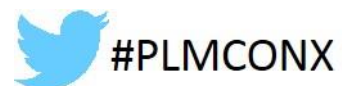# Best Practices and Usage Guidelines for NX Nastran Mesh Gluing
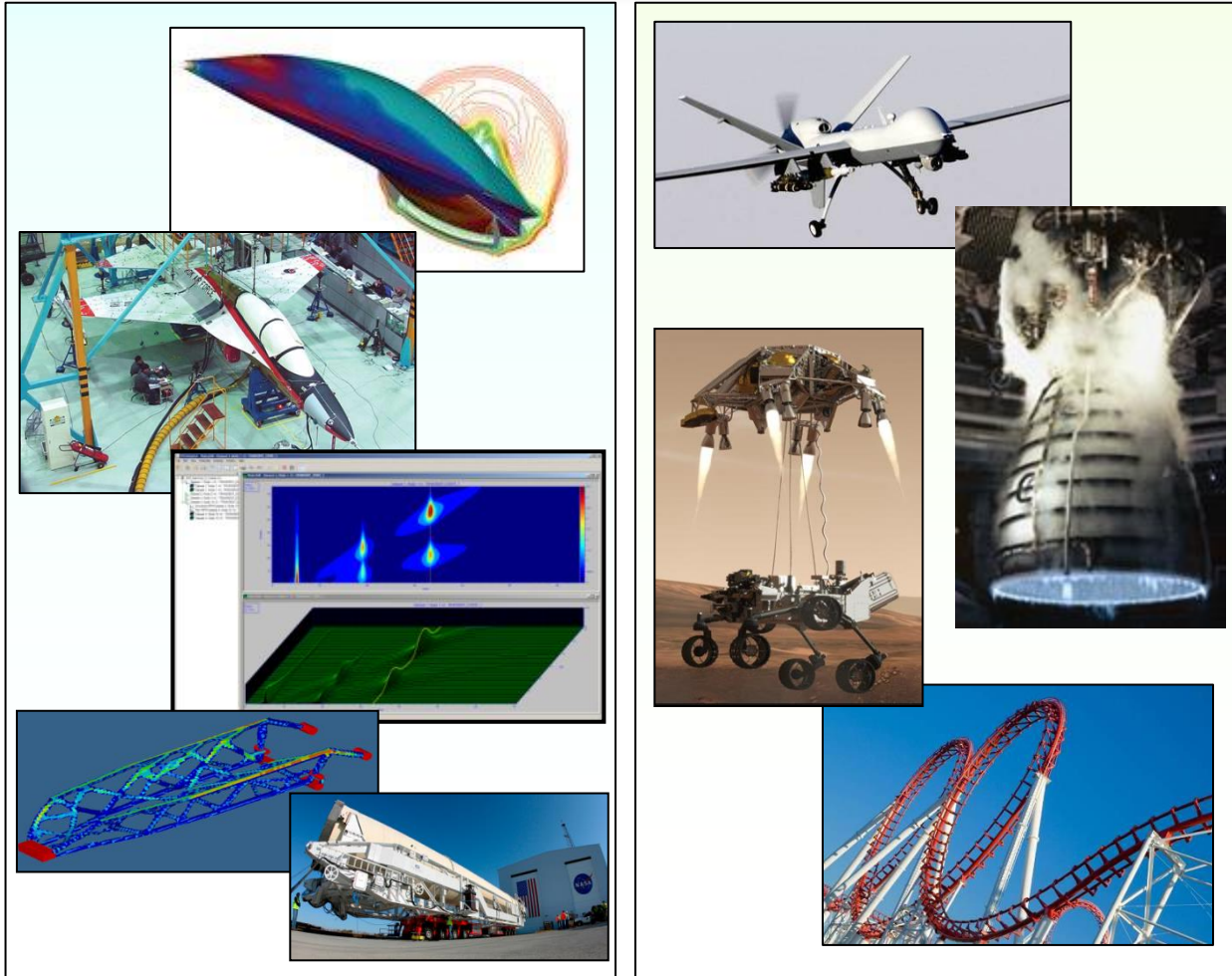
Jonathan Buck
ATA Engineering

Siemens PLM Connection 2014
Orlando, FL
June16-19

#PLMCONX

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Agenda

- Introductory Survey

- Motivation

- Types of glue connections

- Glue parameters/options

- Glue connection types in detail

- Four important model checks when using mesh gluing

- Observations and recommendations

Introductory Survey

- Have you ever struggled to create NX mesh mating conditions or match meshes between parts?

- Have you ever had to remesh a part to attain a conforming mesh with another part?

- Have you ever had two parts with incompatible meshes but couldn't remesh them because you didn't have the CAD?

- Have you ever wished that you could just mesh parts independently and still connect them?

Motivation

- Linear brick elements are often preferred for modeling adhesive, composite, brittle, or orthotropic materials where accurate stress predictions are critical

- Parabolic tetrahedral elements are often preferred for metallic fittings with complex geometry with fillets, holes, light-weighting features, etc., and are not suitable for anisotropic materials

- To accelerate analysis time, NX Nastran mesh gluing offers the promise of joining dissimilar meshes, allowing components to be meshed individually with their preferred approach
  - Note: NX Nastran mesh gluing is intended to create a stiff, elastic connection between parts, **not** to represent adhesive or actual glue

Types of Glue Connections in NX Nastran

Type	Description
Edge-to-Edge	Glue between the edges of shell, axisymmetric, plane stress, and plane strain elements.
Edge-to-Surface	Glue between shell element edges and shell or solid element faces.
Surface-to-Surface	Glue between shell or solid element faces and shell or solid element faces.

NX Nastran Glue Control Parameters

Global Glue Parameters
(default options shown)
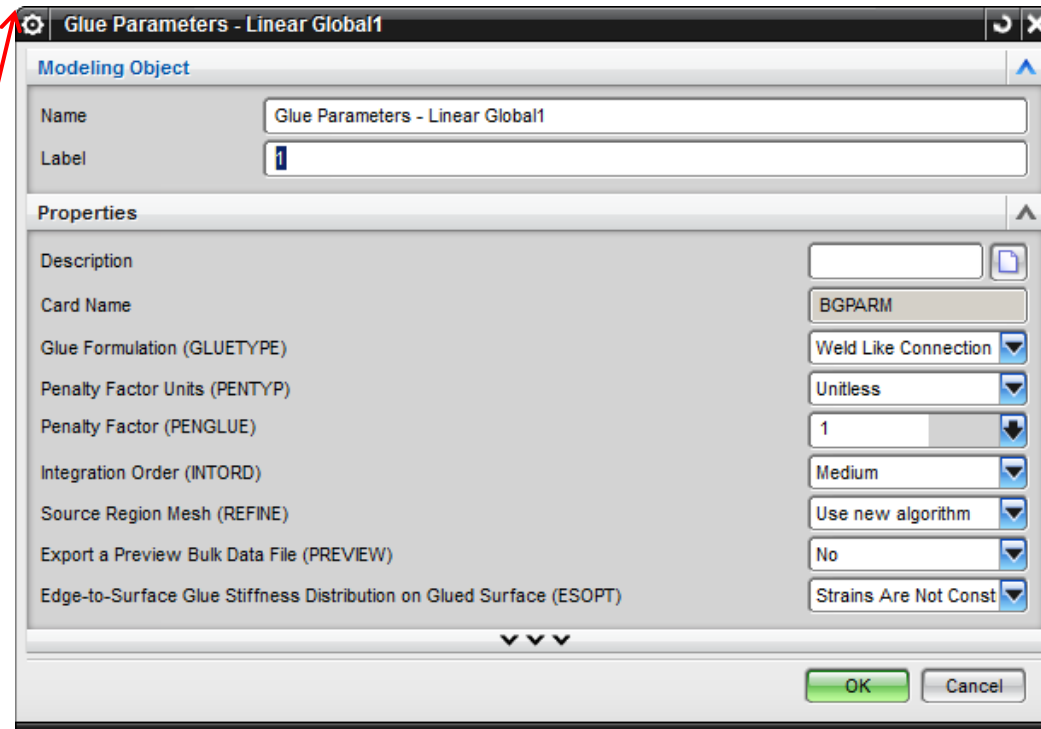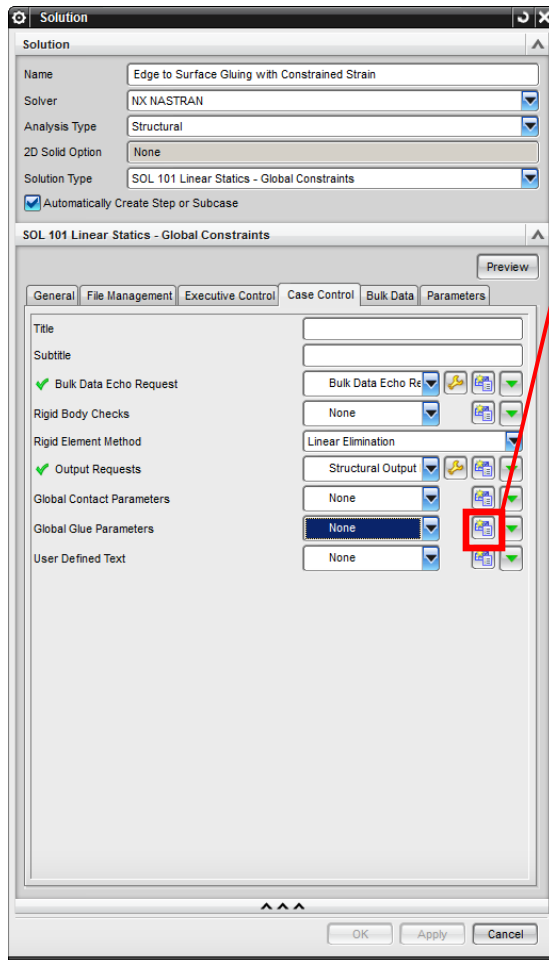
Choose between weld-type and spring-type glue connections

Select units for the desired penalty factor

Enter penalty factor/stiffness for glue connection

Determine number of glue points per element on source face

Refine source face mesh density to correspond to target face

New in NX9! Creates "dummy" elements to visualize the glue connection (Introduced in NX Nastran 8.5)
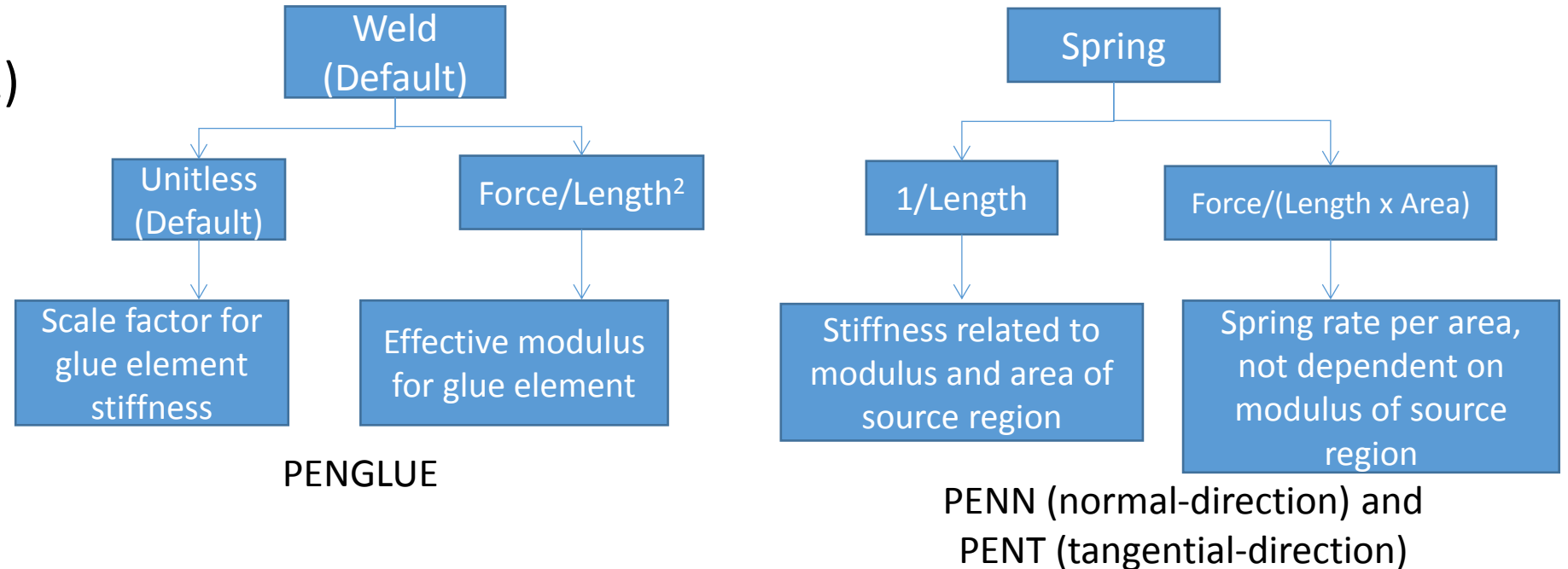
New in NX9! Prevents artificial constraint of strain in the plane of the glued surface

Glue Types and Penalty Factors

Glue Type (GLUETYPE)

Penalty Factor Units (PENTYP)

Penalty Factor

```
                    Weld                              Spring
                  (Default)

        ┌──────────┴──────────┐          ┌──────────────┴──────────────┐
     Unitless            Force/Length²   1/Length         Force/(Length x Area)
     (Default)

  Scale factor for    Effective modulus  Stiffness related to   Spring rate per area,
  glue element        for glue element   modulus and area of    not dependent on
  stiffness                              source region          modulus of source
                                                                region

            PENGLUE                              PENN (normal-direction) and
                                                 PENT (tangential-direction)
```

- Although the spring-type connection appears to offer the advantages of selectively tuning the normal and tangential stiffnesses, the weld-type connection is the preferred method because
  - Is generally more robust and user-friendly to implement
  - It transfers moments at the glued interface (the spring-type connection can introduce artificial rotational energy)
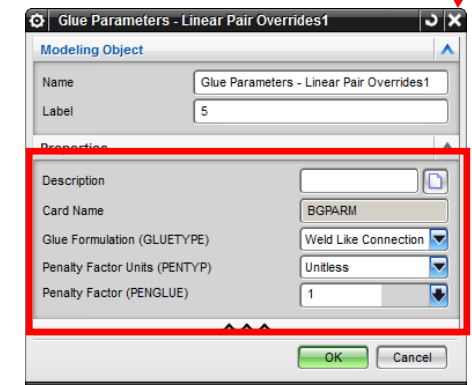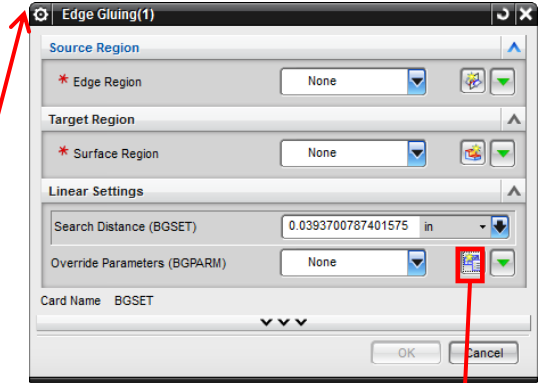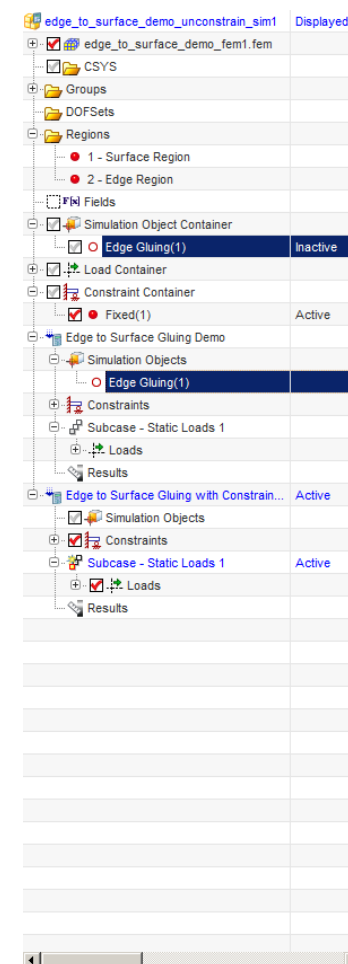
Some Glue Options Can Only Be Set at the Case Control Level

Glue Parameters Available in Solution Case Control Options

Override Global Glue Parameters
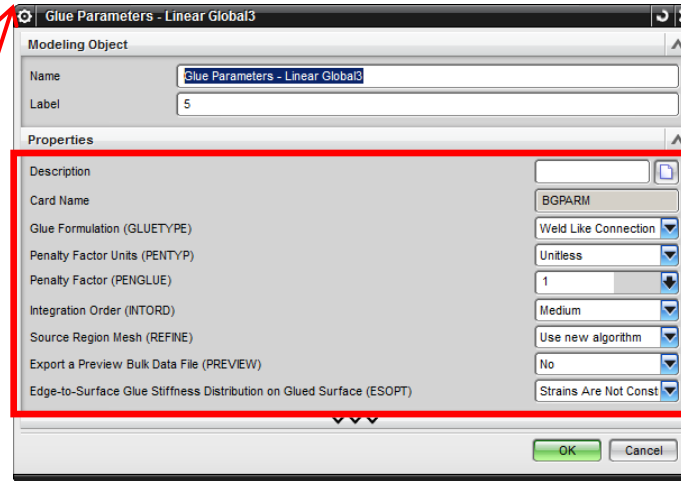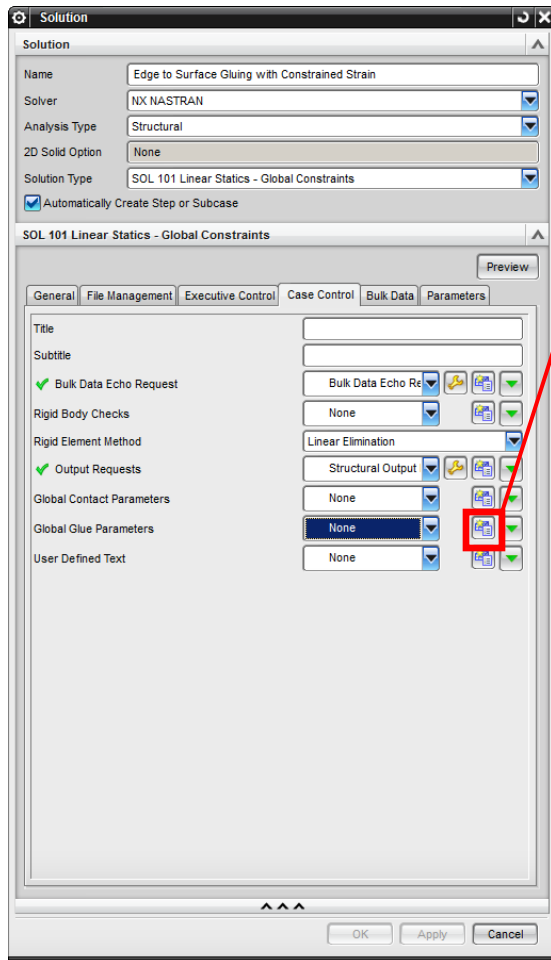
Glue parameters are available within the *.sim file and can be used for assembly FEMs

Combine Multiple Glue Connections with BGADD

- Local glue connections can be defined with unique parameters

- Can then be combined into a single set with BGADD card
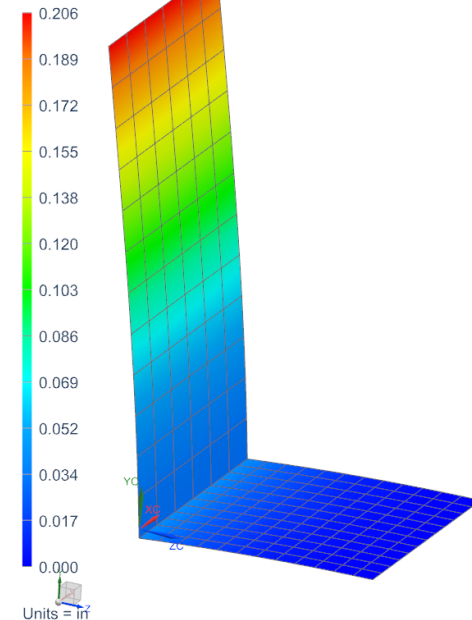 - Local parameter definitions override global parameter definitions

Edge-to-Edge Gluing Guidelines

- Edge-to-edge gluing connects shell edges having faces with any alignment other than perpendicular
    - Consider edge-to-surface gluing instead
- Only the weld-type glue connection is supported
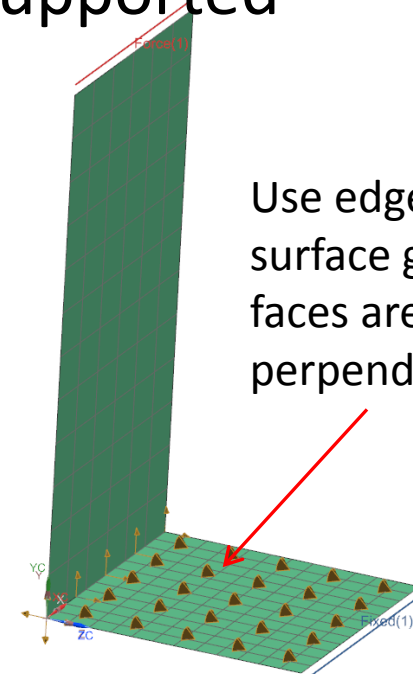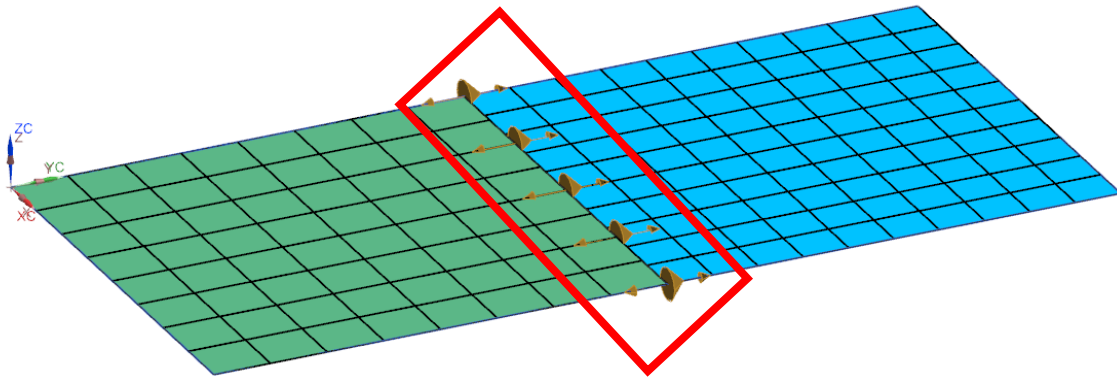
Use edge-to-surface gluing when faces are perpendicular

edge_to_edge_demo_sim1 : Edge to Surface Glue Connection Result
Subcase - Static Loads 1, Static Step 1
Displacement - Nodal, Magnitude
Min : 0.000, Max : 0.206, Units = in
Deformation : Displacement - Nodal Magnitude

0.206
0.189
0.172
0.155
0.138
0.120
0.103
0.086
0.069
0.052
0.034
0.017
0.000

Units = in

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Comparison of Weld-Type Glue Parameters for Edge-to-Edge Gluing

Normal Modes for a Cantilever Plate

edge_to_edge_glue_sim1 : Default Weld Unitless Parameters Result
Subcase - Eigenvalue Method 1, Mode 2, 861.947 Hz
Displacement - Nodal, Magnitude
Min : 0.00, Max : 183.49, Units = in
Deformation : Displacement - Nodal Magnitude

Edge-to-edge glue connection at midspan
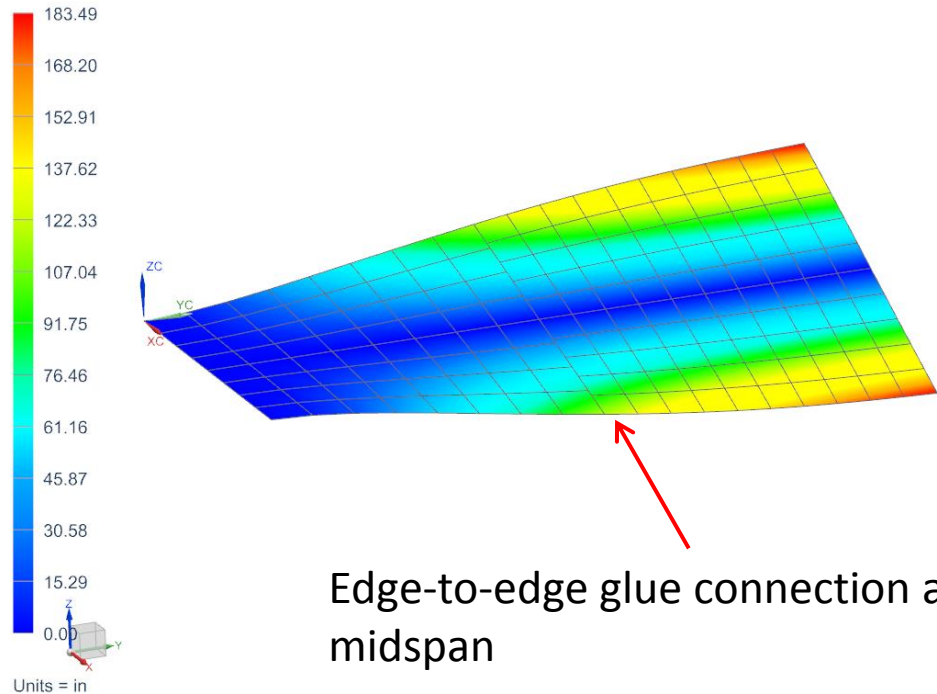
Frequency	Conforming Mesh	Weld-Type Glue Connection				
		Unitless			F/L²	
		0.1x	Default (1.0)	10x	1.0	1.05E+07
1st Mode (Hz)	207.9	208.8	209.1	209.3	13.62	209.1
2nd Mode (Hz)	857.9	861.7	861.9	862.0	194.2	861.9
3rd Mode (Hz)	1286	1301	1306	1307	321.9	1306
4th Mode (Hz)	2781	2794	2794	2795	481.1	2794
5th Mode (Hz)	3462	3464	3468	3470	491.7	3468

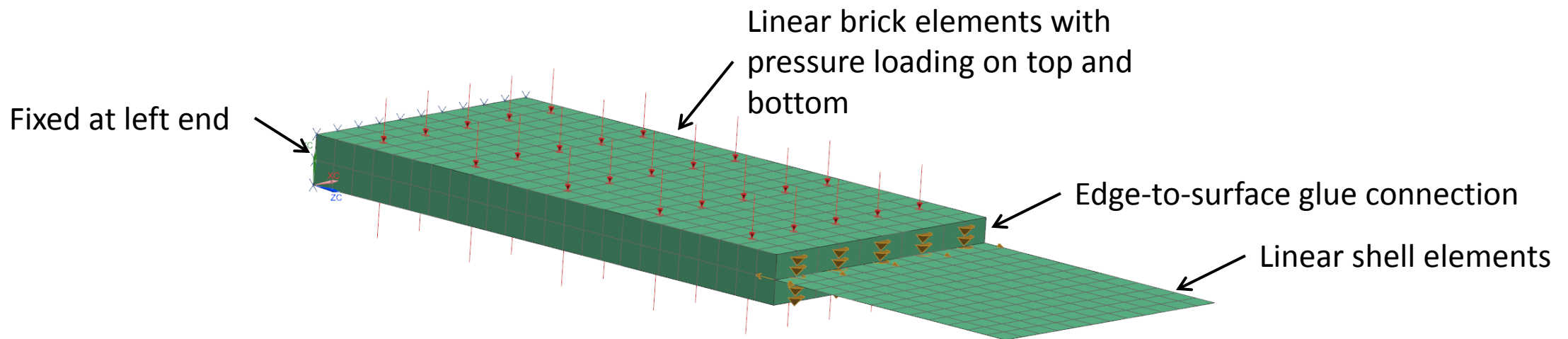| Percent Error	Conforming Mesh	Weld-Type Glue Connection				
		Unitless (Default)			F/L²	
		0.1x	Default (1.0)	10x	1.0	1.05E+07
1st Mode (%)	-	0.4%	0.6%	0.7%	-93.4%	0.6%
2nd Mode (%)	-	0.4%	0.5%	0.5%	-77.4%	0.5%
3rd Mode (%)	-	1.2%	1.6%	1.6%	-75.0%	1.6%
4th Mode (%)	-	0.5%	0.5%	0.5%	-82.7%	0.5%
5th Mode (%)	-	0.1%	0.2%	0.2%	-85.8%	0.2%

Al 2024-T3 modulus (ksi)

Range of weld-type connections with unitless penalty factors gives satisfactory solutions

Non-unitless penalty factor must be tuned to material stiffness
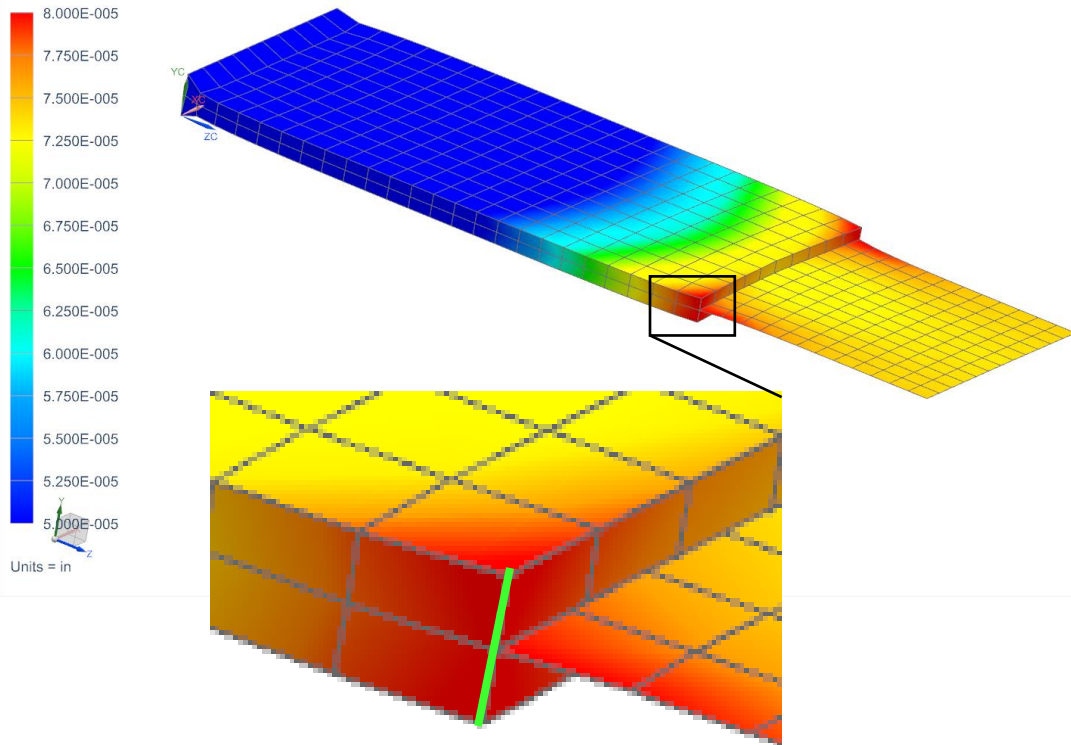
Edge-to-Surface Gluing Guidelines

- Used to connect edges of shell elements to faces of solid elements

- The default option for the edge-to-surface glue stiffness distribution (ESOPT), which does not constrain strains of the solid element faces

Linear brick elements with pressure loading on top and bottom

Fixed at left end

Edge-to-surface glue connection

Linear shell elements

Default Edge-to-Surface Parameter Prevents Artificial Stiffening

Edge-to-Surface Strains Unconstrained

edge_to_surface_demo_unconstrain_sim1 : Edge to Surface Gluing Unconstrained Result
Subcase - Static Loads 1, Static Step 1
Displacement - Nodal, Magnitude
Min : 0.000E+000, Max : 8.071E-005, Units = in
Deformation : Displacement - Nodal Magnitude
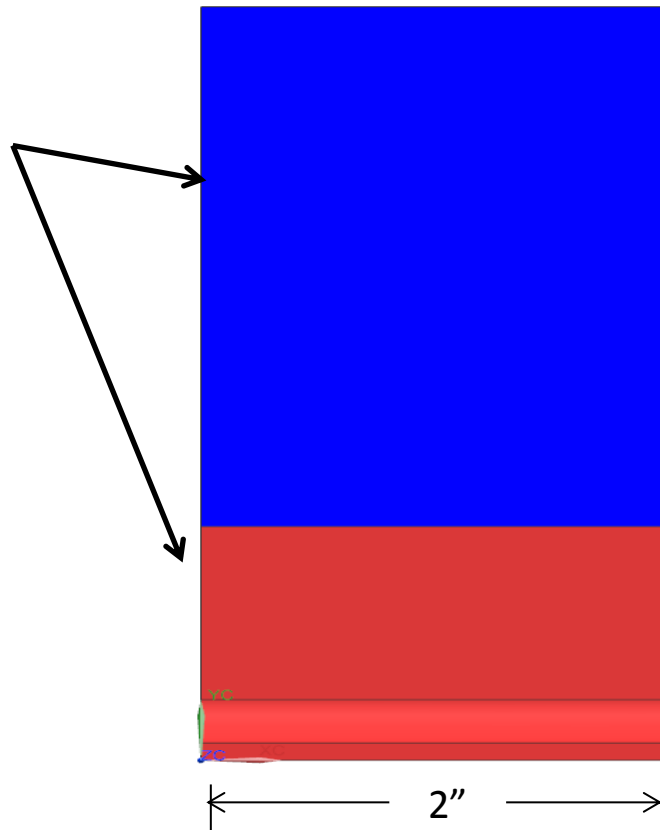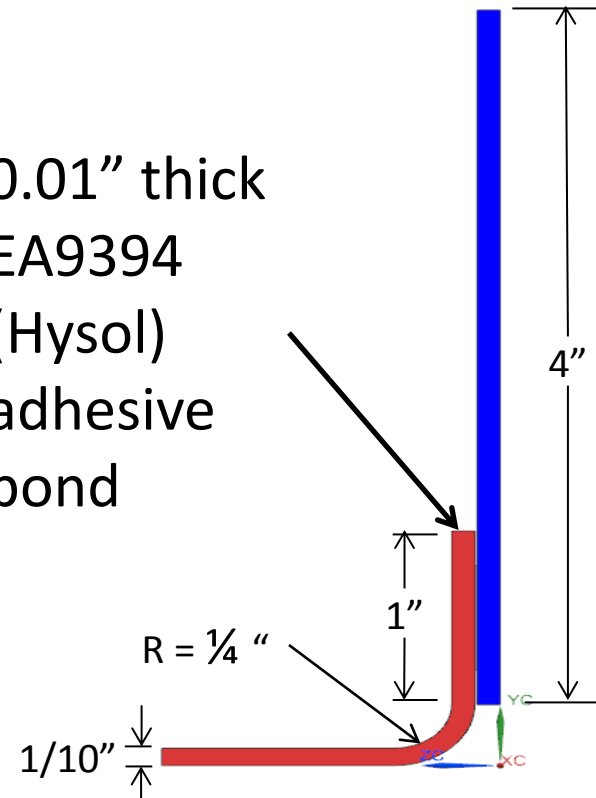
Edge-to-Surface Strains Constrained

edge_to_surface_demo_unconstrain_sim1 : Edge to Surface Gluing Constrained Result
Subcase - Static Loads 1, Static Step 1
Displacement - Nodal, Magnitude
Min : 0.000E+000, Max : 7.958E-005, Units = in
Deformation : Displacement - Nodal Magnitude

Normal strain in shell elements artificially constrains strain on solid face
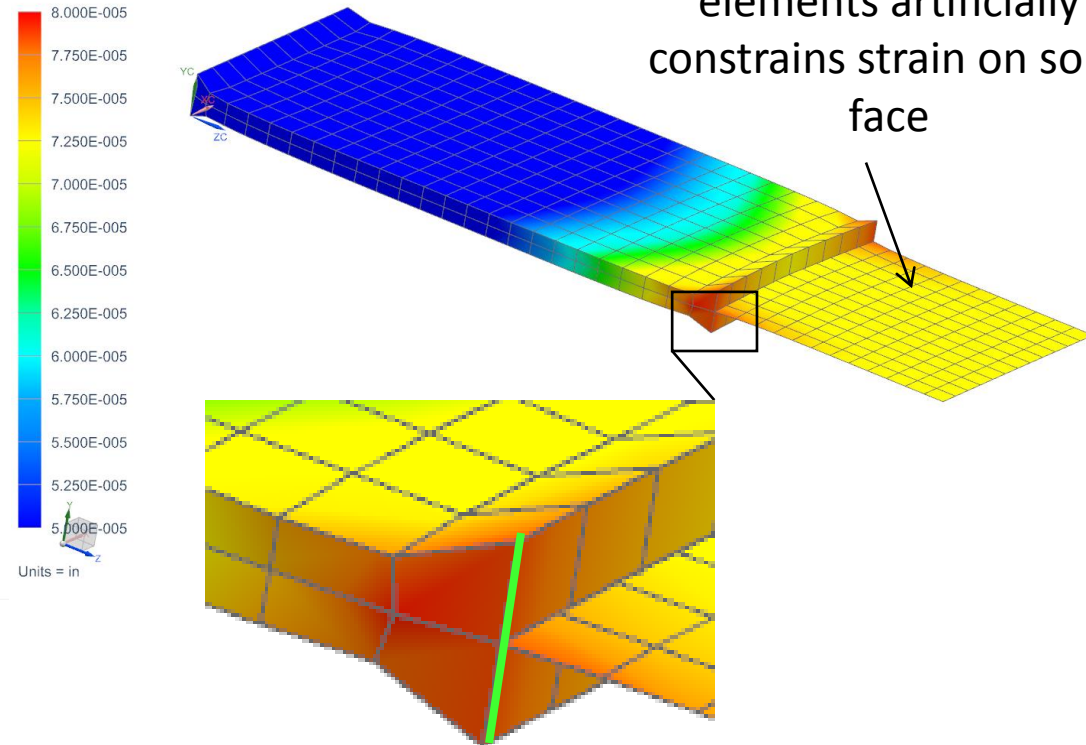
Surface-to-Surface Gluing Example

Generic Bonded Clip and Gusset

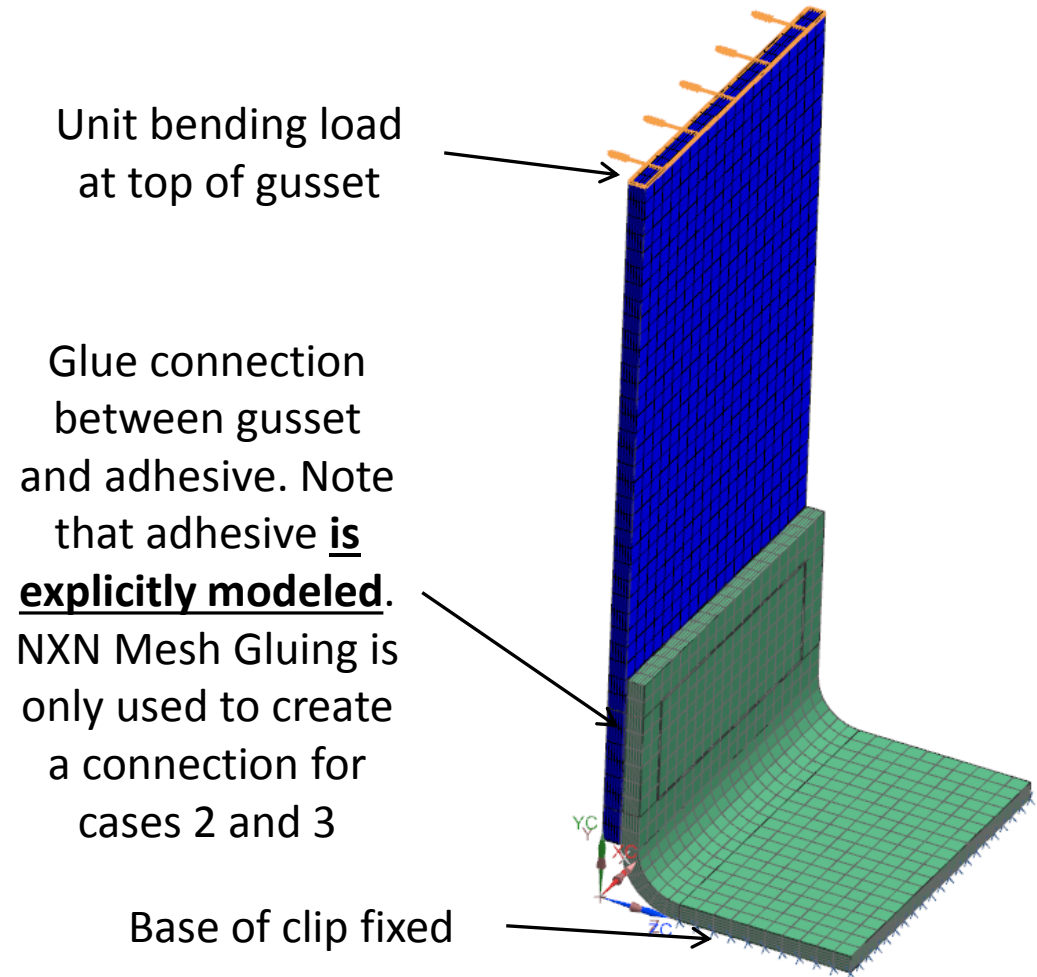Al 2024-T3 gusset and clip
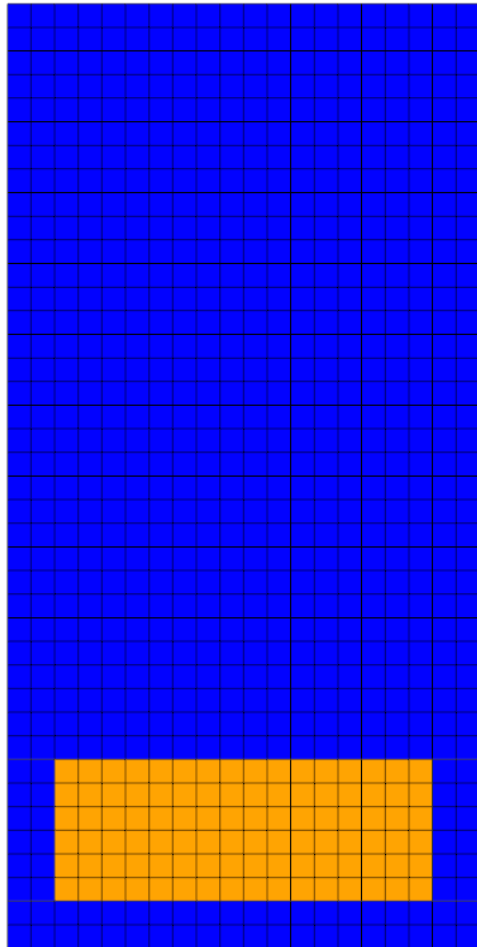
0.01" thick EA9394 (Hysol) adhesive bond

4"

1"

R = ¼ "

1/10"

2"

Finite Element Model Description

6 constant-thickness elements through thickness

Gusset

Adhesive

Clip

6 constant-thickness elements through thickness

Orange area shows adhesive footprint on gusset

1 element through thickness
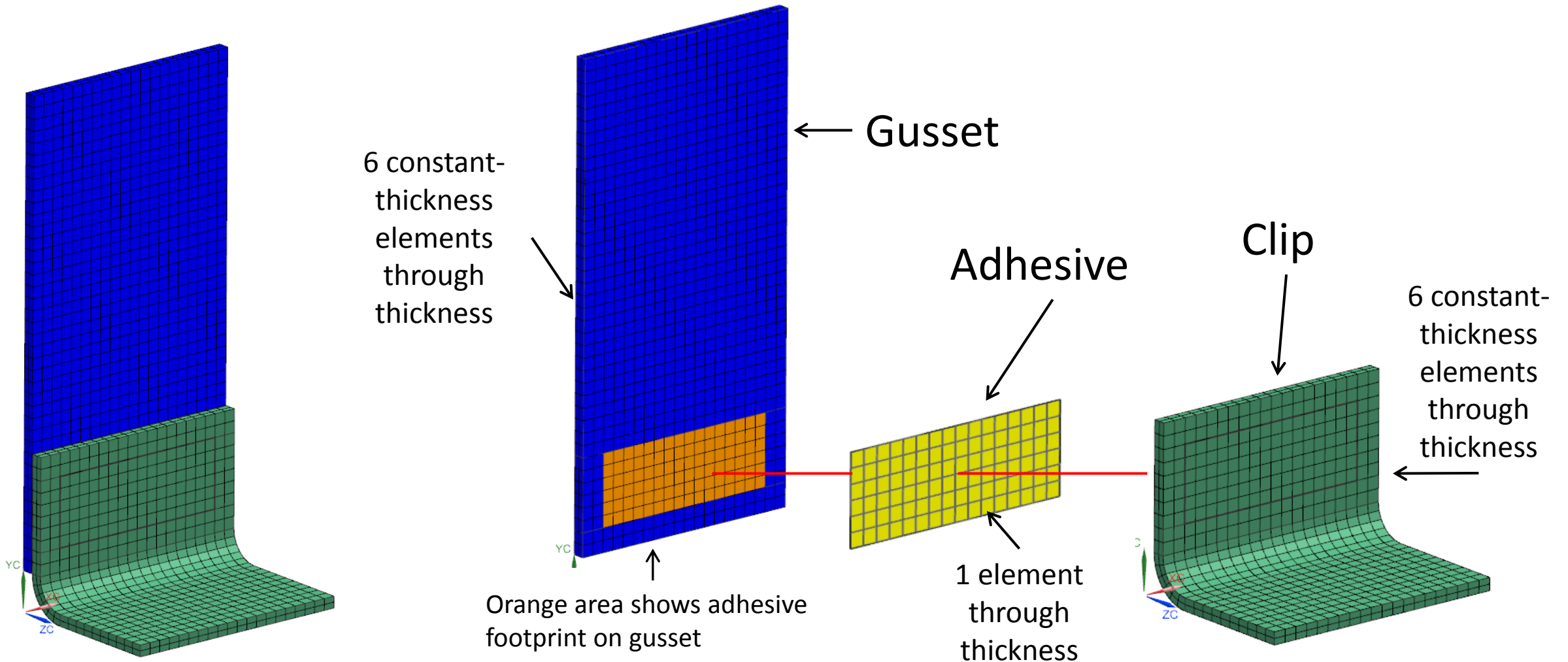
Three Configurations Considered for Bonded Clip Example

1. Adhesive meshed consistently with gusset (shared nodes between elements, no NXN glue)

2. Adhesive connected to gusset with NXN glue (meshes discontinuous but with coincident nodes)

3. Adhesive connected to gusset with NXN glue, nodes on gusset misaligned

• Linear and parabolic brick elements considered

Unit bending load at top of gusset

Glue connection between gusset and adhesive. Note that adhesive **is explicitly modeled**. NXN Mesh Gluing is only used to create a connection for cases 2 and 3

Base of clip fixed

Glued Meshes Have Nodes Aligned and Misaligned

Aligned Mesh

Nodes within footprint of adhesive are coincident with adhesive nodes
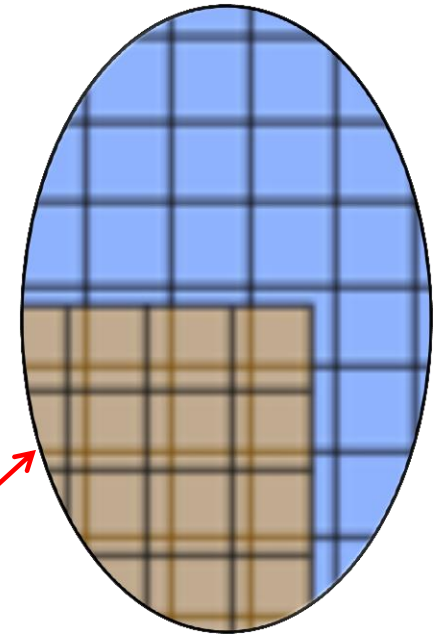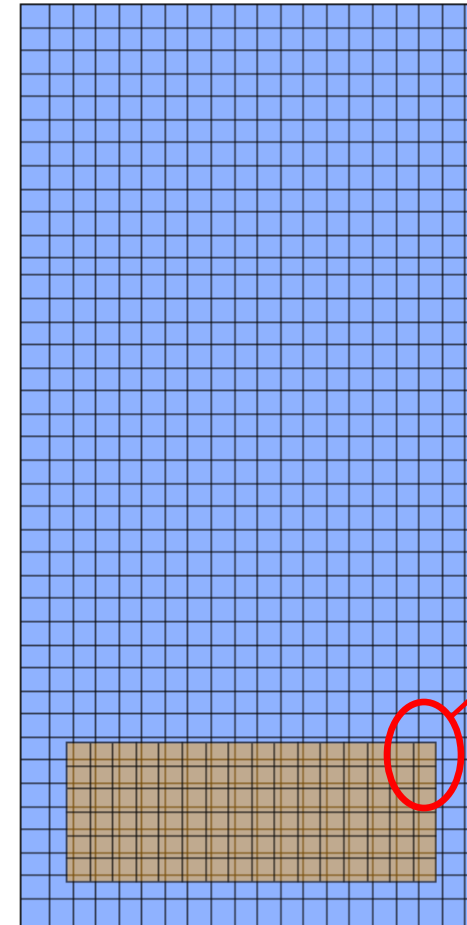
Misaligned Mesh

Nodes translated by (0.025", 0.025") within boundaries of gusset

Nodes on adhesive and gusset surfaces are non-coincident

Parabolic Bricks Reduce Error In Displacement and Adhesive Peel Stress

| Model Configuration No.	Element Formulation	Glue Type	Mesh Alignment	Normalized Tip Displacement	Normalized Peak σzz (Peel)
1	Linear Hex	-	-	1.0	1.0
2	Linear Hex	Weld	Aligned	1.0	1.0
3	Linear Hex	Weld	Misaligned	0.98	1.22

Model Configuration No.	Element Formulation	Glue Type	Mesh Alignment	Normalized Tip Displacement	Normalized Peak σzz (Peel)
1	Parabolic Hex	-	-	1.0	1.0
2	Parabolic Hex	Weld	Aligned	1.0	1.0
3	Parabolic Hex	Weld	Misaligned	1.0	0.95
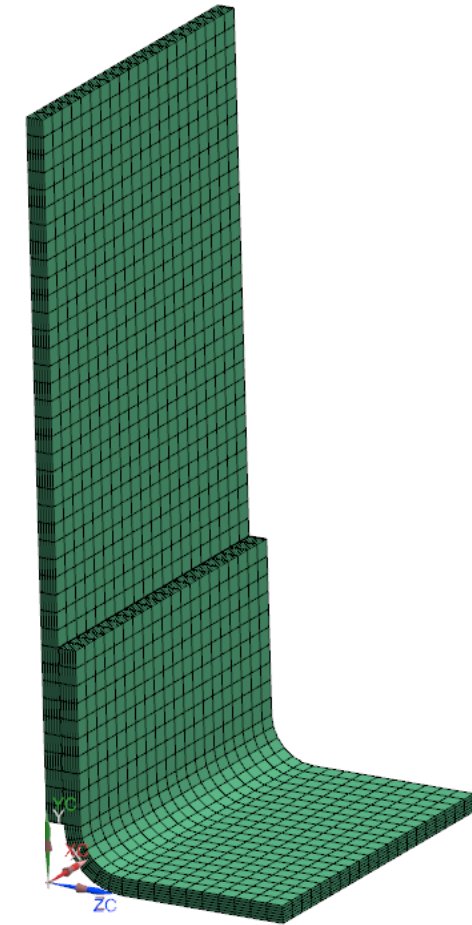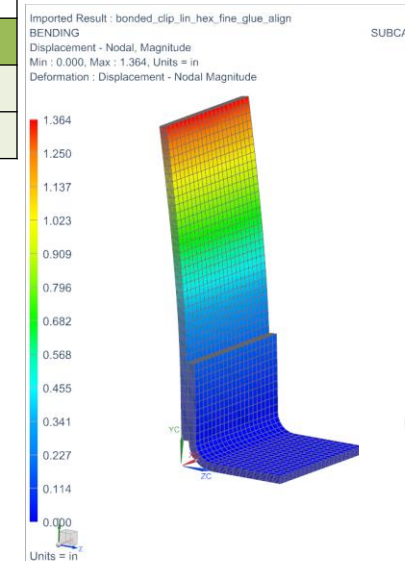
Glue Connection Provides Satisfactory Stiffness to Within 1%

| Element Formulation	Connection	Normalized Natural Frequency				
		1st Mode	2nd Mode	3rd Mode	4th Mode	5th Mode
Linear Hex	Conforming Mesh	1.00	1.00	1.00	1.00	1.00
	Glued, Aligned	1.00	1.00	1.00	1.00	1.00
	Glued, Misaligned	1.01	1.00	1.00	1.00	1.01
Parabolic Hex	Conforming Mesh	1.00	1.00	1.00	1.00	1.00
	Glued, Aligned	1.00	1.00	1.00	1.00	1.00
	Glued, Misaligned	1.00	1.00	1.00	1.00	1.00

Frequencies for linear/parabolic hex models normalized to the corresponding conforming mesh model for each mode to show relative error to "true" solution
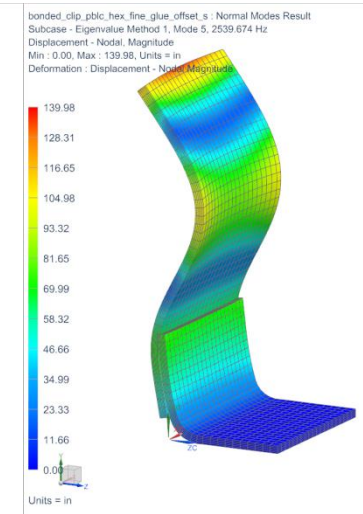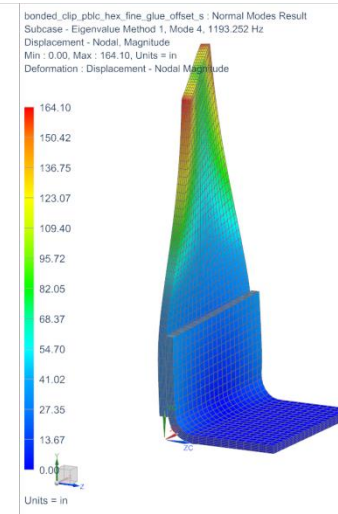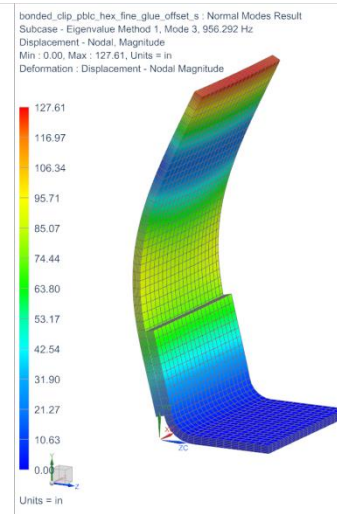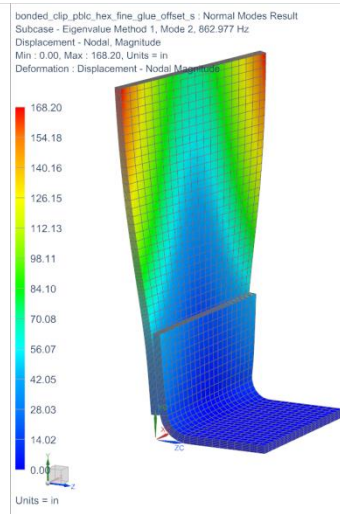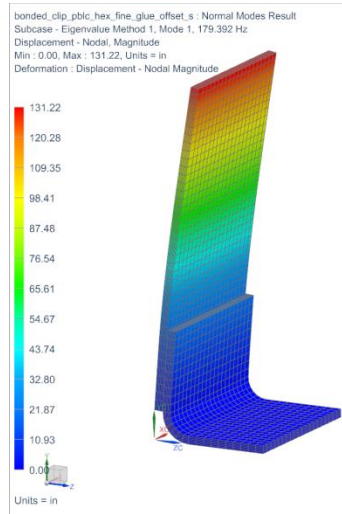
Misaligned Glue Connection Introduces 50%+ Error in Stresses for with Linear Bricks

Stress Components in Gusset

Element Formulation	Connection	Stress Condition	Stress Component	Normalized Stress	Element Formulation	Normalized Stress
Linear Hex	Conforming Mesh	In-plane	YY Tension	1.00	Parabolic Hex	1.00
			XX Tension	1.00		1.00
			YY Compression	1.00		1.00
			XX Compression	1.00		1.00
			In-Plane Shear	1.00		1.00
		Interlaminar	ZZ Tension	1.00		1.00
			YZ Shear	1.00		1.00
			ZX Shear	1.00		1.00
Linear Hex	Glued, Aligned	In-plane	YY Tension	1.00	Parabolic Hex	1.00
			XX Tension	1.00		1.00
			YY Compression	1.00		1.00
			XX Compression	1.00		0.98
			In-Plane Shear	1.00		1.00
		Interlaminar	ZZ Tension	1.00		1.00
			YZ Shear	1.00		1.00
			ZX Shear	1.00		1.00
Linear Hex	Glued, Misaligned	In-plane	YY Tension	1.05	Parabolic Hex	0.93
			XX Tension	1.13		0.83
			YY Compression	1.00		1.04
			XX Compression	1.08		0.87
			In-Plane Shear	1.12		1.17
		Interlaminar	ZZ Tension	**1.57**		**1.18**
			YZ Shear	1.17		0.88
			ZX Shear	**1.45**		**1.00**

σyy, σyx, σyz, σxy, σxz, σxx, σzy, σzz, σzx
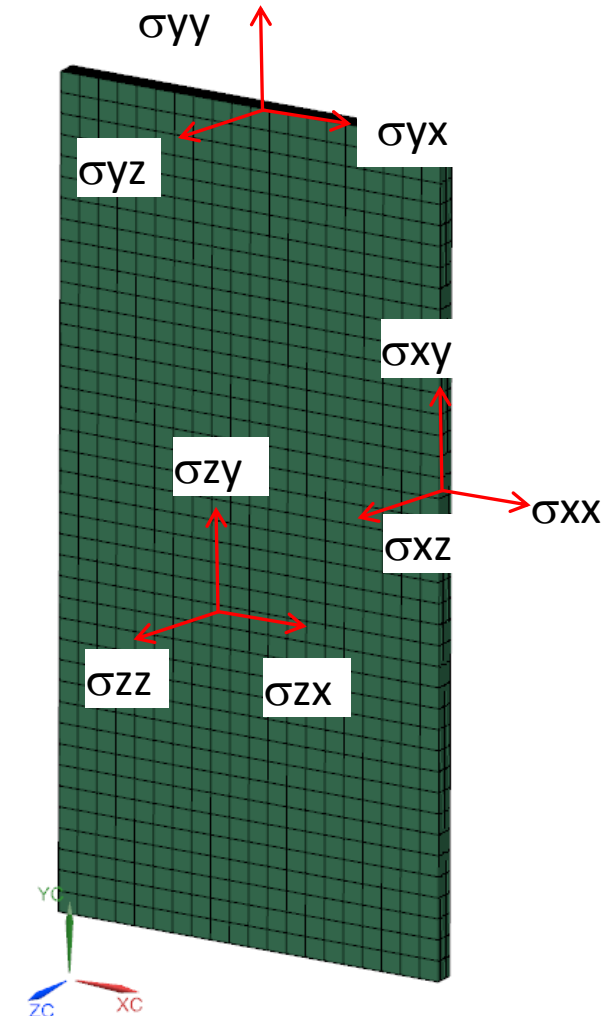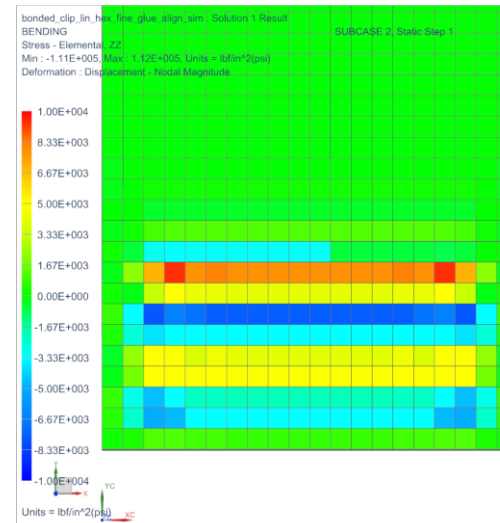
Comparison of Gusset Normal Stresses with Glue Connection for Linear Brick Elements
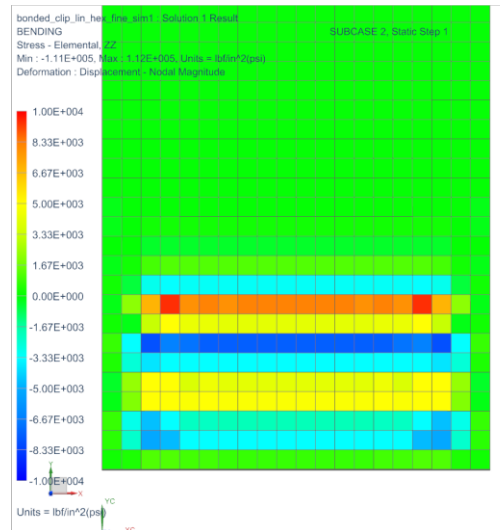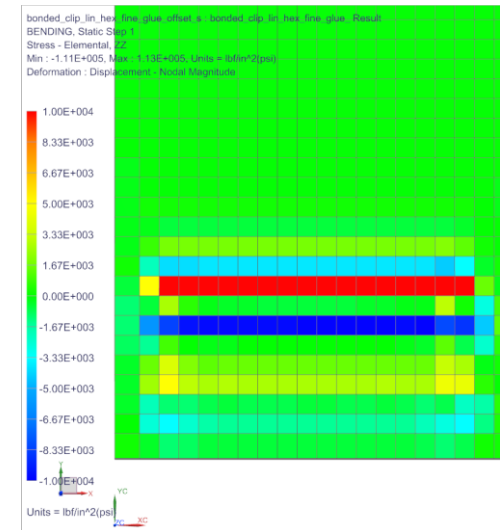
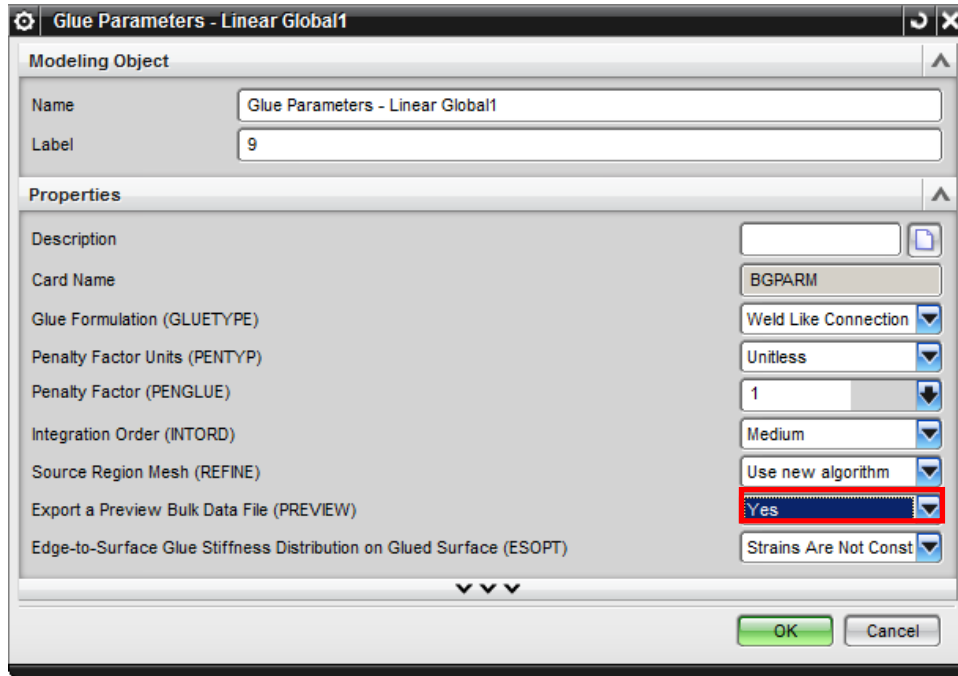**Conforming Mesh** **Glued, Aligned Mesh** **Glued, Misaligned Mesh**

Element centroidal stress contours for normal (through-thickness) stress

Four Important Checks for Glue Connections

- Graphical methods
  1. View glue element preview
  2. Visualize glue results (force, pressure, traction)

- Non-graphical methods
  3. Check *.f06 file for glue diagnostics
  4. Check for grounding that may have been introduced by glue connection

Verifying Glue Connections with Preview

Glue region

Shell elements (blue) representing active element faces on source region

Shell elements (pink) representing active element faces on target region

The preview elements are generated in a new bulk data file from the initial model with the following syntax
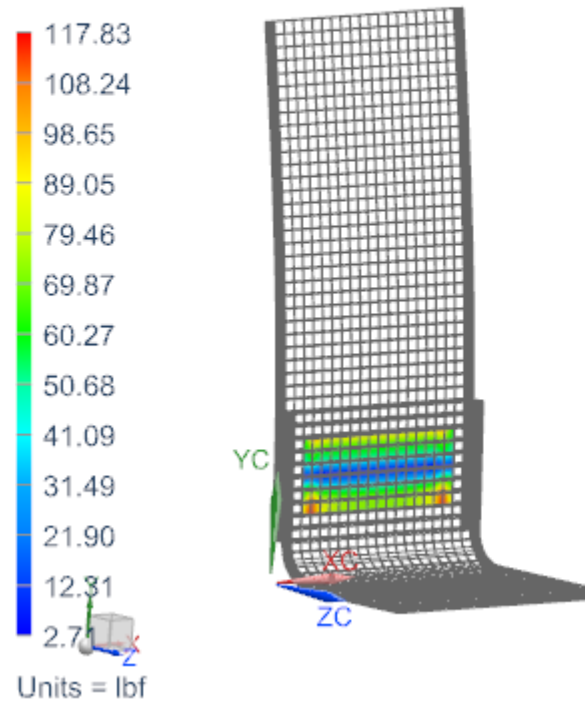<input_file_name>_glue_preview<subcaseid>_<gluesetid>.dat
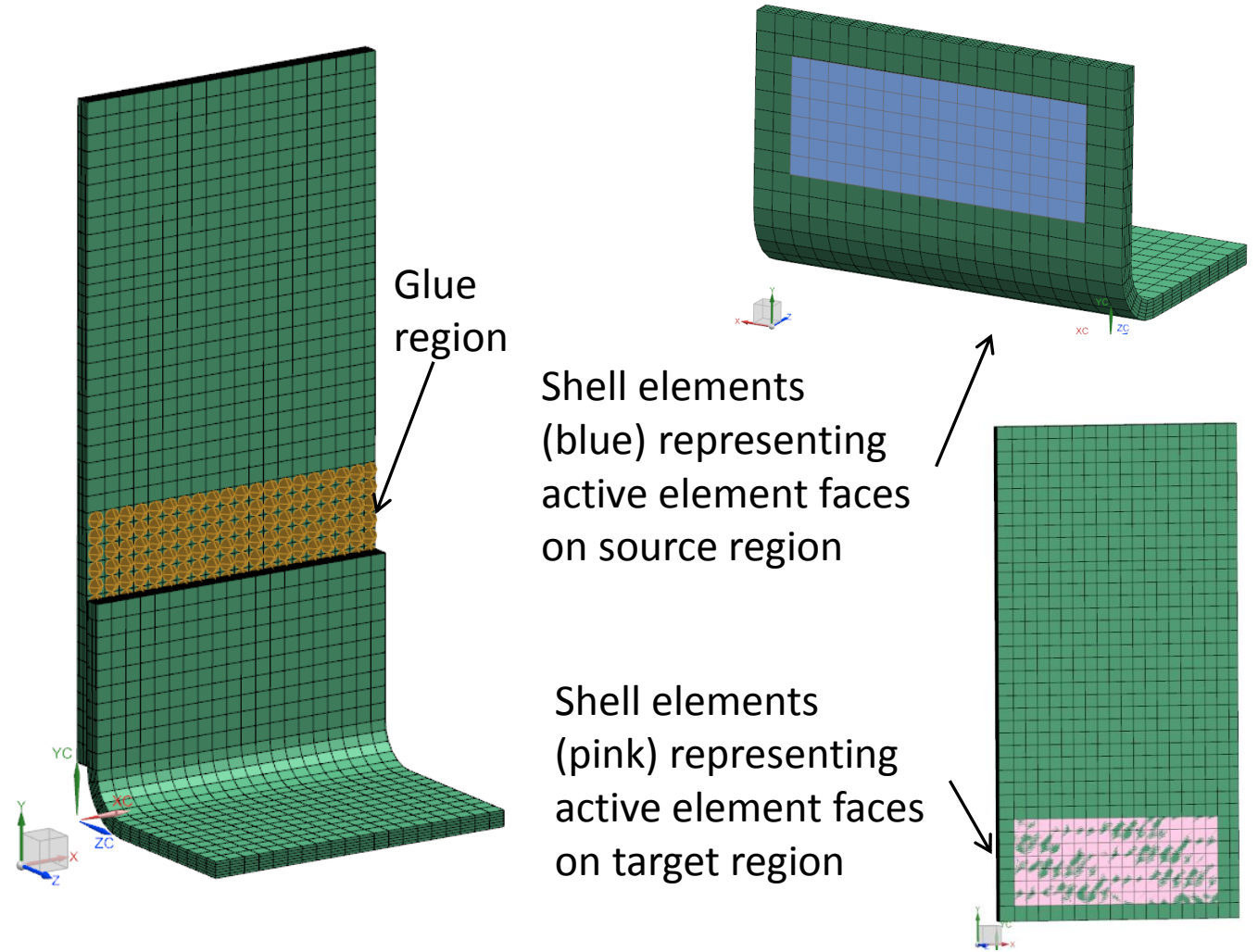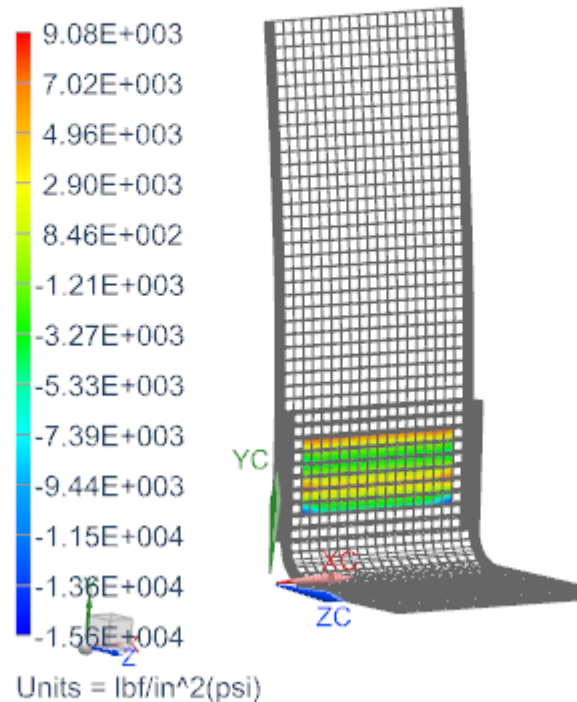
Verifying Glue Connections with Glue Results Output

Glue Force

Imported Result : bonded_clip_lin_hex_fine_glue_align2
BENDING
Glue Force - Nodal, Magnitude
Min : 2.71, Max : 117.83, Units = lbf
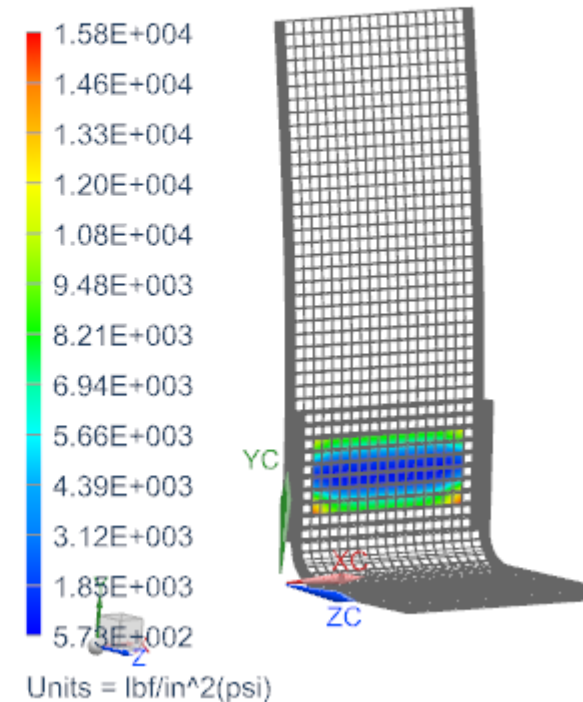Deformation : Displacement - Nodal Magnitude

117.83
108.24
98.65
89.05
79.46
69.87
60.27
50.68
41.09
31.49
21.90
12.31
2.71

Units = lbf

Glue Pressure

Imported Result : bonded_clip_lin_hex_fine_glue_align2
BENDING
Glue Pressure - Nodal, Scalar
Min : -1.56E+004, Max : 9.08E+003, Units = lbf/in^2(psi)
Deformation : Displacement - Nodal Magnitude

9.08E+003
7.02E+003
4.96E+003
2.90E+003
8.46E+002
-1.21E+003
-3.27E+003
-5.33E+003
-7.39E+003
-9.44E+003
-1.15E+004
-1.36E+004
-1.56E+004

Units = lbf/in^2(psi)

Glue Traction

Imported Result : bonded_clip_lin_hex_fine_glue_align2
BENDING
Glue Traction - Nodal, Magnitude
Min : 5.73E+002, Max : 1.58E+004, Units = lbf/in^2(psi)
Deformation : Displacement - Nodal Magnitude

1.58E+004
1.46E+004
1.33E+004
1.20E+004
1.08E+004
9.48E+003
8.21E+003
6.94E+003
5.66E+003
4.39E+003
3.12E+003
1.85E+003
5.73E+002

Units = lbf/in^2(psi)

Verifying Glue Connections with Glue Diagnostics

Nastran issues a warning if glue pairs are separated by an overly large distance

```
**************************************************
    NX Nastran Contact Face Refinement (REFINE)
            (version 9.0 )
**************************************************

*** USER INFORMATION MESSAGE 4690 (REFINE)
    MAXMIMUM REFINEMENT PER FACE: 114
    MINIMUM REFINEMENT PER FACE: 6
*** USER WARNING MESSAGE 4690 (CNTGAPERR)
    The gap between glue faces of some elements in gap pair        2 between
    regions          2 and        4 seems overly large  The largest values are listed
    in the table below:

    ELEMENT      ELEMENT        GAP

      46501       53910     8.05674E+00
      46501       53980     8.05670E+00
      46495       60871     8.03358E+00
      46495       51899     8.01454E+00
      46495       61127     8.01421E+00
      47459       59394     7.98730E+00
      47459       59073     7.98729E+00
      45759       59123     7.98370E+00
      45759       58603     7.98370E+00
      46502       53980     7.98242E+00
```

Double check that **number of glue pairs** is as expected and that Nastran **creates glue connections**

```
*** USER INFORMATION MESSAGE 4690 (FOCOEL)
    CONNECTION STATISTICS

                      GLUE SUBCASE ID:          1
                      GLUE SET ID:            100
                NUMBER OF GLUE PAIRS:            2
      NUMBER OF GLUE ELEMENTS CREATED:        31788
                NUMBER OF GLUE FACES:         8250
      NUMBER OF EFFECTIVE GLUE FACES:         1456

^^^ GLUE STIFFNESS ADDED USING GLUE SET        100 WITH        31788 GLUE POINTS
```
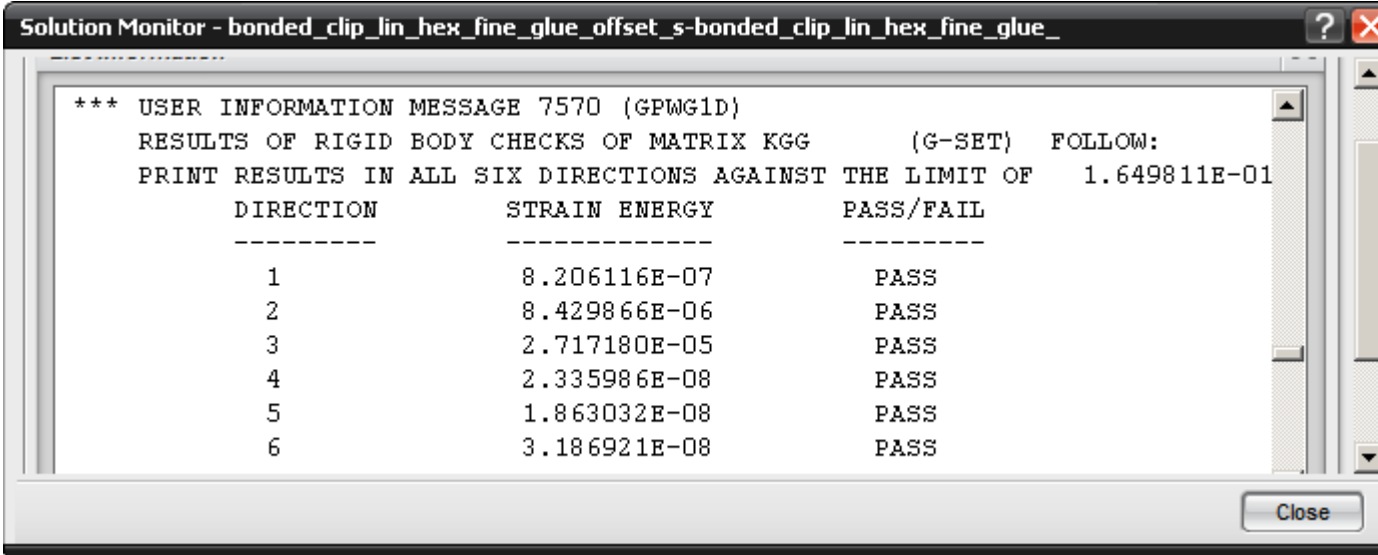
Check for Grounding Effects in Glue Solutions

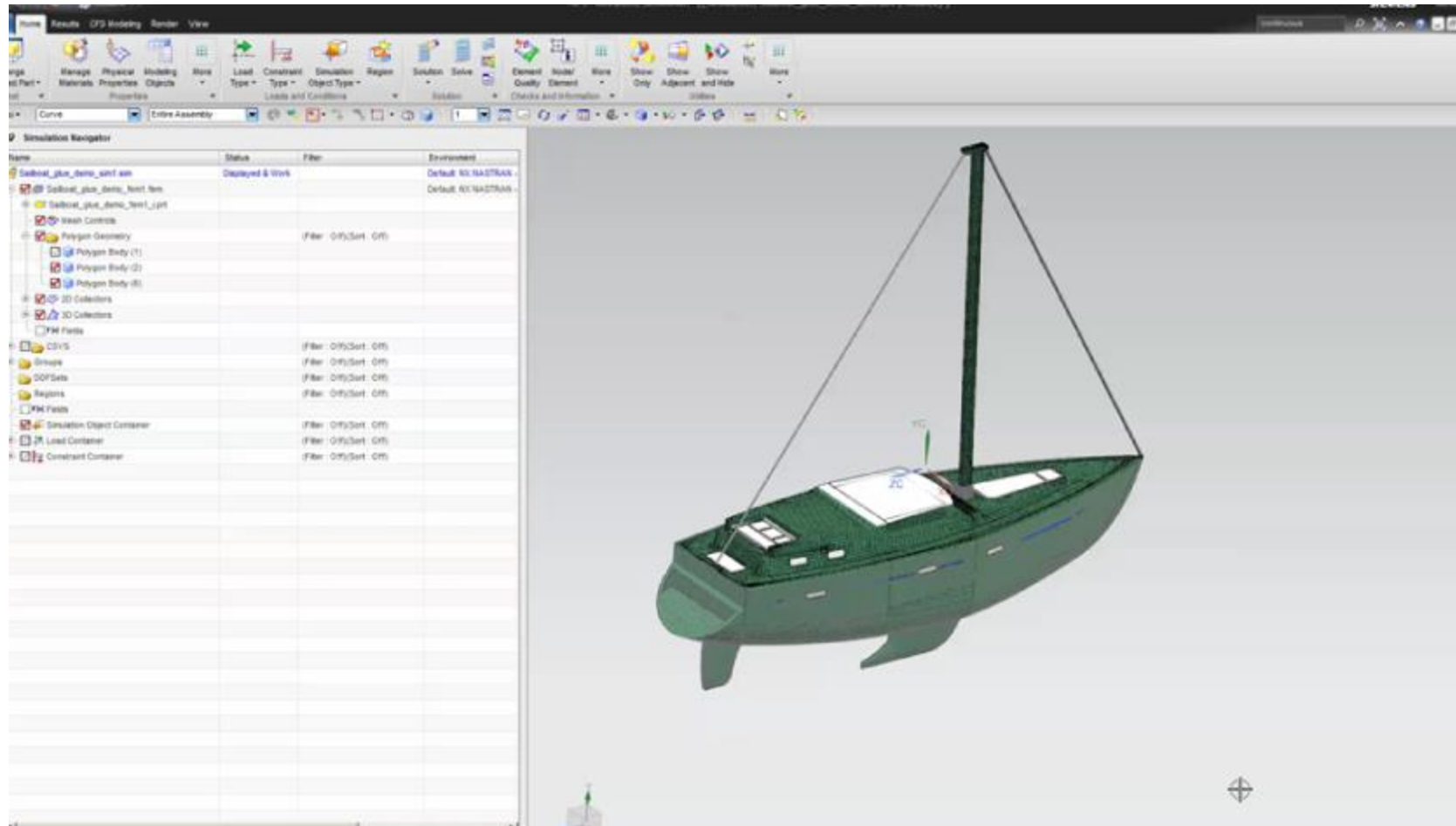- Look for a PASS in all six degrees of freedom

```
Solution Monitor - bonded_clip_lin_hex_fine_glue_offset_s-bonded_clip_lin_hex_fine_glue_

*** USER INFORMATION MESSAGE 7570 (GPWG1D)
    RESULTS OF RIGID BODY CHECKS OF MATRIX KGG      (G-SET)    FOLLOW:
    PRINT RESULTS IN ALL SIX DIRECTIONS AGAINST THE LIMIT OF    1.649811E-01
        DIRECTION           STRAIN ENERGY        PASS/FAIL
        ---------          --------------       ---------
            1               8.206116E-07           PASS
            2               8.429866E-06           PASS
            3               2.717180E-05           PASS
            4               2.335986E-08           PASS
            5               1.863032E-08           PASS
            6               3.186921E-08           PASS

                                                      Close
```

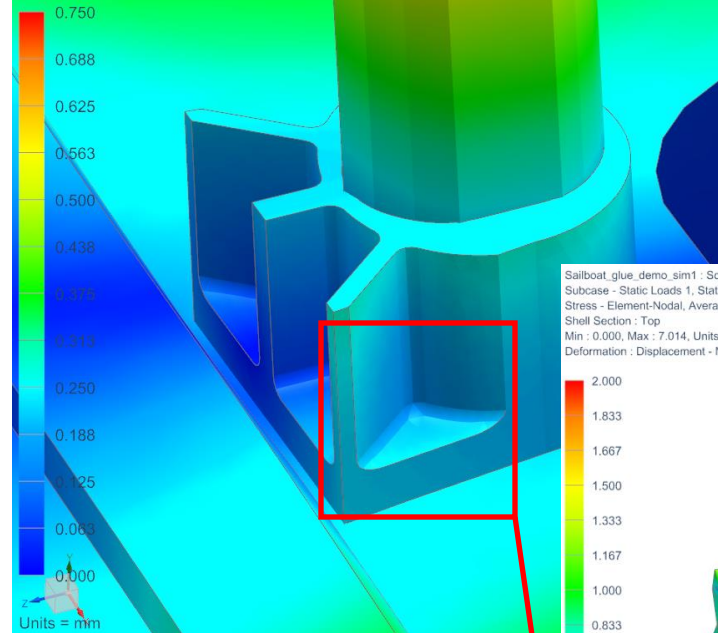# NX Nastran Mesh Gluing Example – Sailboat Mast Plate Adapter Fitting
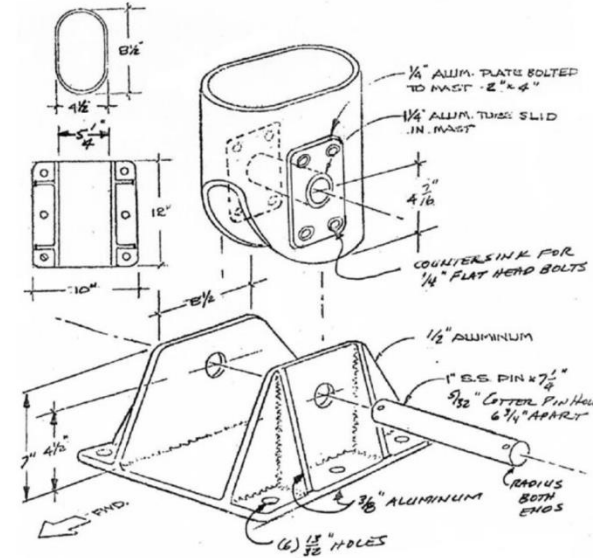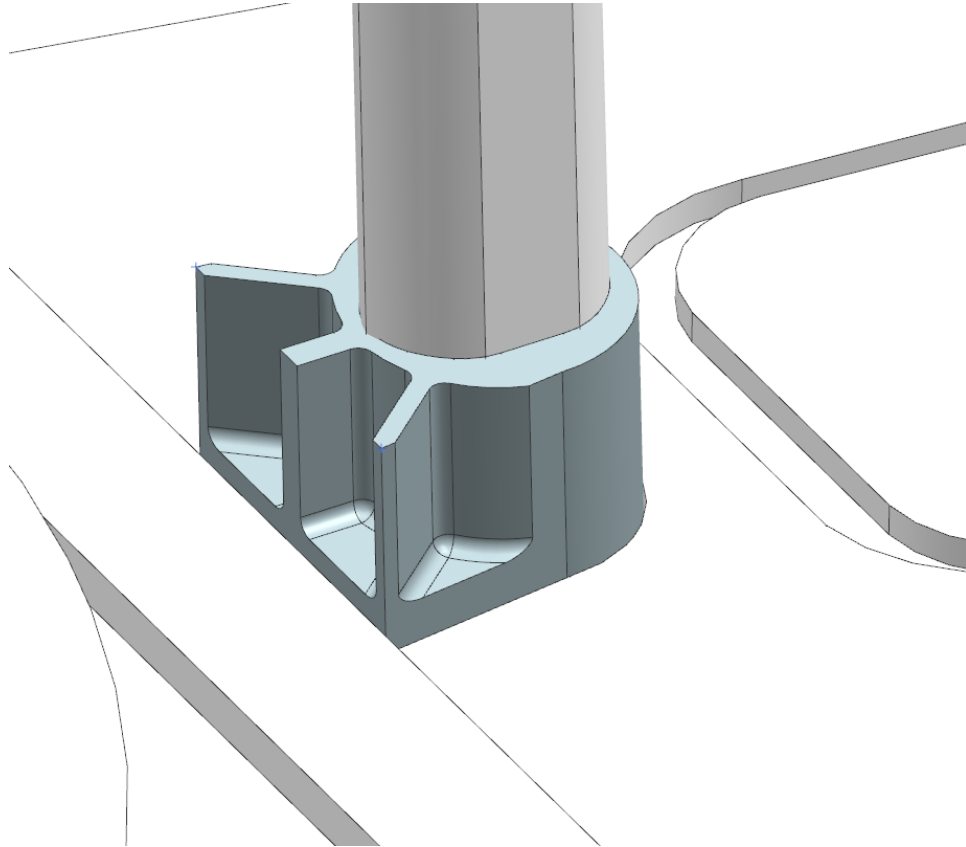
NX Nastran Mesh Gluing Sailboat Demonstration
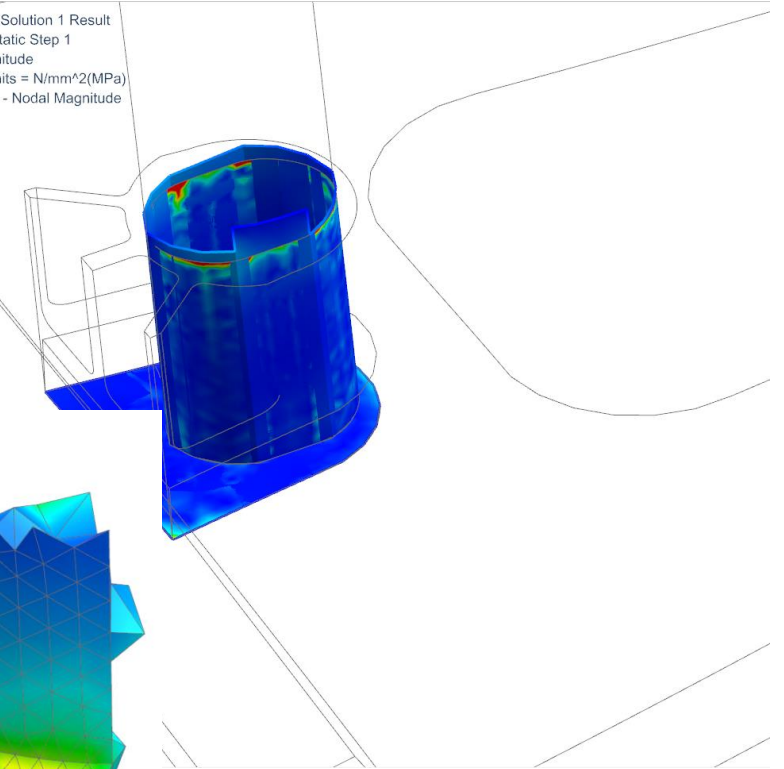
Sailboat Demonstration Sample Results

Guidelines and Best Practices for NX Nastran Mesh Gluing

- NX Nastran mesh gluing provides a simple, straightforward way of attaching dissimilar meshes

- The default glue options (weld, unitless penalty factor) provide the best starting point

- When joining perpendicular shell faces, use edge-to-surface gluing, not edge-to-edge gluing

- Glued meshes provide satisfactory stiffness predictions

- Avoid using gluing near peak stress areas where accurate stress recovery is critical

- Use parabolic elements when using surface-to-surface gluing with solid elements for better stiffness and stress predictions
  - Unless the problem necessitates linear elements, then consider gluing far from the high-stress areas

- Important checks for solutions with glued connections
  1. Inspect glue element preview
  2. Visualize glue connection output (force, pressure, traction)
  3. Check *.f06 file for glue diagnostics
  4. Verify that grounding strain energies are reasonable

Questions?

Tuesday, June 17th, 3:45pm – 4:45pm
Celebration 9

- Accelerate analysis time by joining dissimilar meshes with NX Nastran mesh gluing

Presenter:
Jonathan Buck, ATA Engineering
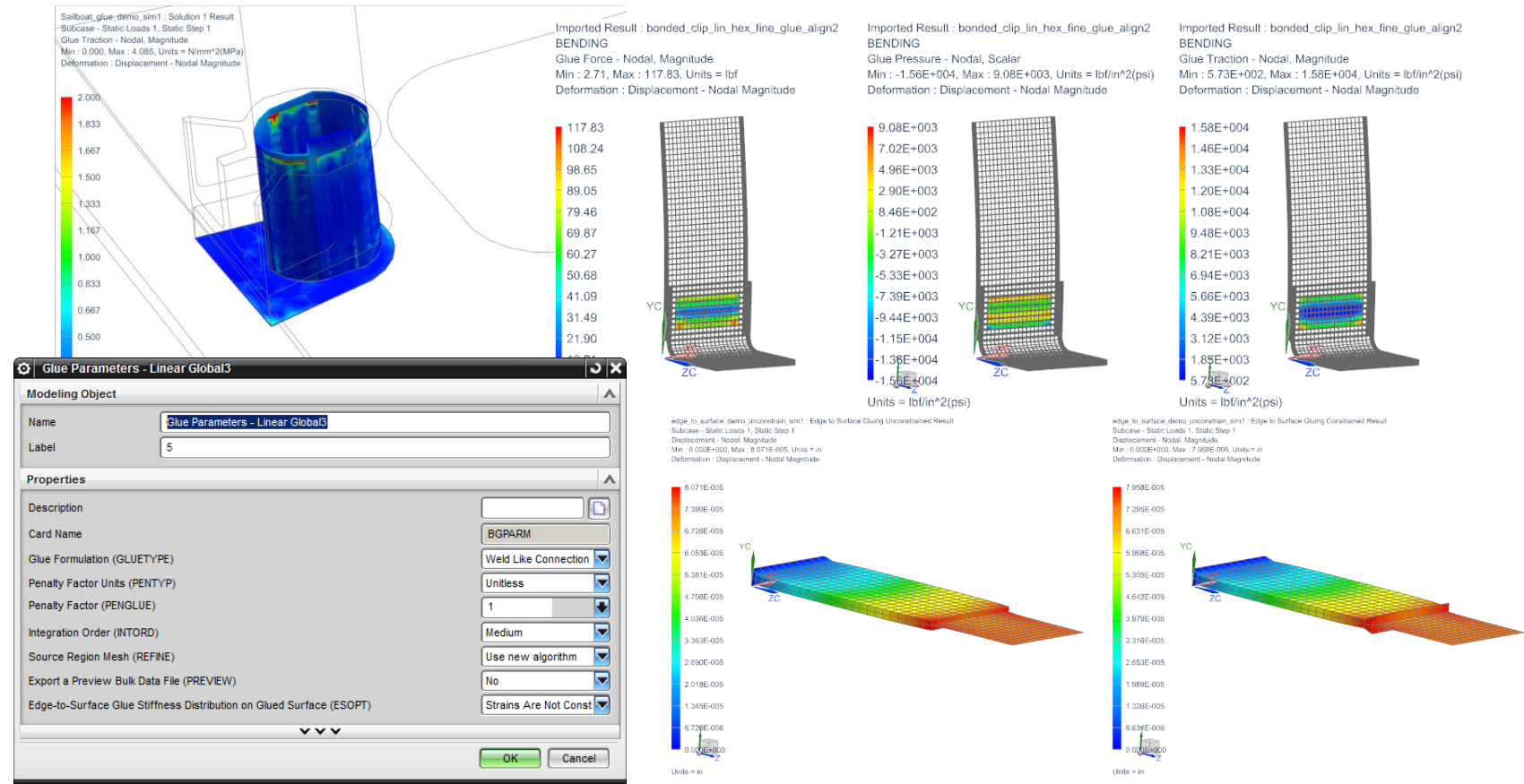
Thank you

Siemens PLM Connection 2014
Orlando, FL
June 16-19, 2014