Ansys / LS-DYNA

NORTH AMERICAN USER FORUM 2023

Creation of Unstructured Splines for IGA-based linear and non-linear solutions in LS-DYNA

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Ansys

Agenda

- Origins and Motivation
- Advantages of IGA
- Generation of IGA shells and solids
- Results
- Ongoing Development and Research

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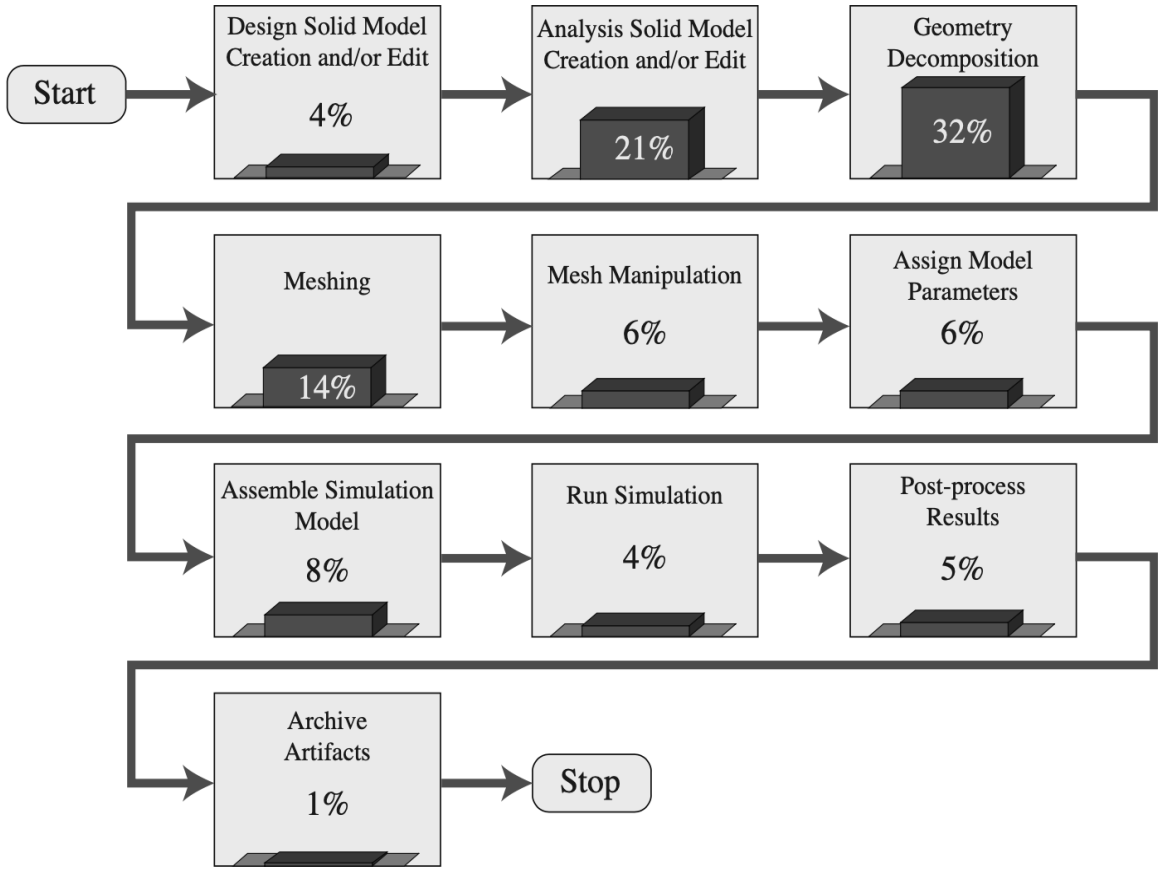
Origins

- Finite element analysis (FEA) models are based on computer aided design (CAD).
- FEA models are *only* an approximation of the geometry. (geometric errors)
- Mesh generation accounts for about 80% time of the overall analysis time.
- The promise of closing the design loop has not been seamlessly realized.
- Major industrial bottlenecks.



courtesy of M HARDWICK and R CLAY, SANDIA NATIONAL LABORATORIES

HUGHES ET AL. Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement, CMAME, 2005.

3100+ citations

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Motivation

- IGA (Isogeometric Analysis) is an emerging technology, and many customers are exploring its adaptation for linear and non-linear simulations in LS-DYNA
- Simulation needs “watertight” or “analysis-suitable” geometry representation
- Motivation at Ansys is to create complete workflow to address industrial expectations from IGA as a technology
- For IGA, body fitted spline surface is generated with the reference of underlying unstructured quad/hex mesh with following benefits:
  - C^2 continuous except C^1 or C^0continuity at Irregular Nodes
  - Based on B-spline and Bezier basis
  - Suitable for analysis and design
  - Surface fitting to CAD/Geometry data

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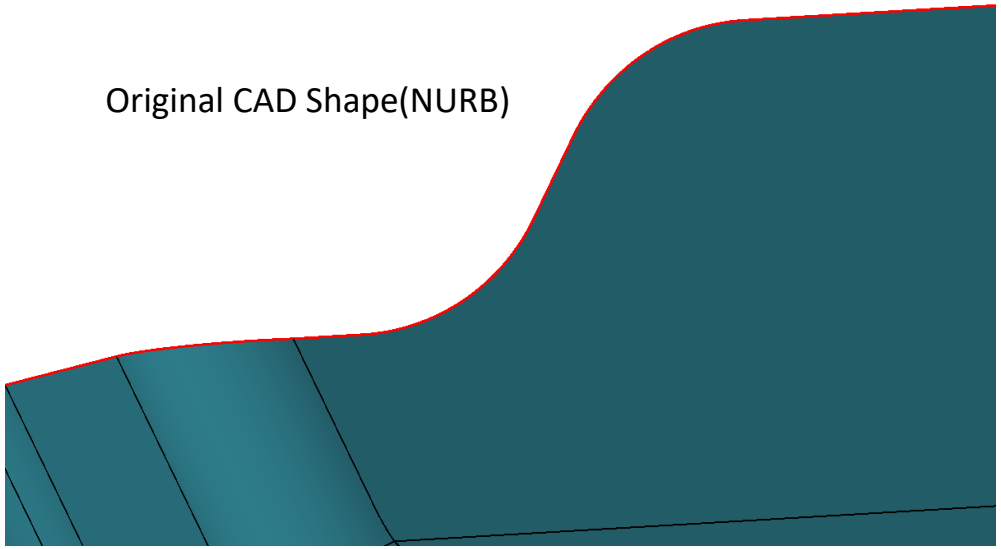
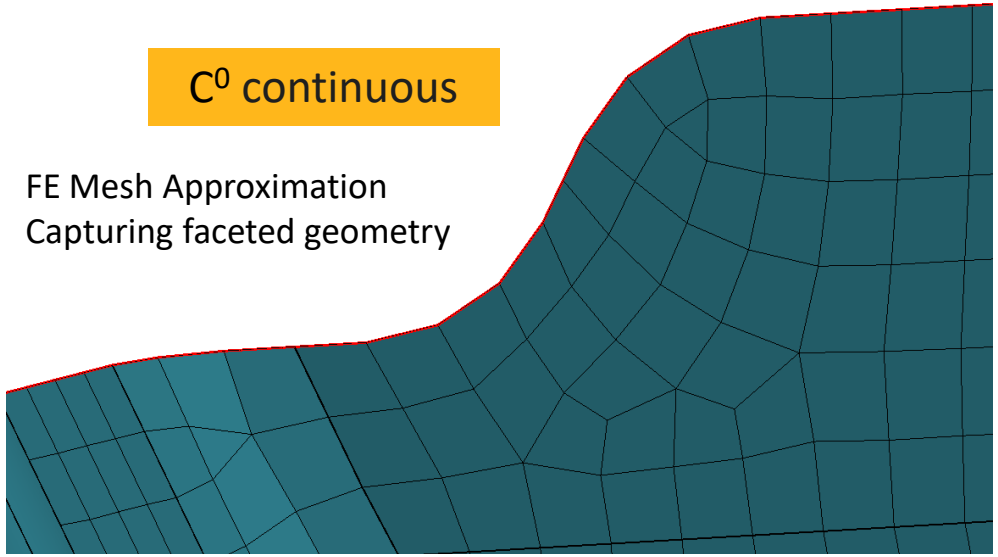
Advantage of Isogeometric Splines over FE Mesh

Original CAD Shape(NURB)

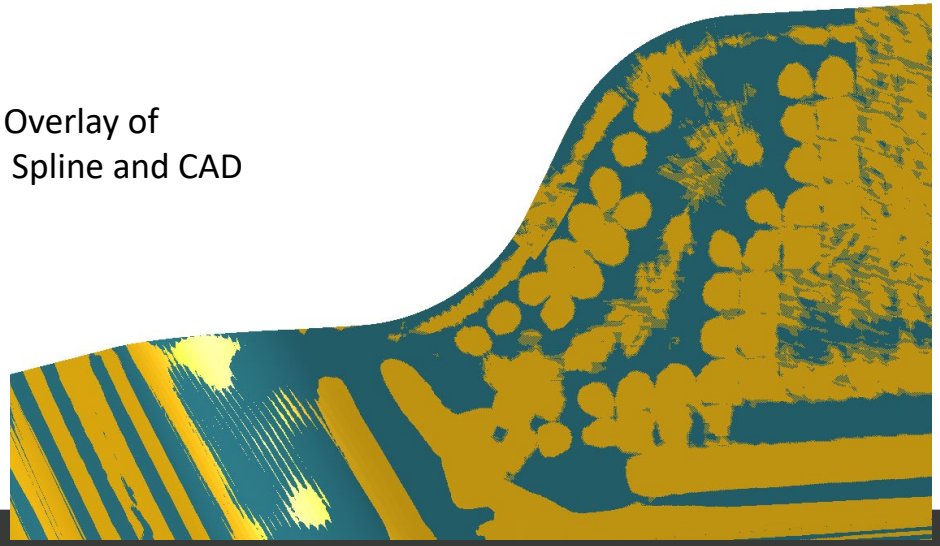


C^0 continuous

FE Mesh Approximation
Capturing faceted geometry

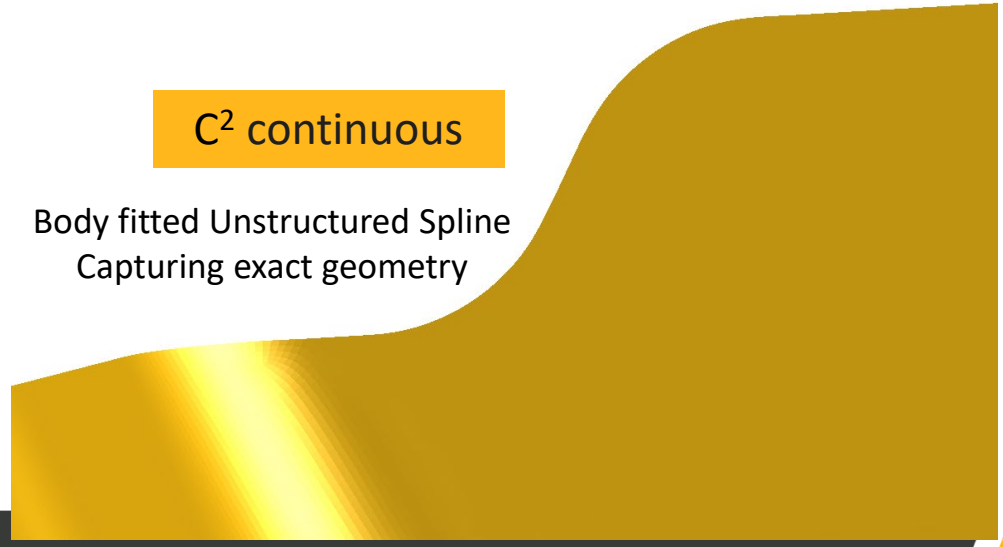


Overlay of
Spline and CAD



C^2 continuous

Body fitted Unstructured Spline
Capturing exact geometry



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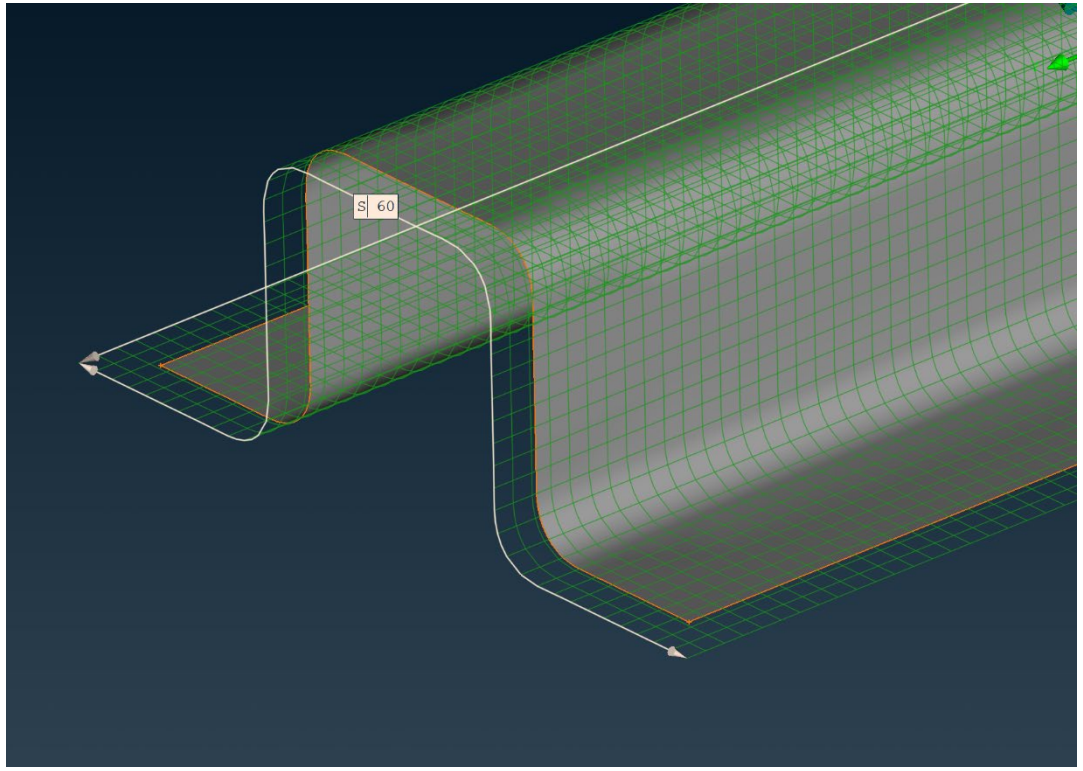
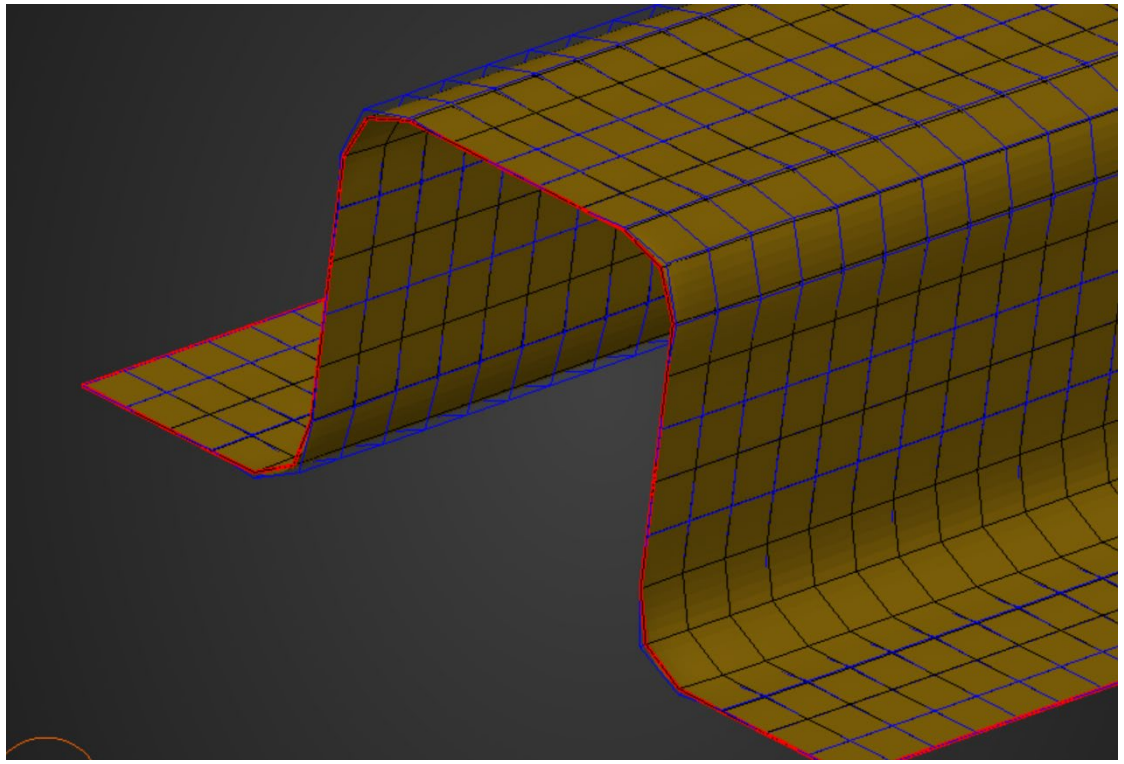
Trimmed NURBS vs Unstructured Spline



Trimmed NURBS



Unstructured spline (Body Fitted)

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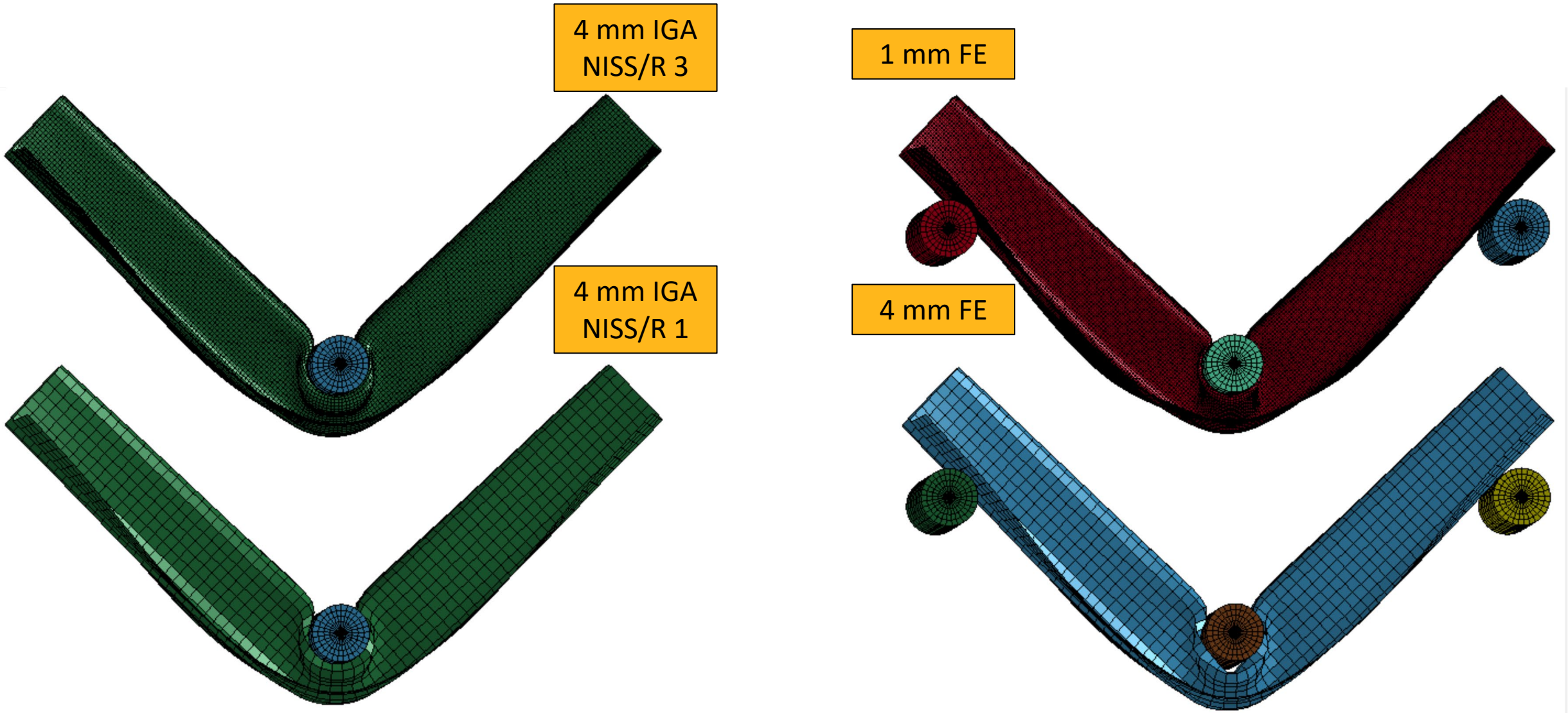
Deformation difference between Spline and FE



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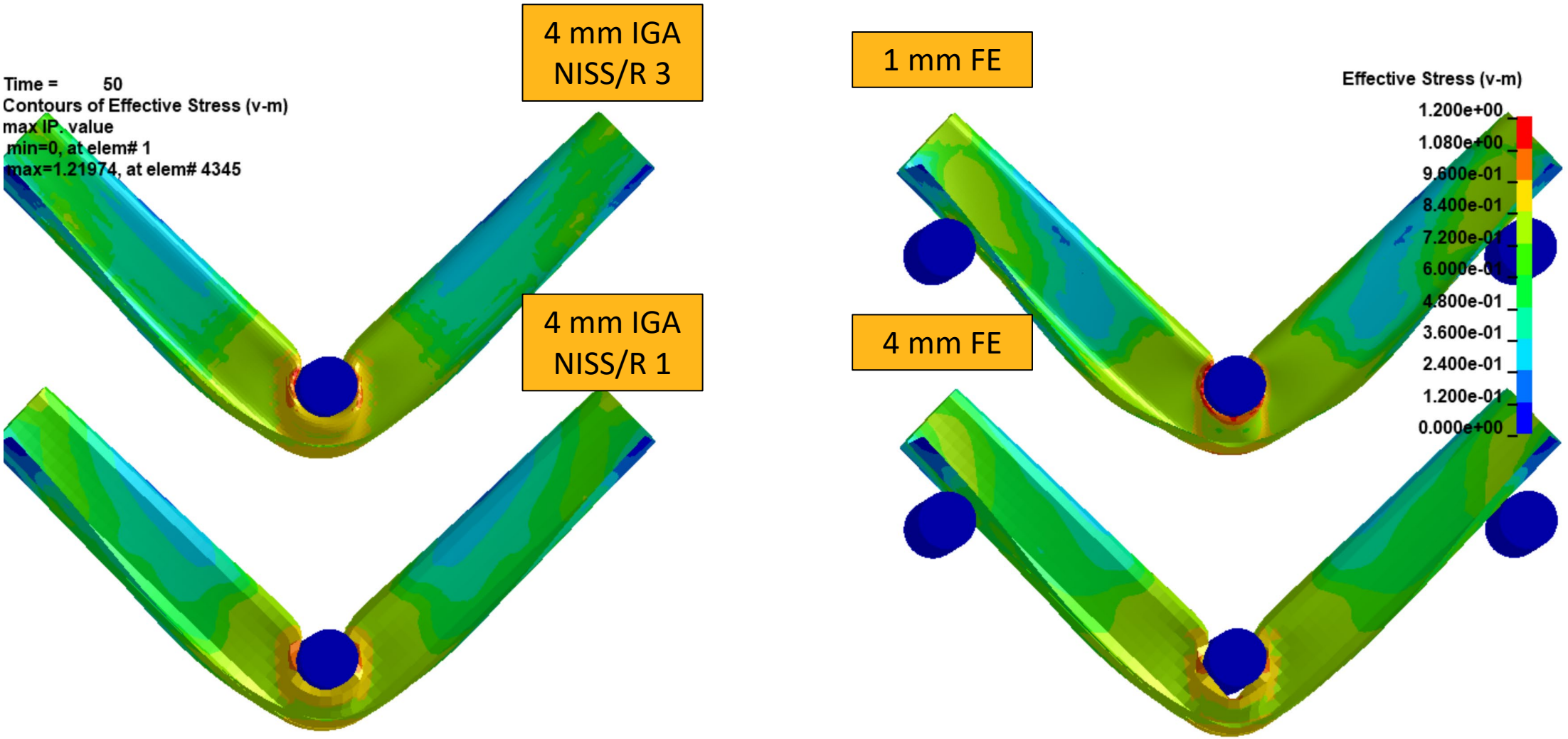
Stress difference between Spline and FE



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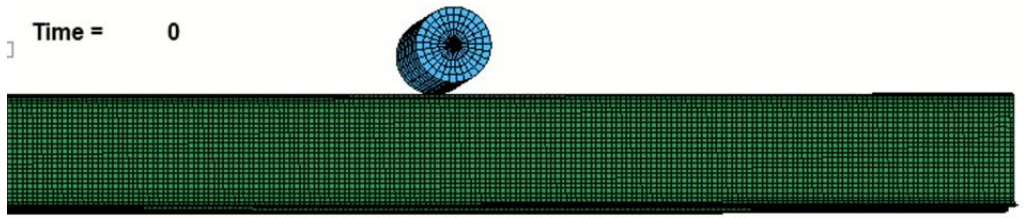
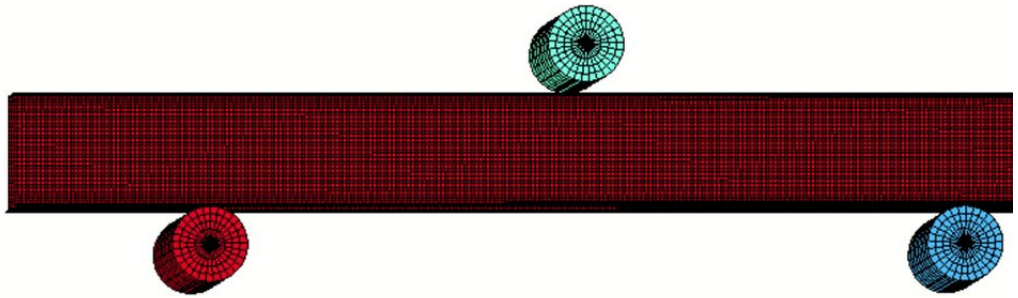
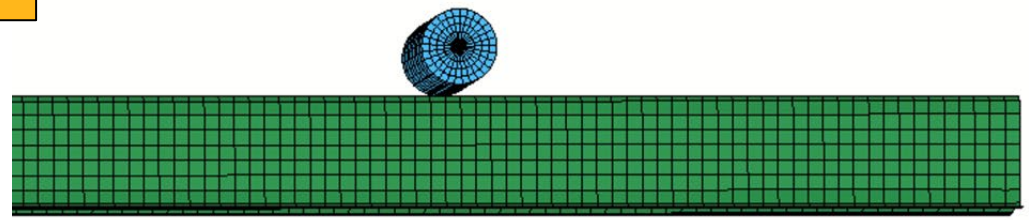
Animation

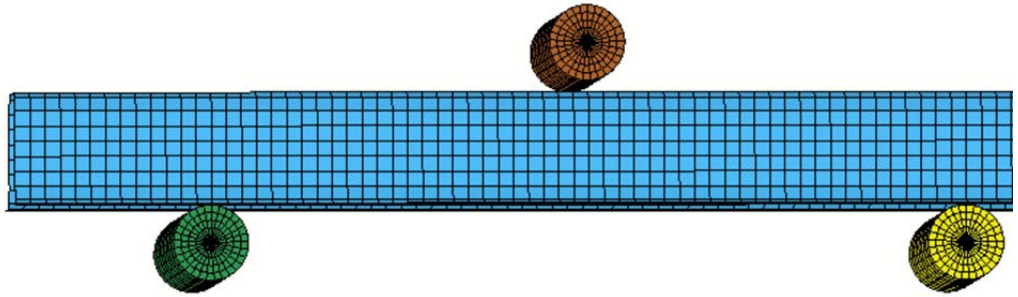




4 mm IGA
NISS/R 3

1 mm FE





4 mm IGA
NISS/R 1

4 mm FE

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Creation of IGA

IGA Exposure

- Beta Release of **PyPrimeMesh APIs** required for Shell Spline generation for IGA in release 24R1

- Exposure in **Workbench Mechanical** through Mesh Workflows

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Creation of splines for IGA

- **Features**
  - Unstructured Shell splines
    - Quadrilaterals to splines.
    - Parameterization check for specified thickness.
  - Volumetric Splines
    - Hexahedral elements to splines
    - Trimmed volumetric splines : Tight integration with LS-DYNA (work in progress)

- **Upcoming developments**
  - Mesh optimization to improve time step
  - Connections and boundary conditions for IGA and hybrid IGA/FEA models
  - Morphing

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Automated Workflow for Shell Spline Generation

Feature Detection → **Feature Based Meshing** → **Repair Topology** → **Defeature Topology** → **Surface mesh and optimizing Quad Mesh** → **Create Unstructured Spline Surface**

- Detect holes, beads, other required features
- Simplify topology, Remove extra vertices to accommodate good quality Quads

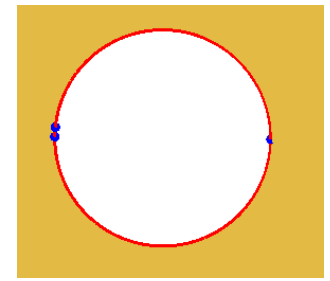
- Defeature Edges around Holes
- Create Offset Layer and Mesh
- Mesh Circular Faces

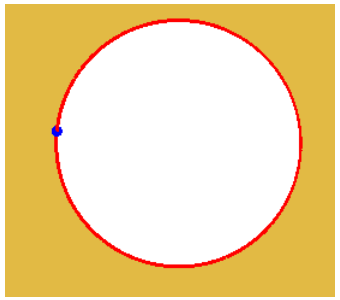
- Repair Edges
- Connect Faces
- Topology Diagnostics

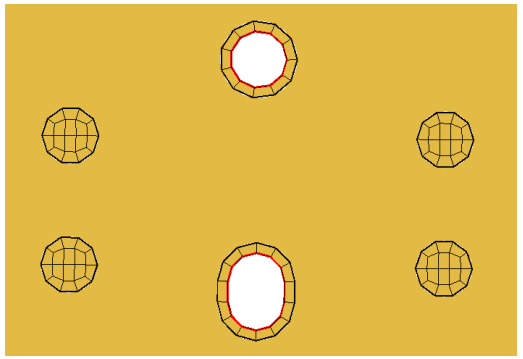
- Remove thin strips
- Defeature sharp edges
- Remove extra vertices

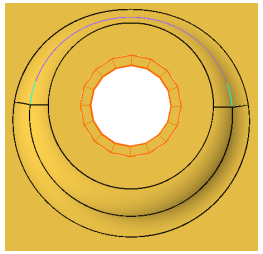
- Surface Meshing
- Mesh optimization to ensure good quality Quads
- Ensure Zero Triangles

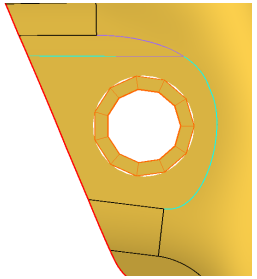
- Create Unstructured Spline
- Write LS-DYNA keyword file











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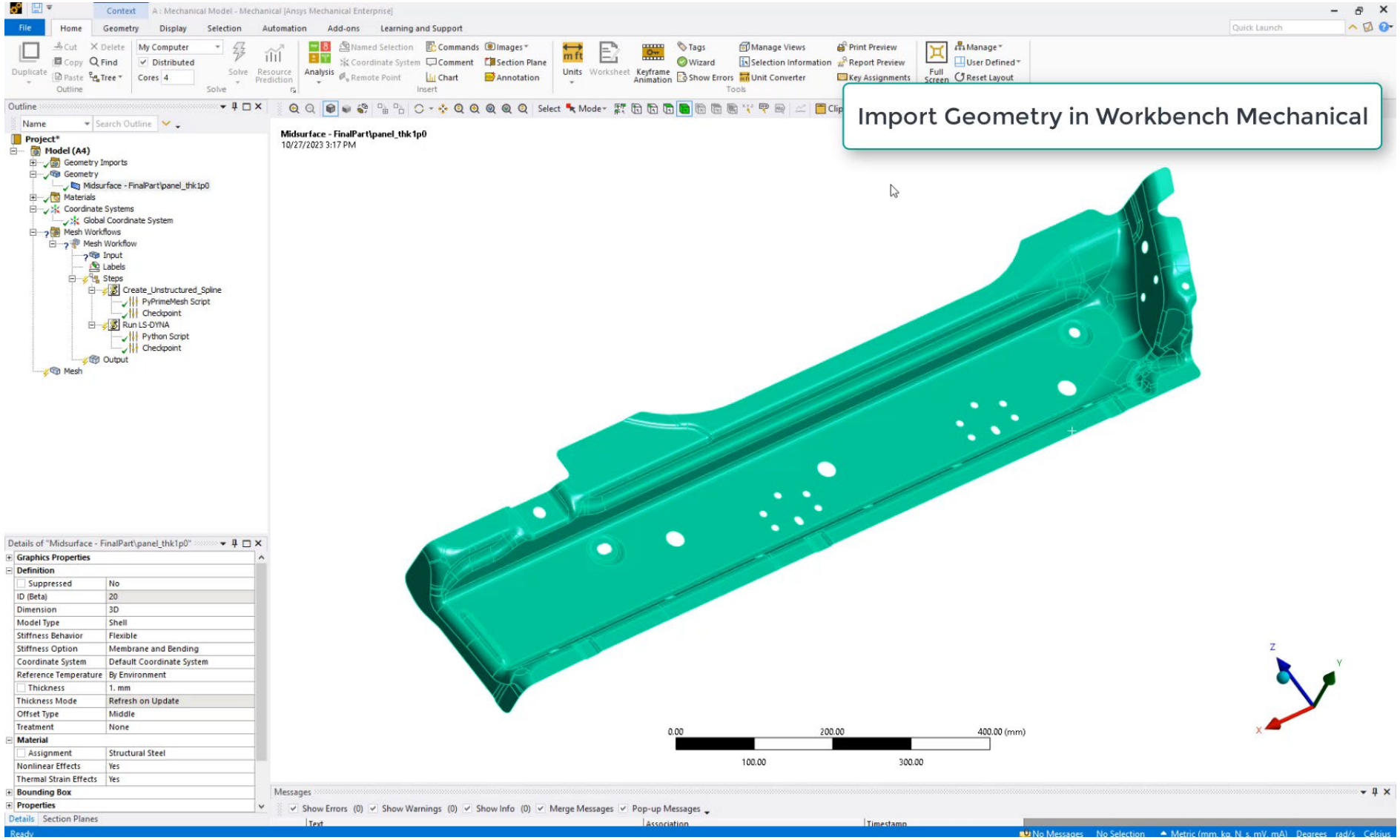
IGA exposure in Workbench Mechanical



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IGA exposure using PyPrimeMesh for Batch workflows

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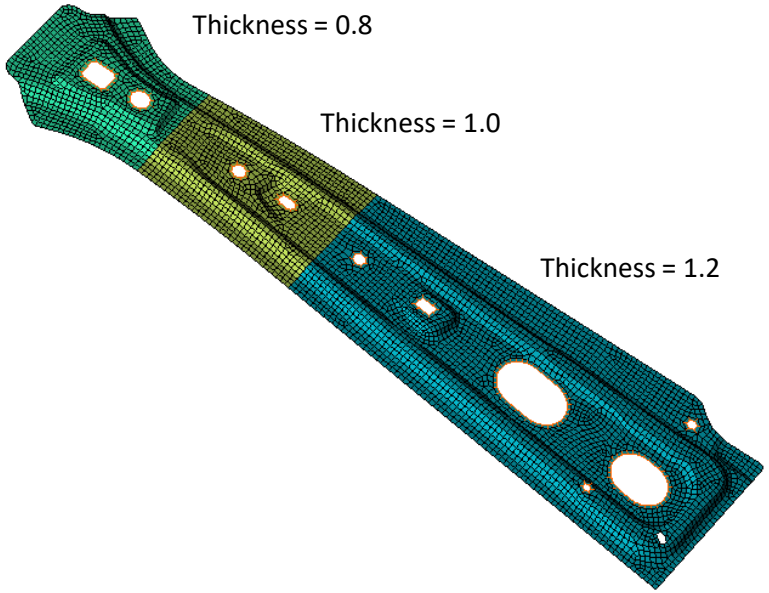
Examples: Shell Splines

Shell Splines

Unstructured quad mesh



Spline surface

Uniform Thickness

Tailer welded part (Different Thickness)

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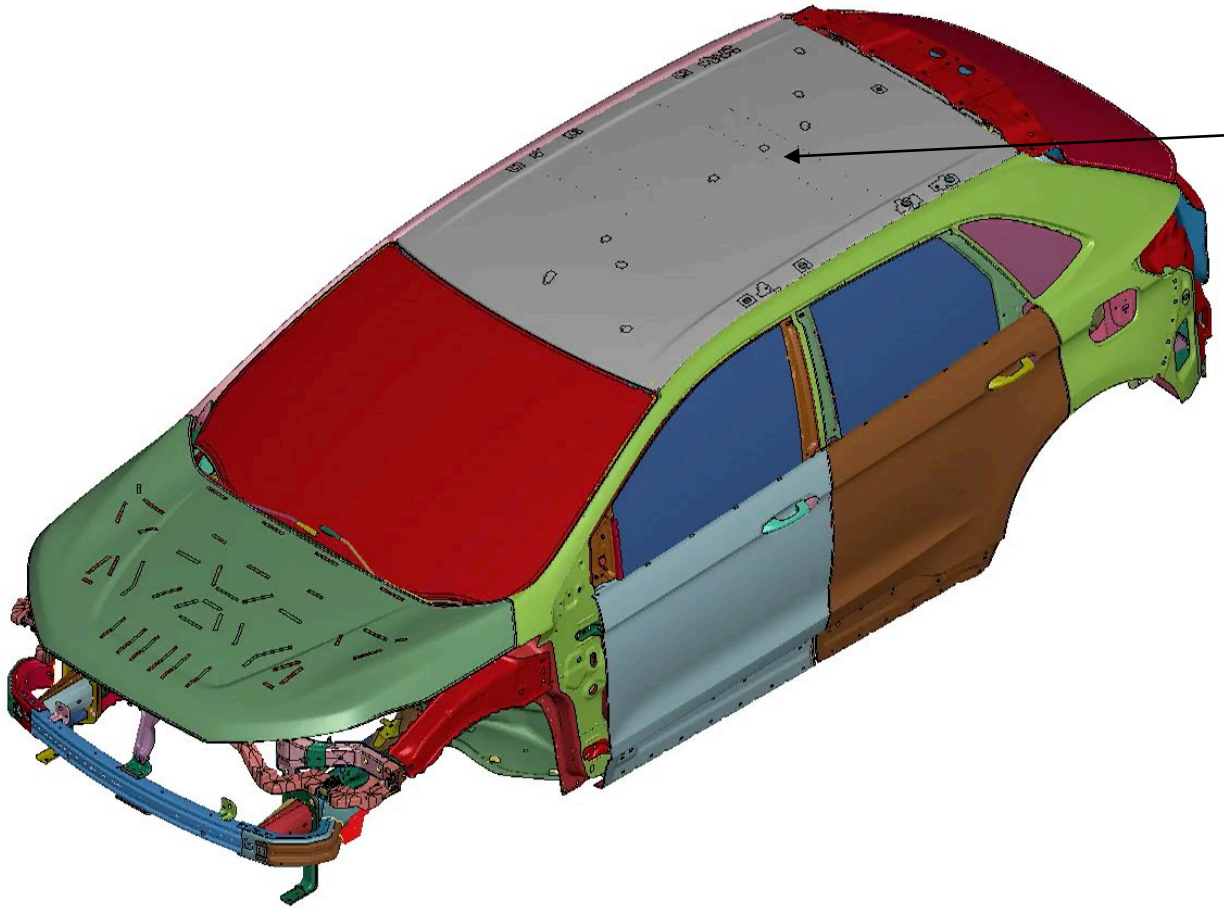
Hybrid FEA/IGA : Roof Crush



courtesy of the Ford Motor Company

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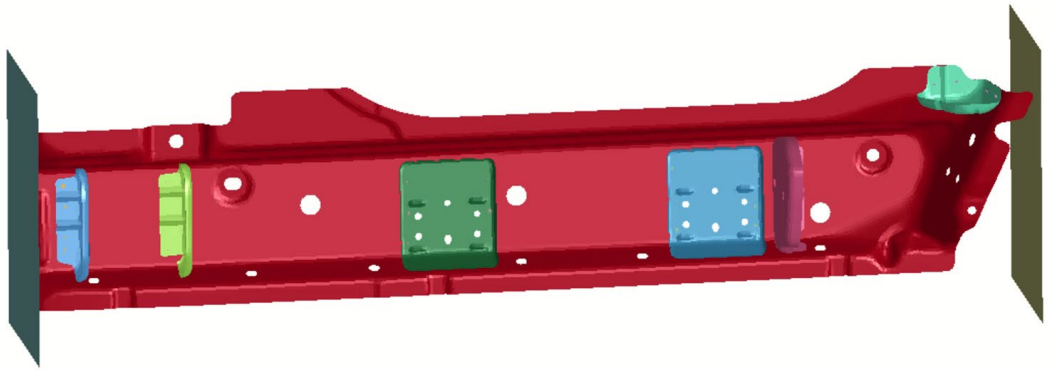
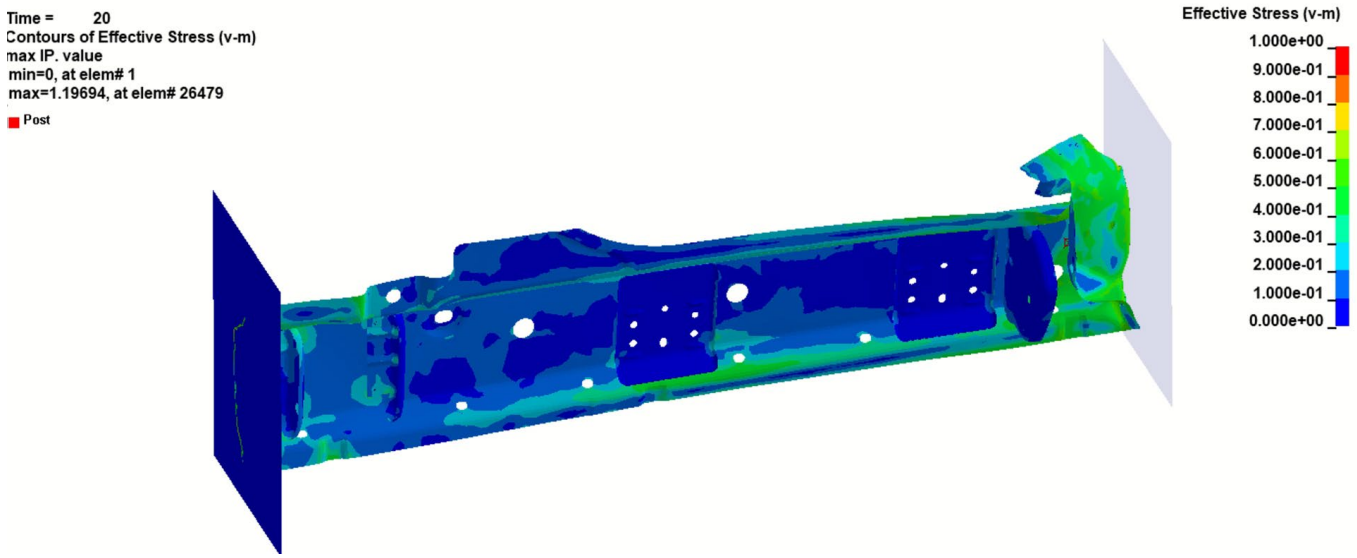
Side Rocker Crush





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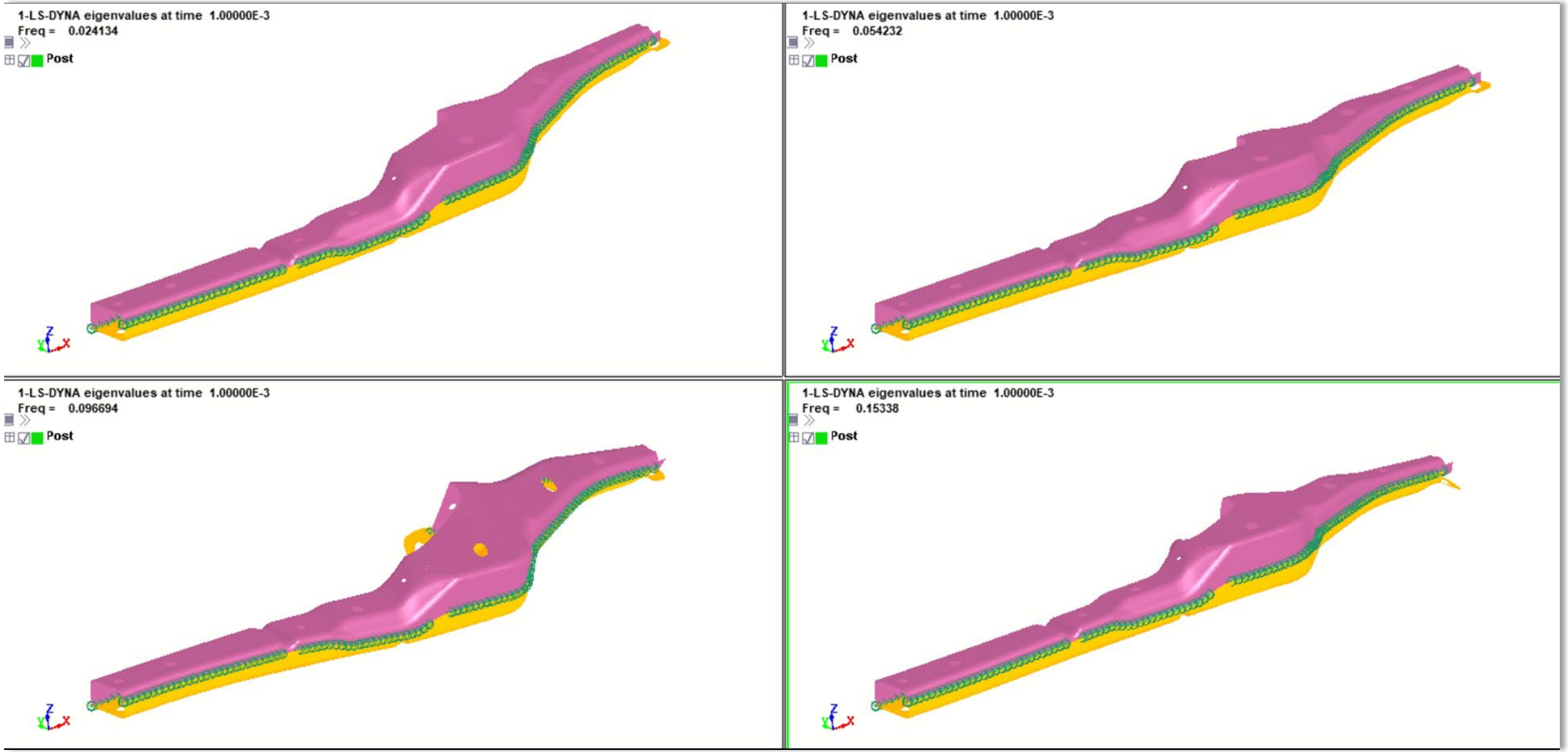
Rails Welded



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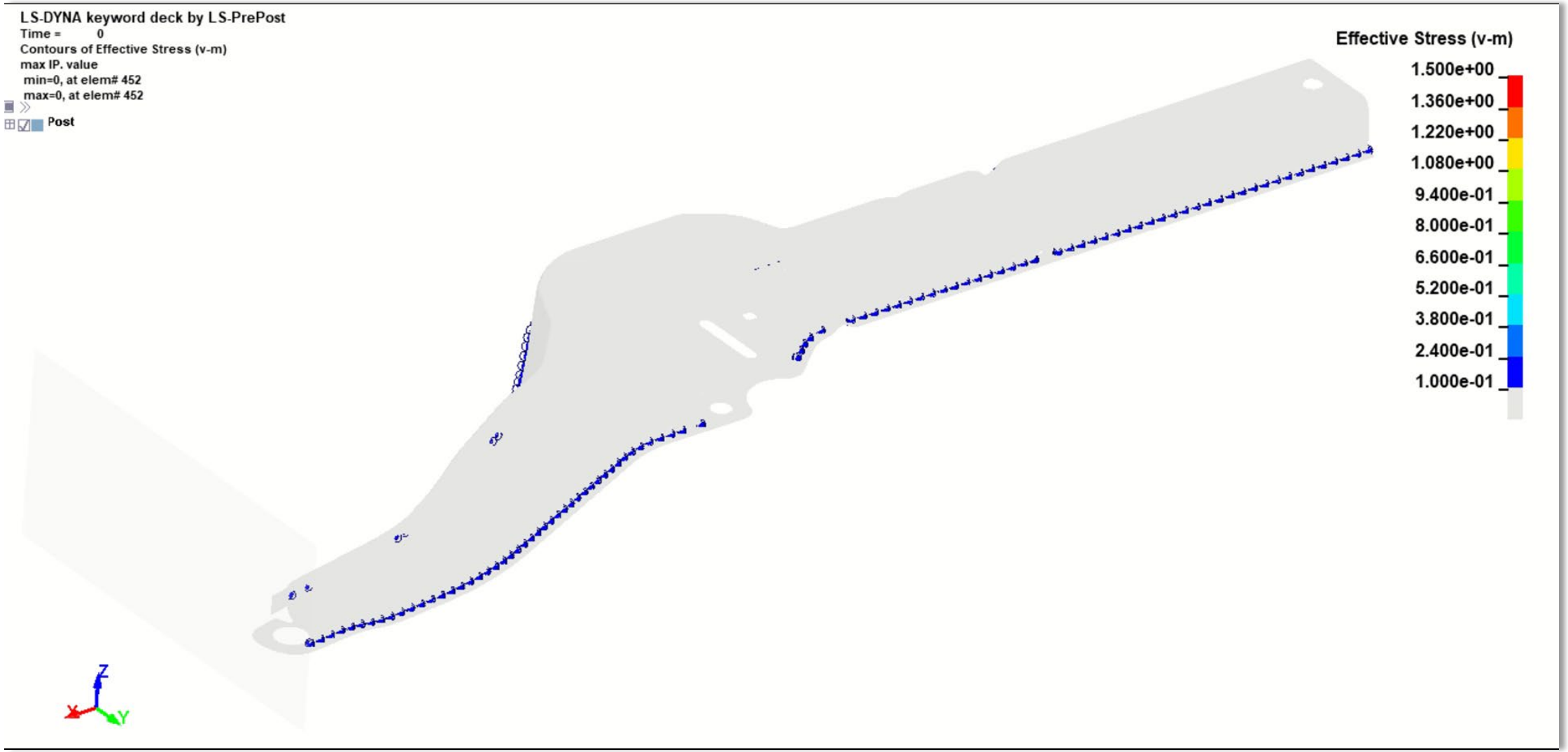
Rail Crush



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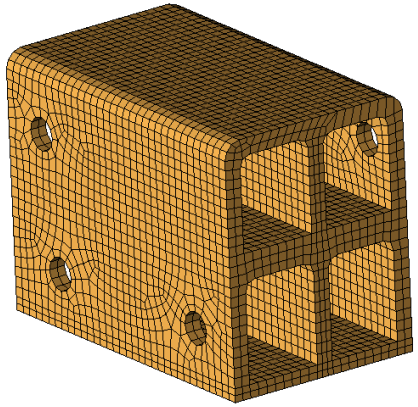
Examples: Volumetric Splines

Hex to Spline

Trimmed solids

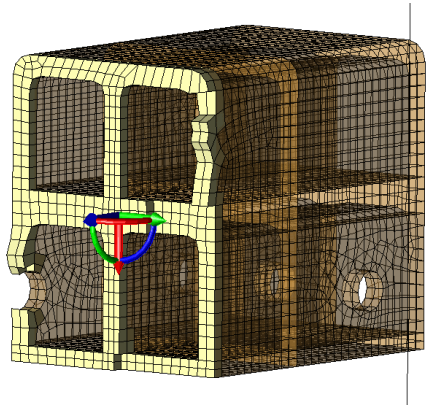
Unstructured Volumetric Splines

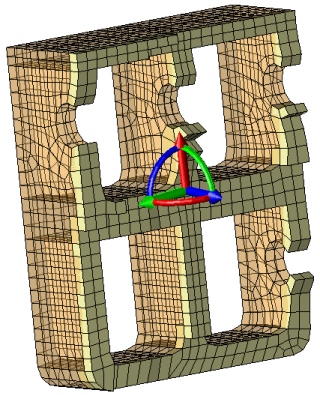
- Automated Process to generate Spline from input unstructured Hex Mesh and projected to cad

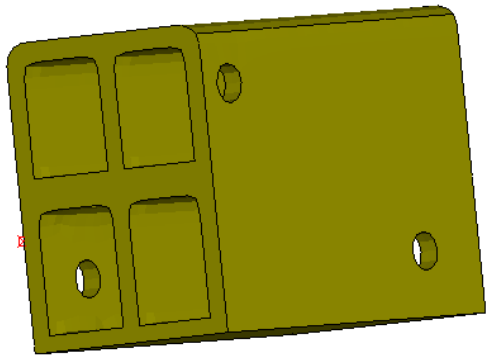


Input Hex Mesh

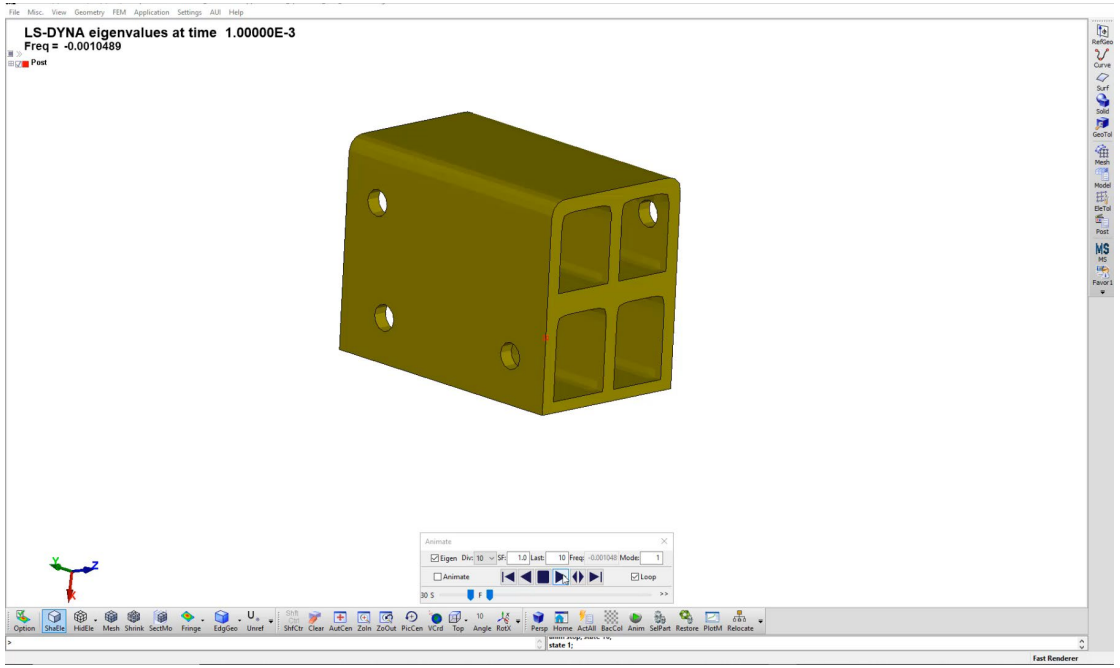
Spline mapped to cad







LS PrePost



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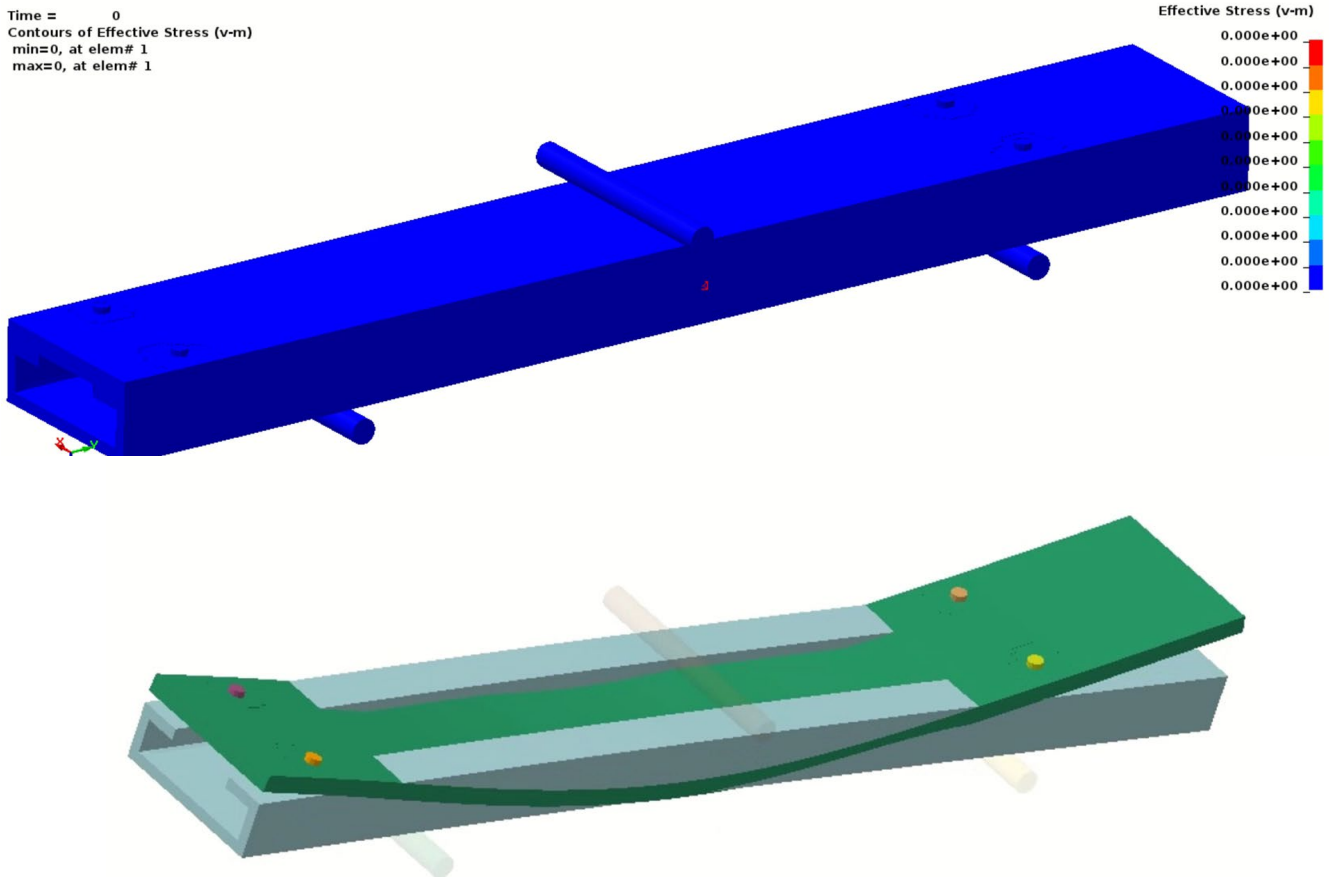
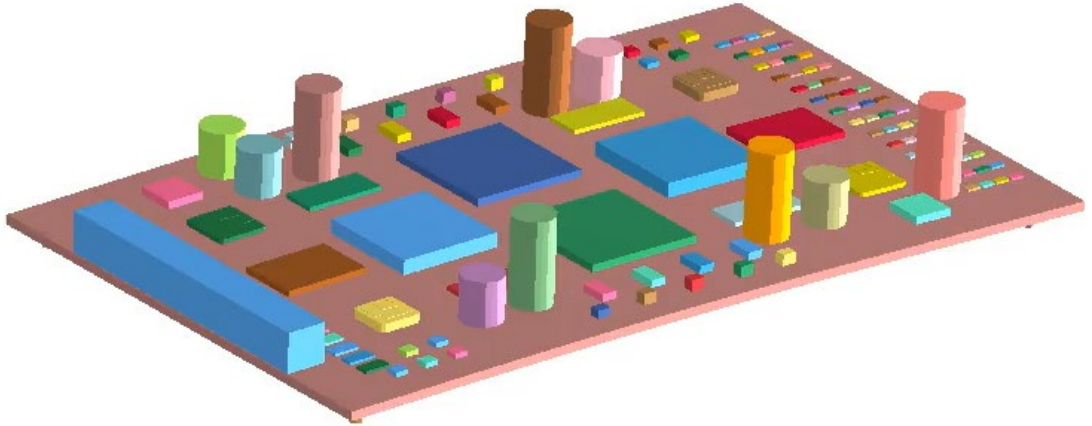
Solid IGA examples:

Hex to Spline



Extruded Solid Rocker insert



PCB

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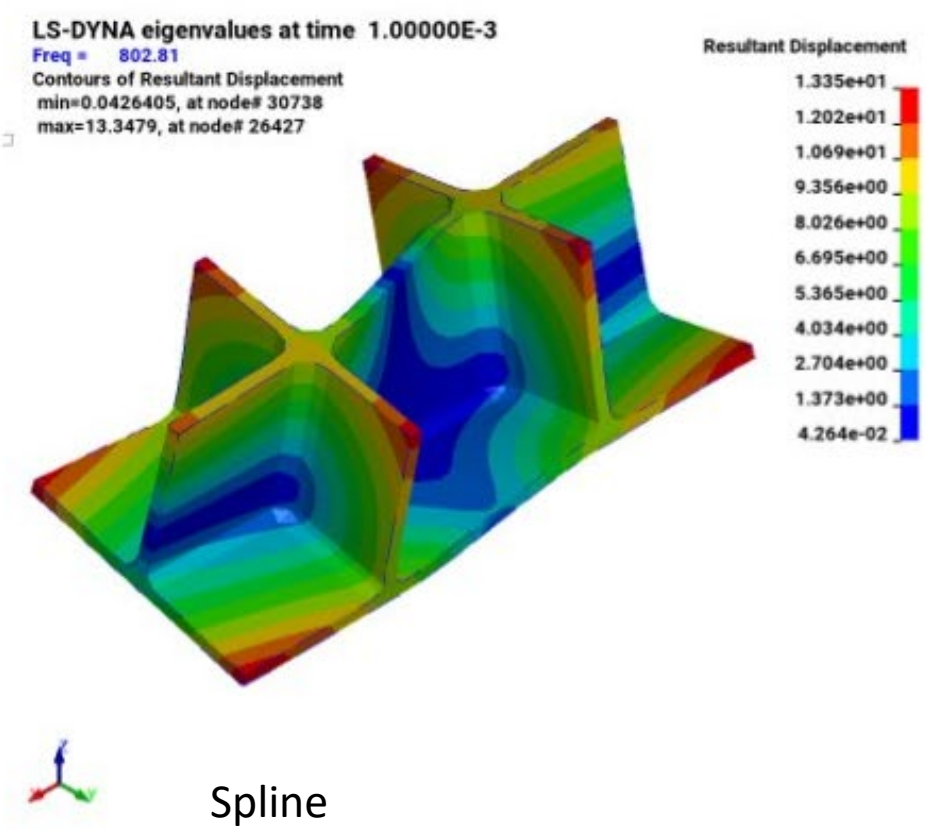
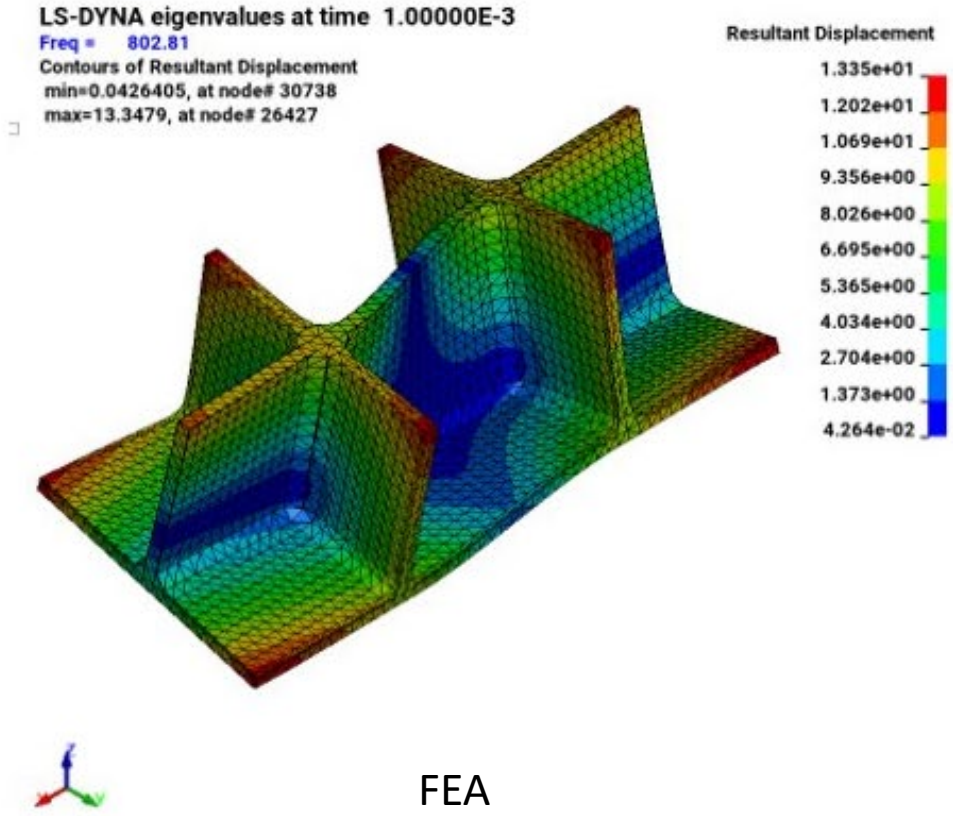
Trimmed Volumetric Splines

- Integration in LS-DYNA solver (Work in progress)



Spline



FEA

Eigenmodes

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Ongoing Development

Ongoing Development: IGA

- Tied contact-based connections
  - These are already possible using

  *CONTACT_TIED_SHELL_EDGE_TO_SURFACE_BEAM_OFFSET (for Shell IGA)

  *CONTACT_TIED_SURFACE_TO_SURFACE_OFFSET (for Solid IGA)
- Other connection methods
  - Constrained Nodal Rigid Bodies
  - Rigid Patches
  - Constrained Extra Nodes
- Mapping of manufacturing data for shells and solids

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Summary

- First version of PyPrimeMesh APIs will be available for IGA in 24R1 as Beta
- Exposure in Workbench will leverage use of IGA technology to Ansys customers
- The automated workflows will show significant time reduction in CAD to Analysis workflows

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Acknowledgements

- We would like to give offer our sincere gratitude to all the hard work done by folks in meshing and solver side without which this work would not have been possible
- Solver
  - Attila Nagy, Dave Benson, Liping Li, Lam Nyugen
- Meshing
  - Jan Frykestig, Sourabh Chadha, Wenyan Wang, Aditya Mukane, Prajna Behera, Abhishek Suresan, Dhisondhar Rajendran

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