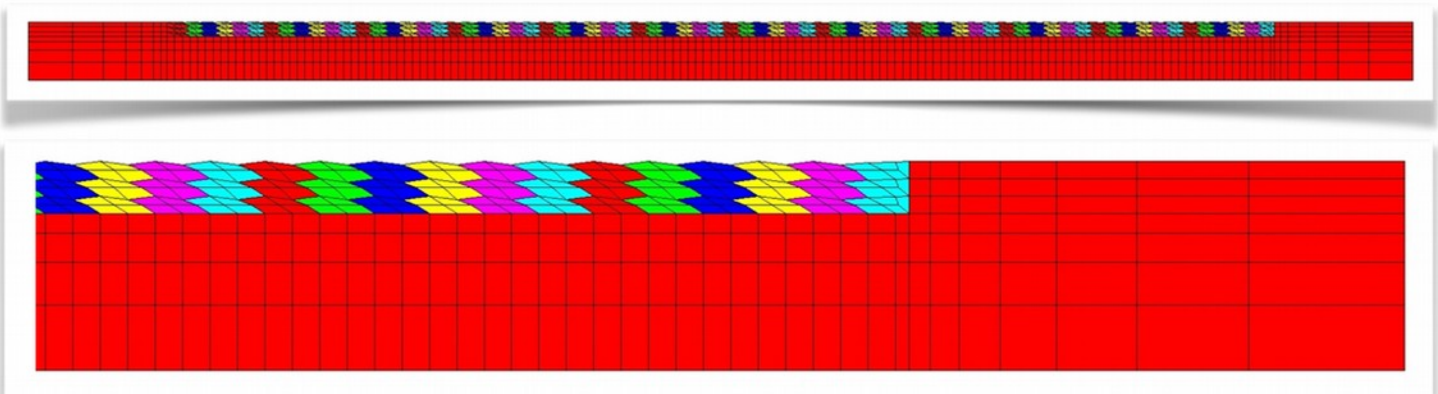


Goldak Technologies

Overlay Weld of Explosion Bulge Test Plate

- 216 Weld Passes
- 133 m of weld
- 26 kg Weld Metal
- 38000 FEM Elements
- 8021 Time Steps
- 56 hrs CPU Time





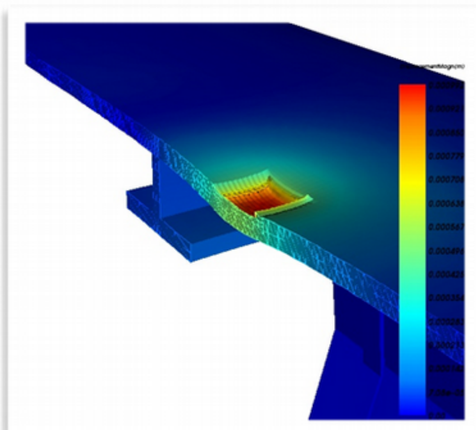
Vr Software Suite

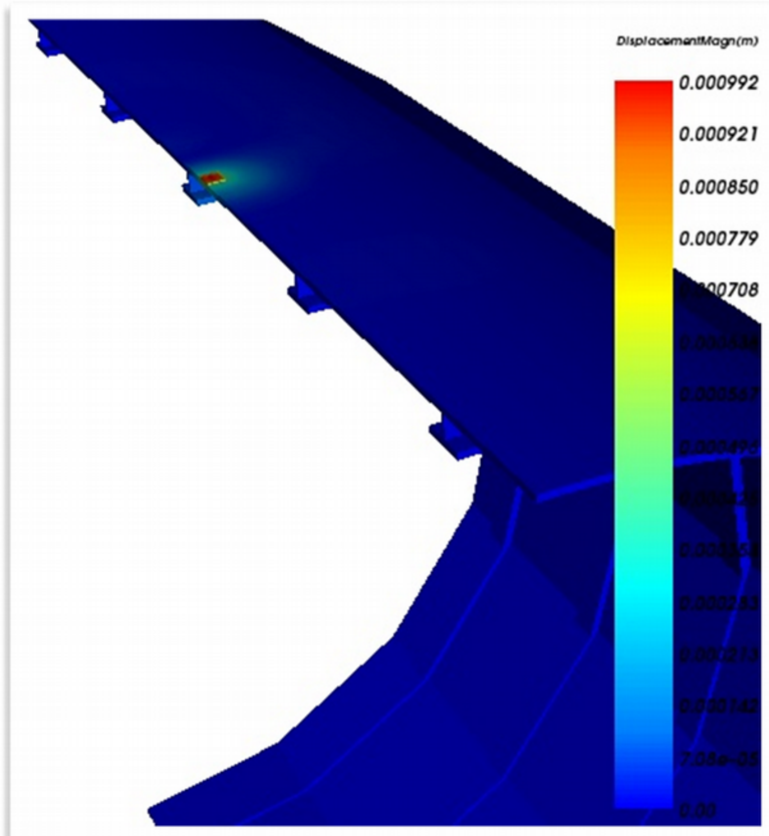
Goldak Technologies Inc.

Goldak Technologies

Displacement due to an Overlay Weld Repair

- 36 Weld Passes
- 0.7 kg Weld Metal
- 32806 FEM Elements
- 1182 Time Steps
- 8 hrs CPU Time





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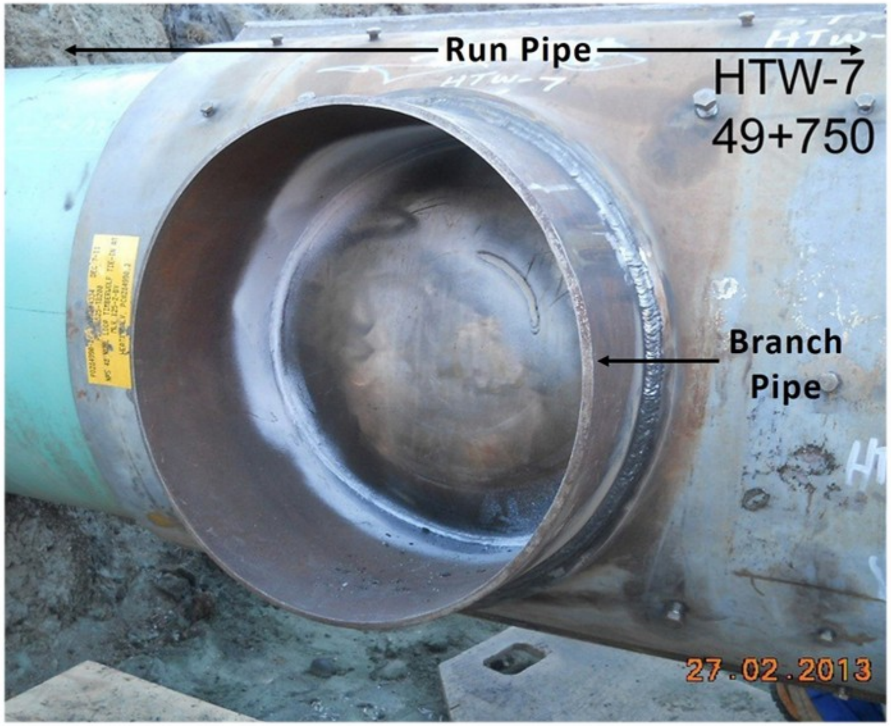
A Branch Tee Being Welded to a Run Line Pipe



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Goldak Technologies

The First Stage of a Hot Tap Weld

Temperbead overlay welds on the run pipe are a base for the branch pipe weld.

Vr Software Suite

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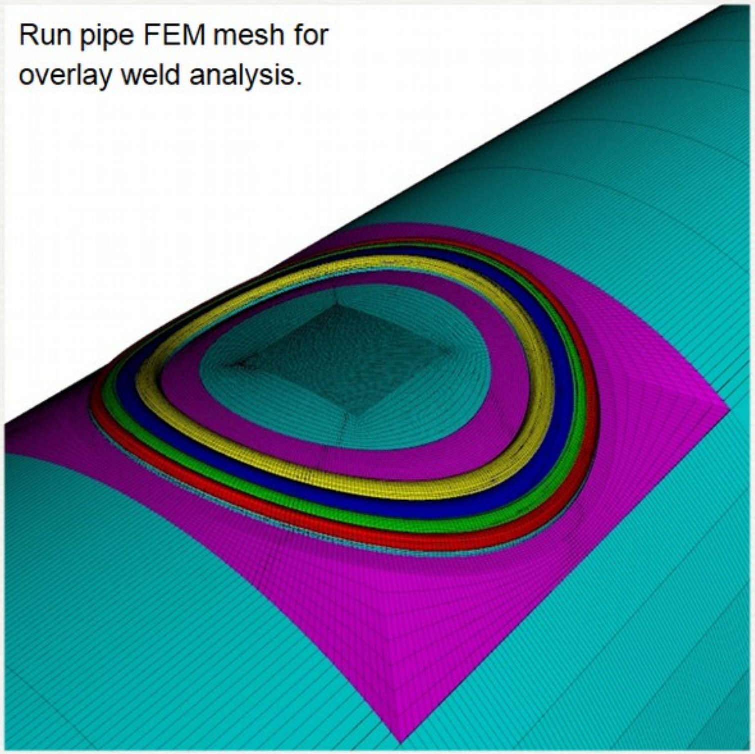
Engineering Example - Pipe T - Connection

Multipass Welding with Cladding and Grinding

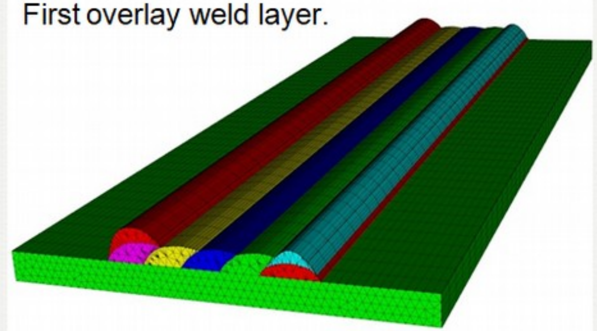
Goldak Technologies

Virtual Analysis of a Hot Tap Weld

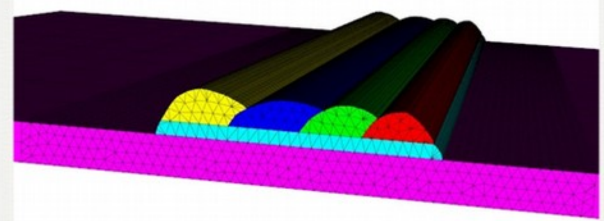
Run pipe FEM mesh for overlay weld analysis.



First overlay weld layer.



Grind overlay weld layer. Then overlay 2nd layer.



Engineering Example - Pipe T - Connection

Multipass Welding with Cladding and Grinding

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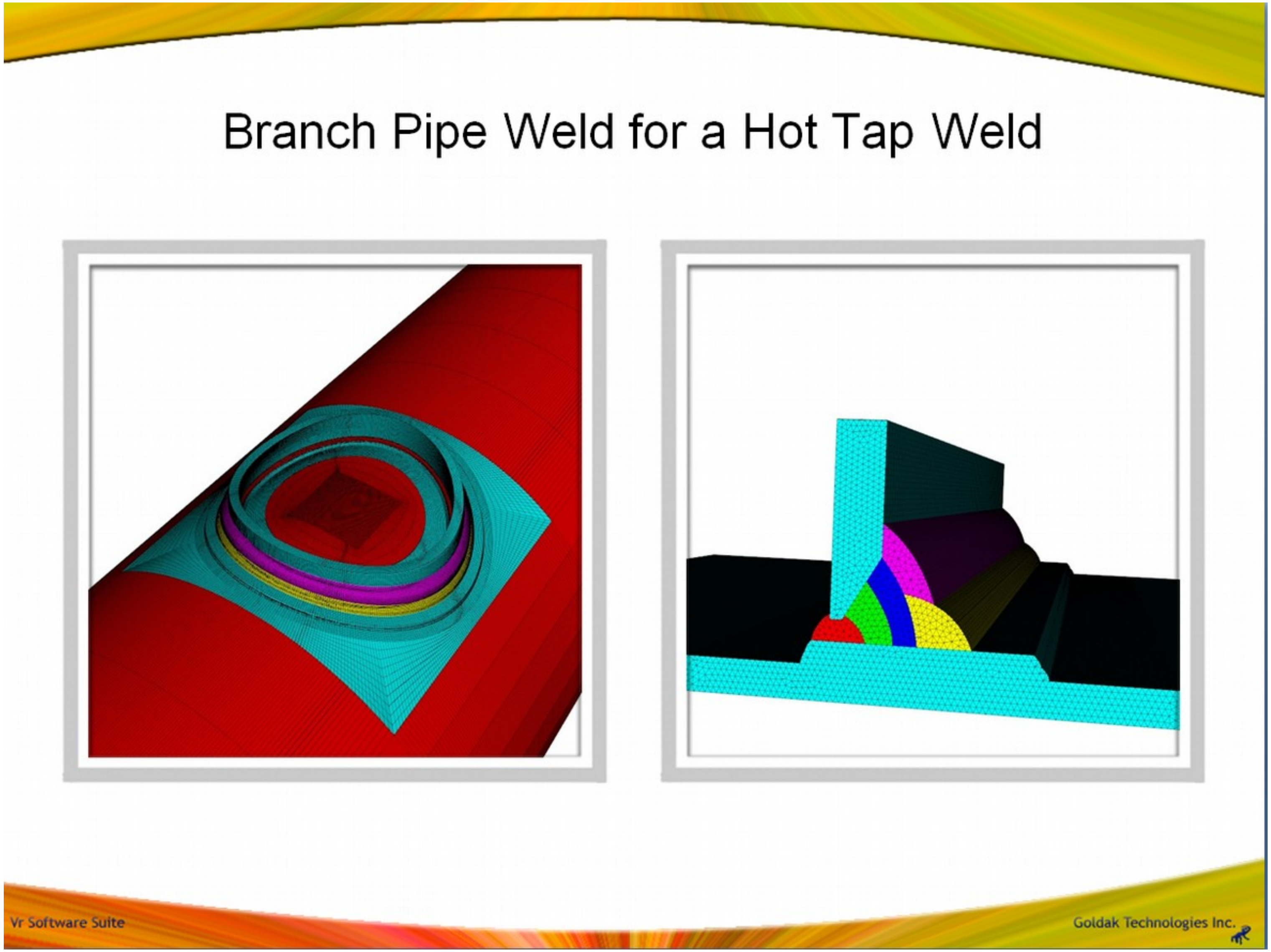
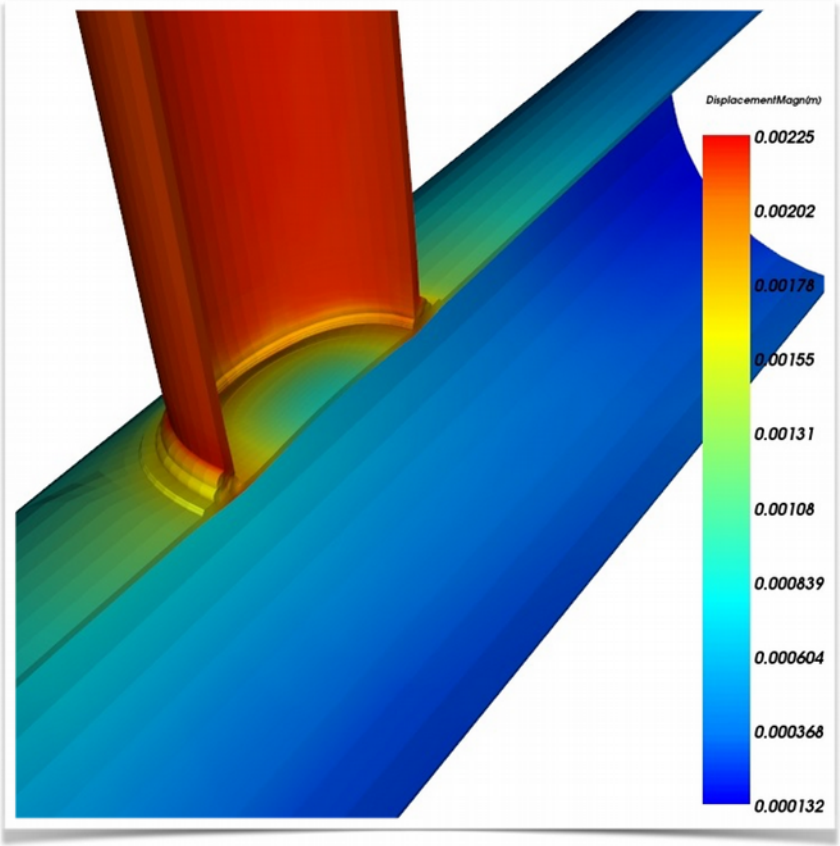


Engineering Example - Pipe T - Connection
Multipass Welding with Cladding and Grinding

Goldak Technologies

Displacement in a Hot Tap Weld

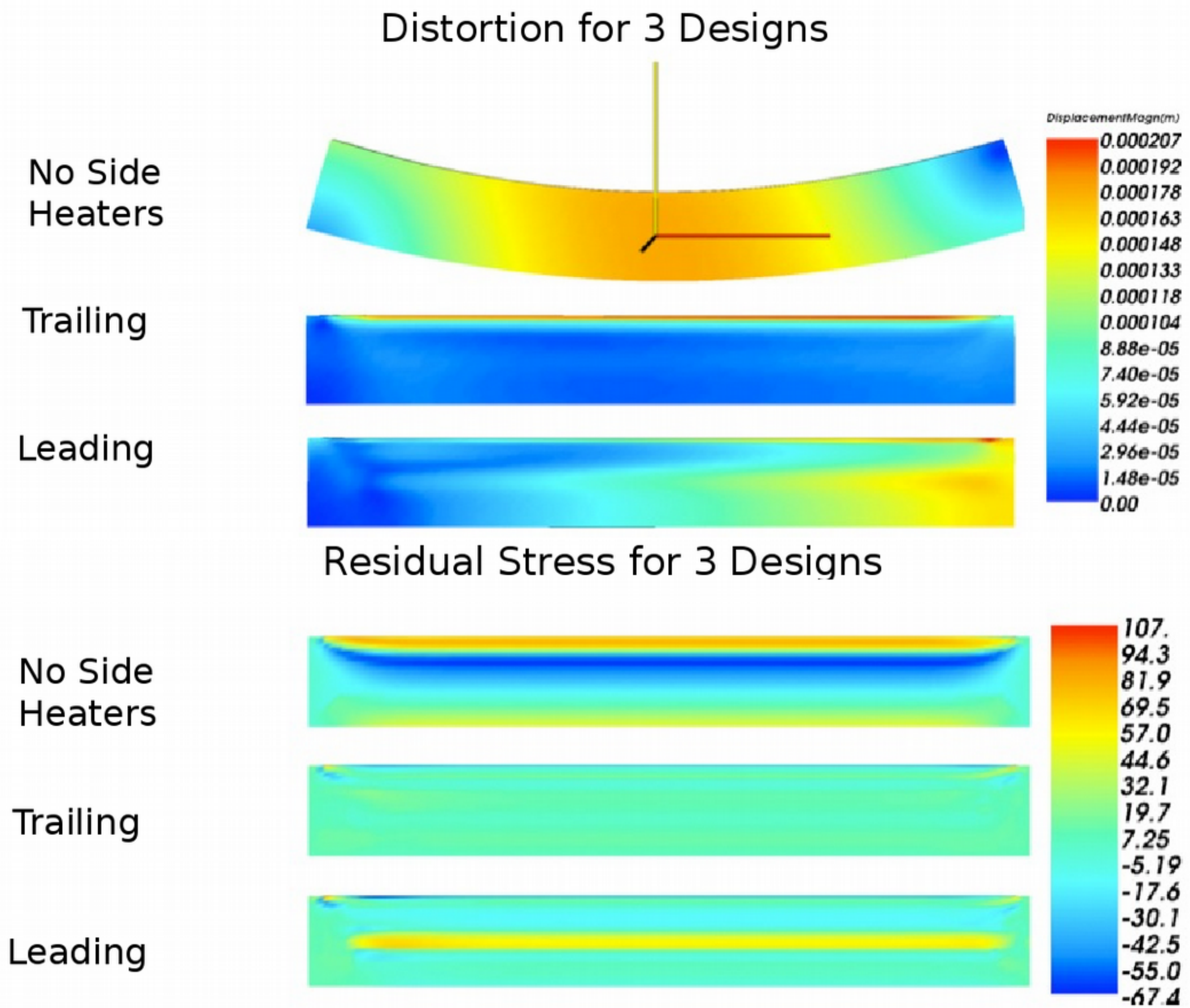


Vr Software Suite

Goldak Technologies Inc.

Design Optimisation with Goldak VrWeld

- **Optimisation Tool**
- **Automatic run of design matrix**
- **According different mitigation methods:**
  - addtional heat source
  - additional cooling source
  - low transformation filler material
- **Based on scientific works**
  - Gao, van der Aa, Eisadeh, Moat, Begg



Goldak Technologies

Ask for publication:
Tschernov, S. ; **Goldak**, J.: Can a weld in welded structure be made with zero residual stress? In: Proceedings of the ASME 2015 Pressure Vessels & Piping Division Conference, 19.-23.7.2015, Boston, Massachusetts, USA

Validation of Distoriton Analysis
Murakawa Plate

Murakawa, H. et. al: Analysis of Twisting Distortion of Thin Plate Stiffened Structure Cause by Welding

Material: Steel SM490A

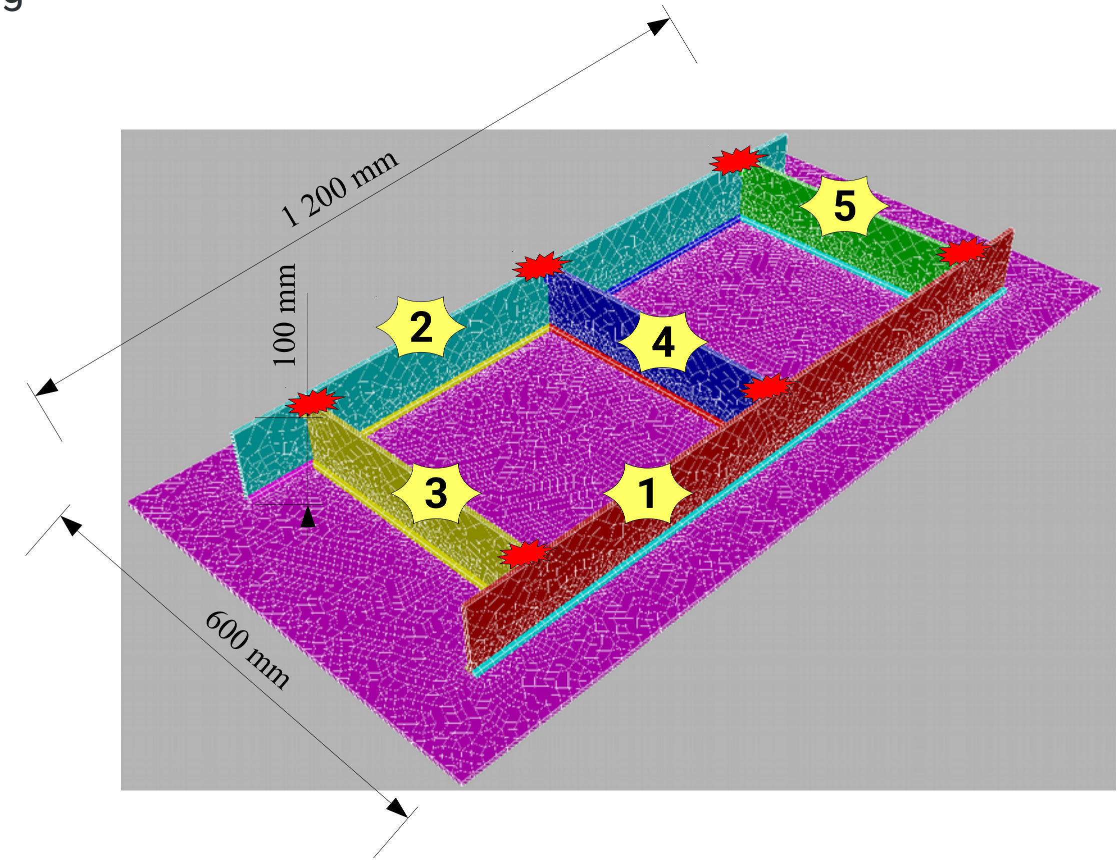
Weld Type:
Double sided fillet weld, z = 6,5 mm (a= 4,6 mm)

Process Parameter:
Current: 170-180 A
Voltage: 24-26 V
Travel Speed: 4,3 mm/s

Weld Sequence: 1 to 5
Weld Direction: not defined
Tack Welds at start and end of each weld
as well on top of the end of short stiffner:

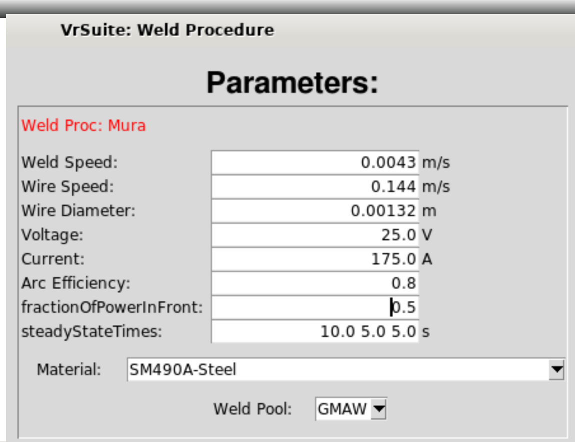
Intermediate time between welds: 5 s
Clamping: no clamping

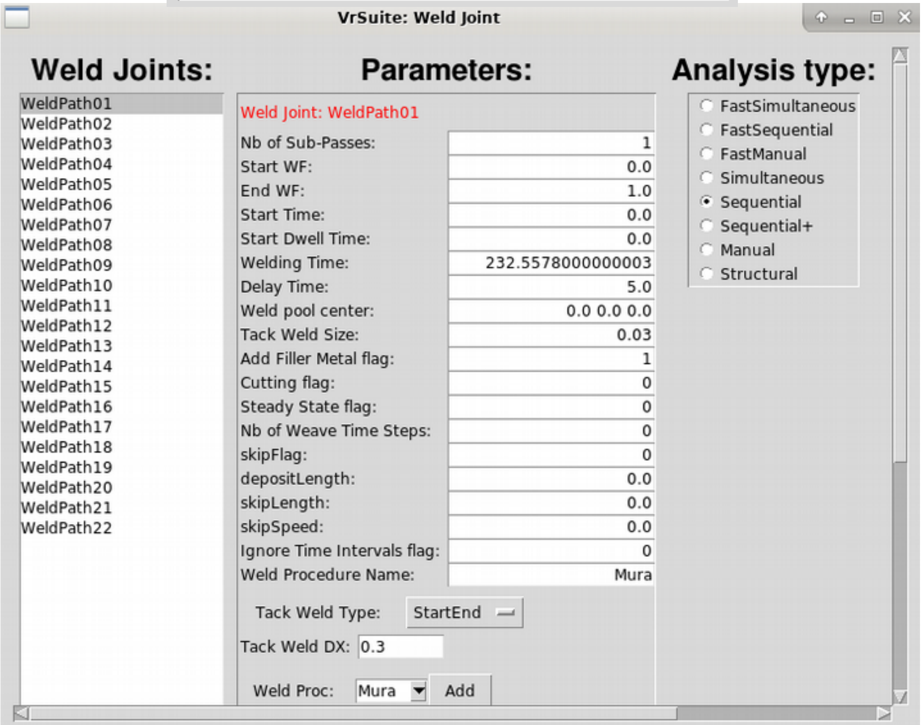
Total length of weld: 7,2 m



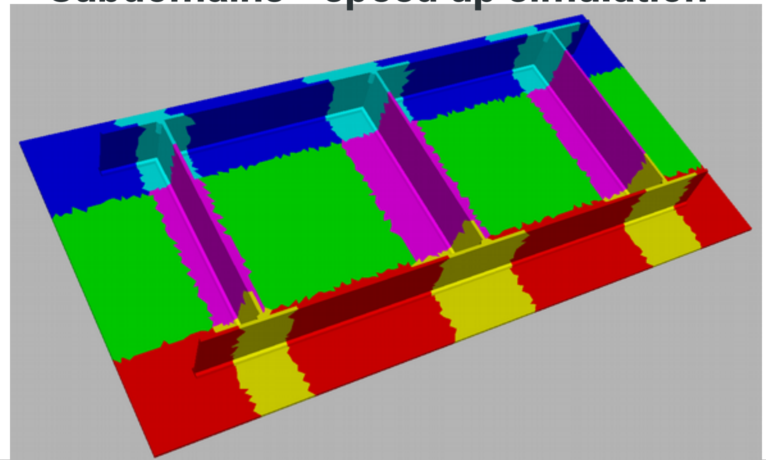
Total length of weld: 7,2 m
Simulation time: 70 h
Model size: 55 000 Elements

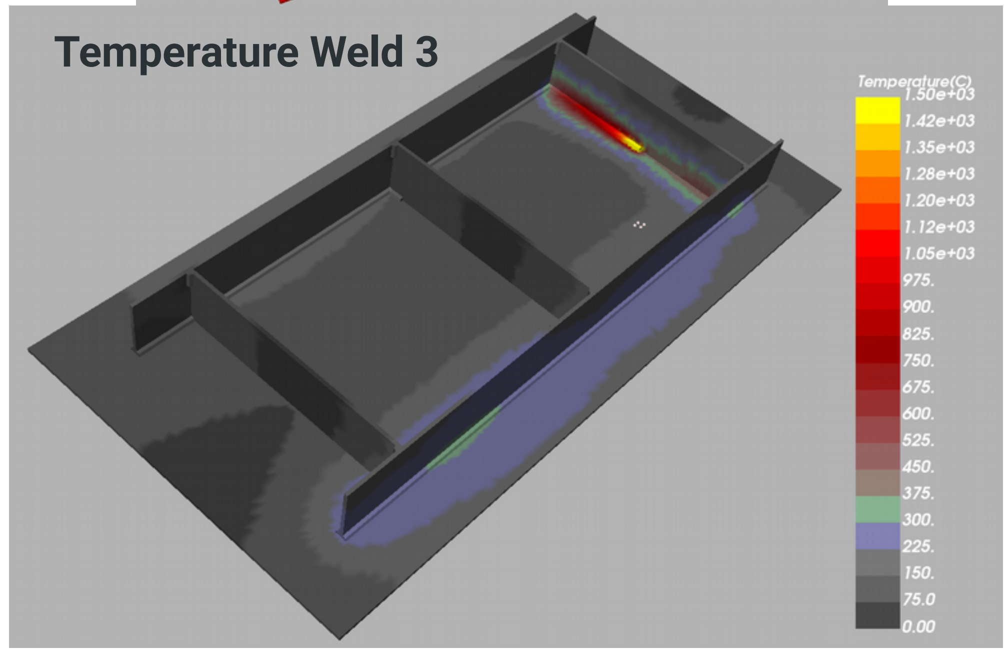
Simulation Model
WPS - Process Plan and Temperature Plot





Subdomains - speed up simulation





Results

Source: Murakawa, H. et. al.

Return of Investment

Cost of Welding Simulation
Performed at company

Requirements:

- Hardware - today a powerfull workstation is sufficient for most applications
- Software - different software solutions are available for customized needs
- Engineer - manpower, educated, to setup and evaluate the simulations

Initial Cost:

- Training incl. License
- Engineer - time to get comfortable with simulation (ca. 6 month)

Anual Cost

• License	25 k€
• Hardware	3 k€
• Engineer	100 k€
• **Sum**	**128 k€**

Cost of Welding Simulation
Demand consulting performed by experts

Requirements:
- nothing - consultant cares for equipment and software for the simulations

Initial Cost:
- nothing

Individual Cost per Project
- Project cost for consulting individual for each project
  - small case, 2 components 1 weld, 1 stage — ca. 2 k€
  - medium case, 5 components 20 welds, 1 stage — ca. 10 k€
  - large case, 20 components, 50 welds, 3 stages — ca. 25 k€
  - Case study with different variants — ca. 20 - 50 k€

State of the art

- many try out loops
- modification of tools and clamps
- Straightening or repair

Sum of the cost: N/A. because it is performed by own workers, nobody counts the wasted hours and nobody recognizes that **100 k€ - 300 k€** might be lost.

Example Company 1:

- Cost for modification of tool: **500 k€**
- Cost for welding simulation: **50 k€**

Example Company 2:

- Cost for welded assembly (large component): **400 k€**
- Cost for welding simulation to approve the manufactoring: **20 k€**
- Risk - total failure of manufacturing **400 k€**

Speed up your Manufacturing with Simulation

How long do I need to perform a welding simulation?

- Process simulation with SimWeld 5 min
- Distortion analysis with DynaWeld or VrWeld
  - small modell 1 day
  - medium model 3 days
  - large model 1 week
  - complex study 2 month

BUT:

every numerical analysis can be performed in design phase - should be started in design phase and is terminated with manufacturing start

AND:

There is no need for correction and adaption in the shop floor if the numerical engineering was successfully performed before.

THUS:

Speed up time is the time wasted prior for modification and repair in manufacturing.

Distortion Analysis Welding

- finding the reasons for certain distortion evolution
- virtual testing of variations

Best practice would be the application of simulation in earlier states for:

- approvement of the prearranged production
- intervention in early states of development,
  if tolerances are not reached or visible distortions problems appear

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

Hartelijk Dank!