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Large Assembly Modeling using Glued Contact

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Presentation Outline

- Glued contact as an assembly modeling technique
  – Pros and Cons
- Two new tools for large assembly modeling
  – Flexible glued contact
  – Beam cross-sectional glued contact
- Applications of flexible glued contact
  – Better load distribution inside a joint
  – Better load distribution inside an assembly
  – More accurate normal modes predictions
- Applications of beam cross-sectional contact

Glued Contact Modeling Overview

- Glued contact ties parts together in both the normal and tangential directions
- MSC Nastran offers two glued contact methods
  - **Node-to-Segment method** – uses Lagrange multipliers
  - **Segment-to-Segment method** – uses the penalty method
- Glued contact can be used to simulate adhesive bonded joints or fastened connections (bolts, rivets, shear pins, etc.)

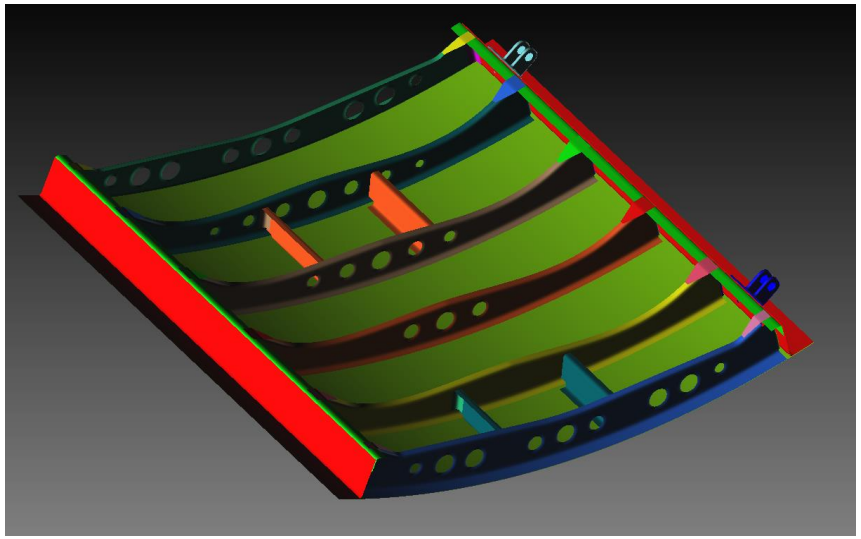
Glued Contact Modeling Overview (cont.)

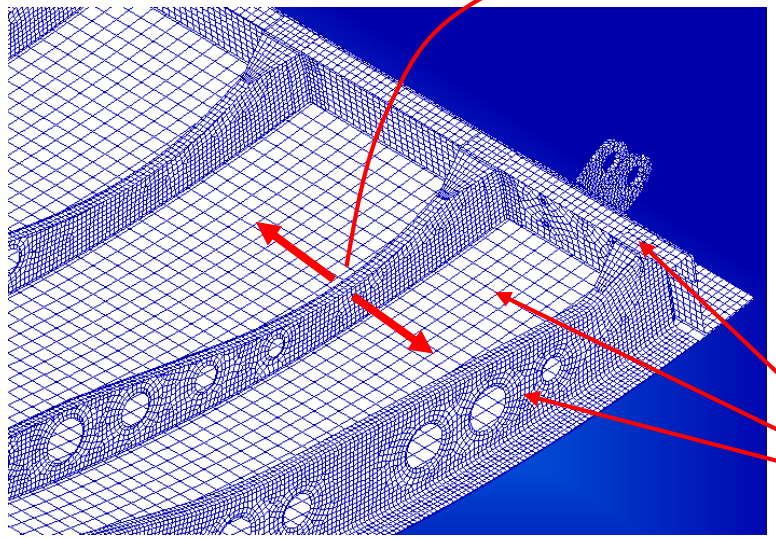
- When compared to the discrete fastener (CFAST, CBUSH, etc.) modeling method, glued contact has the following advantages and disadvantages:
- **Advantages**
  - Glued contact is much easier and faster to set up than the discrete fastener method
  - Enables quick design iterations by allowing the components to be re-meshed and repositioned easily

- **Disadvantages**
  - It cannot recover individual fastener loads
  - It represents a rigid connection which affects the accuracy of load distribution and normal modes predictions

Glued Assembly Model - Advantages

- The benefit of glued contact is demonstrated in the landing gear door assembly shown below
- Glued contact allows the ribs to be re-meshed and/or repositioned inside the assembly during design tradeoff studies



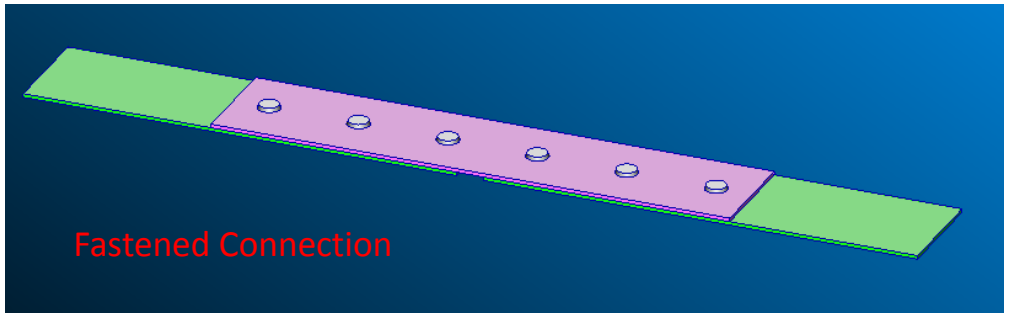


Glued Assembly Model - Disadvantages

- The downside of glued contact is that it represents a **rigid connection** which affects the accuracy of load distribution and normal modes predictions
  - This rigidity can lead to the overestimation of end loads and peaking at runout details and part edges
  - It can also affect load distribution in an assembly
  - It also tends to overestimate modal frequencies
  - Therefore glued contact should not be used where the joint detailed forces and stresses are of interest. Glued contact is more appropriate for providing a load path away from areas of interest.

Flexible Glued Contact - Introduction

- Flexible glued contact adds flexibility to the traditional glued contact. It is available only for the Segment-to-Segment contact method which uses the penalty method.
- One possible application is the simulation of fastened joints



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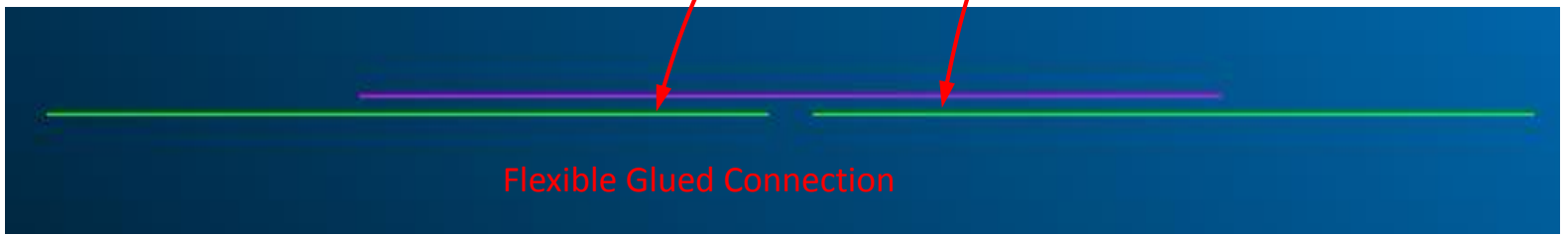


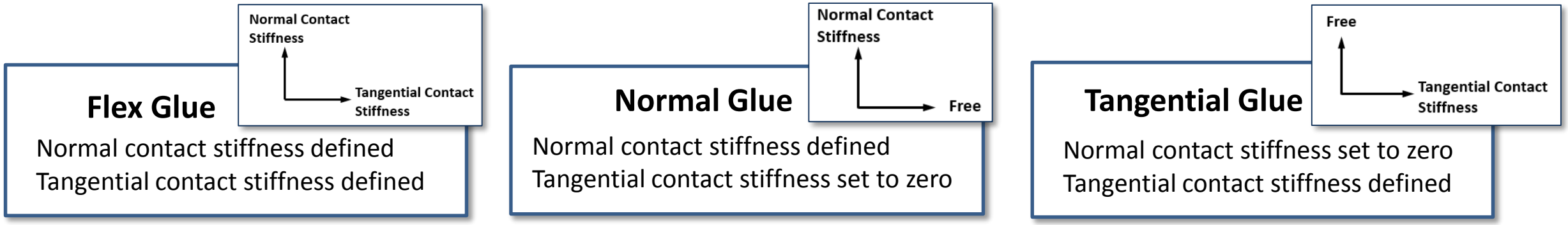
Flexible Glued Joint with normal contact stiffness and tangential contact stiffness defined by the user

Normal Contact Stiffness

Tangential Contact Stiffness

Flexible Glued Contact – How to Define It

- To activate flexible glued contact, do the following:
  - Turn on flexible glue flag **FGCFLG**=1
  - Define normal contact stiffness **FGCNST** and tangential contact stiffness **FGCTST**
  - Contact stiffness values can be defined **locally** for individual contact pairs or **globally** for all contact pairs in one shot
  - Optionally specify a point to sum total glued force/moment
  - FGCNST and FGCTST can be tuned individually or set to zero to simulate different joint designs



Possible flexible glued contact scenarios

Flexible Glued Contact – Advantages

- Advantages of flexible glue over rigid glue
  - Better load distribution inside a joint
  - Better load distribution inside an assembly
  - More accurate normal modes predictions

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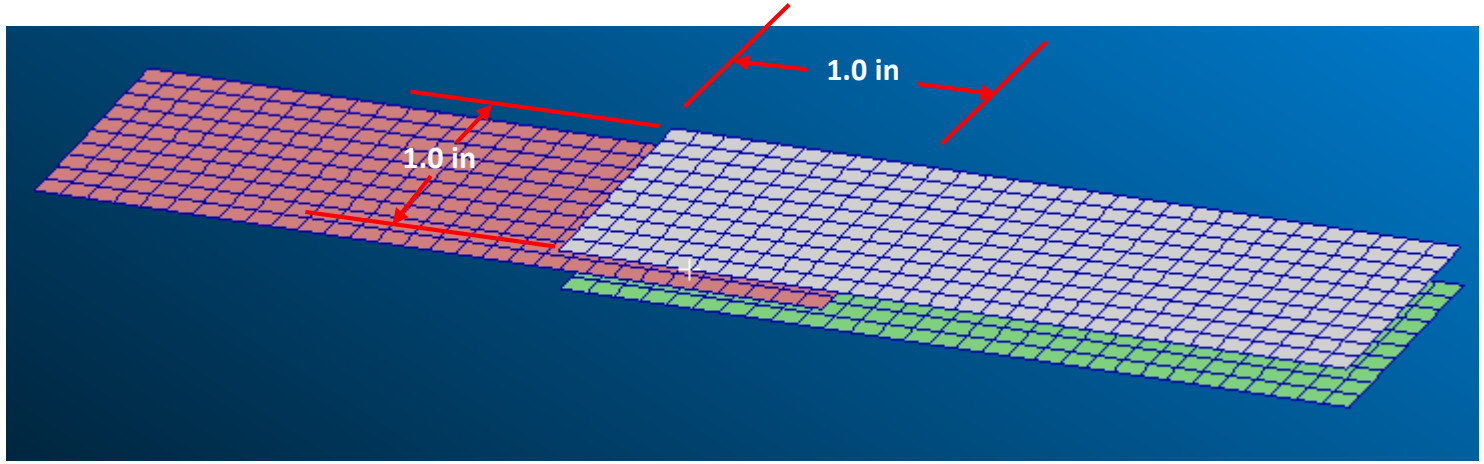
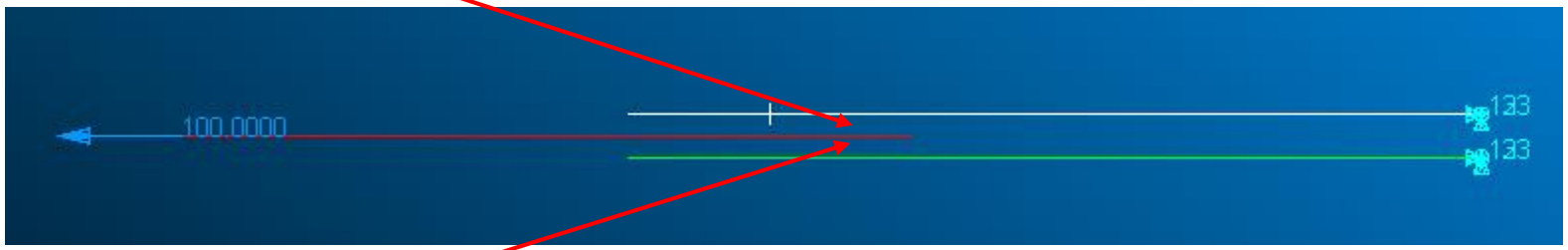
Load Distribution Inside a Glued Joint

- Double lap adhesive bonded joint example modeled by flexible glue



Flexible Glue

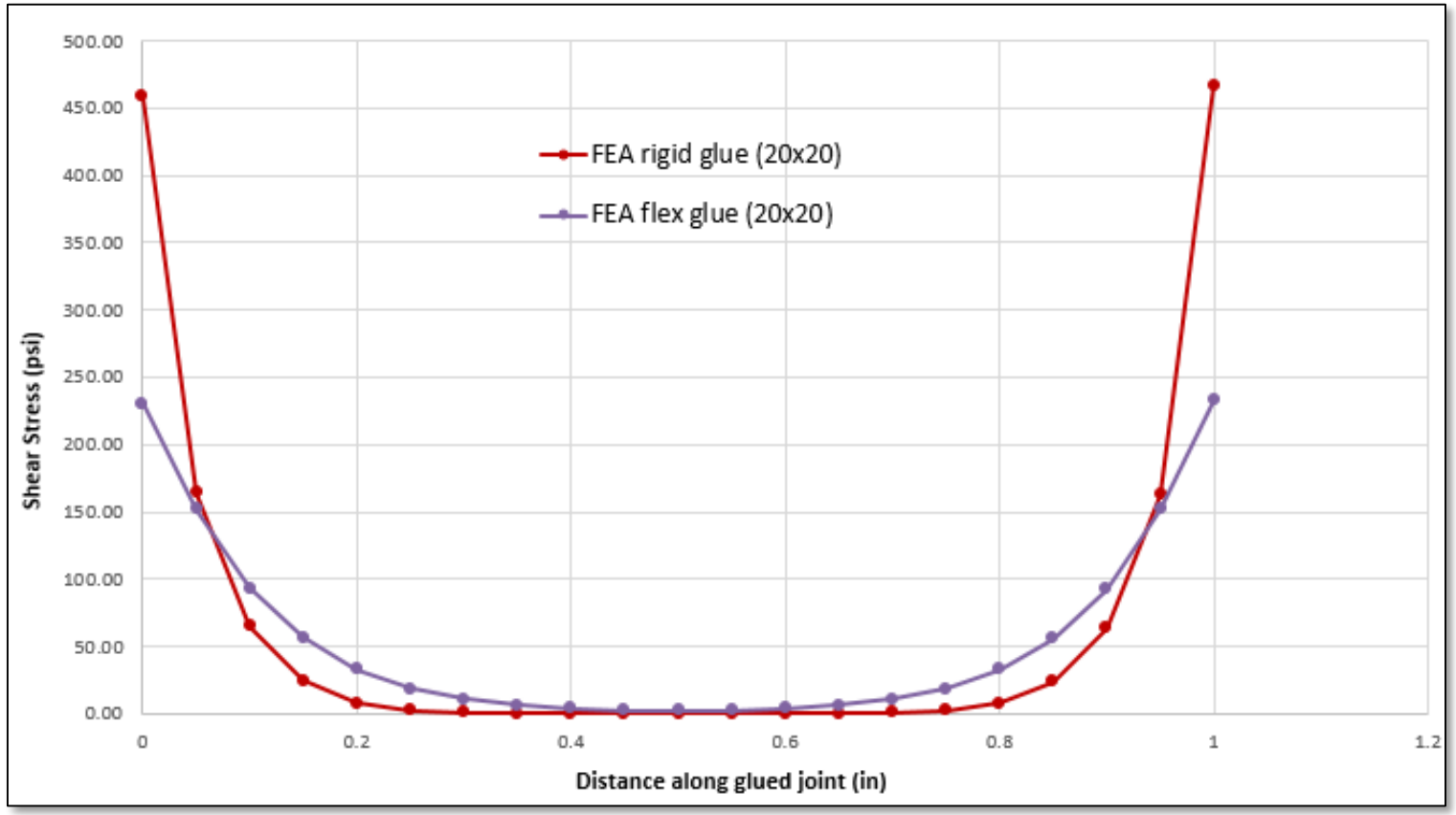


Flexible Glue

Ref: Report No. DOT/FAA/AR-05/12 Methods of Analysis and Failure Predictions for Adhesively Bonded Joints of Uniform and Variable Bondline Thickness, May 2005, Yuqiao Zhu and Keith Kedward

Shear Stress Distribution Inside a Glued Joint

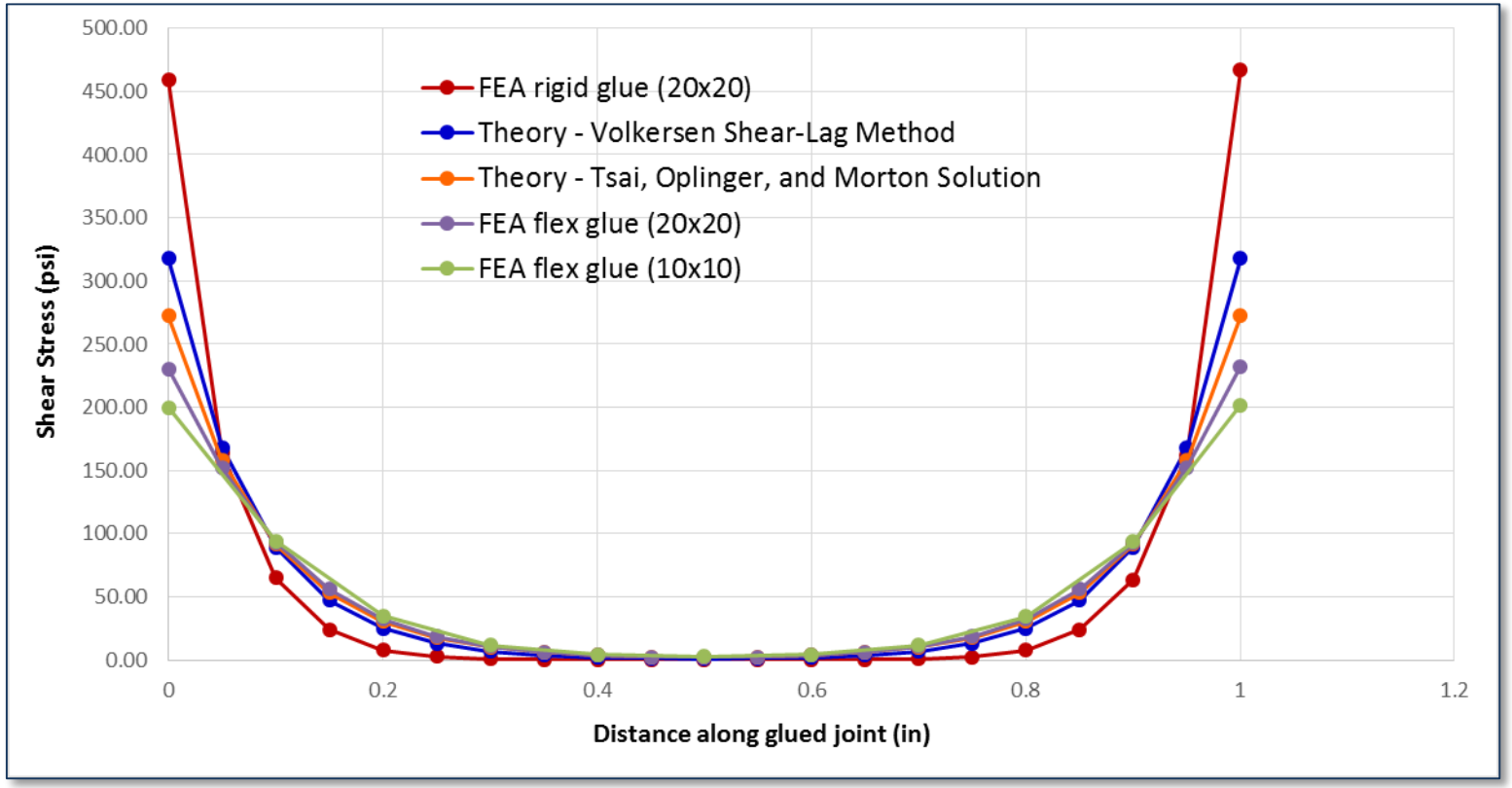
- Rigid glue vs. flexible glue
  - Rigid glue shear stress peaks unrealistically at ends of joint



Tangential contact stiffness FGCTST = G/t and Normal contact stiffness FGCNST = E/t

Shear Stress Distribution Inside a Glued Joint

- Rigid glue vs. flexible glue vs. theory
  - Flexible glue in reasonable agreement with theory

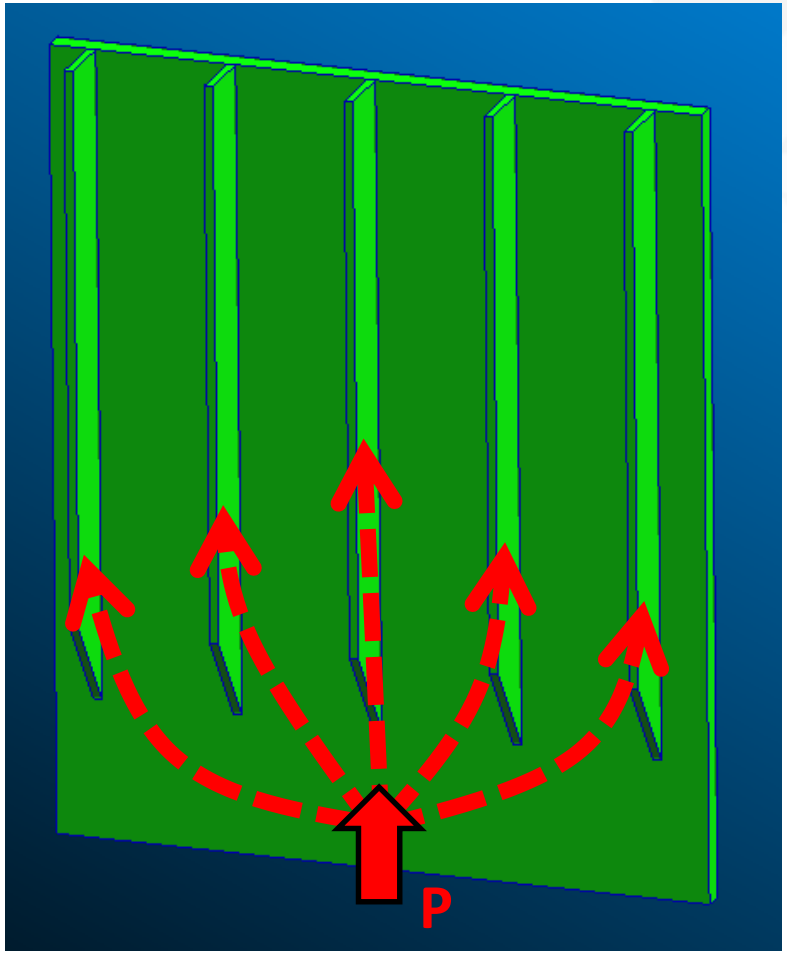


Flexible Glued Contact – Advantages

- Advantages of flexible glue over rigid glue
  - Better load distribution inside a joint
  - Better load distribution inside an assembly
  - More accurate normal modes predictions

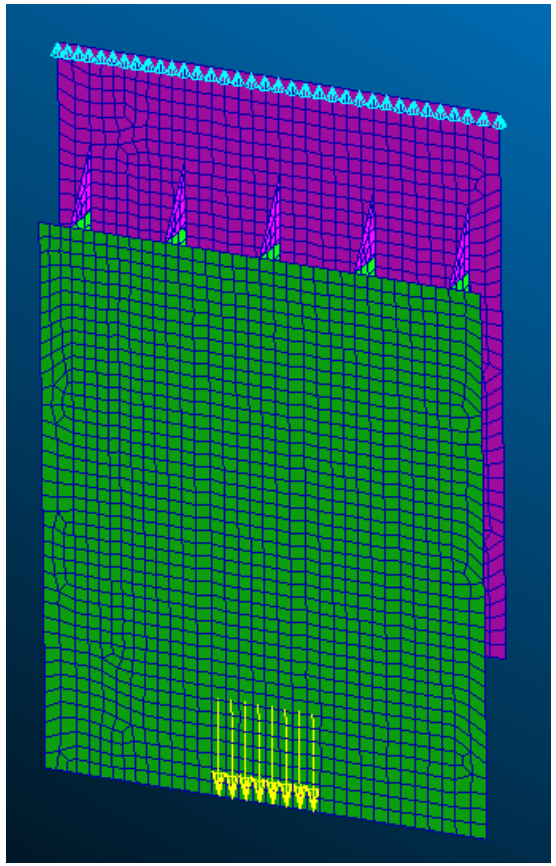
Load Distribution Inside an Assembly

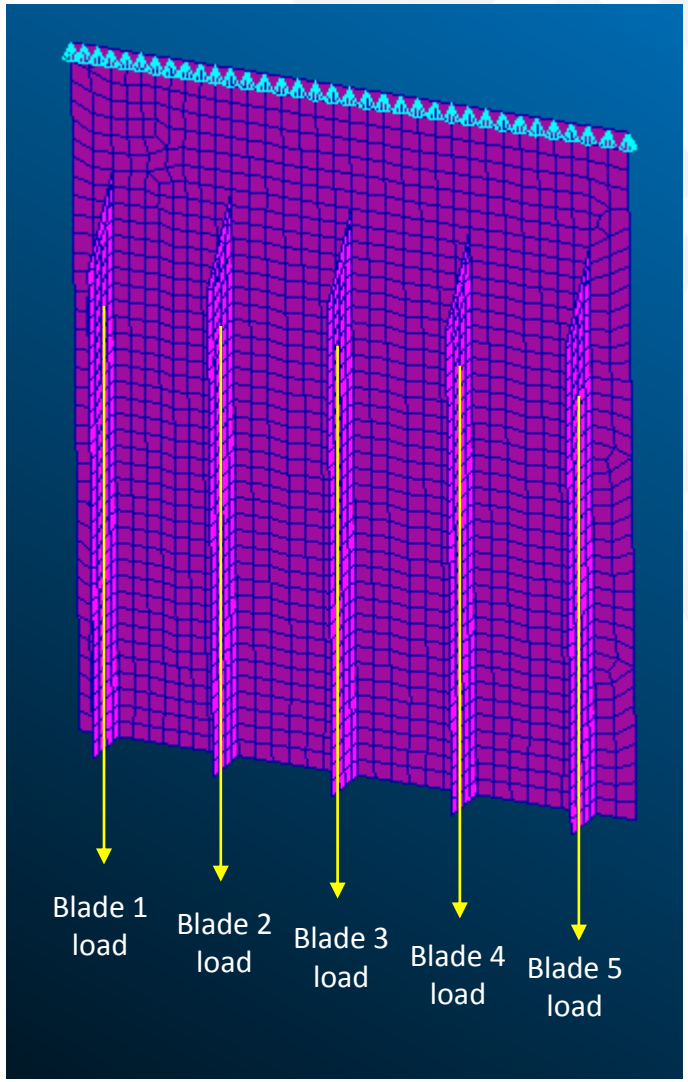
- Load path is driven by stiffness, and a stiffer region attracts more load
- So a more accurate representation of joint stiffness will result in more accurate load distribution among the different members in the assembly
- Flexible glued contact can help achieve this more accurate load distribution



Glued Assembly Example

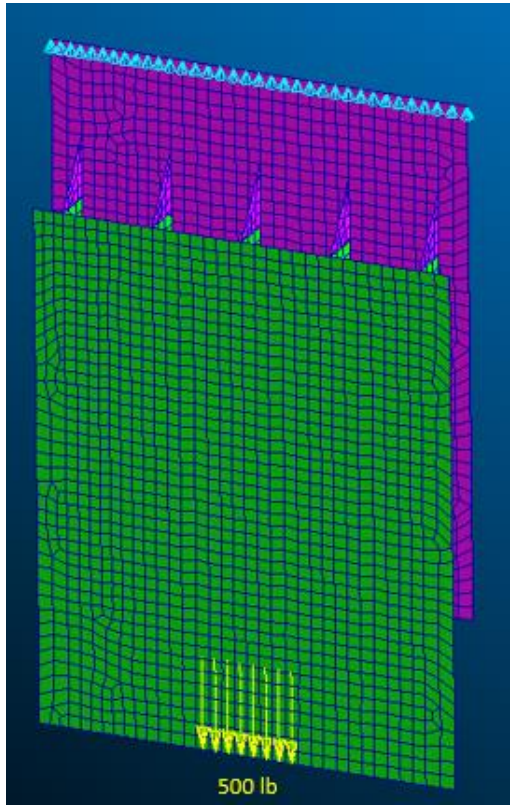
- In this example, load is transferred between two panels, each with 5 blades that are fastened by rivets
- The load path through the 5 shear connections is a function of the joint stiffness
- Glued contact is used to simulate the connections

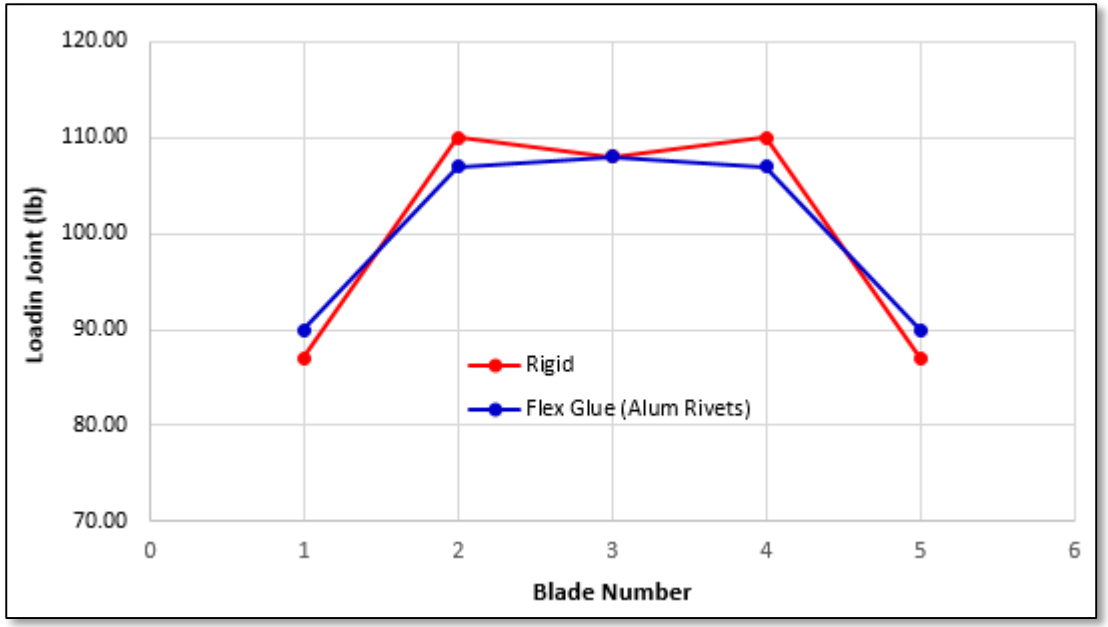




Glued Assembly Example (cont.)

- The load is apply around the centreline of the lower panel
- With rigid glue, the load is carried mostly by the 3 center blades
- With flexible glue simulating the riveted joints, the load is spread out more realistically to the outer blades



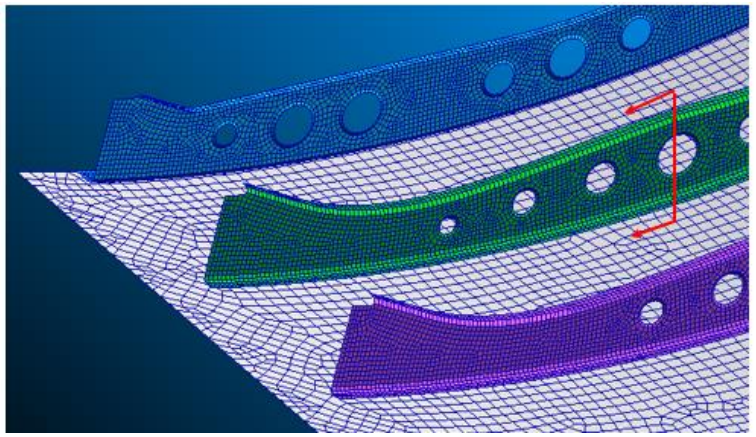


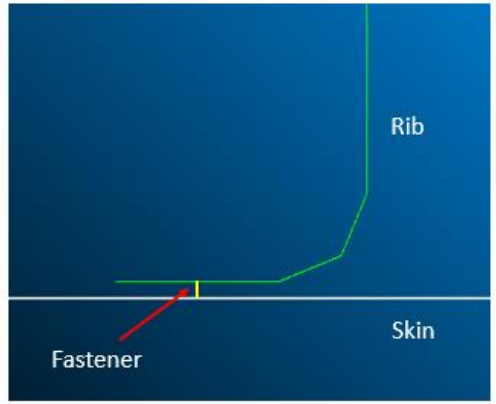
Flexible Glued Contact – Advantages

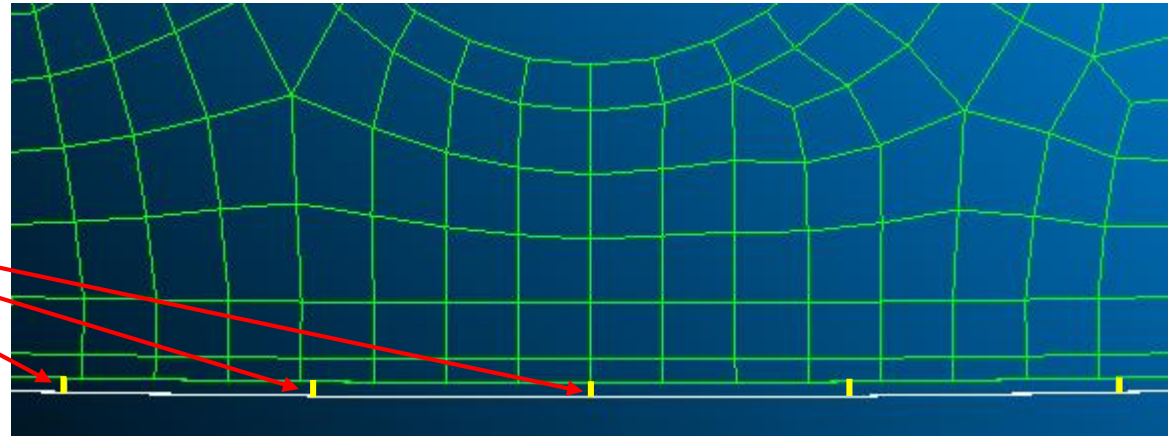
- Advantages of flexible glue over rigid glue
  - Better load distribution inside a joint
  - Better load distribution inside an assembly
  - More accurate normal modes predictions

Static Loads Models Using Fasteners

- Discrete fasteners element (CFAST, CBUSH, etc.) are used to model fastened joints
- Touching contact can be added to further improve the accuracy of the joint modeling by simulating the interaction between the fastened members
- The discrete fastener method works well in a static analysis where the purpose is to determine fastener loads





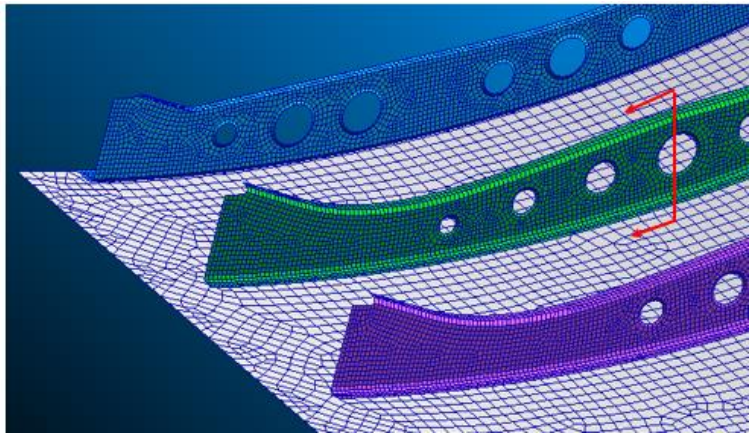


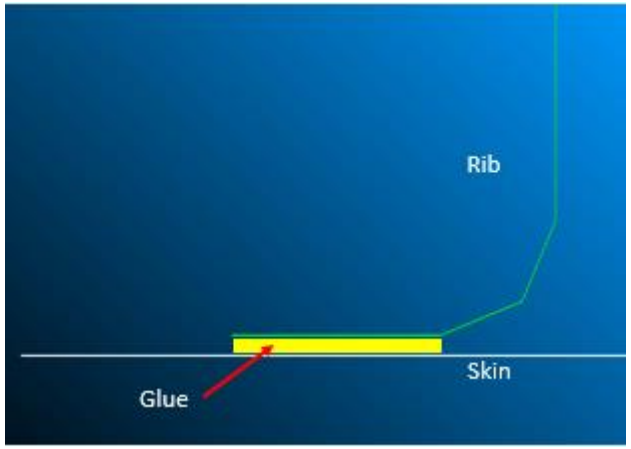
Normal Modes Models Using Fasteners

- In a normal modes model with discrete fasteners, the modal frequencies predicted could be **lower** than test results
- This is because the interaction between the attached members is not simulated
- Touching contact is a nonlinear technique which cannot be used in a linear analysis

Normal Modes Models Using Glued Contact

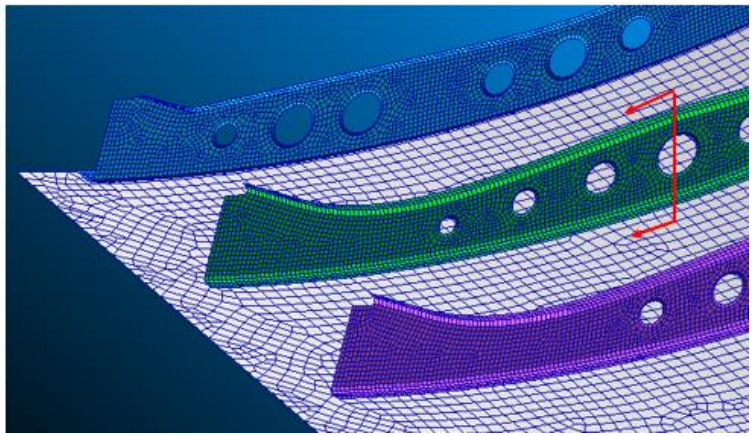
- Glued contact could be used in place of discrete fasteners in normal modes analysis
- But because the glue is rigid, the glued contact technique could produce modal frequencies that are **higher** than test results

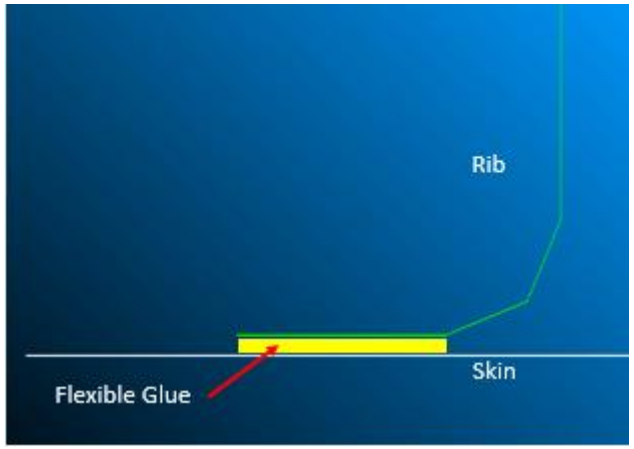


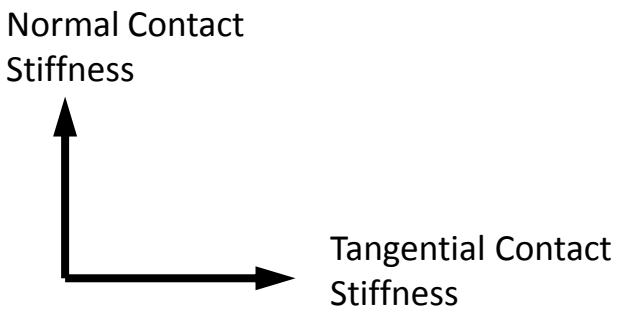


Normal Modes Models Using Flexible Glued Contact

- Flexible glued contact combines the best of both techniques
  - Fastener shear stiffness represented by glue tangential contact stiffness
  - Part interaction in the normal direction represented by glue normal contact stiffness
  - Normal modes can be tuned by adjusting glue stiffness values

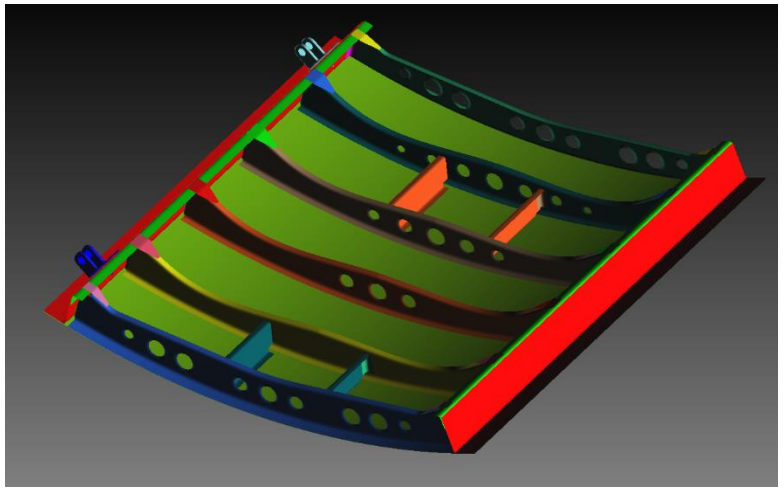


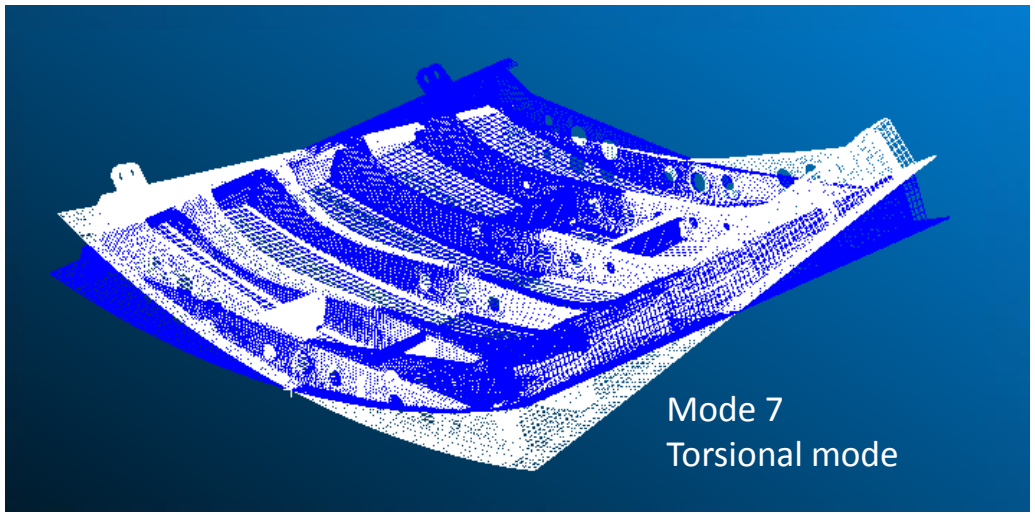




Normal Modes Results Comparison

- A free-free normal modes analysis of a landing gear door assembly was performed using three different methods
- For mode 7, flexible glue falls in between discrete fastener and rigid glue
- Flexible glue can be tuned in normal/tangential directions to match the test normal modes results

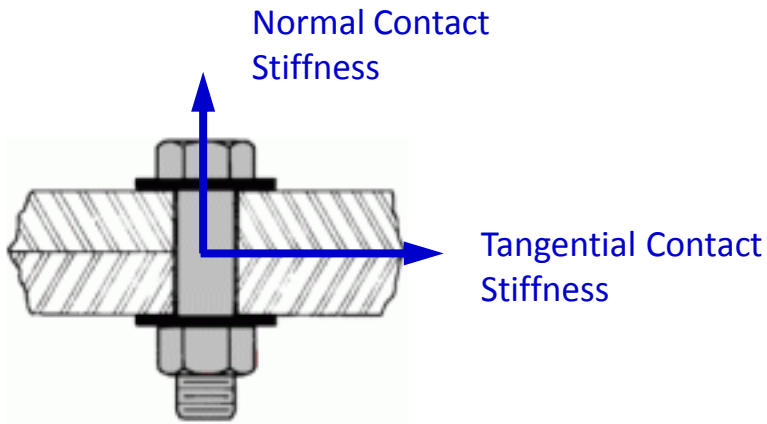




Discrete Fasteners	Flexible Glue	Rigid Glue
4.76 Hz	5.82 Hz	8.53 Hz

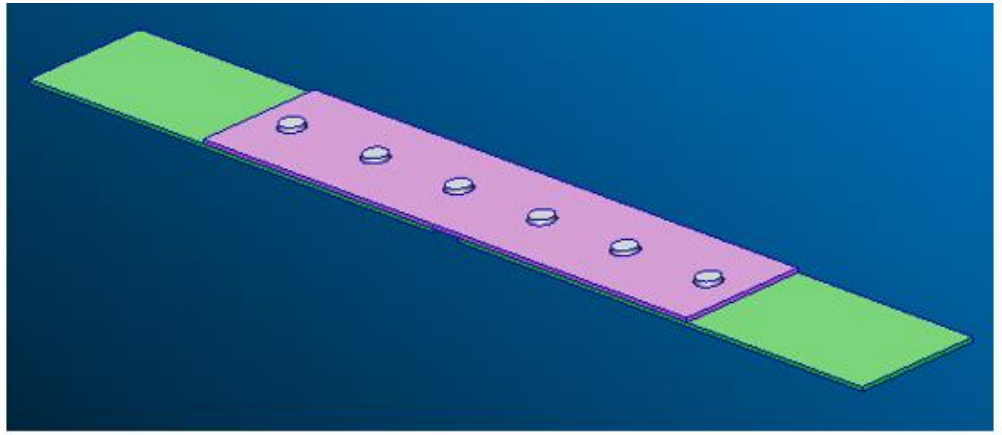
How to Estimate Tangential and Normal Contact Stiffness Values for Fastened Joints

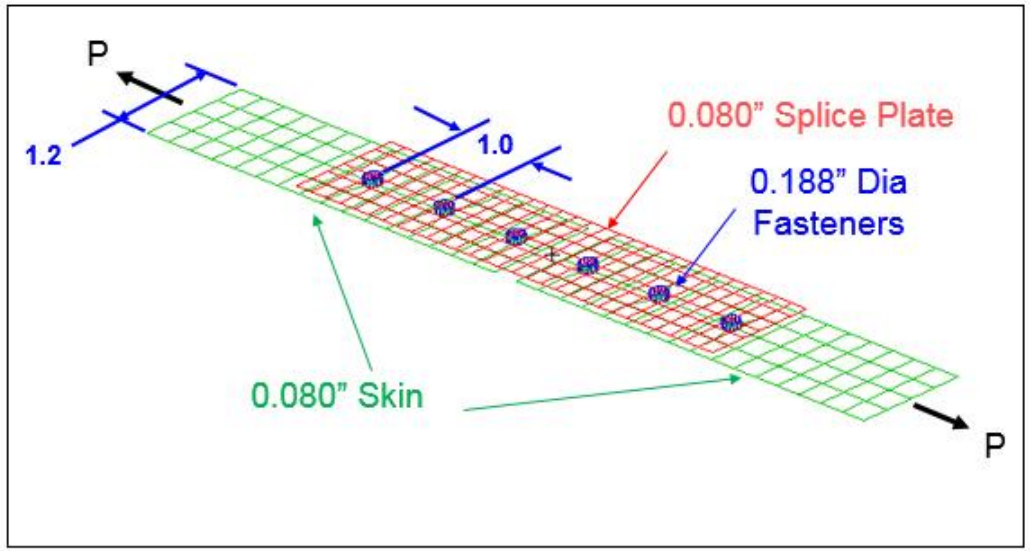
- Flexible glued contact requires two input – normal stiffness and tangential stiffness
- For a fastened connection, these two glue stiffness values can be estimated from the fastener stiffness



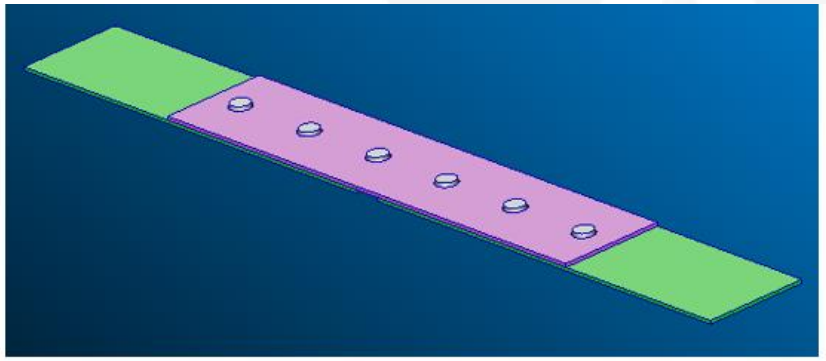
How to Estimate Tangential and Normal Contact Stiffness Values for Fastened Joints (cont.)

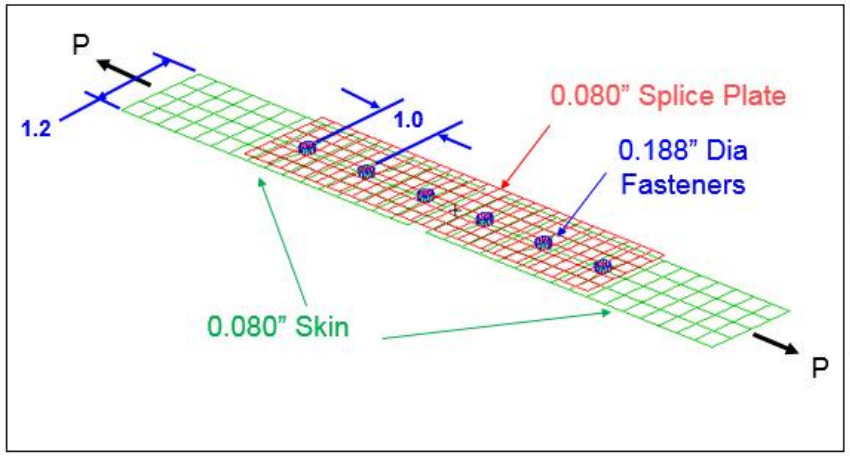
- A splice joint example is used to demonstrate the estimate of glued contact normal and tangential stiffness values





Estimating Glue Stiffness Values

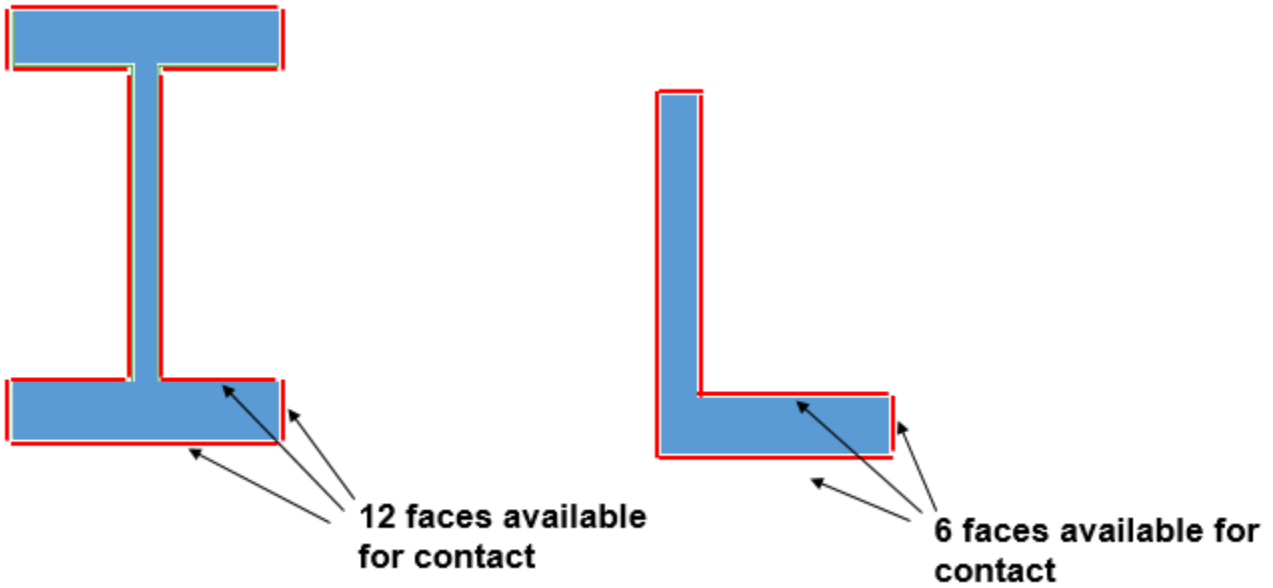




- The fastener stiffnesses based on the Huth formulation are
  - $\mathbf{K}_{axial}$ = 2.776x10^6 lb/in
  - $\mathbf{K}_{shear}$ = 1.836x10^5 lb/in
- The effective area belonging to each fastener is
  - **A** = glued joint width x fastener spacing = 1.2" x 1.0" = 1.2 in^2
- The smeared stiffness values are
  - $\mathbf{K}_{normal} = \mathbf{K}_{axial}/\mathbf{A}$ = 2.776x10^6/1.2 = 2.31x10^6 lb/in^3
  - $\mathbf{K}_{tangential} = \mathbf{K}_{shear}/\mathbf{A}$ = 1.836x10^5/1.2 = 1.53x10^5 lb/in^3
- Input into Nastran
  - **FGCNST** = $\mathbf{K}_{normal}$ = 2.31x10^6
  - **FGCTST** = $\mathbf{K}_{tangential}$ = 1.53x10^5
- Because the fastener stiffnesses are smeared over the glued joint, the resulting deflections are only approximations and will not exactly match a fastener model.

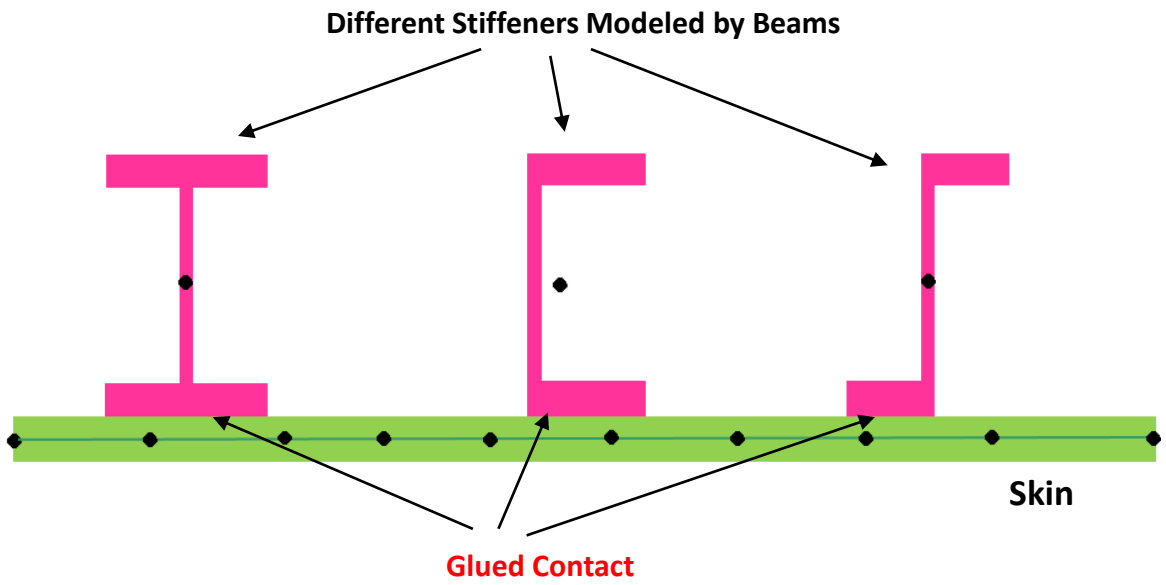
Beam Cross-Sectional Contact

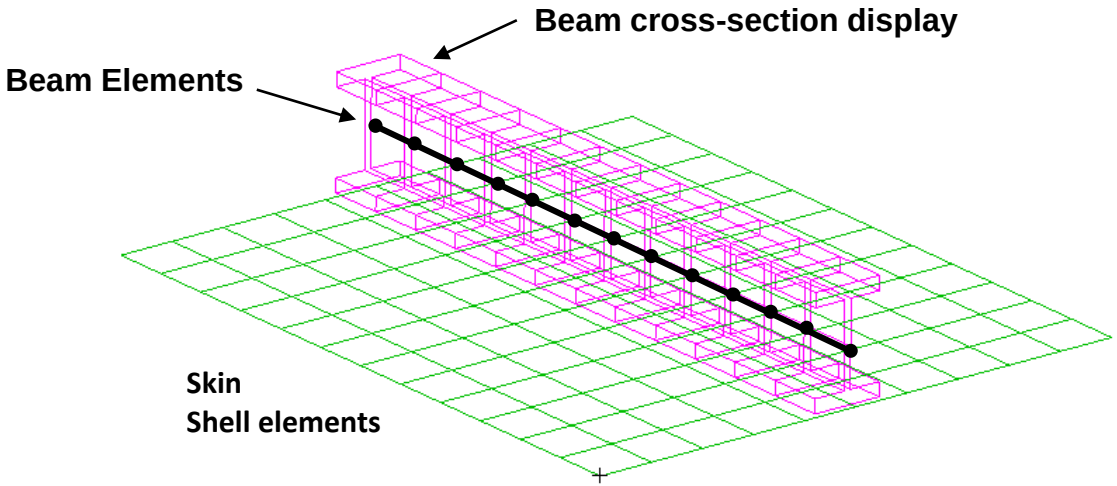
- Another tool designed to speed up the assembly modeling process is the beam cross-sectional contact
- This capability allows beam cross-section boundary faces to participate in glued contact



Beam Cross-Sectional Contact (cont.)

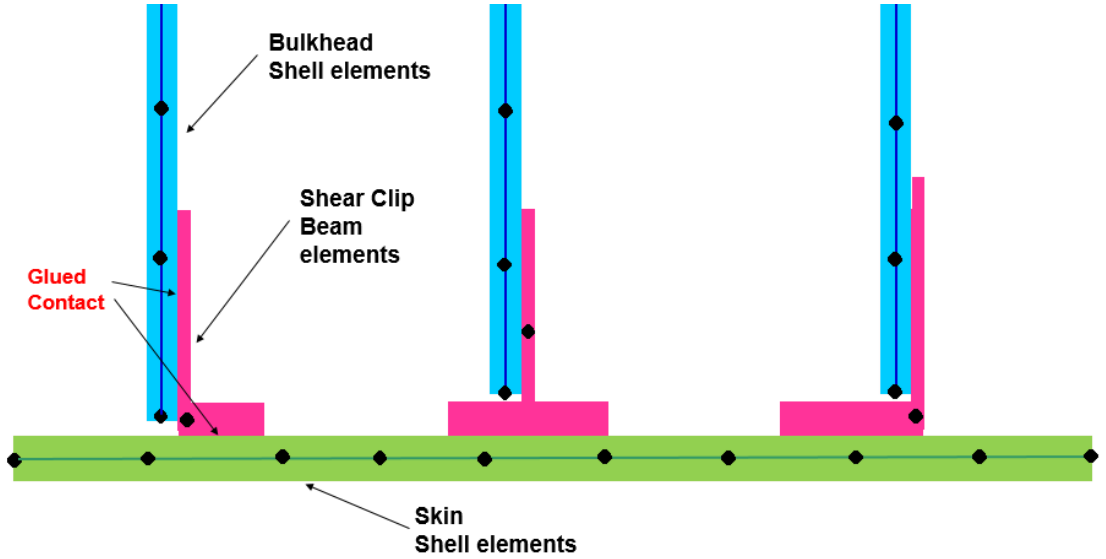
- Example of a glued beam/shell stiffened panel





Beam Cross-Sectional Contact (cont.)

- Beam cross-sectional contact is also a convenient way to model members in a built-up assembly
- For example, shear clips can be modeled by beams as shown below which are glued to other shell members
- This allows different beam sections to be easily swapped in and out and repositioned in an assembly



Conclusions

- Two new tools for assembly modeling were presented
  - Flexible glued contact
  - Beam cross-sectional contact
- Application examples showing the benefit of switching from rigid glued to flexible glued contact
  - Better load distribution inside a joint
  - Better load distribution inside an assembly
  - More accurate normal modes predictions

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Thank You!

For more information, please contact
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