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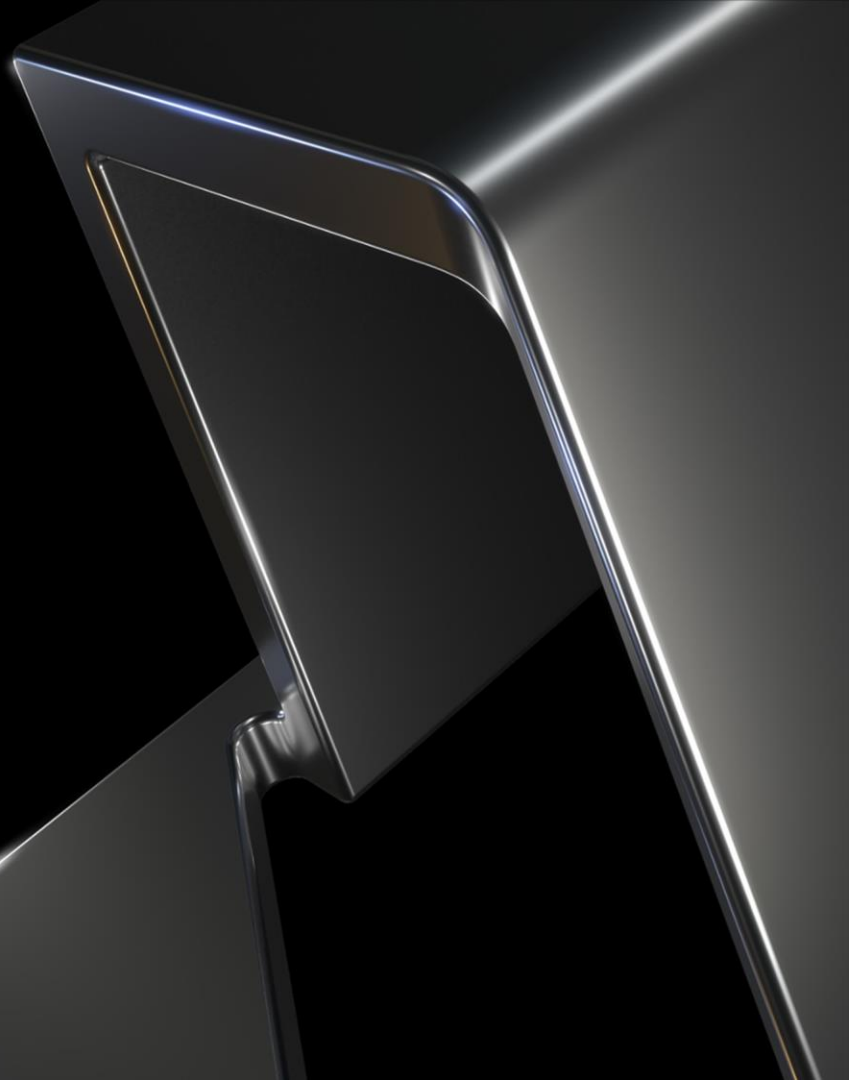
Combining Solid, Shell, and Line Elements with Inventor Nastran

Ed Gillman

Manufacturing Applications Expert | Denver, CO



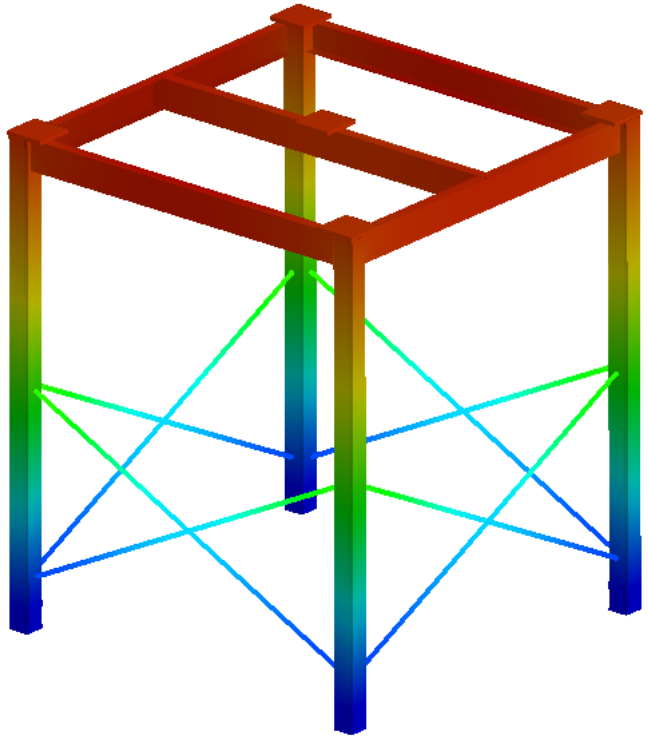
About the Speaker

Ed Gillman
MFG Applications Expert – IMAGINiT Technologies

- Mechanical Engineer
- Experience in Aerospace, Product Development, and Advanced Manufacturing
- Autodesk Skillset – Nastran, CFD, CAM, Generative Design
- Denver, Colorado
- Hiking, Biking, Rock Climbing, Skiing, and Curling

Learning Objectives

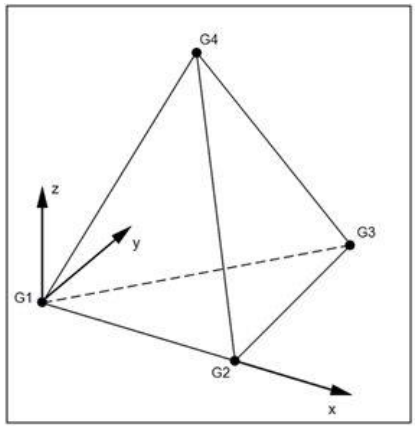
- Explain the difference between solid, shell, and line elements
- Connect different elements using various techniques
- Bond shell element structures using continuous meshing
- Efficiently simplify CAD geometry into Nastran idealizations



Inventor Nastran Element Types

Solid Elements

3D – 3 DOF

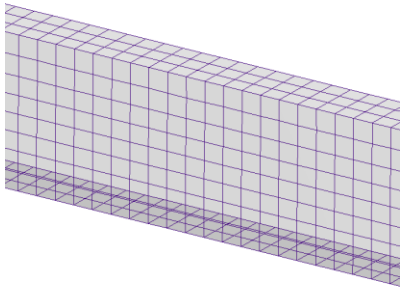


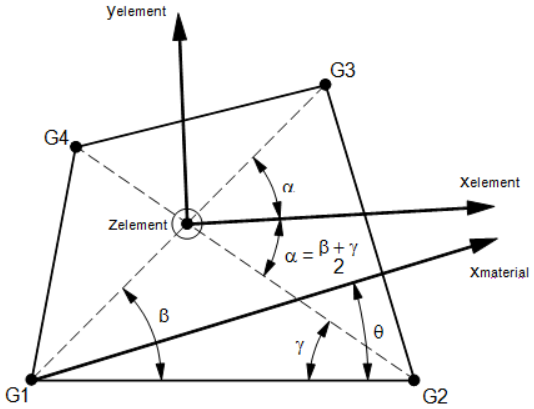
Overview

- Nodes have 3 Translational DOF (TX, TY, TZ)
- Model requires little preparation
- Constraints and Loads can be added to any entity (face, edge, vertex)
- Long processing times
- Can be too stiff for thin-walled components

Shell Elements

2D – 5 DOF



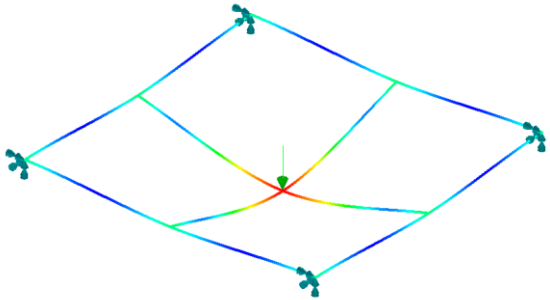


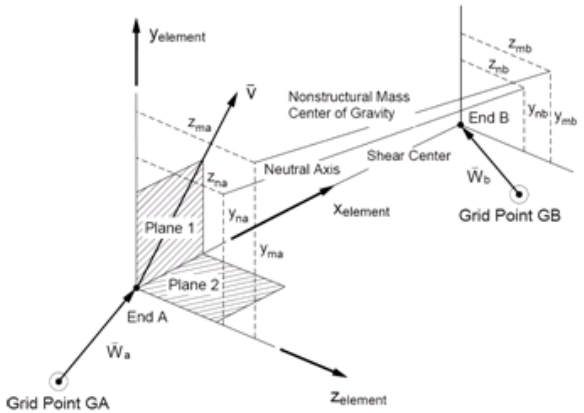
Overview

- Nodes have 5 DOF (TX, TY, TZ, RX, RY)
- More accurate for bending and buckling of thin-walled components
- Fast processing times
- Continuous meshing of welded structures (no contacts required)
- Requires more CAD simplification
- Can't mesh complex parts (hubs, shafts, castings)

Line Elements

1D – 6 DOF





Pros

- Nodes have 6 DOF (TX, TY, TZ, RX, RY, RZ)
- Easy to verify results with hand calculations
- Only requires a wireframe sketch
- Great for large structures
- Fast solve times
- Can’t model complex connections (bolted, pinned)

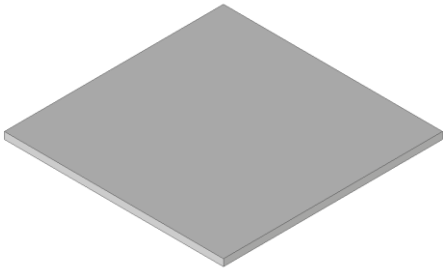
When to use Shell Elements

Length / Thickness Ratio

10.0	11.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0

Solids

Shells



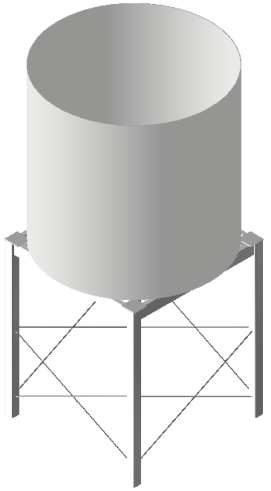
Example: 8” x 8” x 0.25” plate.

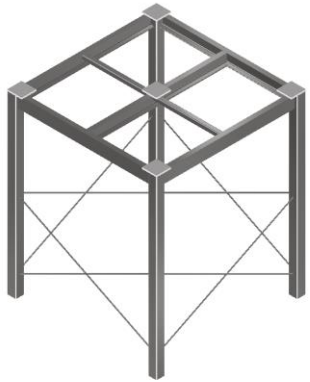
L/t = 8/0.25 = 32 – Shell elements are recommended

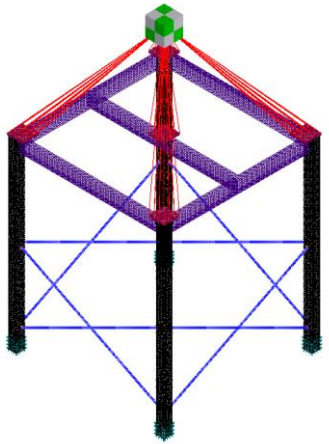
Benefits of Mixed Element Modeling

Example: Large Water Tank Frame

	Solid Elements Only	Mixed Element Mesh
# of Elements	674,331	29,721
# of Contact Sets	43	2
Solve Time	10 minutes	30 seconds







Other things that slow down with large element counts:

Opening Files, Editing Loads/Constraints, Viewing Results

Tips for Analyzing Large Structures

1

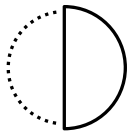
Apply a mixed element mesh to limit total number of nodes

2

Apply continuous meshing to shell mesh to reduce total number of contact pairs

3

Apply 1/2 or 1/4 symmetry to limit overall model size

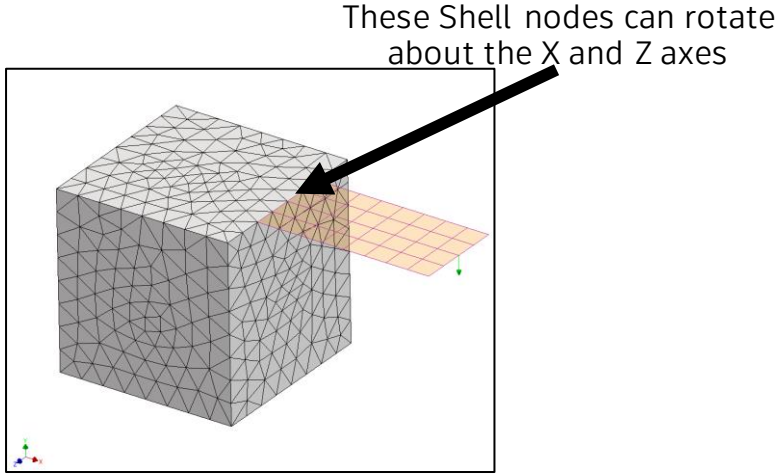


4

Simplify non-structural masses to Forces, Moments, or Concentrated Mass

Connecting Different Element Types

Shells to Solids

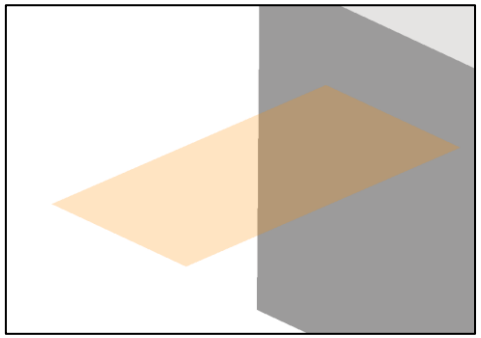


DOF Mismatch

Shell edges bonded to a Solid will act like a hinge

- Result will be an E5000 error or a very large displacement (e.g. 70,000 in)
- Bonded contact will not fix this issue
- Need to connect the rotational DOF

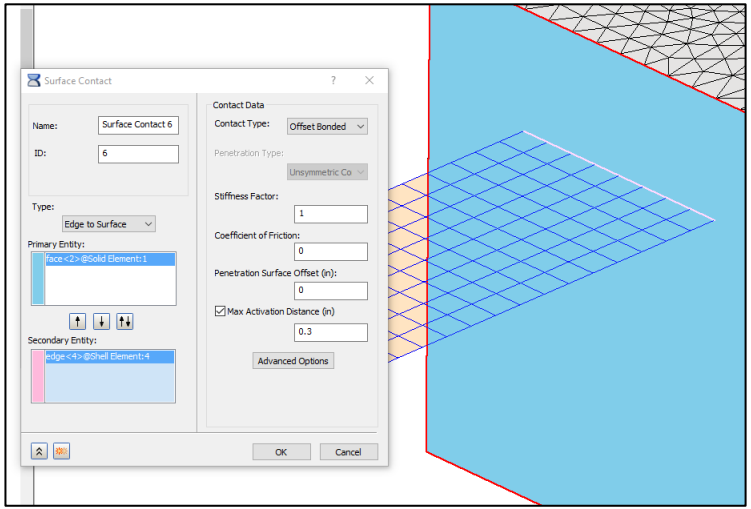
Shells to Solids



Option 1

Apply an Offset Bonded contact between the solid face and the shell edge

- Simplest method for connecting these elements
- Activation distance 10-20% larger than mesh size
- Difficult to control the contact area
- Can create stress singularity at shell corners

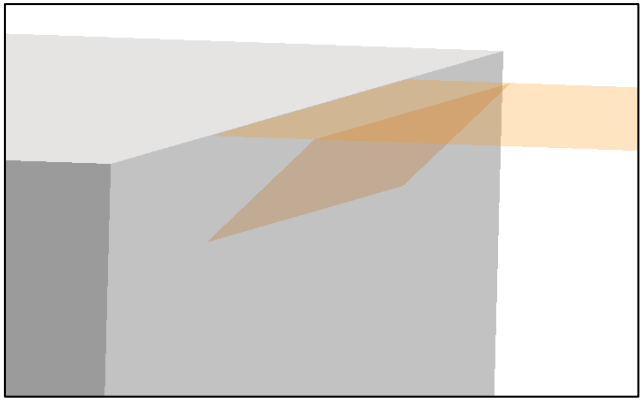


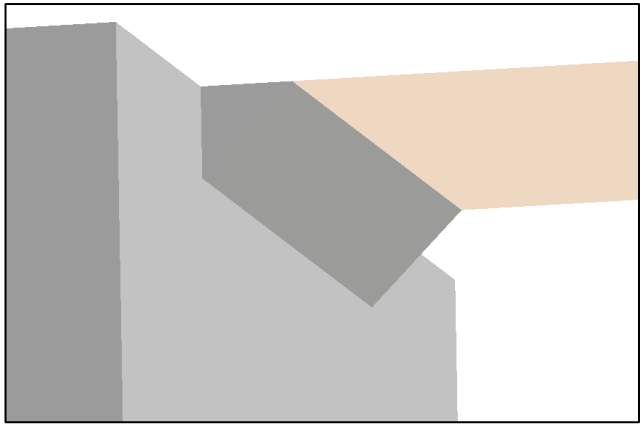
Shells to Solids

Option 2

Add a Solid or Shell weld geometry

- Try to match the size and shape of the weld
- Use Bonded contact between weld and shell
- Solid bead might create a stress singularity
- More prep time required



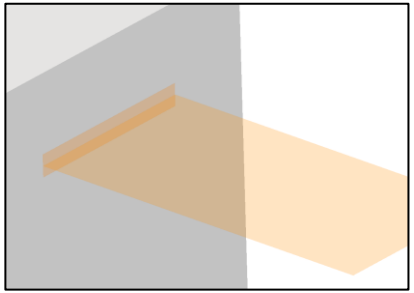


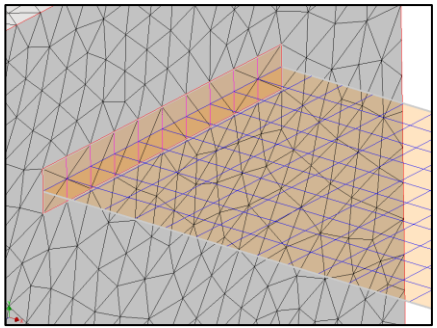
Shells to Solids

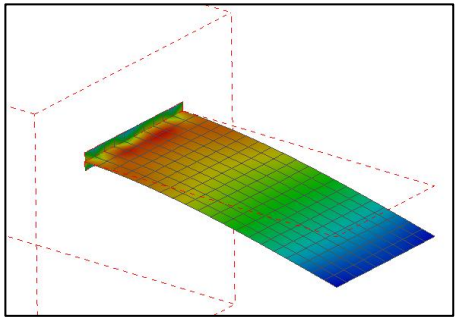
Option 3

Create a “T” connection with additional perpendicular surface

- “T” surface idealization thickness should be small (e.g. 0.001”)
- Connect shell elements with continuous meshing
- Offset Bonded contact between “T” Surface and Solid Face
- More control over the size of the contact area
- Split solid face around “T” to get a better mesh alignment



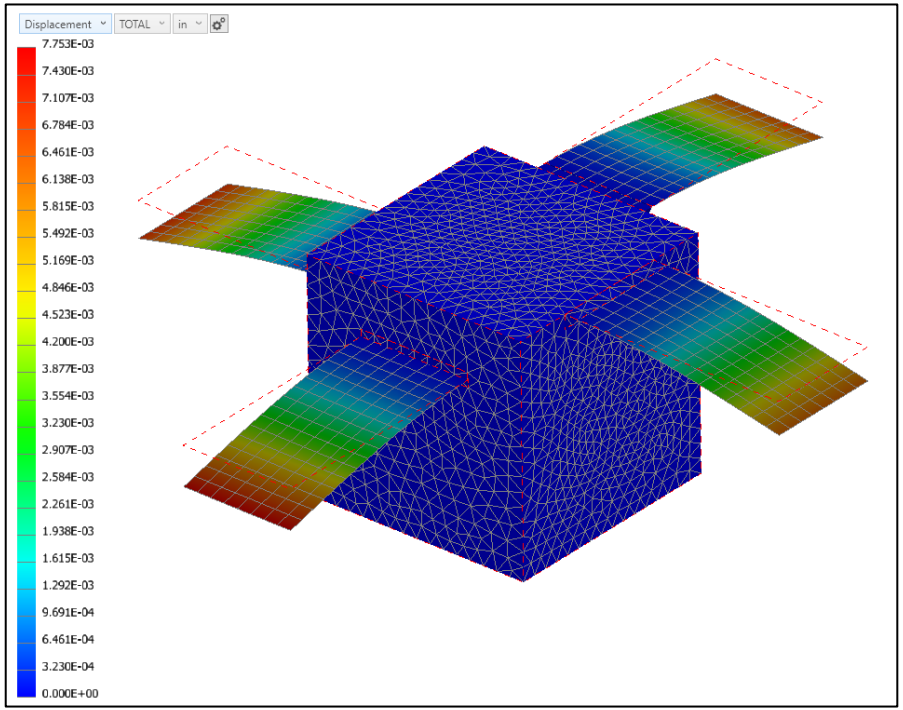




Shells to Solids

Take your pick!

- All methods yield similar results
- Offset Bonded can create stress singularities
- Option 1 and 3 are preferred

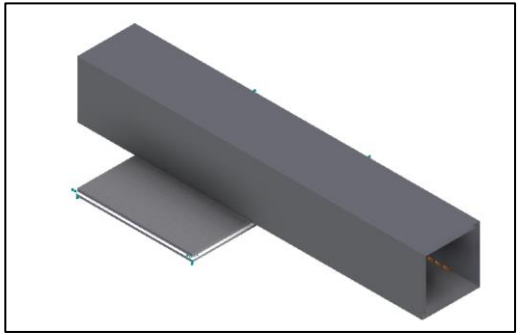


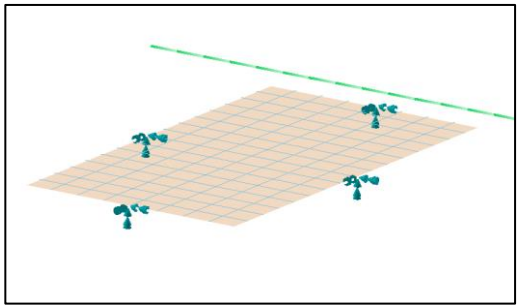
Lines to Shells/Solids

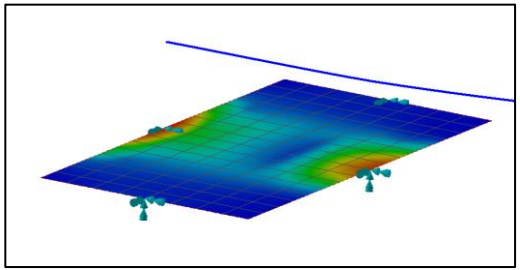
Scenario 1 - Parallel

Apply an Edge-to-Surface Bonded contact

- Primary Entity – Face of Shell
- Secondary Entity – Line Element
- Increase Max Activation Distance to span the gap
- Splits may be required





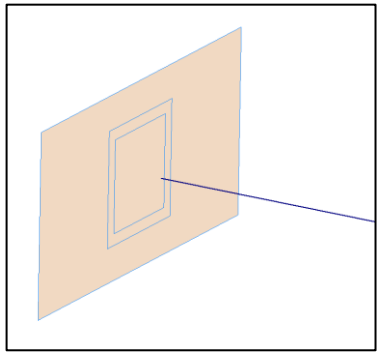


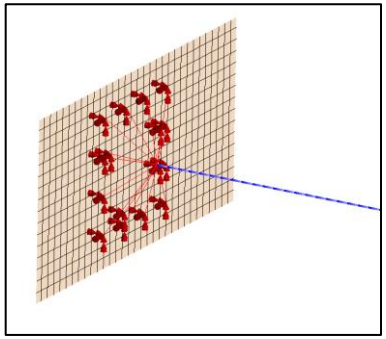
Lines to Shells/Solids

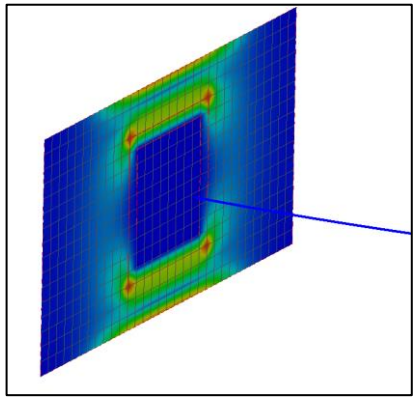
Scenario 2 - Axial

Use RBE2 to connect line to shell face

- Split shell with silhouette of line element cross section
- Attach Rigid Body Connector from endpoint of line to split face of shell
- There must be a gap between the endpoint and the surface





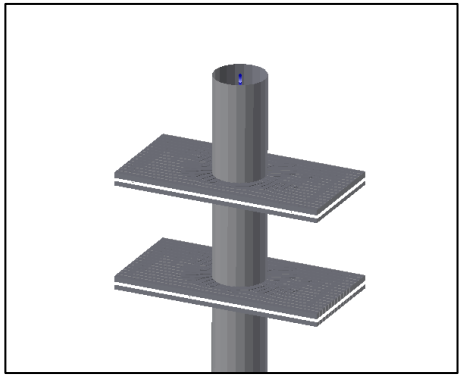


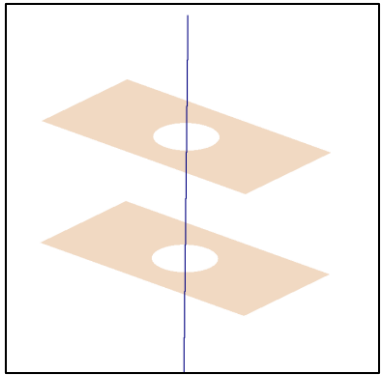
Lines to Shells/Solids

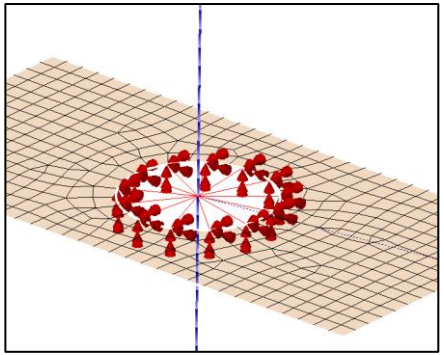
Scenario 3 - Edge

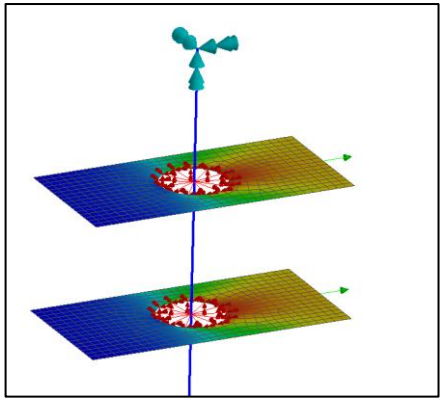
Use RBE2 to connect line to shell edge

- Split line element sketch to create a node point for a Rigid Body Connector
- Attach Rigid Body Connector from line node point to shell edge
- Same approach can be used to connect lines to solids







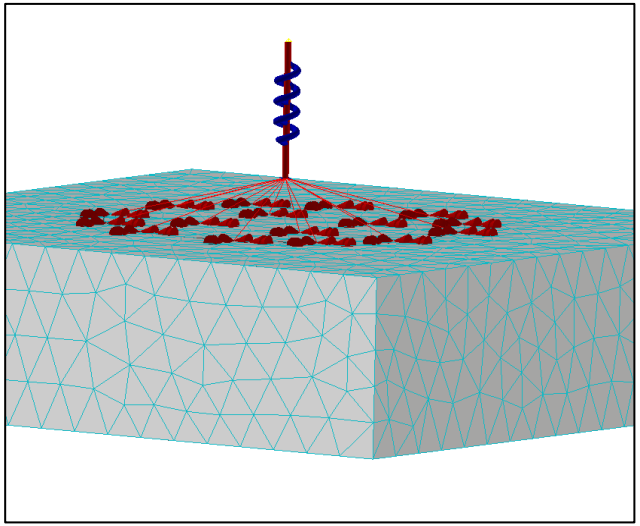


Spring Connectors to Shells/Solids

Best Practice

Required to transfer spring stiffness to larger surface area

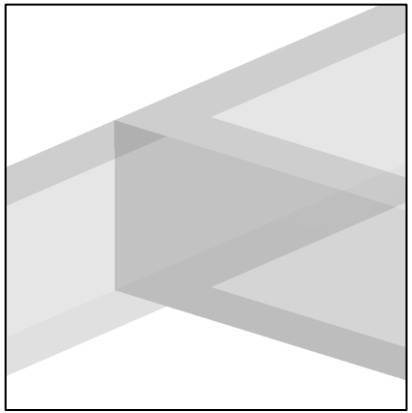
- End point of spring connector can not share node with solid face
- Include a small gap
- Split surface with silhouetted matching approximate spring diameter

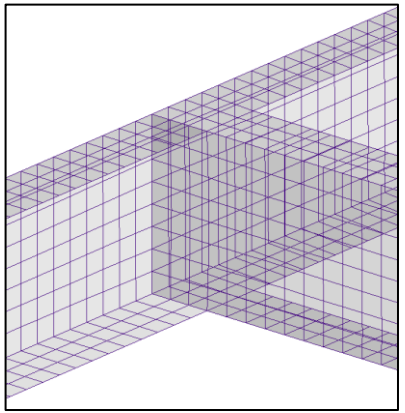


Shells to Shells

Continuous Meshing

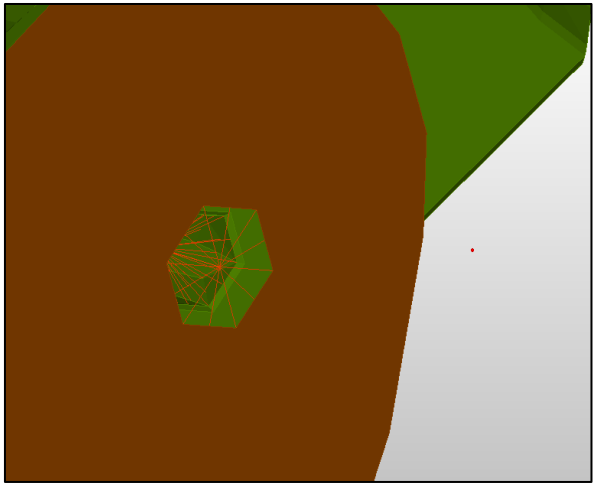
- Connects elements on the edge of a shell to the edge or face of the adjacent shell
- Edge and Face must be co-planar
- Loads are transferred directly from one element to the next
- No contacts required!
- Shell elements only





Continuous Meshing

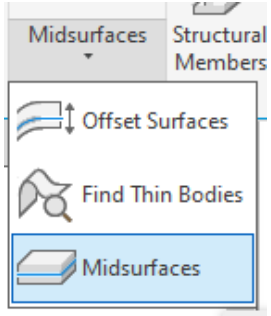
- Always verify the mesh and connections in the Nastran Editor
- Older versions of Inventor Nastran (2018, 2019, 2020, 2021) had some bugs with continuous meshing
- Issues stemmed from boundary conditions or connectors applied to shell edges
- E.g. – load missing from edge or additional constraints added

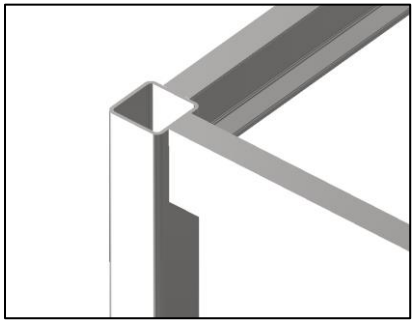


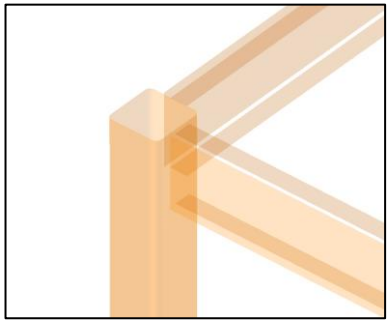
Simplifying CAD Geometry for FEA

Inventor Nastran Surface Tools

- Offset Surface and Midsurface tools leave gaps in the model
- Makes Continuous Meshing difficult
- Doesn't handle Channel and Angle shapes well
- Can't create splits for constraints, loads, connectors, etc



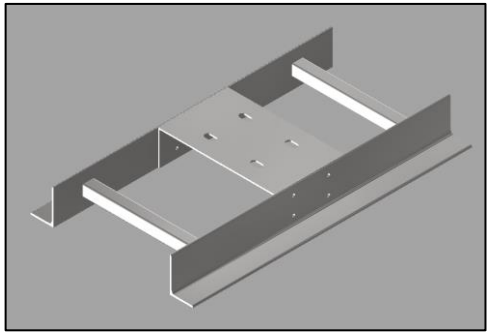




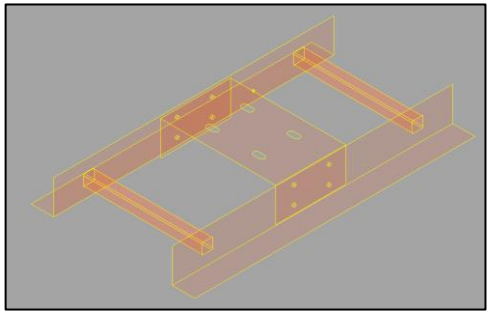
Inventor Simplification Tools

Pro Tips

- Derive assemblies into part files to use surfacing tools
- Use Level of Detail representations and Model States to your advantage
- Trim/Extend Surface tools required to create a continuous shell mesh



Assembly File

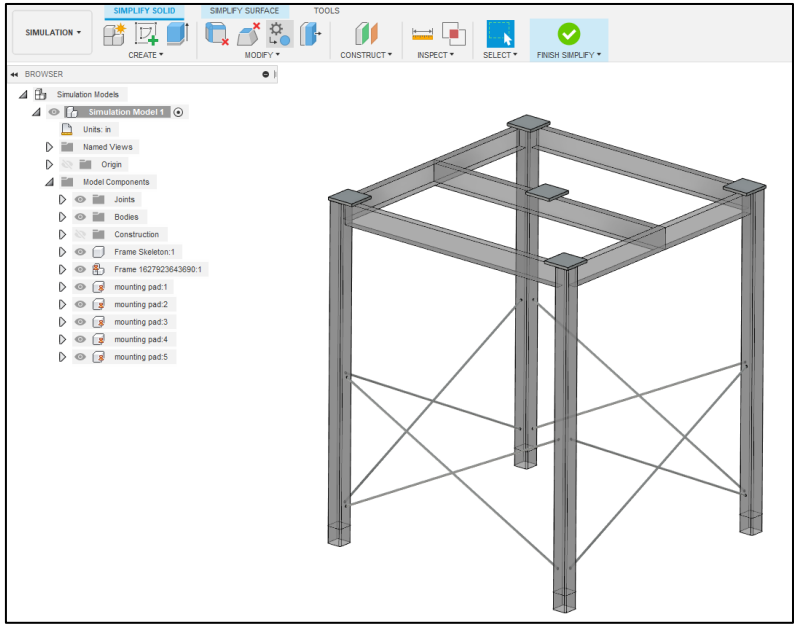


Surface Part File

Fusion 360 Simplify Workspace

Overview

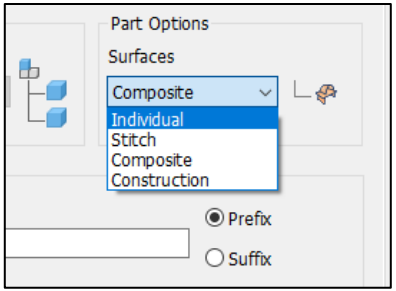
- More simplification tools than Inventor
- Best option if associativity with original model is not required
- Direct Modeler
- Key Tools:
    - Offset Surface
    - Replace with Primitives
    - Split Face

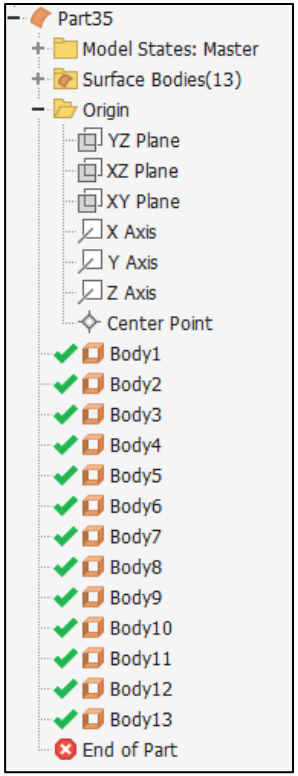


Importing .step Files to Inventor

Pro Tips

- Use .stp format
- Import surfaces as “Individual” to allow unique shell element idealizations
- Use Inventor 3D sketch tools to create line elements from solids






Demonstration

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