



Model checking in LS-DYNA - from pre to post simulation

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Document information

Doc. no.:

Revision: 1

Prepared for: Webinar

Project no.:

Approved by:

Release date: 2020-04-16

Distribution: Approved for public release

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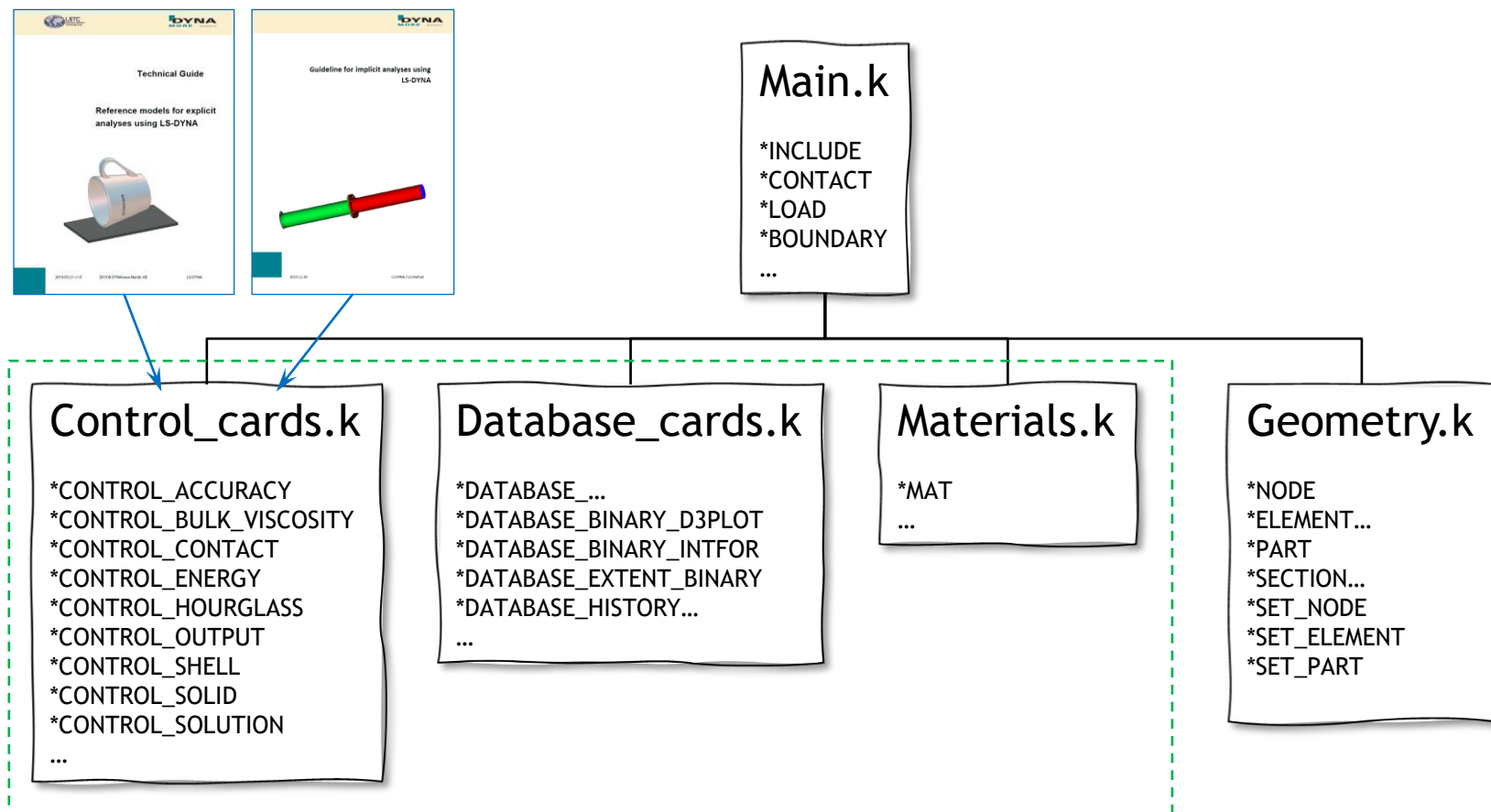
Example: Finding errors on a cab model used for ROPS evaluation.



Introduction

- Why do we perform model checking?
 - Make sure that we get correct and consistent results.
 - Save time.
- This webinar aims to do the following
 - Recommend a good practice by which the number of errors from start to finish in the project are minimized.
 - Give an overview of the current model checking tools that exist in the softwares that we provide.
 - Point at some simulation/modelling errors that are not found by the model checkers.

Suggested modelling structure



Rarely changed ⇒

- Few errors are introduced.
- All normal results are always available.
- Prepared settings for different types of analyses.

Loading your model in preprocessor

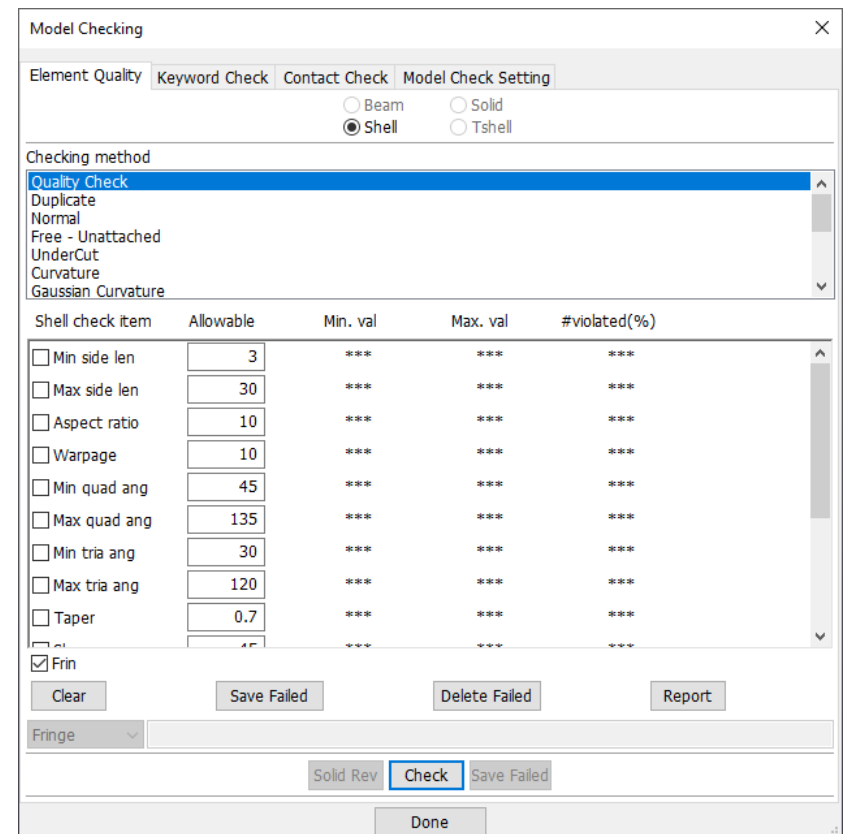
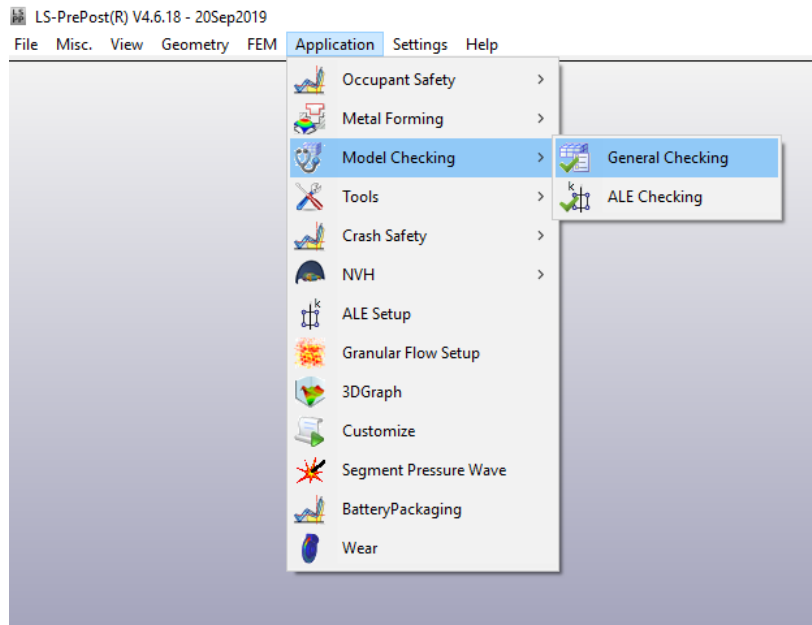
- When your model is loaded in a preprocessor, some basic checks are performed.
 - Wrong formatting of keywords
 - Unrecognized keywords
 - Duplicate keywords, nodes, elements, etc.
 - Include files not found
 - Node set not found
 - TAB character exist in keyword
 - ...
- Read all these messages and take necessary actions.
- Note! Encrypted files can not be read by any preprocessor. Therefore, this input data can not be checked either.

Tools for checking your model

- Different types of checkers (pre and post) are available in:
 - LS-PrePost
 - Primer
 - Ansa
 - DYNAtools
 - ...
- Many of the checking options are similar in LS-PrePost, Primer and Ansa
- Different tools could indicate different problems, e.g. different contact checkers can show different initial penetrations. Which one is correct then?
 - The answer is always: LS-DYNA. Updates/improvements on for instance contact treatment will cause the behavior to change between LS-DYNA versions. Model checkers in general don't care which LS-DYNA version you are running.

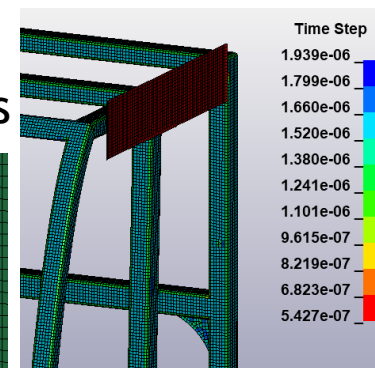
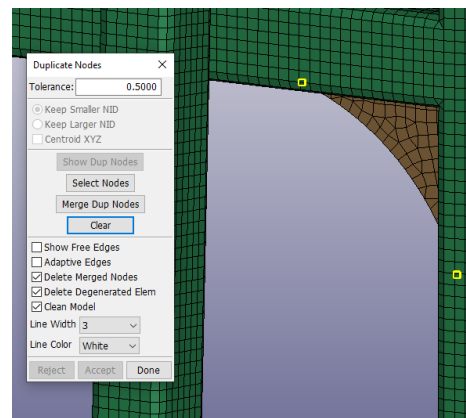
Model checker in LS-PrePost

- Accessed through the “Application” menu.
- Use late version for support of newer keywords. Current production version is 4.7 (development 4.8).



Model checker - element quality

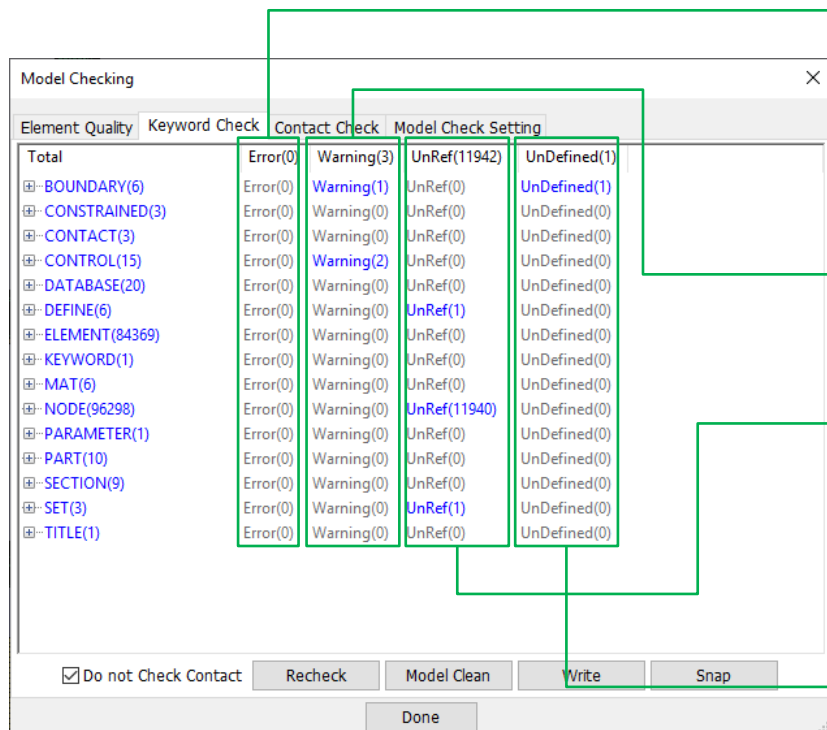
- Element quality may refer to many different things
 - Element shape
 - Element type
 - Connectivity of elements
 - Duplicate nodes?
 - Beams or shells connected to solids by sharing nodes?
 - Tied contacts for connecting parts, what about the rotational degrees of freedom?
- Element shape can be checked by the model checker
- Element type is recommended in DYNAmore Nordic guidelines
- Connectivity can be checked by
 - Duplicate nodes in LS-PrePost.
 - Tied contact checker in LS-PrePost.
 - Eigenvalue analysis.
 - Primer or Ansa.



Keyword checker

- Lists potential problems for all keywords in the model.

Possible meaning:



Error: Critical mistake that probably needs to be fixed.

Warning: Settings deviate from normal or default settings.

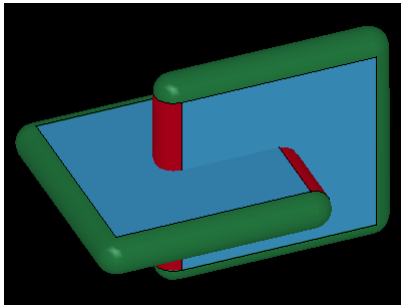
Unreferenced: Keyword not used in the current model.

Undefined: Missing entity in model, e.g. referenced curve.

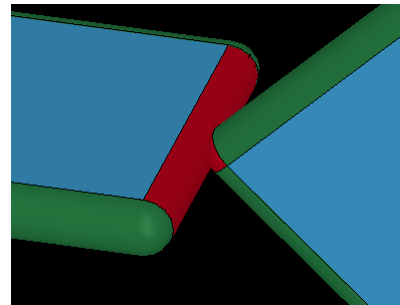
Note: A missing entity could be present in an encrypted include file.

Contact checker - penetration definitions

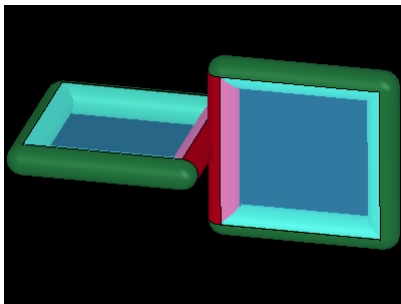
Crossed edges



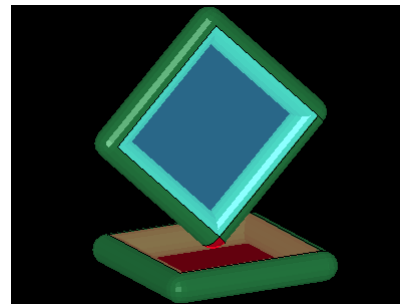
Node-to-edge penetration



Edge-to-edge penetration



Node-to-surface penetration



Contact checker

- Contacts may be checked one at a time or all at once.
- Tied contact may also be checked, showing which nodes that are tied and which are not.
- ByParts: Contact is checked without having to define contacts. The intention is to look for geometrical overlaps. The check fakes a single surface contact check (with SSTHK=0) and considers:
 - Thicknesses (taken from section cards).
 - Node-to-surface penetrations.
 - Free_edge-to-Free_edge penetrations.
 - Node-to-edge penetrations.
- Contact: This check also considers:
 - Parameters related to contact thicknesses.
(SST, MST, SFST, SFMT, SHLTHK, SLDTHK, SSTHK, OPTT, SFT, TH, TH_SF...)
 - Which entities that may come into contact.

The screenshot shows the 'Model Checking' dialog box with the 'Contact Check' tab selected. The 'Penet' radio button is chosen, and the 'Contact' radio button under 'ByParts' is also selected. The list of entities to be checked includes '1(19000001) AUTOMATIC_SURFACE_TO_SURFACE_MORTAR PSET 111 PART 1 (sub:1) Pusher to Cab' and '2(19000111) AUTOMATIC_SINGLE_SURFACE_MORTAR PSET 111 ALL 0 (sub:1) Cab internal contact'. The 'Show' section has 'CE' and 'Penet' checked, with 'Slave', 'Master', and 'Both' buttons. The 'SF' value is set to 1.0, and the 'Ignore <' value is 0.0. The 'Automatic Fixing' section has 'Lock Nodes' unchecked, 'Move' set to 100 % of penet, and 'Run' set to 4 iterations. The 'Manual Fixing' section has 'Flip Node' unchecked. At the bottom, there are 'Check', 'Fix', 'Undo', 'Write', and 'Done' buttons.

Model check setting

- Values for the checker can be set, saved and loaded.

Model Checking

Element Quality | Keyword Check | Contact Check | Model Check Setting

General:

Gen thick: 0.5

Fabric thick: 0.25

Beam thick: 0

CT(BSORT): 3

CT(SFS): 1

CT(SFM): 1

3Node Ang: 1

Spot min len: 0.5

Spot max len: 8

CR(DTMIN): 0

DE_CURVE(a1): 0

DE_CURVE(o1): 0

DE_CURVE(pt): 1000

MA_SW(SIGY): 0

☒ BeamFix 1.1

ALE:

CR_ALE(AFAC): -1

CR_ALE(WF): 0

CR_TIMESTEP: 0

Element Quality:

Shell:

Min Len: 3 Max Len: 30

Ratio: 10 Warpage: 10

MinQ Ang: 45 MaxQ Ang: 135

MinT Ang: 30 MaxT Ang: 120

Taper: 0.7 Skew: 45

Jacob: 0.6 Chr Len: 1

Area: 5 Feat Ang: 30

Step: 1e-06

Solid/Tshell:

Min Ang: 5 Max Ang: 175

Distortion: 10 Chr len: 0

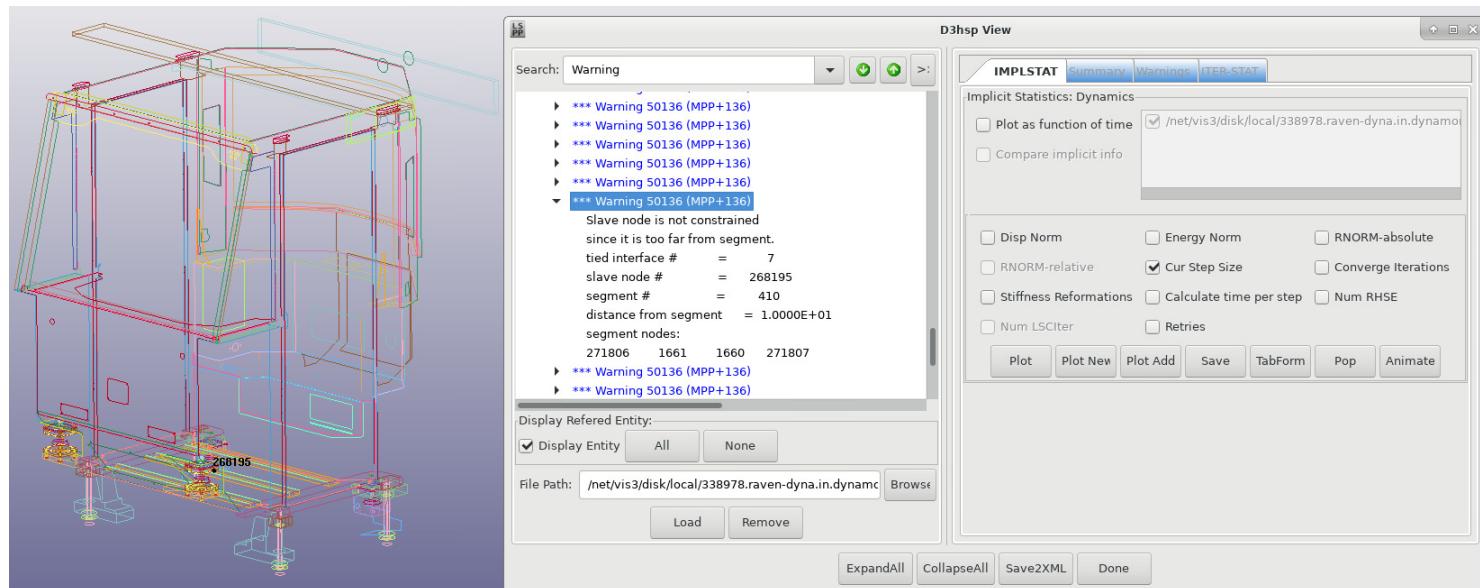
Ratio: 10 Volume: 0

Apply Savepre Loadpre

Done

What does LS-DYNA say? / d3hsp viewer

- Search for Warnings/Errors in all message files and d3hsp.
- I have seen own scripts being used for:
 - fringing contact penetrations
 - creating sets of entities with problems for display purposes
- With d3hsp viewer in LS-PrePost
 - Different parts of the d3hsp file is available in groups
 - Easier to scroll through content and look at all Warnings
 - Highlight things on the model that are problems (blue text only)



What to check for in post-processing

■ Mass increase

- Available as “added mass” in *DATABASE_GLSTAT.

■ Energy balance and strange energies

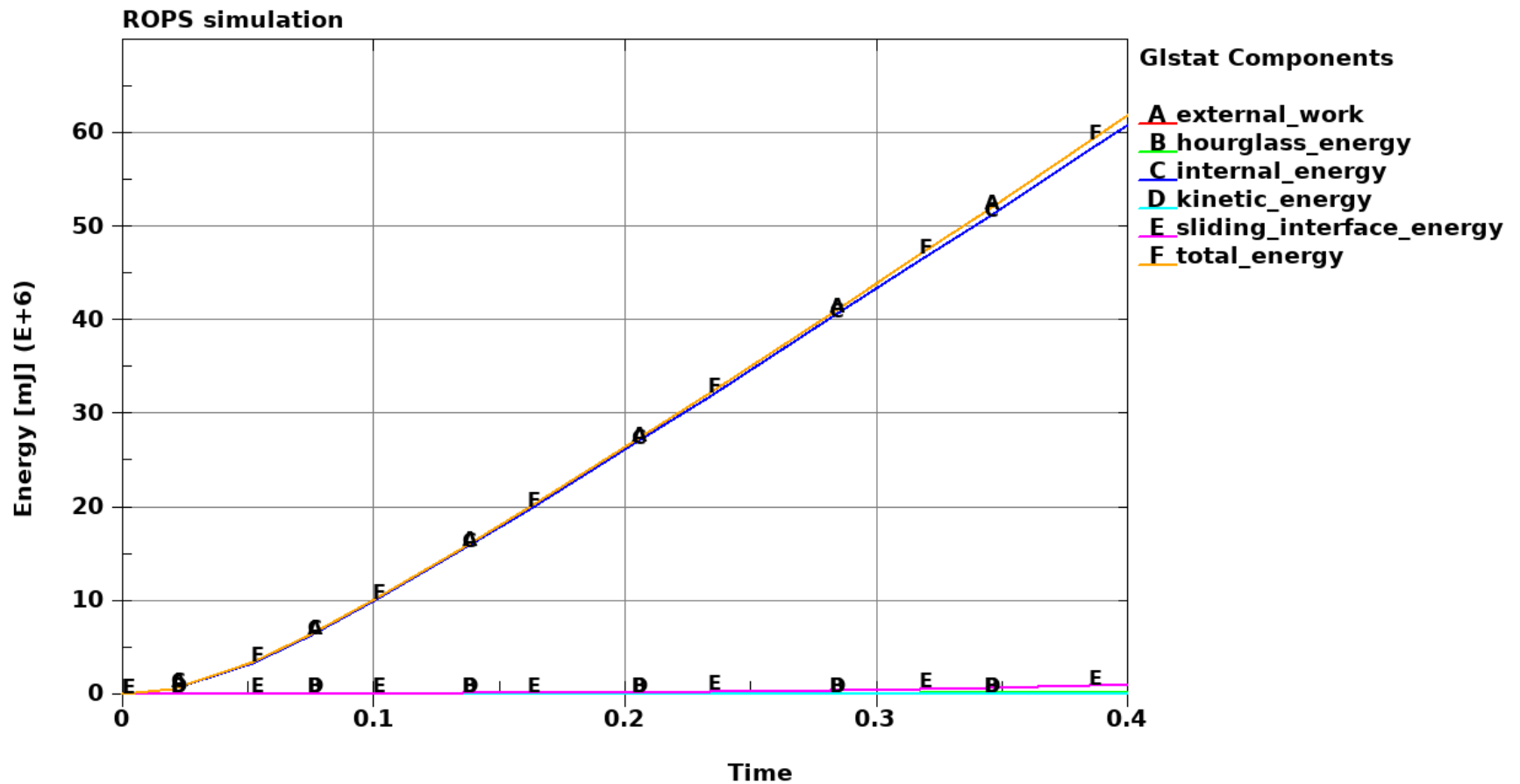
- Switch on output of all energies on *CONTROL_ENERGY, e.g. set HGEN=2 (not default).

$$\underbrace{E_{kin} + E_{int} + E_{si} + E_{rw} + E_{damp} + E_{hg}}_{E_{total}} = E_{kin}^0 + E_{int}^0 + W_{ext}$$

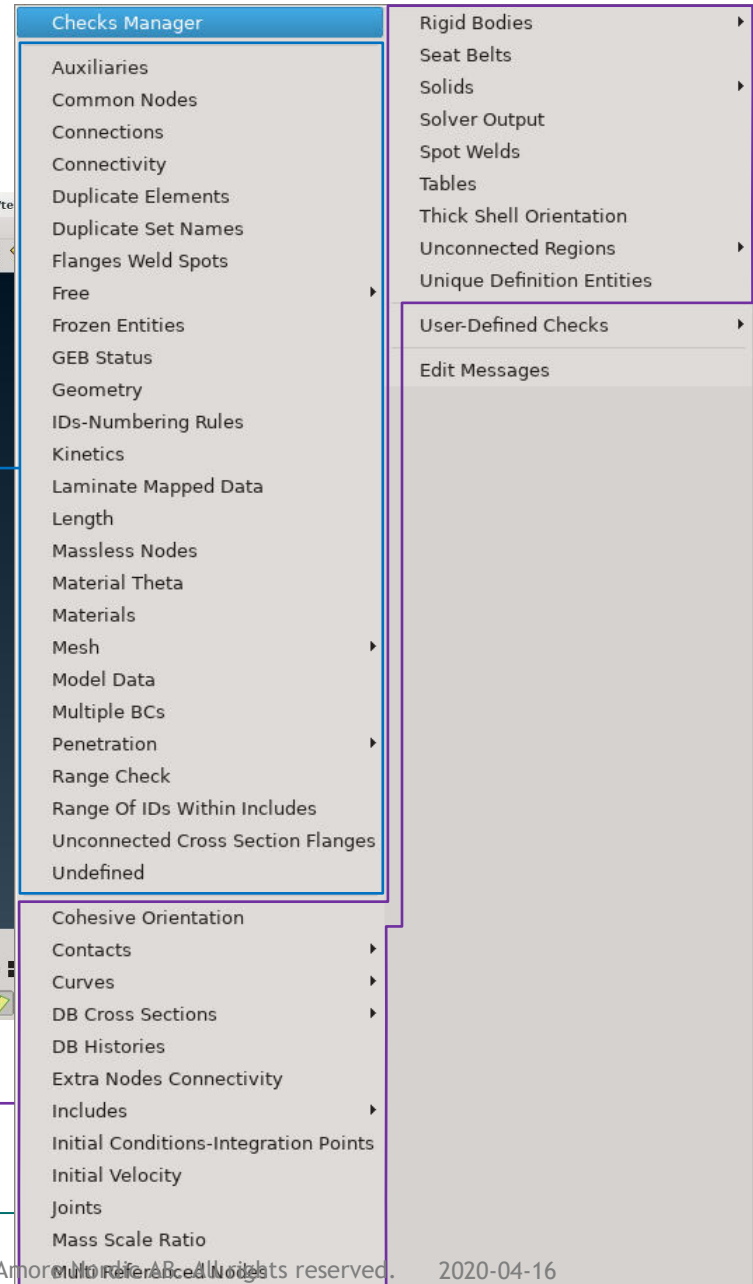
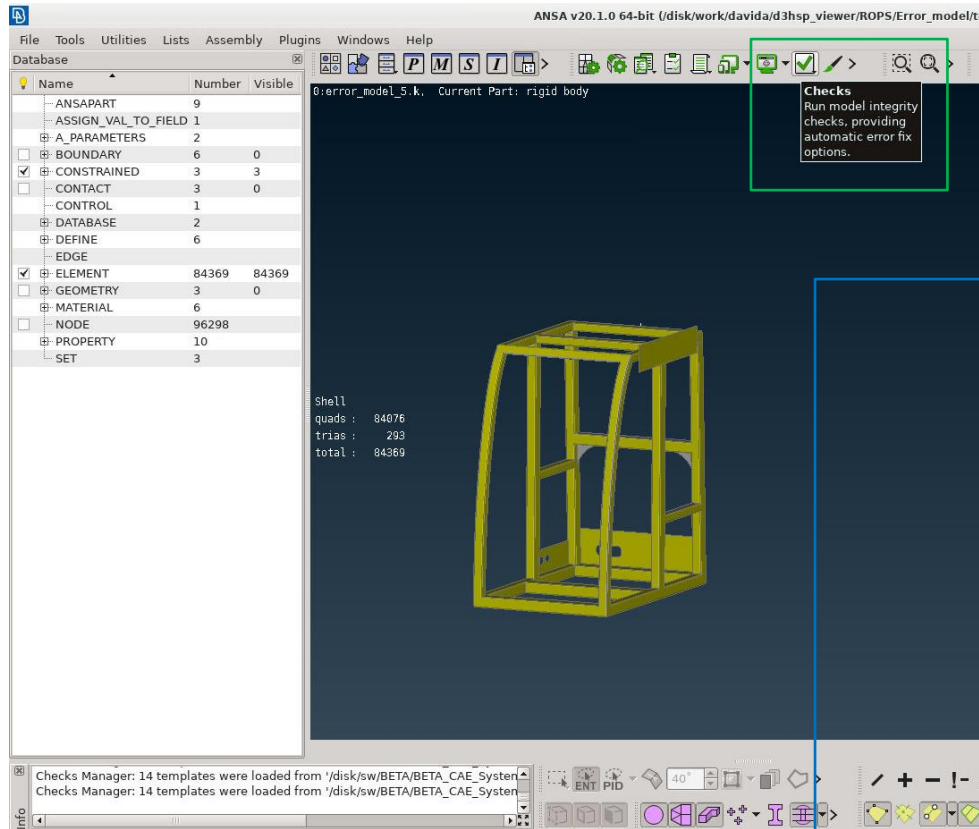
E_{kin}	= current kinetic energy
E_{int}	= current internal energy
E_{si}	= current sliding interface energy (including friction)
E_{rw}	= current rigid wall energy
E_{damp}	= current damping energy
E_{hg}	= current hourglass energy
E_{kin}^0	= initial kinetic energy
E_{int}^0	= initial internal energy
W_{ext}	= external work

Energy balance in example model

- Successful implicit ROPS simulation (lateral loading).



Ansa model check

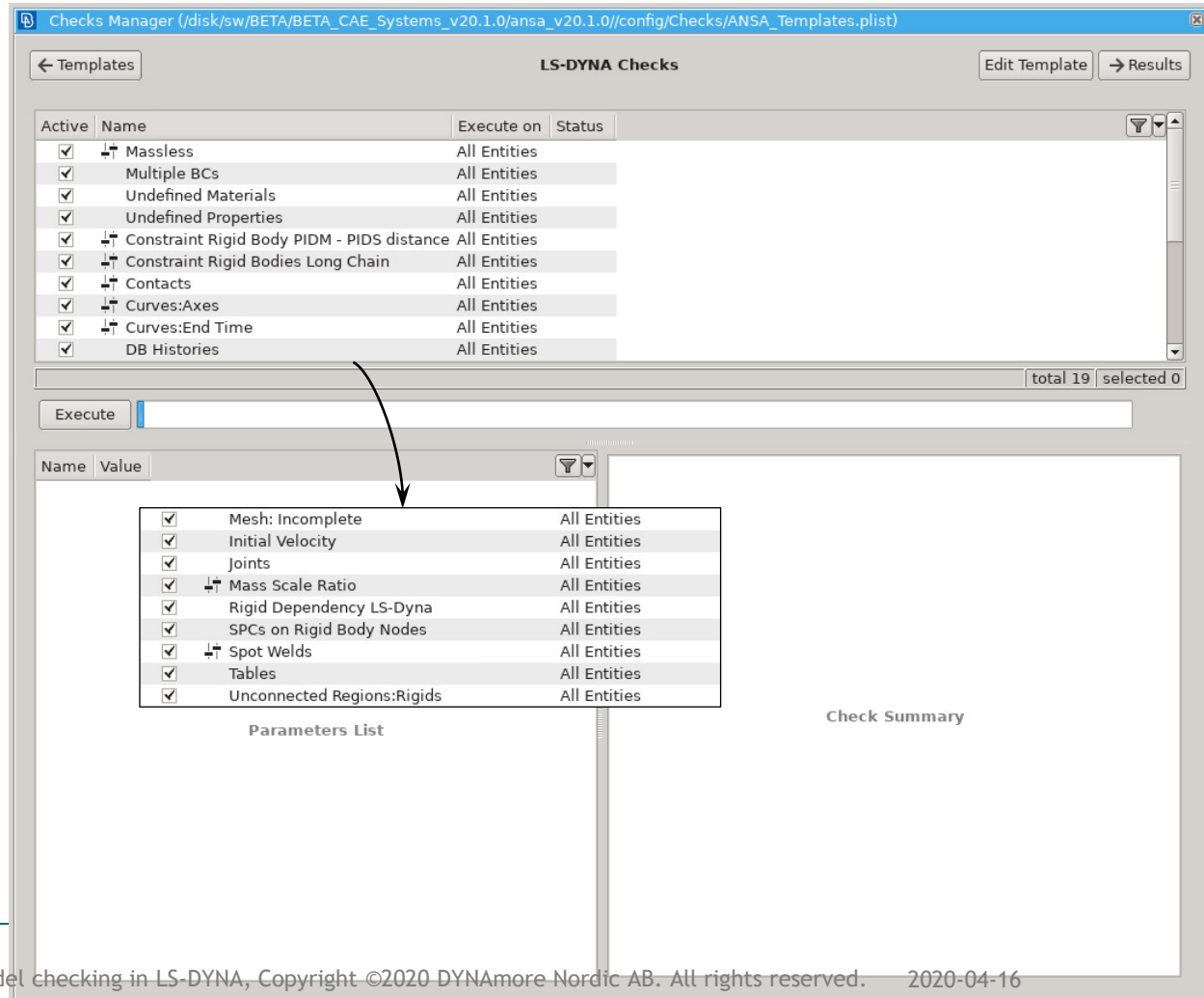


General checks

LS-DYNA specific checks

Ansa Checks manager

- A group of selected checks can be performed simultaneously, a suggestion of LS-DYNA checks is prepared.



Selection of Ansa model checks (Chapter 21 in Ansa manual)

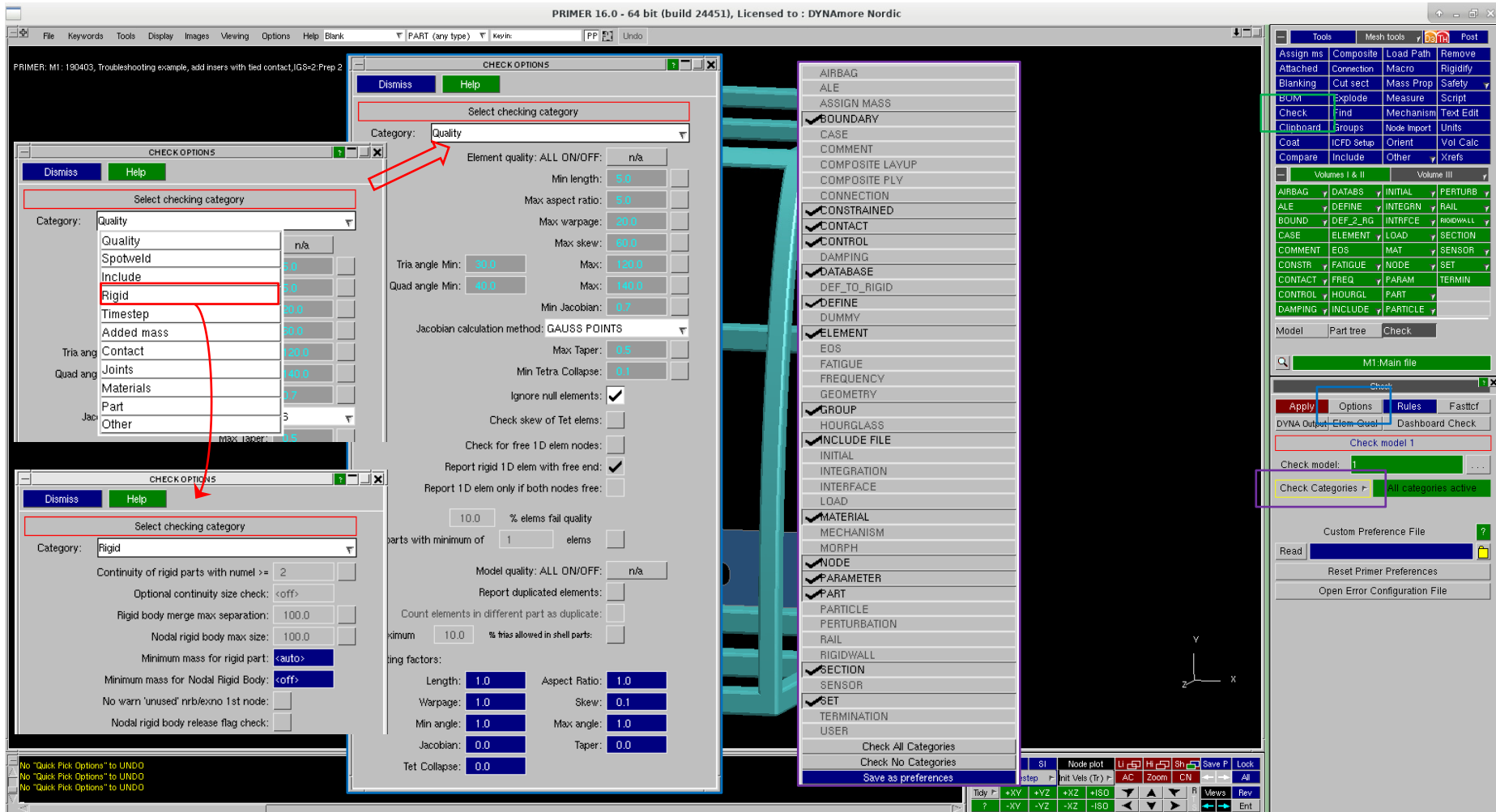
- Check > Connectivity - Detect unconnected assemblies
- Rigid bodies in LS-DYNA (more info on next slide)
- Check contacts from solver (only for tied contacts so far)
- Unconnected regions (same property but disjoint volumes) - RIGID BODIES!
- Joint check
 - Are nodes rigid/deformable? Do nodes of joint belong to the correct parts or perhaps several parts? Do the nodes coincide? Perpendicularity/colinearity of vectors defined by the nodes (depends on joint type)?
- Constrained extra nodes check (too far from rigid body?)
- Database cross section check
- PIDM-PIDS distance (constrained rigid bodies distance too long?)

Ansa model check - rigid bodies in LS-DYNA

- Node belonging to two or more different parts.
- Node belonging to two or more different nodal rigid bodies.
- Node belonging to a rigid part and a nodal constraint set.
- Node belonging to two or more different constrained extra nodes.
- Node having the same degree of freedom constrained in more than one set.
- Node belonging to a constrained extra node and a rigid part.
- Node belonging to a constrained extra node and a nodal constraint set.
- Collapsed nodal rigid bodies (or nodal constraint sets generally), initially created on sets of nodes that belonged to a part which has been deleted.
- *CONSTRAINED_EXTRA_NODES, *LOAD_RIGID_BODYs or *CONSTRAINED_RIGID_BODIESs that are associated with deformable part.
- Seatbelt accelerometers, retractors and slings that are connected to deformable elements.
- Boundary Prescribed Rigid Motion that is associated with deformable part.
- "Slave" rigid bodies with more than one "master".

Primer model checker

- To run: Check -> Options -> Check Categories -> Apply



Primer model checker - results

- Results are presented in a tree-structure.

PRIMER 16.0 - 64 bit (build 24451), Licensed to : DYNAmore Nordic

PRIMER: M1: 190403, Troubleshooting example, add inners with tied contact, IGS=2, Prep 2

ERROR [4]

- PRESCRIBED_MOTION [1]
 - BPRM: Loadcurve <lcid> referenced but not defined (1)
 - 5 (M1/BPRM5)
- CONTACT [2]
 - F Constrained TIED/SPOTWELD contact contains rigid part(s) (1)
 - 4 (Tied contact back plate to frame)
 - Opt card A: <SBOPT> only valid <SOFT> = 2 (4)
 - 4 (Tied contact back plate to frame)
 - 19000001 (Pusher to Cab)
 - 19000003 (Tied contact)
 - 19000111 (Cab internal contact)
- DEFINE_CURVE [1]
 - DEFINE_CURVE referenced but not defined (1)
 - 1005 A1/LC1005

WARNING [5]

- CONTACT [1]
 - F Unexpected non zero <SBOPT> when SOFT.ne.2 : Set parameter SBOPT to 0 on contact (4)
 - 4 (Tied contact back plate to frame)
 - 19000001 (Pusher to Cab)
 - 19000003 (Tied contact)
 - 19000111 (Cab internal contact)
- CONTROL [1]
 - Omitting populated data field <ncdof> from "CON"
 - M1/CONTROL_SOLUTION
- NODE [2]
 - Node has no structural cross references (can be)
 - F Constrained extra node is massless : Delete Node
 - 3713720 (M1/N3713720)
 - 3713721 (M1/N3713721)
- PART [1]
 - Prescribed motion X on rigid part (t=0) but missing node initial velocity (1)
 - 1 (Load distributing device)

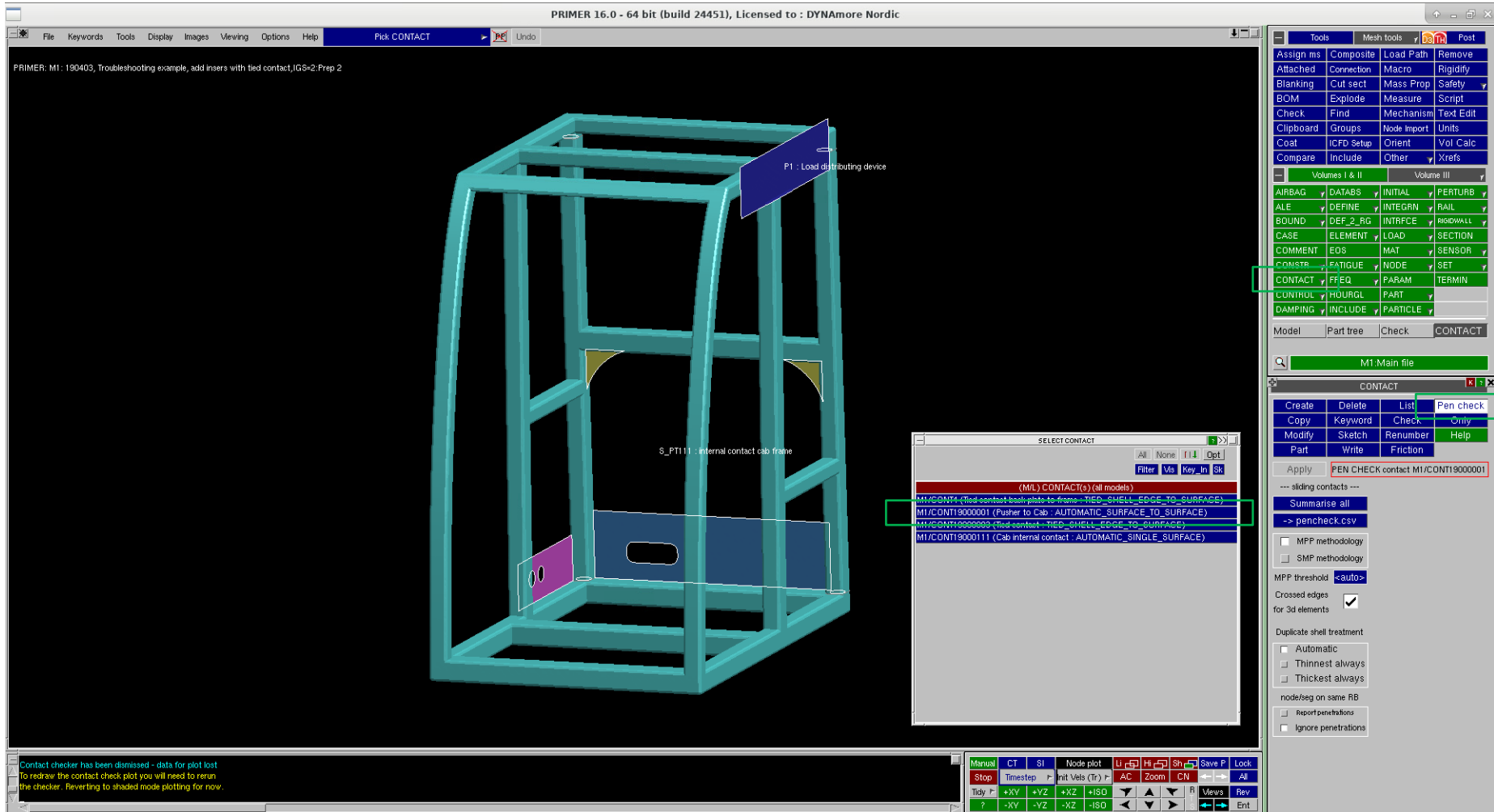
Entity type counts:

Entity type	(No.)	# errors	# warn	# fixable
BOUNDARY	6	1	0	0
CONSTRAINED	3	0	0	0
CONTACT	4	5	4	5
CONTROL	15	0	1	0
DATABASE	20	0	0	0
DEFINE	7	1	0	0
ELEMENT	84369	0	0	0
GROUP	1	0	0	0
INCLUDE FILE	1	0	0	0
MATERIAL	6	0	0	0
NODE	96441	0	11942	2
PARAMETER	2	0	0	0
PART	11	0	1	0
SECTION	9	0	0	0
SET	3	0	0	0

Errors usually indicate a model that will not initialize within LS-DYNA or will be of poor quality. Warnings are indications of bad modelling practice and/or integrity.

Primer contact check

- Defined contacts can be checked individually or all at once...



Primer contact check

- ...and visualized in different ways.



Selection of Primer model checker features

■ Pre-analysis checking, e.g.

- Contour plot of Density, Yield stress, Poisson's ratio, Young's modulus and Material number (e.g. 20 for *MAT_RIGID).
- Checks can be switched on, e.g.
 - Check for large CNRBs.
 - Distance between volumes that make up one rigid body is too large.
 - Duplicated elements, elements that share nodes and part definition.
 - ...
- Using “attached” recursively can help to find unattached things in the model.
- Do not perform model check on, or limit to, selected includes.
- Visualization of friction coefficients between entities.
- Ability to set LS-DYNA version that model will be run with.

■ Checking during the analysis

- Read LS-DYNA output files and highlight selected entities (see next slide).

■ Post-analysis checking

- Using REPORTER: Automatically create a report showing an energy balance plot, added mass, etc. with a script.

Highlighting from output data

The screenshot displays the LS-DYNA software interface. The main window shows a 3D model of a car frame. A 'Dyna output file viewer' window is open, displaying a list of time steps. The 'Smallest Timesteps [2500]' section is highlighted, showing a list of time steps with their corresponding element IDs and time values.

Element ID	Time (d3hsp)
-shell 102145	100002 5.4270E-07
-shell 102145	100002 5.4270E-07 (mes0014)
-shell 102144	100002 5.4801E-07 (d3hsp)
-shell 102144	100002 5.4801E-07 (mes0013)
-shell 102304	100002 5.4922E-07 (d3hsp)
-shell 102304	100002 5.4922E-07 (mes0013)
-shell 102225	100002 5.5285E-07 (mes0013)
-shell 102225	100002 5.5285E-07 (d3hsp)
-shell 174600	100006 6.5049E-07 (mes0015)
-shell 174600	100006 6.5049E-07 (d3hsp)
-shell 181017	100006 6.5049E-07 (mes0017)
-shell 181017	100006 6.5049E-07 (d3hsp)

The 'Dyna output file viewer' window also includes a 'Read Dyna' section with a 'Read Dyna output' button and a 'Dyna file directory' field set to 'BOPS/Error_model/IMPL'. The 'Output files found' section lists several files, including 'd3hsp', 'mes0000', 'mes0001', 'mes0002', 'mes0003', 'mes0004', 'mes0005', 'mes0006', 'mes0007', and 'mes0008'.

Did you know...?

- Both LS-PrePost and Primer can load two versions of the same model and highlight differences.

LS-PrePost(R) V4.8 (Beta) - 06Apr2020(15:10)-64bit sk/work/davida/d3hsp_viewer/ROPS/Error_model/error_model.key

File Misc. View Geometry FEM Application Settings Help

190403, Troubleshooting example, add inserts with tied contact,IGS=2:Prep 2

Assembly 1
FEM Parts
Keyword Entity
Boundary
Contact
Define
Set

Model Compare

Summary Info Common Keywords Model1 only Model2 only

Keyword count : 1
Keyword ID range : 12 To 12

Field #1	Field #2	Field #3	Field #4	Field #5	Field #6	Field #7	Field #8	Field #9
Card #0	SLSFAC	RWPNAL	ISLCHK	SHLTHK	PENOPT	THKCHG	ORIEN	ENMASS
Value 1	0.100000	0.0	2	0	0	1	0	0
Value 2	0.100000	0.0	2	0	0	1	0	0
Card #1	USRSTR	USRFRC	NSBCS	INTERM	XPENE	SSTHK	ECDT	TIEDPRJ
Value 1	0	0	0	0	0.0	0	0	0
Value 2	0	0	0	0	0.0	0	0	0
Card #2	SFRIC	DFRIC	EDC	VFC	TH	TH_SF	PEN_SF	
Value 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Value 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

ViewAll Draw Keyword 1 Keyword 2

WriteSummary WriteDetail Done

Model Selection

Select Compare

1:190403, Troubleshooting example, add in
2:190403, Troubleshooting example, add in

Keyword
D3PLOT

1st Model 2nd Model
1 2

Compare

Type: Stress

Components Name:
x-stress
y-stress
z-stress

State:

Fringe Diff

Done

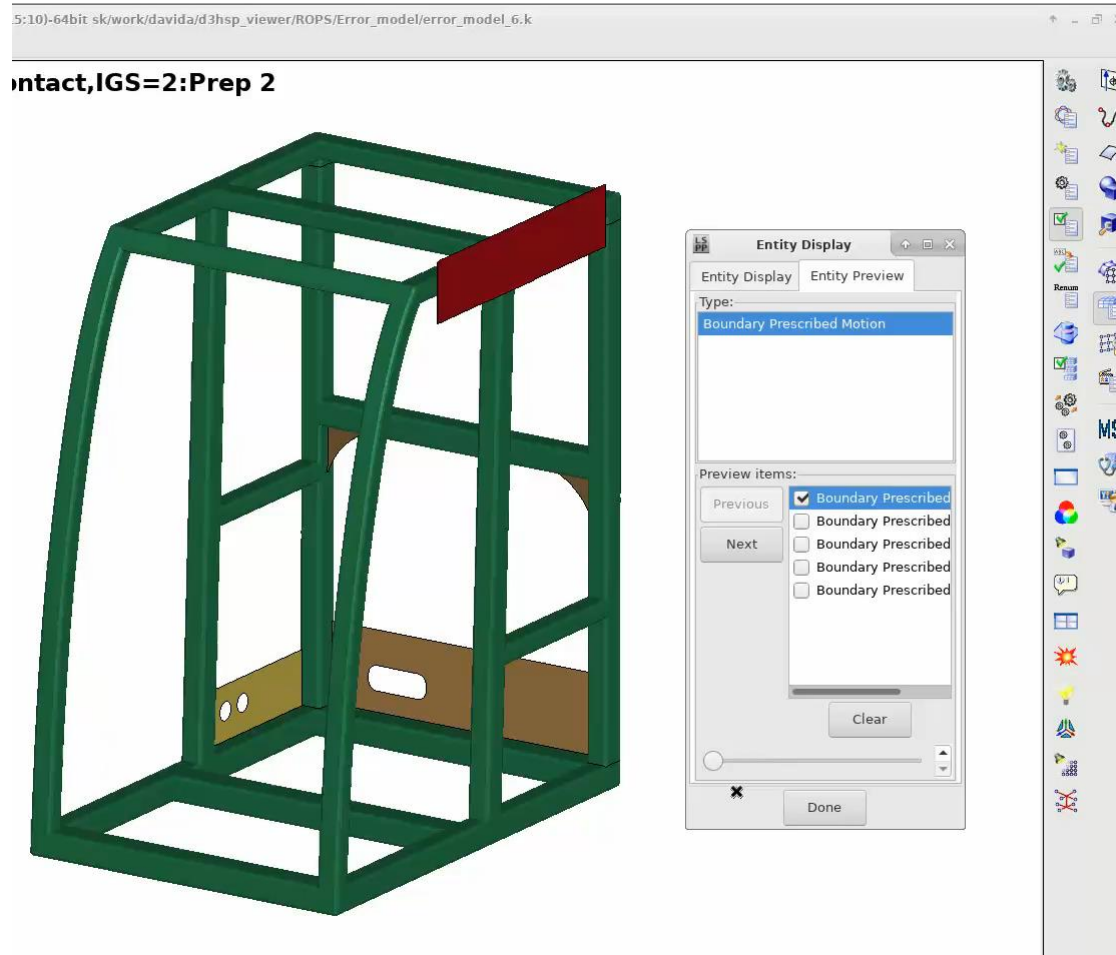
Model Selection

kwcmp compare 12

Fast Renderer

Did you know...?

- In LS-PrePost, prescribed rigid body motions can be visualised before the simulation.



Potential errors not captured by model checkers

- Have you used consistent units throughout your model?
 - Are the shell thicknesses correct?
 - Are the material directions correct?
 - Are the orthotropic friction directions correct?
 - Are the connections correct? Beams and shells connected to solids?
 - Perform a visual inspection of your results.
 - Realistic deformation?
 - Contact releases or malfunctions?
 - Realistic plastic strains?
 - ...
 - Is the applied modelling technique a good representation of the real physics?
 - Are your rigid bodies really rigid?
 - Do your boundary conditions affect the results?
 - Are your material models calibrated and valid?
 - Is the applied friction feasible?
 - Mesh convergence?
 - Inappropriate control card settings. Remedy: Read DYNAmore guidelines.
- } Visualize in preprocessor.

Summary

- Follow modelling guidelines, either your own or DYNAmore Nordic provided recommendations.
- Run some form of checks before simulation of your model.
 - Manually using your preferred softwares.
 - In batch mode (Ansa, Primer, using scripts, etc.).
- Consider all Warning messages given in the output files.
- In post-processing, check for mass increase and energy balance.

Further reading

- <https://www.dynalook.com/conferences/15th-international-ls-dyna-conference/modeling/getting-your-model-2018right2019-2013-checking-before-during-and-after-your-ls-dyna-r-analysis/view>
(Primer conference paper)
- Primer checking tutorial: <https://www.youtube.com/watch?v=4pSrZ9cAdbY>
- 2020-02-18 DYNAmore Nordic Webinar:
Jointing techniques between shell and solid elements
- 2020-02-25 DYNAmore Nordic Webinar:
Troubleshooting convergence problems in LS-DYNA implicit

Thank you!

