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Nordic LS-DYNA
User's Conference 2018

Welding Structure Simulation
- Extended Beyond the Borders of Academic Testcases -

Exemplarily Demonstrated by Simulating the Assembly of Welded Car Body Components

Introduction of the „Free Motion-Filler-Technology“

Dipl.-Ing. Jens Rohbrecht, Dr.-Ing. Tobias Loose

Content

- The conflict between academic testcases and industrial requirements
- Industrial requirements
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  - Different welding operations
  - Gap detection
  - Buckling
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  - Main task: prediction of distortion (matching of tolerance demands)
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  - Assembly procedure
  - Example for buckling
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The conflict between academic testcases and industrial requirements

In the past the welding structure simulation mainly was used for the prediction of distortions and/ or residual stresses of **non large devices** and was investigated and benchmarked on **small testcases**.

Meanwhile it is state of the art to achieve good results and excellent fit to reality with this method.

The problem is, that small cases are not of great interest in industrial applications, because **physical tests often are more efficient** than simulations.

In cases of large structures and multi stage assemblies like in the production of car bodies the relation of cost and benefit changes.

Experiments become more and more expensive, especially when large manufacturing tools have to be changed without knowing the result of this.

Here simulation helps to save costs in tool design and manufacturing design.

→ Only if welding simulation significantly helps to save costs in manufacturing design it will be accepted in the industry.

→ That is only true in cases of expensive physical testing, which means large structures and assemblies.

Industrial Requirements In Detail

Model size:
More than 1.000.000 elements are no rare cases anymore

Different welding operations

- MSG welding with wire and comparable processes
- Laser welding with wire/ without (remote)
- Resistance spot welding
- Tack weldings
- Multilayer weldings

Gap detection

- Necessary for tolerances and weldability
- Influences the number and positions of tack weldings and/ or tools

Industrial Requirements In Detail

Buckling

- Buckling can occur in different shapes:
  - Large buckling areas with high deviation
  - Small deviation but long sinusoidal shape mainly near the weldings of long seams

Assemblies

- Many industrial cases are based on manufacturing in more than one step
- Assembling of deformed devices is an own task of simulation

Main task: prediction of distortion (matching of tolerance demands)

- Additional to tolerances the visibility of distortion is of high interest
- Variations of weld sequences, clamping tools (position, amount, operating times) in order to find better alternatives
- In cases of mass production all interventions have to comply with given cycle times
- Sometimes fast results are required (1 – 2 weeks), when intervention becomes necessary in late states of design. In such cases mostly there are not many possibilities left.

How Simulation Can Help

As shown before, it is a great advantage, to **start the simulation in early design states**.

Some more details about this:

- In very early states of the development of new car models the design of the production processes has to be started simultaneously.
- Production facilities may be determined before the entire manufacturing process is ensured with respect to given target tolerances.
- For example production steps (stations), cycle times of manufacturing, robot types and their amount and even areal conditions are fixed.

→ If problems appear in the later phase of development, the possibilities of intervention become smaller.

Overview Of Special Simulation Techniques

Free motion filler method

State of the art:

- Add filler elements of weld seams to the model from begin on
- For not yet welded seams use of a small trick in the material properties by reduction of the Youngs Modulus
- This is necessary to enable degrees of freedom in the filler nodes to follow the distortions of the structure
- The filler elements are joined to components either by directly connected meshes or due to tied contact.
- activation of Youngs Modulus during the pass of heat source

Problems:

- For stability reasons the remaining stiffness cannot be reduced too far, so that the remaining rest is high enough to impact the relative movement of components and falsify the calculated distortions.
- Possible gap formations are supressed

Overview Of Special Simulation Techniques

Free motion filler method

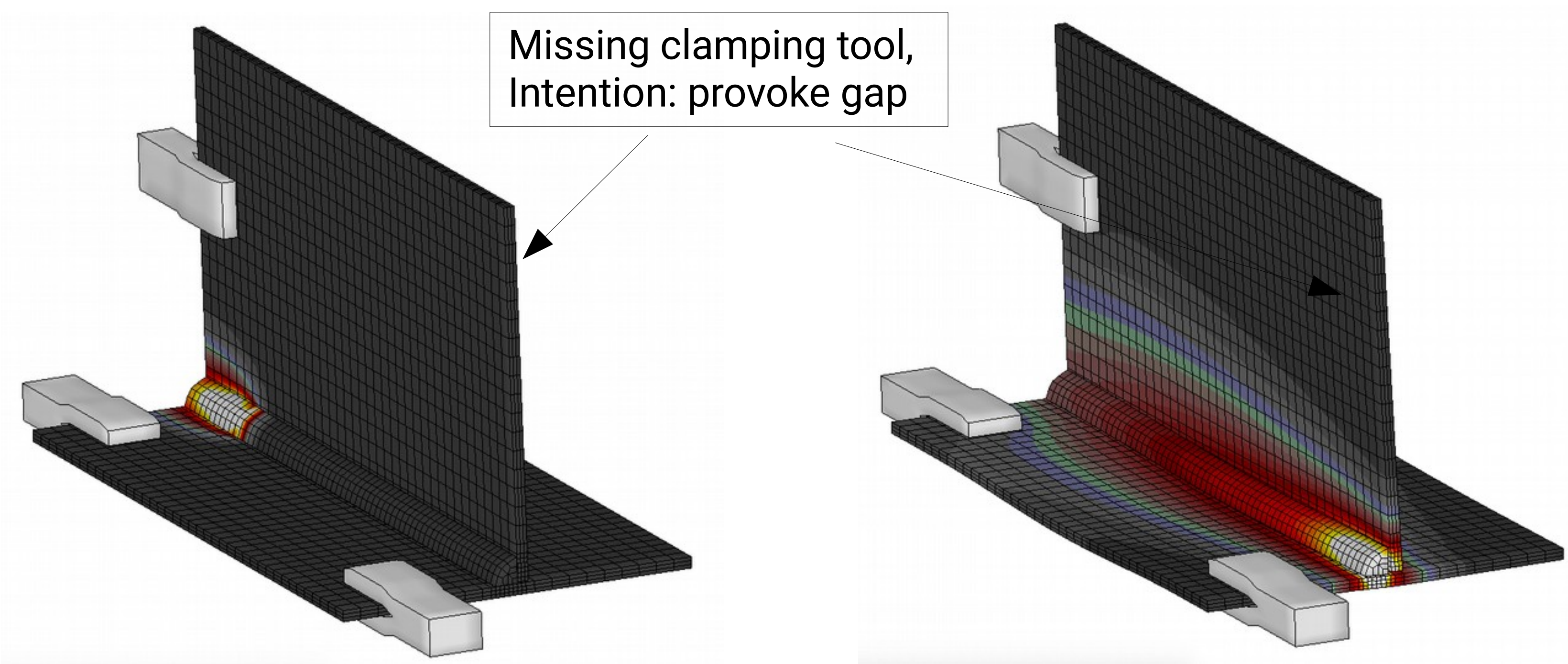
The “free-motion-filler-technology” overcomes this issue and allows a free motion of filler elements without negative impact on distortions by:

- Use of the special LS-DYNA welding contact. This contact enables an automatic **local** switch to tied conditions initialized by exceeding a given temperature (fusion temperature of material).
  This contact only connects in areas, where the melting point was reached.
  The keyword is:
  *CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_MORTAR_TIED_WELD_THERMAL_ID
- Keeping the filler elements in as free as possible motion, until the welding torch will melt up the material, but supress a separation.

Overview Of Special Simulation Techniques

Free motion filler method

The “free-motion-filler-technology” shown in an example:



Welding torch, start of welding

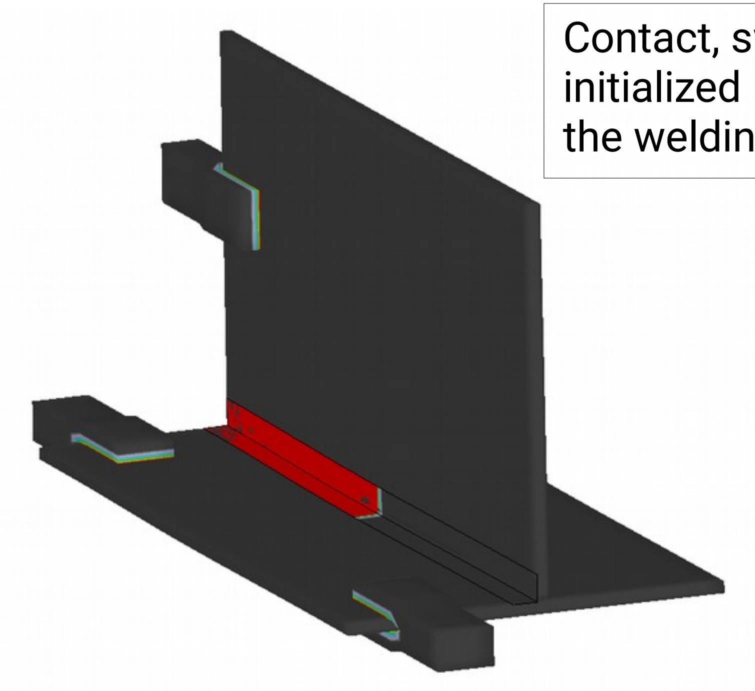
Welding torch, end of welding

Overview Of Special Simulation Techniques

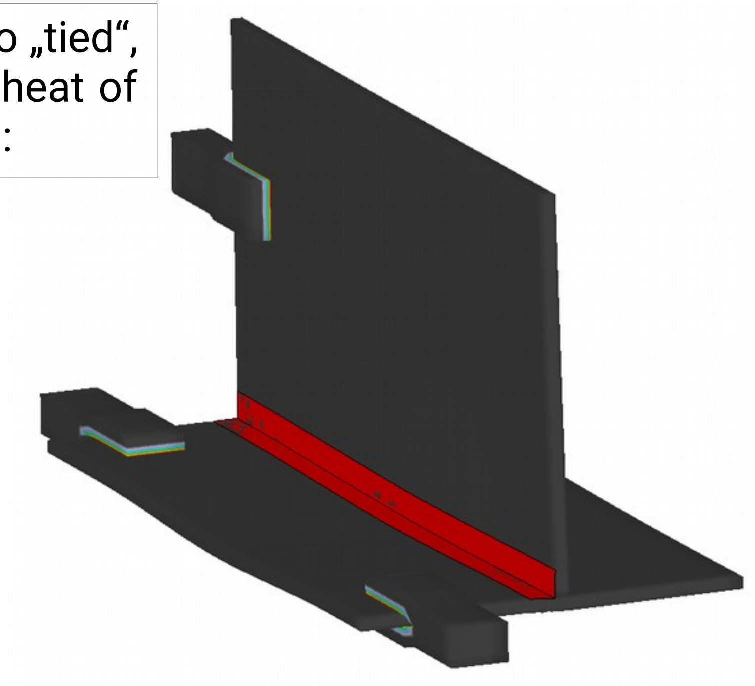
Free motion filler method

The “free-motion-filler-technology” shown in an example:

Contact, switch to „tied“, initialized by the heat of the welding torch:



Contact state, half welded

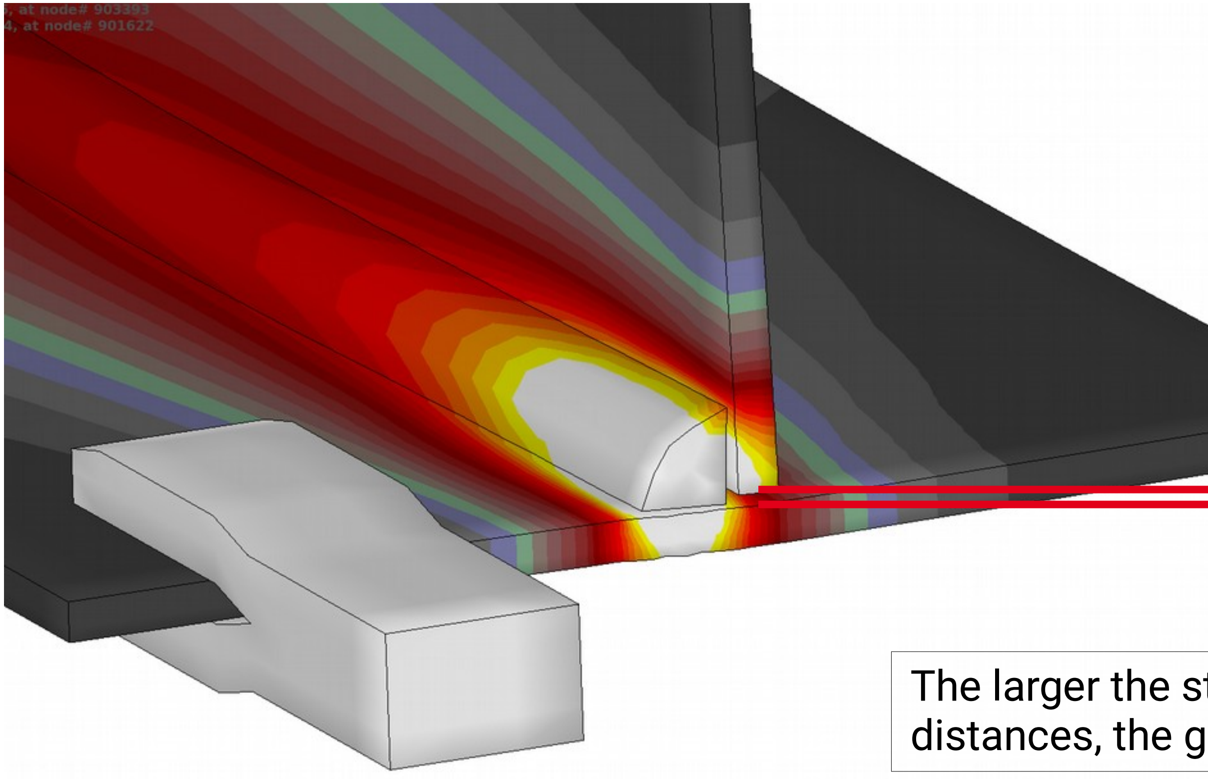


Contact state, end of welding

Overview Of Special Simulation Techniques

Free motion filler method

The “free-motion-filler-technology” shown in an example:



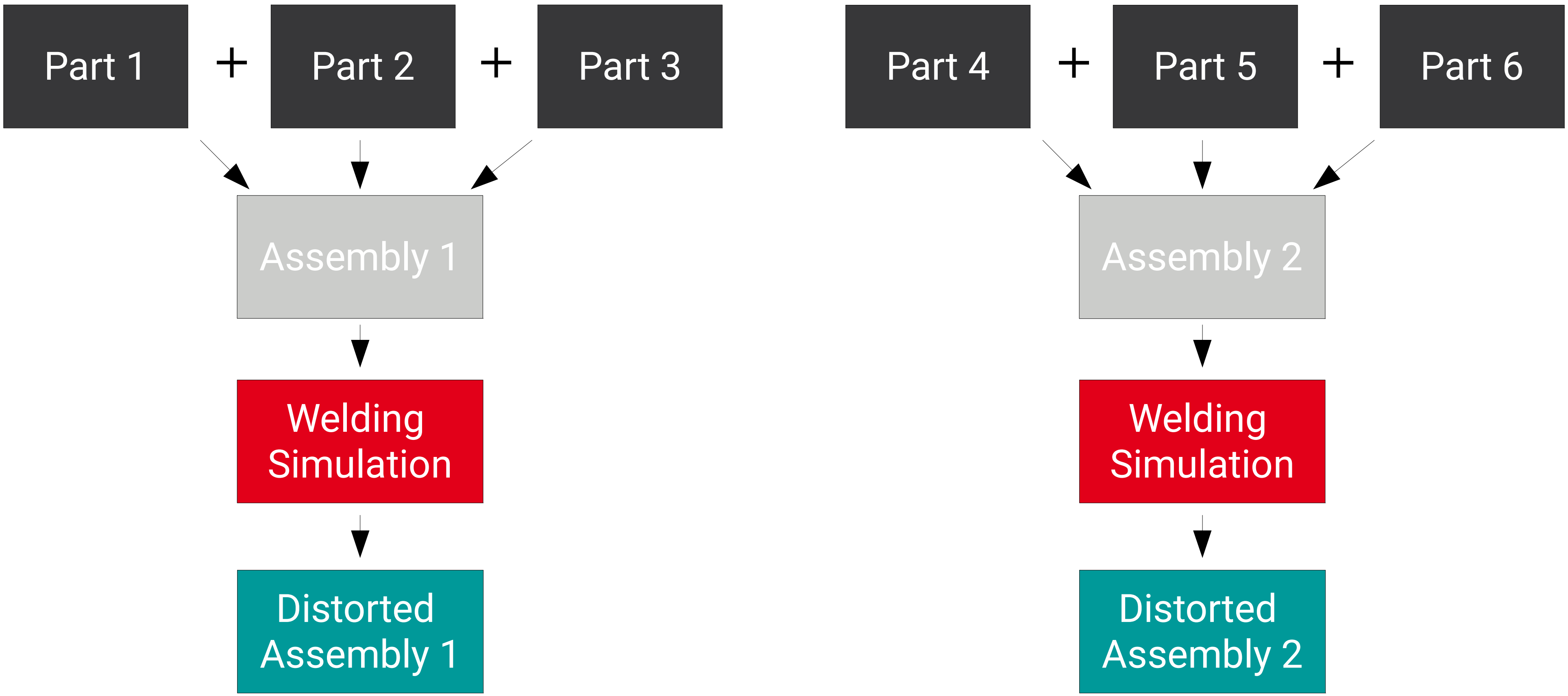
Missing clamping tool,
Intention: provoke gap

Gap formation

The larger the structure, the greater the tool distances, the greater the gap.

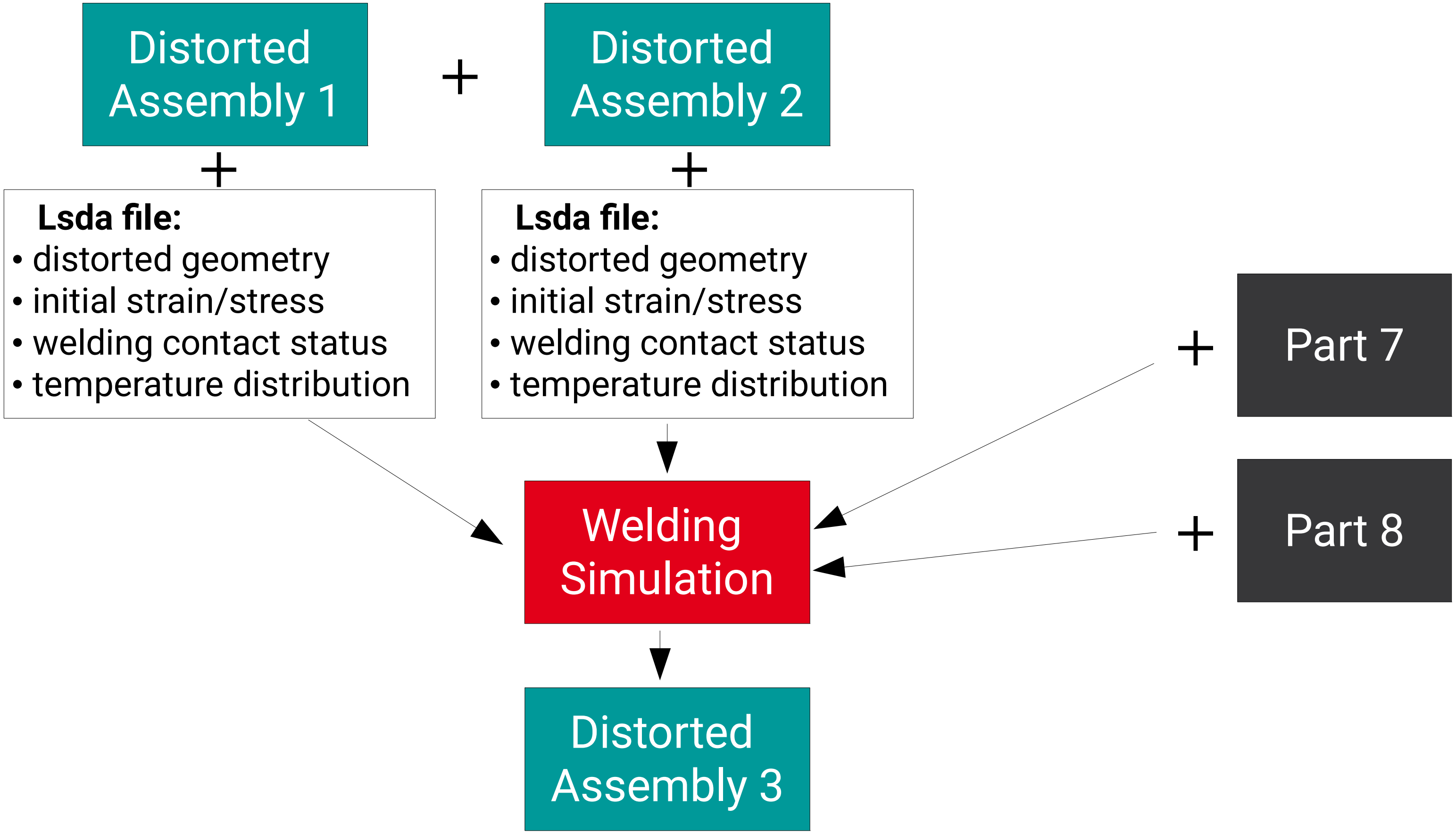
Overview Of Special Simulation Techniques

Assembly procedure



Overview Of Special Simulation Techniques

Assembly procedure



Overview Of Special Simulation Techniques

Assembly procedure: One example:

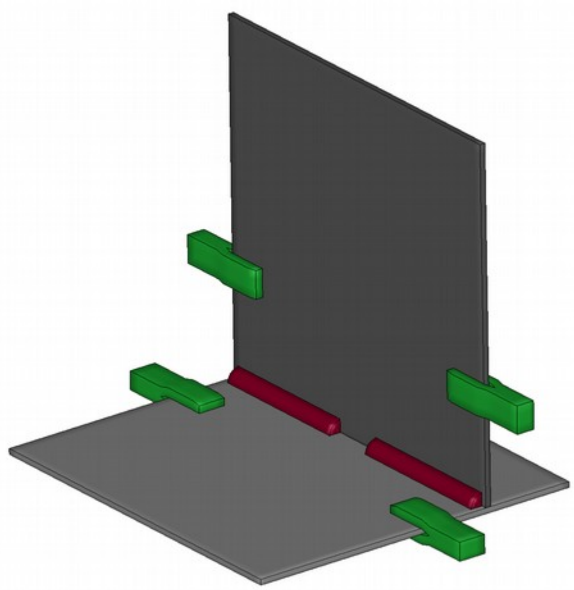
Step 1:
Welding 1,
2 weld seams

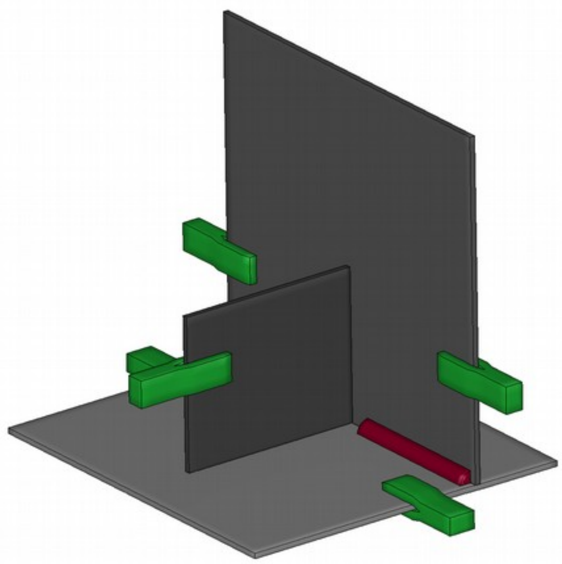
+

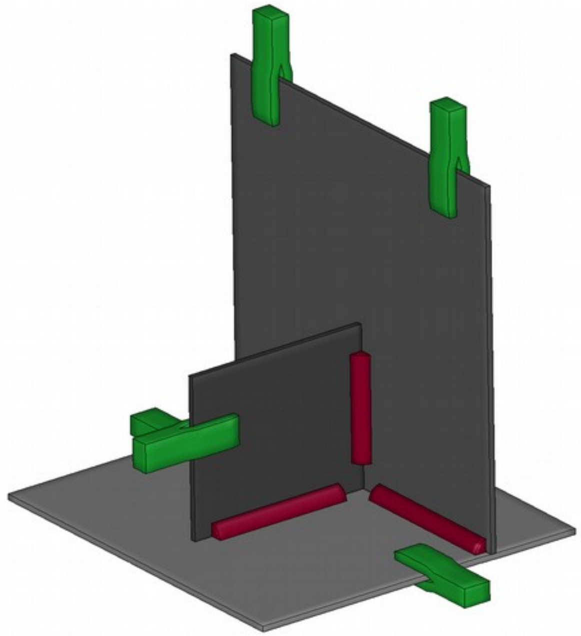
Step 2:
Assembly, adding a
stiffening plate

+

Step 3:
Welding 2,
adding 2 new weld seams





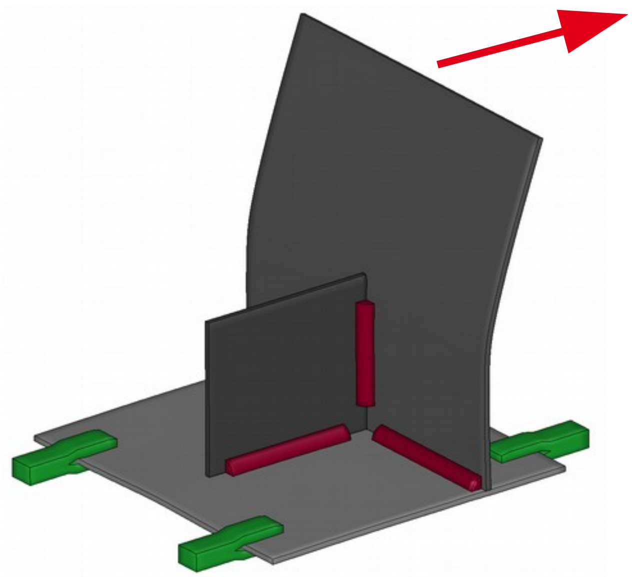


Overview Of Special Simulation Techniques

Assembly procedure: One example:

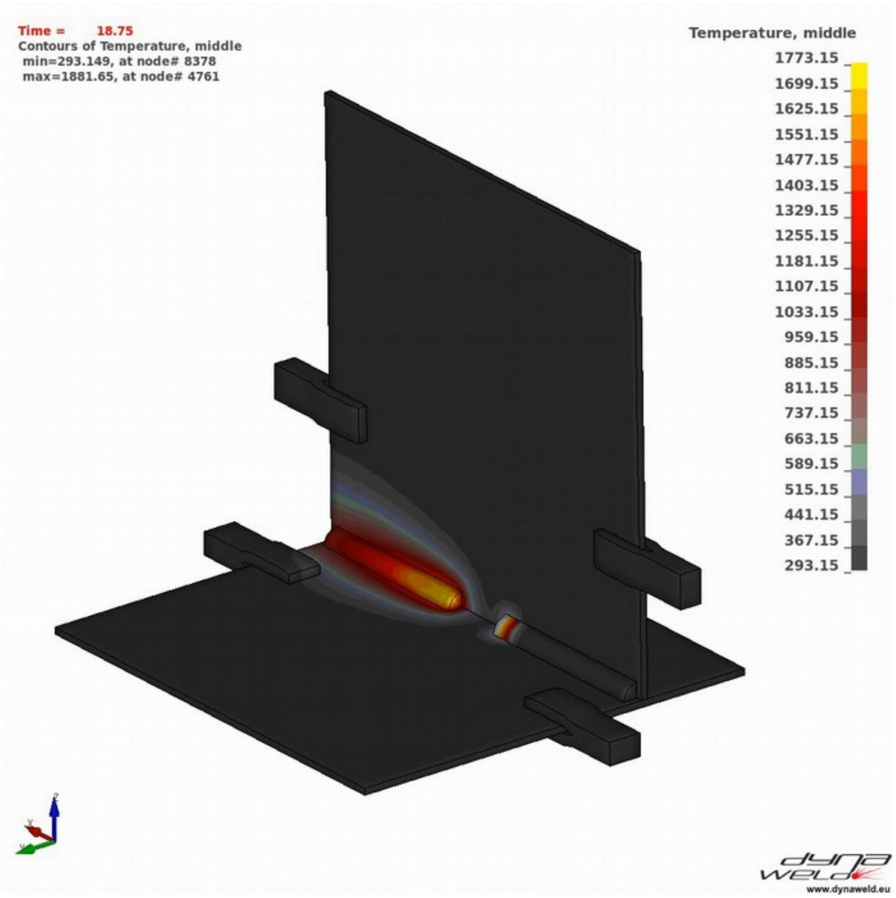
Step 4:
Load test

The load test will show, how local contact switches to „tied“ work.

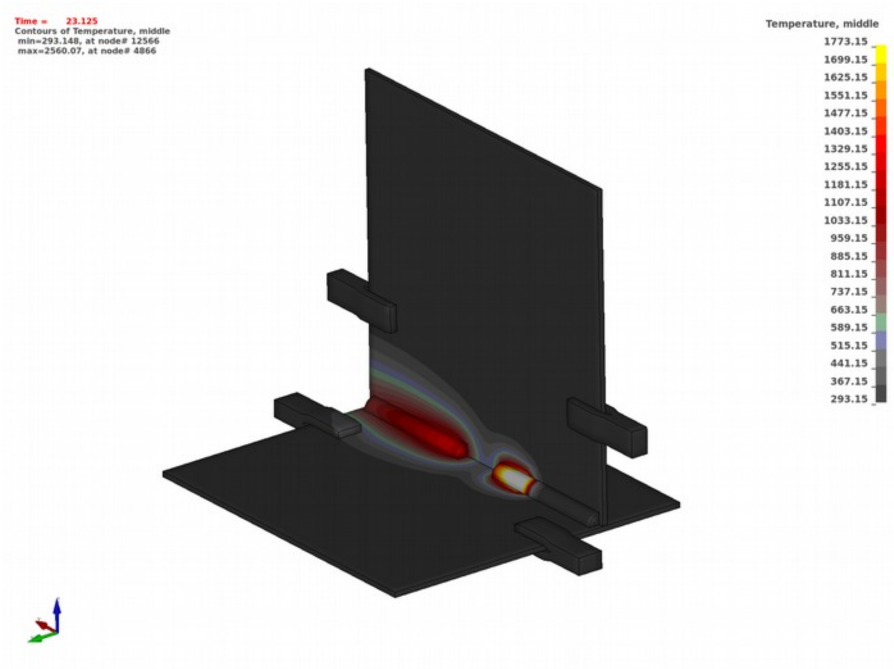


Overview Of Special Simulation Techniques

Assembly procedure: One example:



Step 1:
Welding 1,
2 weld seams



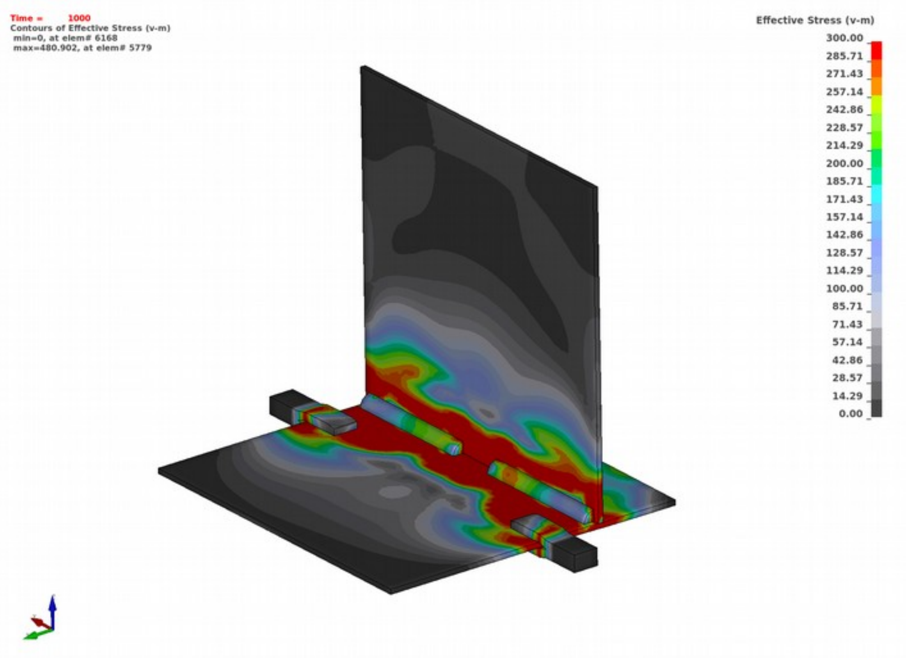
Overview Of Special Simulation Techniques

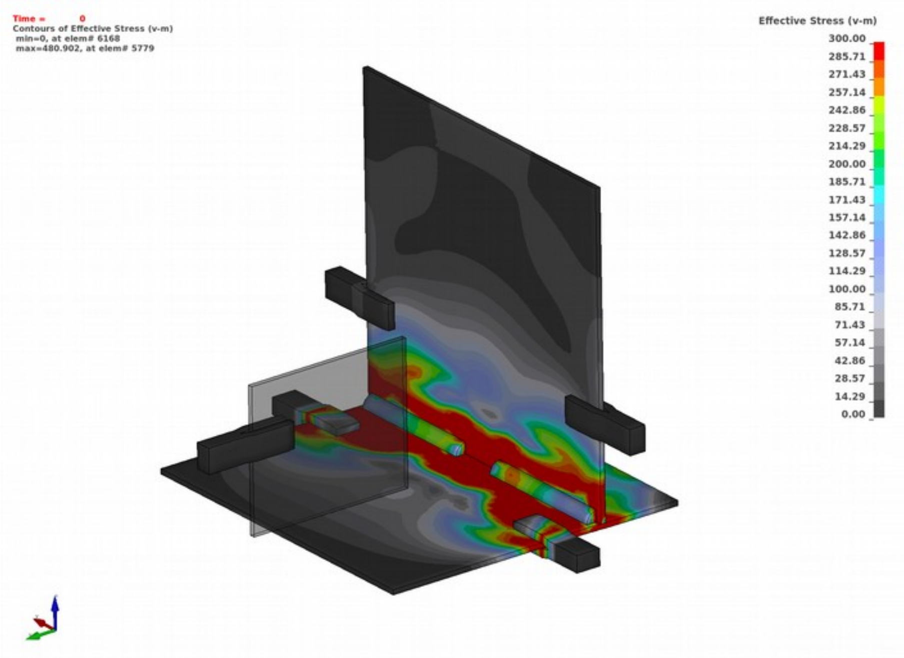
Assembly procedure: One example:

Step 1:
Welding 1,
Von Mises Stress, end of process

+

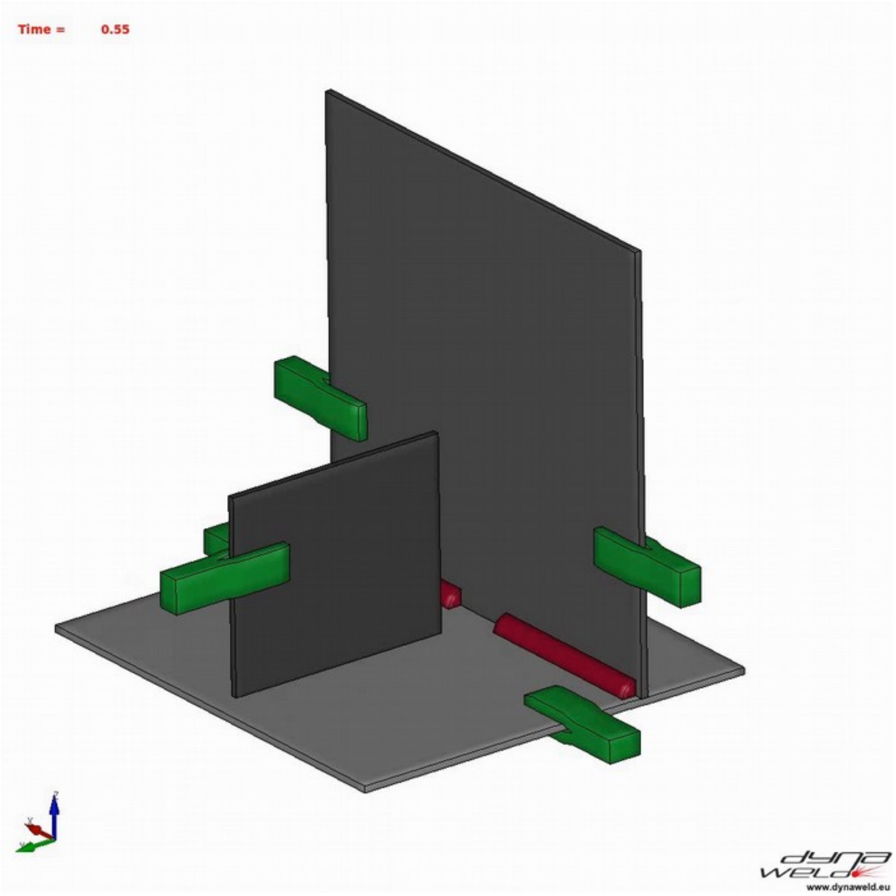
Step 2:
Assembly, adding a stiffening plate
Von Mises Stress, begin of process





Overview Of Special Simulation Techniques

Assembly procedure: One example:



Step 2:
Assembly, adding a stiffening plate
The plate is slowly inserted because of the structural distortions coming from the previous welding process

This example shows, that assembly sometimes is an own simulation.
In industrial cases where greater distortions can be present, it becomes more complicated.

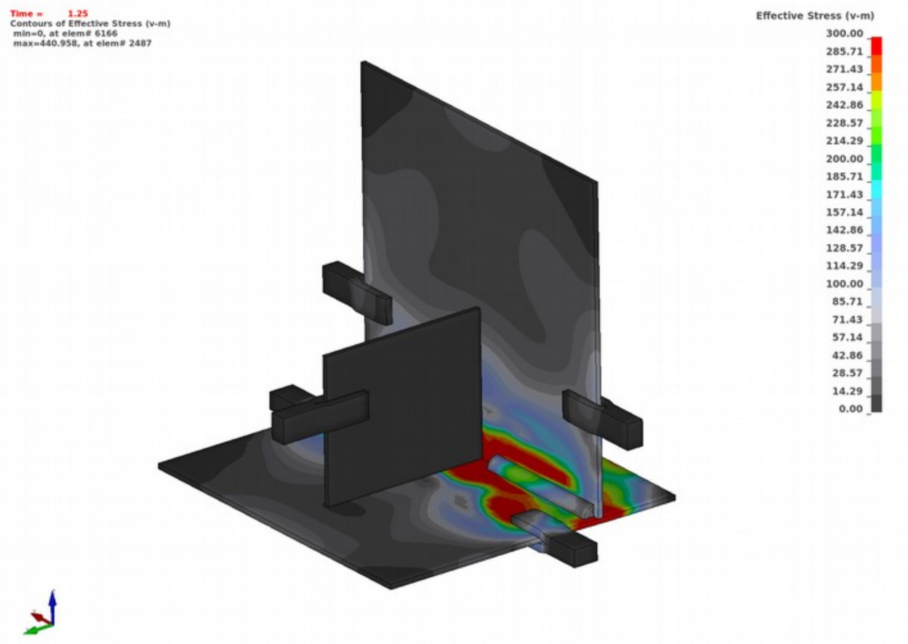
Overview Of Special Simulation Techniques

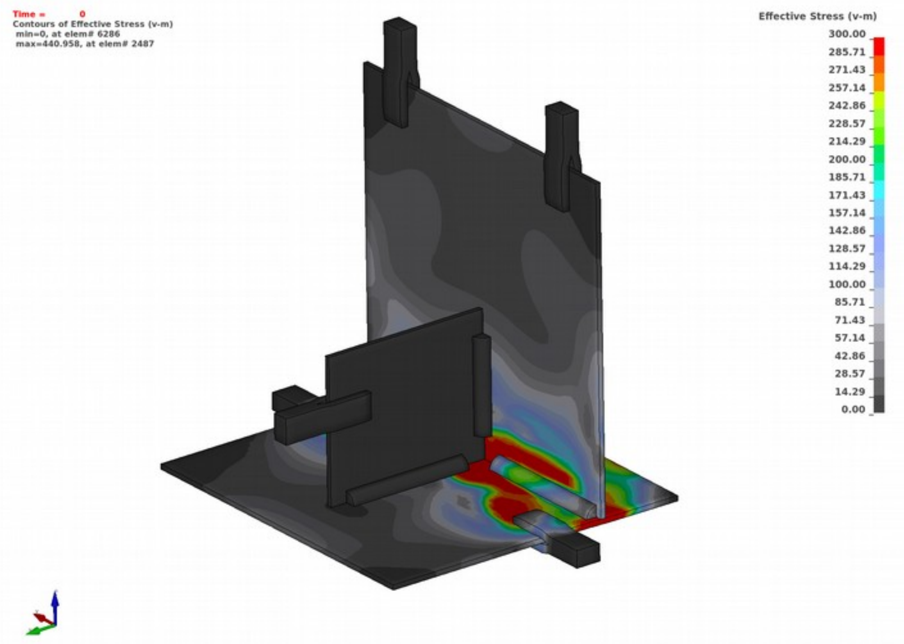
Assembly procedure: One example:

Step 2:
Assembly 1,
Von Mises Stress, end of process

+

Step 3:
Welding 2
Von Mises Stress, begin of process

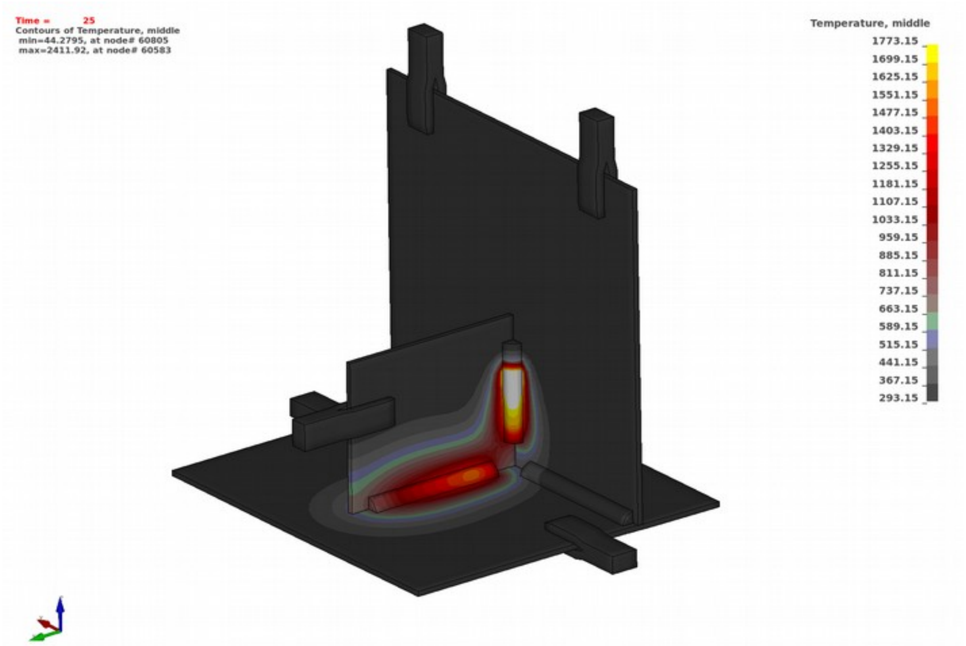




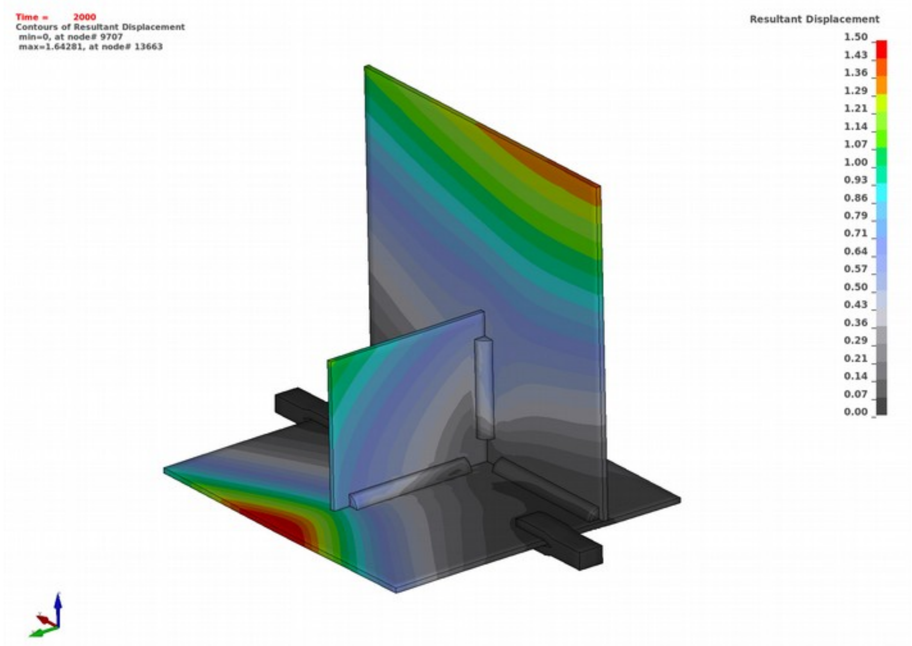
Overview Of Special Simulation Techniques

Assembly procedure: One example:

Step 3:
Welding 2,
2 more weld seams, temperature during welding



Step 3:
Welding 2,
Distortions at end of process



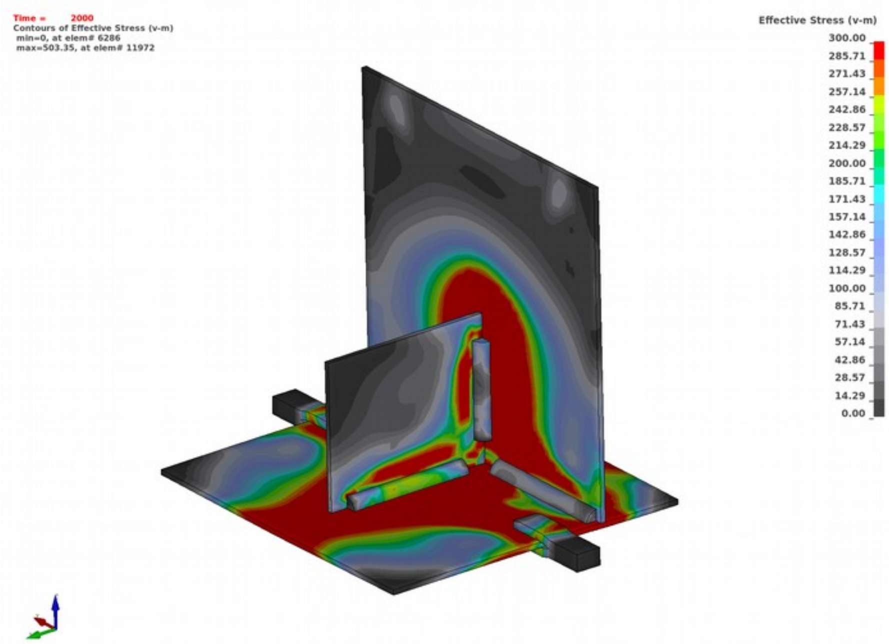
Overview Of Special Simulation Techniques

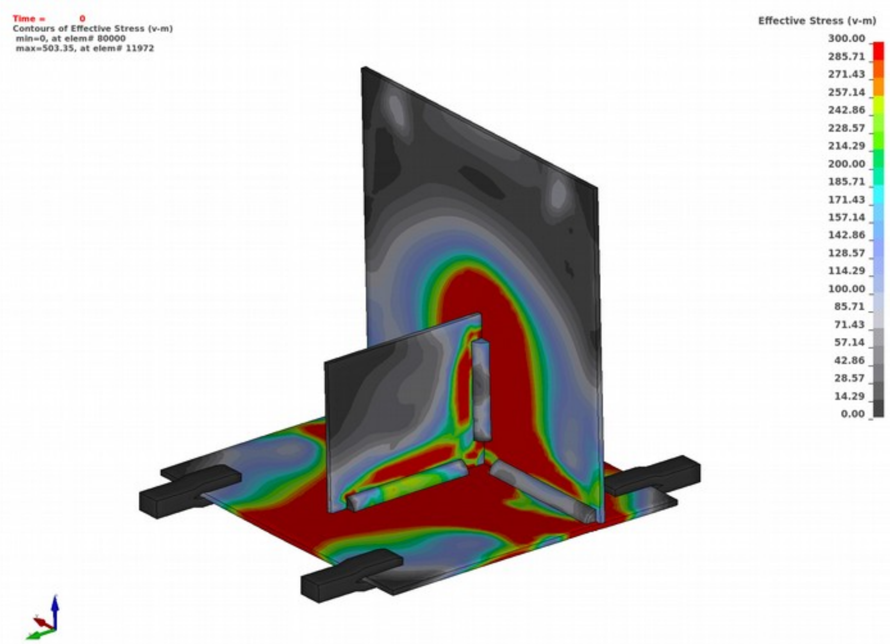
Assembly procedure: One example:

Step 3:
Welding 2,
Von Mises Stress, end of process

+

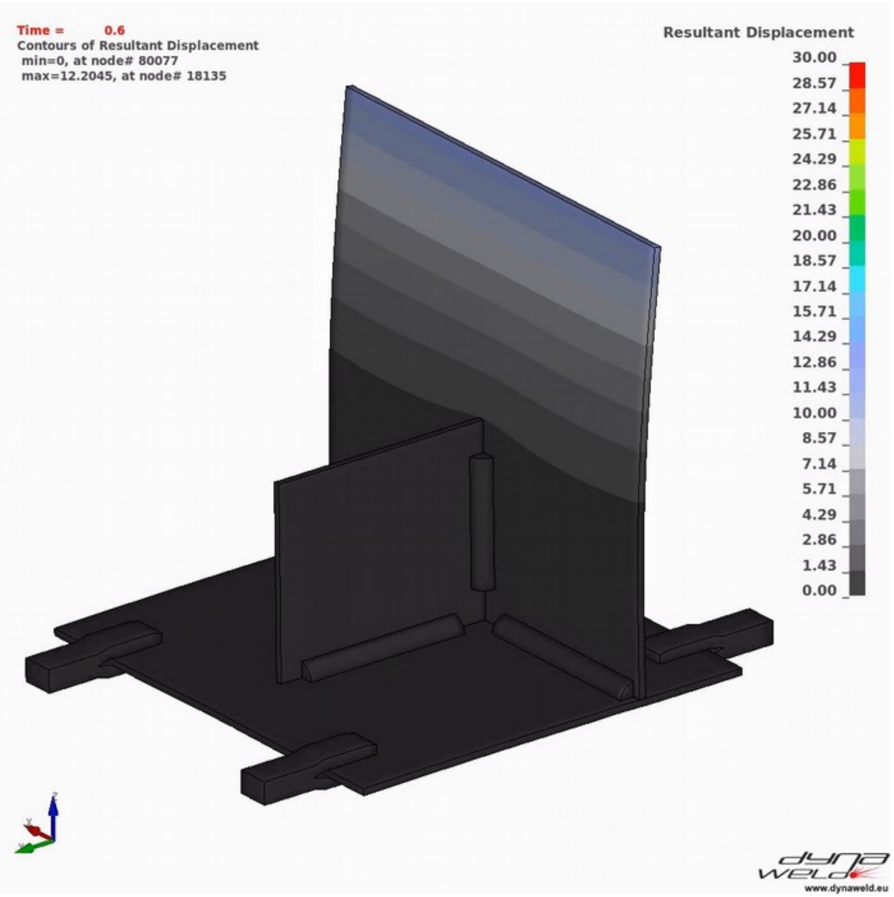
Step 4:
Load test
Von Mises Stress, begin of process



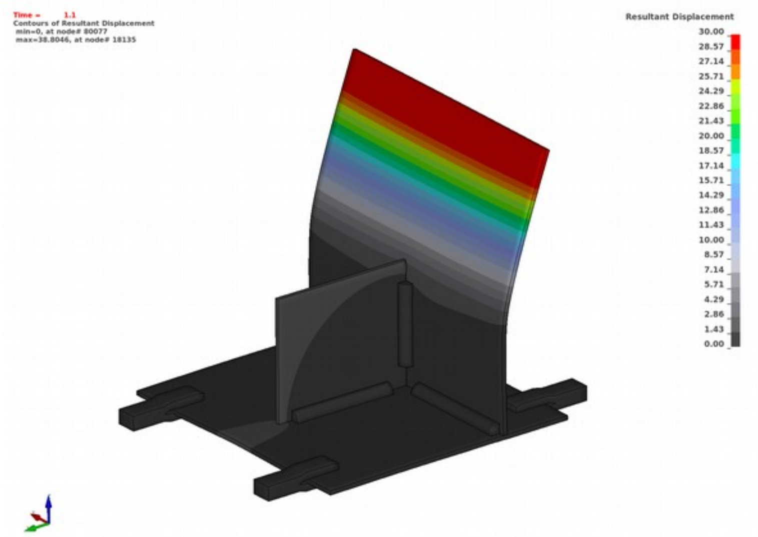


Overview Of Special Simulation Techniques

Assembly procedure: One example:



Step 4:
Load test, increasing static load



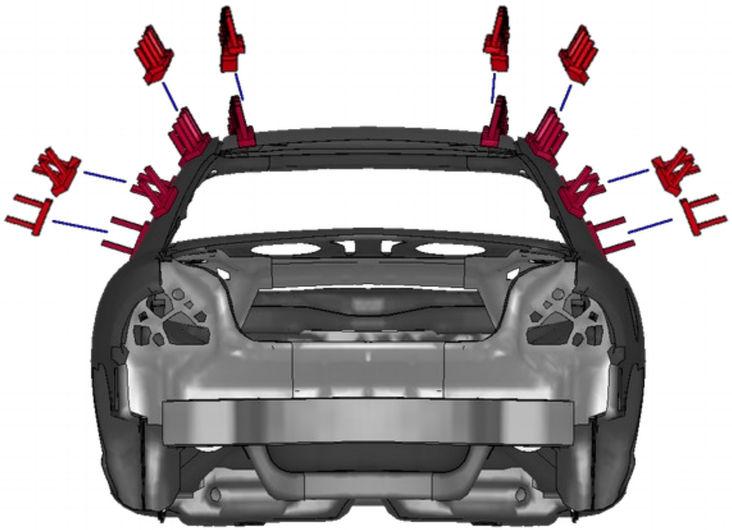
This example shows, that the connections due to the welding processes where transferred correctly

Overview Of Special Simulation Techniques

Example for buckling

DynaWeld Car:
Welding process of the roof

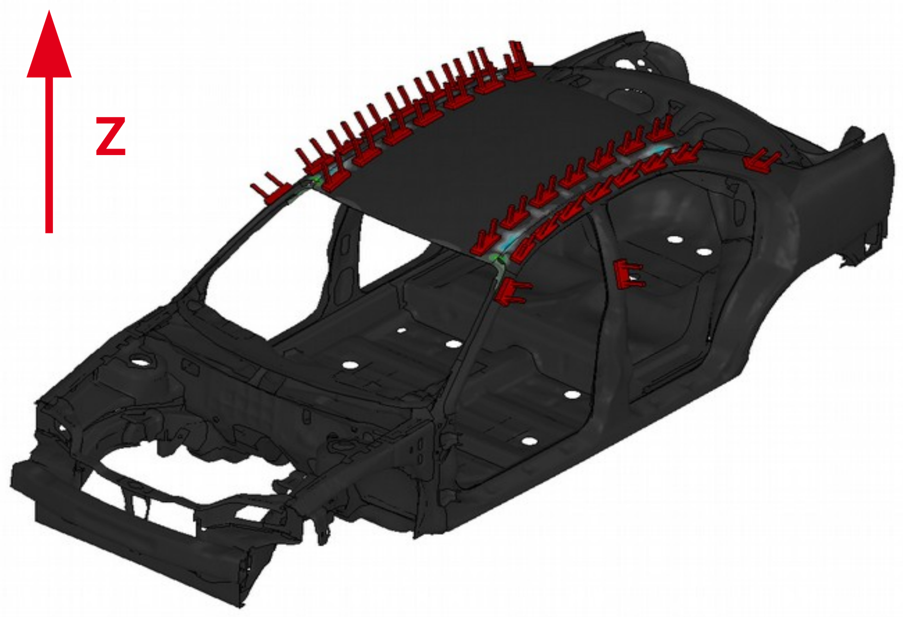
DynaWeld Car:
Motion of the clamping tools

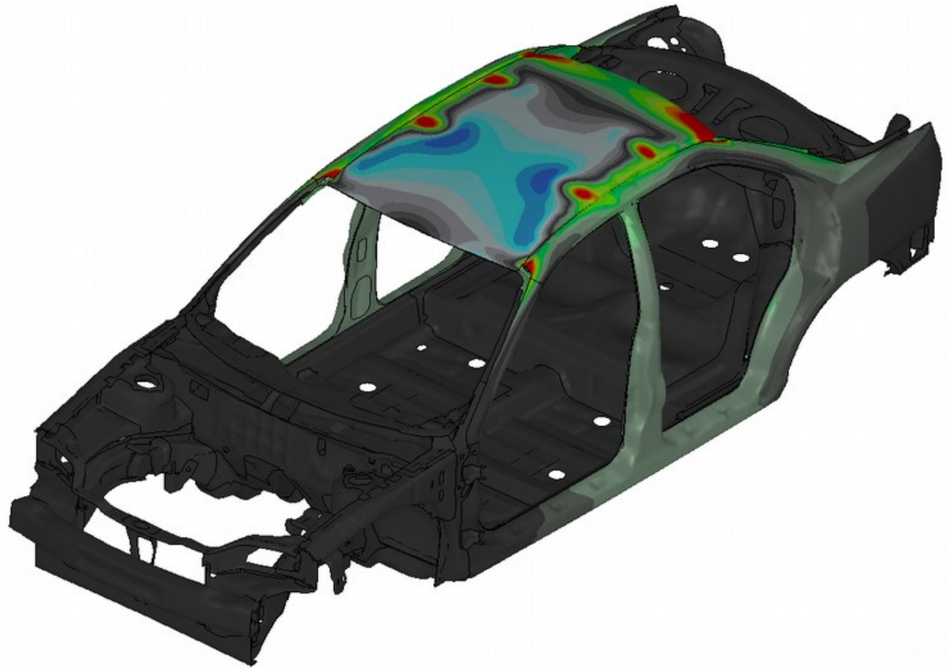


Overview Of Special Simulation Techniques

Example for buckling

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





Overview Of Special Simulation Techniques

Example for buckling

DynaWeld Car:
Detail: Buckling of the roof, 5 times scaled

The DynaWeld Car is an own creation of DynaWeld.
As we cannot show any example from real industrial cases, we decided to create our own car model.
The process -welding of the roof- , shown here, is not an optimum of manufacturing process.
Intentionally we created a process with high distortions. In this case, mainly the tools in size and position are responsible for the relatively high distortions.

Conclusions/ Summary

- There sometimes is a conflict between academic testcases and industrial requirements
- Industrial requirements are much higher than small test cases can show
- Simulation is only requested, if costs for experiences are high
- The main task is prediction of distortion
- Some details being necessary for academic models may be neglected in industrial cases in order to keep the large structures computable.
- It requires some experience to decide, which details have lower influence, which ones high
- Correct assembling influences are much higher than some small details

Conclusions/ Summary

- Development of special simulation techniques is necessary to fulfill the requirements
  - Filler modelling methods
  - Assembly procedure
- Development of the solver is mandatory
  - Robustness
  - Special functions
  - Assembly
  - Precise energy input of welding heat

Thank You Very Much