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

David Aspenberg, PhD
DYNAmore Nordic AB

Document information

Doc. no.:
Revision: 1
Prepared for: Webinar
Project no.:
Approved by:
Release date: 2020-04-16
Distribution: Approved for public release

DYNAmore Nordic AB
Brigadgatan 5
SE-587 58 LINKÖPING
Sweden

Org. no. 556819-8997
EC VAT: SE556819899701

Phone: +46 (0)13 236680
Fax: +46 (0)13 214104
E-mail: info@dynamore.se
Web: www.dynamore.se

Contents

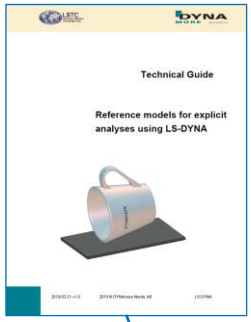
- Introduction
- Suggested modelling structure
- Loading your model in preprocessor
- Tools for checking your model
- LS-PrePost tools
  - Model checker
  - Model compare
  - d3hsp viewer
    - d3hsp output – warnings etc.
    - Implicit convergence plot
- Ansa and Primer model checkers
- Did you know…?
- Potential errors not captured by model checkers
- Summary
- Further reading

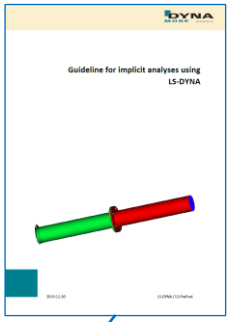
Example: Finding errors on a cab model used for ROPS evaluation.

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





Main.k

*INCLUDE
*CONTACT
*LOAD
*BOUNDARY
…

Control_cards.k

*CONTROL_ACCURACY
*CONTROL_BULK_VISCOSITY
*CONTROL_CONTACT
*CONTROL_ENERGY
*CONTROL_HOURGLASS
*CONTROL_OUTPUT
*CONTROL_SHELL
*CONTROL_SOLID
*CONTROL_SOLUTION
…

Database_cards.k

*DATABASE_…
*DATABASE_BINARY_D3PLOT
*DATABASE_BINARY_INTFOR
*DATABASE_EXTENT_BINARY
*DATABASE_HISTORY…
…

Materials.k

*MAT
…

Geometry.k

*NODE
*ELEMENT…
*PART
*SECTION…
*SET_NODE
*SET_ELEMENT
*SET_PART

Rarely changed $\Longrightarrow$

- 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.

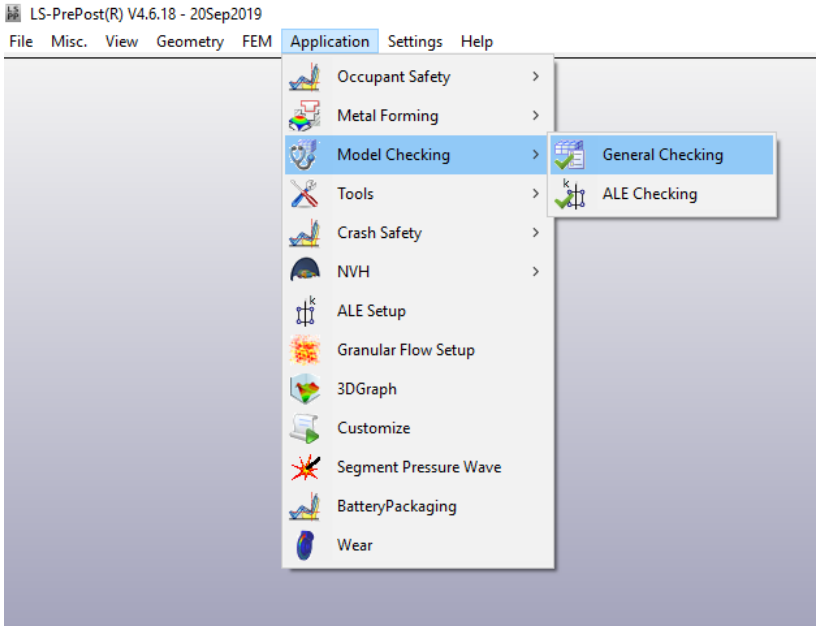
- Note! Encrypted files can not be read by any preprocessor. Therefore, this input data can not be checked either.

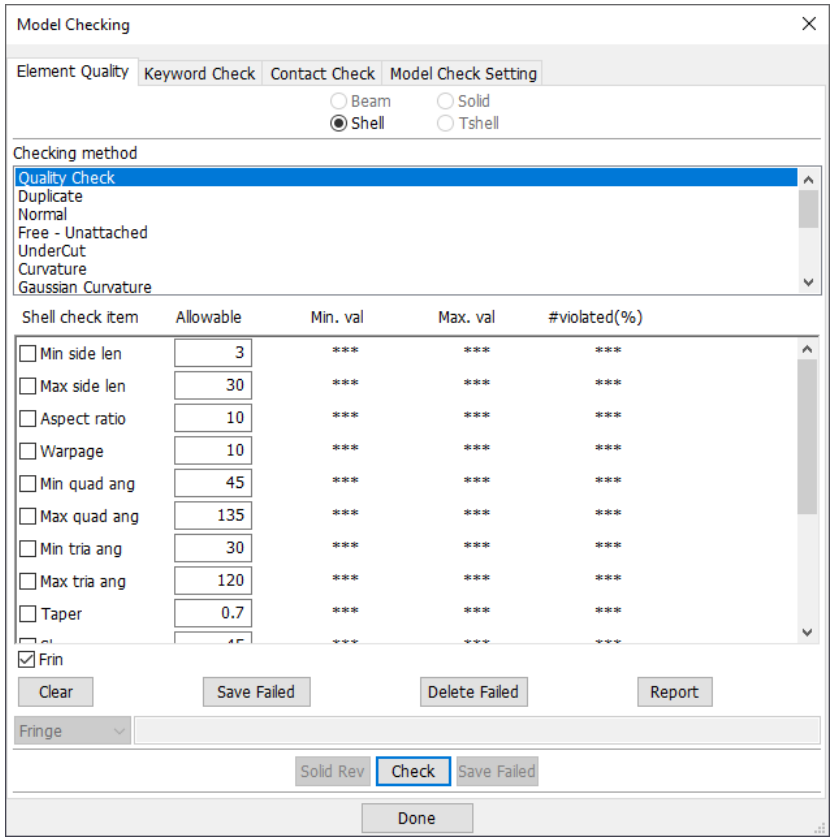
Tools for checking your model

- 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

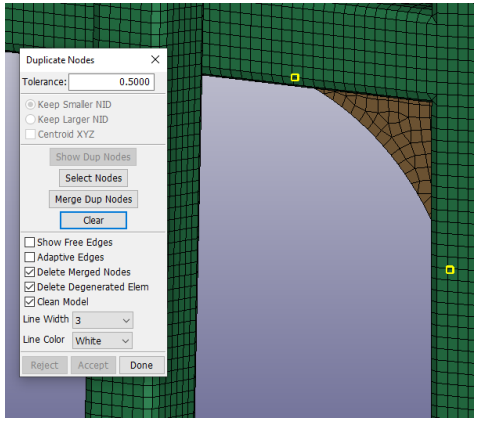
- Accessed through the “Application” menu.
- Use late version for support of newer keywords. Current production version is 4.7 (development 4.8).

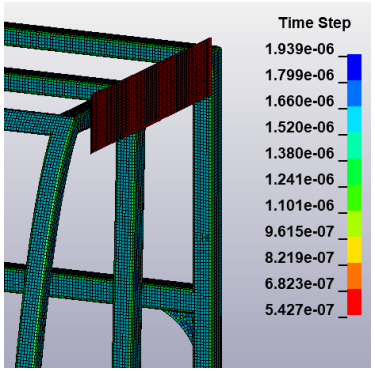




Model checker – element quality

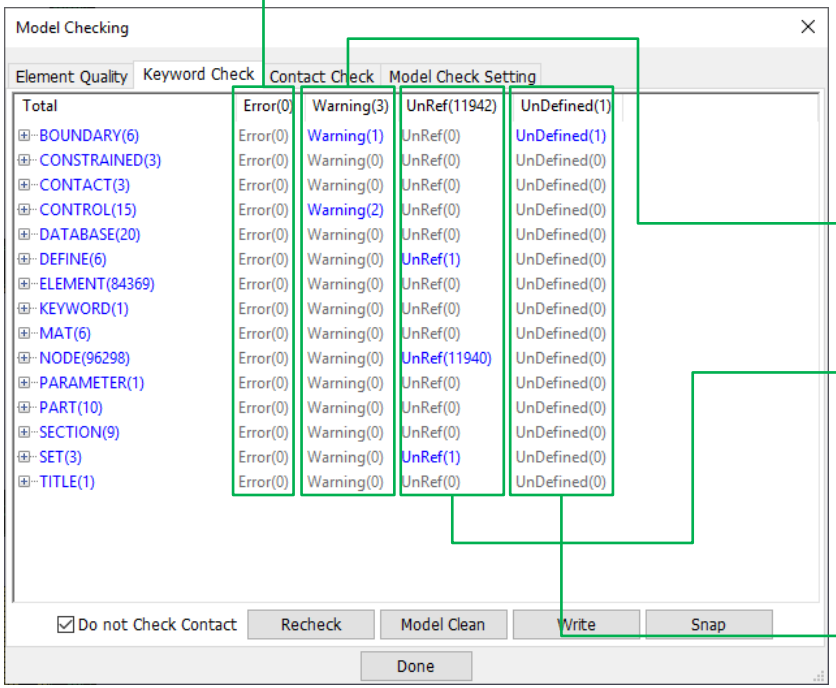
- Element quality may refer to many different things
  - Element shape
  - Element type
  - Connectivity of elements
    - Duplicate nodes?
    - Beams or shells connected to solids by sharing nodes?
    - Tied contacts for connecting parts, what about the rotational degrees of freedom?
- Element shape 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.

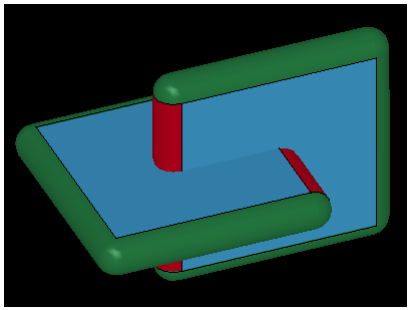
Unreferenced: Keyword not used in the current model.

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

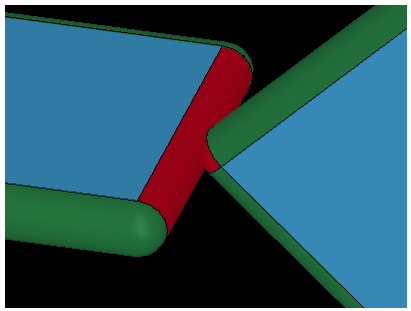
Note: A missing entity could be present in an encrypted include file.

Contact checker – penetration definitions

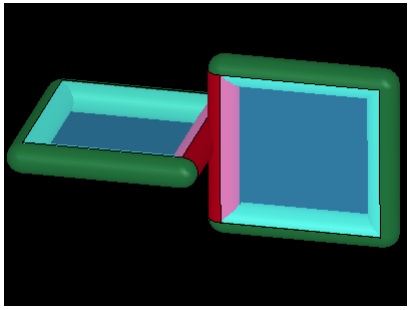
Crossed edges



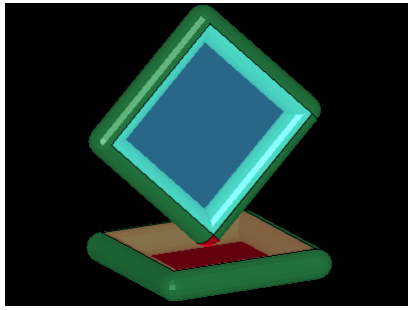
Node-to-edge penetration



Edge-to-edge penetration

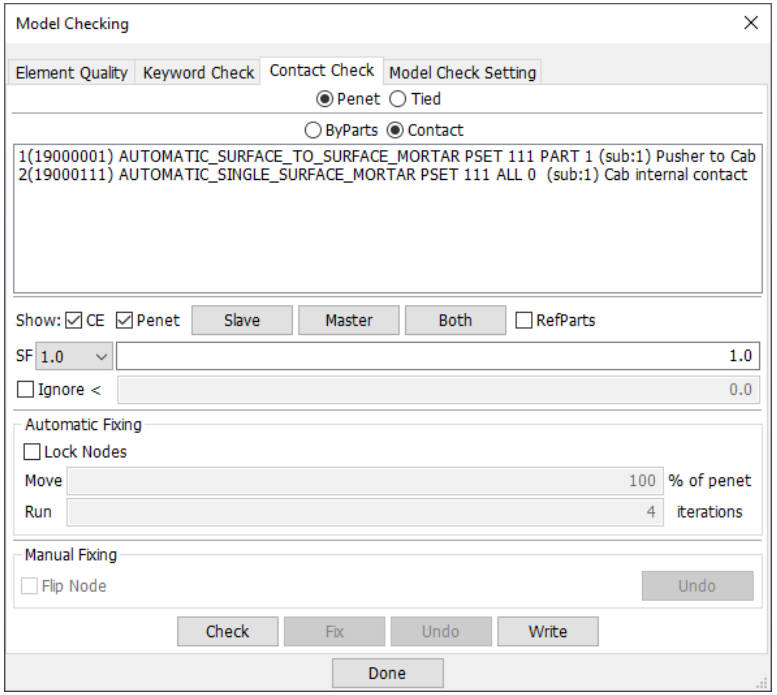


Node-to-surface penetration



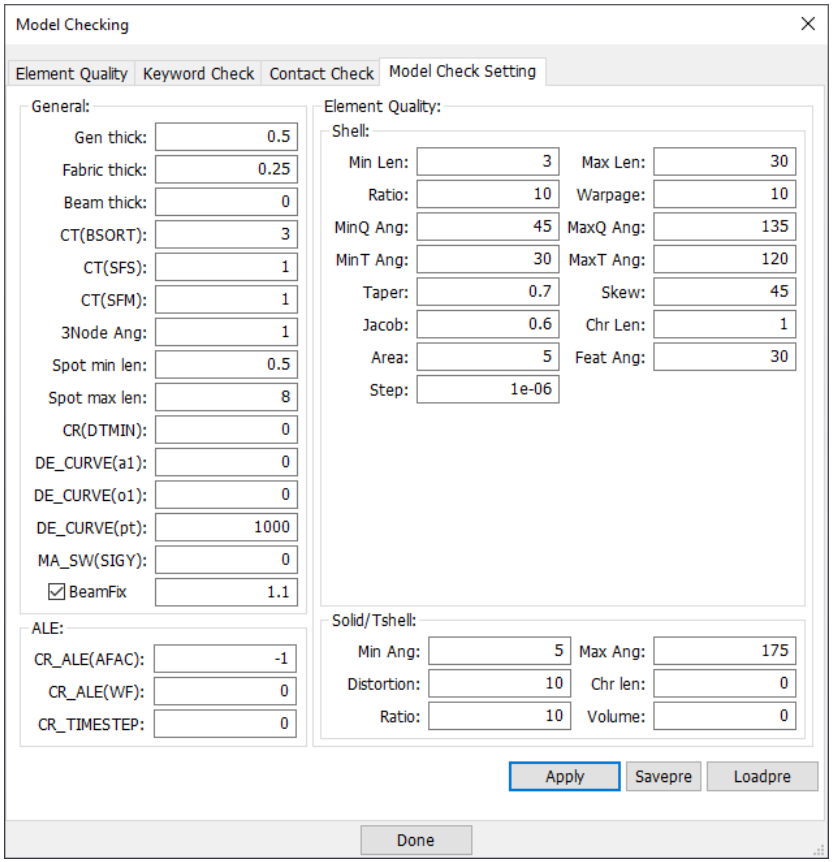
Contact checker

- 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.



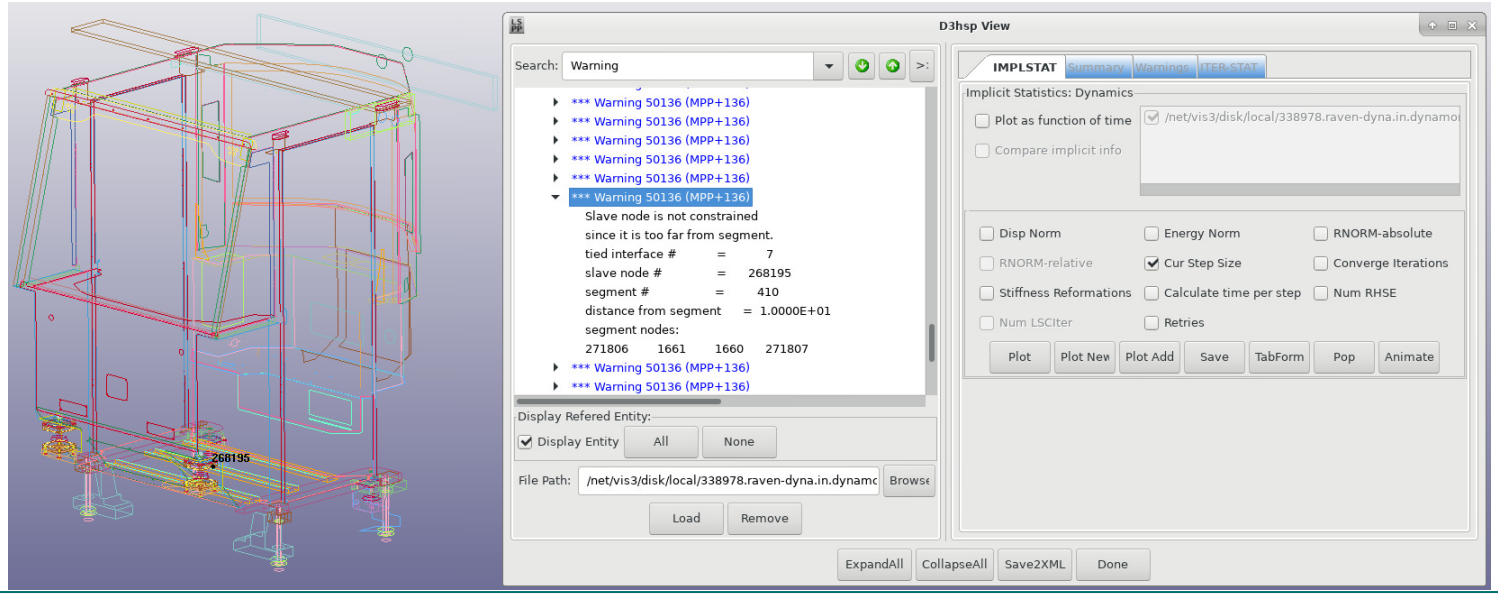
Model check setting

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



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

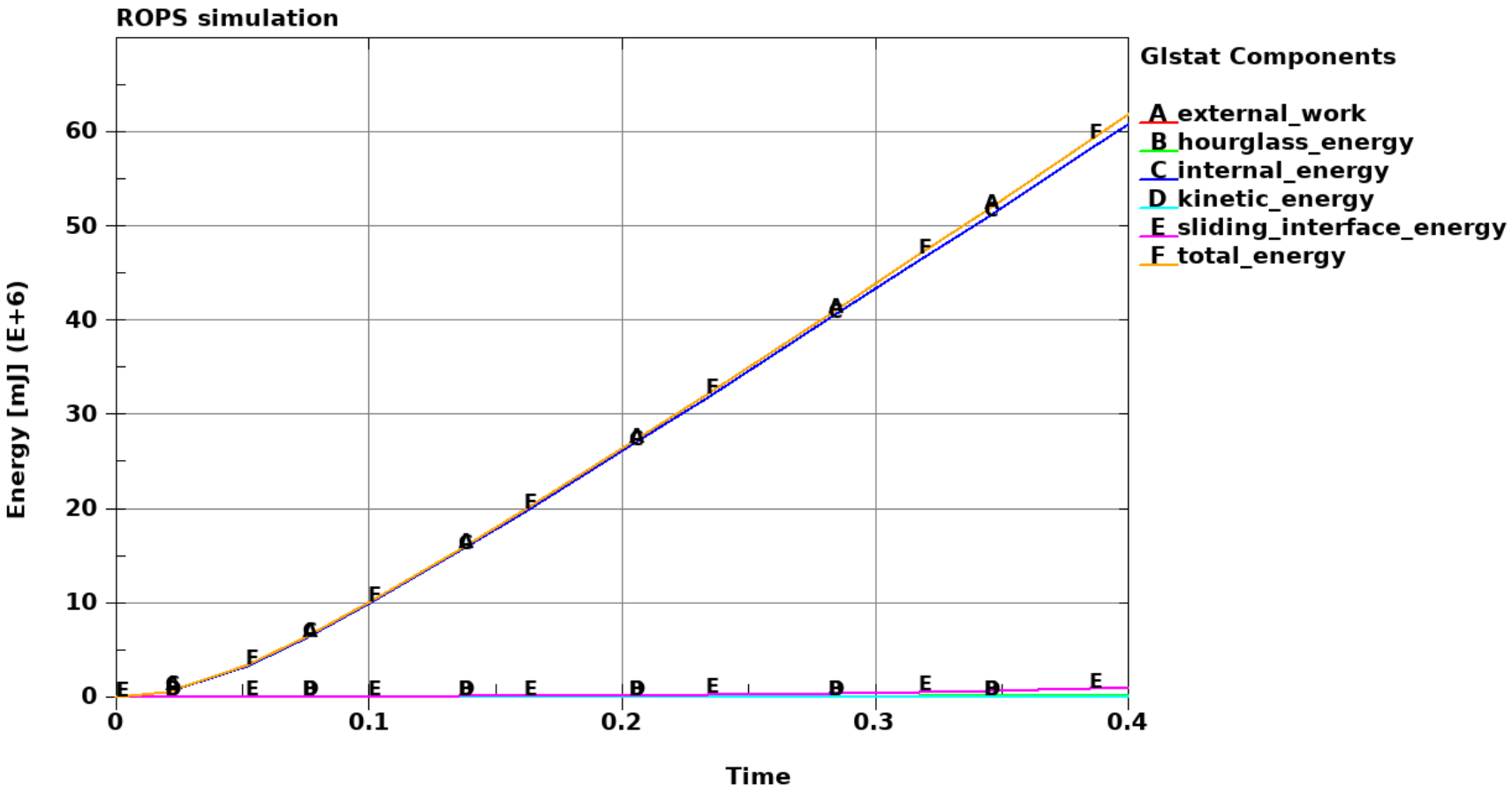
- Mass increase
  - Available as “added mass” in *DATABASE_GLSTAT.
- Energy balance and strange energies
  - Switch on output of all energies on *CONTROL_ENERGY, e.g. set HGEN=2 (not default).

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

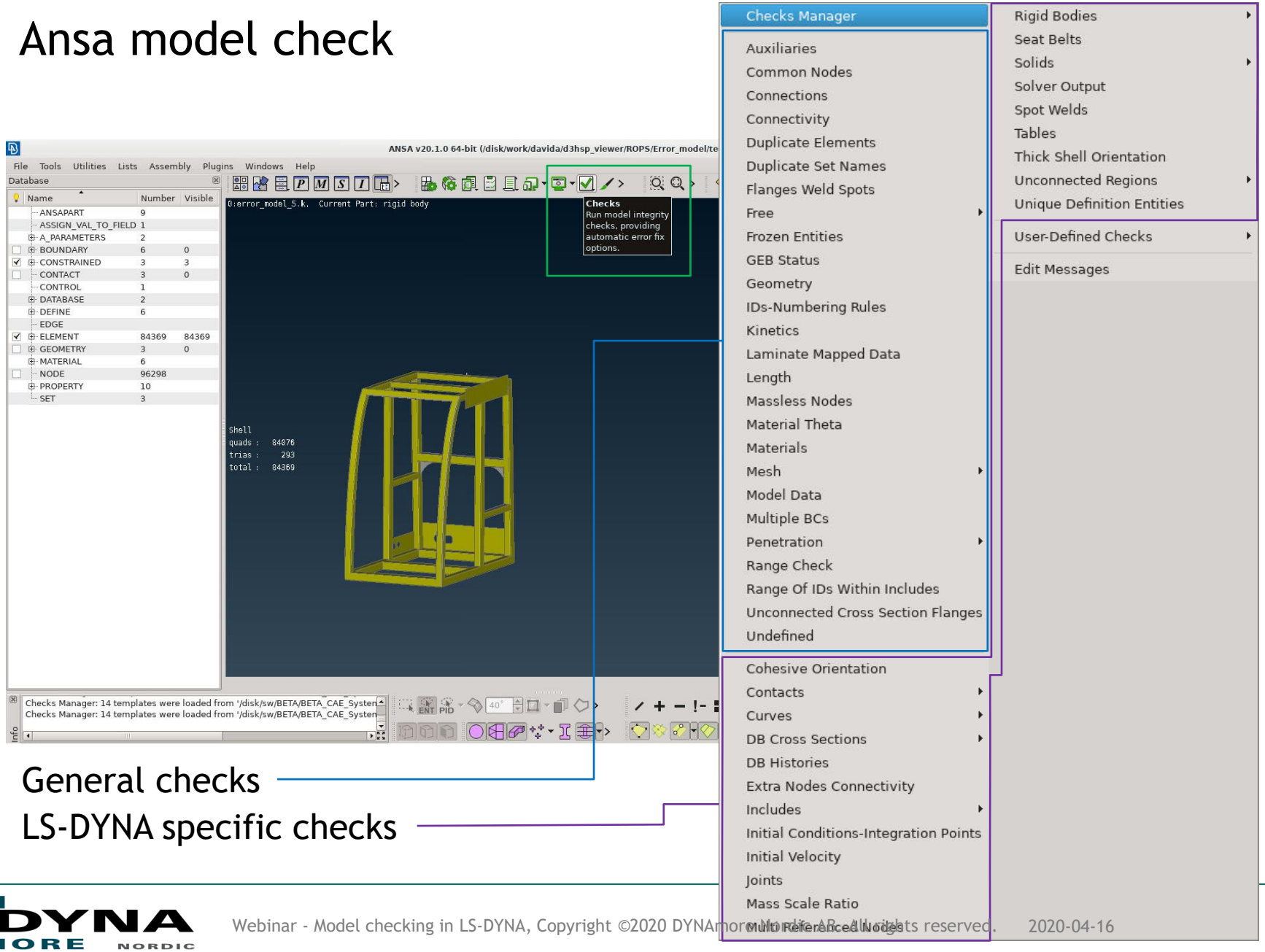
E_{kin} = current kinetic energy
E_{int} = current internal energy
E_{si} = current sliding interface energy (including friction)
E_{rw} = current rigid wall energy
E_{damp} = current damping energy
E_{hg} = current hourglass energy
E_{kin}^{0} = initial kinetic energy
E_{int}^{0} = initial internal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

Energy balance in example model

- Successful implicit ROPS simulation (lateral loading).



Ansa model check

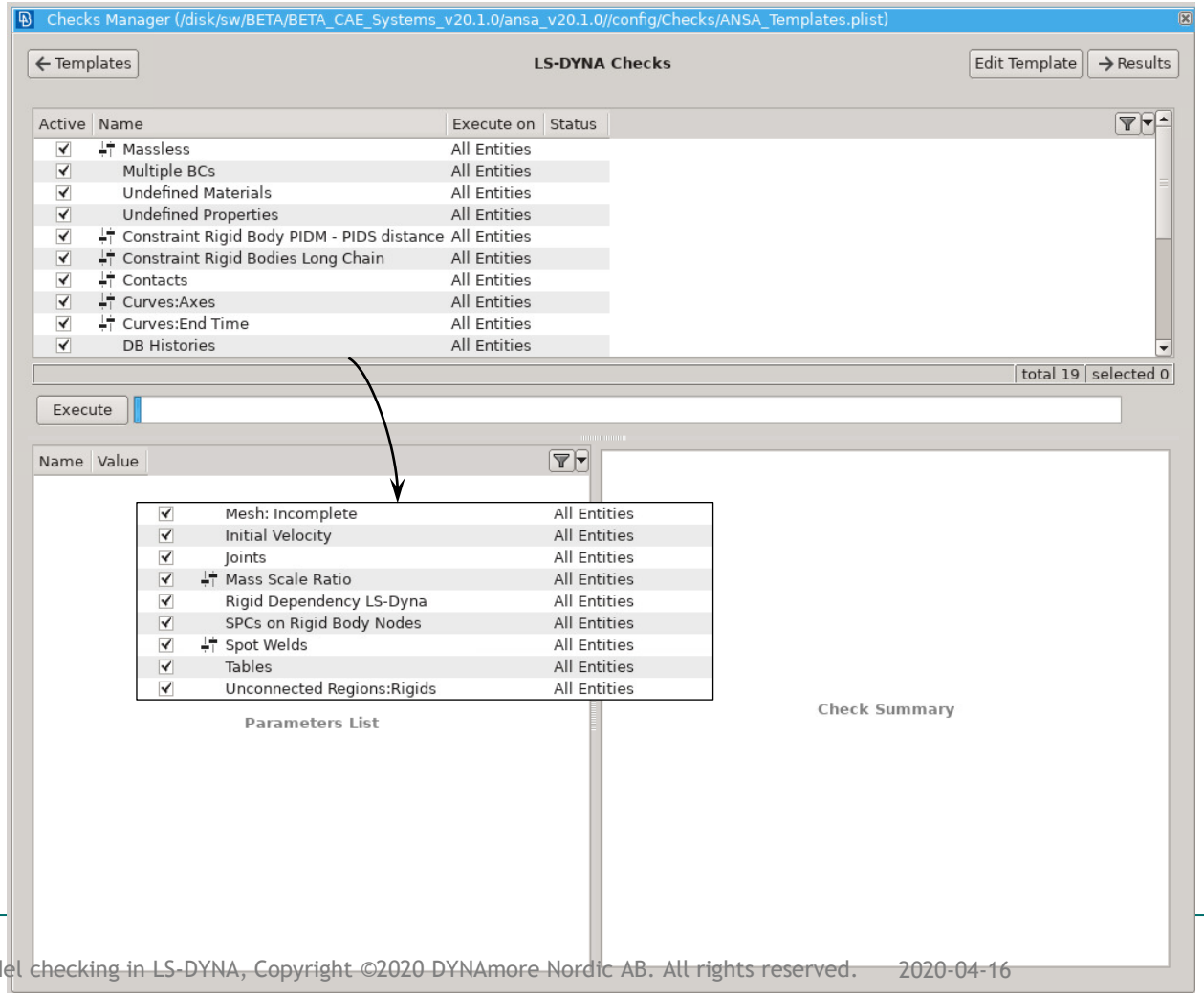


General checks

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)

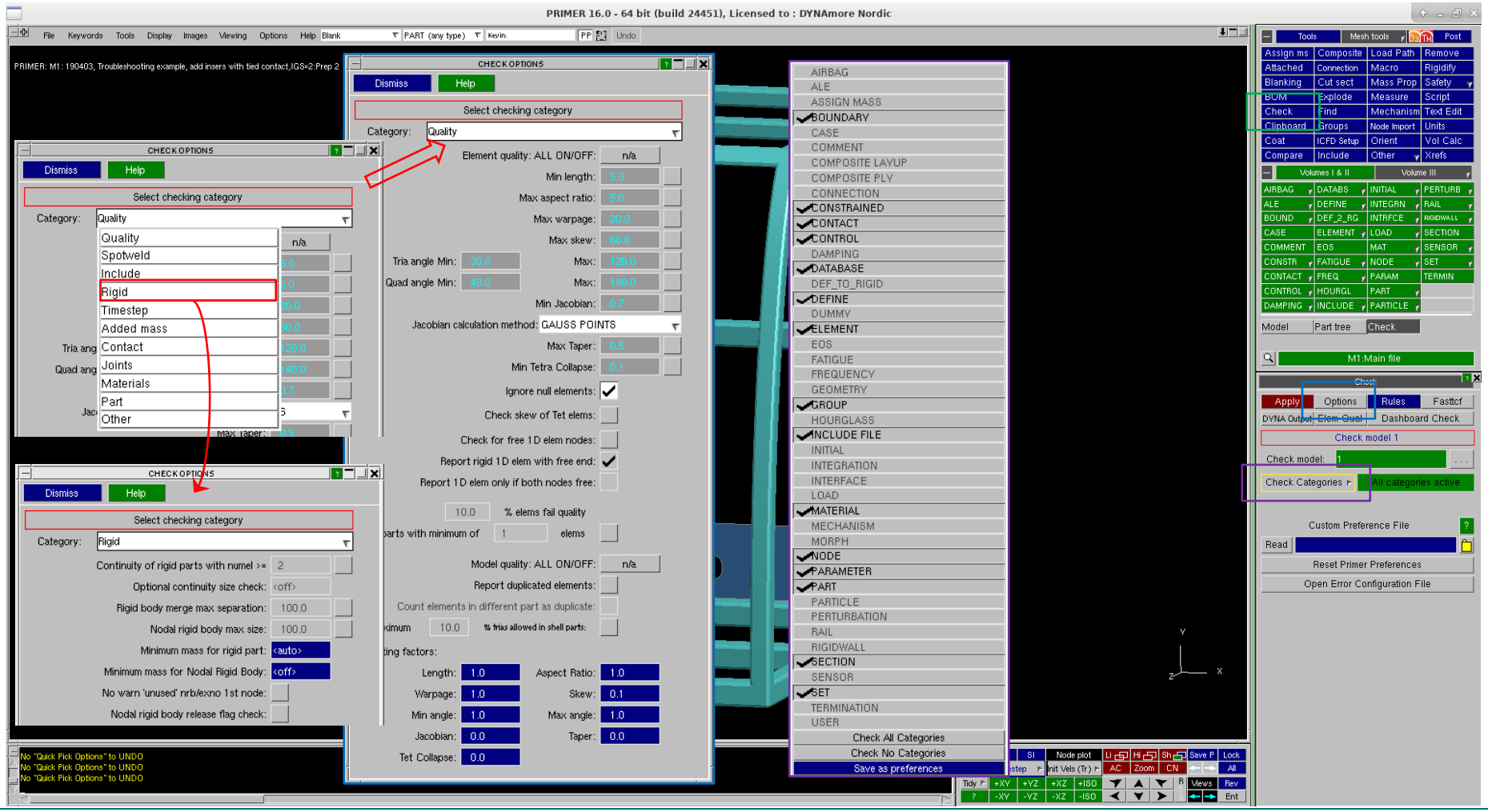
- Check > Connectivity – Detect unconnected assemblies
- Rigid bodies in LS-DYNA (more info on next slide)
- Check contacts from solver (only for tied contacts so far)
- Unconnected regions (same property but disjoint volumes) – RIGID BODIES!
- Joint check
  - Are nodes rigid/deformable? Do nodes of 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 sliprings that are connected to deformable elements.
- Boundary Prescribed Rigid Motion that is associated with deformable part.
- "Slave" rigid bodies with more than one "master".

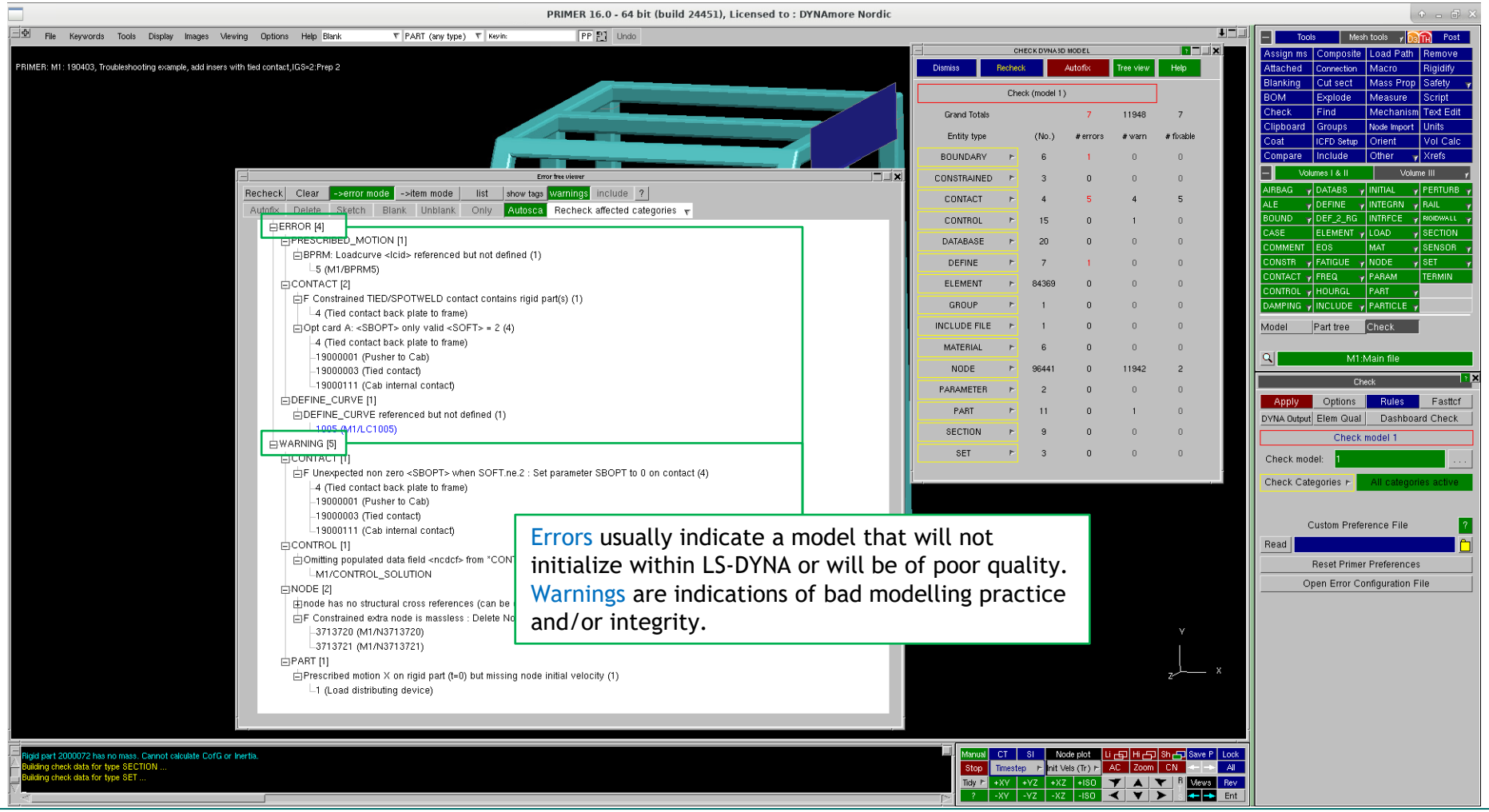
Primer model checker

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



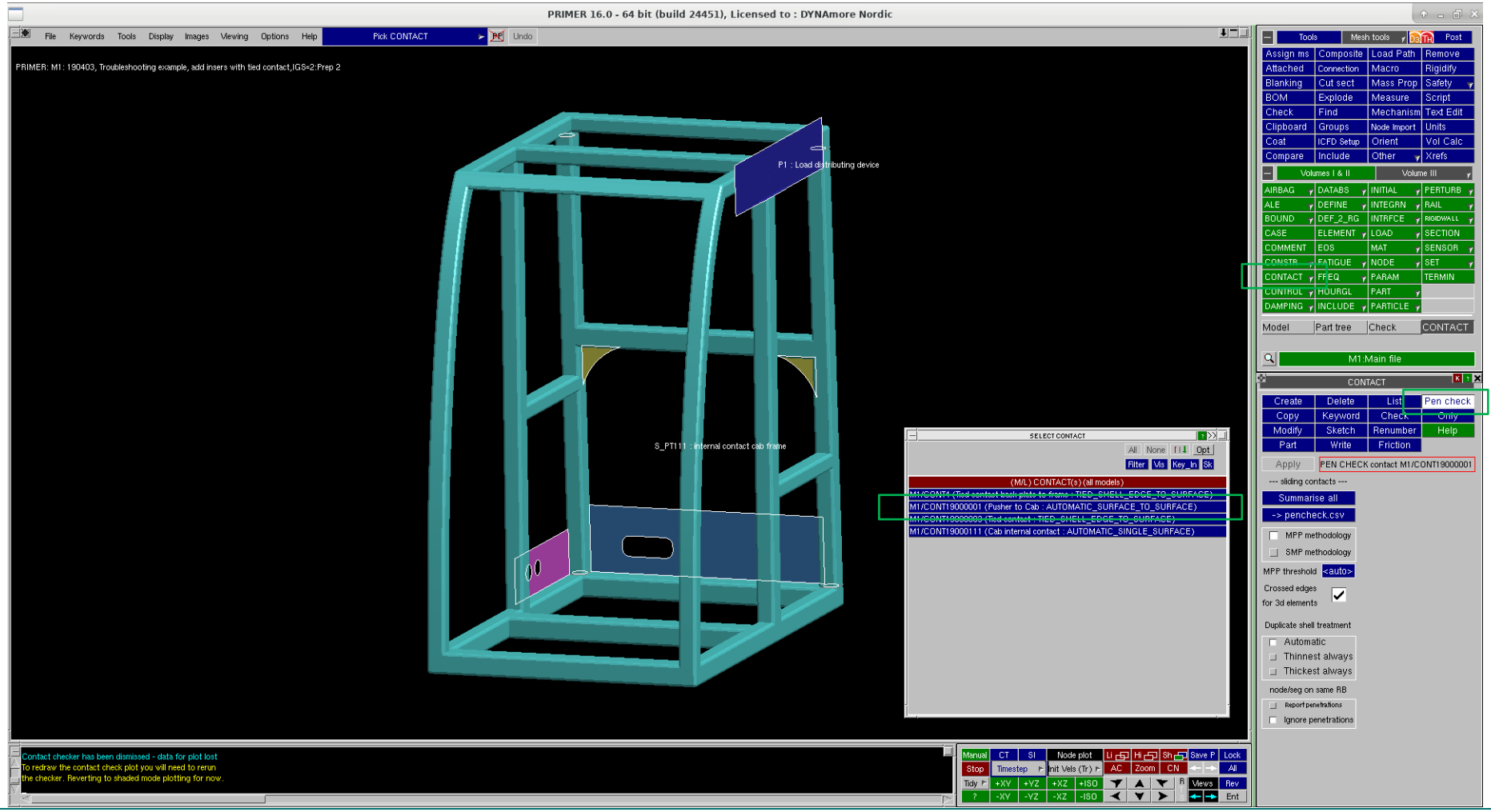
Primer model checker – results

- Results are presented in a tree-structure.



Primer contact check

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



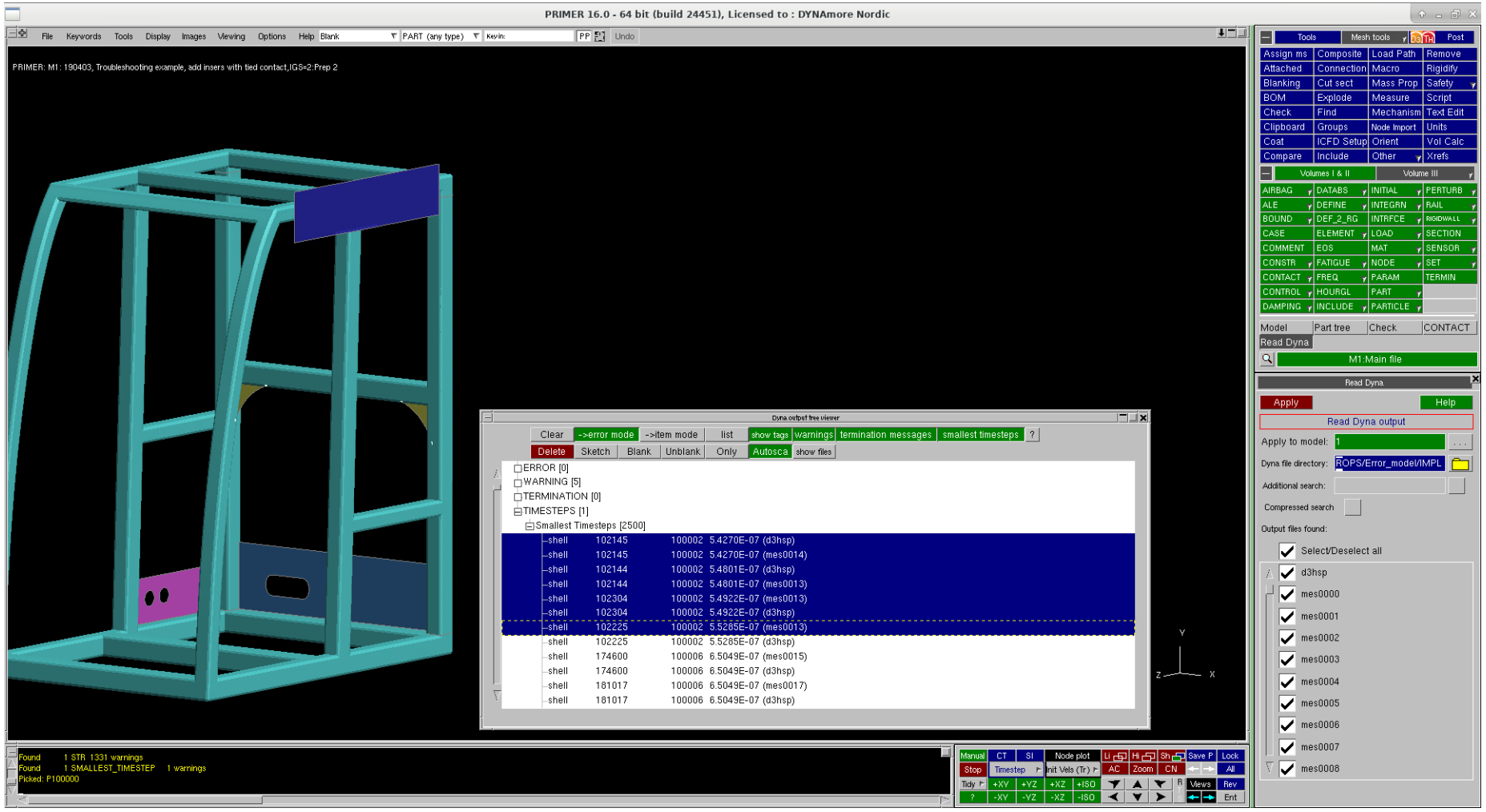
Primer contact check

- ...and visualized in different ways.

Selection of Primer model checker features

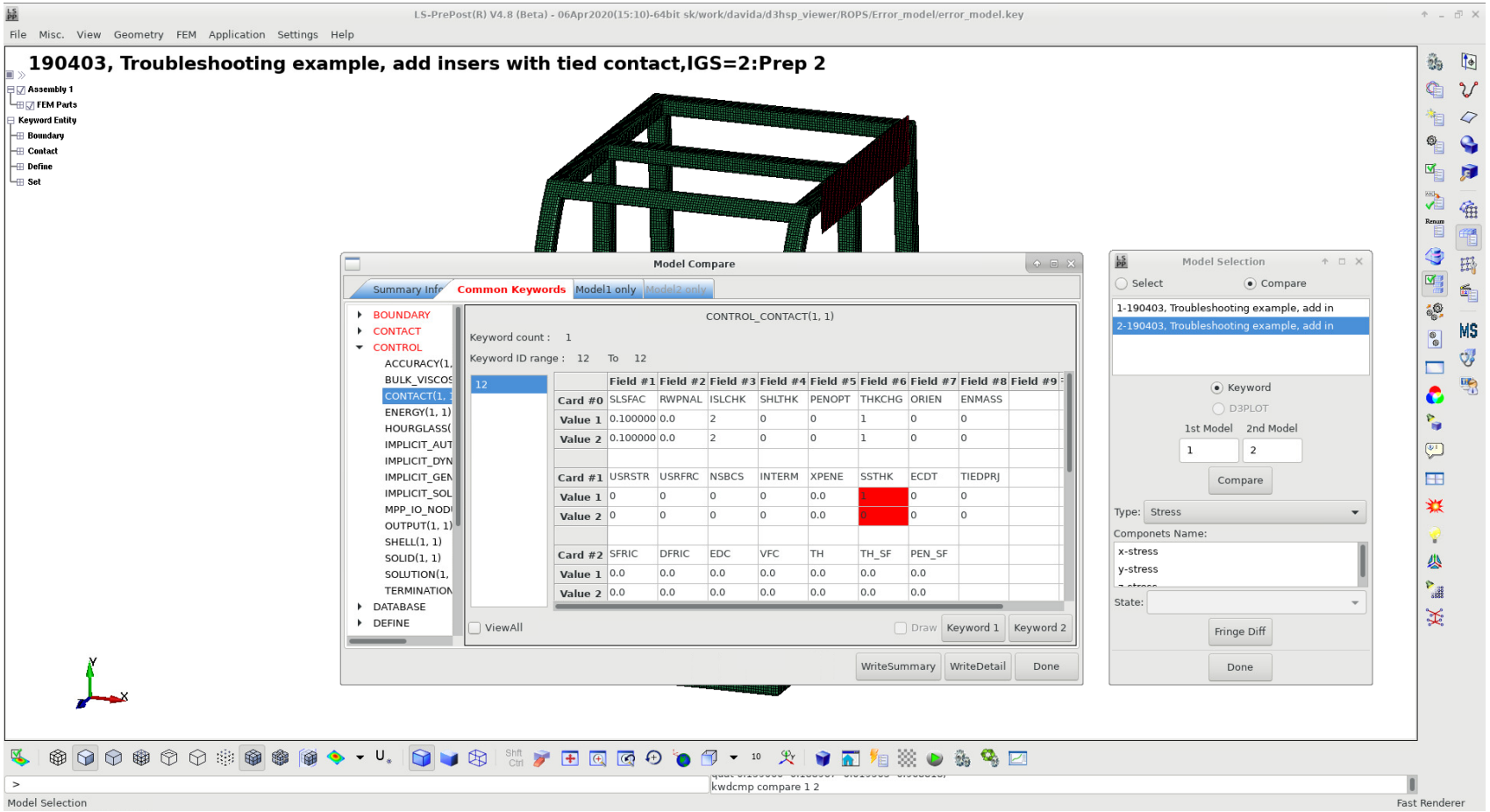
- Pre-analysis checking, e.g.
  - Contour plot of Density, Yield stress, Poisson's ratio, Young's modulus and Material number (e.g. 20 for *MAT_RIGID).
  - Checks can be switched on, e.g.
    - Check for large CNRBs.
    - Distance between volumes that make up one rigid body is too large.
    - Duplicated 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



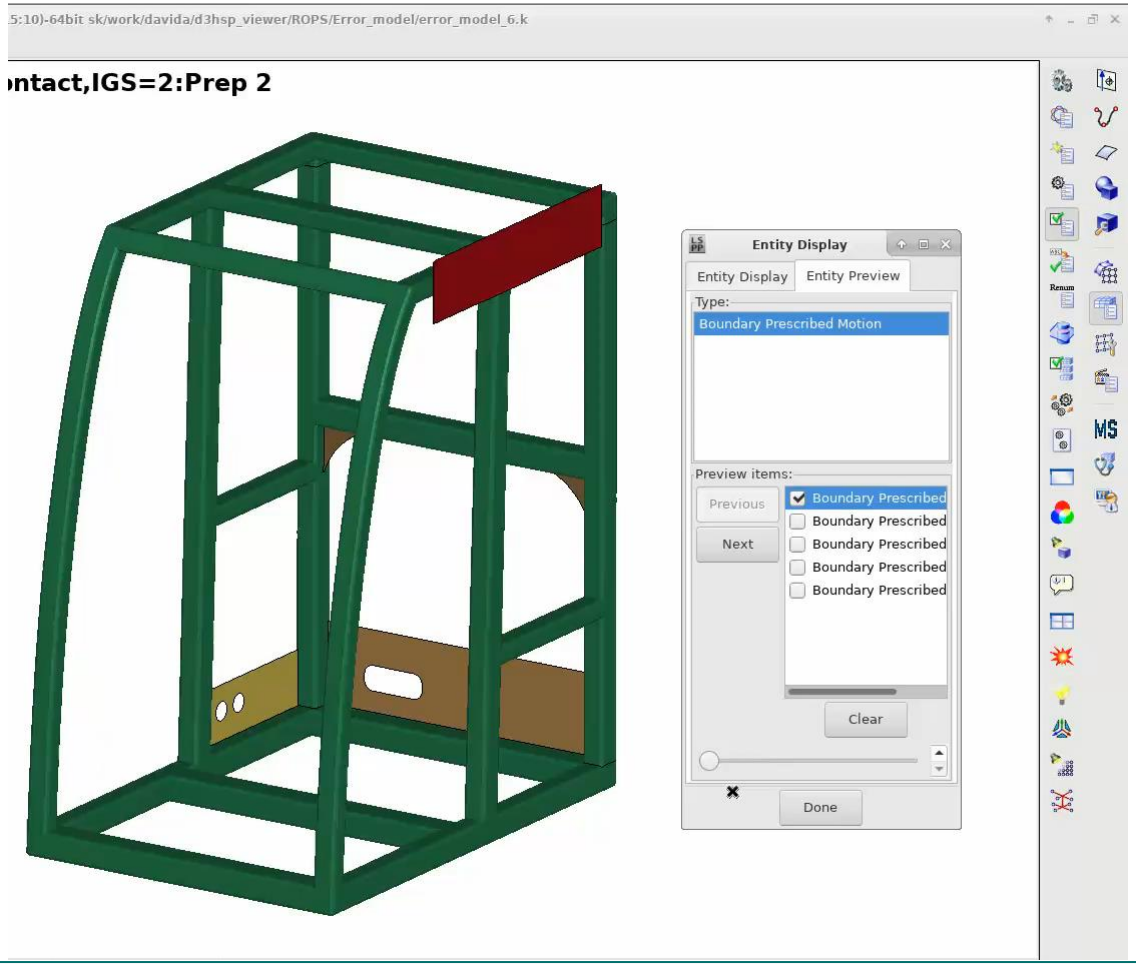
Did you know…?

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



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?

Visualize in preprocessor.

- 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.

Summary

- Follow modelling guidelines, either your own or DYNAmore Nordic provided recommendations.
- Run some form om 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!

DYNA MORE

Your LS-DYNA distributor and more