Sub-modeling in LS-DYNA

Webinar 2020-12-03

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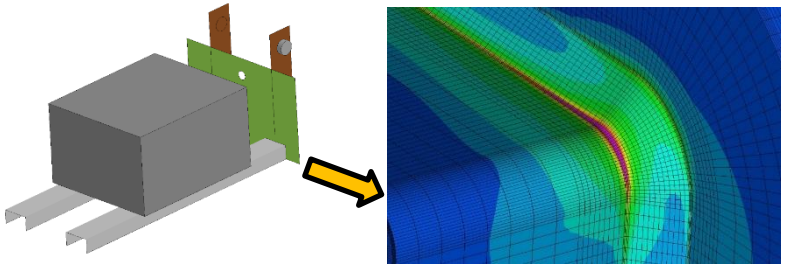
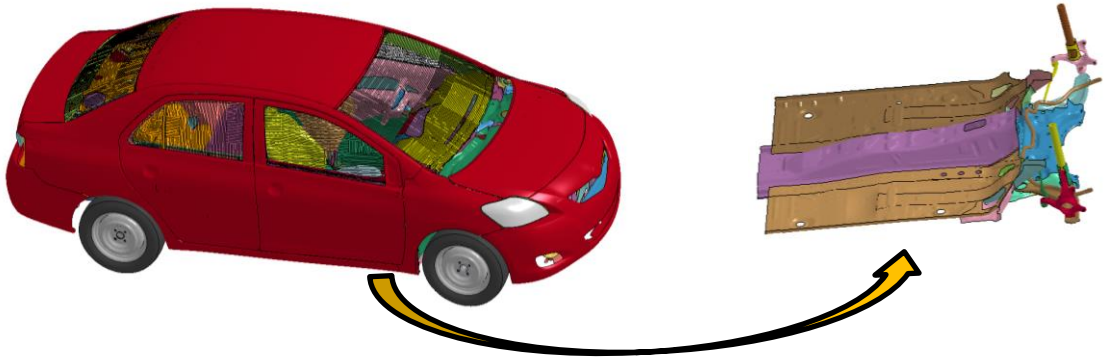
Sub-modeling in LS-DYNA

- Common applications
  - Mesh refinement of areas with large stress gradients
  - Sub-system analysis
- Why?
  - Efficiency!
  - Boundary behavior more realistic in some cases
- Heads-up!
  - Displacements/velocities at the defined interface needs to be ‘converged’
  - Multi-level sub-modeling may truncate errors…



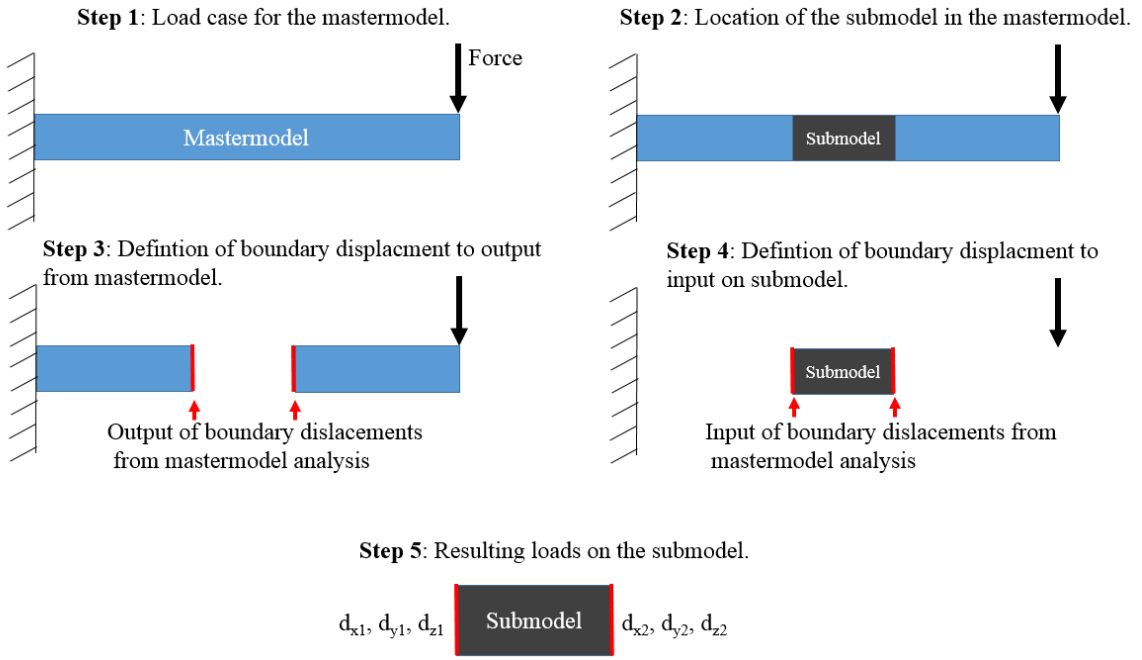


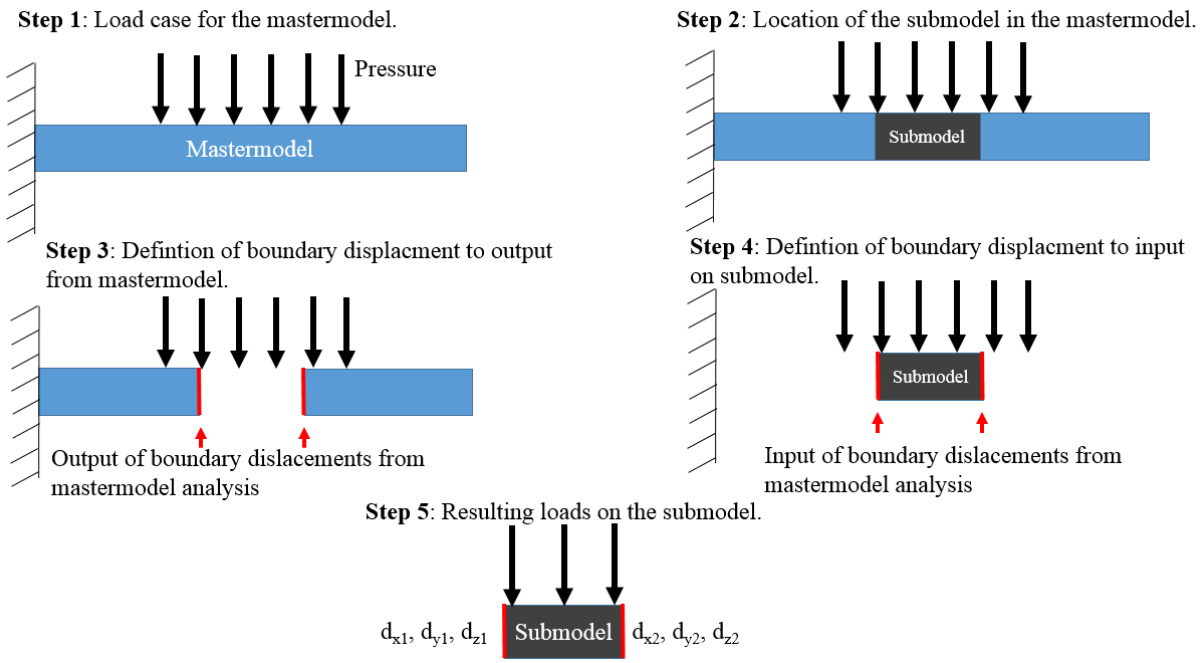
Sub-modeling in LS-DYNA

- Displacement driven – no force option
- Care must be taken to ensure that the displacements/velocities are adequately resolved
- Not always sufficient to define sub-model conditions on all boundaries
  - If the load is known on a boundary, apply the load instead
  - Make sure that the model is large enough to avoid boundary effects in the area of interest

Sub-modeling in LS-DYNA

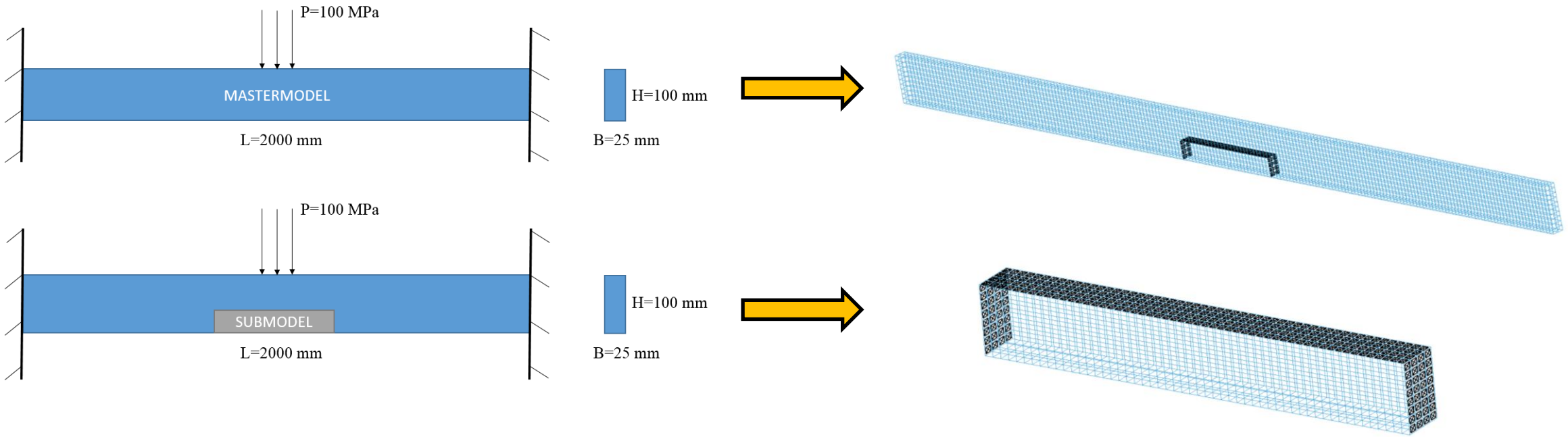
- Externally applied may need to be defined in the sub-model





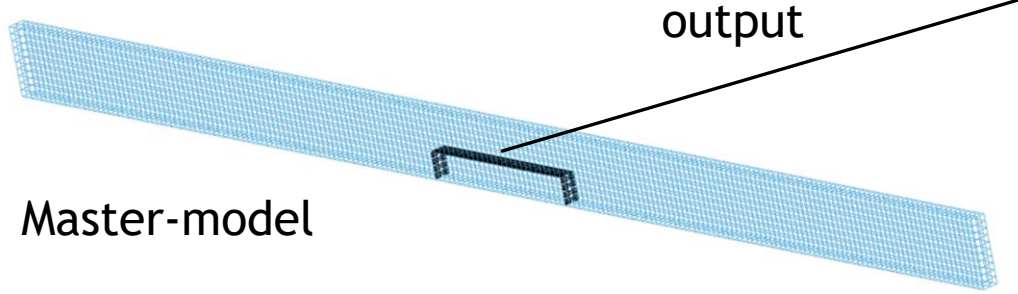
Sub-modeling in LS-DYNA

- How it works (very simplified)



Sub-modeling in LS-DYNA

- How it works (very simplified)

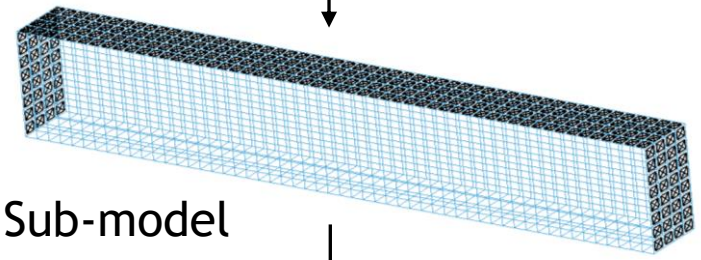


output

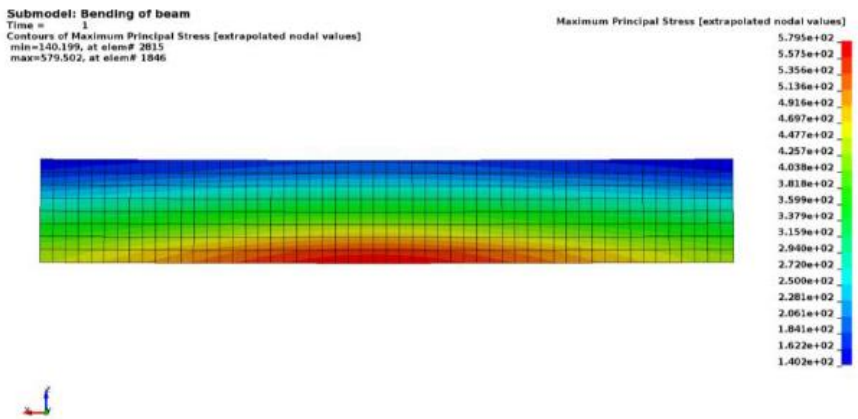
Master-model

Translations and rotations at defined interface

input



Sub-model



To ‘connect’ master- and sub-model initial coordinates are used in search of matches.

To drive the sub-model
***BOUNDARY_PRESCRIBED_MOTION**
***DEFINE_CURVE**
***CONTACT_TIED**
are created by LS-DYNA

Sub-modeling in LS-DYNA

- Keywords for sub-model analysis

*INTERFACE_COMPONENT_FILE

INTERFACE_COMPONENT_*OPTION

INTERFACE_LINKING_DISCRETE_NODE_*OPTION

*INTERFACE_LINKING_EDGE

*INTERFACE_LINKING_FILE

*INTERFACE_LINKING_NODE

*INTERFACE_LINKING_SEGMENT

The “COMPONENT”-keywords apply to the master part of the analysis.

The “LINKING”-keywords apply to the sub-model part of the analysis.

Sub-modeling in LS-DYNA

- Defining the master-model
  - Define interface output

***INTERFACE_COMPONENT_FILE**

Purpose: Allow for the specification of the file where the component interface data should be written, and the optional use of a new binary format for that data.

Card 1	1	2	3	4	5	6	7	8
Variable	Filename							
Type	A80							
Default	none							

Optional Card.

Card 2	1	2	3	4	5	6	7	8
Variable	Format							
Type	I							
Default	2							

VARIABLE	DESCRIPTION
FNAME	Name of the file where the component data will be written
FORMAT	File format to use: EQ.1: Use old binary file format EQ.2: Use new LSDA file format

***INTERFACE_COMPONENT**_OPTION1_{OPTION2}

Available values for OPTION1 include:

NODE

SEGMENT

OPTION2 only allows the value:

TITLE

Card 1	1	2	3	4	5	6	7	8
Variable	ID	Title						
Type	I	A70						
Default	none	None						

VARIABLE	DESCRIPTION
ID	ID for this interface in the linking file
Title	Title for this interface

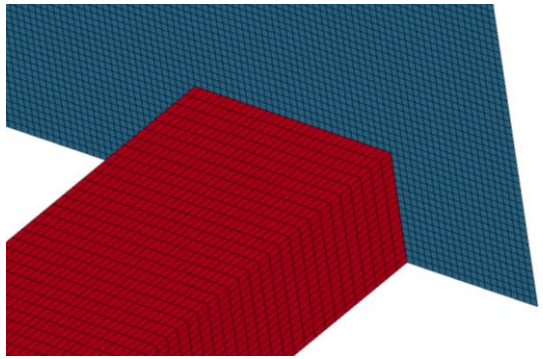
Card 2	1	2	3	4	5	6	7	8
Variable	SID	CID	NID					
Type	I	I	I					

VARIABLE	DESCRIPTION
SID	Set ID, see *SET_NODE or *SET_SEGMENT.
CID	Coordinate system ID
NID	Node ID

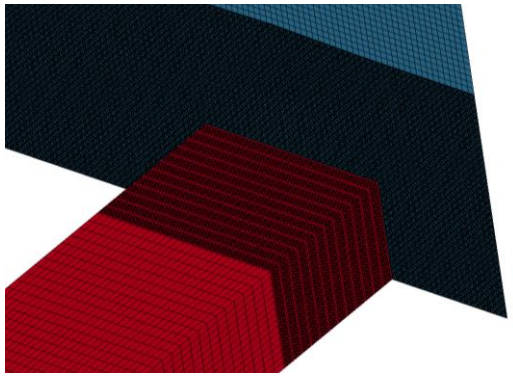
Z=filename on command line may be used instead of *INTERFACE_COMPONENT_FILE

Sub-modeling in LS-DYNA

- Defining the master-model
  - Define interface output



Master-model



Master-model SID=100

*INTERFACE_COMPONENT_SEGMENT

Card 2	1	2	3	4	5	6	7	8
Variable	SID	CID	NID					
Type	I	I	I					

optional

```
*INTERFACE_COMPONENT_SEGMENT
$#     SID      CID      NID
       100
*INTERFACE_COMPONENT_FILE
$#   FNAME
Interface
$# FORMAT
             2
```

Z=filename on command line may be used instead of *INTERFACE_COMPONENT_FILE

***INTERFACE_COMPONENT_FILE**

Purpose: Allow for the specification of the file where the component interface data should be written, and the optional use of a new binary format for that data.

Card 1	1	2	3	4	5	6	7	8
Variable	Filename							
Type	A80							
Default	none							

Optional Card.

Card 2	1	2	3	4	5	6	7	8
Variable	Format							
Type	I							
Default	2							

VARIABLE	DESCRIPTION
FNAME	Name of the file where the component data will be written
FORMAT	File format to use: EQ.1: Use old binary file format EQ.2: Use new LSDA file format

Sub-modeling in LS-DYNA

- Defining the master-model
  - Use FORMAT=2 on *INTERFACE_COMPONENT_FILE
  - OPIFS on *CONTROL_OUTPUT is used to define the output frequency to the interface-file

*CONTROL_OUTPUT

Card 1	1	2	3	4	5	6	7	8
Variable	NPOPT	NEECHO	NREFUP	IACCOP	OPIFS	IPNINT	IKEDIT	IFLUSH
Type	I	I	I	I	F	I	I	I
Default	0	0	0	0	0.	0	100	5000

Sub-modeling in LS-DYNA

- Defining the sub-model
  - Define interface input

***INTERFACE_LINKING_FILE**

Purpose: Allow for the specification of the file from which the component interface data should be read.

Card 1	1	2	3	4	5	6	7	8
Variable	Filename							
Type	A80							
Default	none							

VARIABLE	DESCRIPTION
FNAME	Name of the file from which the component data will be read

***INTERFACE_LINKING_SEGMENT**

Purpose: Link segments to an interface in an existing interface file. The interface file is specified using *INTERFACE_LINKING_FILE or by including "L=**filename**" on the execution line.

Segment Set ID Card. Include as many cards as desired. Input ends at the next keyword ("*") card.

Card 1	1	2	3	4	5	6	7	8
Variable	SSID	IFID						
Type	I	I						

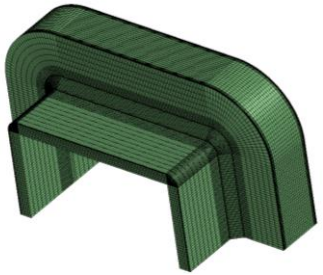
VARIABLE	DESCRIPTION
SSID	Segment set to be moved by interface file.
IFID	Interface ID in interface file.

L=filename on command line may be used instead of *INTERFACE_LINKING_FILE

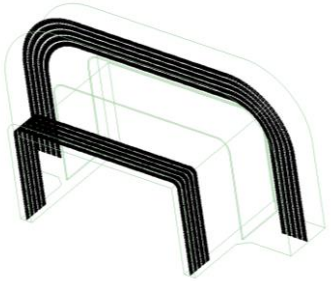
Note! In some versions of LS-DYNA the user may need to use the command line option.

Sub-modeling in LS-DYNA

- Defining the sub-model
  - Define interface input



sub-model



sub-model SSID=200

L=filename on command line may be used instead of *INTERFACE_LINKING_FILE

Note! In some versions of LS-DYNA the user may need to use the command line option.

***INTERFACE_LINKING_FILE**

Purpose: Allow for the specification of the file from which the component interface data should be read.

Card 1	1	2	3	4	5	6	7	8
Variable	Filename							
Type	A80							
Default	none							

VARIABLE	DESCRIPTION
FNAME	Name of the file from which the component data will be read

Only one *INTERFACE_LINKING_SEGMENT permitted!

*INTERFACE_LINKING_SEGMENT

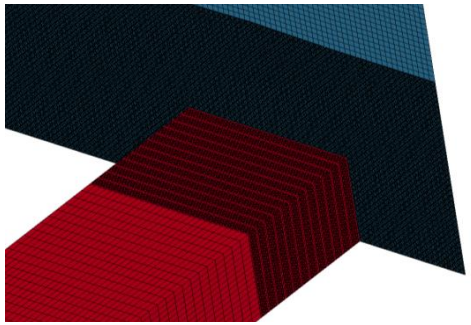
Card 1	1	2	3	4	5	6	7	8
Variable	SSID	IFID						
Type	I	I						

```
*INTERFACE_LINKING_SEGMENT
$#    SSID     IFID
        200        1
*INTERFACE_LINKING_FILE
$#   FNAME
Interface
```

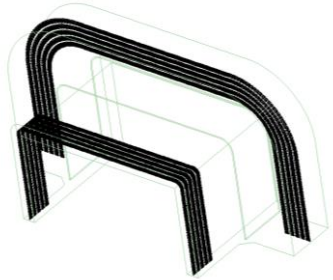
Sub-modeling in LS-DYNA

- Defining the sub-model
  - IFID = Interface ID in interface file
    - Based on “ID” if TITLE-option is used
    - Else, based on order of input

```
*INTERFACE_COMPONENT_SEGMENT
$#     SID       CID       NID
       102
       100
       101
*INTERFACE_COMPONENT_FILE
$#   FNAME
Interface
$# FORMAT
             2
$
$
*INTERFACE_LINKING_SEGMENT
$#    SSID     IFID
       200        2
*INTERFACE_LINKING_FILE
$#   FNAME
Interface
```



Master-model SID=100



Sub-model SSID=200

```
*INTERFACE_COMPONENT_SEGMENT_TITLE
$#      id                                                        title
        3interface 3
$#    SID       CID       NID
      102         0         0
*INTERFACE_COMPONENT_SEGMENT_TITLE
$#      id                                                        title
        1interface 1
$#    SID       CID       NID
      100         0         0
*INTERFACE_COMPONENT_SEGMENT_TITLE
$#      id                                                        title
        2interface 2
$#    SID       CID       NID
      101         0         0
*INTERFACE_COMPONENT_FILE
$#   FNAME
Interface
$# FORMAT
             2
$
$
*INTERFACE_LINKING_SEGMENT
$#    SSID     IFID
       200        1
*INTERFACE_LINKING_FILE
$#   FNAME
Interface
```

Sub-modeling in LS-DYNA

- Keywords – sub-model input

*INTERFACE_LINKING_FILE

File containing the interfaces to drive the sub-model. Only one permitted!!!

***INTERFACE_LINKING_FILE**

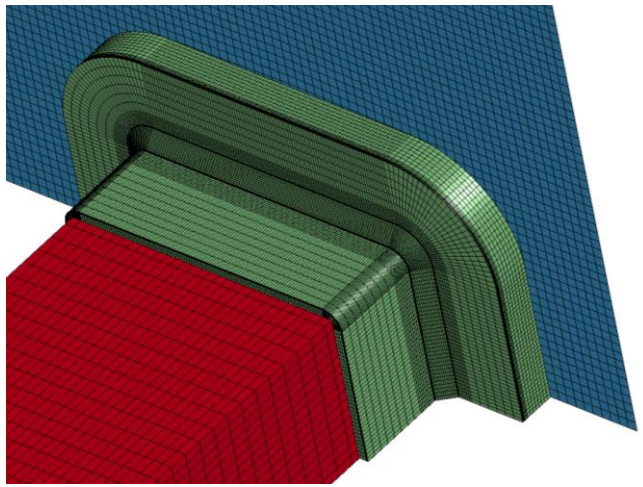
Purpose: Allow for the specification of the file from which the component interface data should be read.

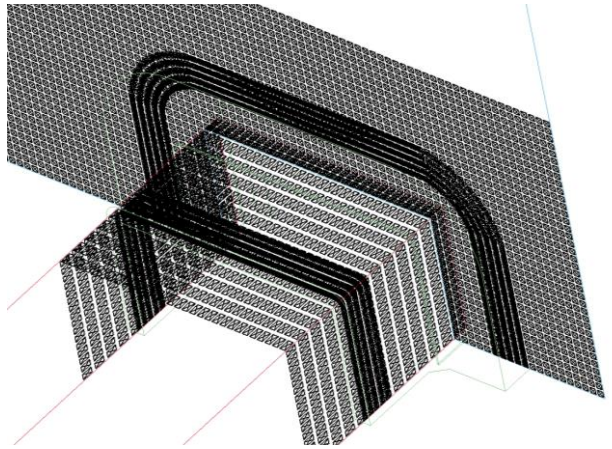
Card 1	1	2	3	4	5	6	7	8
Variable	Filename							
Type	A80							
Default	none							

VARIABLE	DESCRIPTION
FNAME	Name of the file from which the component data will be read

Remarks:

If L= is used on the command line, this card will be ignored. There is no option to specify the file format, as the file format is automatically detected.

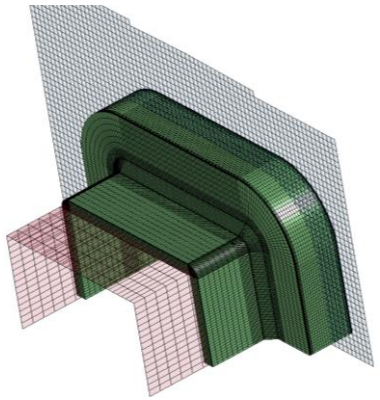


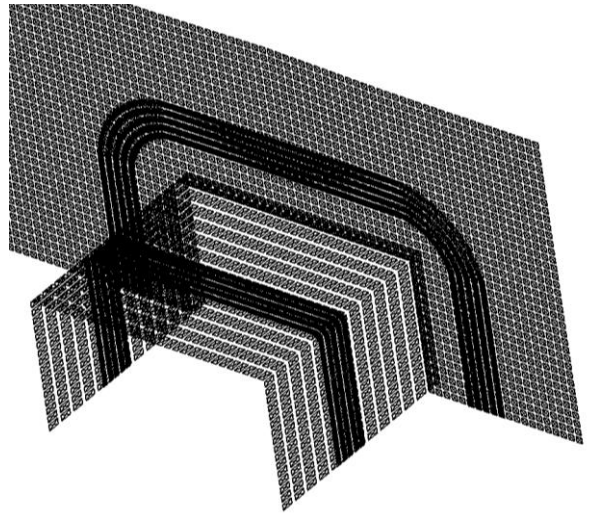


Sub-modeling in LS-DYNA

- Recommendations
  - For solid and shell elements master – _COMPONENT_NODE / SEGMENT
  - For solid and shell elements sub – LINKING_NODE / SEGMENT / EDGE
  - For beam and discrete elements – LINKING_NODE / DISCRETE_NODE

- When connecting a master shell mesh to a solid
  sub-model mesh use overlap to make sure
  that moments are transferred properly.

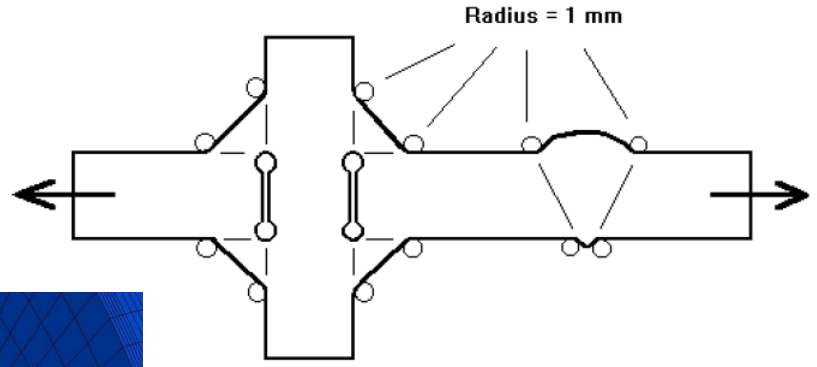


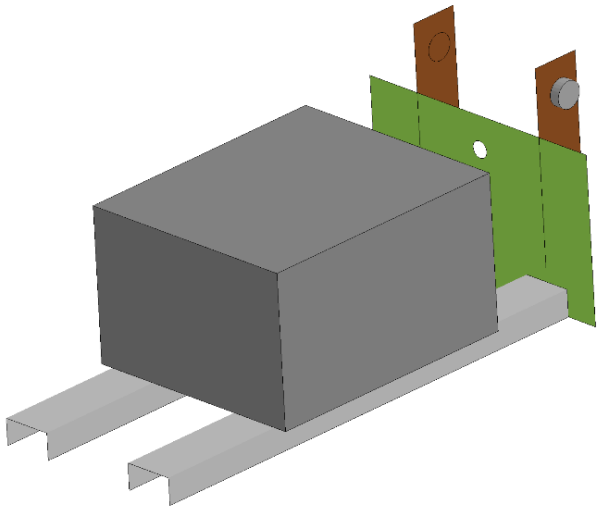


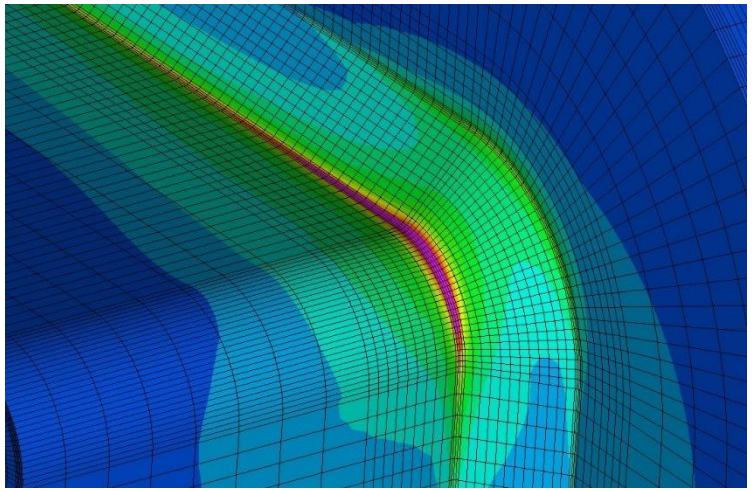
- Since the linking is defined by the set(s) in the _LINKING_-commands a large area may be defined as master node/segment. This may speed-up pre-processing.
- Be careful when changing the sub-model. Does it affect the global stiffness? Need to apply changes to the master-model and re-run?
- Make sure that the sub-model region is large enough – no boundary effect in area of interest.

Sub-modeling in LS-DYNA

- Example: Effective-Notch Stress Metod i LS-DYNA
  - Modeling according to IIW - ”...element size max. r/4”



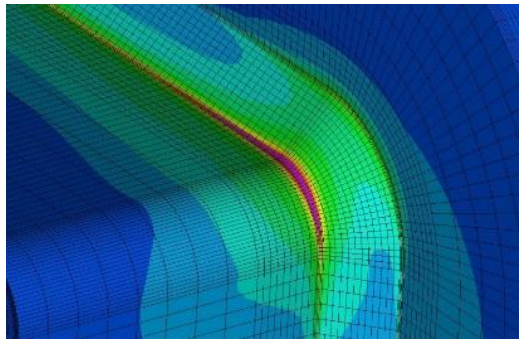


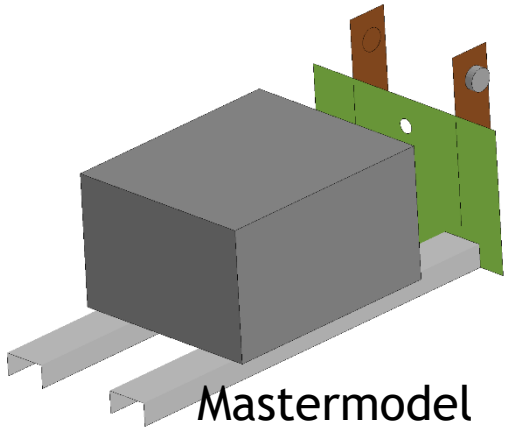


Coarse Master-model

Detailed weld in sub-model

Sub-modeling in LS-DYNA

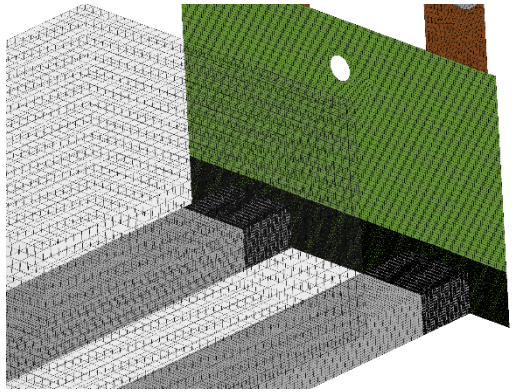




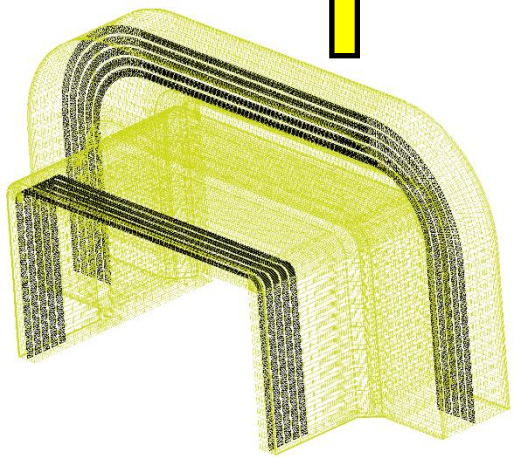
Mastermodel

Shell master-model to a solid sub-model:

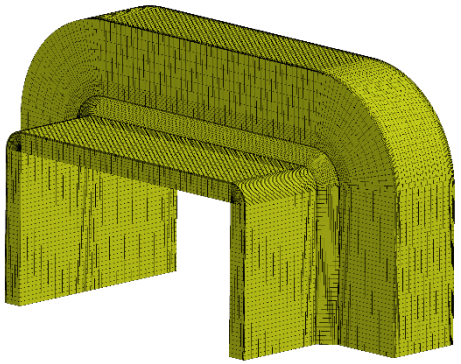
- **Make sure that the interfaces overlap to capture secondary effects (bending)**



Segment set



Segment set

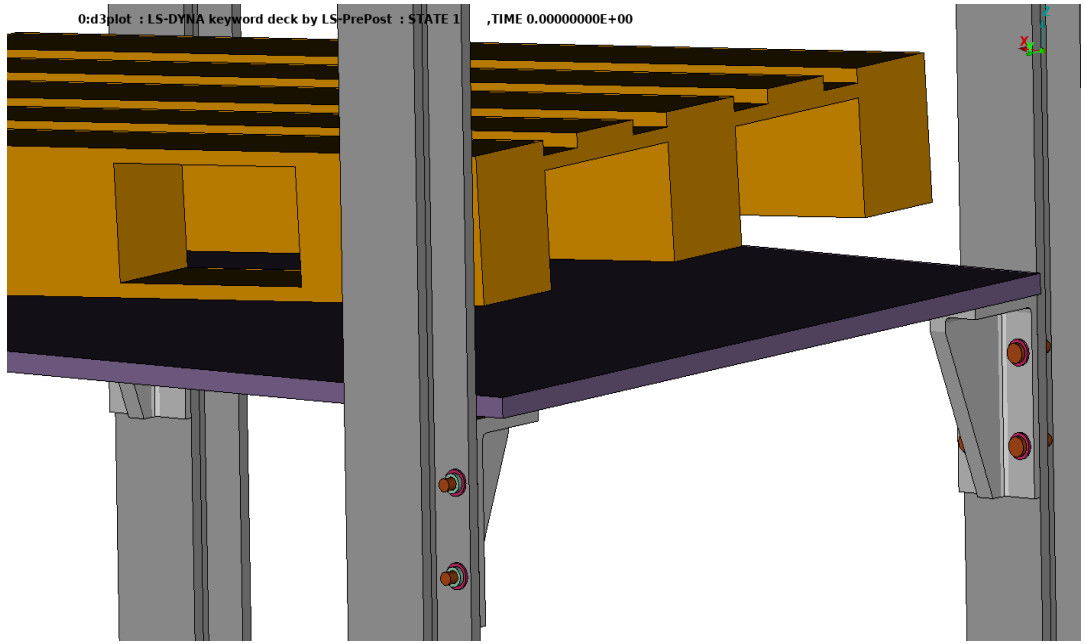


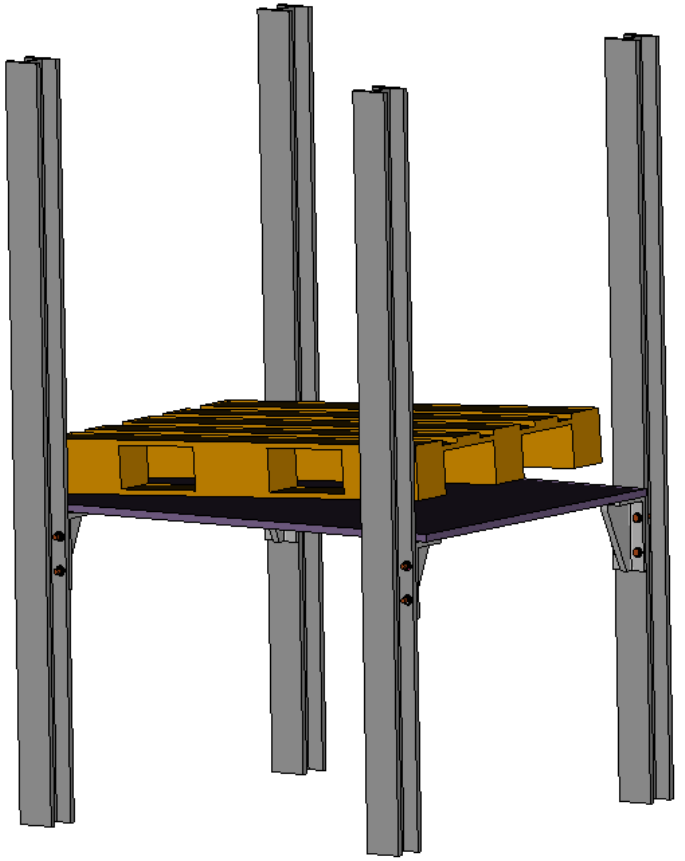
sub-model

The tied condition is defined by searching of mates to the slave (sub-model). This means that the master set can be selected more random.

Sub-modeling in LS-DYNA

- Example: Fatigue analysis of an impact load scenario
  - Pallet drop on storage shelves
  - Analysis of fatigue damage in bracket radii





Sub-modeling in LS-DYNA

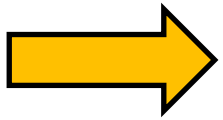
- Example: Fatigue analysis of an impact load scenario
  - Pallet drop on storage shelves
  - Analysis of fatigue damage in bracket radii

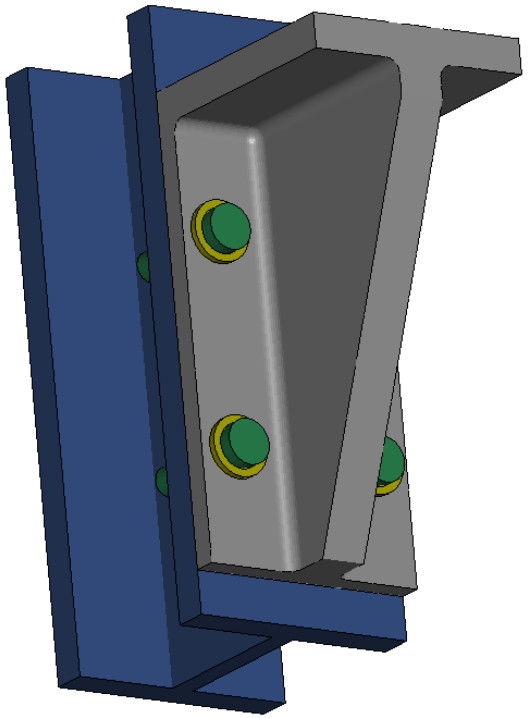
Solution strategy:

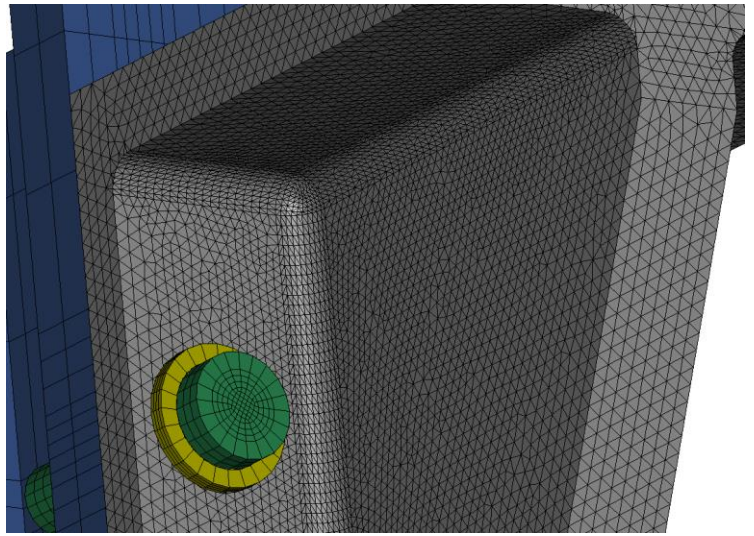
1. Explicit simulation of complete load case
   a. Coarser mesh
   b. Interface output for sub-modeling
2. Sub-model analysis
   a. Fine mesh.
   b. Using the interface output in (1)
   c. Element output (elout) of elements for fatigue analysis
3. Time domain fatigue analysis using
   a. Only on selected elements
   b. Stress based, high-cycle fatigue
   c. S-N curve input

Sub-modeling in LS-DYNA

- Example 3: Fatigue analysis of an impact load scenario
  - FE-models





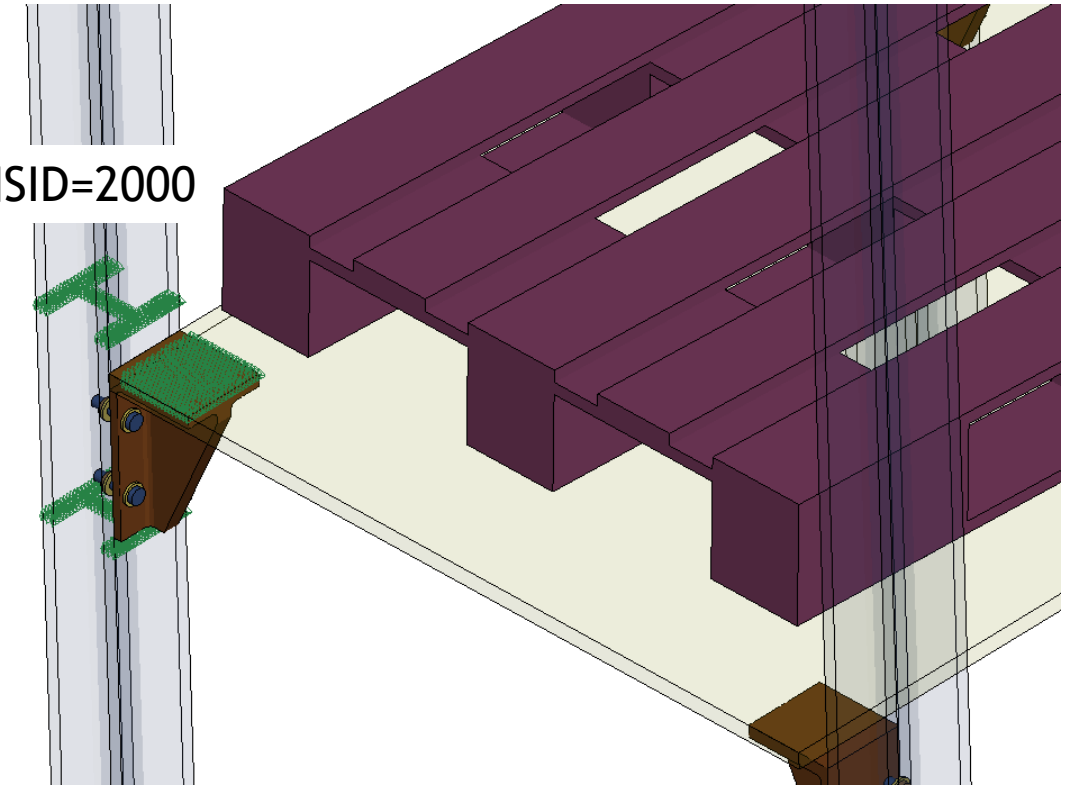


Master-model

Sub-model

Sub-modeling in LS-DYNA

- Example 3: Fatigue analysis of an impact load scenario
  - Master-model



*INTERFACE_COMPONENT_NODE_(TITLE) (1)

1	ID	Title	
	1	Master	
2	NSID	CID	NID
	2000	0	0

COMMENT:

*INTERFACE_COMPONENT_FILE (1)

1	FILENAME	
	interface_file	Browse
2	FORMAT	
	2	

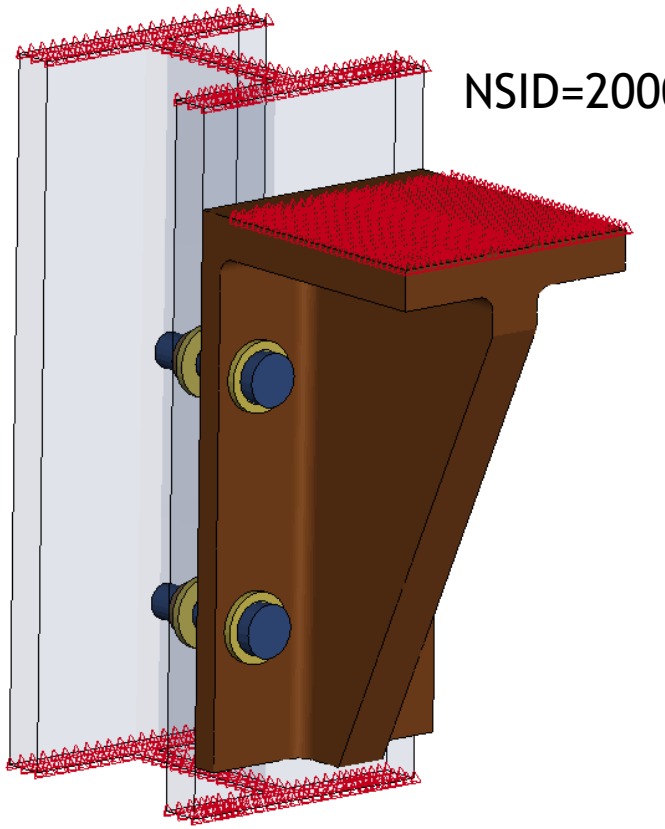
COMMENT:

*CONTROL_OUTPUT (1)

1	NPOPT	NEECHO	NREFUP	IACCOP	OPIFS	IPNINT	IKEDIT	IFLUSH
	0	0	0	0	1.000e-04	0	100	5000
2	IPRTF	IERODE	TET10S8	MSGMAX	IPCURV	GMDT	IP1DBLT	EOCS
	0	0	2	50	0	0.0	0	0

Sub-modeling in LS-DYNA

- Example 3: Fatigue analysis of an impact load scenario
  - Sub-model



*INTERFACE_LINKING_NODE_SET (1)

	NSID	IFID	FX	FY	FZ
1	20000	1	0	0	0

*INTERFACE_LINKING_FILE (1)

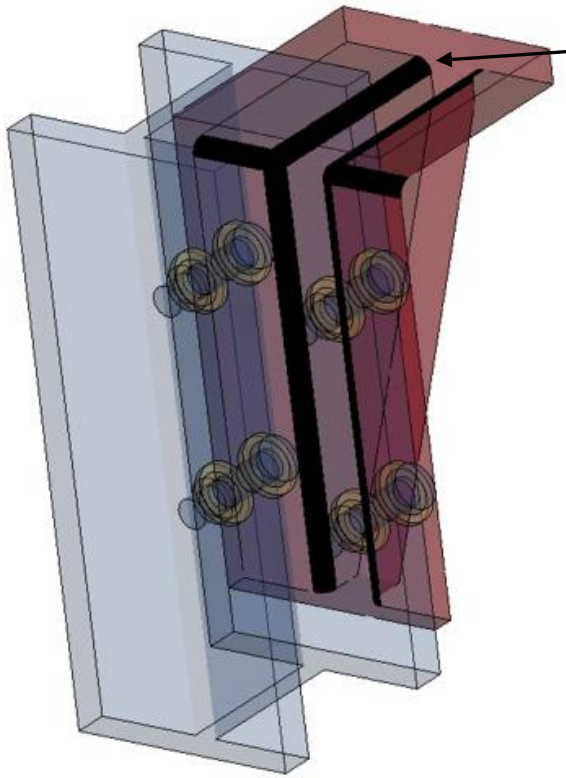
	FILENAME
1	interface_file

Browse

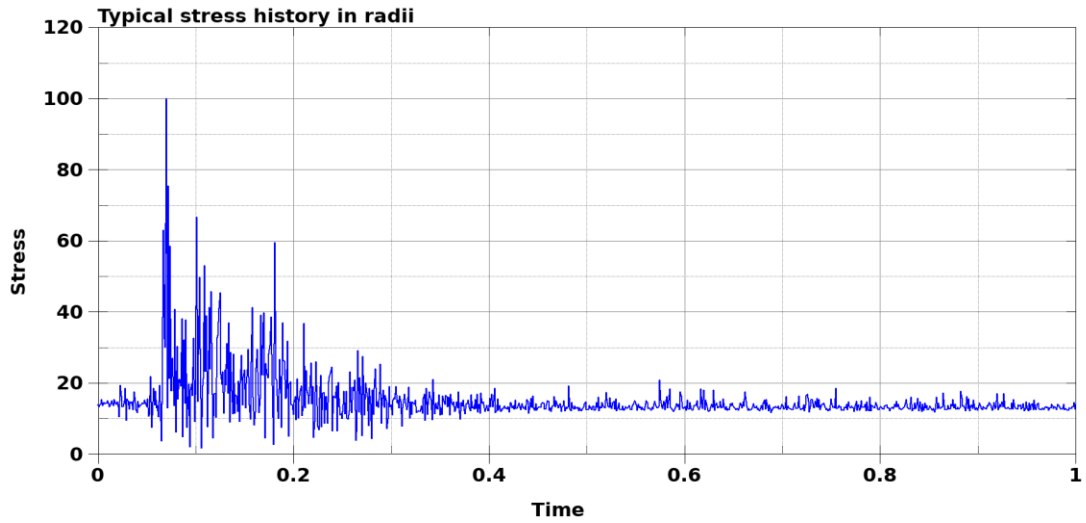
Sub-modeling in LS-DYNA

- Example 3: Fatigue analysis of an impact load scenario
  - Sub-model

Using the time-domain fatigue solver
In LS-DYNA R12.0.0



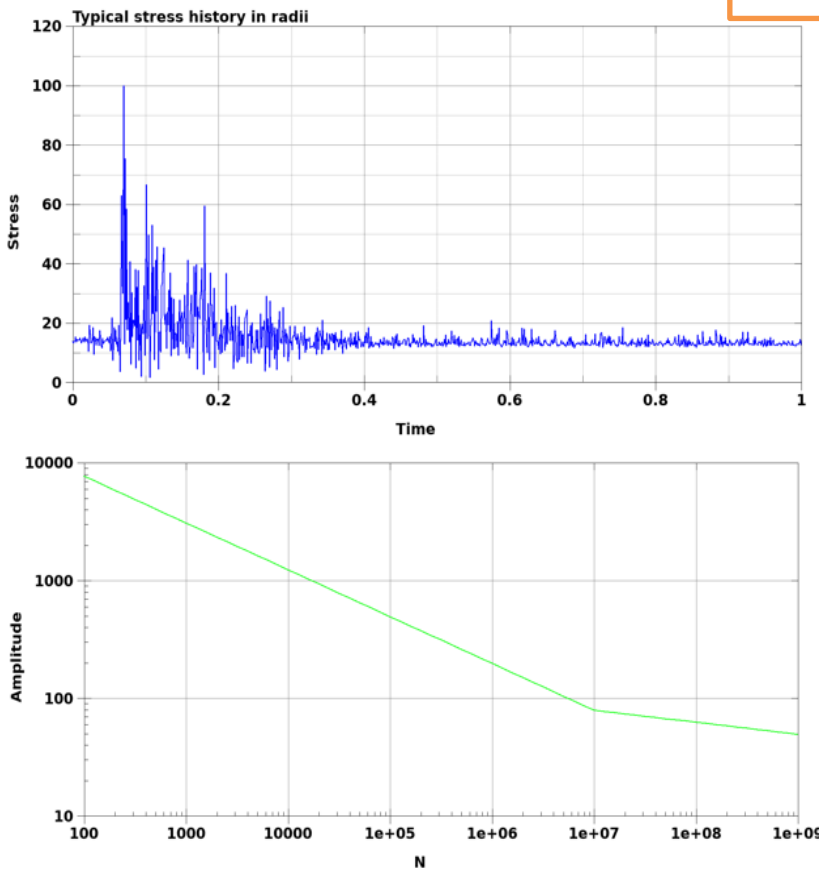
Element set for output through
*DATABASE_HISTORY_SHELL_SET
& *DATABASE_ELOUT

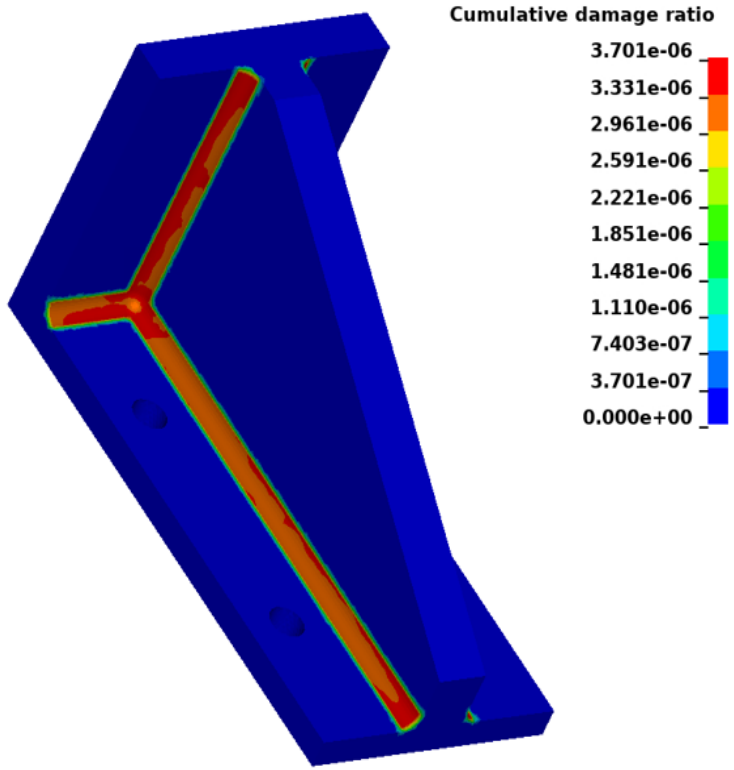


Sub-modeling in LS-DYNA

- Example 3: Fatigue analysis of an impact load scenario
  - *FATIGUE_MEAN_STRESS_CORRECTION
  - *FATIGUE_ELOUT
  - *MAT_ADD_FATIGUE
  - *FATIGUE_MULTIAXIAL
  - *FATIGUE_D3FTG

Using the time-domain fatigue solver
In LS-DYNA R12.0.0





Sub-modeling in LS-DYNA

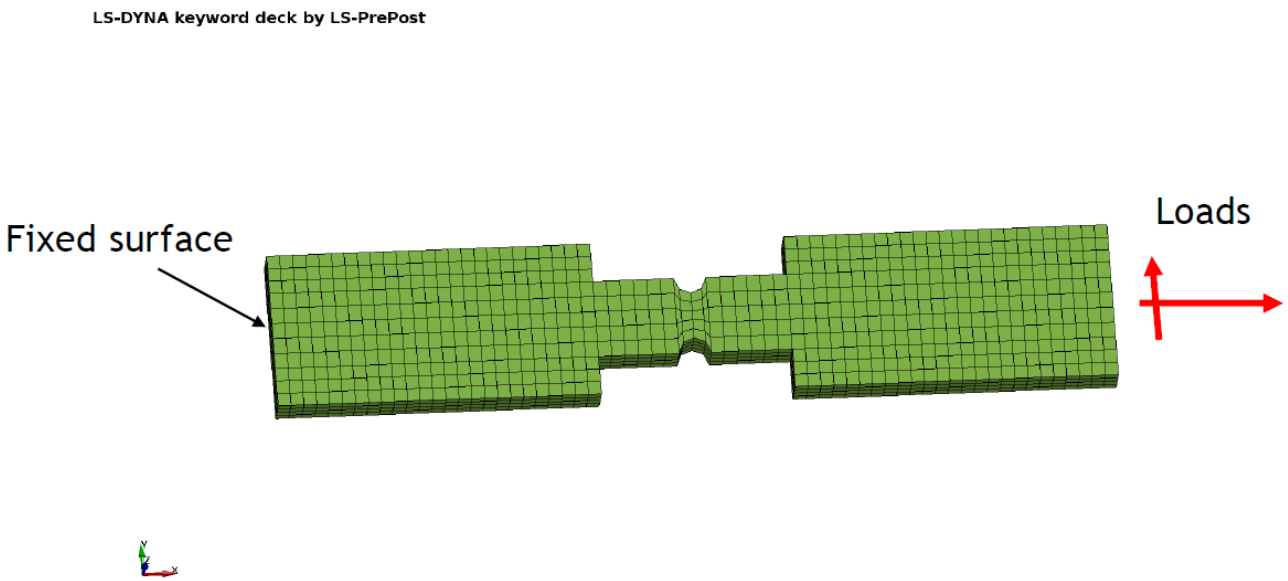
- Using direct d3plot results
  - Benefit: No need for an identification run of the master-model
  - Drawback: More manual work

How to?

- Run master-model
- Identify sub-model area
- Create sub-model
  - Geometry
  - Interfaces
  - BPM’s and curves
  - Tied contact
- Run sub-model

Sub-modeling in LS-DYNA

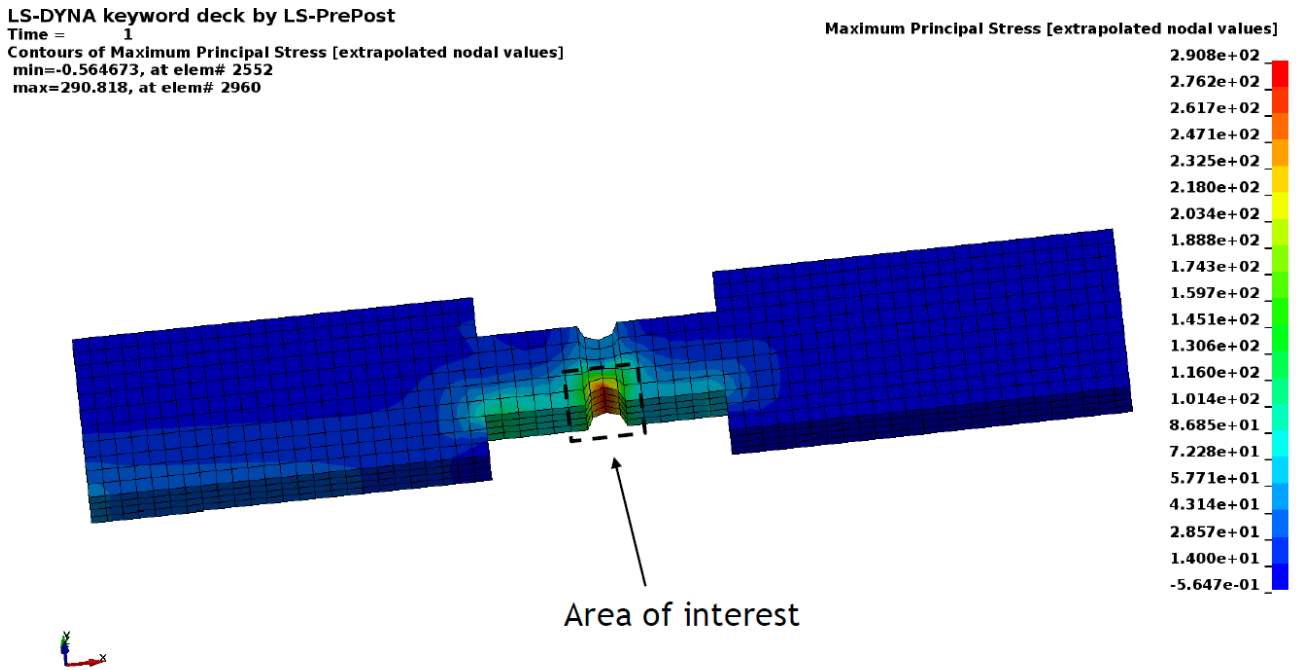
- Using direct d3plot results
- Mastermodel and load case



Sub-modeling in LS-DYNA

- Using direct d3plot results

- Mastermodel result

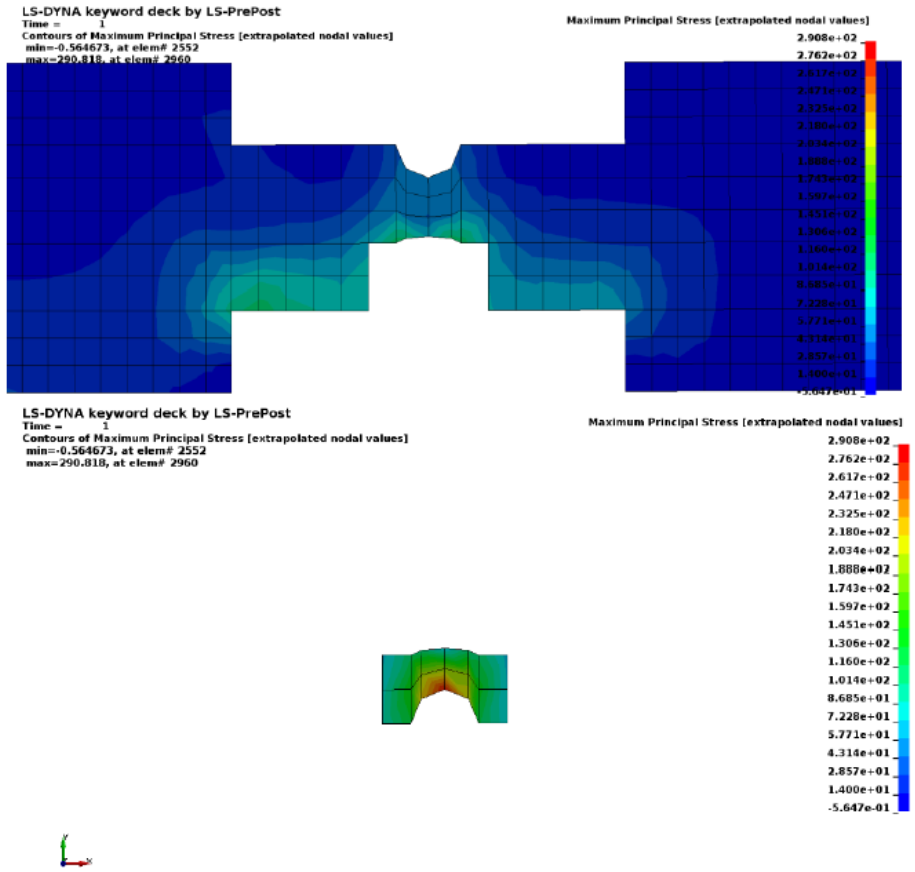


Sub-modeling in LS-DYNA

- Using direct d3plot results

- Create sub-model
  - Choose only the elements of interest

    (blank and reverse….)

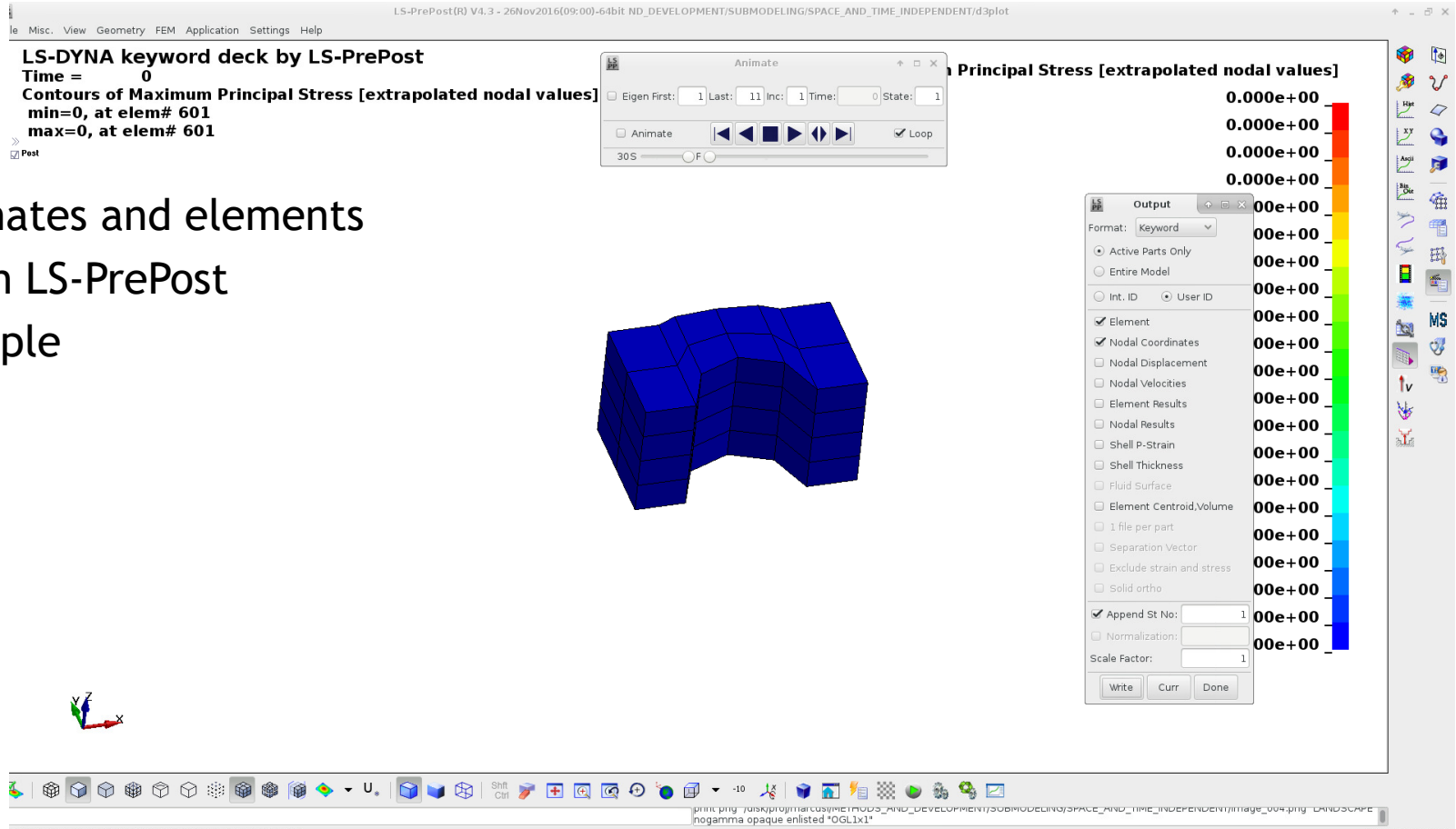


Sub-modeling in LS-DYNA

- Using direct d3plot results

- Create sub-model
  - Output initial nodal coordinates and elements through the output meny in LS-PrePost

  File name: geo.k in this example

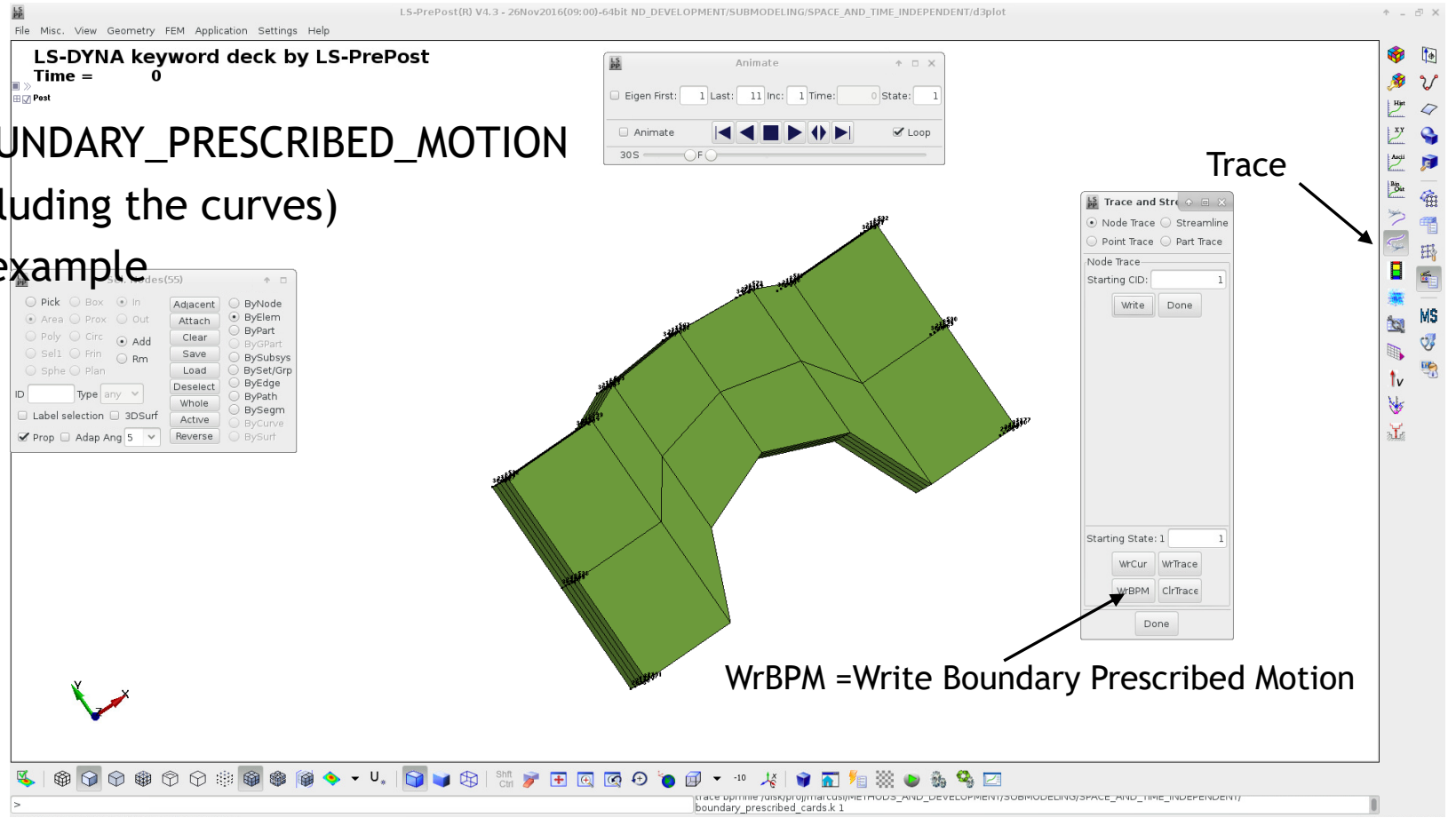


Sub-modeling in LS-DYNA

- Using direct d3plot results

- Create sub-model
  - Use “Trace” to output *BOUNDARY_PRESCRIBED_MOTION for all selected nodes (including the curves)

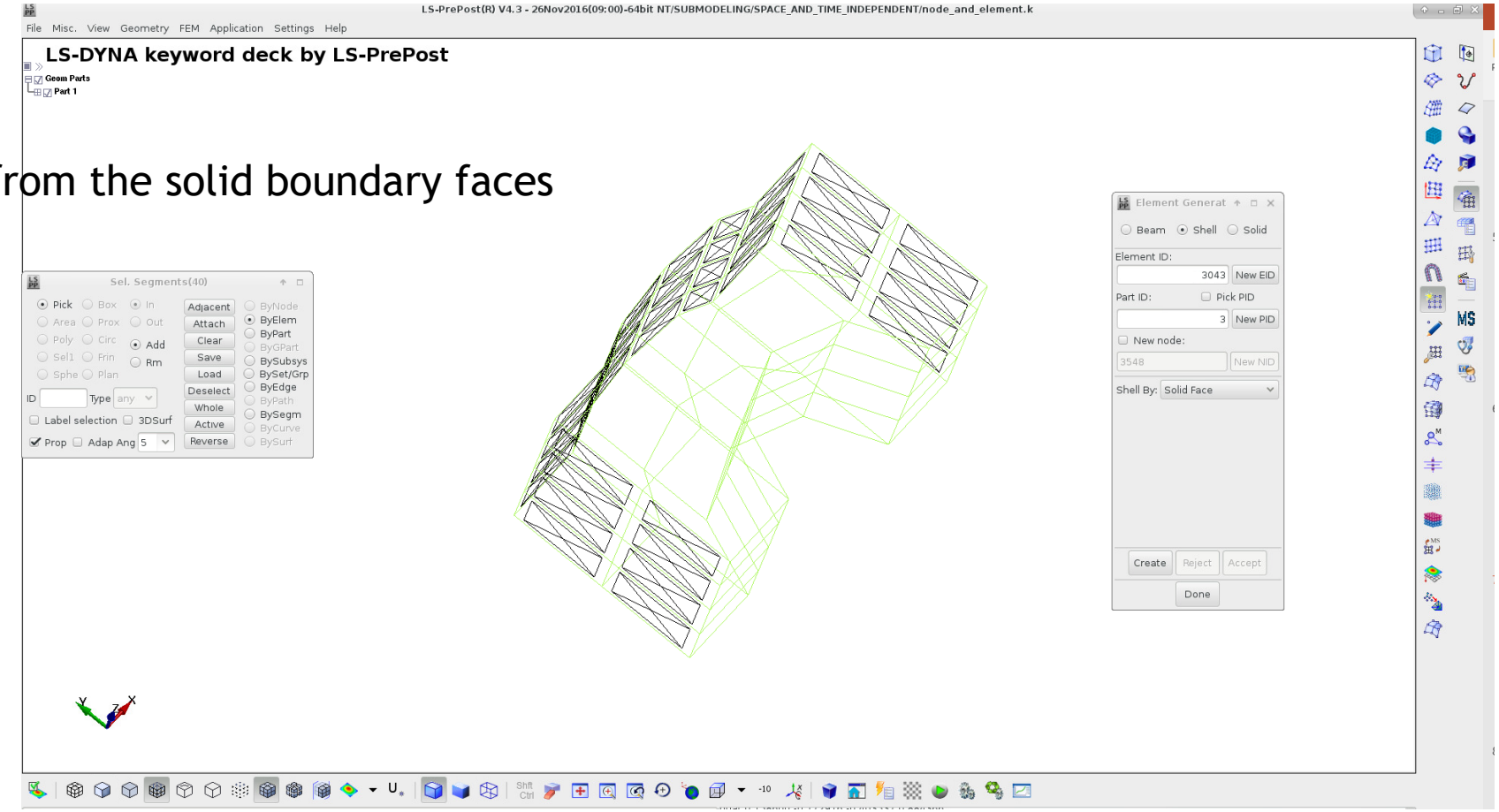
  Save file as WrBPM.k in this example



Sub-modeling in LS-DYNA

- Using direct d3plot results

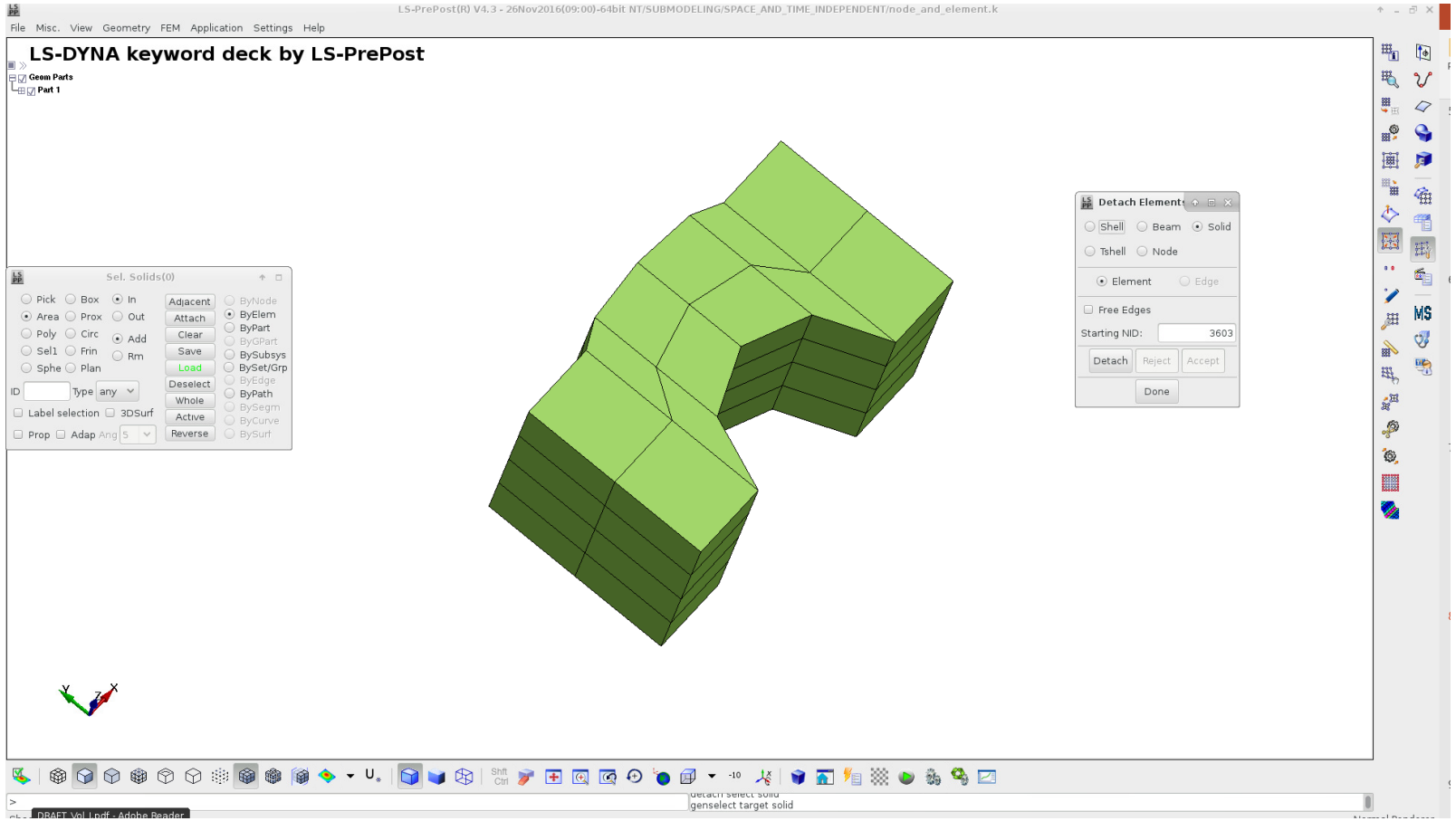
- Create sub-model
  - Open geo.k
  - Create shell elements from the solid boundary faces



Sub-modeling in LS-DYNA

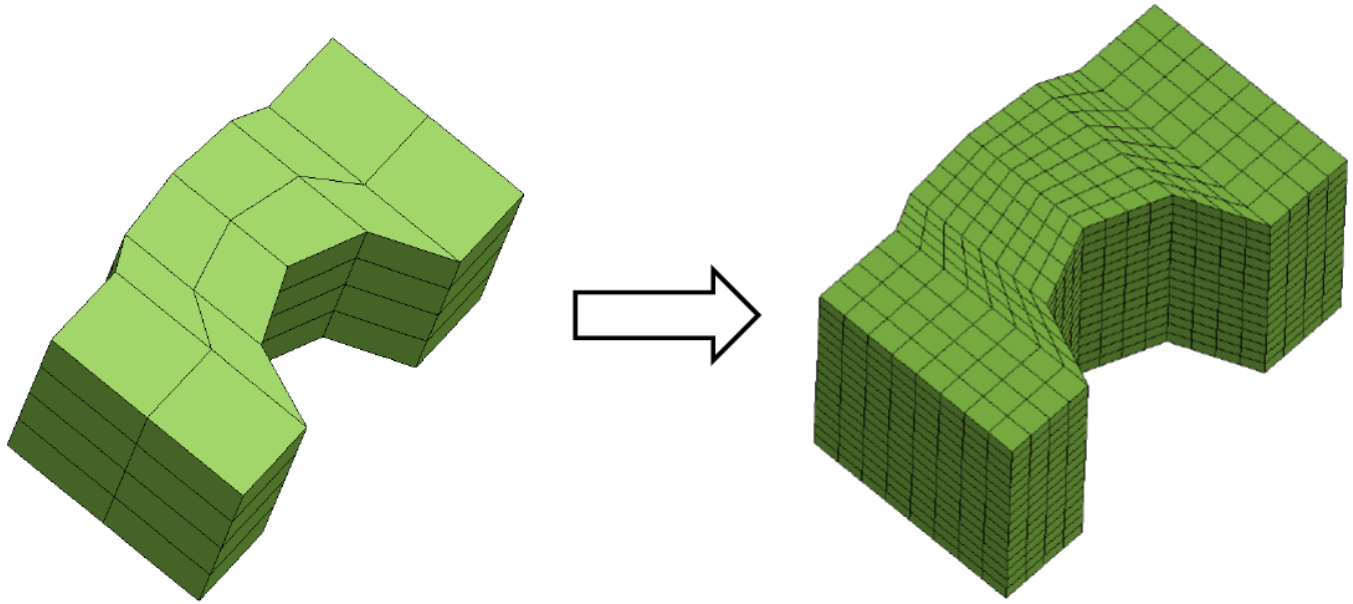
- Using direct d3plot results
- Create sub-model
  - Detatch shells from solids

To make sure that the node numbering on the master side does not change one select to detatch the slave part.



Sub-modeling in LS-DYNA

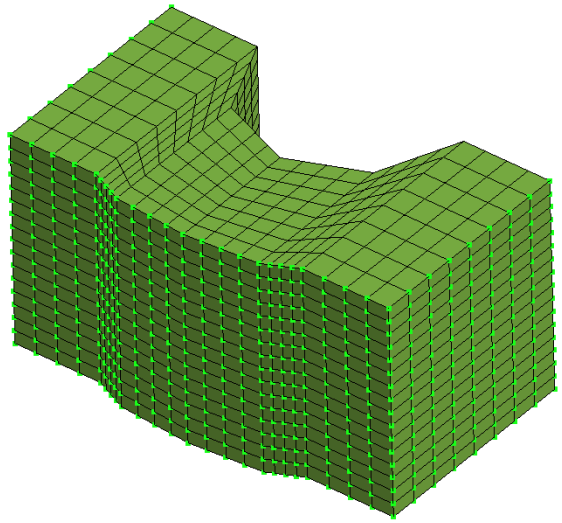
- Using direct d3plot results
- Create sub-model
  - Make changes



Sub-modeling in LS-DYNA

- Using direct d3plot results

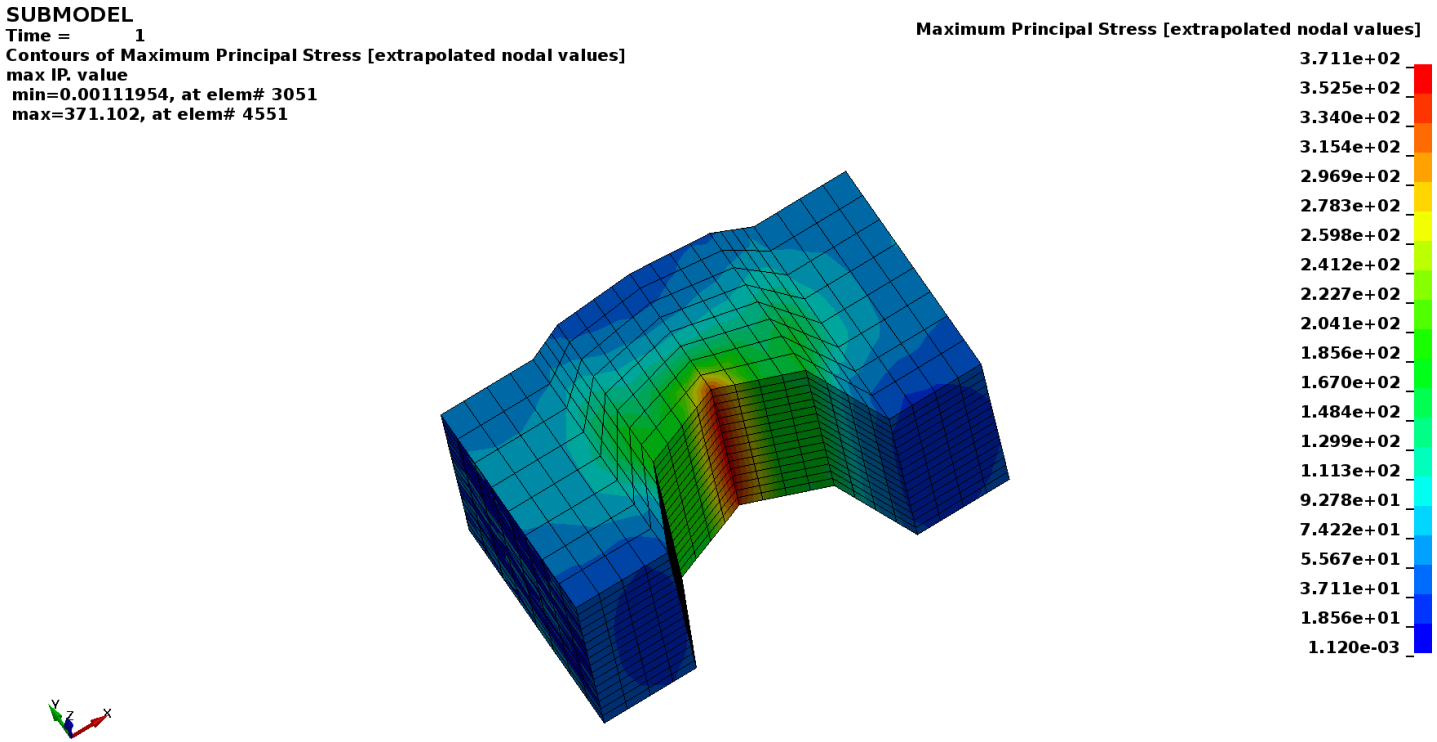
- Create sub-model
  - Define tied contact



Sub-modeling in LS-DYNA

- Using direct d3plot results

- Create sub-model
  - Complete the set-up as usual
  - Include the WrBPM.k-file
  - Run the sub-model



More information

DYNAmore Nordic AB customer support: support@dynamore.se

Public LS-DYNA example models: www.dynaexamples.com

Public LS-DYNA FAQ: www.dynasupport.com

Conference paper download: www.dynalook.com

Thank you!

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