Welding Simulations in LS-DYNA and LS-PrePost

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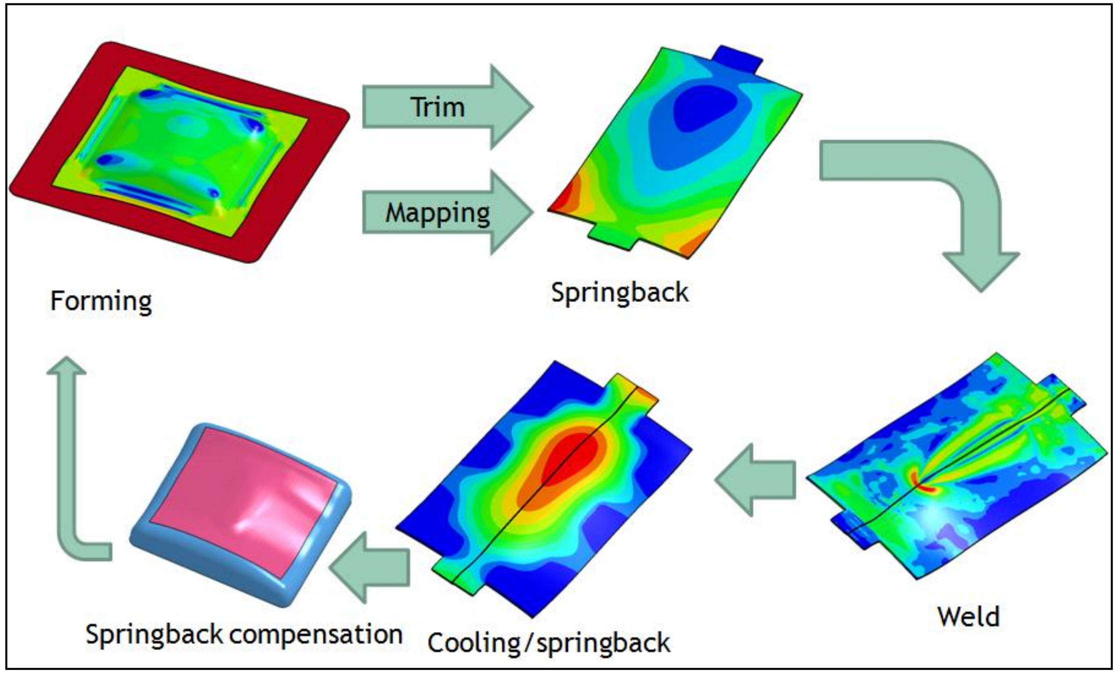
Welding Simulations

- The welding process will affect the structure both locally in the heat affected zones and on a global level with the residual distortion
- By simulating the welding process we can gain knowledge of the local stresses and strains in the welding zones. The phase transformations in the zones can also be simulated.
- With the prediction of the residual distortion of the structure it´s possible to compensate for this deformation. The welding process can also be optimized to reduce the distortion



Material Models

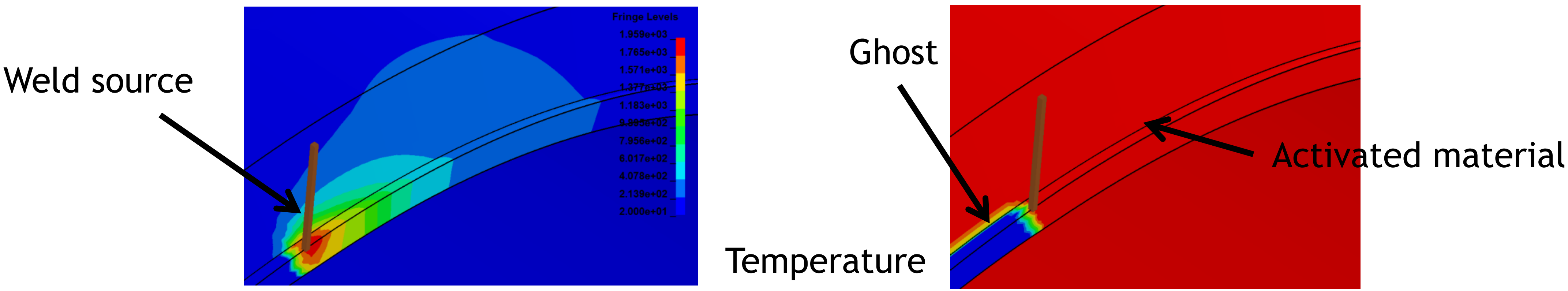
- *MAT_CWM (*MAT_270)
- *MAT_THERMAL_CWM (*MAT_T07)
- Solid and shell elements
- Load curve/Table hardening input
- The model also includes Anneal functionality. Above a specified temperature, all the history variables, such as hardening and back stress, are set to zero.

Card 1	1	2	3	4	5	6	7	8
Variable	MID	RO	LCEM	LCPR	LCSY	LCHR	LCAT	BETA
Type	A8	F	F	F	F	F	F	F
Default	none	none	none	none	none	none	none	None

Card 2	1	2	3	4	5	6	7	8
Variable	TASTART	TAEND	TLSTART	TLEND	EGHOST	PGHOST	AGHOST	
Type	F	F	F	F	F	F	F	
Default	none	none	none	none	none	none	none	

Material Models

- *MAT_CWM (*MAT_270)
- *MAT_THERMAL_CWM (*MAT_T07)
- The element can either be ”Solid”, ”Liquid” or ”Ghost”.
  - Solid: Material is activated in a previous weld pass
  - Liquid: Material will be activated in the current weld pass
  - Ghost: Material will not be activated in the current weld pass
- When the temperature reaches a specified temperature, material is activated and recieves ”material” properties.



Material Models

- *MAT_UHS_STEEL (*MAT_244)
  - Initially implemented for hot stamping processess
  - Model the growth of different phases in the material during heating and cooling
  - Ghost functionality included
  - Shell and solid element
  - Chemical composition of material as input

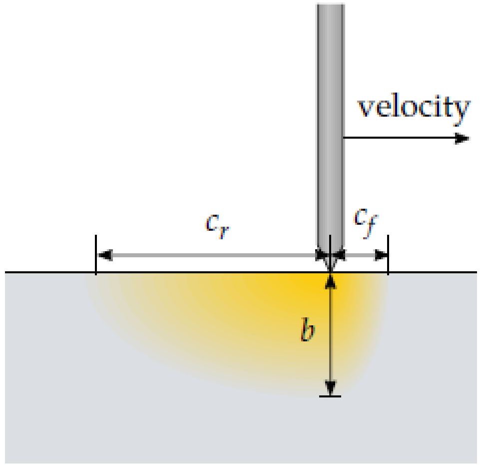
- *MAT_GENERALIZED_PHASE_CHANGE (*MAT_254)
  - Up to 24 different phases
  - Different phase transformation laws

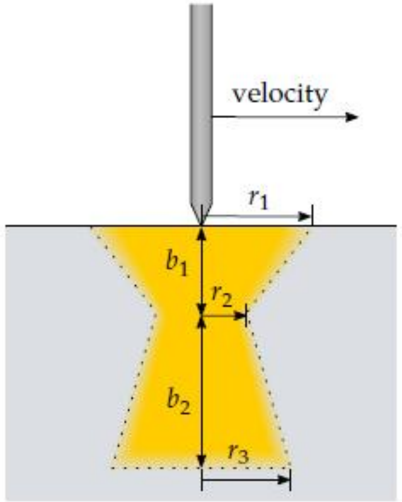
History variables for MAT_244

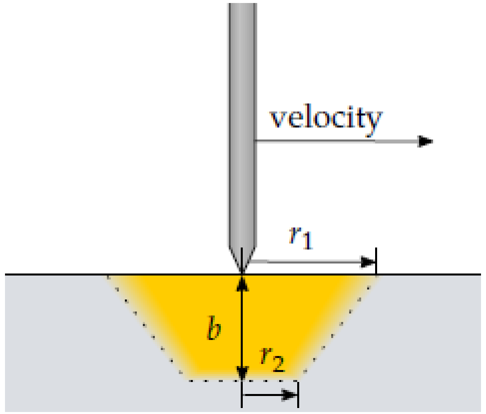
History Variable	Description
1	Amount austenite
2	Amount ferrite
3	Amount pearlite
4	Amount bainite
5	Amount martensite
6	Vickers hardness
7	Yield stress
8	ASTM grain size number (a low value means large grains and vice versa)

Heat Source

- *BOUNDARY_THERMAL_WELD_TRAJECTORY
- Heat source movement implemented in the thermal solver
- Heat source follows a node string defined in *SET_NODE
- User controlled integration for accurate heat input
- Goldak, double ellipsoidal, double cone and frustum heat sources



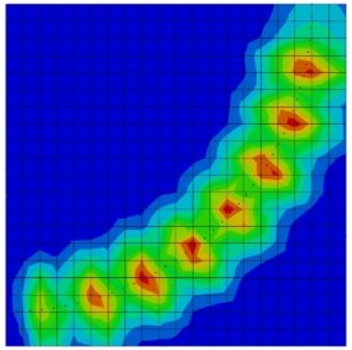




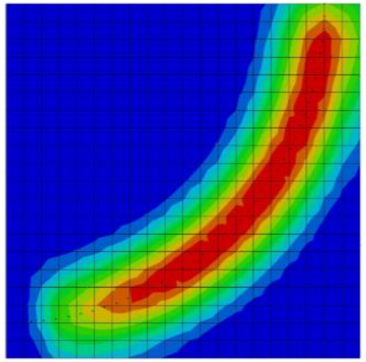
Heat Source

- There is a restriction of how large thermal timesteps that can be used in an incremental welding simulation before loosing accuracy.
- The heat source can only step forward approximately one element/timestep.
- A sub-cycling option is available for the heat source to take larger thermal timesteps, but make sub-cycling timestep between.
- This option can be used to decrease the simulation time.

NCYC=1, one sub-cycle over each thermal timestep



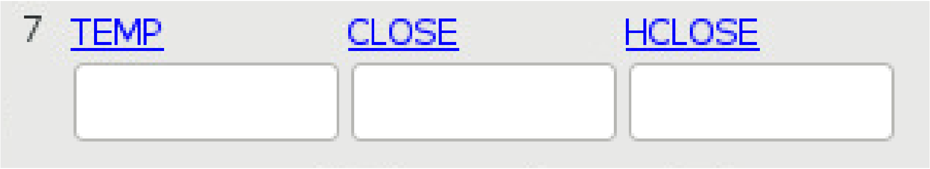
NCYC=10, ten sub-cycles over each thermal timestep



Temperature field

Weld Contact

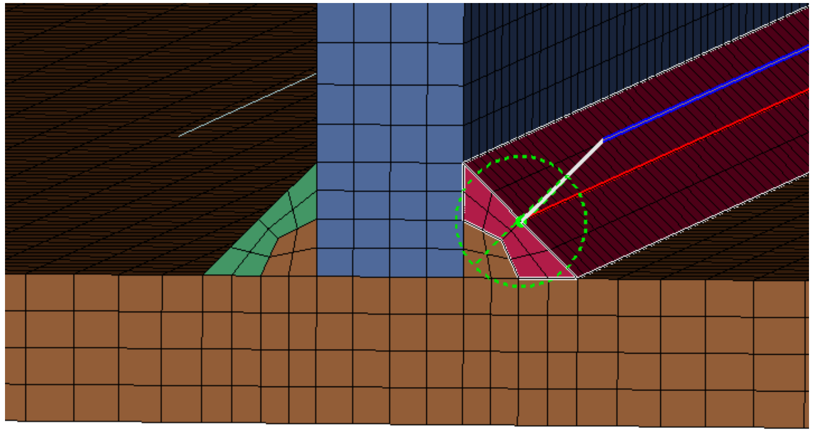
- *CONTACT_AUTOMATIC_SURFACE_TO_SURFACE_TIED_WELD
- When regions of contact surfaces are heated to the welding temperature and come in contact, the nodes are tied.
- The contact works as a standard sliding contact when the temperature is below the welding temperature
- An MORTAR option is also available

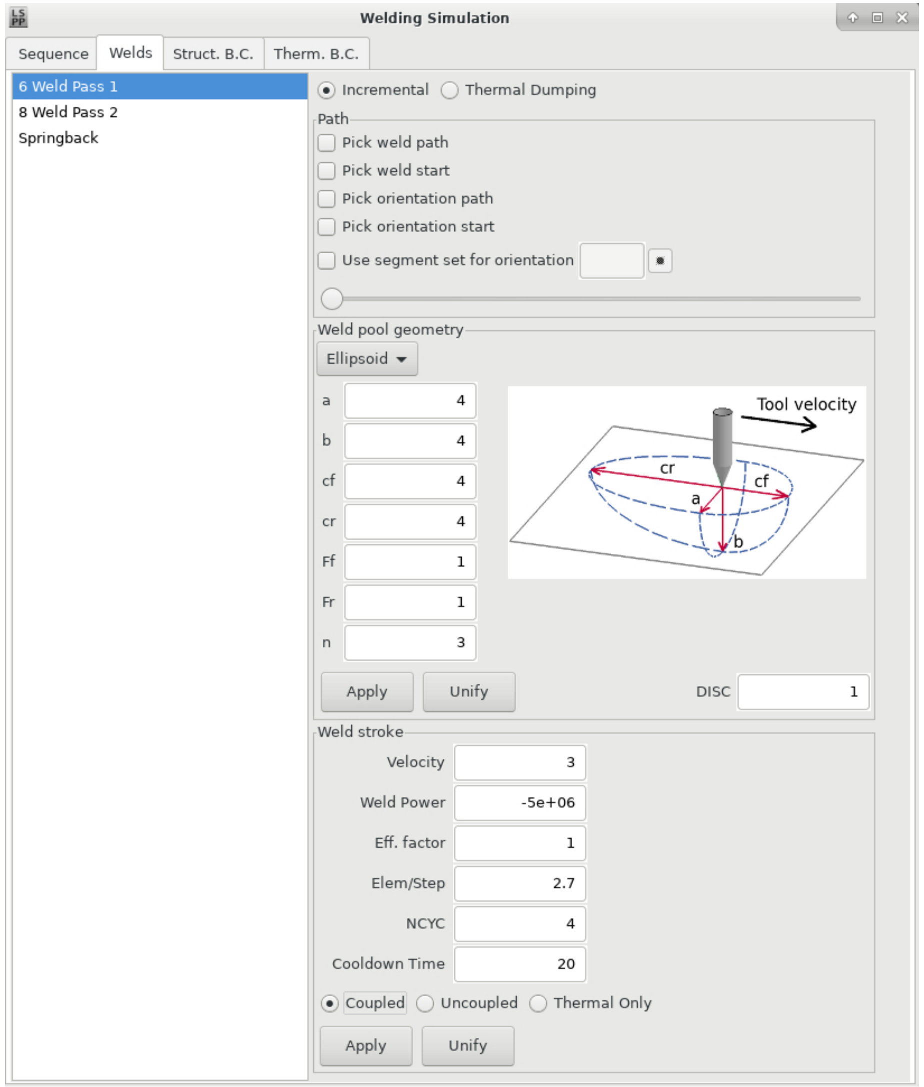


- Input for TIED_WELD contact:
  - TEMP: Minimum temperature required on both surfaces for tying
  - CLOSE: Surfaces closer than CLOSE are tied
  - HCLOSE: Thermal contact conductivity for a tied interface

LS-PrePost Weld GUI

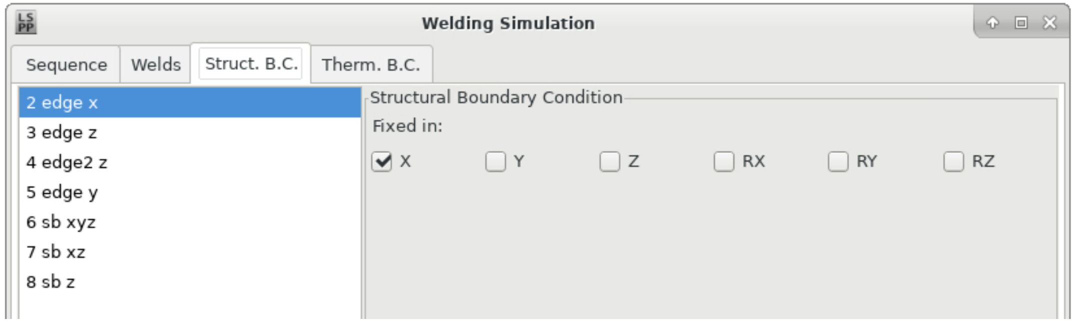
- Application -> Tools -> Welding Simulation
- Define the different weld and orientation paths
- Set specific weld input
  - Weld pool geometry
  - Velocity
  - Weld power

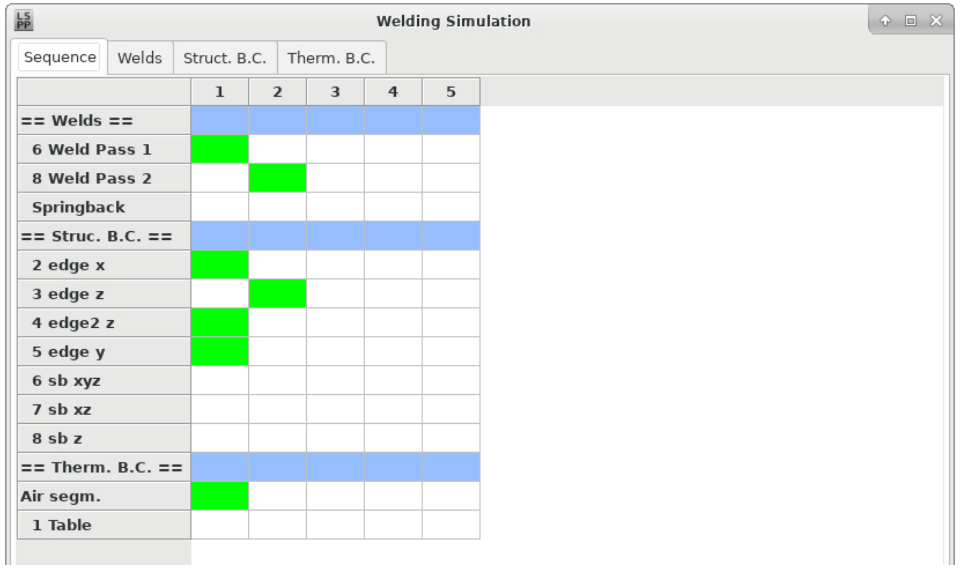


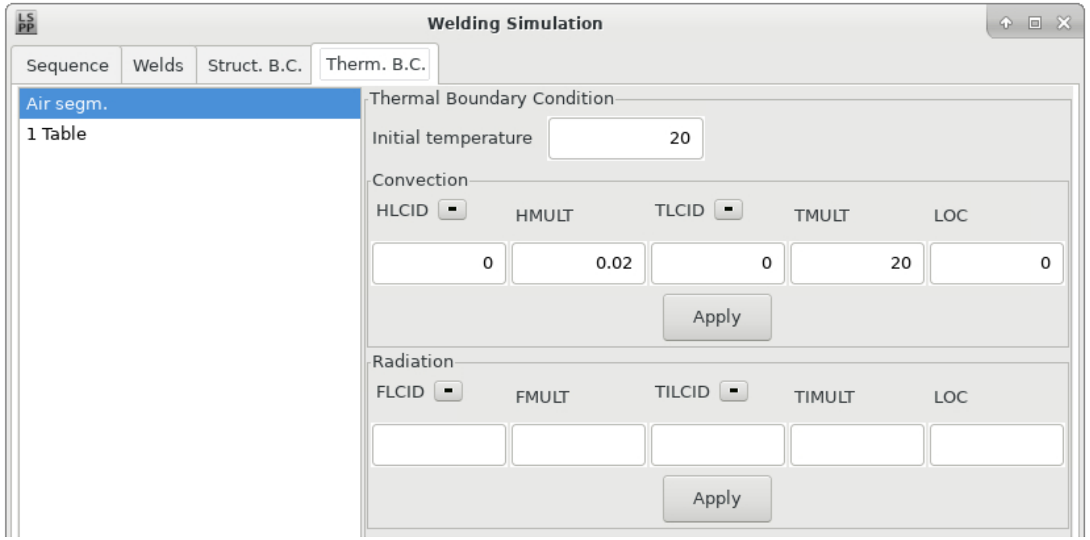


LS-PrePost Weld GUI

- Define the welding order and set boundary conditions to each weld pass
- Possible to run single or multiple weld passes in one simulation
- The welding setup can be saved in a wld-file and used later

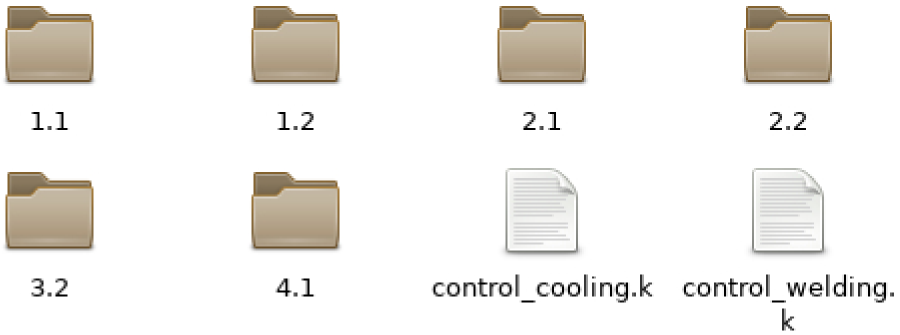






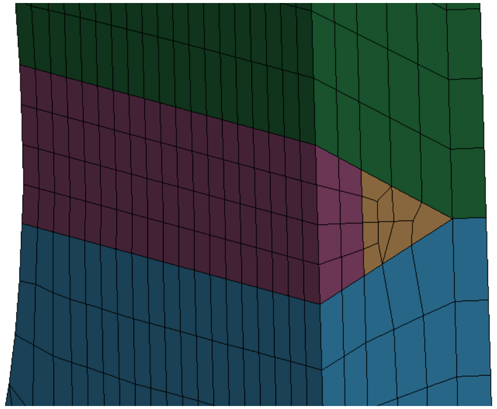
LS-PrePost Weld GUI

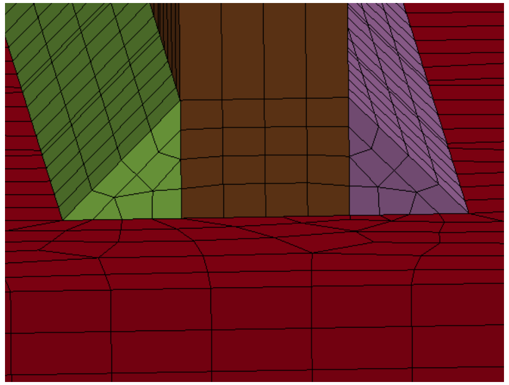
- The output from the Weld GUI is ready-to-run input decks where the welding and cooling stages is separated for each weld pass
- This enables a quick and easy way to run models with many weld passes



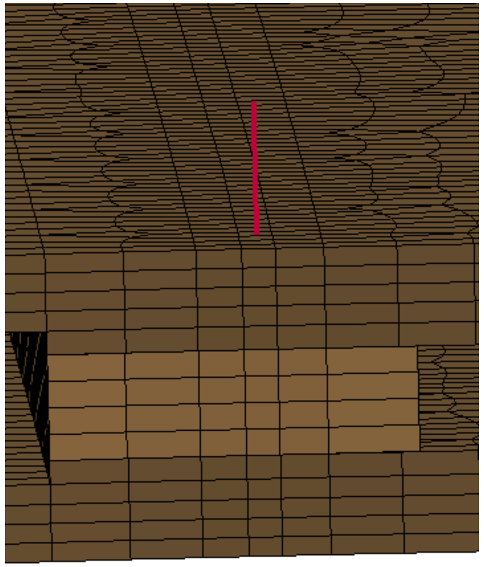
Welding Techniques

- With welding using filler material the weld passes are modeled in separate parts
- The ghost functionality are used for the parts that will not be activated during the current simulation



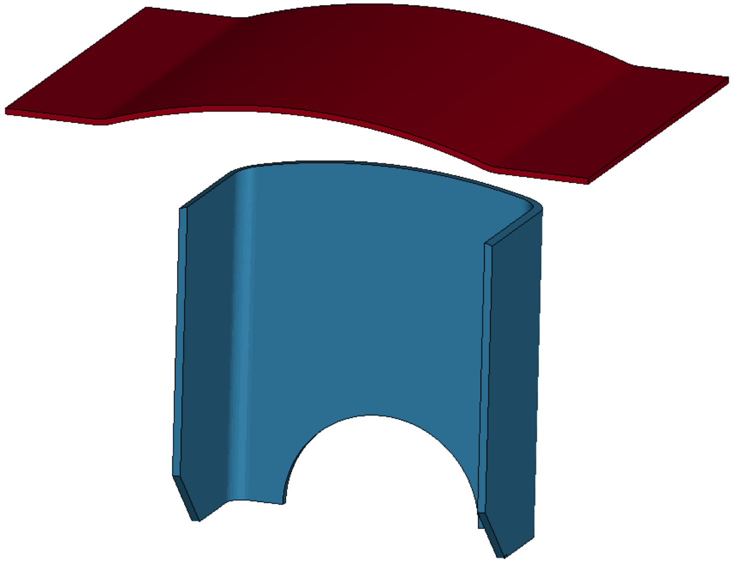


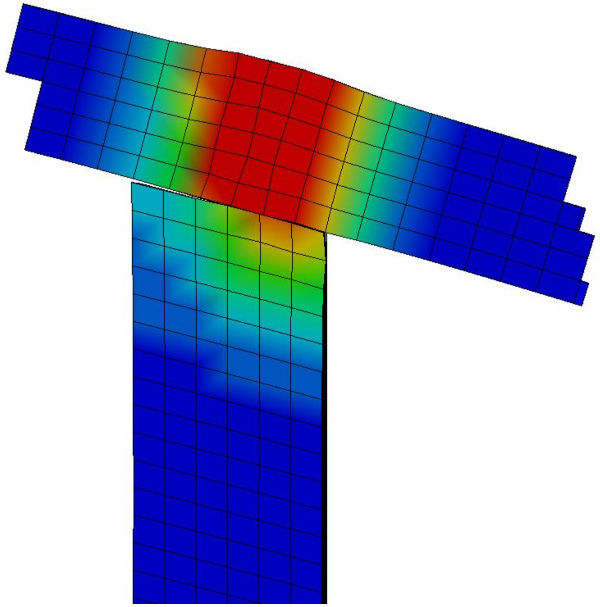
- For other cases the filler material is not needed and the ghost functionality in the material model is not used
- In these cases the weld contact can be used to model the joining of the different parts



Welding Techniques

- The heat source is applied on top of the upper plate
- Adjustments of the weld pool geometry can be made to make sure that the heat is applied through the thickness
- When the heat source passes, the elements in the interface will be tied against each other (if the temperature criteria in the contact is reached)





Welding Techniques

Temperature

Von Mises Stress

Thermal Dumping

- One of the issues with welding simulations is quite long simulation times due to many timesteps, and the number of timesteps is also dependant of the weld lengths

Incremental approach

Weld stage → Cooling stage

- Fixed thermal and implicit timestep

- Auto thermal and implicit timestep

- Hypothesis: The stresses and shrinkage in the weld lines are quite uniform and is not dependant of the incremental approach
- Solution: Heat the full weld lines simultaneously

Thermal dumping approach

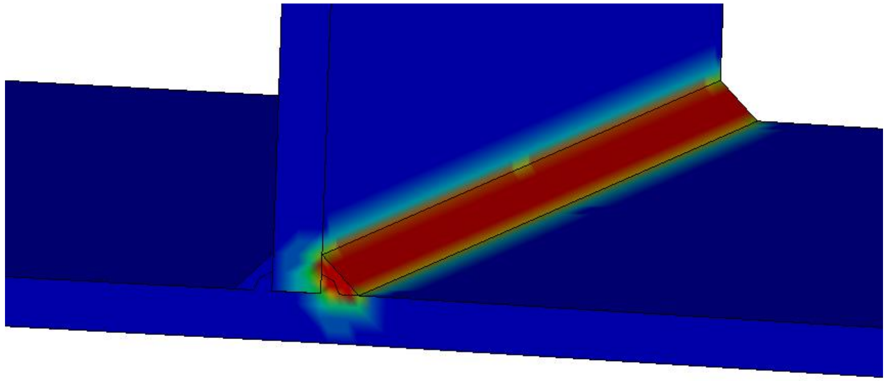
Heating and cooling stage

- Auto thermal and implicit timestep

Thermal Dumping

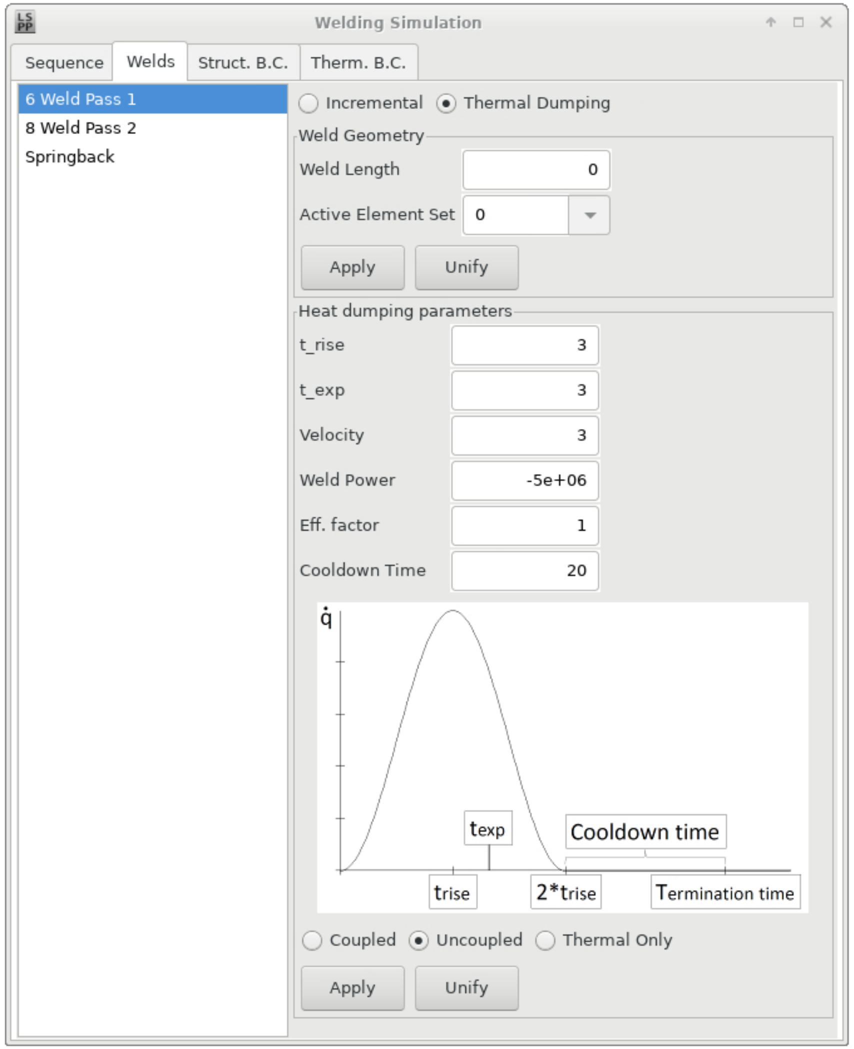
- There are several different thermal dumping techniques that are used when it comes to welding simulations.
- One example is the inherent strain method where a strain field is applied in the weld lines, and the thermal part is completely removed.

- The method presented here is a thermo-mechanical approach which is based on the physics of welding.
- The intention with this method is to apply the <u>equivalent amount of energy</u> as with an incremental approach, and also to capture the <u>temperature history</u> in the weld.



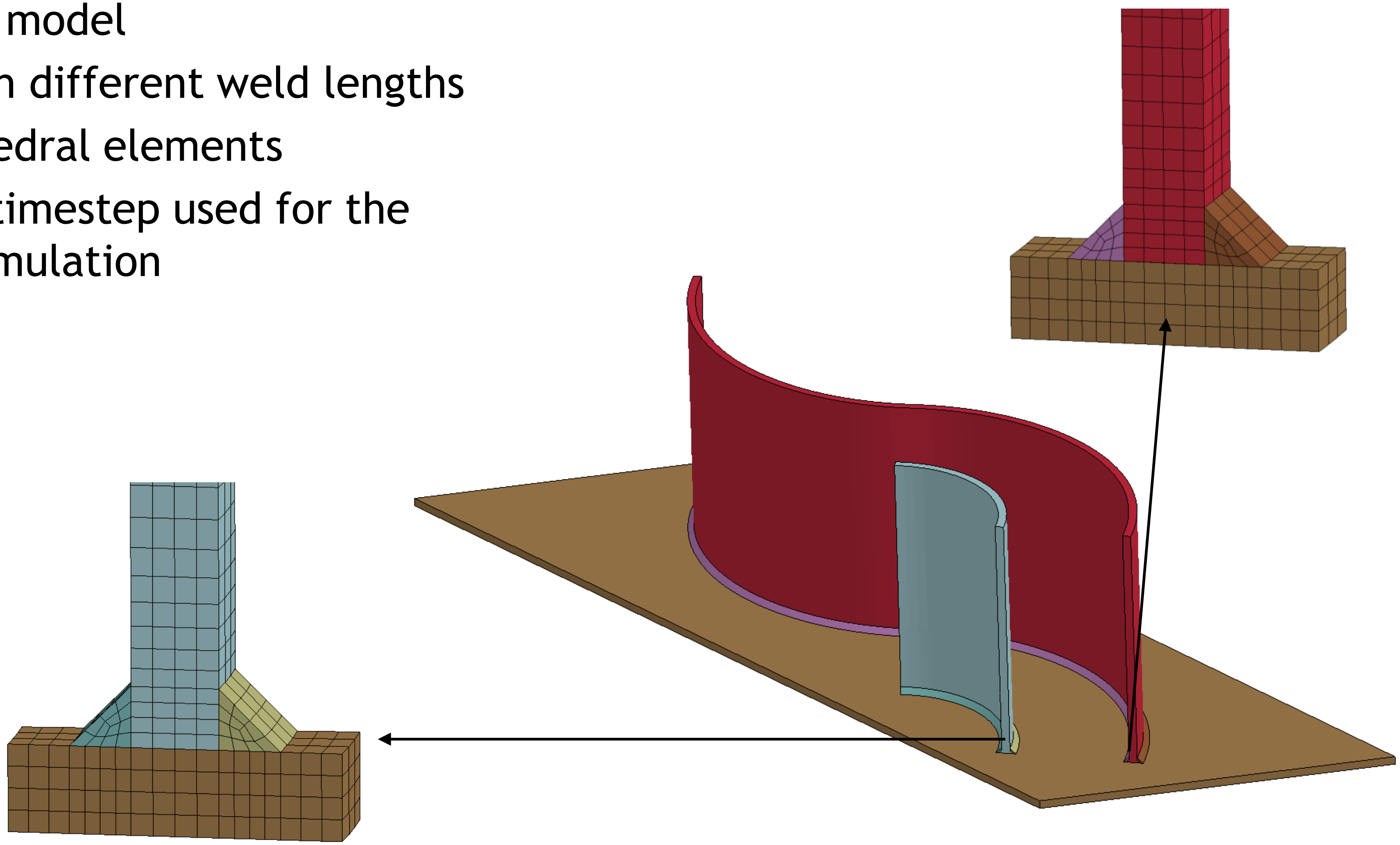
Thermal Dumping

- The thermal dumping method is also available in the LS-PrePost Weld GUI
- For more detailed explanation on how to use this method, see “*181106_Webinar_Welding_and_AM_using_LS-DYNA.pdf*” on Dynamore Nordic Client area

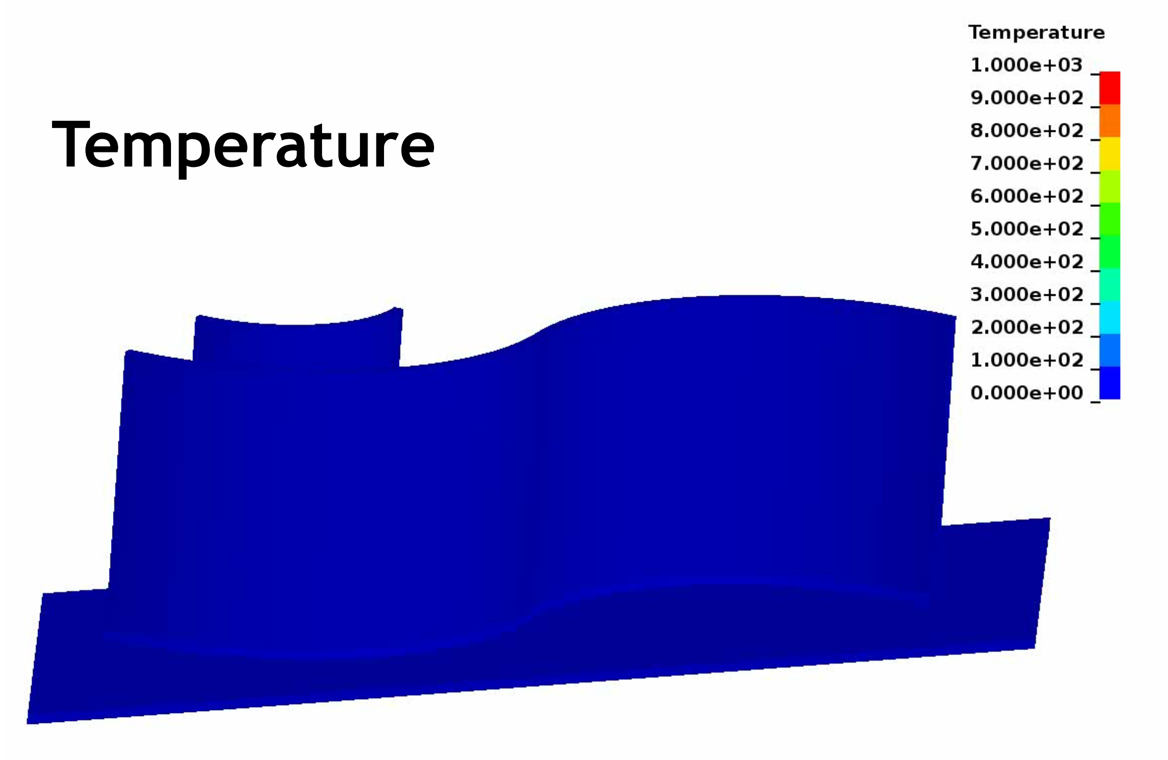


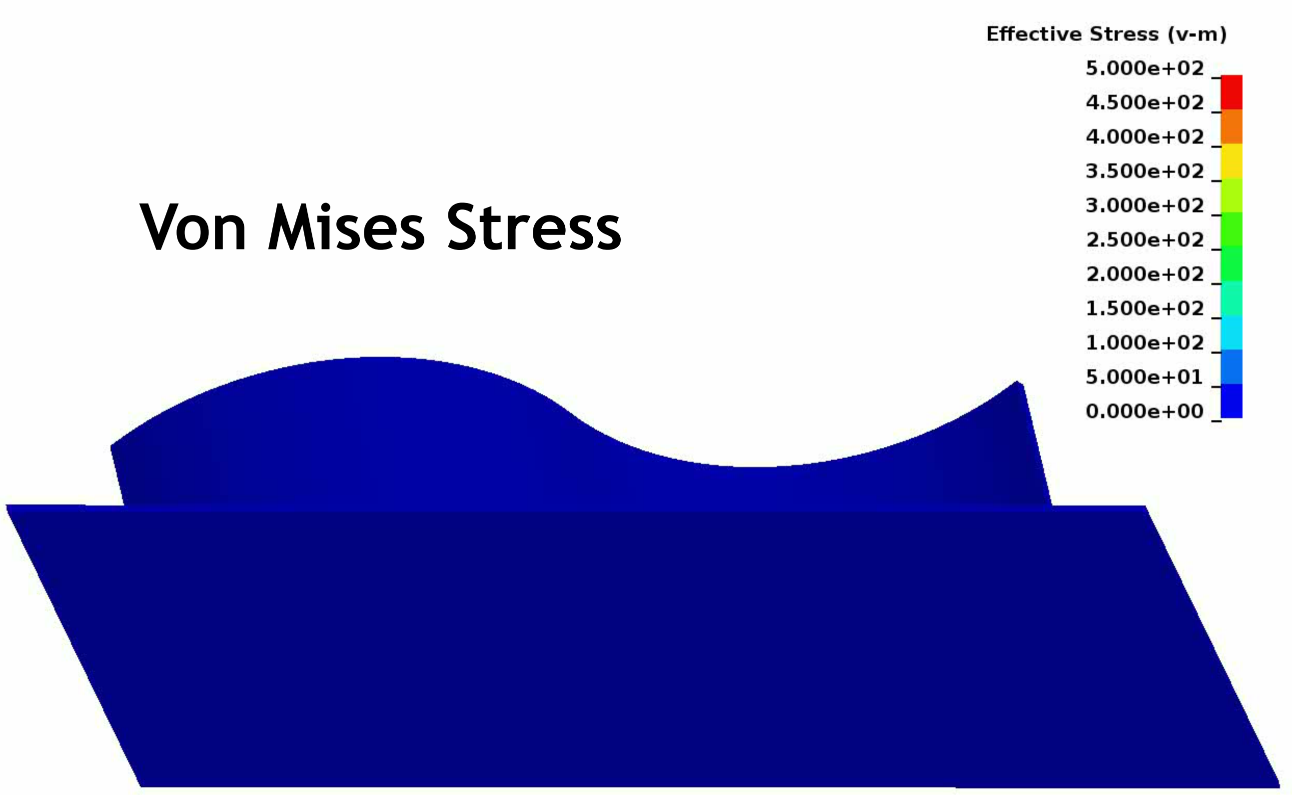
Thermal Dumping

- Curved T-joint model
- Two plates with different weld lengths
- 120 000 hexahedral elements
- 1.5 elements/timestep used for the incremental simulation

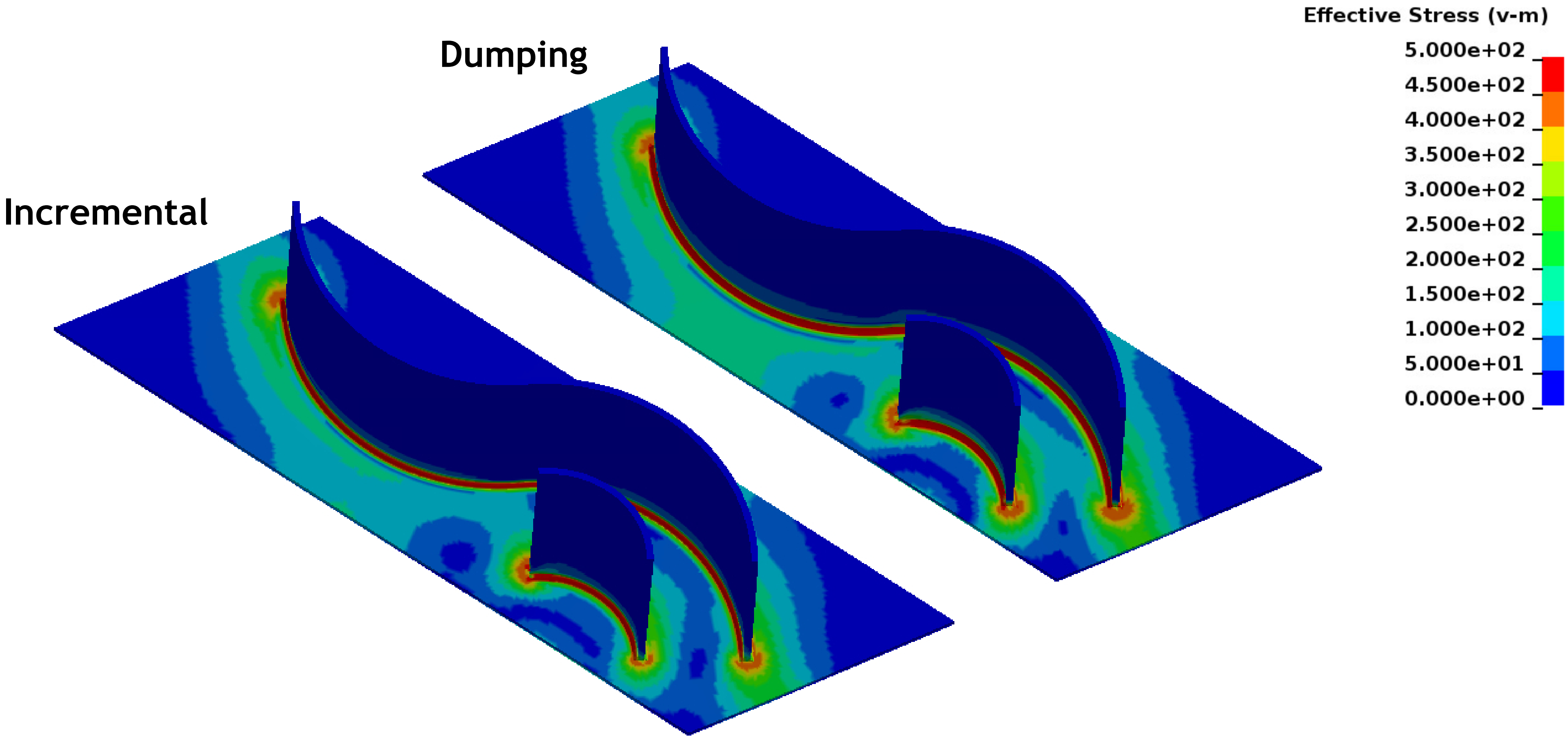


Thermal Dumping

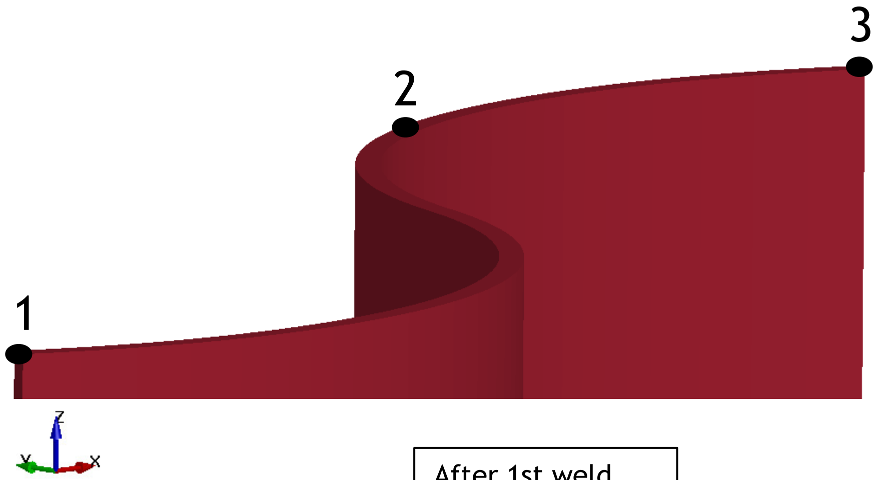




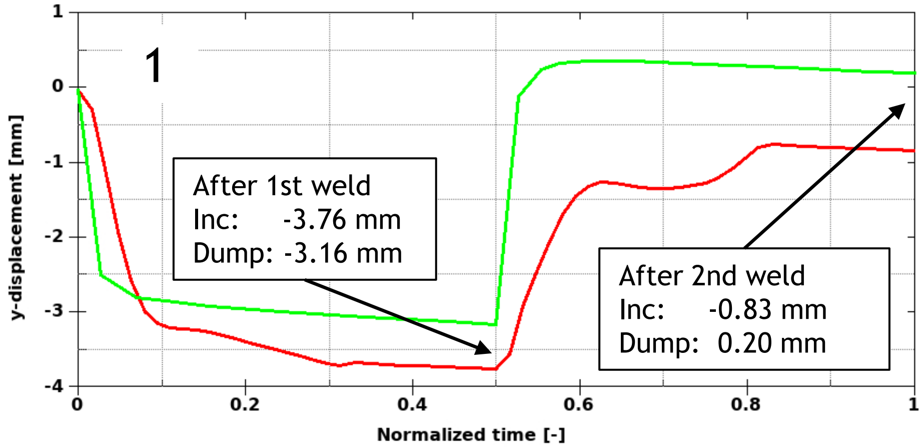
Thermal Dumping

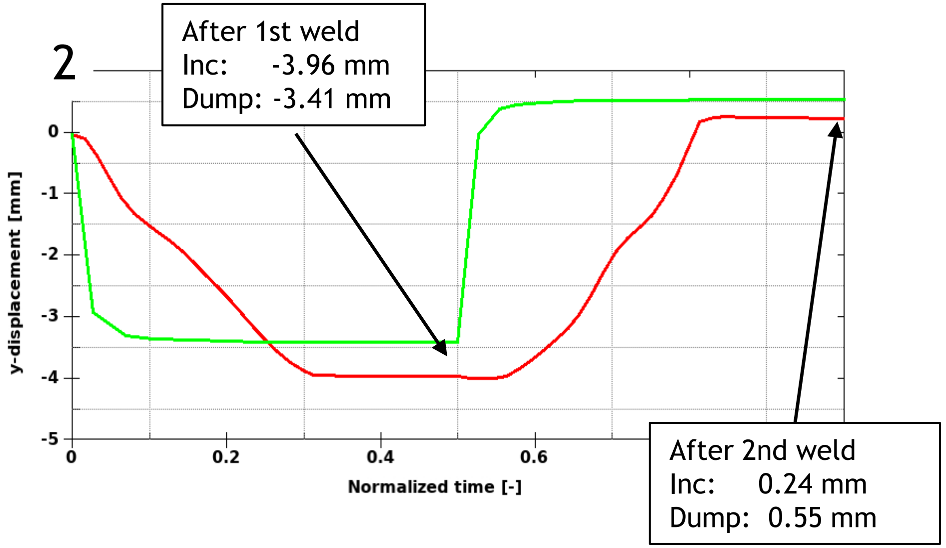


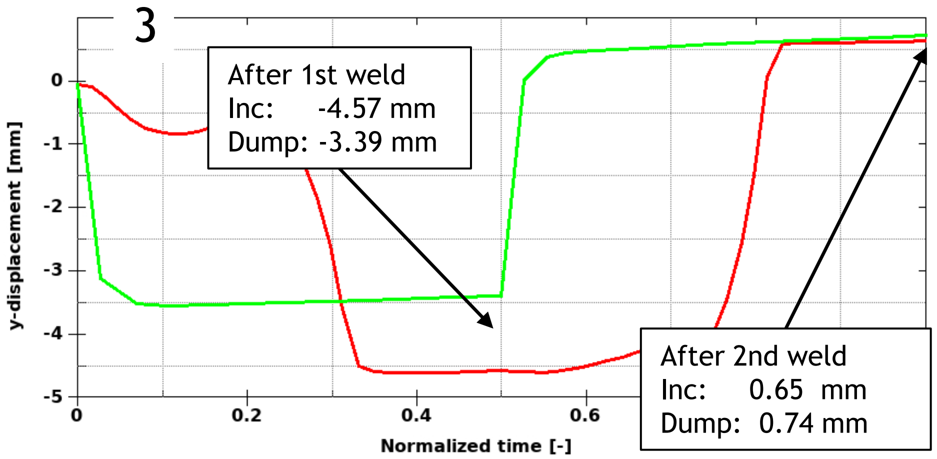
Thermal Dumping



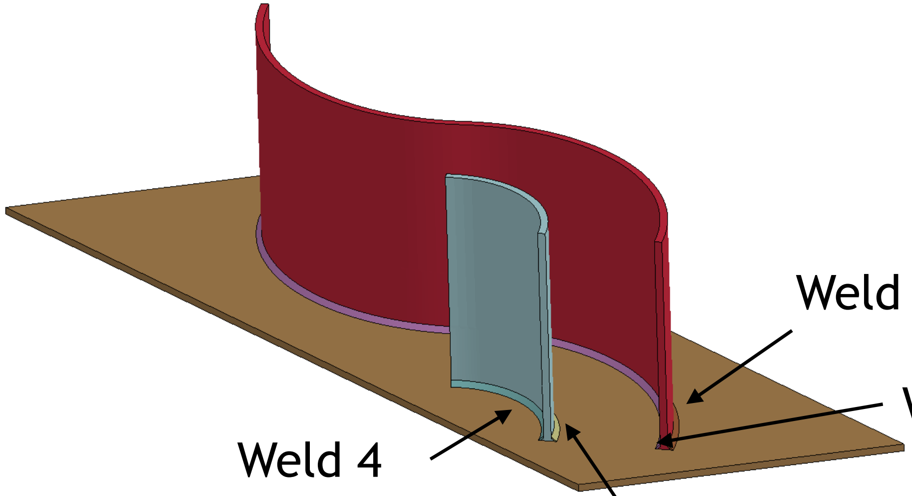
Incremental Dumping







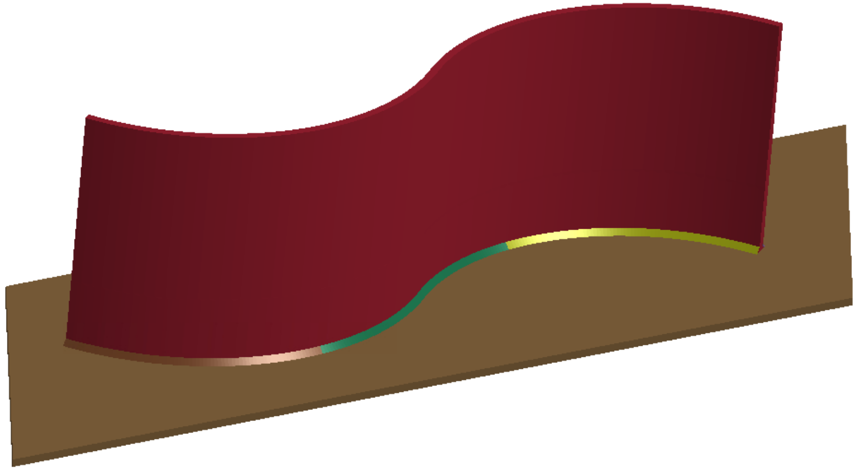
Thermal Dumping

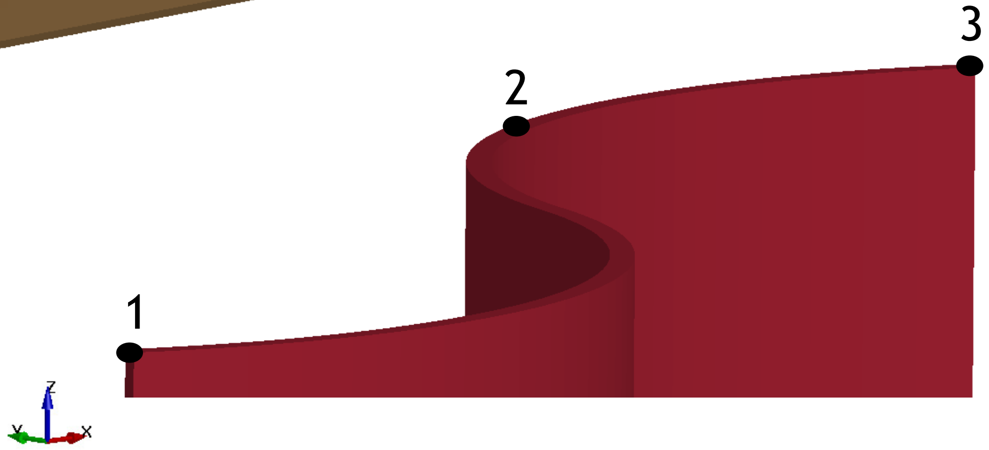


Weld (Heating and cooling)	Inc	Dump
1	1.08 h	9 min
2	1.09 h	10 min
3	25 min	8 min
4	26 min	9 min
Tot	**4.08 h**	**36 min**

Thermal Dumping

- To increase the accuracy of the dumping method the weld line can be split into sections where the heat is applied consecutively





Point 1	After 1st weld	After 2nd weld
Inc	-3.76 mm	-0.83 mm
Dump	-3.16 mm	0.20 mm
3 split dump	-3.55 mm	-0.22 mm

Point 2	After 1st weld	After 2nd weld
Inc	-3.96 mm	0.24 mm
Dump	-3.41 mm	0.55 mm
3 split dump	-3.98 mm	0.42 mm

Point 2	After 1st weld	After 2nd weld
Inc	-4.57 mm	0.65 mm
Dump	-3.39 mm	0.74 mm
3 split dump	-4.25 mm	0.65 mm

Conclusion

- With the implemented features such as heat source, material model and contacts, it´s possible to simulate the welding process in LS-DYNA
- The welding simulation can be included in the overall process chain to predict the residual distortions and the material properties in the heat affected zones
- The GUI in LS-PrePost makes it easy for the user to setup multiple weld passes and quickly change order and boundary conditions for each pass
- With the thermal dumping technique it´s possible to decrease the simulation times and get faster predictions of the residual distortions

Thank you!

Your LS-DYNA distributor and more