Jointing techniques between shell and solid elements

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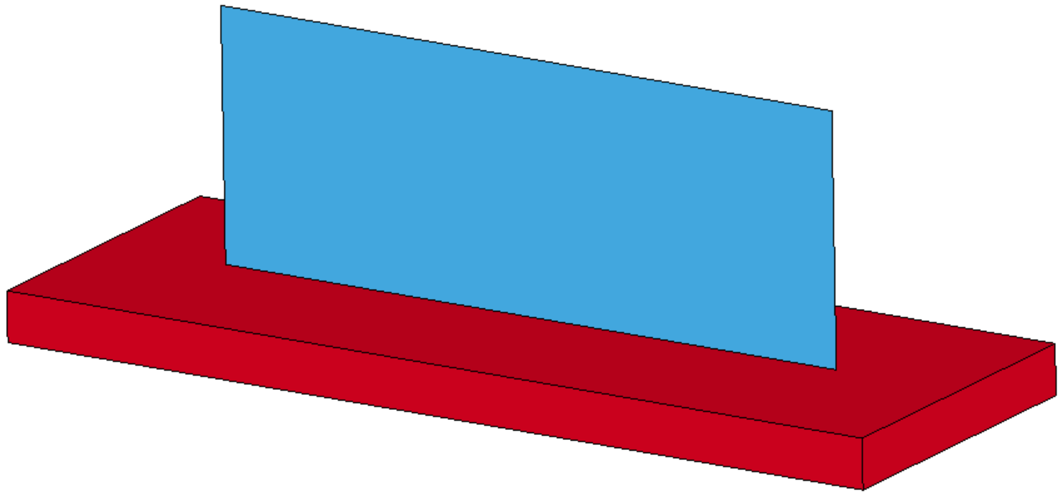
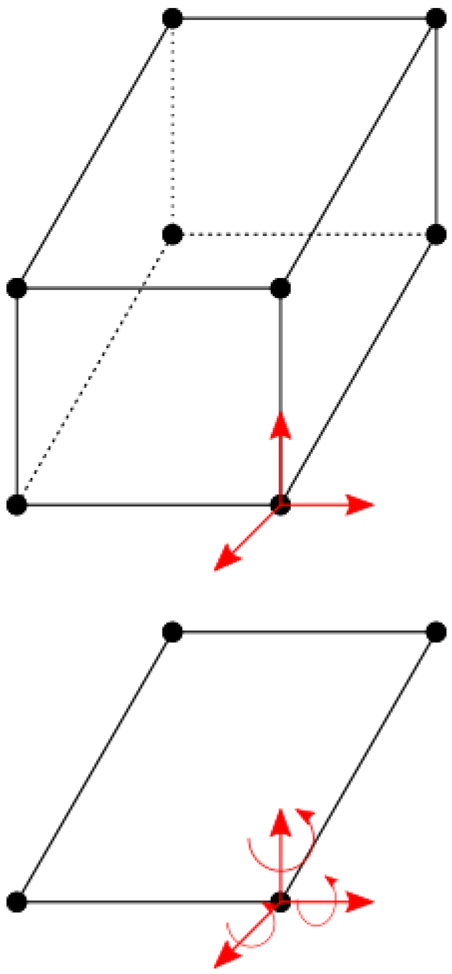
Introduction

- Historically shells have been used for most parts in vehicle modelling. With new material, a need to capture failure etc., an increase of parts being modelled using solid elements are emerging.
- During this presentation, several different methods for connecting shell and solid elements will be presented. Some methods will be applied to study a case with a T-shaped joint between a shell and solid plate.



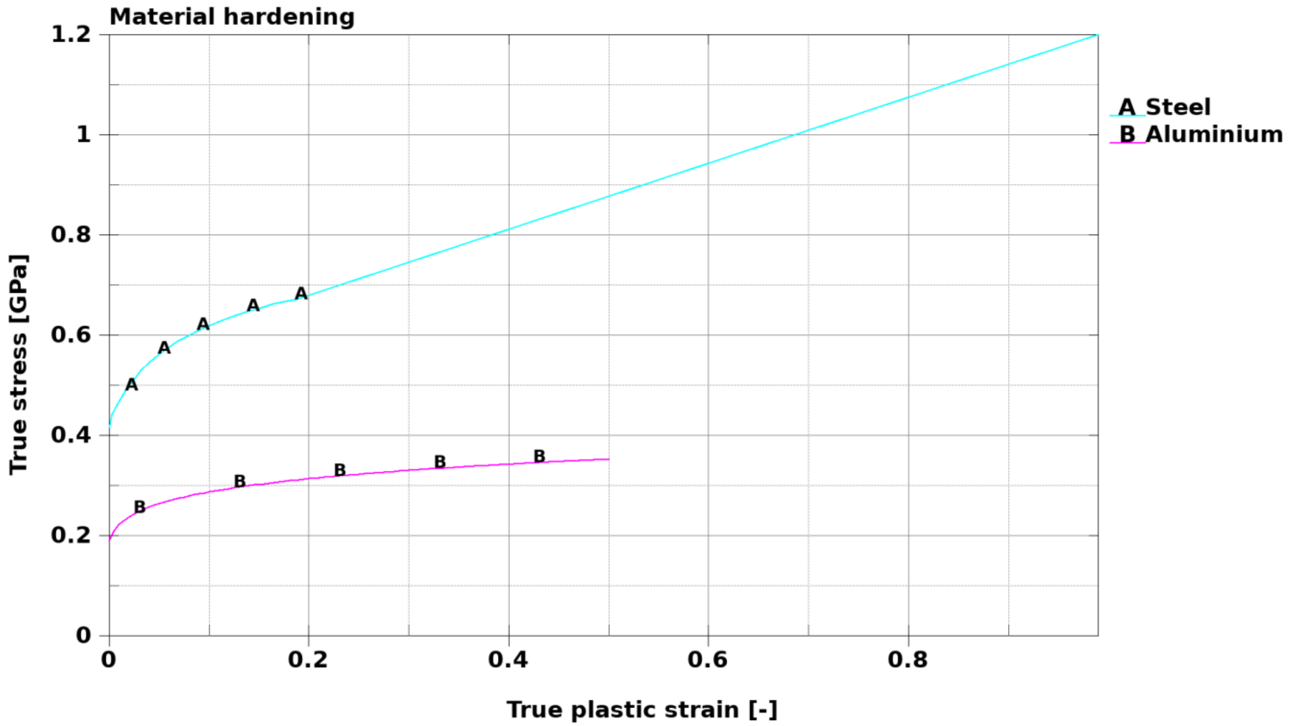
Introduction

- In a solid element each node contains 3 degrees of freedom (DOF), that is the three orthogonal spatial translation directions.
- While in a shell element, each node in addition to the translational DOF they also have three rotational DOF, one around each spatial axis.
- So if nodes are shared between solid and shell parts the rotational DOF will not be transmitted from the shell to the solid as the rotational DOF is not present in the solid element formulation.



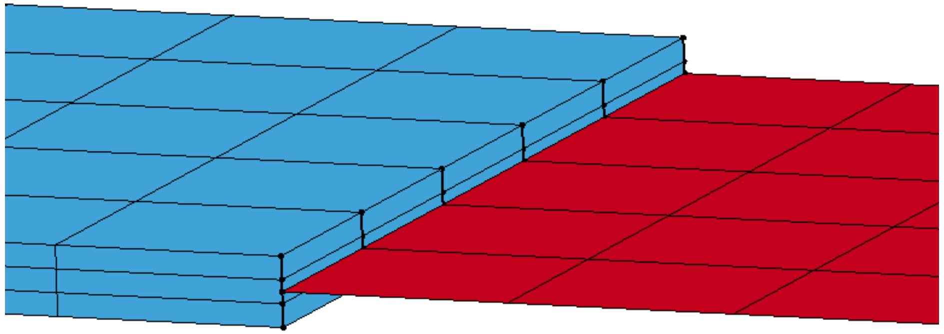
Introduction

- R11.1, single precision.
- Control cards from explicit guidelines.
- kg, mm, ms, kN, GPa
- A steel material and an aluminum material. isotropic using MAT_24 material model, no failure.
- Constant timestep of 0.5E-6 s
- Mass scaling

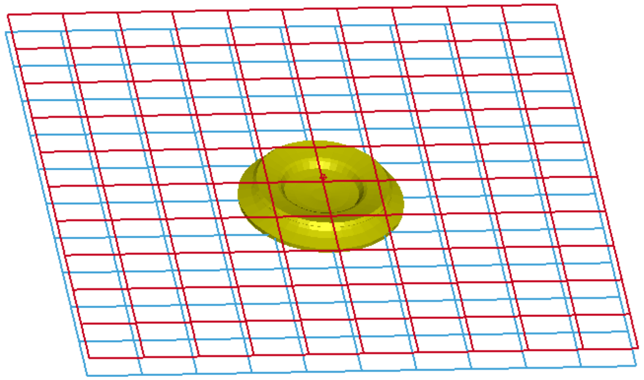


Introduction

- *CONSTRAINED_INTERPOLATION, redistributes load from a node to its surrounding nodes. This load can be a translational force or rotational moment. Often used to model interfaces.



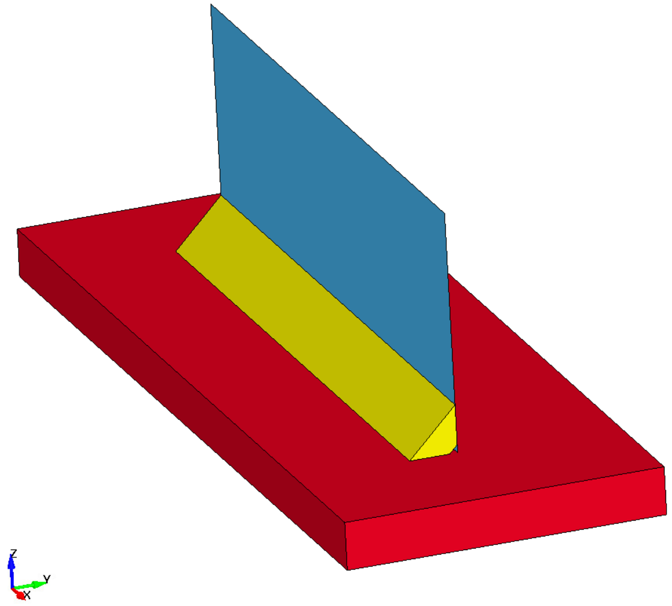
- *CONSTRAINED_SPR2, used to define self-piercing rivet with failure. Uses a plastic-like damage model with failure, defined by a node at the center of two sheets. Nodes in the sheets that lay inside a given diameter is projected and locked to the defined node. For solid nodes, this method does not transmit rotational DOFs.

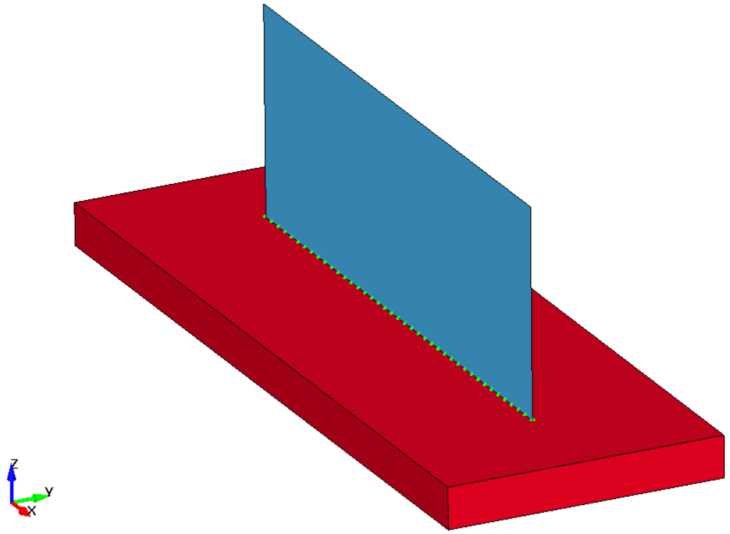


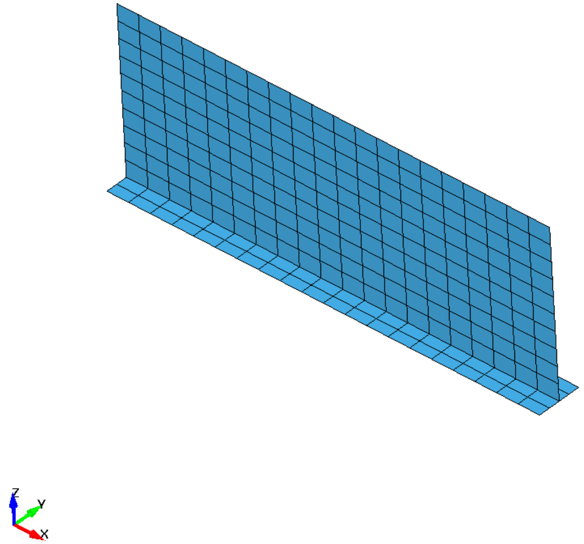
- None of these methods will be covered during this presentation

Introduction

- Three different methods will be presented here:
  - Modelling the joint using solid elements
  - By the *CONTACT_TIED_SHELL_EDGE_TO_SOLID contact
  - Finally using extra shell elements covering the solid element

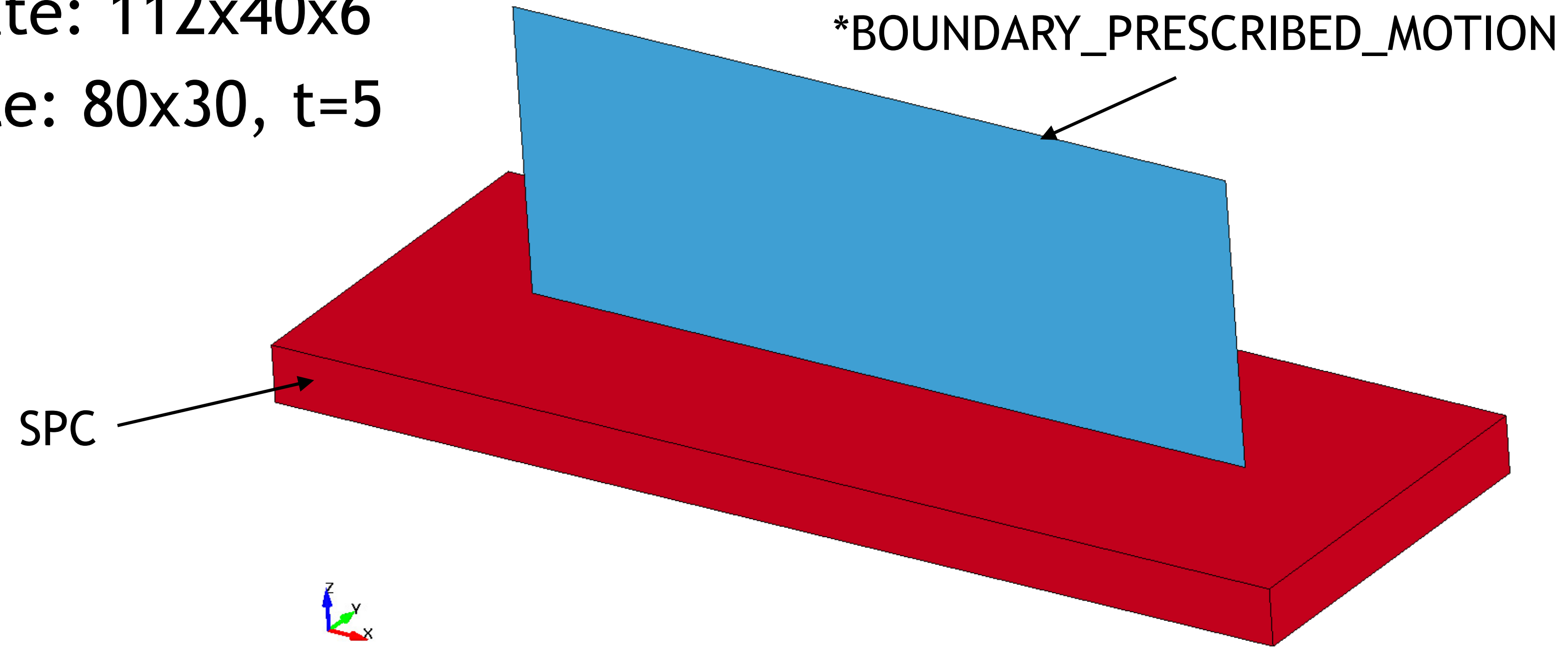






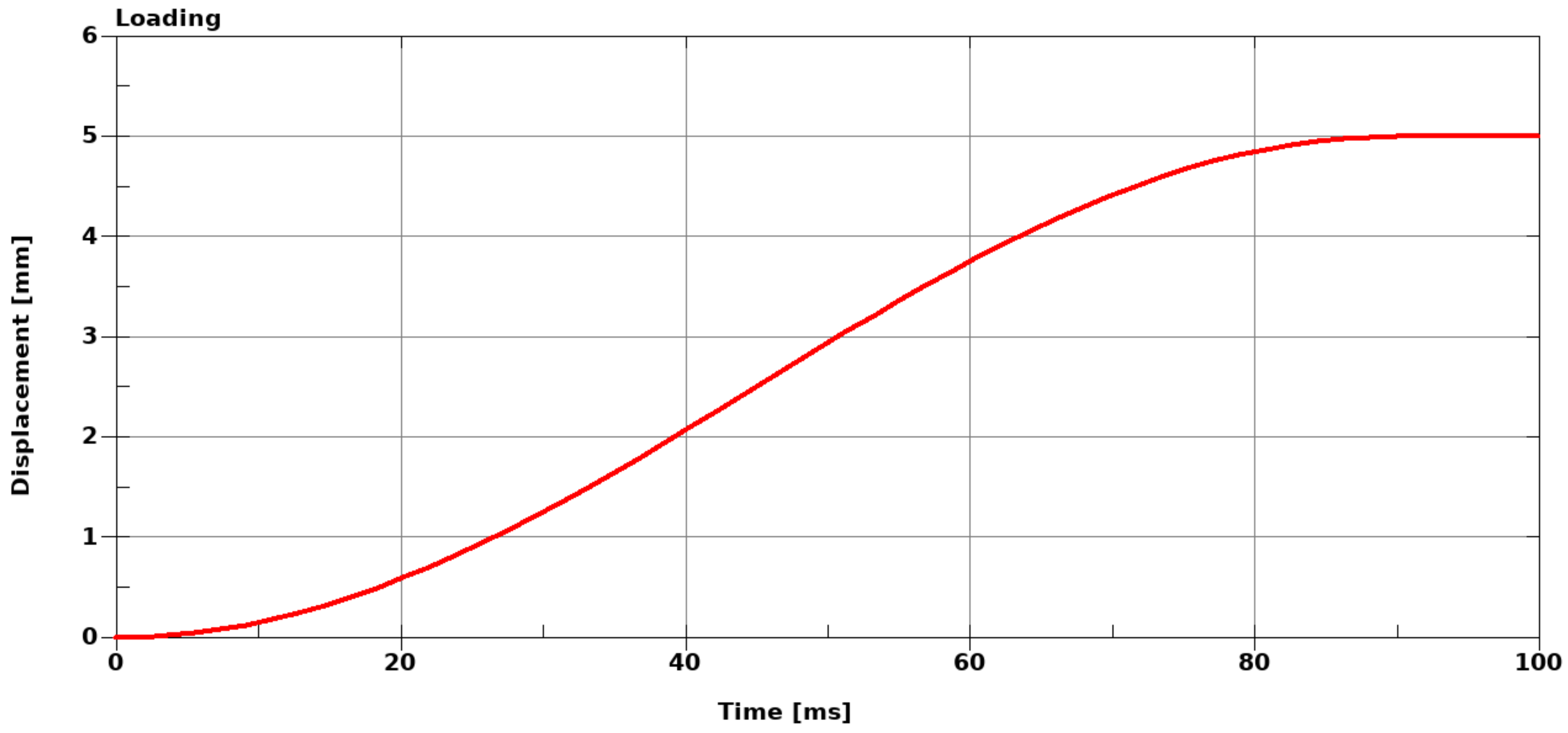
T-joint

- *BOUNDARY_PRESCRIBED_MOTION along the top nodes of the shell plate
- SPC fully constrained along the long sides of the solid
- Three different prescribed motions with the same magnitude of 5mm.
- In the x-direction, y-direction and z-direction.
- Dimensions of the solid plate: 112x40x6
- Dimension of the shell plate: 80x30, t=5



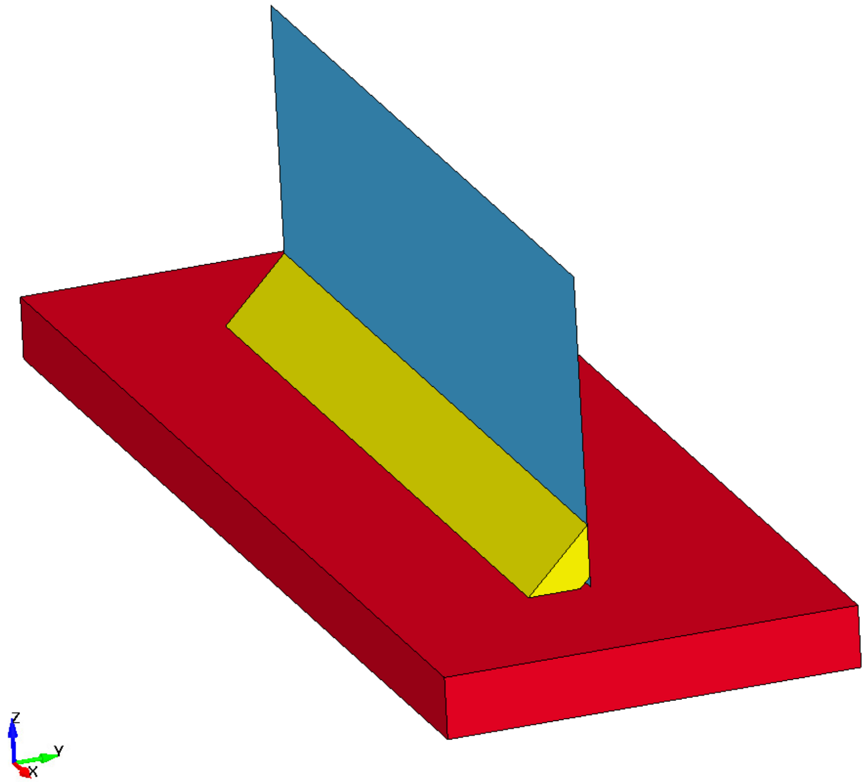
T-joint

- Loading curve used for the motion.



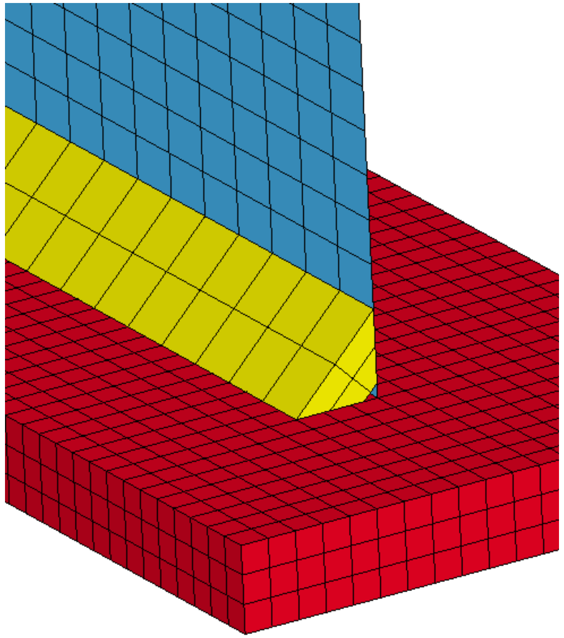
Solid joint

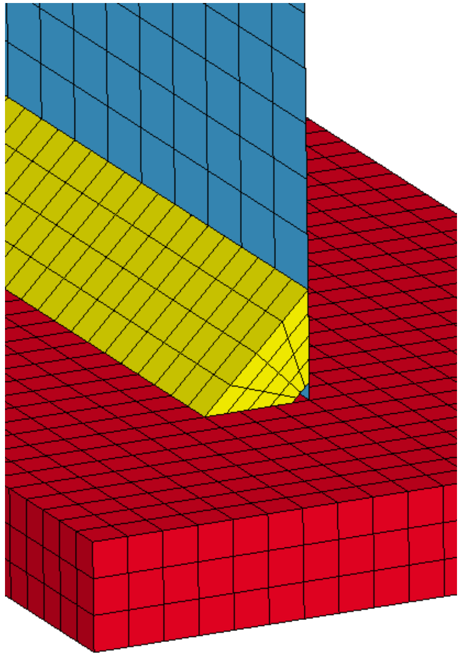
- Using a solid part to model a joint.
- *CONTACT_TIED_NODES_TO_SURFACE x2, for solid-joint and shell-joint tying.
- Slave: joint using segment set.
- Master: PID for solid and shell.
- *CONTACT_AUTOMATIC_SINGLE_SURFACE
  SOFT = 2, SHLEDG = 1 of
  part_set for shell and solid plate.
- ELFORM = 1 for solid – hourglass 6
- ELFORM = 2 for shell – hourglass 4
- 2mm solid elements
- 4x3mm shell elements



Solid joint

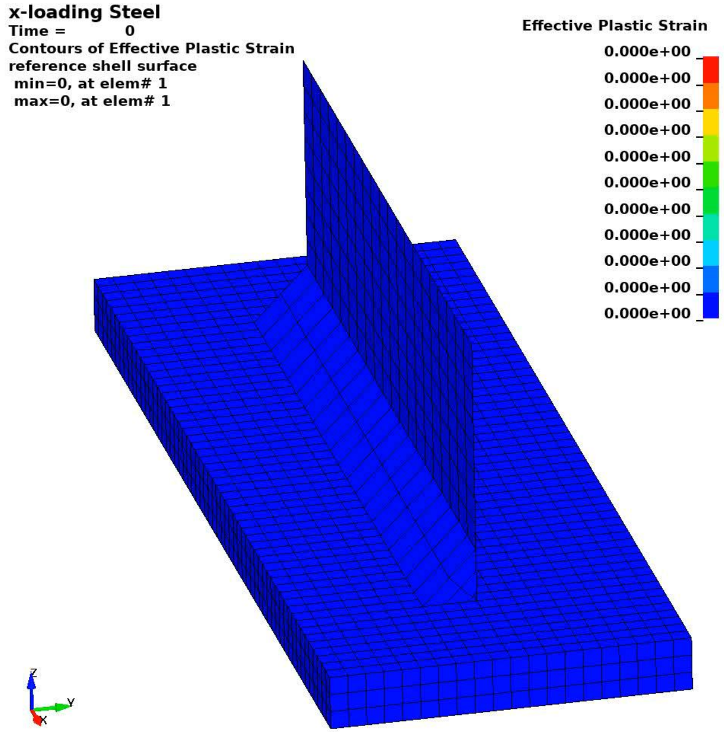
- Two different mesh sizes, one to match the shell element size, and one finer mesh were each joint element is split into 8 elements.
- The in-plate length of the joint is 5 mm.

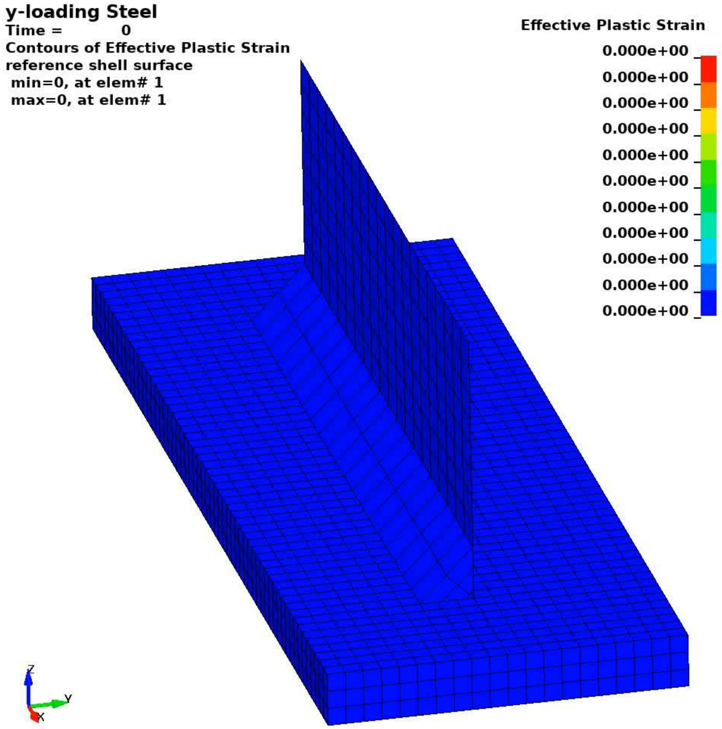


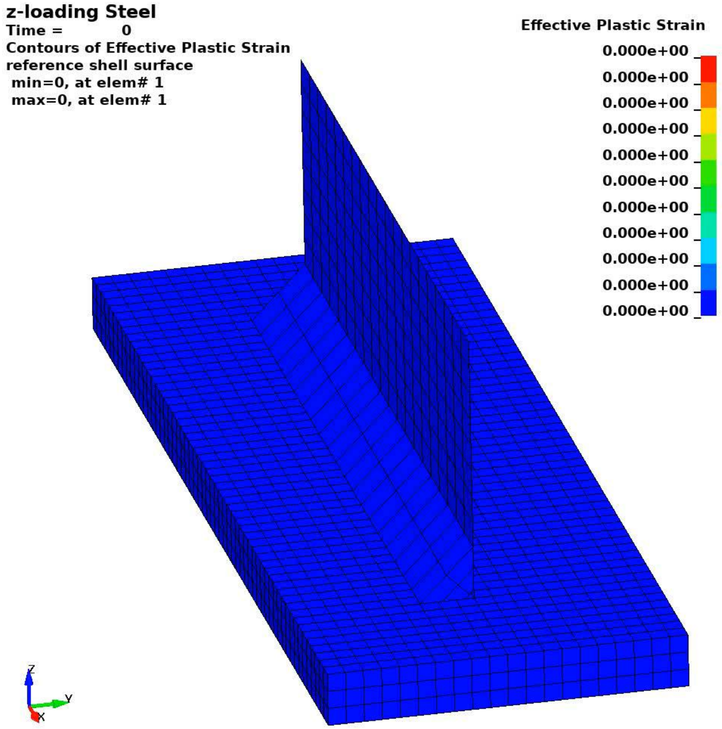


Results solid joint

- Results for the steel material

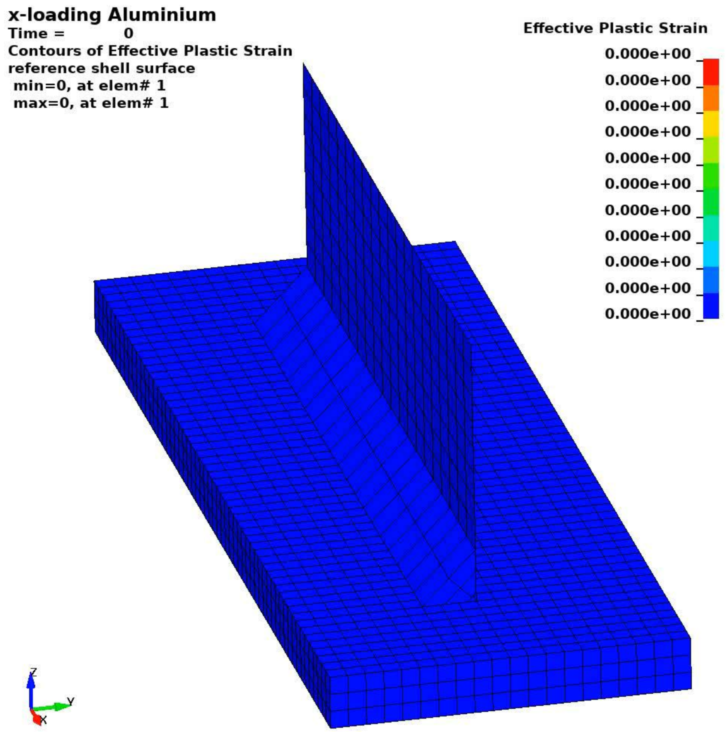


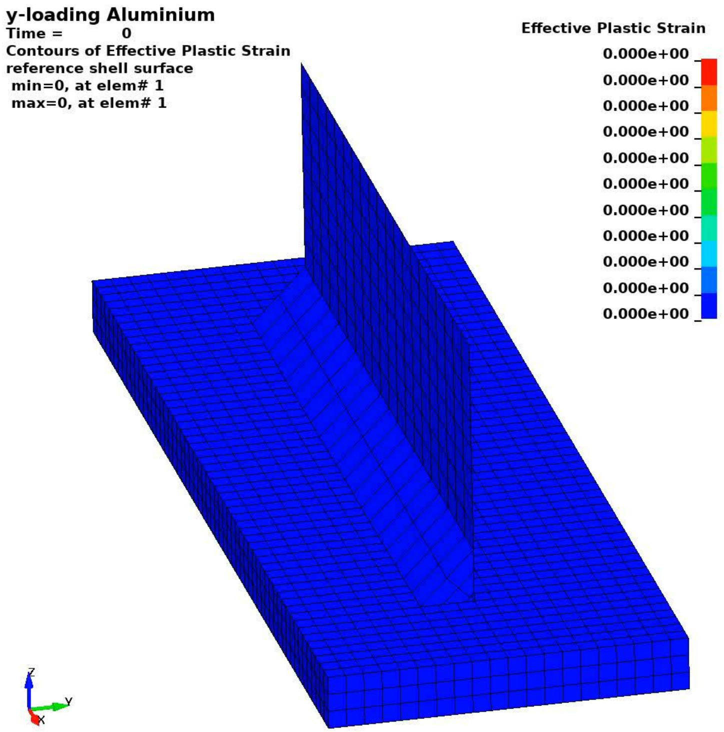


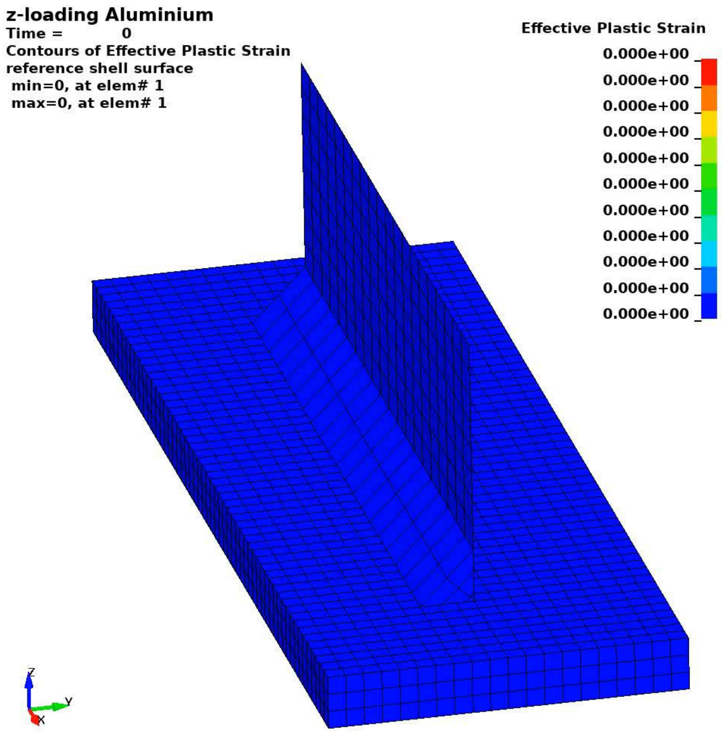


Results solid joint

- Results for the aluminium material

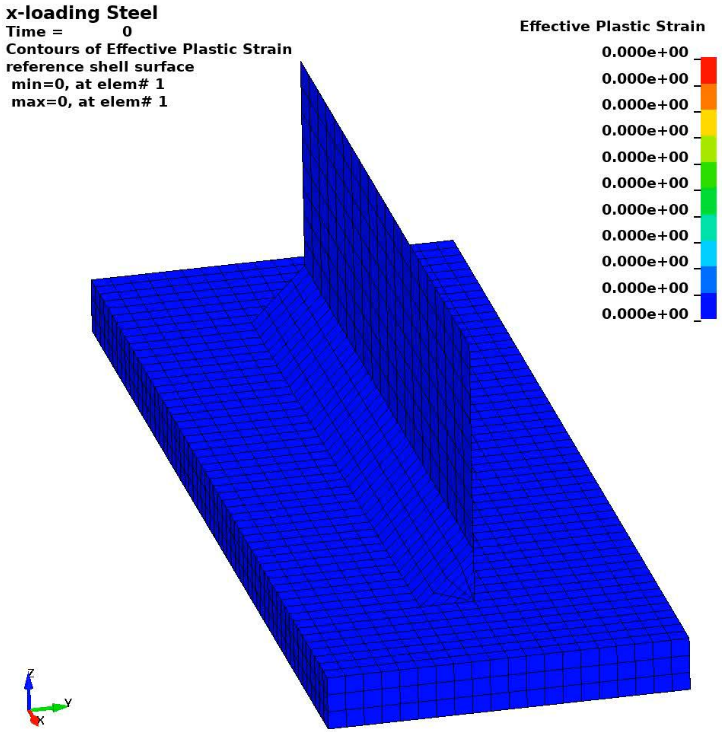


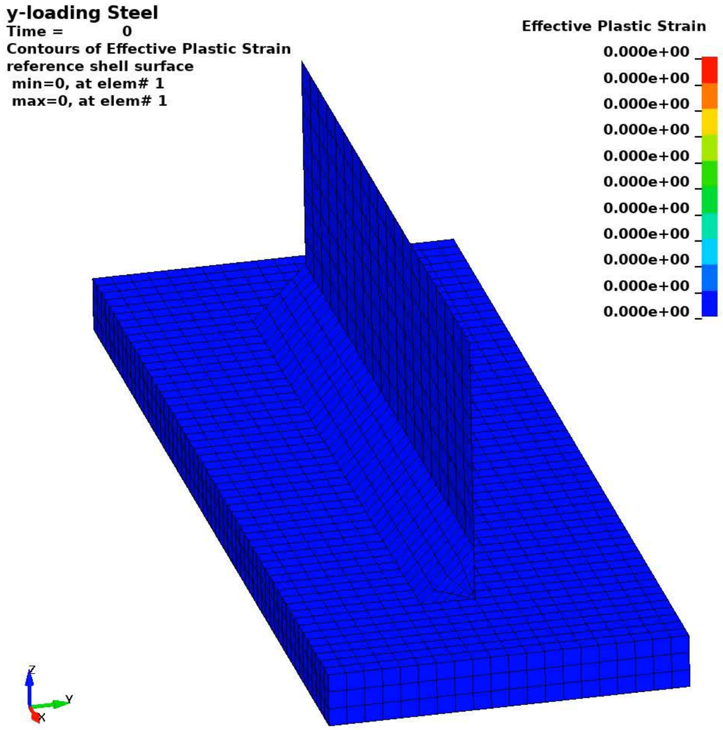


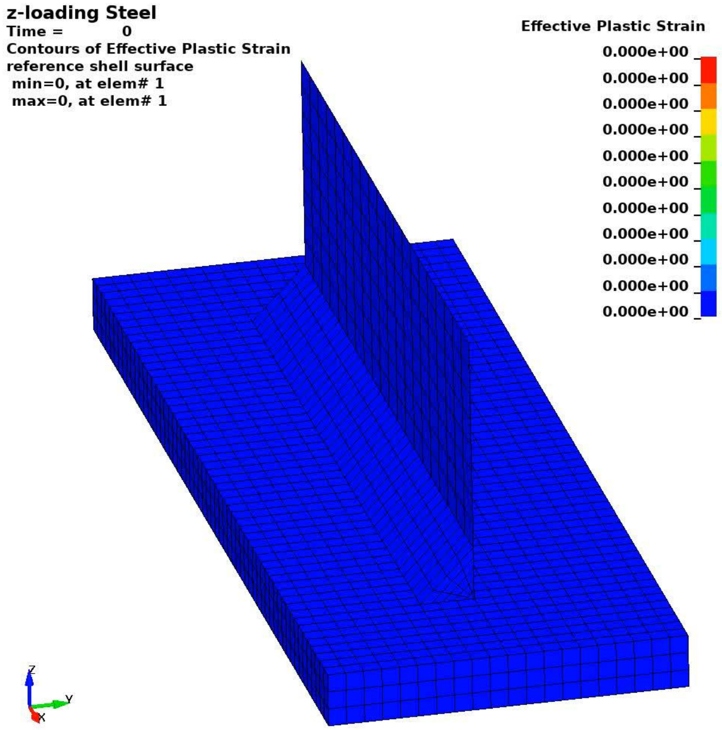


Results solid joint

- Results for the steel material

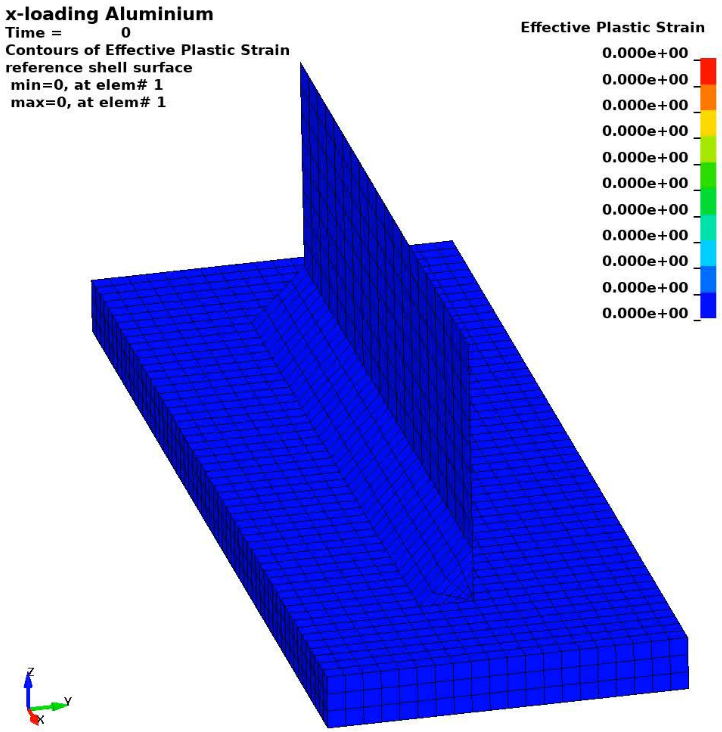


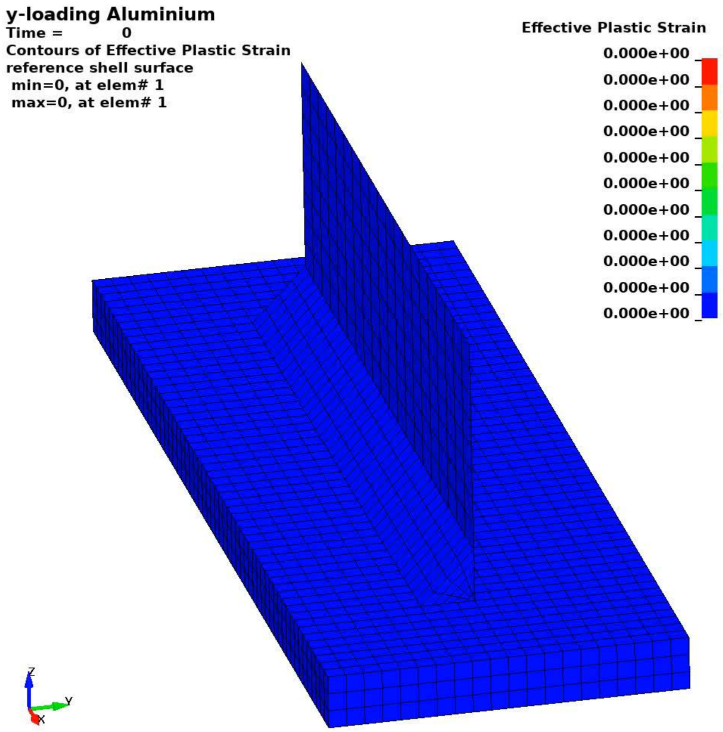


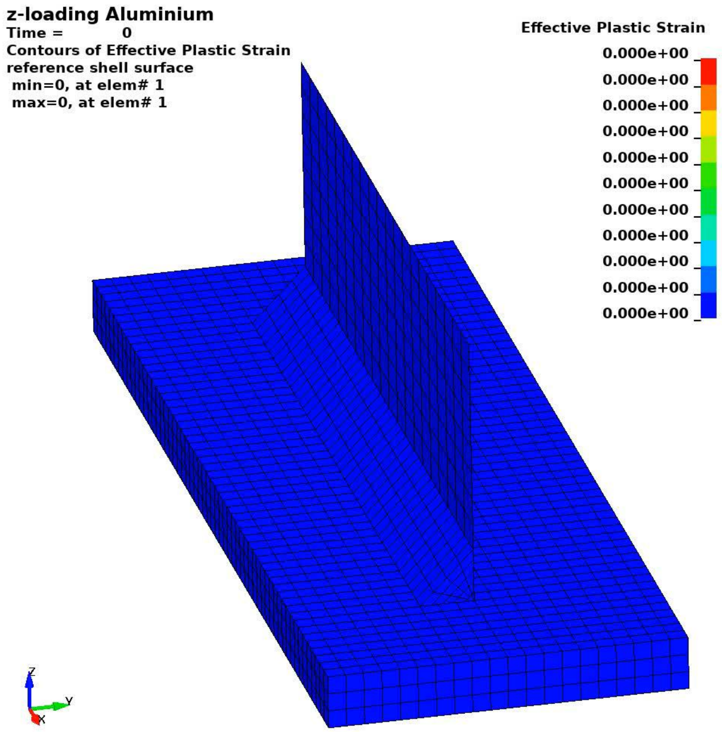


Results solid joint

- Results for the aluminium material

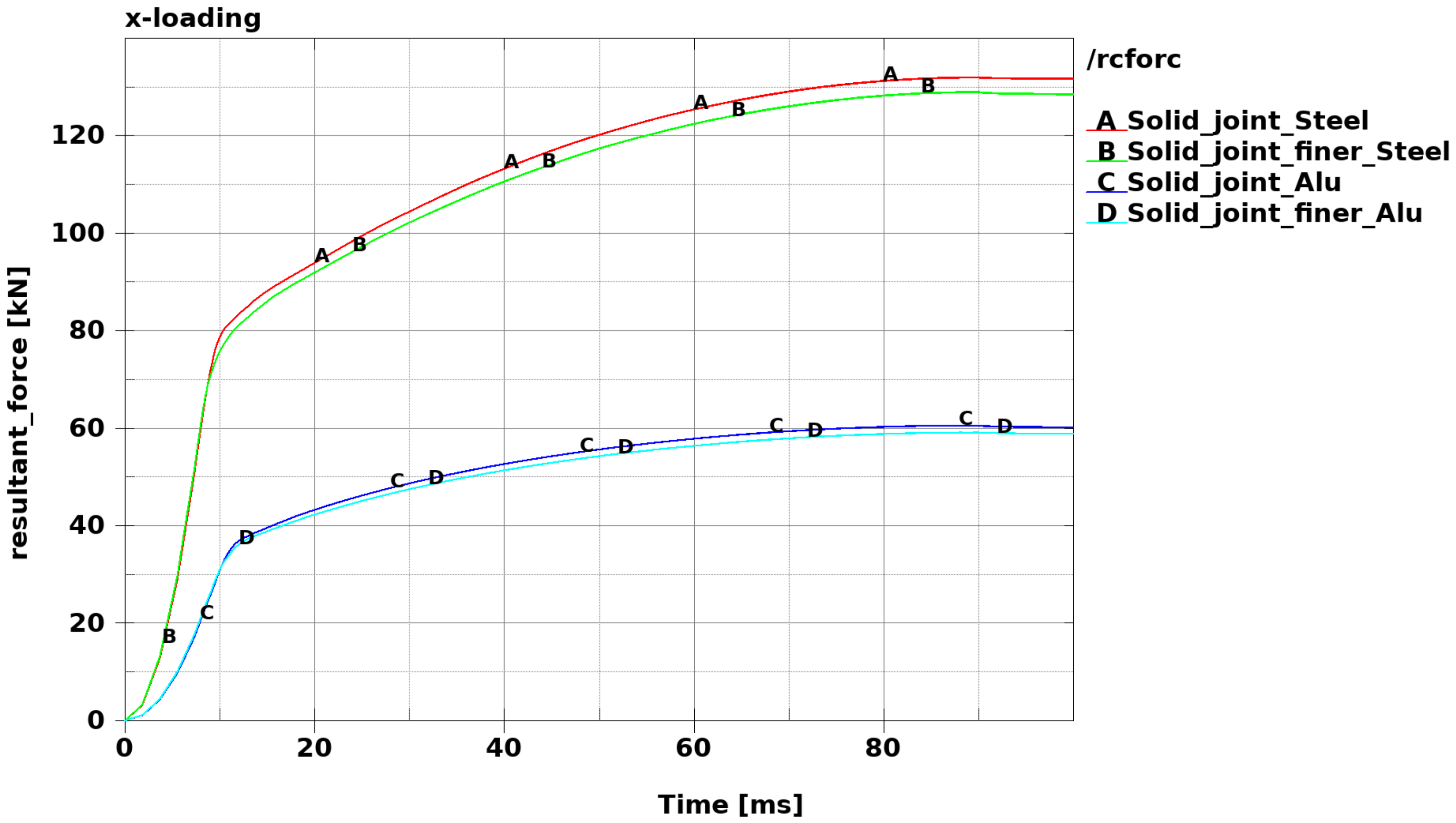






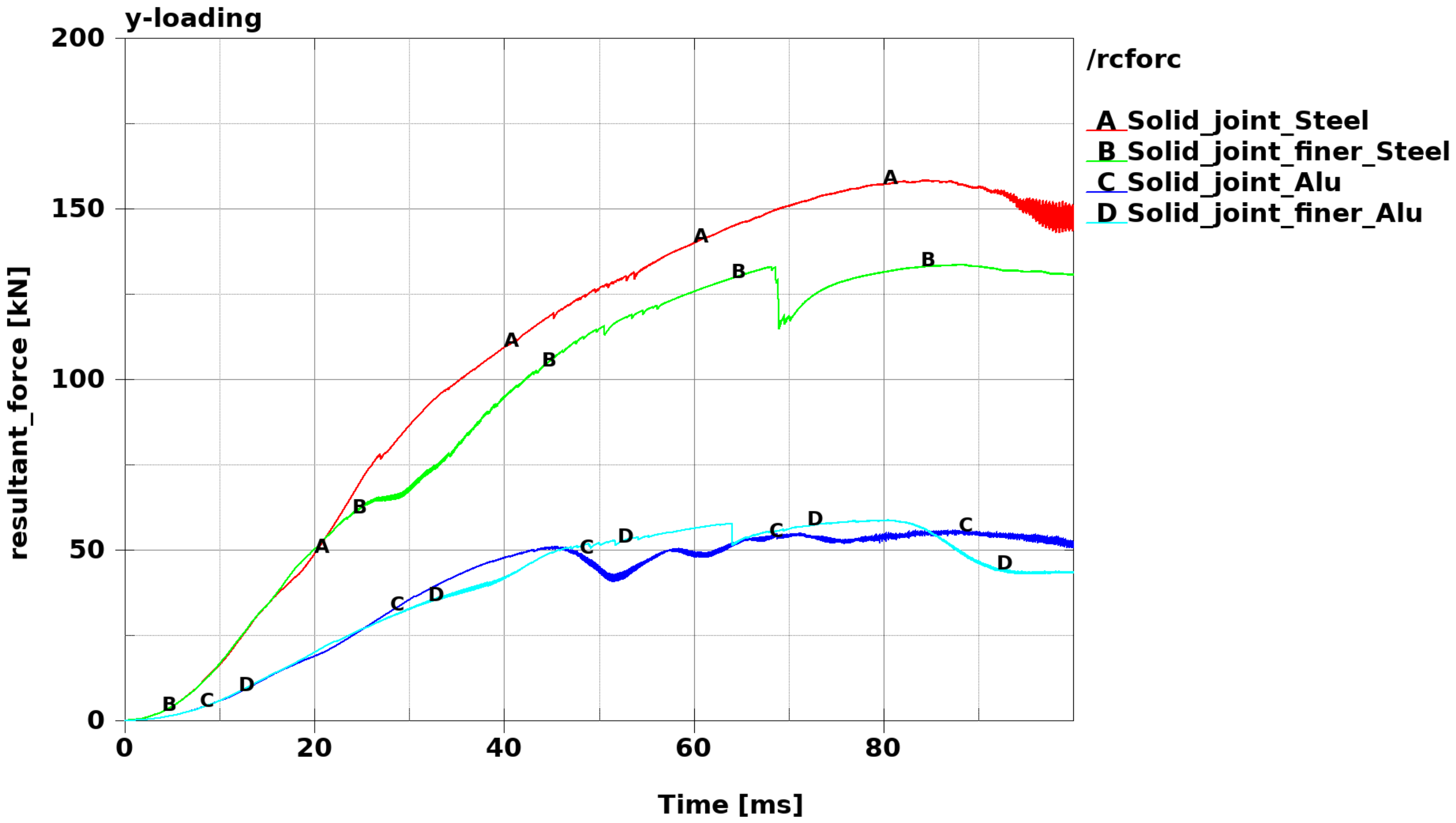
Results solid joint

- Similar behavior between the two mesh sizes.



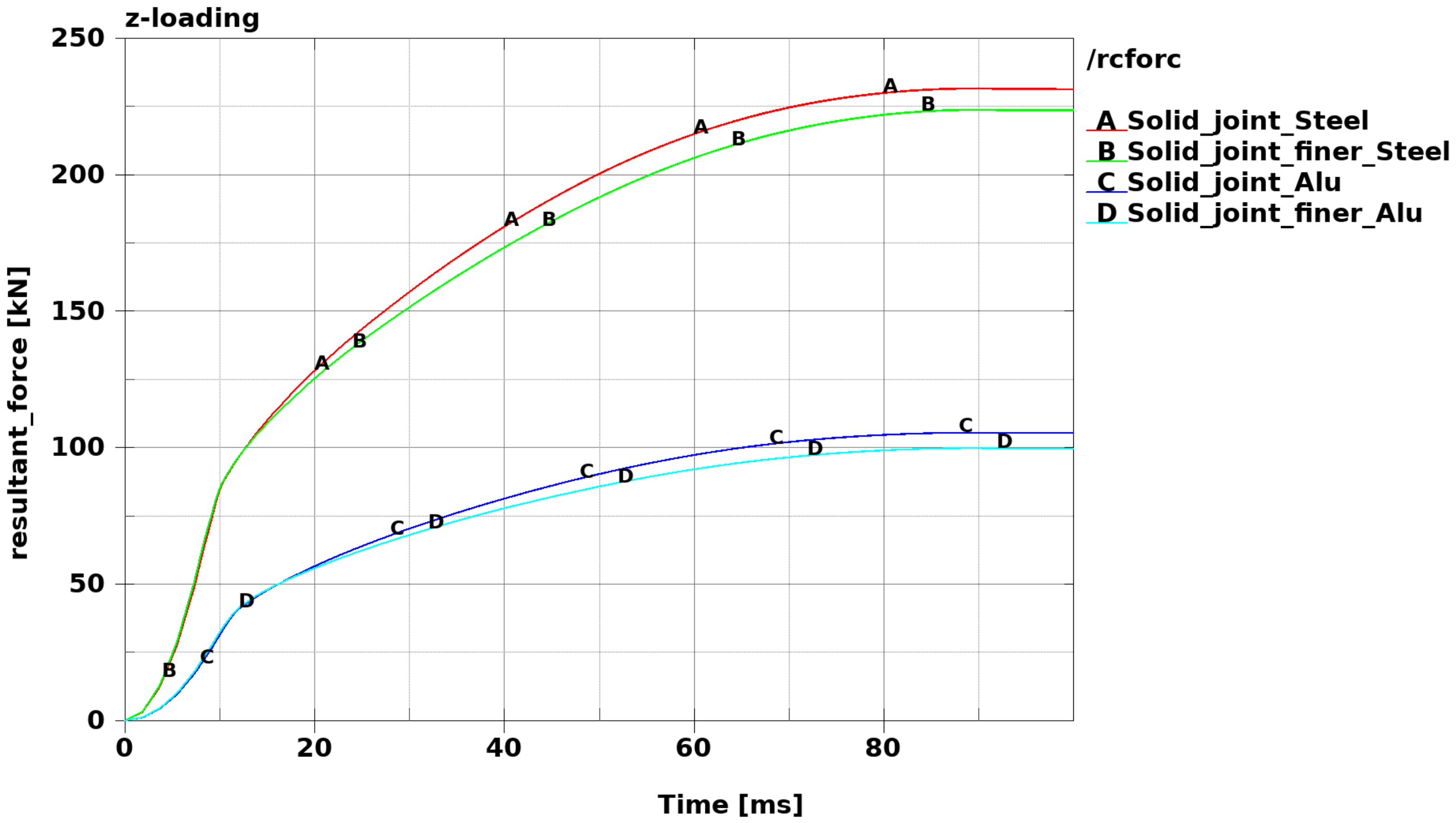
Results solid joint

- The drop in the finer curve comes from the single surface contact which has a square edge for the shell.



Results solid joint

- Similar behavior between the two mesh sizes.
- From now only the coarser mesh case will be used in comparison



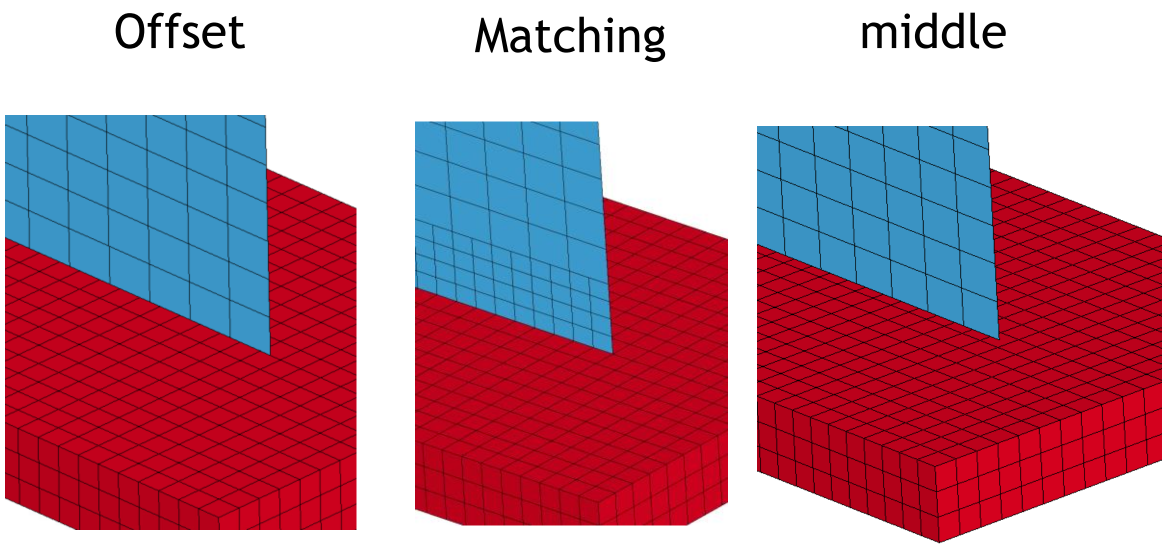
Summary solid joint

- Advantages of the solid joint method
  - Visibility, you can see visually see the joint for simpler pre- and post-processing
  - Should be simple to generate, for example by sweeping along a 3-D curve
  - Possibility to define different material data in the joint itself to better match test behavior
  - Intuitive, modelling of the actual physical joint

- Disadvantages of the solid joint method
  - Higher element count
  - Added complexity in terms of material data and calibration

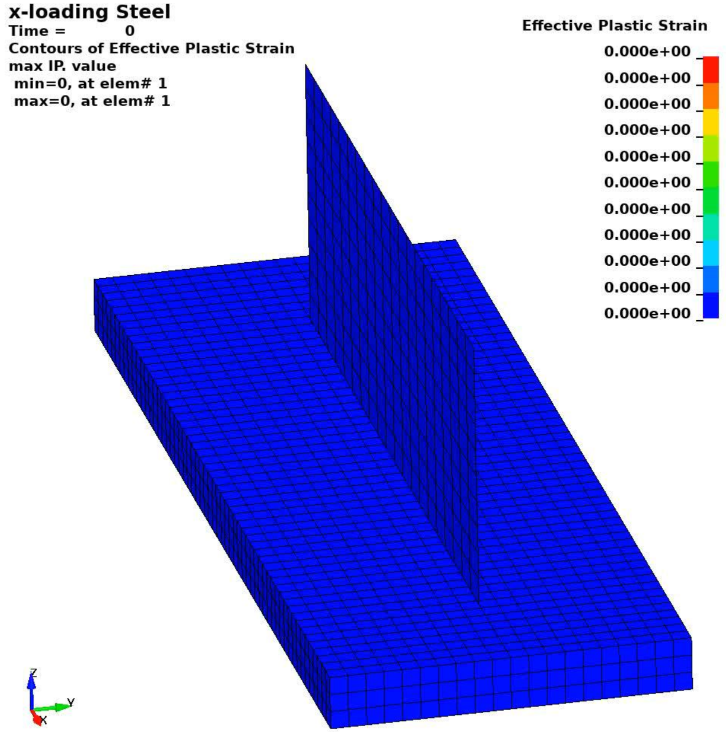
*CONTACT_TIED_SHELL_EDGE_TO_SOLID

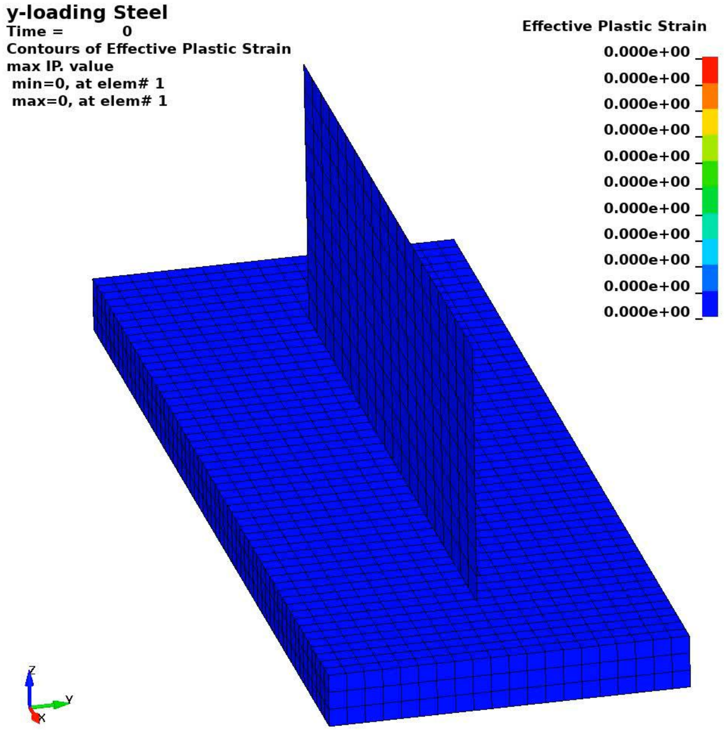
- ” TIED_SHELL_EDGE_TO_SOLID is intended for tying shell edges to solids or beam ends to solids, that is, situations where only the slave side nodes have rotational degrees-of-freedom.”
- Simple to setup, Node_set for the nodes at the bottom of the shell mesh which are to be tied, set as contact slave.
- Master: PID of the solid part.
- Three cases, one with a coarser shell mesh, with nodes offset in relation to the solid mesh, one with matching nodes and one with nodes located in the middle of the solid segment.

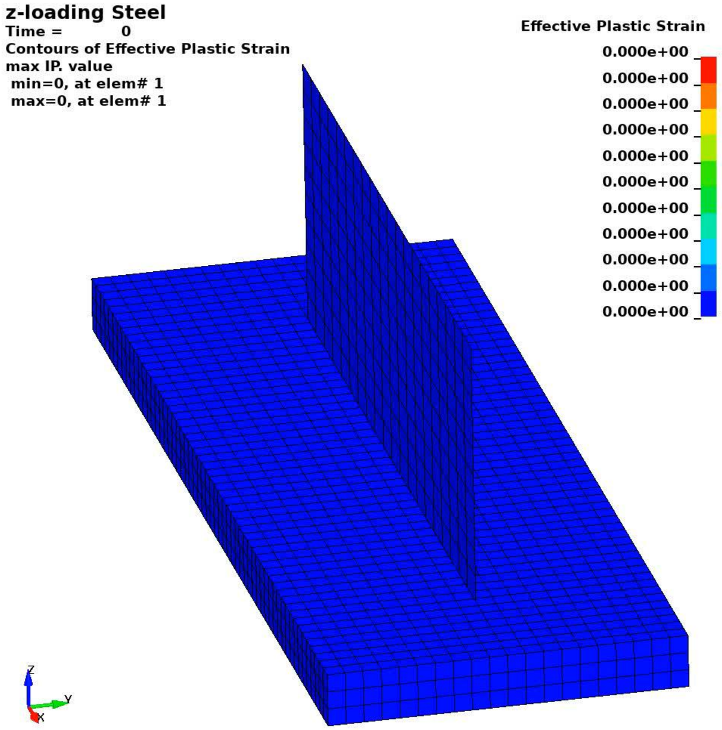


Results tied shell edge to solid offset

- Results for the steel material

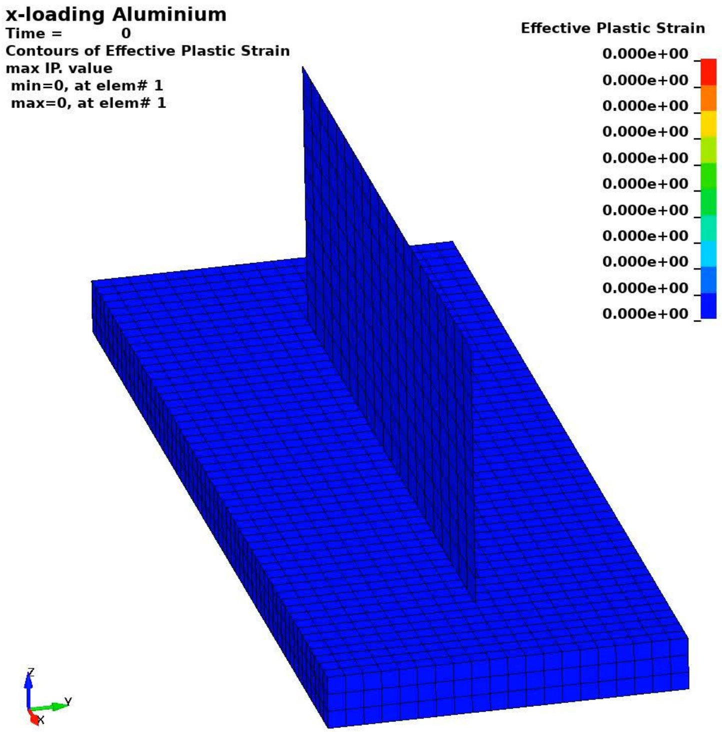


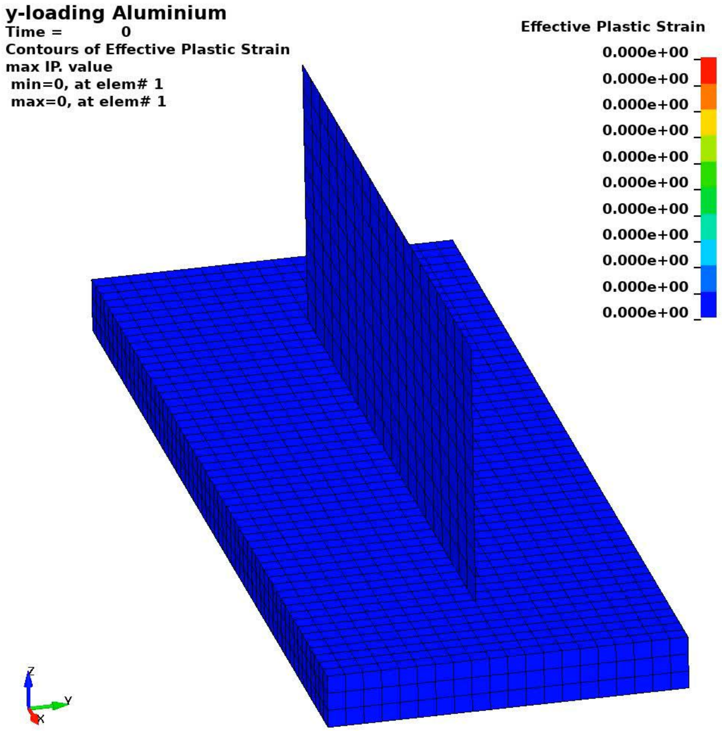


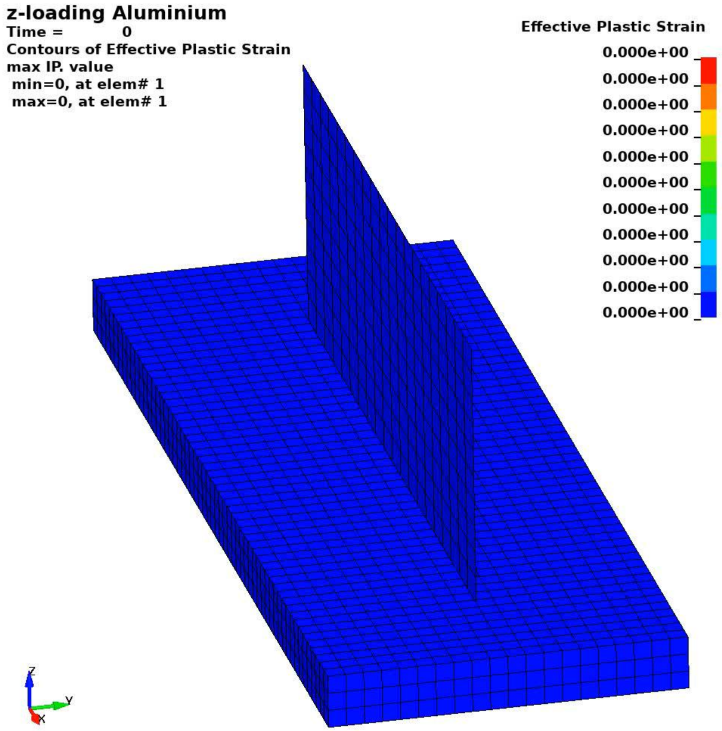


Results tied shell edge to solid offset

- Results for the aluminium material

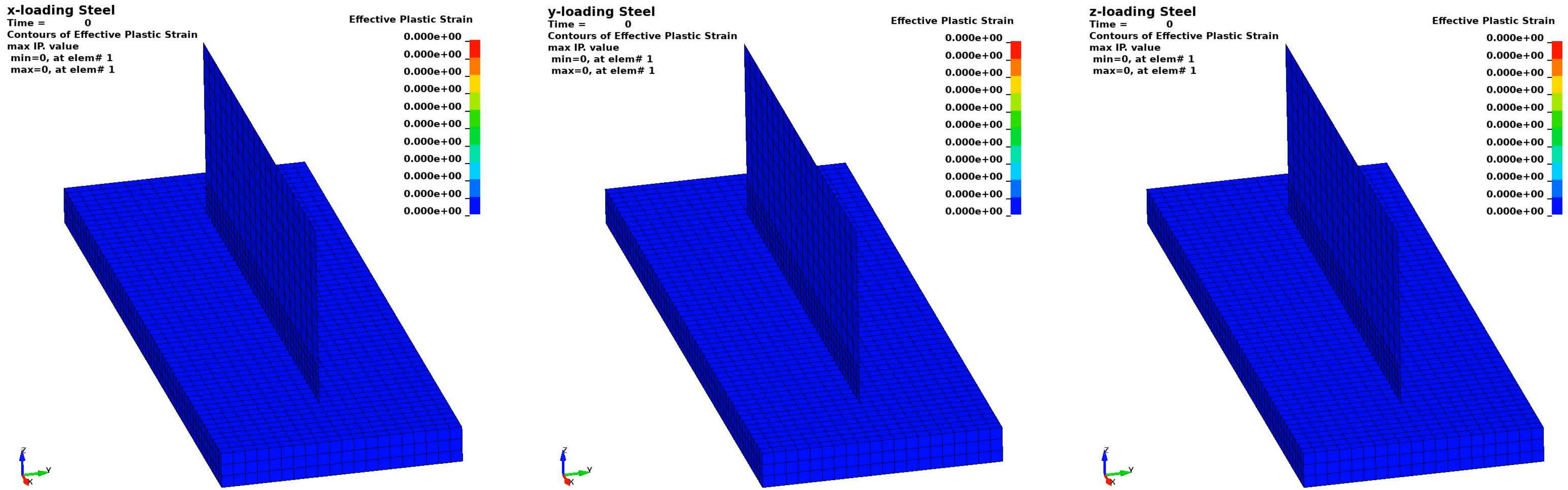






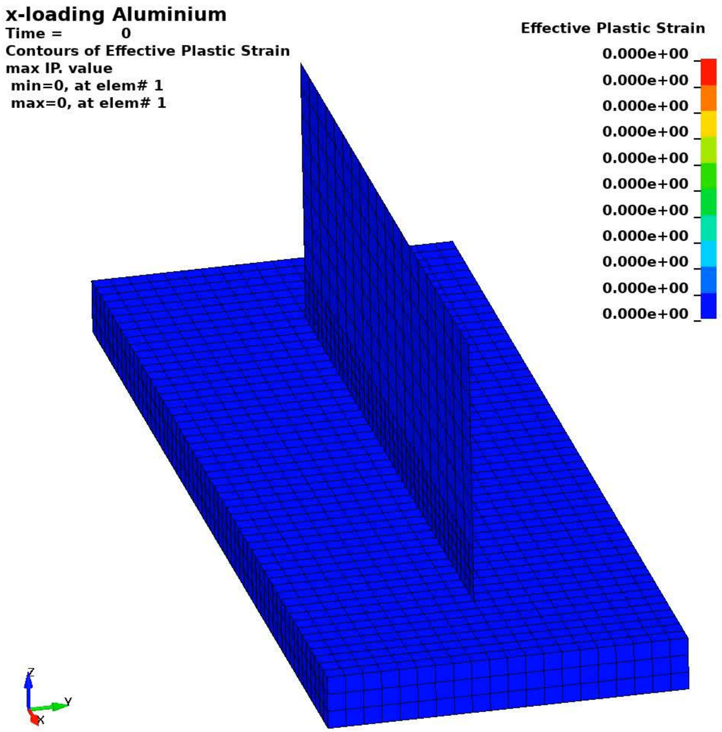
Results tied shell edge to solid matching

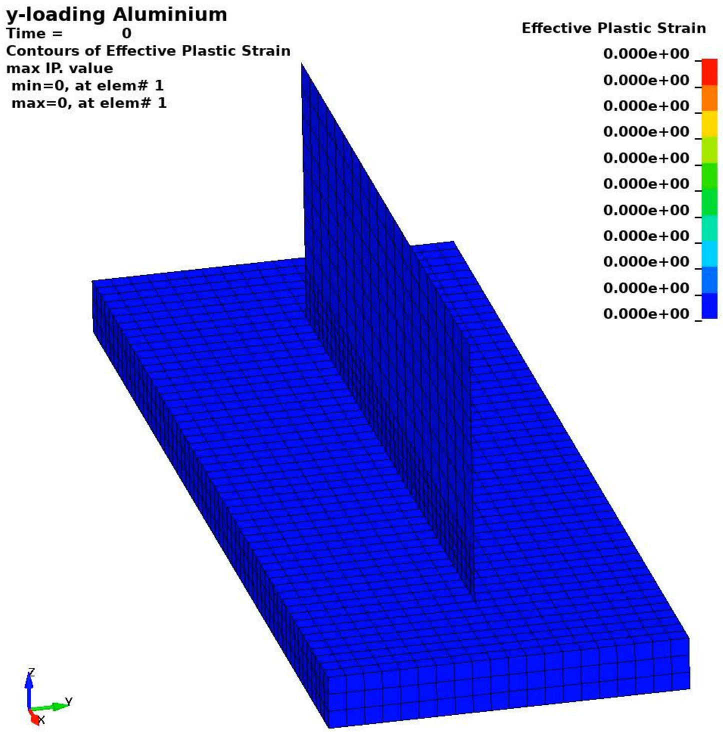
- Results for the steel material

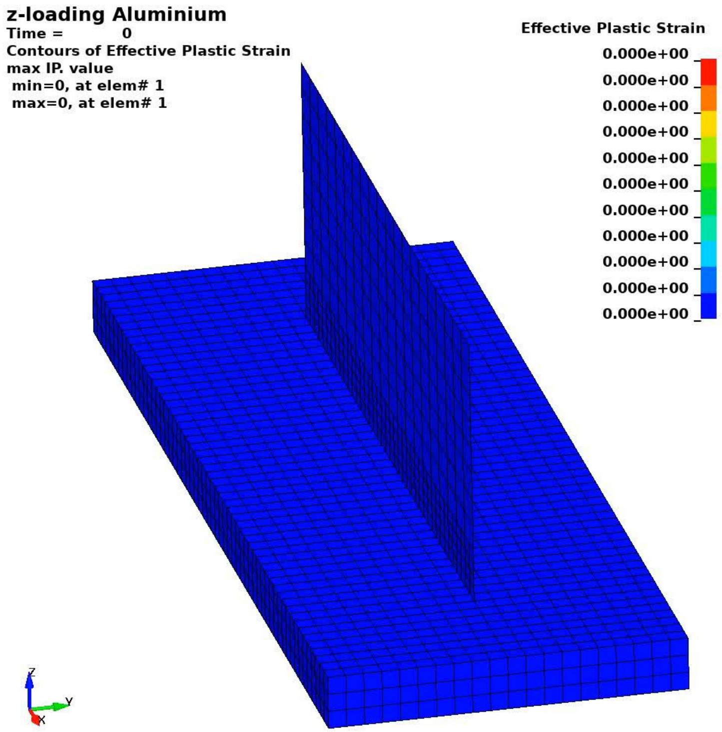


Results tied shell edge to solid matching

- Results for the aluminium material

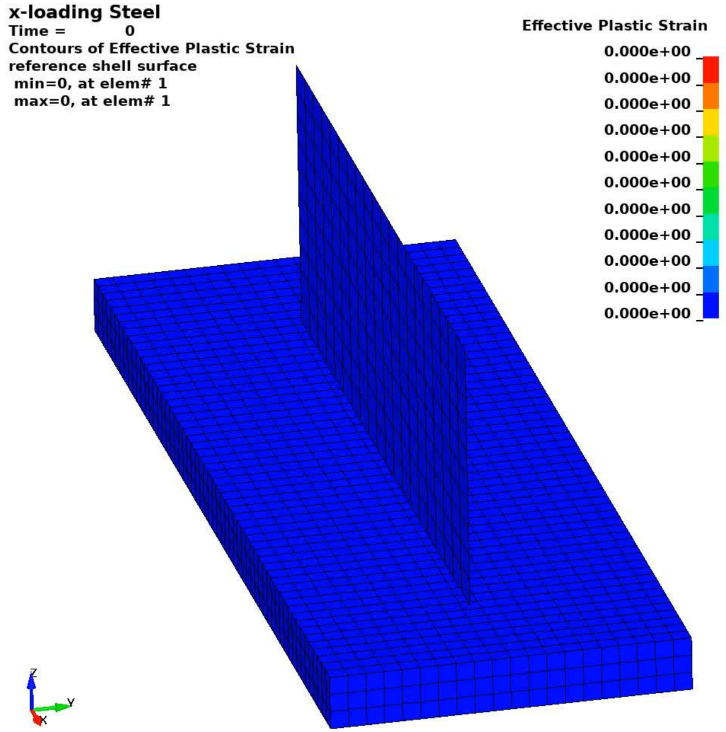


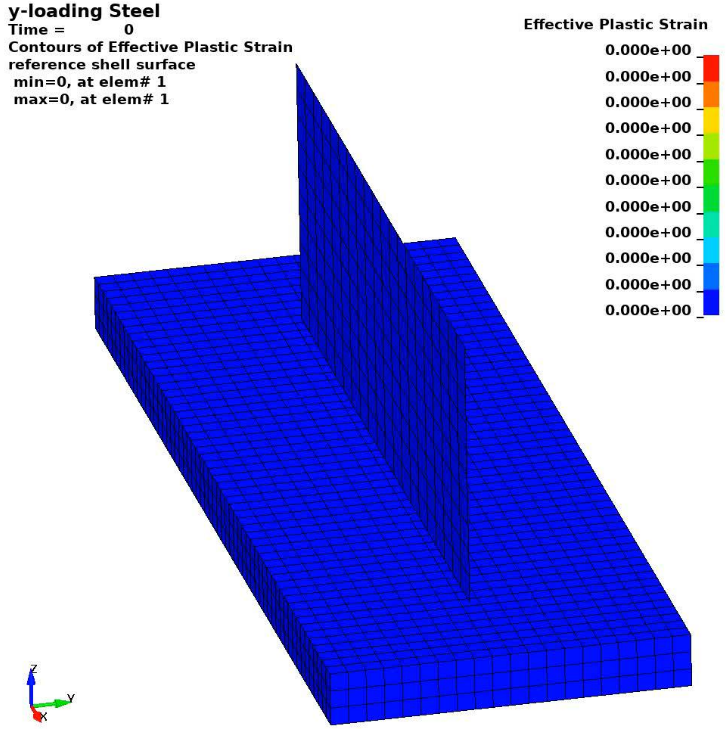


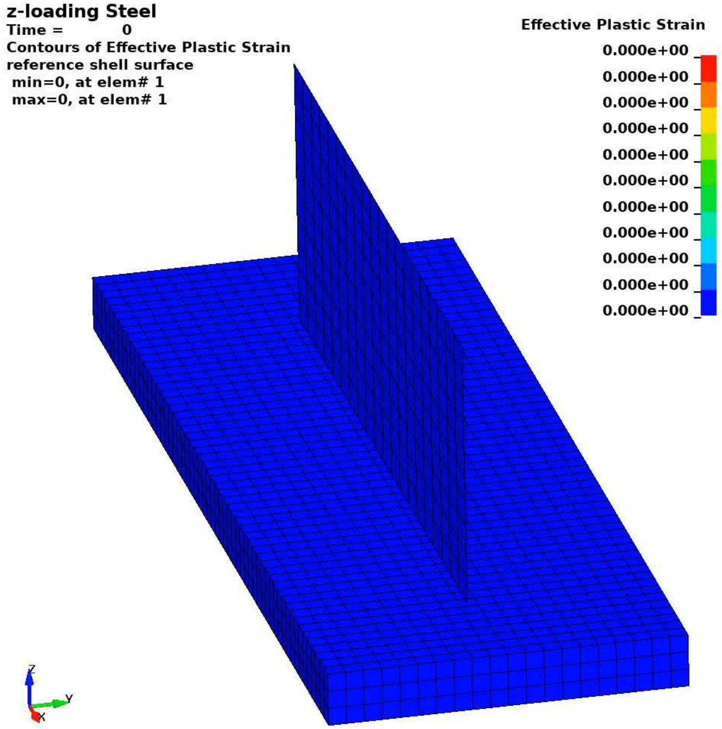


Results tied shell edge to solid middle

- Results for the steel material

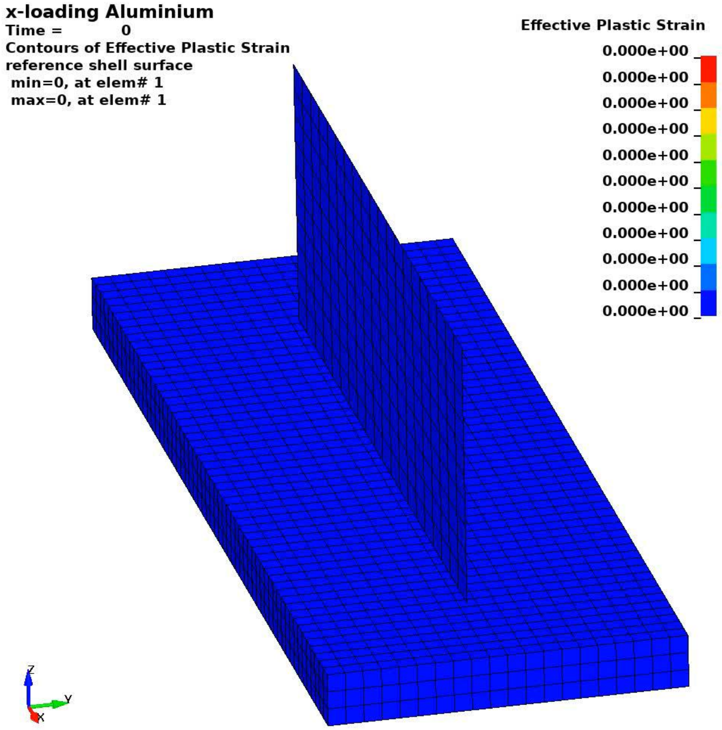


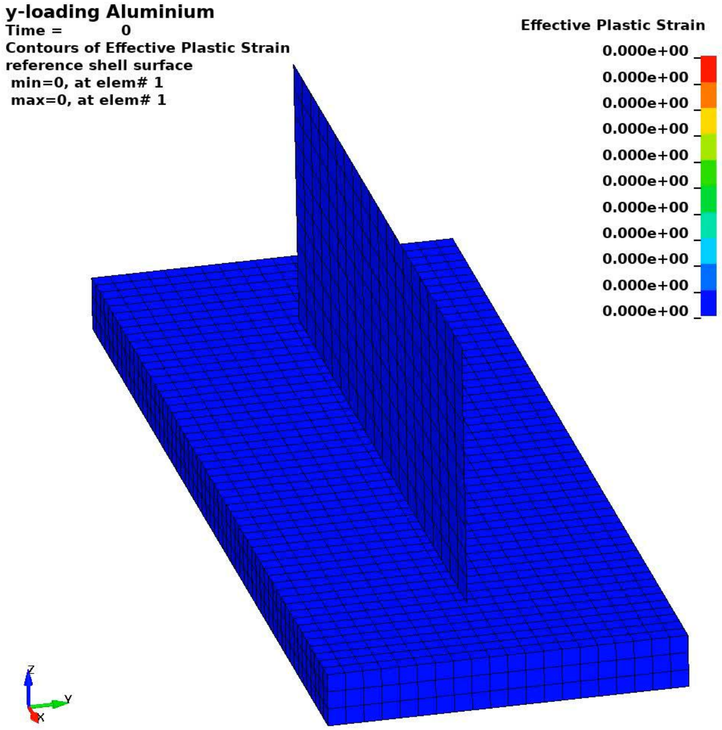


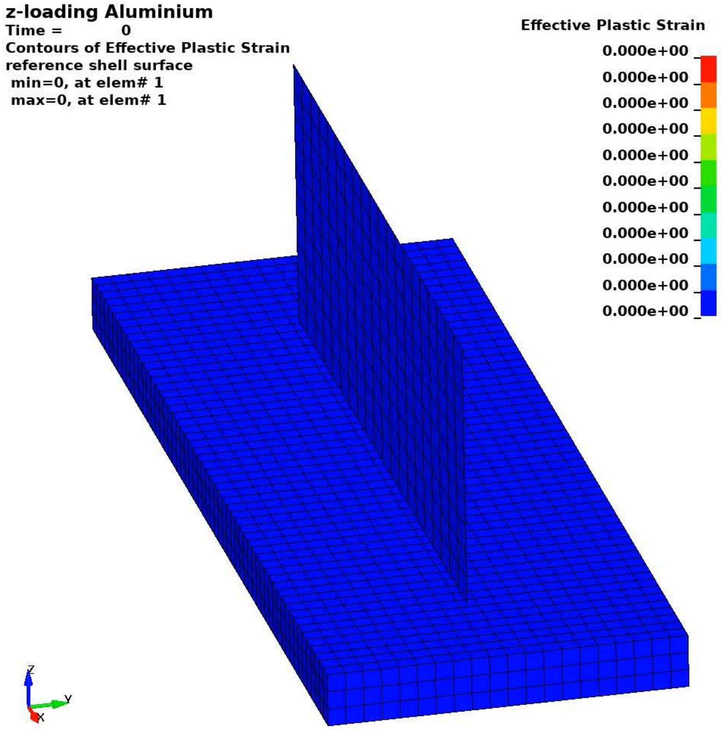


Results tied shell edge to solid middle

- Results for the aluminium material

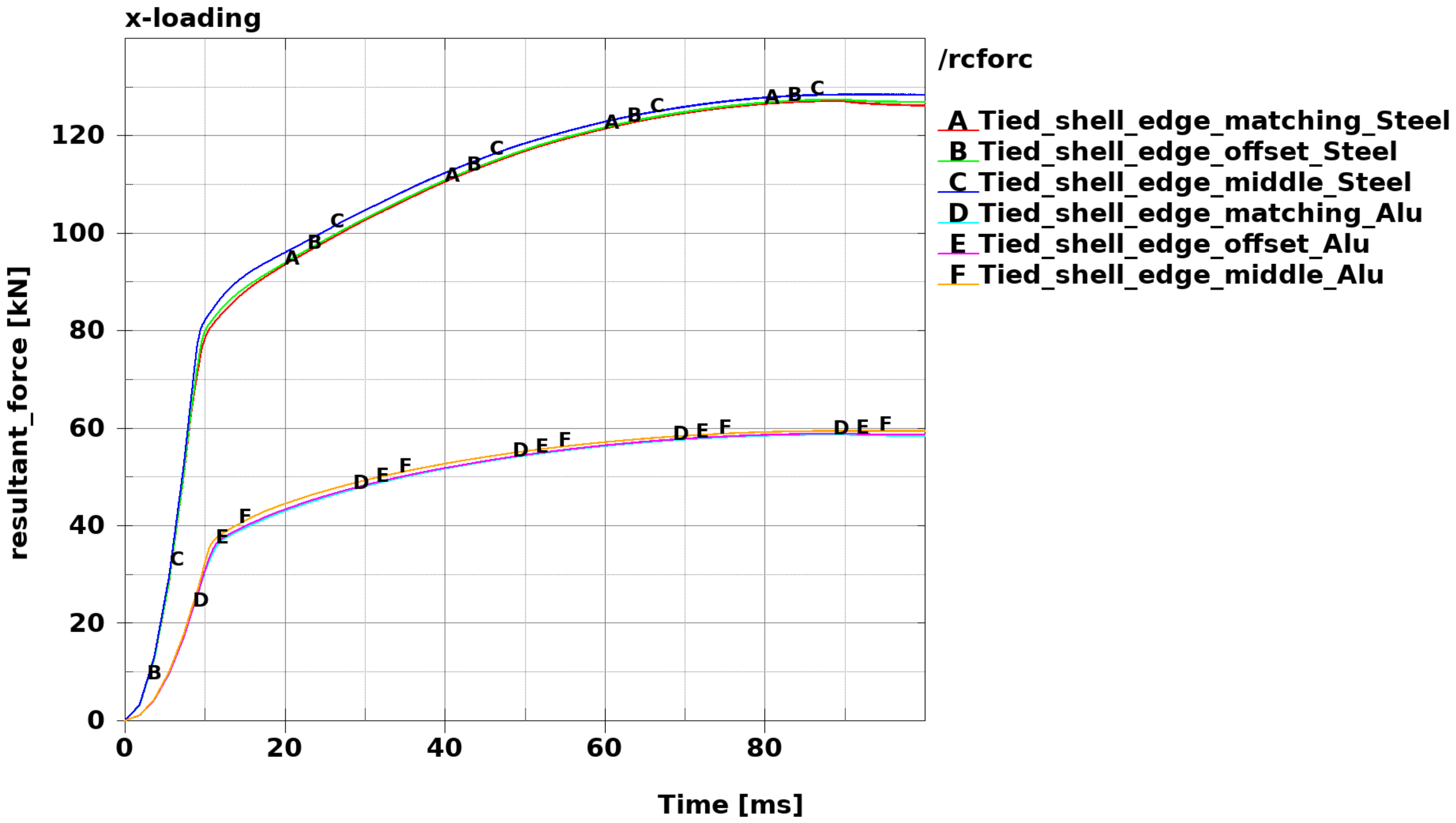






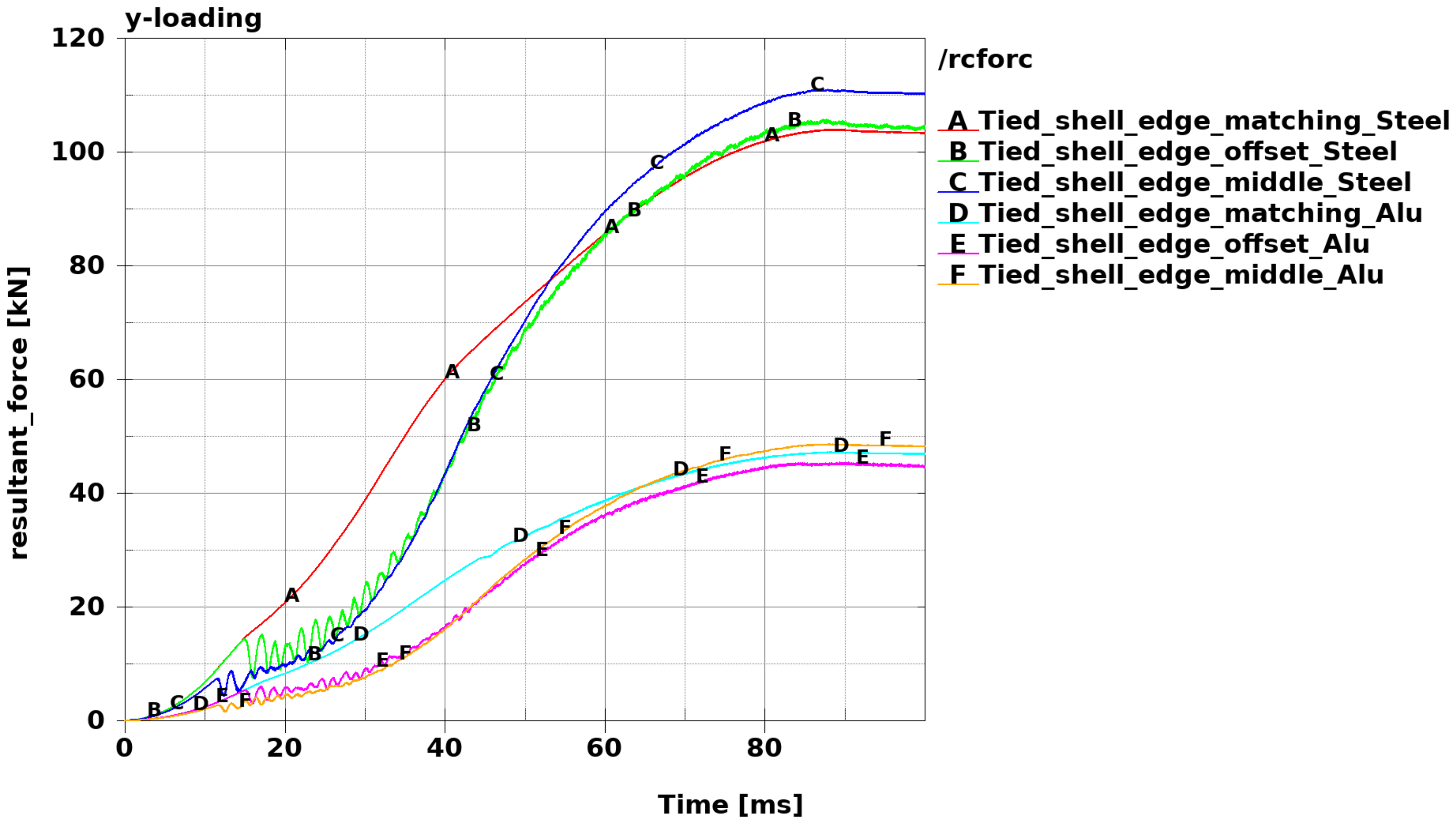
Results tied shell edge to solid

- No clear difference can be observed between the Three cases.



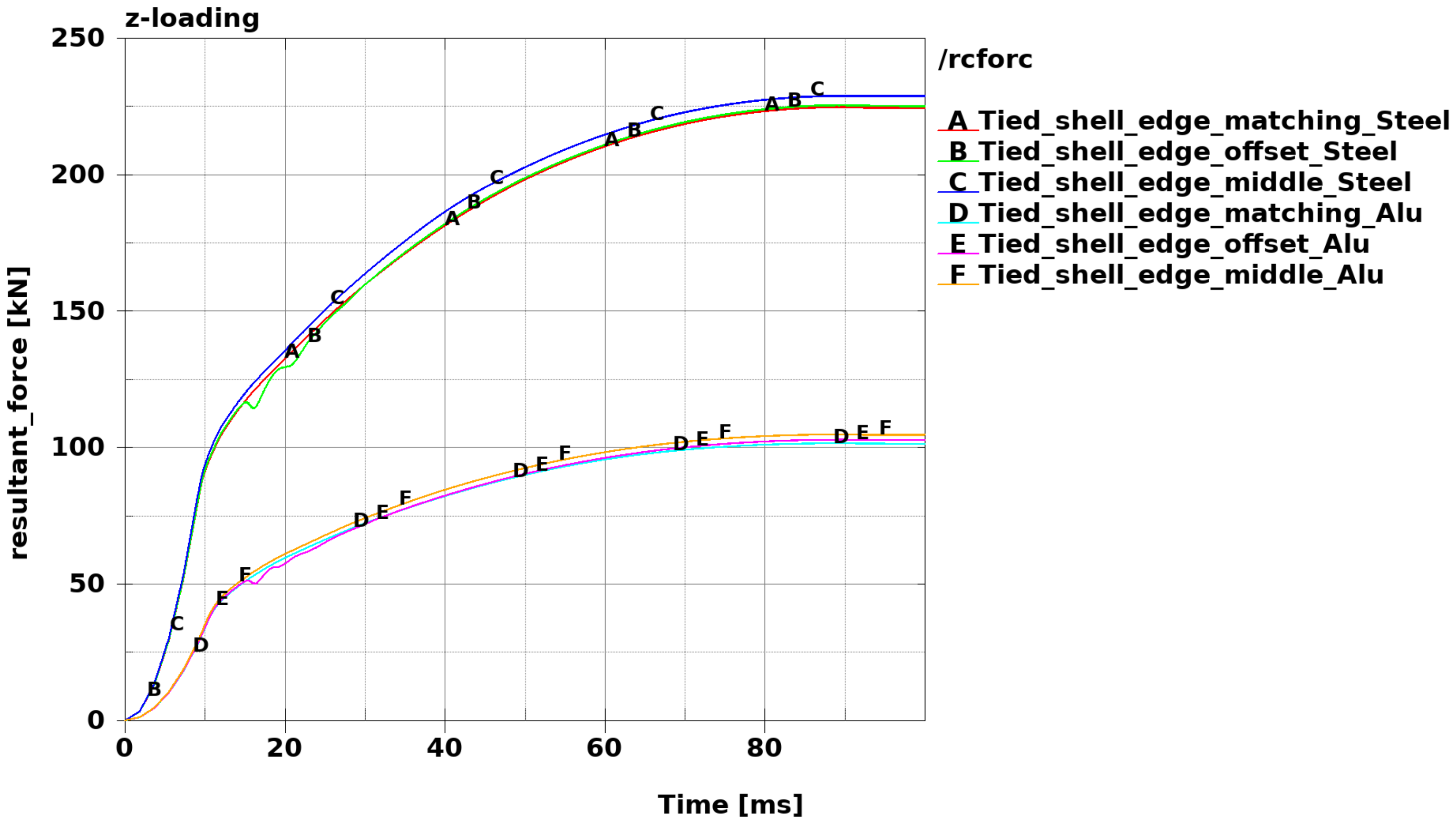
Results tied shell edge to solid

- Here a more oscillating behavior can be seen for the offset case. While the middle case does not oscillate as much but becomes slightly stiffer for the steel material.



Results tied shell edge to solid

- Some oscillations for the offset case, but very similar.
- From now only the case with matching nodes will be used in comparison



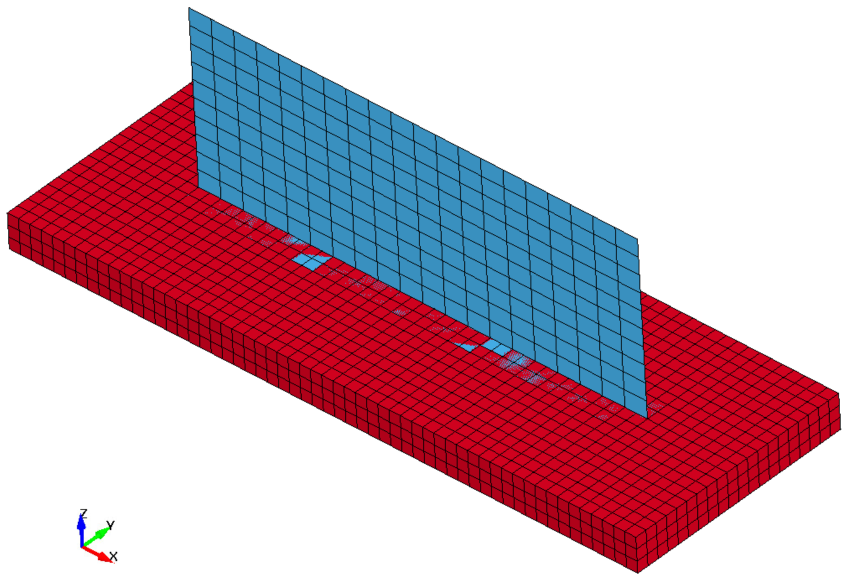
Summary tied shell edge to solid

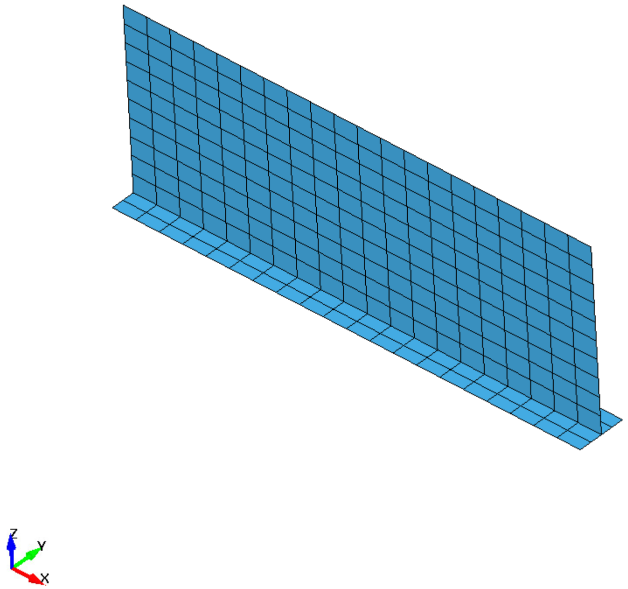
- Advantages of the shell edge to solid method
  - Simplicity, it is simple to setup the analysis by just adding the contact
  - Does not require additional elements

- Disadvantages of the shell edge to solid method
  - No visible additional parts adds a higher level of complexity regarding postprocessing
  - Not that much flexibility in terms of material and such to fit behavior against test
  - Some dependency of slave node placement on master segment

T shaped shell to solid

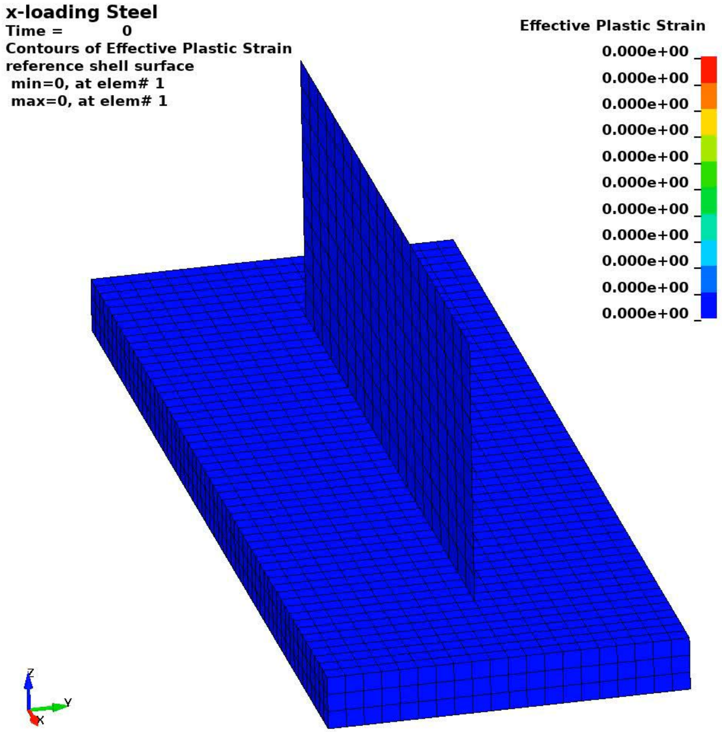
- Joining by creating a t-joint shaped shell mesh which is tied to the solid.
- Distributes so not only one line of nodes in the solid part is tied.
- *CONTACT_TIED_NODES_TO_SURFACE
  - Two segments, the bottom of the shell part as slave and top of solid as master.

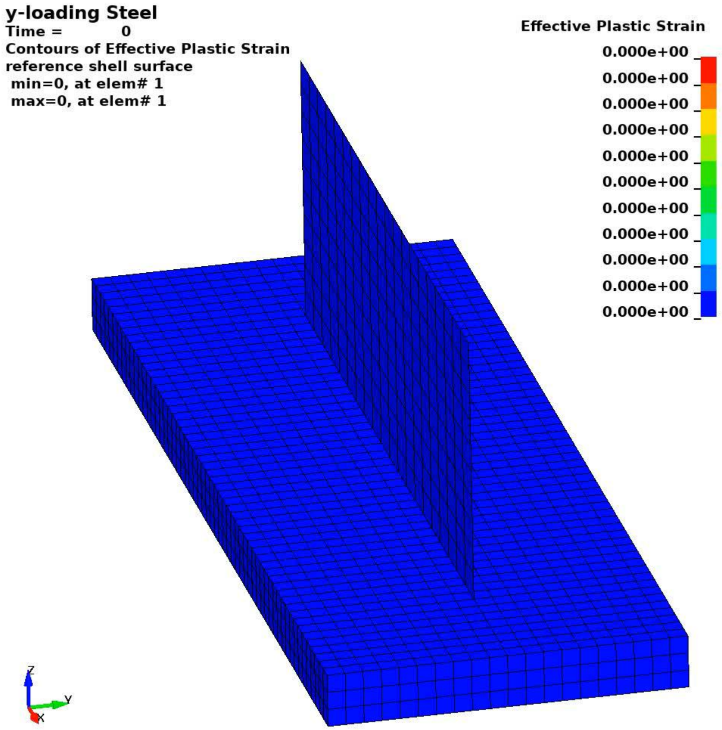


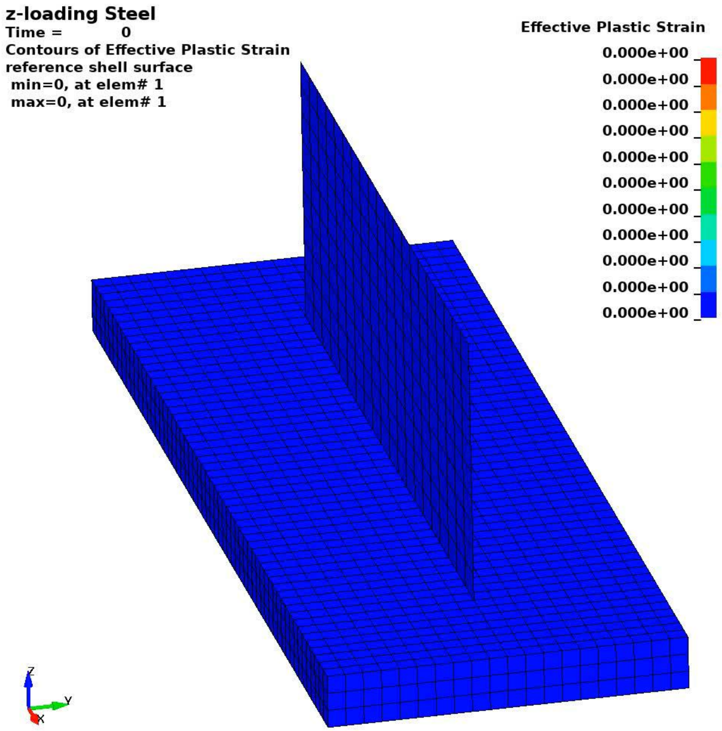


Results T shaped shell to solid

- Results for the steel material

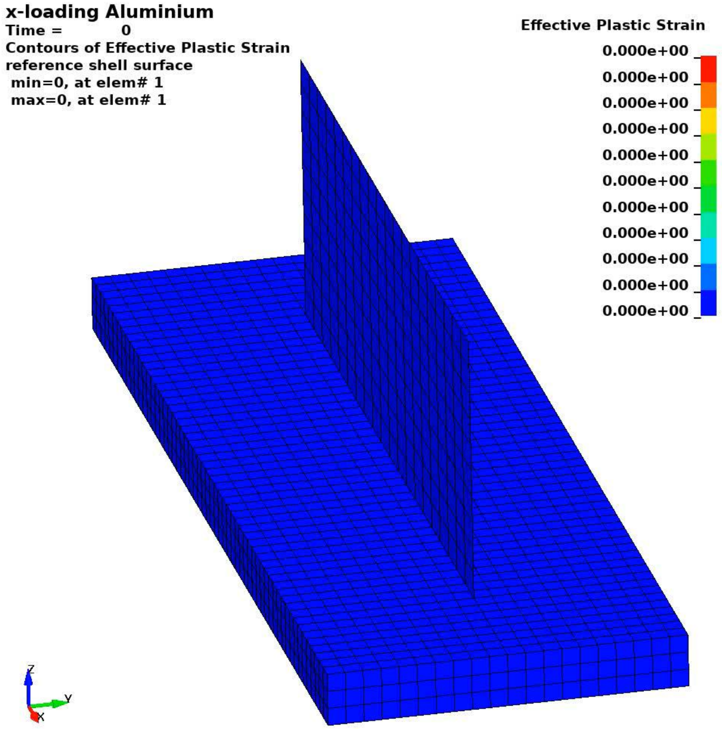


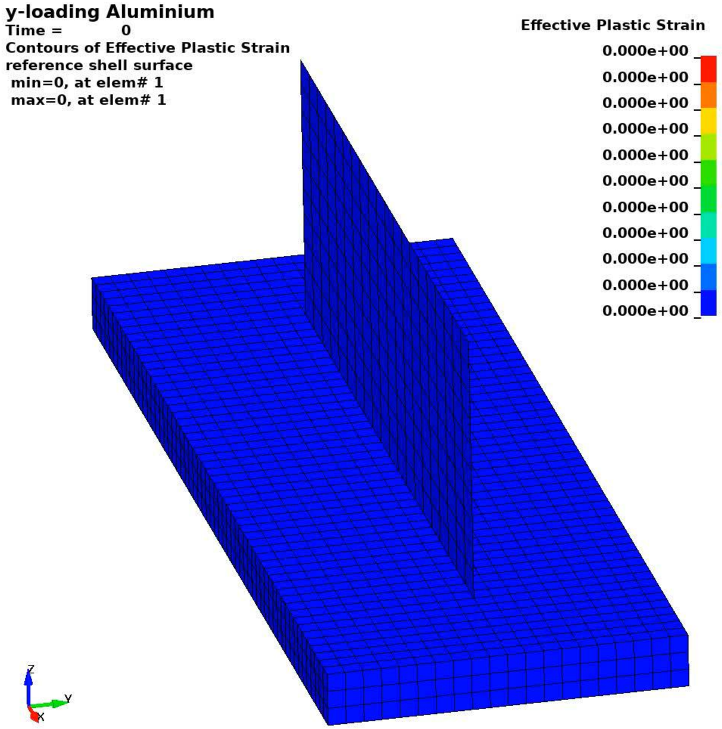


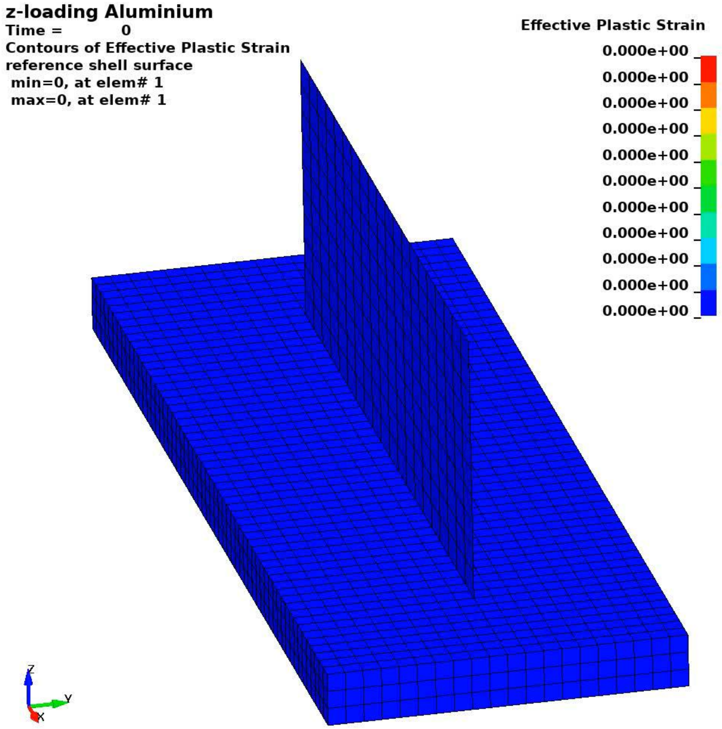


Results T shaped shell to solid

- Results for the aluminium material

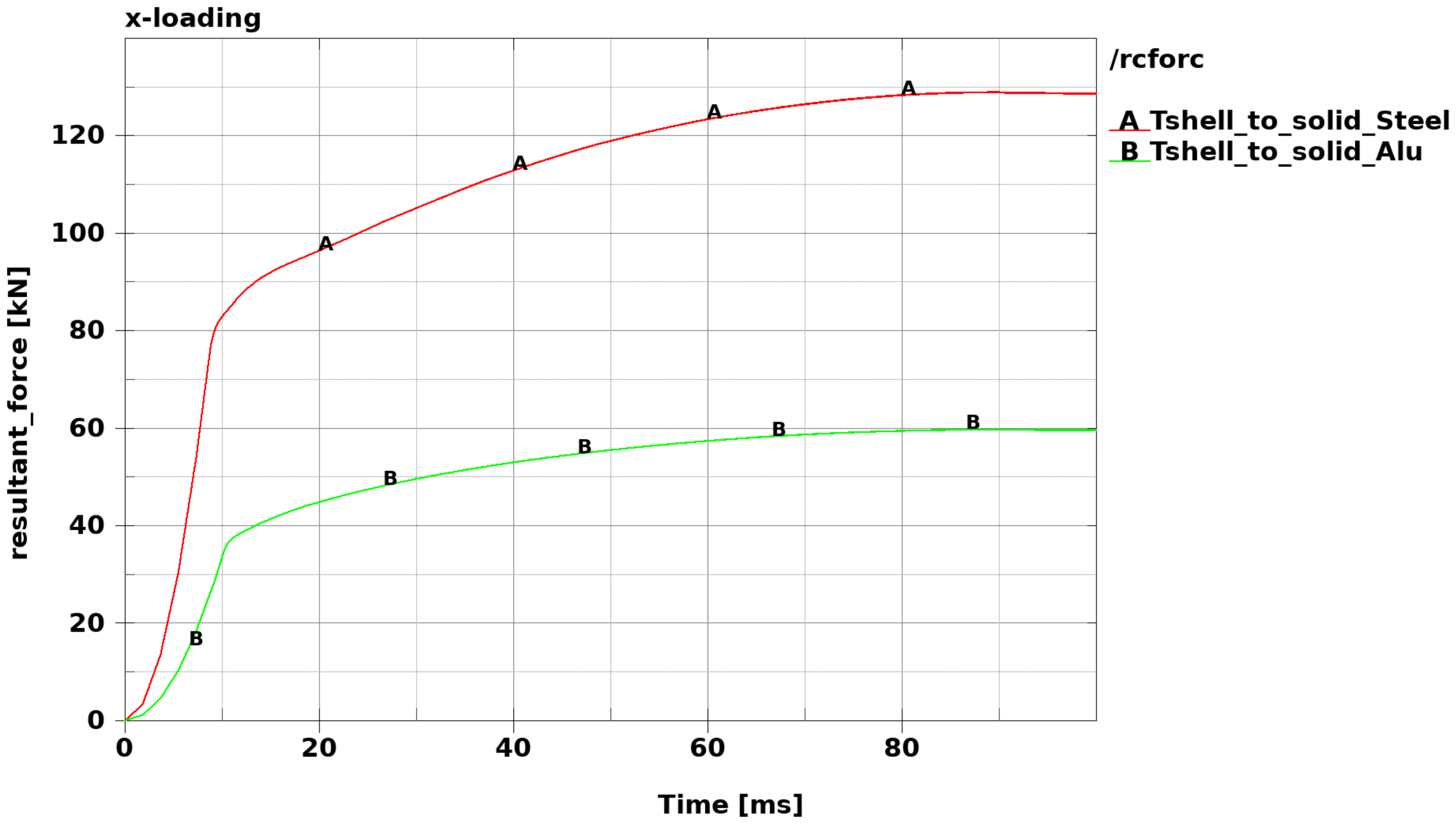






Results T shaped shell to solid

- Transmits force well and as expected. Very similar behavior between the steel and aluminium.



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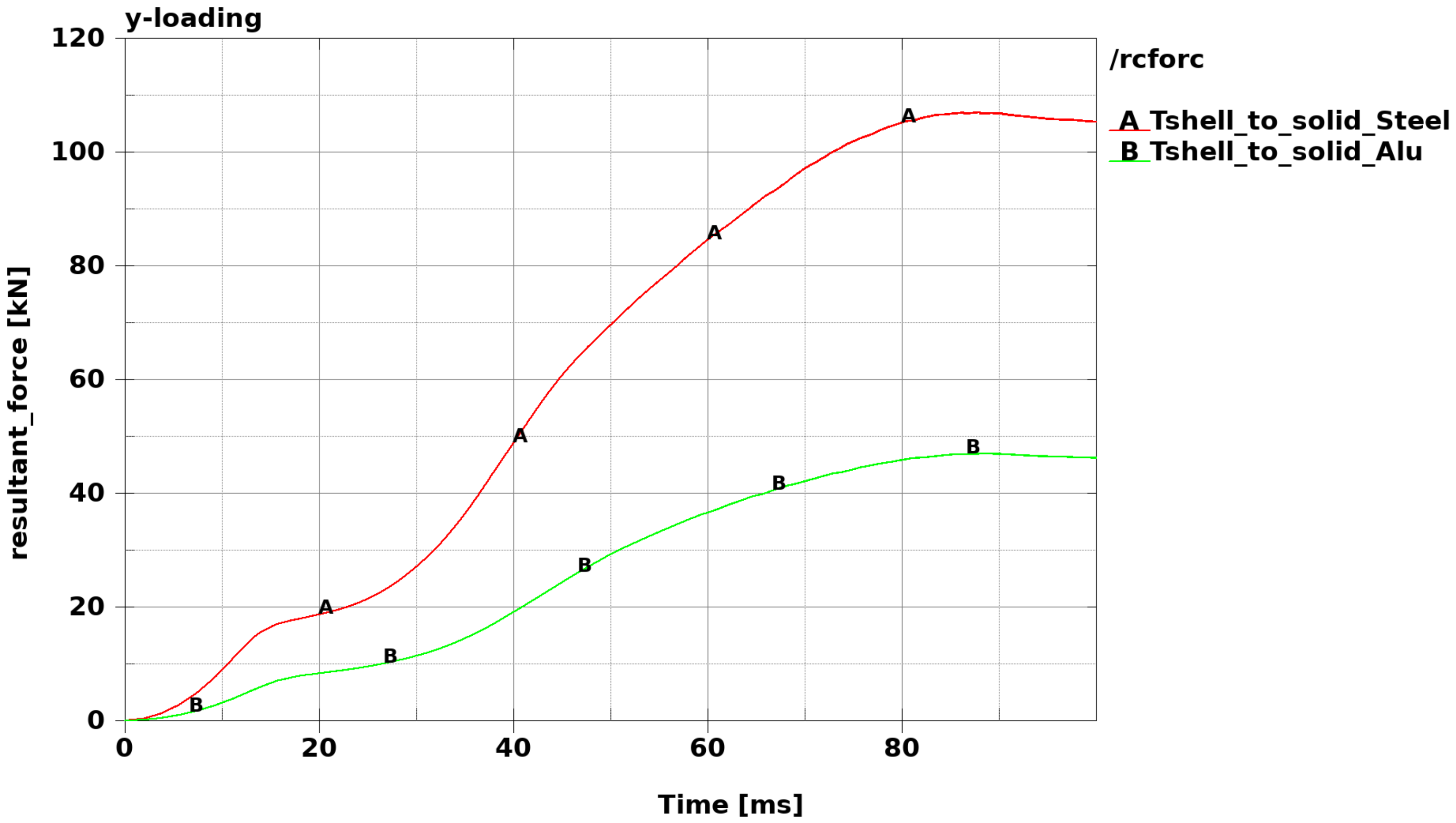

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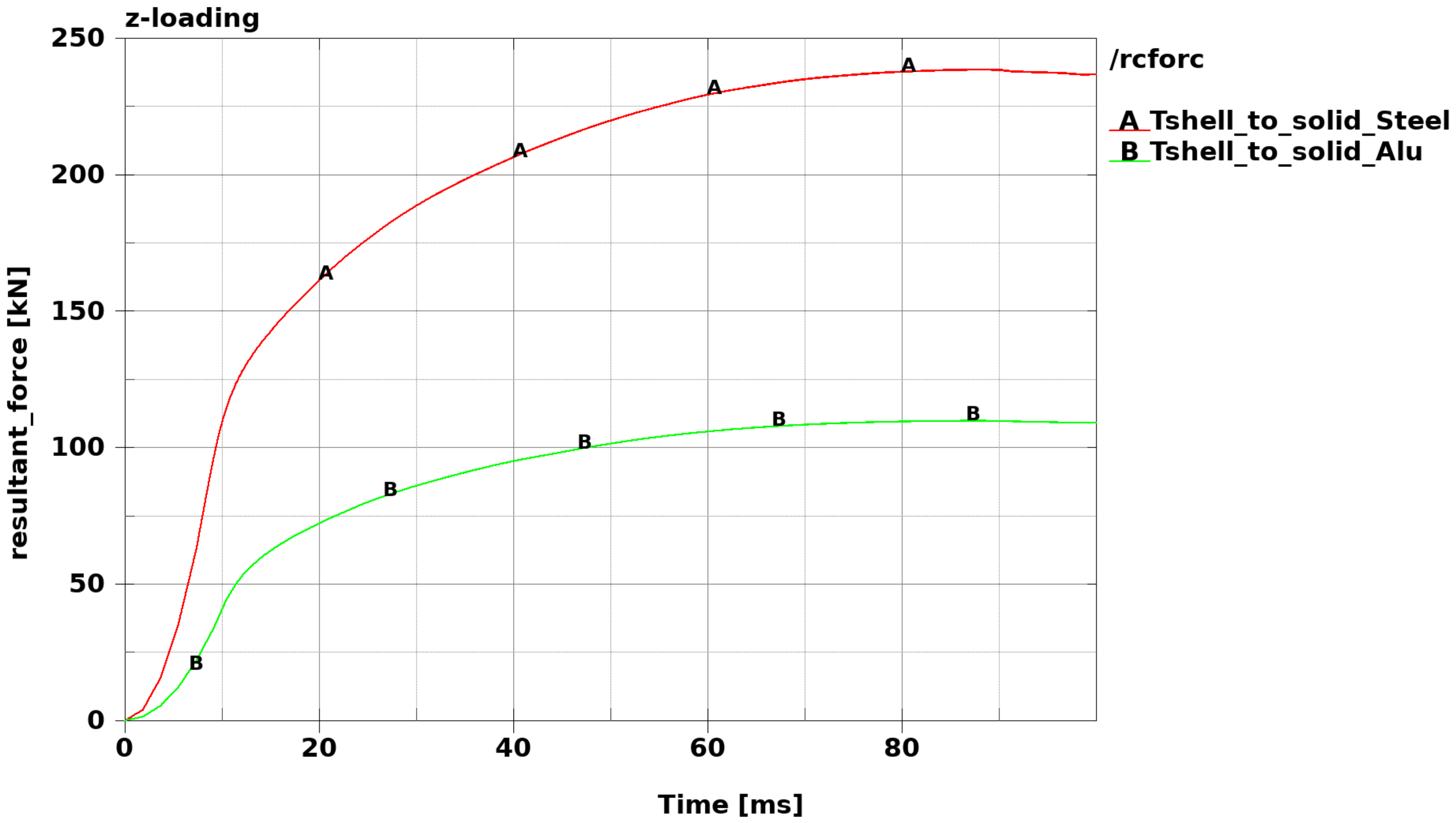


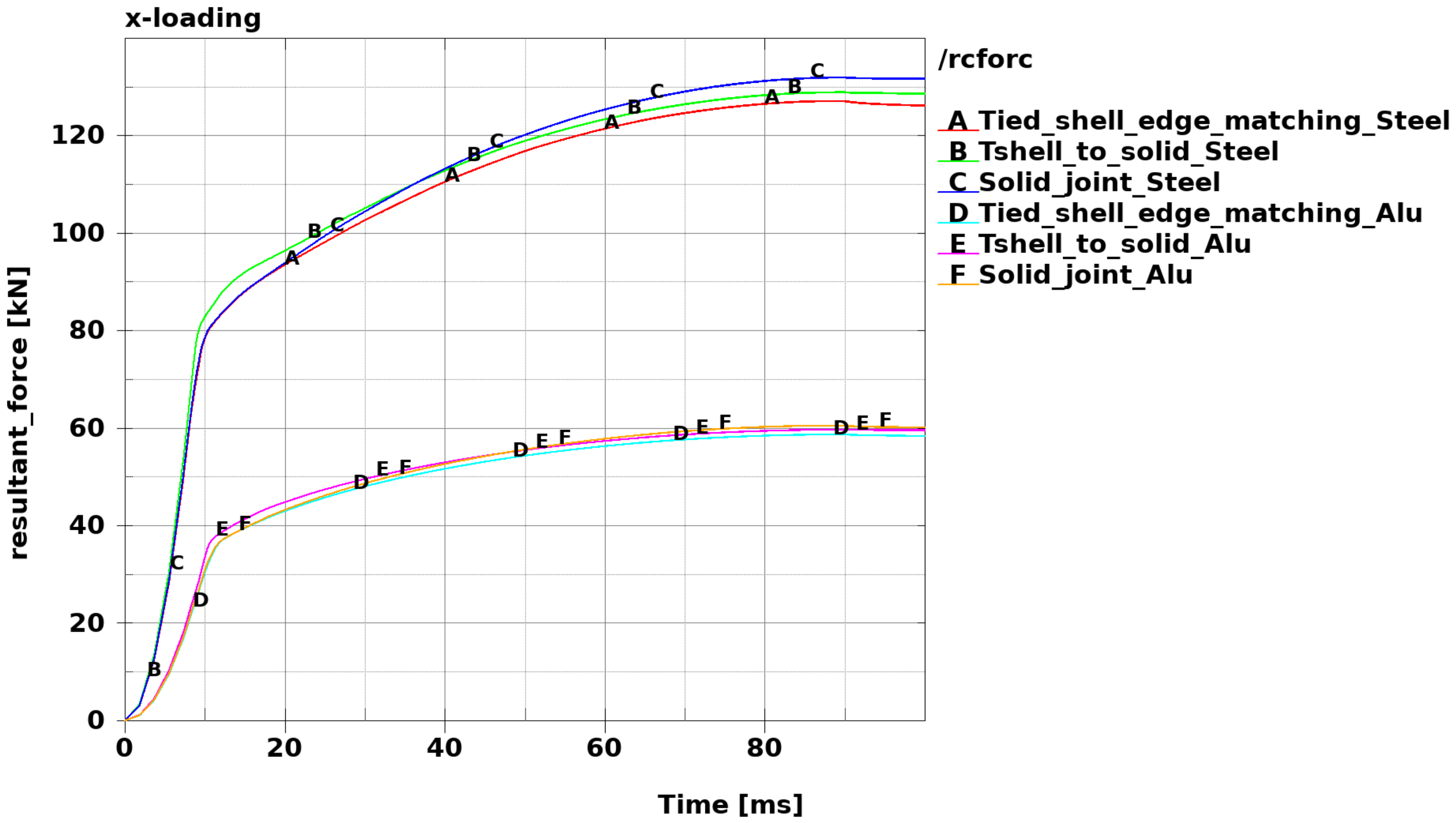
Summary T shaped shell to solid

- Advantages of the T shaped shell method
  - Should be simple to generate in a pre-processing stage
  - Possibility to fit parameters such as material data, size of the shells, thickness to match test behavior
  - Computationally cheap to use shell elements in relation to solid elements for the joint

- Disadvantages of the T shaped shell method
  - Added complexity in terms of material data and calibration

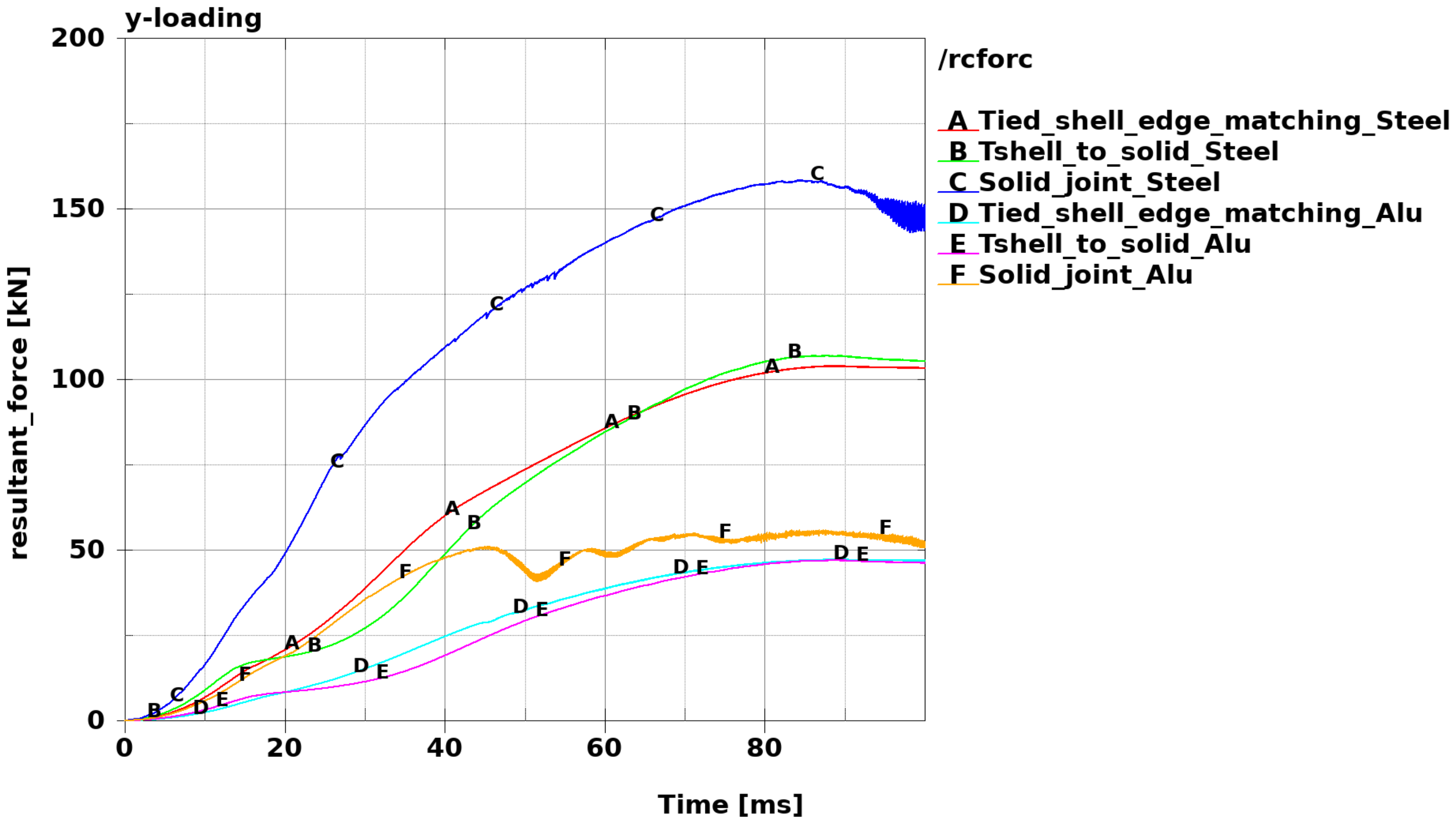
Comparison of the different methods

- Very similar behavior between all models and only clear difference is between the materials which is expected.



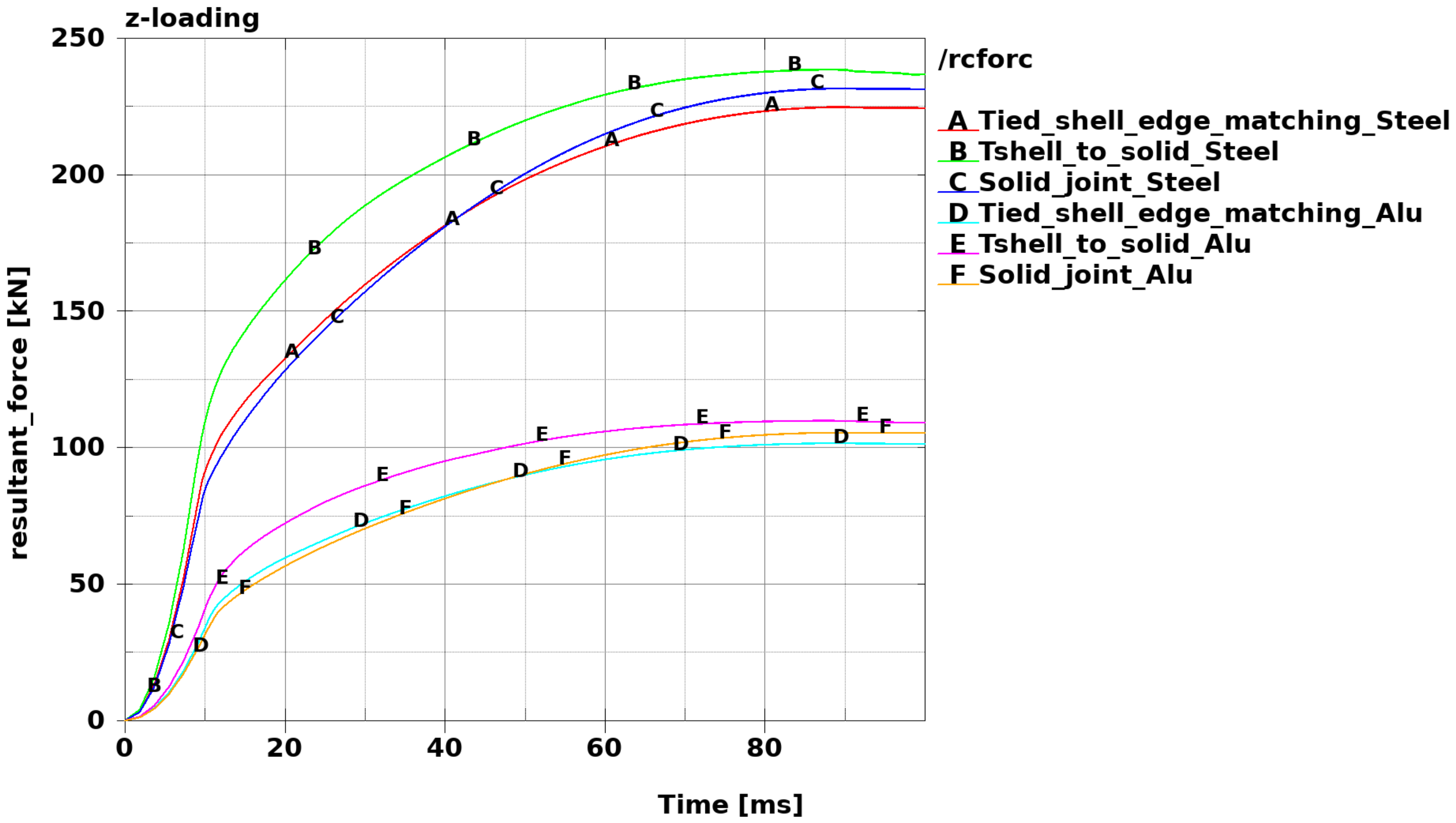
Comparison of the different methods

- Difference between the solid joint method and the other methods. The solid joint gets stiffer for this case, but that is dependent of the size of the joint.
- The T-shaped shell method is similar to the tied shell edge to solid.



Comparison of the different methods

- Very similar behavior between all models except the T-shaped shell method which is stiffer in comparison to the rest. It also has the largest contact area.



Summary of the different methods

- All methods gives reasonable results!
- The joint method with highest complexity and versatile would be to model the joint itself using solid elements.
- Using the approach where a layer of shells are used to distribute the forces into the plate will have the possibility correlate material parameters with tests.
- Using the shell edge to solid provides a simple and quick way of joining shells and solid, and it works!

Thank you!

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