Weld simulation in LS-DYNA and LS-PREPOST

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LS-DYNA One code strategy

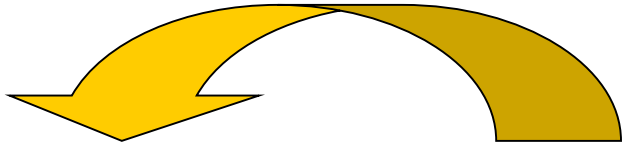
"Combine the multi-physics capabilities into one scalable code for solving highly nonlinear transient problems to enable the solution of coupled multi-physics and multi-stage problems"

Explicit/Implicit	✓
Heat Transfer	✓
Mesh Free EFG,SPH,Airbag Particle	✓
User Interface Elements, Materials, Loads	✓
Acoustics Frequency Response, Modal Methods	✓
Discrete Element Method	✓

Incompressible Fluids	R7
CESE Compressible Fluid Solver	R7
Electromagnetism	R7

Welding capabilities - Solver

- State of the art parallelization
- Thermal and Mechanical solvers are run in a staggered approach



Mechanical Solver

Based on the actual temperature the mechanical solver calculates:

- Forces and corrseponding stress
- Temperature dependent constitutive material properties
- Thermal expansion
- Update of the actual geometry

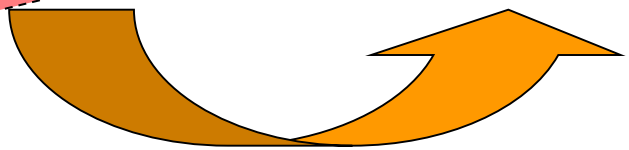
Thermal Solver

based on the actual geometry the thermal solver calculates:

- Heat from weld source
- Heat conductance
- Cooling from convection
- Update of the actual temperature.

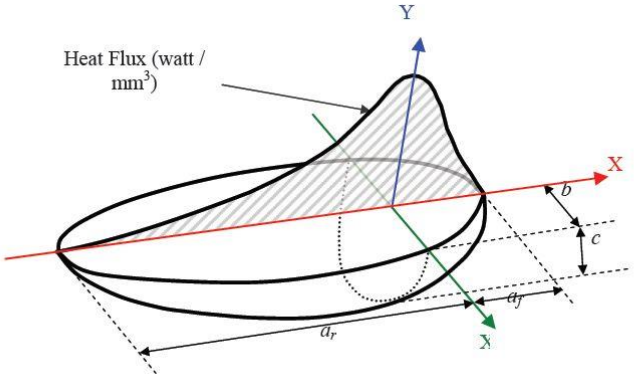
Explicit/Implicit (SMP & MPP)

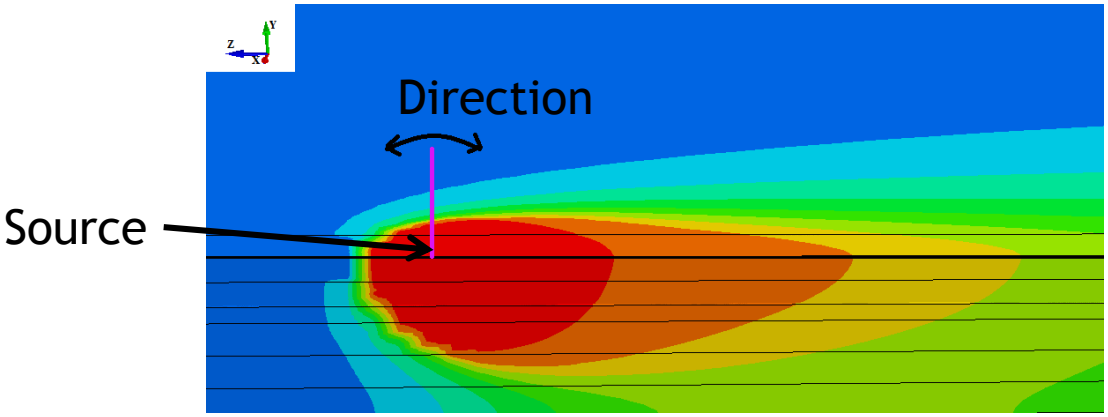
Implicit (SMP & MPP)



LS-DYNA welding capabilities – Weld Source

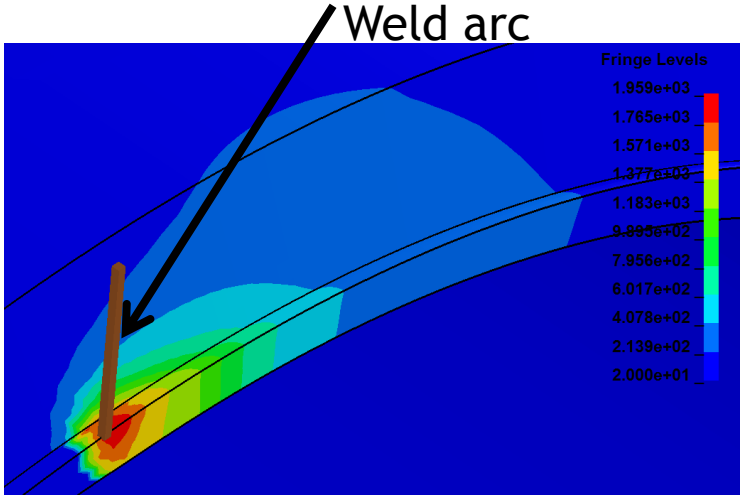
- The weld source is modeled using a Goldak double ellipsoid heat source.
- The type of weld is chosen by using different geometry of the heat source.
- It is defined by geometrical measures a_r, a_f, b and c
- Also, the power distribution can be adjusted from rear to front.



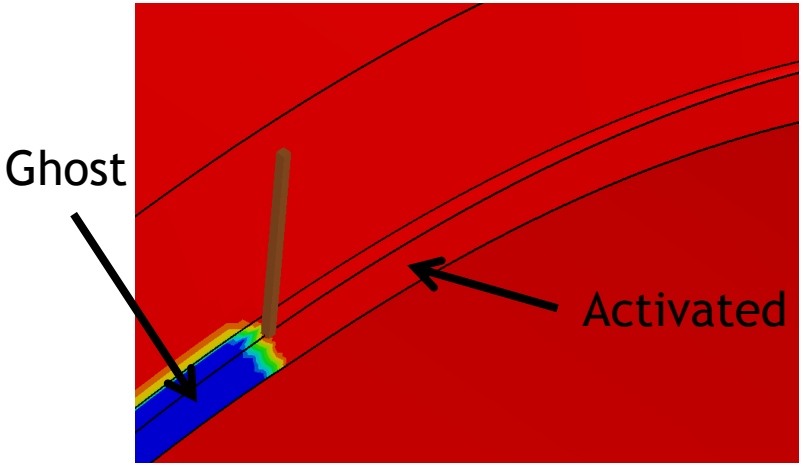


LS-DYNA welding capabilities – Material

- The element can either be solid, ”Liquid” or ”Ghost”.
- When the material is ”Ghost” it has the following properties:
  - Low Stiffness
  - No thermal expansion
  - Specific heat related to the heating of the material from the weld arc
  - No thermal conductivity
- When the temperature reaches a specified temperature, material is activated and recieves ”material” properties.



Temperature

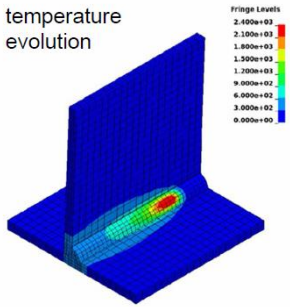


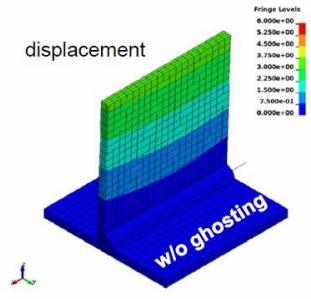
LS-DYNA welding capabilities – Material

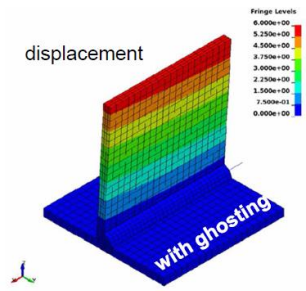
- Apart from the ghost element function, the material model also includes Anneal functionality.
- Above a specified temperature, all history variables such as hardening and back stress are set to zero.
- However, the stresses are calculated from equilibrium equations.
- The material model includes piecewise hardening whith seamless isotropic/kinematic portions.
- All properties are temperature dependent

MAT_244

- *MAT_UHS now has the possibility to have element activation by temperature similar to *MAT_CWM
- Supports annealing where history variables are cancelled out.
- Can be combined with *MAT_CWM_THERMAL
- By default, the phase start temperatures are the same for both heating and cooling.
- When using advanced kinetics input (REACT=1), the start temperatures can be input as load curves.
- Temperature dependendent thermal expansion for austenite and hard phases
- Added load curve for transformation induced strains.

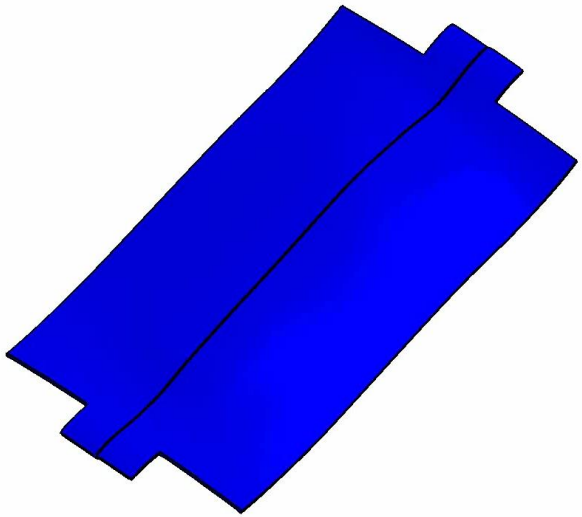




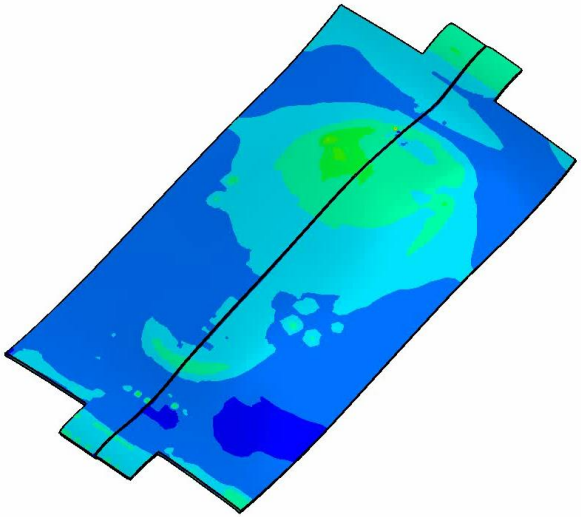


Recent developments for thermo-mechanically coupled simulations in LS-DYNA with Focus on welding processes, Thomas Klöppel, Tobias Loose, 10th European LS-DYNA Conference 2015, Würzburg, Germany, 2015

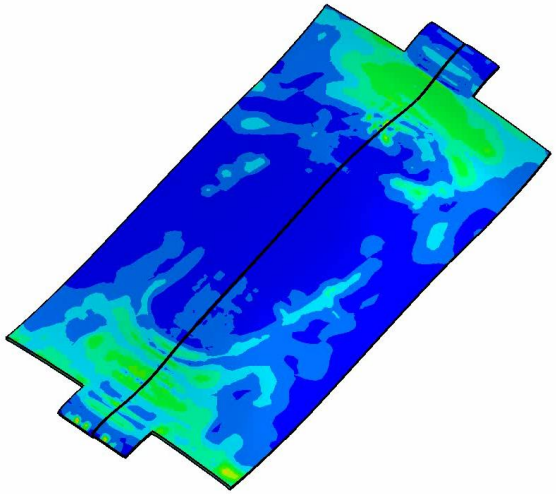
LS-DYNA welding capabilities – Material



Temperature



Effective plastic strain

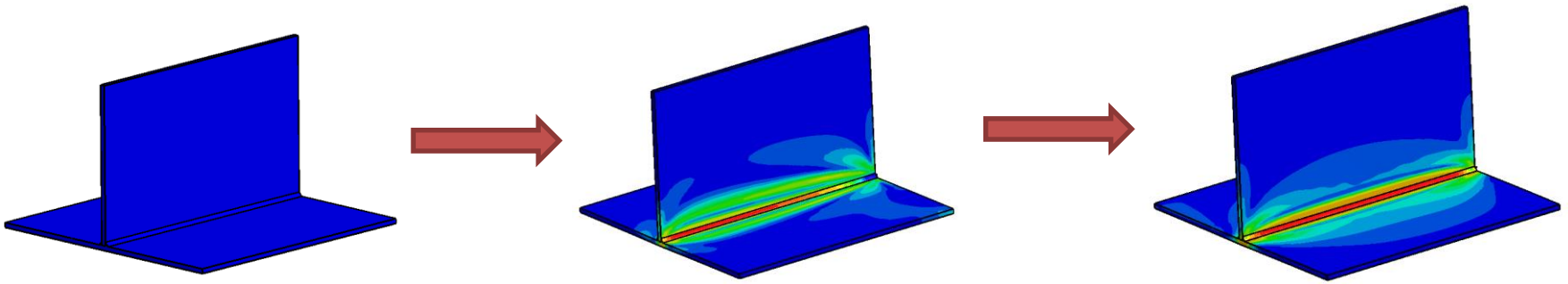


Von Mises stress

Pre-processing issues

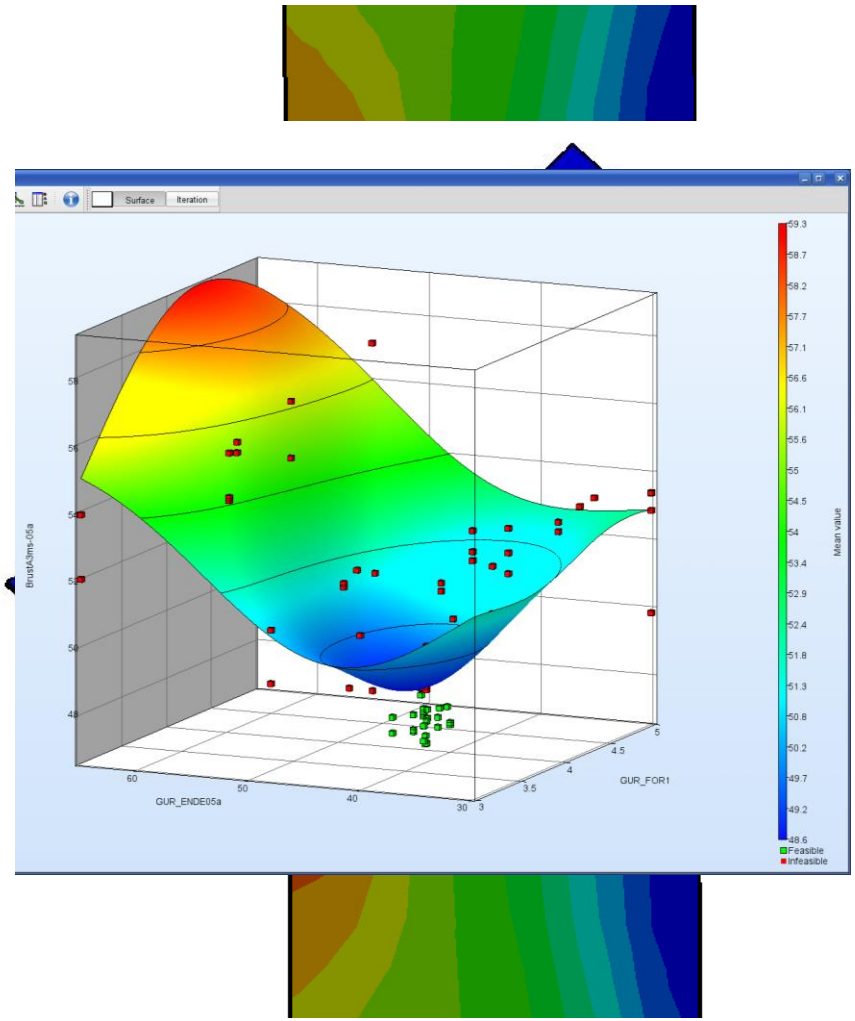
- Set weld path of source and direction node
- Set the weld speed, type and power
- Assign the clamping
- Assign the thermal Boundary conditions
- Assign material data (ghost, liquid or solid)
- Determine the process order
- Quickly becomes complicated for multistage analysis – Pre-processor is needed

Temperatures, deformation and history variables are transferred through the process



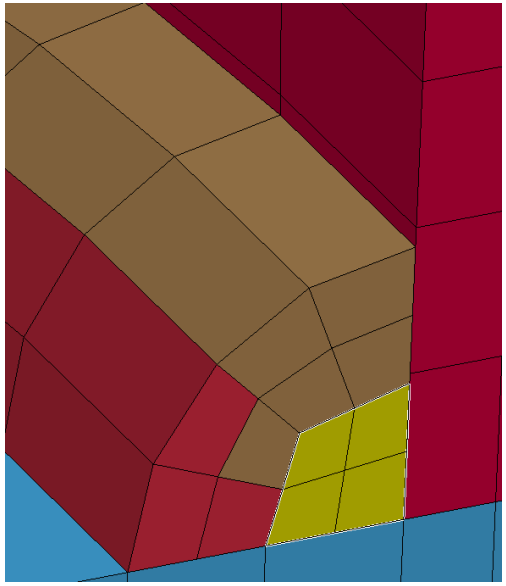
Pre-processor goals

- Set up weld path and weld direction
- Easy to change welding order
- Automatic transfer of results from one stage to the next
- Automatic switch of material from Ghost, Liquid and Solid
- Easy setup of clamping and thermal BC for each process step
- Connection to optimization software



Input to Weld simulation setup

- Geometry of structure and welds
- Weld and orientation paths as beam elements.
- The mesh can be generated by other pre-processor such as ANSA or ANSYS workbench and imported to LS-PREPOST
- The welds can be either merged to the structure or connected by thermal “tied”contacts.
- Material of structure and welds
- Sets of nodes that define mechanical boundary constraints
- Segments that define the different thermal boundaries.



*MAT_CWM_(TITLE) (270) (1)

TITLE

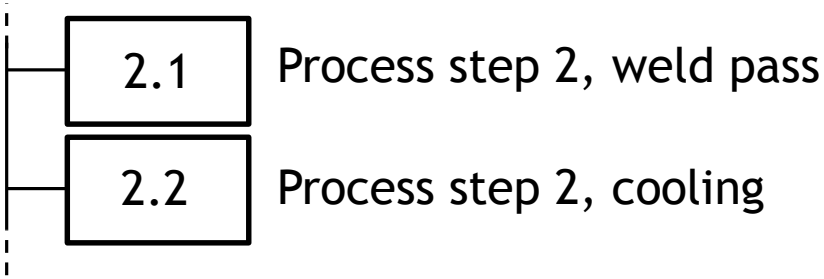
1	MID	RO	LCEM	LCPR	LCSY	LCHR	LCAT	BETA
	1	7.800e-09	1	2	3	4	5	0.0
2	TASTART	TAEND	TLSTART	TLEND	EGHOST	PGHOST	AGHOST	
	900.00000	1000.00000	950.00000	960.00000	1000.00000	0.2000000	1.000e-06	
3	T2PHASE	T1PHASE						
	800.00000	900.00000						

Control files and output

- LS-PREPOST includes recommended Welding and Cooling ”control files”.
- The file can be edited by the user or if a control file is placed in the working directory, LS-PREPOST will use that file instead of the default.

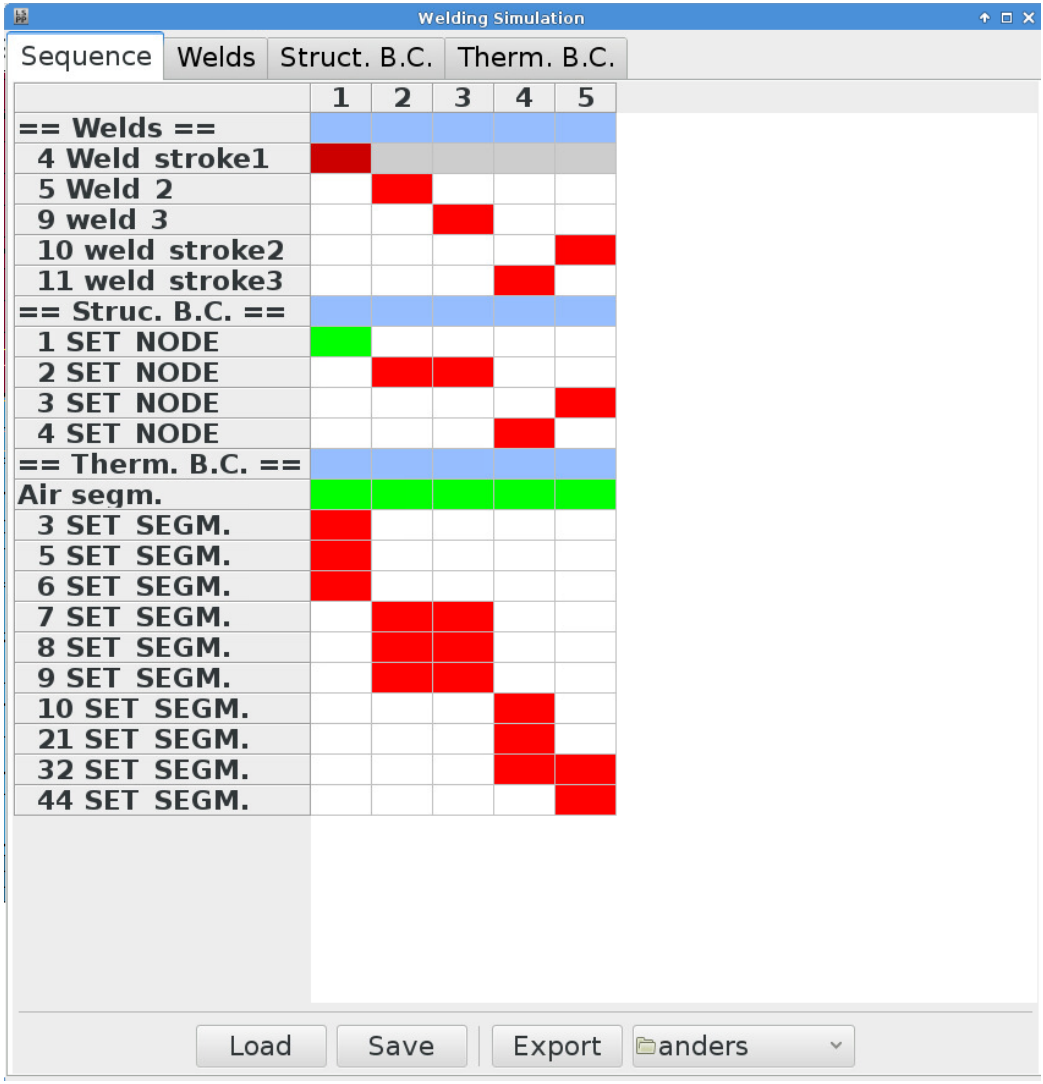
```
$# Default control keyword file for welding simulation
$# Parameter "dt" defined from LS-PrePost welding interface
*KEYWORD
*CONTROL_IMPLICIT_GENERAL
$#  imflag        dt0     imform      nsbs       igs     cnstn      form     zero_v
         1&dt                  2         1         2         0         0         1
*CONTROL_IMPLICIT_SOLUTION
$#  nsolvr     ilimit     maxref     dctol     ectol     rctol     lstol     abstol
         2         11         15 1.0000E-3 1.0000E-31.0000E+10 0.9000001.0000E-20
$#   dnorm     diverg      istif   nlprint    nlnorm   d3itctl     cpchk
         2          1          1         1         2         0         0
$#  arcctl     arcdir     arclen    arcmth    arcdmp
         0          0      0.000         1         2
$#   lsmtd      lsdir       irad      srad      awgt      sred
         1          2      0.000     0.000     0.000     0.000
```

- Each welding pass and cooling is written into its own directory.



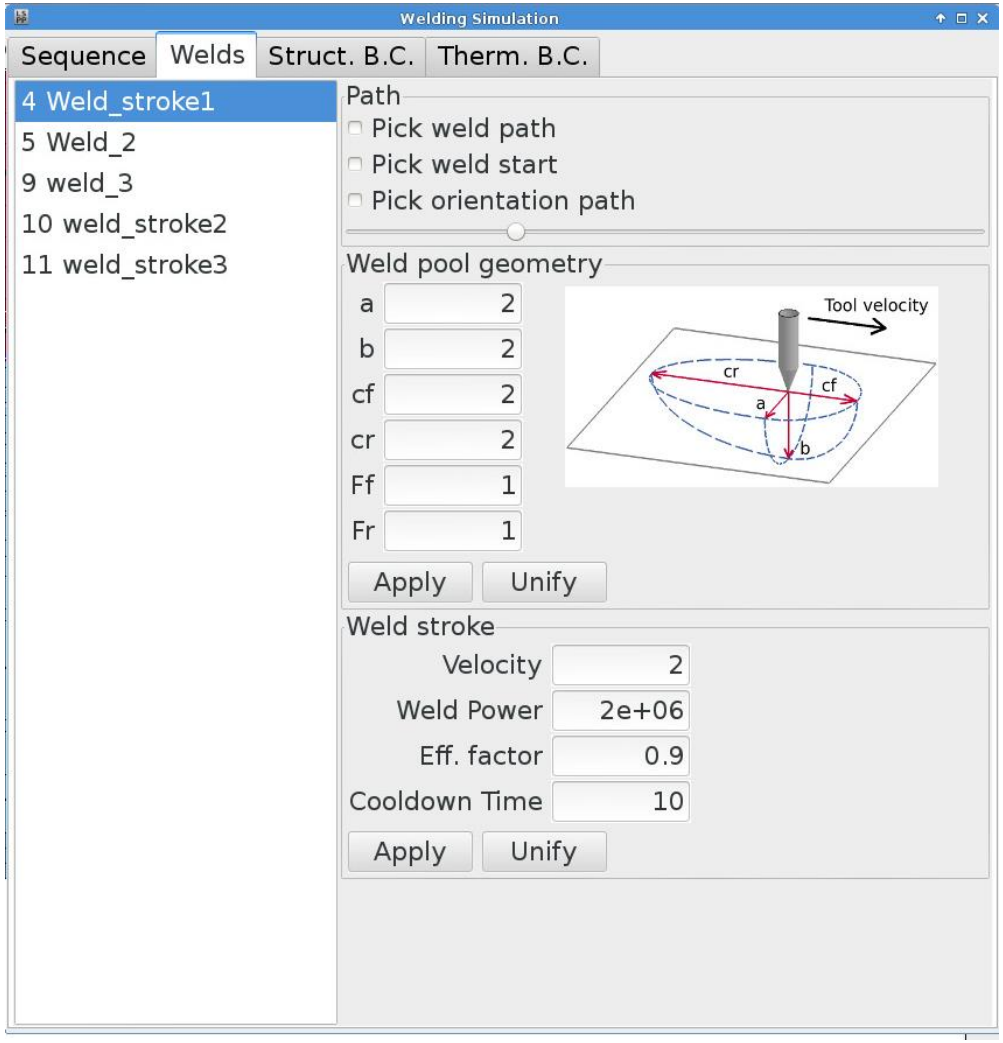
Pre-processing – Welding plan

- By clicking the boxes, the welding order is determined.
- Possibility to add or remove stages.
- Double clicking on the rows opens the corresponding definitions.
- To each weld, corresponding clamping and thermal boundary condition can be chosen.
- If the properties are defined, the box is coloured green.
- When the process is set up, an LS-DYNA input file is exported.
- The setup of the welding simulation can be saved/loaded from an ASCII file.



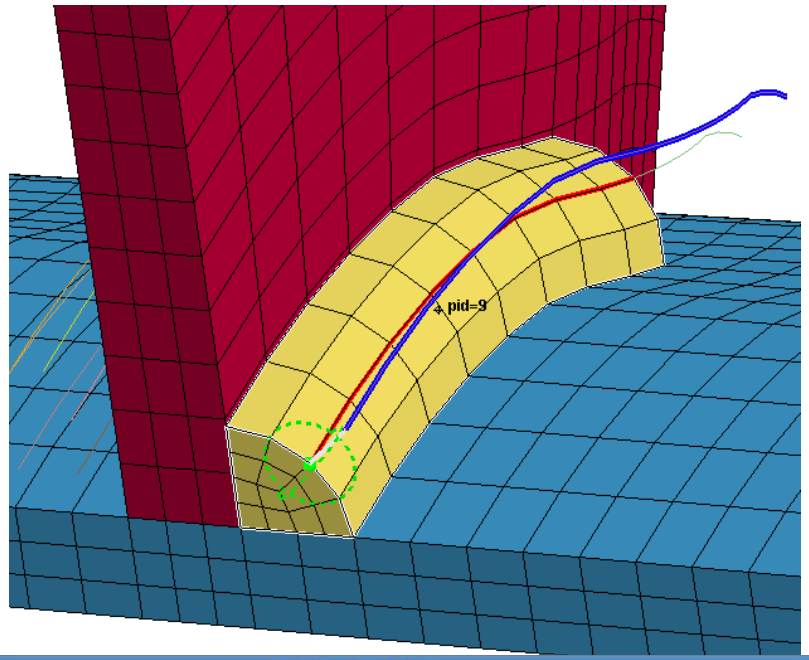
Pre-processing – Weld properties

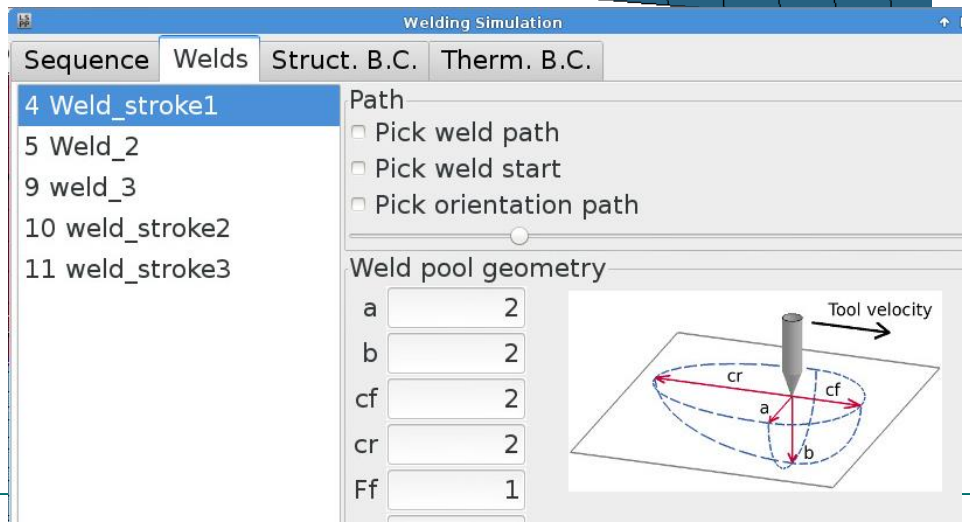
- Each weld has its own property regarding:
  - Pool geometry (GOLDAK)
  - Velocity
  - Power
  - Efficiency
  - Cooldown time
- The user can specify the number of timesteps/element
- Weld path and orientation is identified by clicking
- Possibility to unify an input to several welds.
- Solution timestep is determined by timesteps per element.



Pre-processing – Weld path

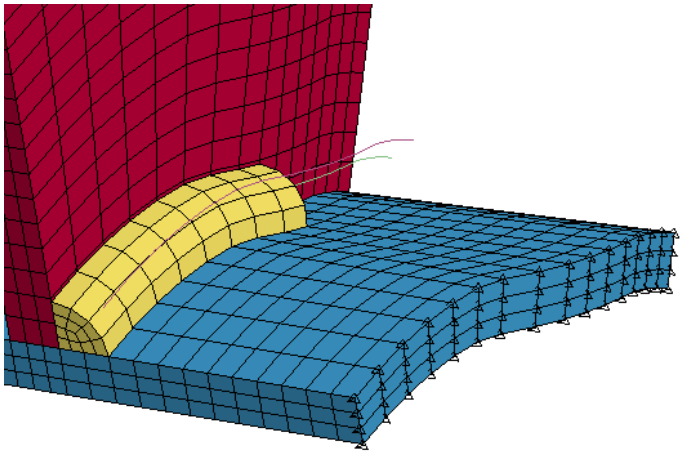
- Path and orientation is determined by “beam” elements.
- Selected by clicking
- Weld can be animated by slider
- Weld pool geometry is visible in the geometry window

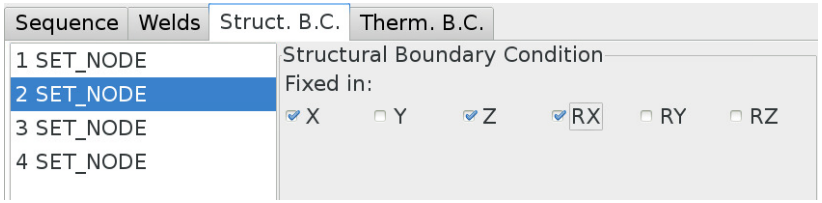


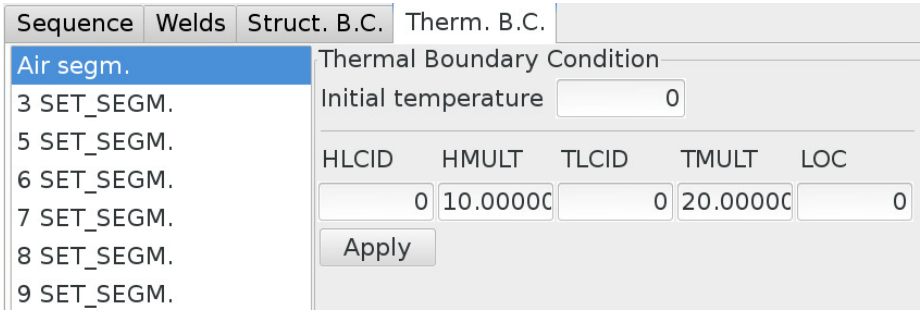


Pre-processing – Boundary conditions

- Mechanical constraints are applied on sets of nodes.
- Visible in graphics window at selection
- Air cooling is automatically identified
- Other cooling boundaries (such as clampings) are identified by sets of segments



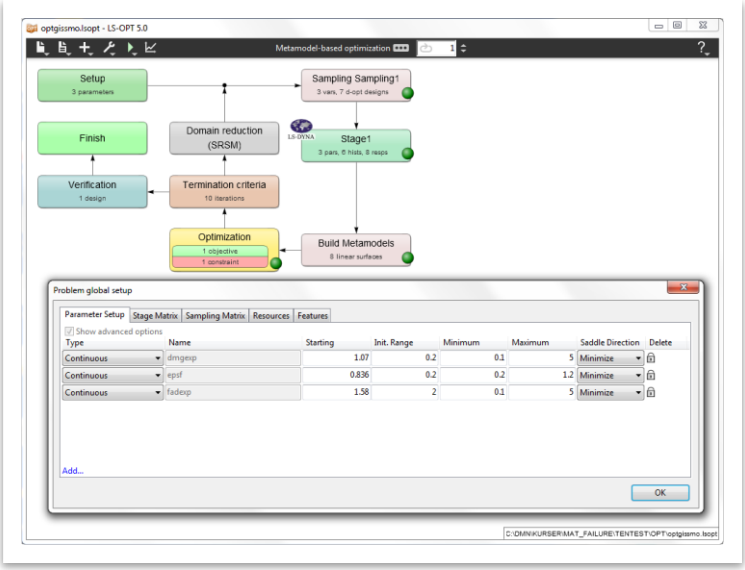




Pre-processing – Weld optimization

- The welding simulation setup is output to an ASCII file.
- The ASCII file can be used together with LS-OPT to optimize weld order, heat input, cooling times etc.

```
$ Welding simulation - LS-PrePost 4.3 (Beta) - 19May2015(11:00)
$
*SEQUENCE
$  STAGEID
         1
         2
         3
         4
         5
*STAGE
$  STAGEID      TYPE        ID
         1         1         4
         1         3         0
         2         1        10
         2         3         0
         3         1        11
         3         3         0
         3         3        21
         4         1         9
         4         3         0
         4         3        21
         5         1         5
         5         3         0
         5         3        21
*WELDITEM
$      TYPE        ID  HEADPART ORIENPART STARTNODE
         1         4        21        17      3227
```



Summary

- LS-DYNA has a one-code strategy together with long term commitment of running large models with high level of parallelization.
- This makes the LS-DYNA software a strong contender for incremental welding simulations.
- To solve the pre-processing issues, DynamoreNordic has started the process of developing a module for welding simulations in LS-PREPOST
- The pre-processor will solve the main issues of setting up production type welding simulations.
- We are open for suggestions from users for further development.
- BETA version in early fall 2015.

Thank you!

DYNA MORE

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