Weld simulation in LS-DYNA and LS-PREPOST

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“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”

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<thead>
<tr>
<th>Explicit/Implicit</th>
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- 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 corresponding 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
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 receives ”material” properties.
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 with 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 dependent 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

PASS 1  ➔  COOL 1  ➔  PASS 2

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.
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.

```plaintext
# Default control keyword file for welding simulation
# Parameter "dt" defined from LS-PrePost welding interface
*KEYWORD
  *CONTROL_IMPLICIT_GENERAL
    # imflag  dt0  imform  nsbs  iqs  cnstn  form  zero_y
    ldt   2  1  2  0  0  0  1
  *CONTROL_IMPLICIT_SOLUTION
    # nsolvr  ilim  maxref  dctl  ectl  xctl  lstol  abstol
    2  1  15  1.0000E-3  1.0000E-31  1.0000E+10  0.5000001  1.0000E-20
    # dnorm  diverg  istif  nlprint  nlnorm  d3itctl  cpchk
    2  1  1  1  1  2  0  0
    # arctol  arcdir  arclen  arcmth  arcdmp
    0  0  0.000  1  2
    # lsmtol  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.

Process step 2, weld pass

2.1

Process step 2, cooling

2.2
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 Boundary Conditions Image](image.png)
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.
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!

Your LS-DYNA distributor and more