Propped Cantilever Mesh Convergence Study using Hexahedral Elements

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Contents

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Introduction

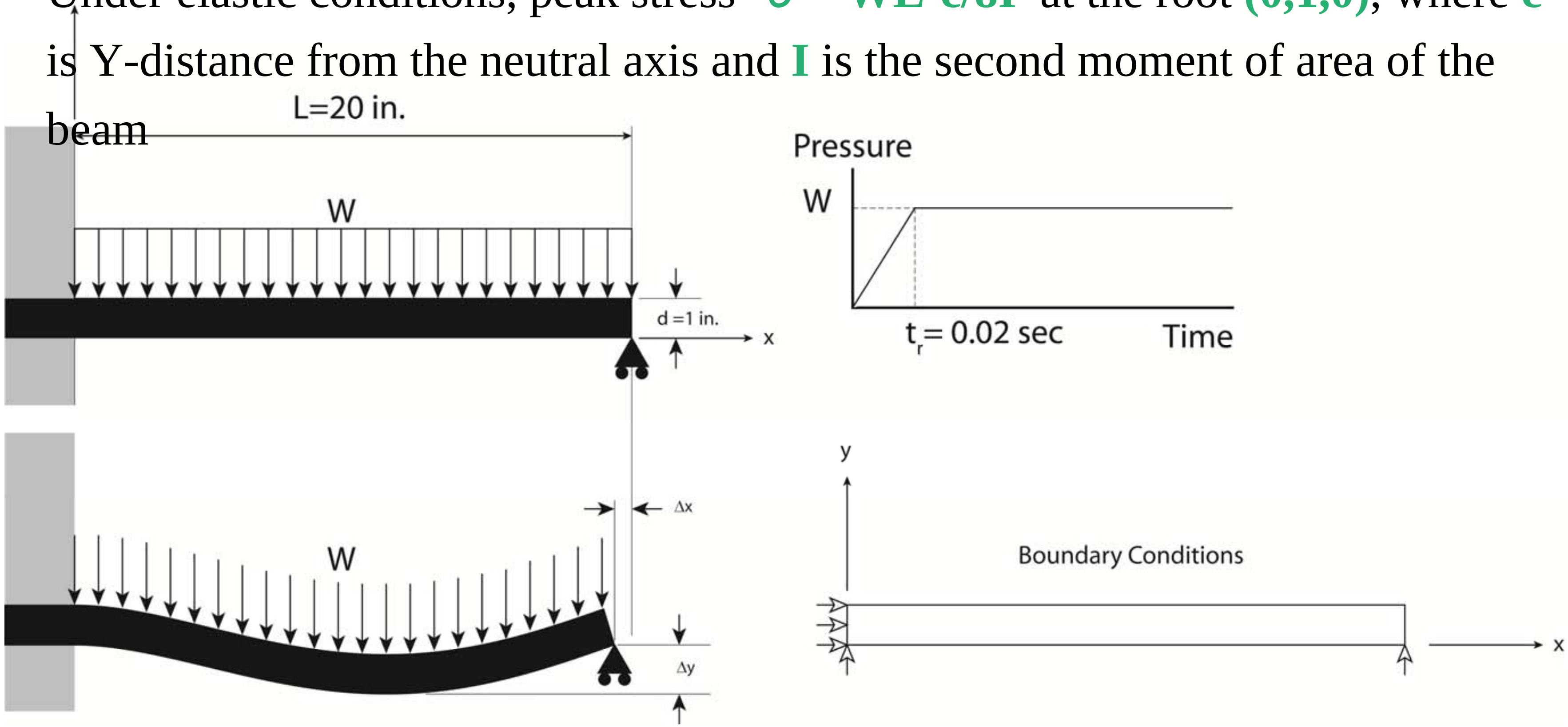
Task Group on Computational Modelling for Explicit Analysis in the ASME Boiler and Pressure Vessel Code

- Founded August 2008 to develop a quantitative finite-element modelling guidance document for explicit dynamic analyses,
- The guidance document will include a series of element convergence studies to aid designers in establishing the mesh refinement necessary
- These studies will also aid reviewers evaluating the quality of the FE models and the apparent accuracy of their results.

This paper summarises one of these studies.

Convergence Problem Definition

- Propped cantilever under a uniformly distributed load
- Ramp time set to be an order of magnitude greater than the lowest natural frequency
- Under elastic conditions, peak stress **σ =WL²c/8I** at the root **(0,1,0)**, where **c** is Y-distance from the neutral axis and **I** is the second moment of area of the beam



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Convergence Problem Definition (continued)

- Stainless steel
- Elastic-plastic with power-law-hardening:

$$\sigma = \sigma_y + A \varepsilon_p^n$$

  - E = 28,000 ksi
  - σ_y = 30 ksi
  - A = 192 ksi
  - n = 0.74819
  - ν = 0.3
  - ρ = 7.385x10^{-4} lbf s^2 in^{-4}

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Convergence Problem Definition (continued)

- Three loadings:
  - W = 100 psi. Fully elastic
  - W = 240 psi. Formation of plastic hinges
  - W = 500 psi. High plasticity
- Element: 8 noded brick elements
- One element wide
- Mesh density:
  - 2, 3, 5, 7 and 9 elements through the beam thickness
  - Aspect ratios (AR) = L_x/L_y = 10, 2, 1 and 0.5.

Total: 5 x 4 = 20 different meshes x 3 load cases = 60 runs.

Analyses

- Analysed in
  - **LS-DYNA** - Arup and Westinghouse Electric (WE)
  - **ABAQUS/Explicit** - Idaho National Laboratory (INL)
- Additional variables:
  - Element formulations :
    - Fully-reduced, single-integration-point (run with hourglass control)
    - Fully-integrated, selectively-reduced (run without hourglass control, not required)
  - Loads applied as ‘Nodal’ (constant) or ‘Traction’ (area-based) loads
  - Runs with elastic elements at the supports

Analyses

	Single-point Fully plastic Nodal load	Single-point Fully plastic Traction load	Single-point Elastic corners Nodal load	Single-point Elastic corners Traction load	Fully-integrated Fully plastic Nodal load
LS-DYNA (Arup)	All loads All meshes	All loads All meshes	All loads All meshes	All loads All meshes	All loads All meshes
LS-DYNA (WE)	All loads All meshes	500 psi only 9x360 only			500 psi only All meshes
ABAQUS/Explicit (INL)		All loads All meshes	500 psi only All meshes	500 psi only All meshes	

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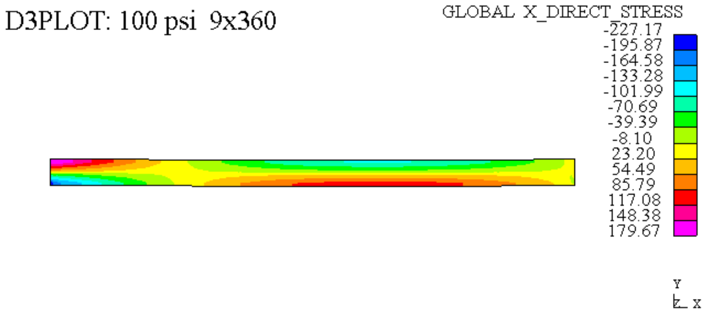
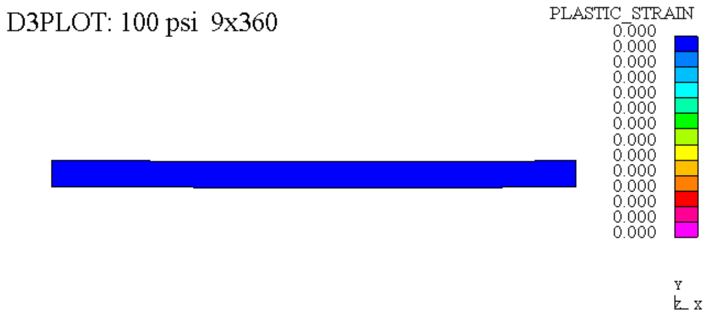
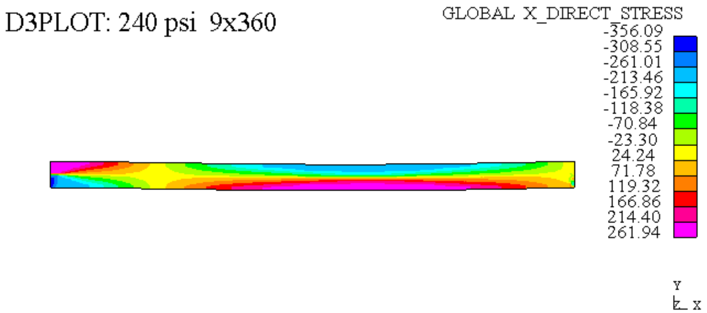
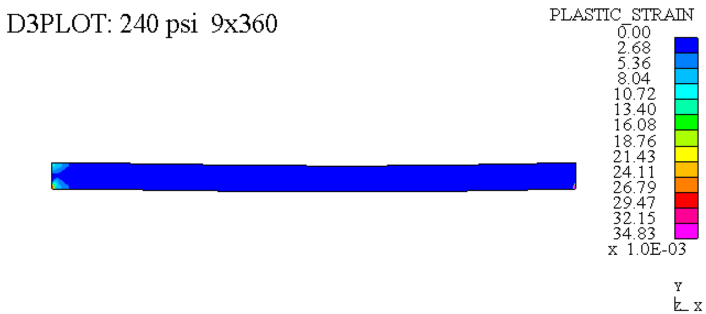
Results

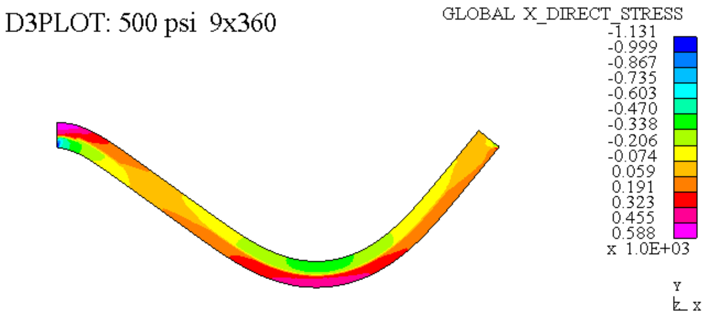
From the finest mesh, 9x360 elements, AR = 0.5

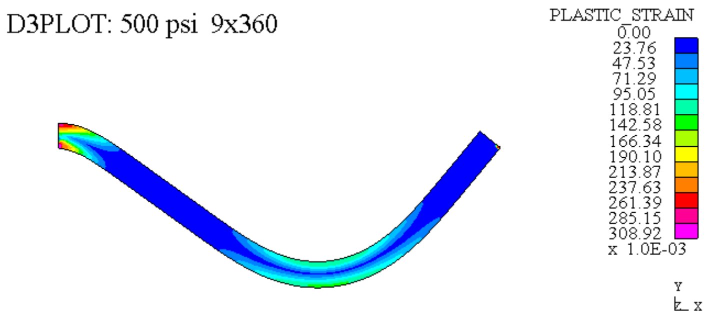




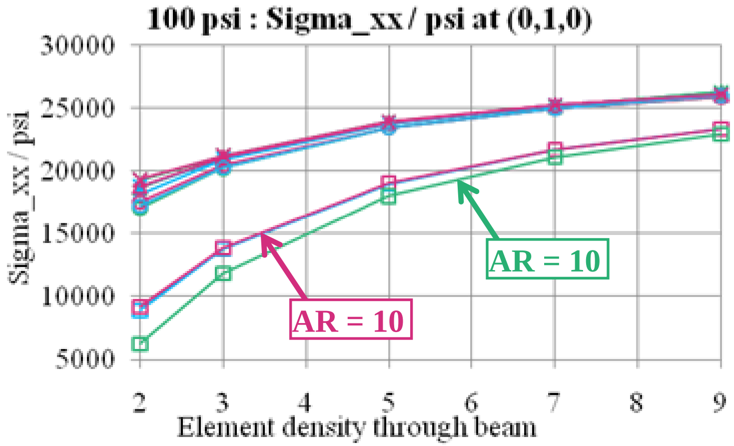


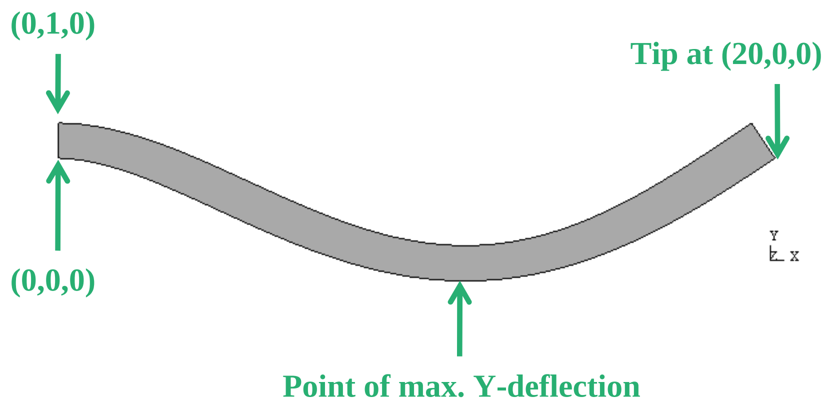


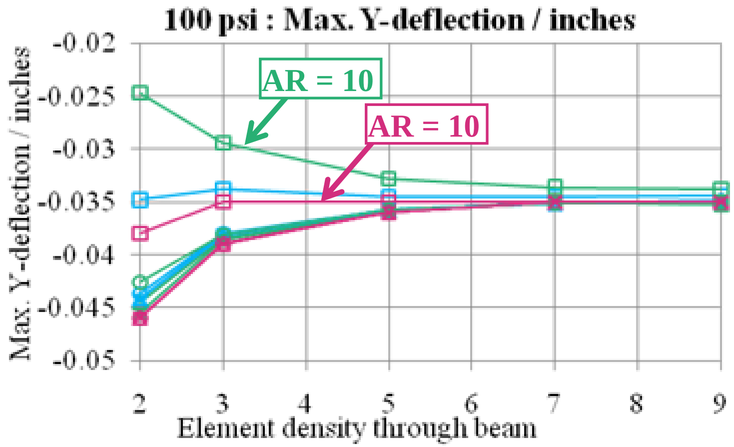


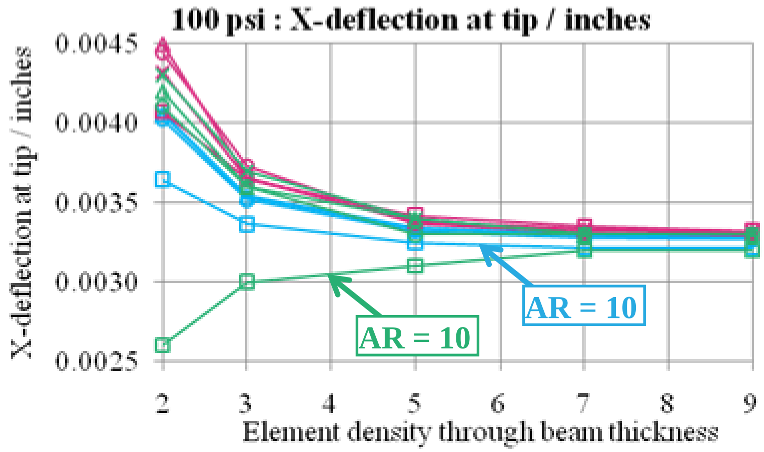


Comparison:
LS-Dyna vs. LS-Dyna vs. ABAQUS, 100 psi

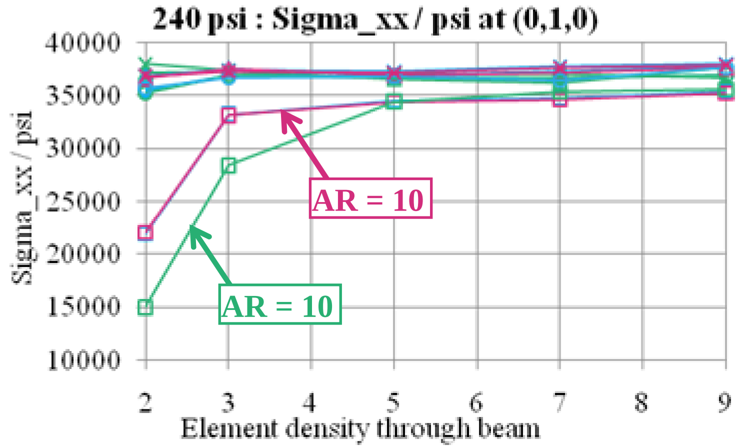




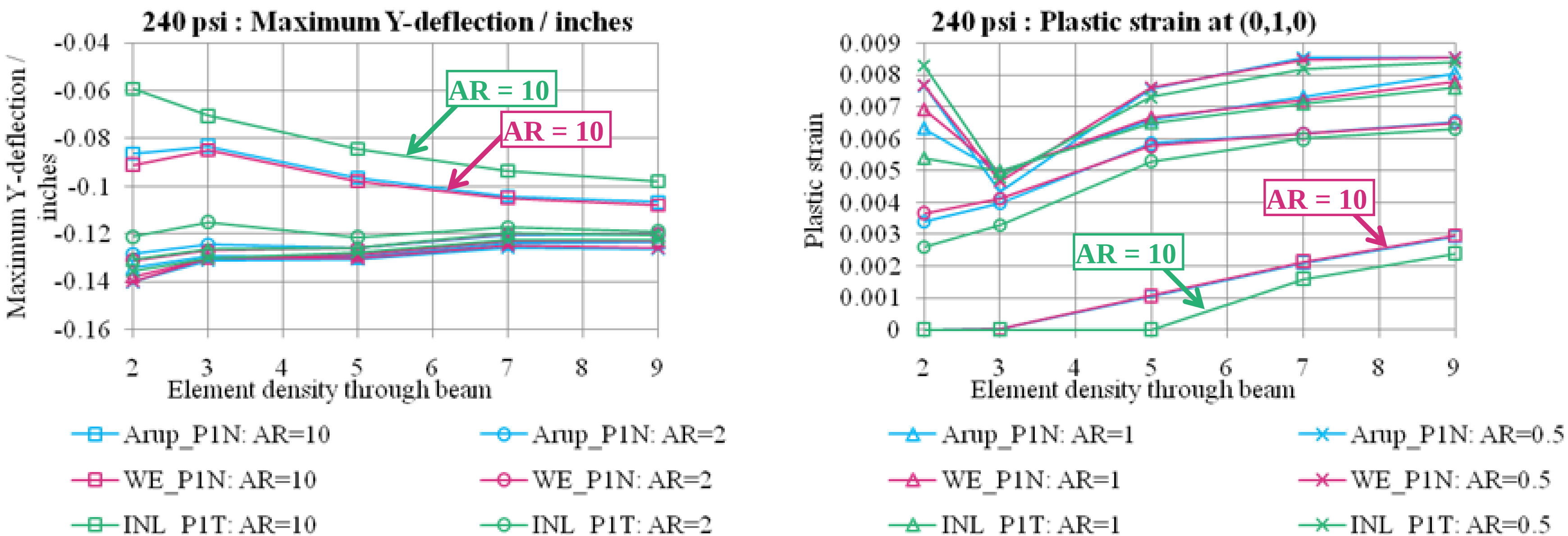




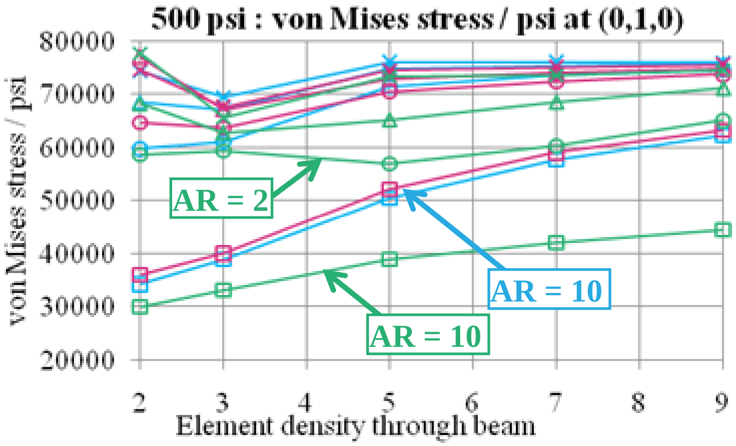
Comparison:
LS-Dyna vs. LS-Dyna vs. ABAQUS, 240 psi



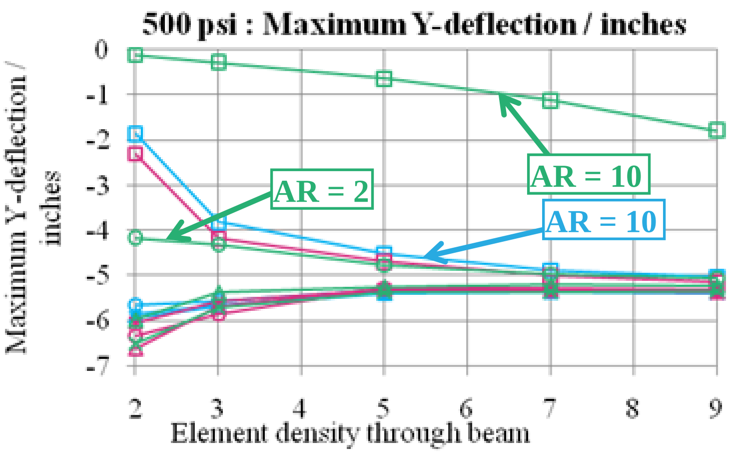
- Very rapid convergence of stresses and deflections, except for AR =10
- Slower convergence for plastic strains

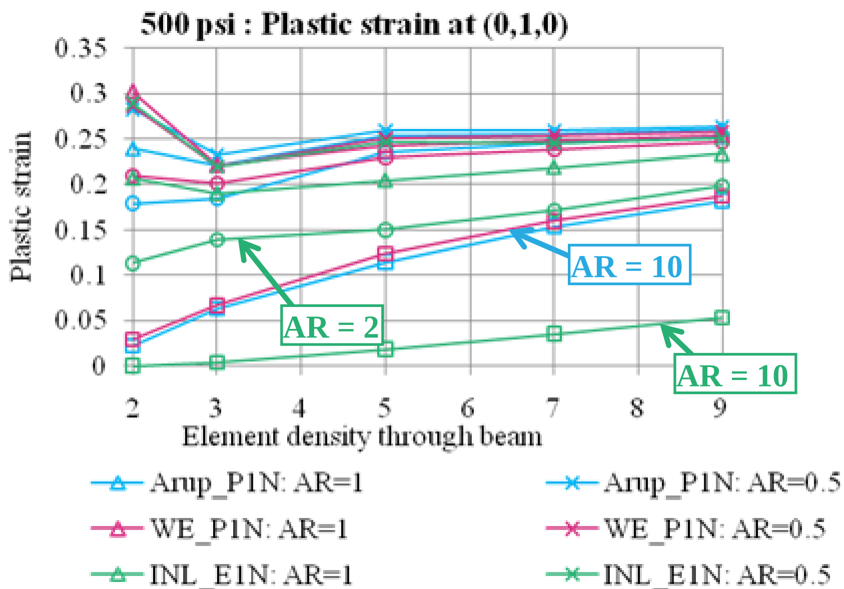


Comparison:
LS-Dyna vs. LS-Dyna vs. ABAQUS, 500 psi



- Convergence of stresses is more similar to 100 psi than 240 psi
- ABAQUS plastic strain results are slower to converge than LS-Dyna results





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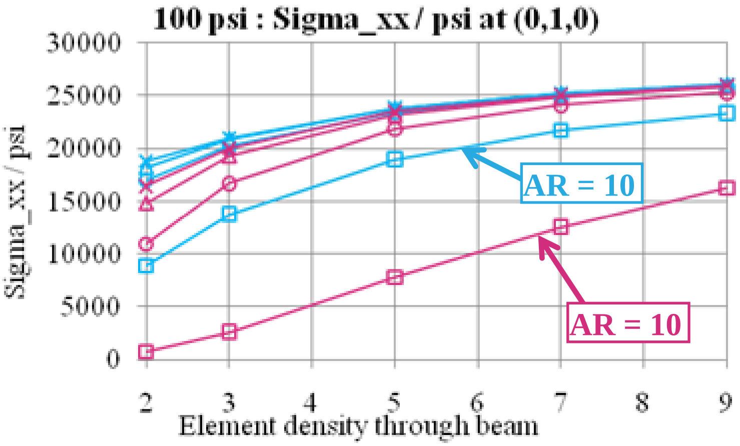
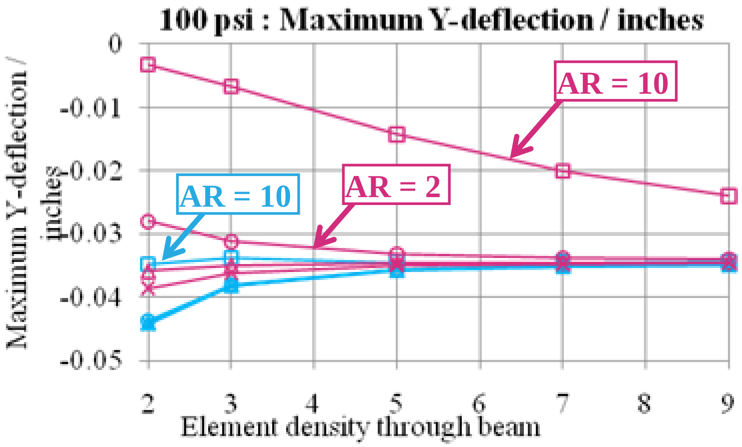
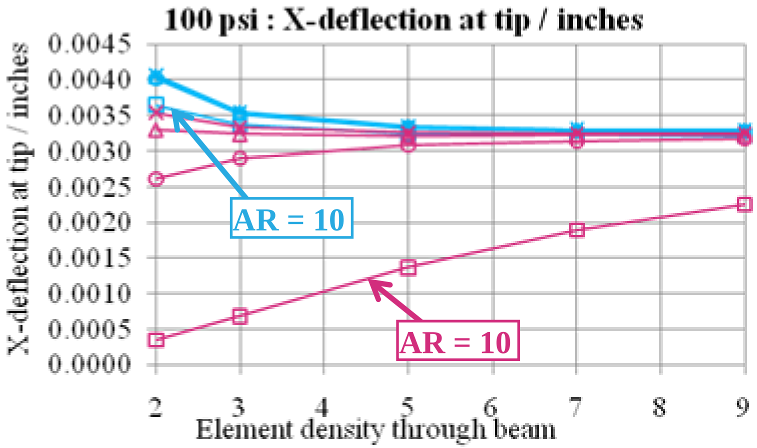
Comparison:
1-integration-point vs. Fully-integrated, 100 psi



- Very similar convergence with element density through the beam
- Fully-integrated are much stiffer at higher aspect ratios





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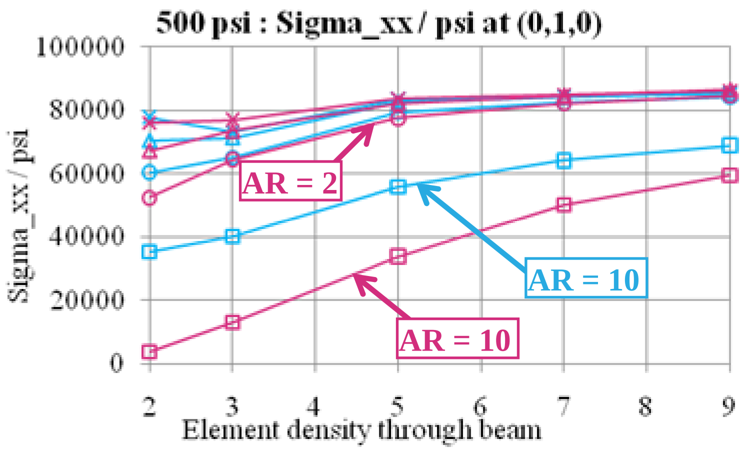
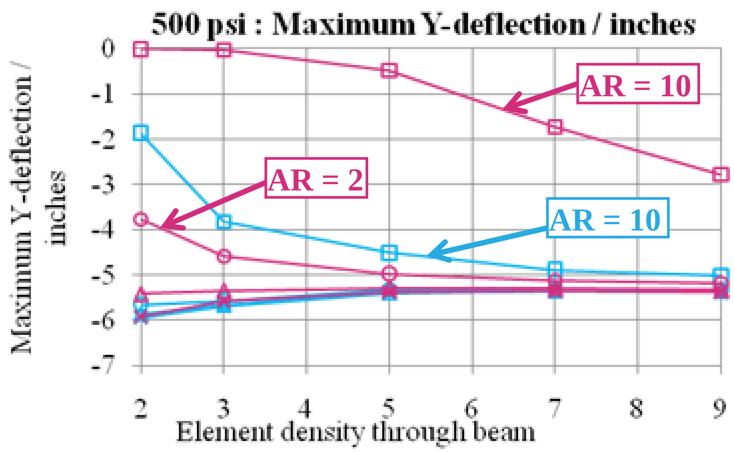
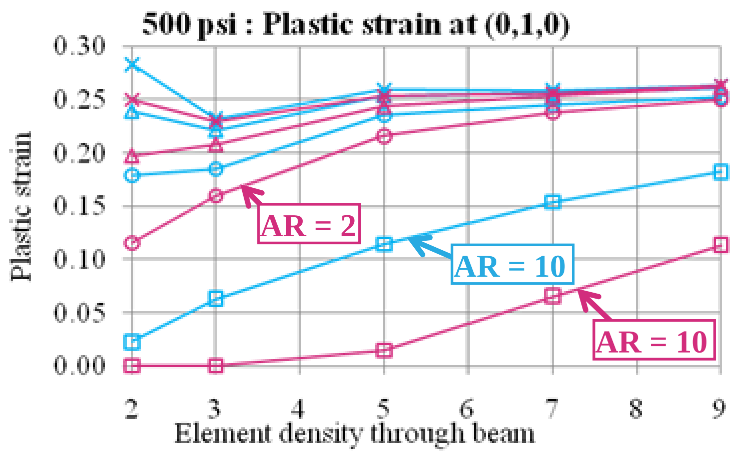
Comparison:
1-integration-point vs. Fully-integrated, 500 psi



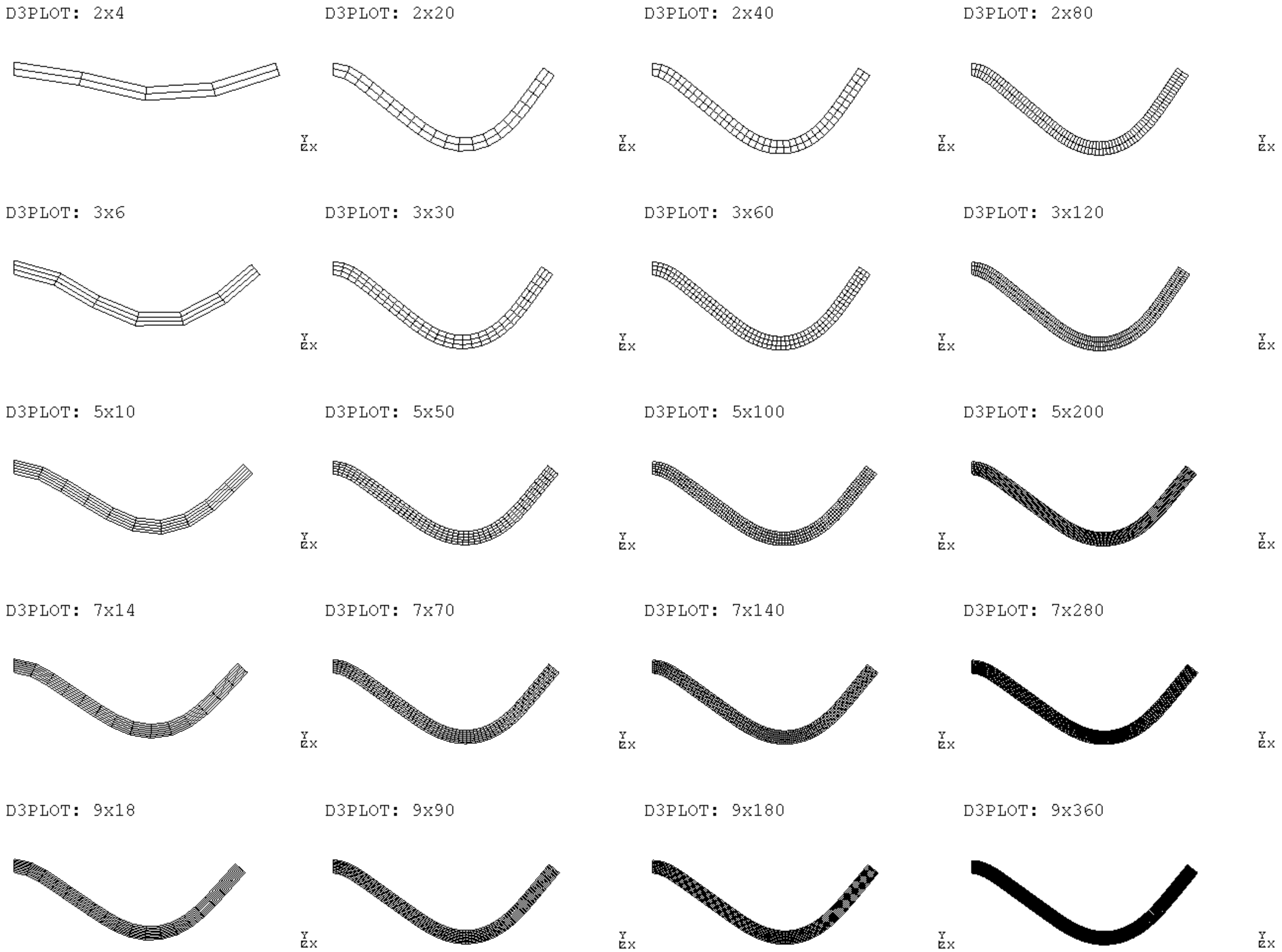
- Very similar convergence with element density through the beam
- Fully-integrated (8-pt) are much stiffer at higher aspect ratios



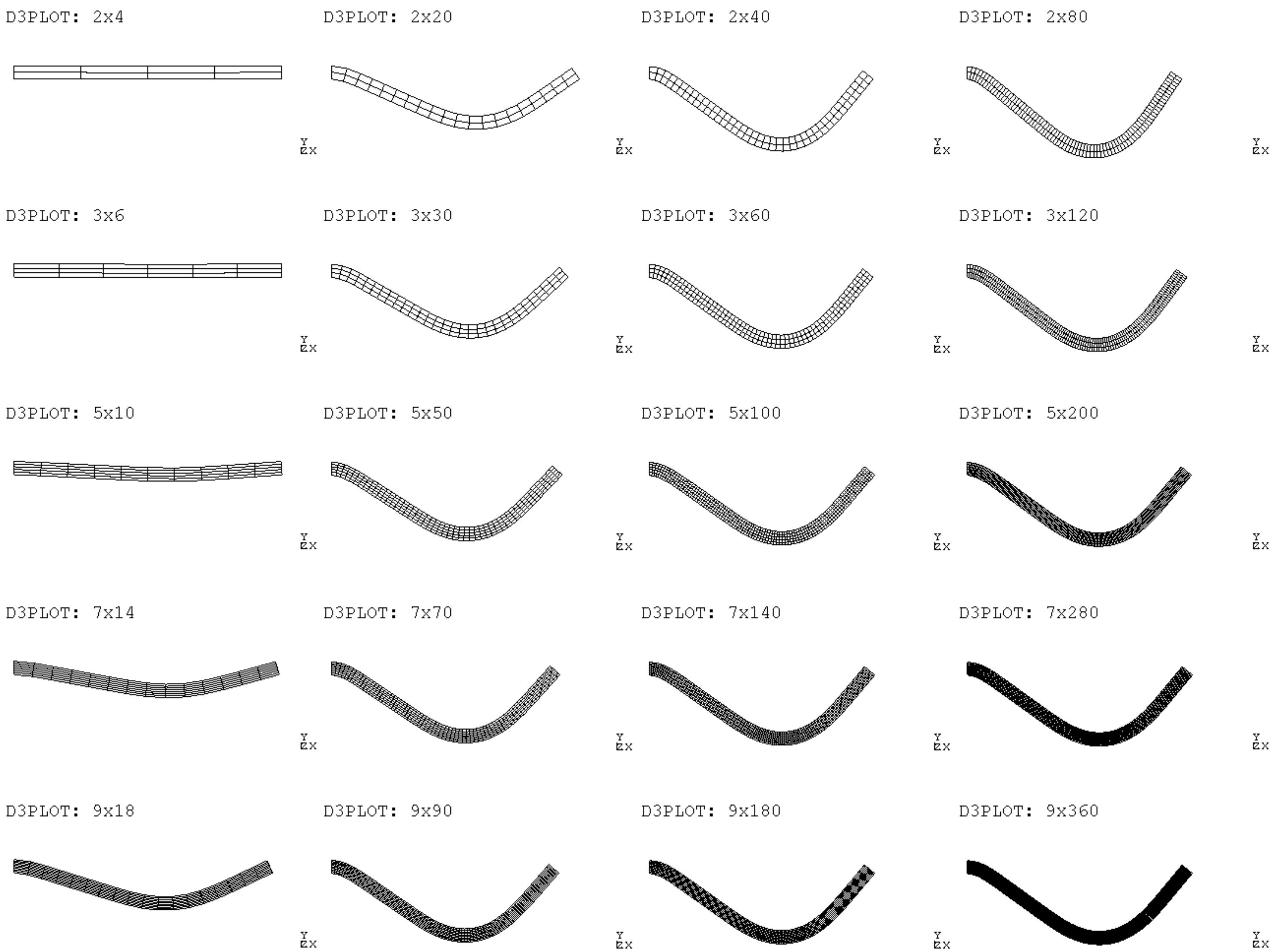


Arup_P1N: AR=10 | Arup_P1N: AR=2 | Arup_P1N: AR=1 | Arup_P1N: AR=0.5
ARUP_P8N: AR=10 | ARUP_P8N: AR=2 | ARUP_P8N: AR=1 | ARUP_P8N: AR=0.5

Single-integration-point, nodal load, 500 psi



Fully-integrated, nodal load, 500 psi



Conclusions

- AR=10 inadequate.
- 7 elements through thickness to get convergence.
- Single-integration-point elements:
  - Produced accurate results that are relatively insensitive to mesh density;
  - Were more sensitive to through-beam mesh density than to aspect ratio; and
  - Required careful tuning of their hourglass controls
- Fully-integrated elements:
  - Produced a stable and well-controlled deformation without the need to tune hourglass controls or introduce fully-elastic elements;
  - Beware of ‘shear-locking’ in large aspect ratio.
- Traction vs. Nodal load: only made a difference at 500 psi (7.5 % reduction in deflection for Traction load), after extreme deformation reduced the surface area.