FLAT PLATE PUNCTURE TEST CONVERGENCE STUDY

PATRAM 2010

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Introduction

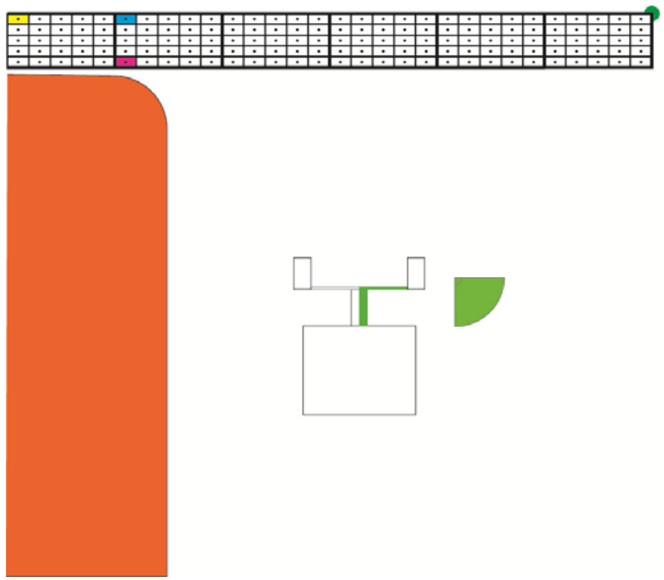
- The ASME Task Group on Computational Modeling for Explicit Dynamics is developing a set of standard problems to illustrate the difference between a “good” analysis and a “bad” one for problems that involve large strains.

- The IAEA TS-R-1 regulatory puncture test is one problem type that can result in large strains.

- The convergence study of this paper uses a punch problem that is similar to the regulatory puncture test to compare finite element meshes.

Problem Statement

- Quarter symmetry
- Mild steel punch 15.24 cm in diameter with a 2.54 cm corner radius
- 25 mm thick stainless steel plate 1 m in diameter
- Plate is initially moving down at 4.47 m/s
- Distributed mass at edge of plate with total mass of 55,340 kg
- Punch is vertically restrained at base



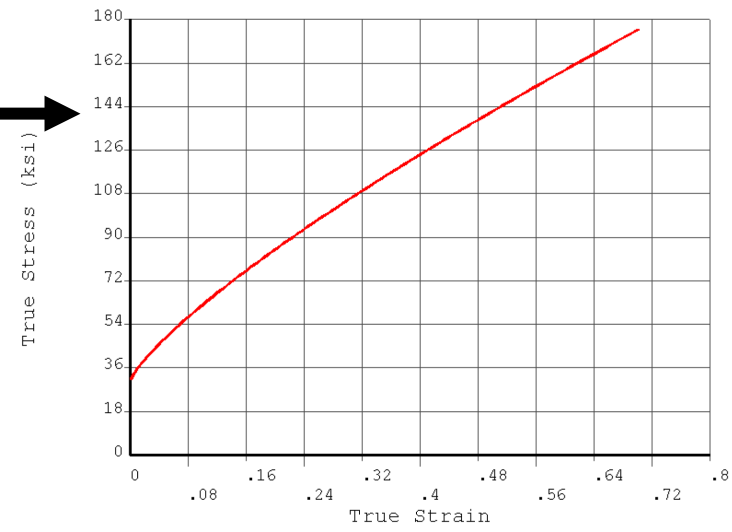
Problem Statement (cont'd)

- **Investigate meshes of 2, 3, 5, 7, and 9 elements through the plate thickness**
- **Use element aspect ratios of ½, 1, and 2**
- **Plate material: power plasticity law**

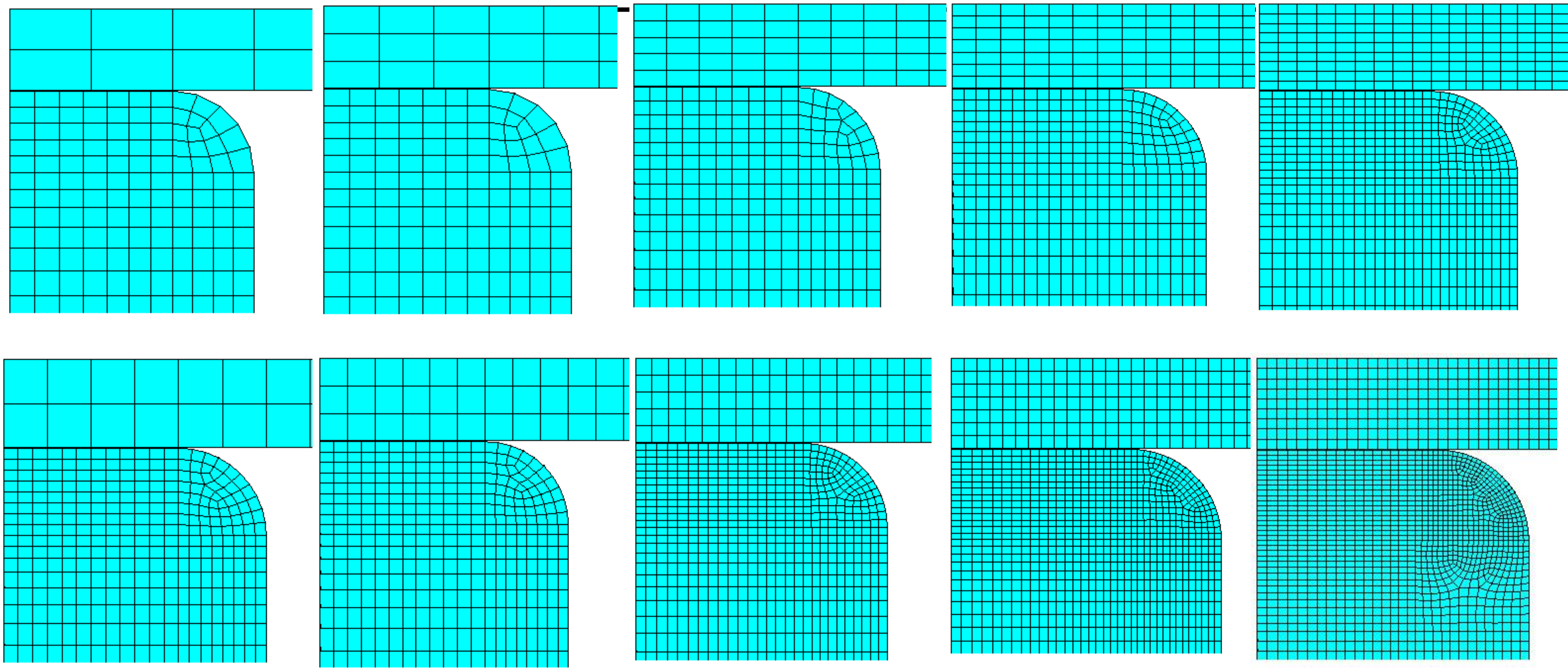
$$S_{yield} = S_{y0} + 192{,}000(\varepsilon^{p})^{0.78}$$

  - **ε^{p} = equivalent plastic strain**
  - **S_{y0} =initial yield strength=30ksi**
- **Punch material: Bilinear**
  - **S_{yield} = 42 ksi, E_{tan} =300 ksi**
- **Hour glass control: stiffness based**

Uniaxial True Stress/Strain



Finite Element Meshes



- **Analyses were also conducted with same punch mesh but twice as many elements along the plate.**

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Analysis Codes Used

- ABAQUS-Explicit (INL, SRNL)
- LS-DYNA (Westinghouse, NAC, Arup)
- 3D hex elements
- Both codes were run with single point integration and with fully integrated elements

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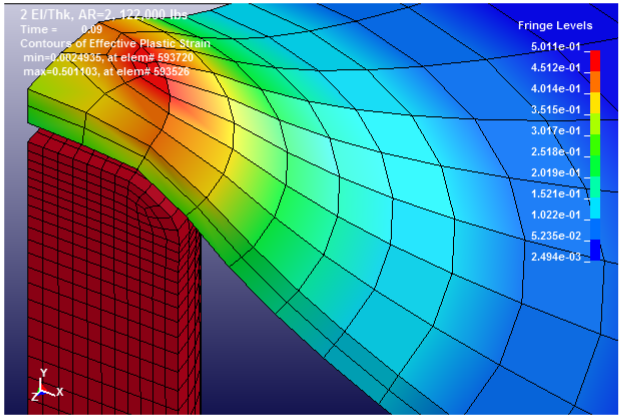
Reported Results

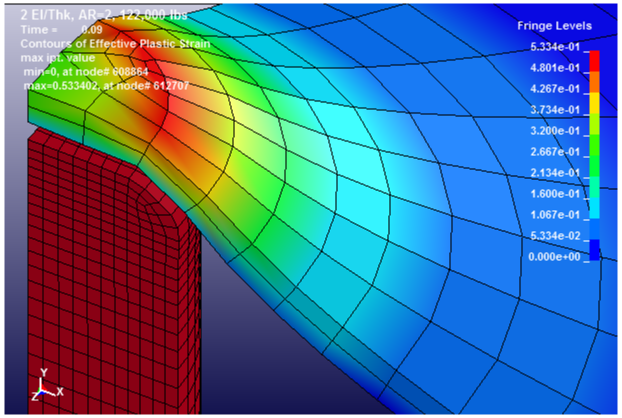
- Plastic strains at center of the plate, radius 5 cm, and radius 10 cm from the center of the plate
- Maximum deflection at center of the plate top surface
- Maximum deflection at edge of the plate top surface
- Contour plots of plastic strain

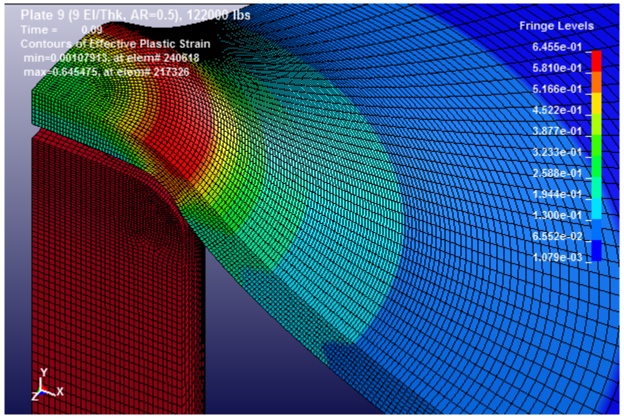
Example Deformed Shapes

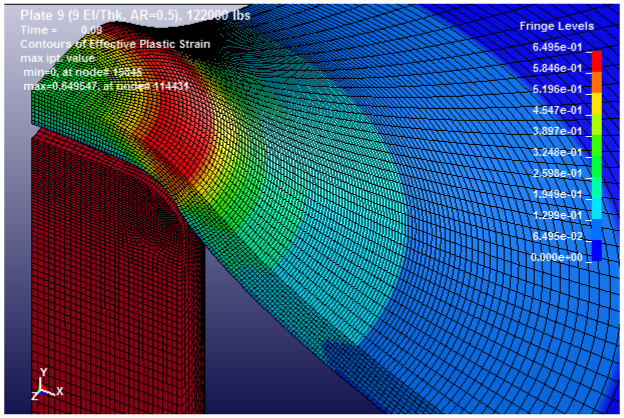
Reduced Integration

Fully Integrated









Code-to-Code Comparison - Strains

- **Case with 7 elements through the thickness and a 1:1 element aspect ratio**

		Top Center	Top 5 cm	Bot 5 cm	Top 10 cm	Bot 10 cm
SRNL - Abaqus	reduced	0.279	0.648	0.418	0.215	0.205
SRNL - Abaqus	full	0.276	0.639	0.407	0.214	0.206
Westinghouse - DYNA	reduced	0.280	0.618	0.399	0.212	0.202
Westinghouse - DYNA	full	0.277	0.620	0.398	0.211	0.202
INL - Abaqus	reduced	0.278	0.620	0.397	0.212	0.202
INL - Abaqus	full	0.276	0.617	0.394	0.211	0.202
Arup - DYNA	reduced	0.280	0.626	0.413	0.211	0.202

Code to Code Comparisons – Deflections (in)

- **Case with 7 elements through the thickness and a 1:1 element aspect ratio**

		Top Center	Top @ Edge
SRNL - Abaqus	reduced	0.432	7.985
SRNL - Abaqus	full	0.429	7.988
Westinghouse - DYNA	reduced	0.544	8.007
Westinghouse - DYNA	full	0.536	8.020
INL - Abaqus	reduced	0.543	8.016
INL - Abaqus	full	0.539	8.014
Arup - DYNA	reduced	0.534	8.019

Mesh-to-Mesh Comparison

- **From DYNA with reduced integration elements**

Elements thru Thickness	Aspect Ratio	EPS Top Center	EPS at r=5$^+$cm		EPS at r=10$^+$cm		Max Δy (in.)[(1)]	
			Top	Bottom	Top	Bottom	Top Center	Top OD
2	2	0.3063	0.4358	0.3138	0.1876	0.1730	-0.188	-7.275
2	1	0.2718	0.5344	0.3966	0.2008	0.1901	-0.176	-7.352
2	0.5	0.2823	0.5658	0.4231	0.2056	0.1946	-0.216	-7.404
3	2	0.2725	0.5180	0.3500	0.1996	0.1908	-0.545	-7.902
3	1	0.2757	0.5754	0.3987	0.2057	0.1936	-0.560	-7.954
3	0.5	0.2939	0.6154	0.4502	0.2067	0.1981	-0.560	-7.965
5	2	0.2824	0.5941	0.4250	0.2035	0.1939	-0.546	-7.986
5	1	0.2769	0.6083	0.4106	0.2094	0.1985	-0.547	-7.992
5	0.5	0.2848	0.6240	0.4199	0.2113	0.2012	-0.544	-7.986
7	2	0.2799	0.6178	0.4100	0.2089	0.1993	-0.539	-8.014
7	1	0.2800	0.6175	0.3991	0.2123	0.2017	-0.544	-8.007
7	0.5	0.2853	0.6310	0.4094	0.2133	0.2034	-0.537	-7.997
9	2	0.2783	0.6224	0.4058	0.2108	0.2006	-0.540	-8.016
9	1	0.2805	0.6259	0.3868	0.2135	0.2035	-0.541	-8.004
9	0.5	0.2817	0.6262	0.3771	0.2145	0.2047	-0.541	-7.996

Lessons Learned from this Problem

- It is important to have similar meshes in the plate and the punch to avoid mismatch in curvature

- A very careful characterization of the problem is necessary
  - Certain default analysis controls can result in differences
  - The implementation for an option in the codes may be different though they may have the same identification

Conclusions

- **Even experienced analysts may not all choose the same parameters for a loosely defined problem**

- **For a well defined problem, different codes and different analysts obtain the same results**

- **For this problem, with a fairly gentle bending of the plate, a converged solution happens with a fairly coarse mesh**

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