Element verification and comparison for Sierra/SM explicit dynamics problems

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Abstract: The goal of this project is to study the affects of element selection on the Sierra/SM explicit solution to four common dynamics problems. A total of nine elements are used for all problem; a table to the right shows each of the elements. Every model is run multiple times with varying spatial and temporal discritization in order to ensure convergence. The first three problems are compared to analytical solutions, and all numerical results, independent of mesh density, are found to be sufficiently accurate. The penetration problem is found to have a high mesh dependence in terms of element type, mesh discritezation, and meshing scheme. Also, the time to solution is shown for each problem in order to facilitate element selection when computer resources are limited.

Element Shape	8 Noded Hexahedral				4 Noded Tetrahedral		10 Noded Tetrahedral		
Formulation	Mean Quadrature	Selective Deviatoric	Q1P0	Fully Integrated	Mean Quadrature	Nodal Based	Uniform Gradient	Fully Integrated	Composite

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Non-Linear Material Model

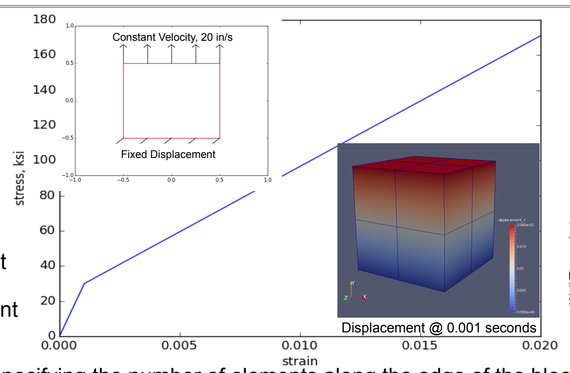
Material Properties:
- Elastic-plastic material model
- Density = 0.00074 slinch/in^3
- Young's modulus = 29 Msi
- Poisson's ratio = 0.3
- Yield stress = 30 ksi
- Hardening modulus = 10 Msi
- Beta = 1.0

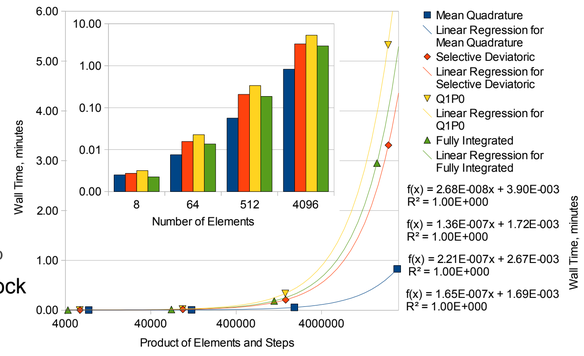
Boundary Conditions:
- The +Y surface is subject to a constant velocity of 20 in/s
- The -Y surface has a fixed displacement

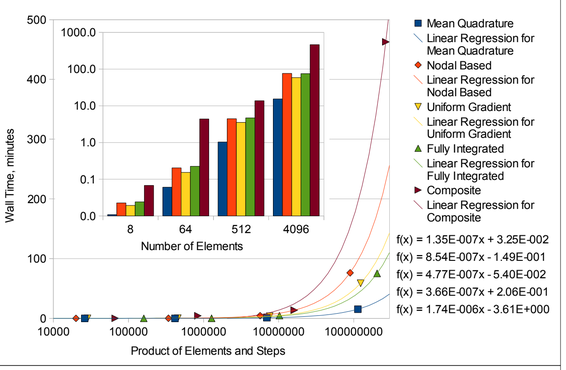
Spatial Discretization:
- The mesh density was controlled by specifying the number of elements along the edge of the block
- There were four meshes per element with 2,4,8 and 16 edge elements

Temporal Discritization:
- The 8 edge element mesh was used for the temporal discritization
- The first run used the default time step

The second and third run used ½ and ¼ of the default time step, respectively





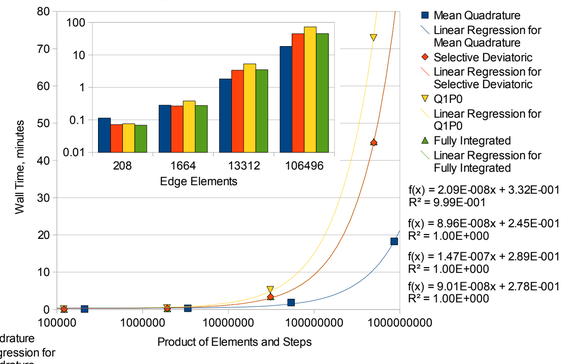


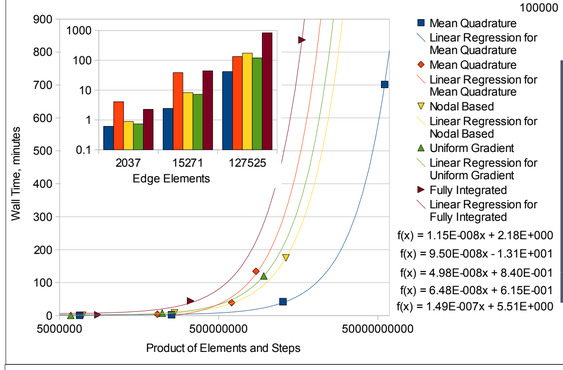
Impact Model

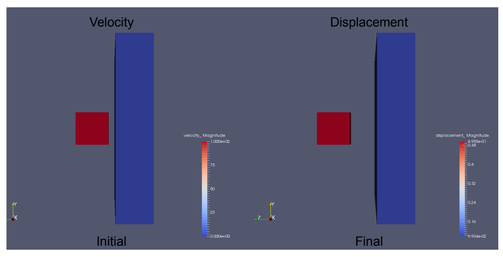
Material Properties:
- Elastic material model
- Density = 7.4e-4 slinch/in^3
- Young's modulus = 29 Msi
- Poisson's ratio = 0.0

Boundary Conditions:
- The block is subject to an initial velocity of 100 in/s
- The plate is initallly at rest

Spatial Discritization:
- Four meshes with element lengths of 1/2, 1/4, 1/8 and 1/16 of an inch





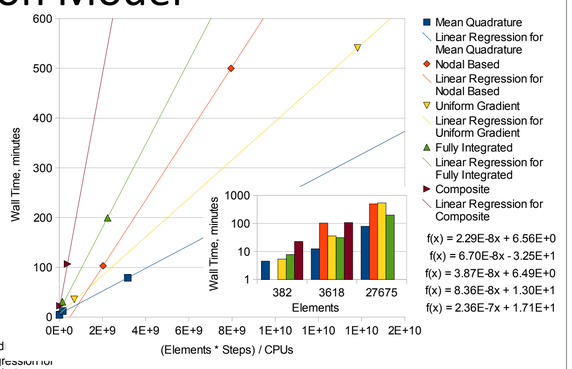


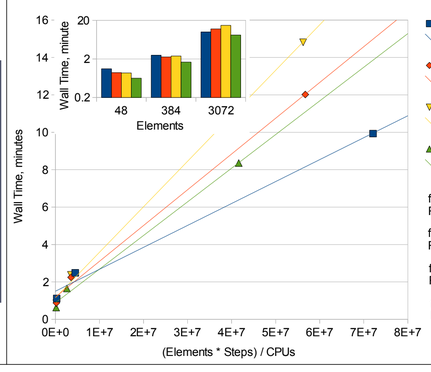
Friction Model

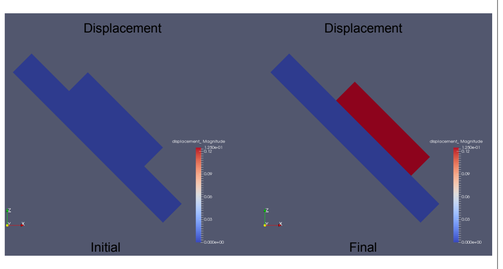
Material Properties:
- Elastic material model
- Density = 7.4e-4 slinch/in^3
- Young's modulus = 29 Msi
- Poisson's ratio = 0.3

Boundary Conditions:
- The lower plate has a fixed displacement velocity of 100 in/s
- The upper plate is iinitially at rest
- Gravity is applied in the -Y direction

Spatial Discritization:
- Threee meshes with element lengths of 1/2, ¼ and 1/8 of an inch





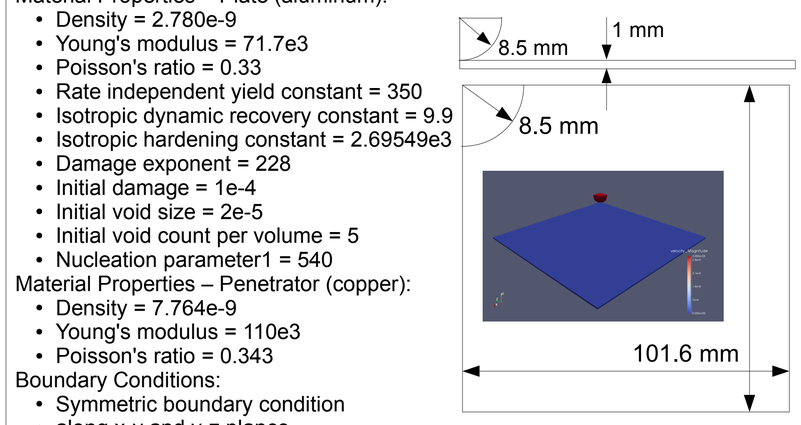


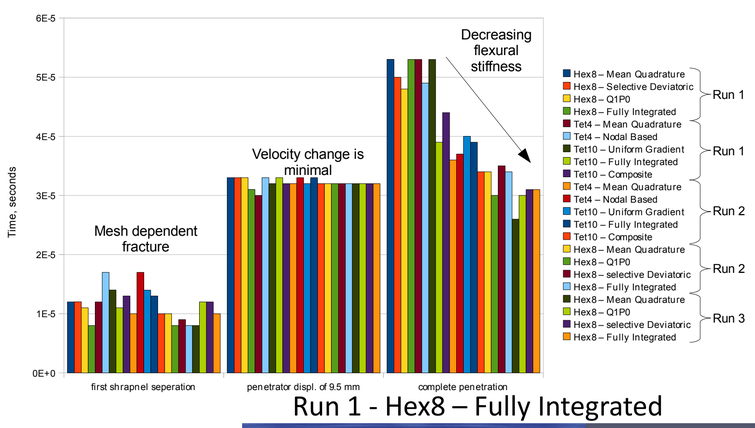
Penetration Model

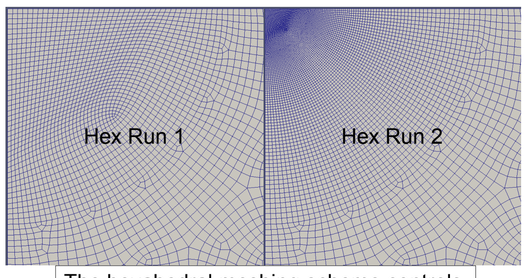
Material Properties – Plate (aluminum):
- Density = 2.780e-9
- Young's modulus = 71.7e3
- Poisson's ratio = 0.33
- Rate independent yield constant = 350
- Isotropic dynamic recovery constant = 9.9
- Isotropic hardening constant = 2.69549e3
- Damage exponent = 228
- Initial damage = 1e-4
- Initial void size = 2e-5
- Initial void count per volume = 5

Material Properties – Penetrator (copper):
- Density = 7.764e-9
- Young's modulus = 110e3
- Poisson's ratio = 0.343

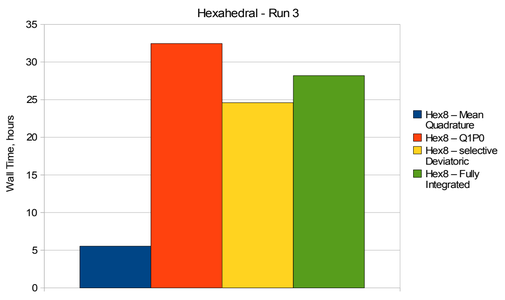
Boundary Conditions:
- Symmetric boundary condition
- along x-y and y-z planes
- Initial velocity of -300 m/s for the penetrator

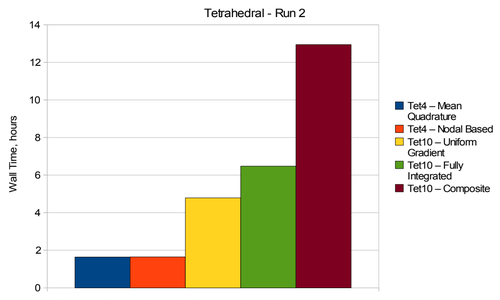




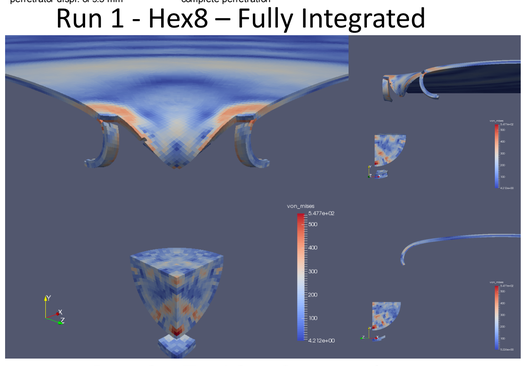


The hexahedral meshing scheme controls the fracture pattern, because the fracture propagates along the mesh lines

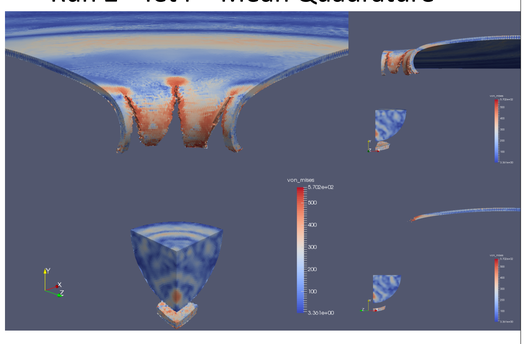




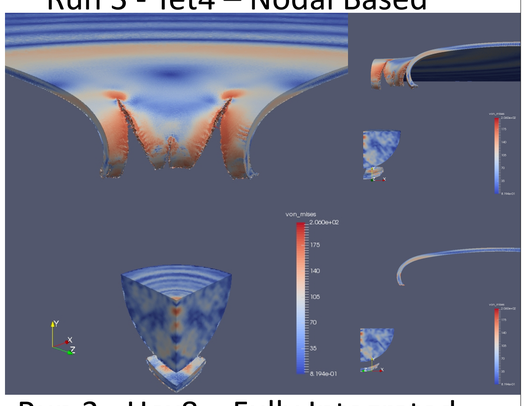
Run 1 - Hex8 – Fully Integrated



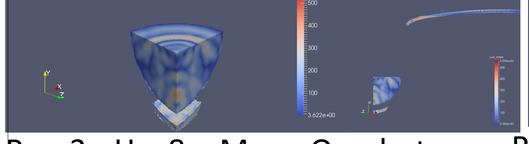
Run 2 - Tet4 – Mean Quadrature



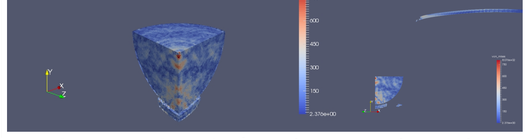
Run 3 - Tet4 – Nodal Based



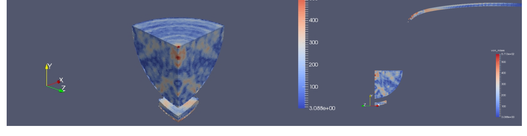
Run 2 – Tet10 – Uniform Gradient



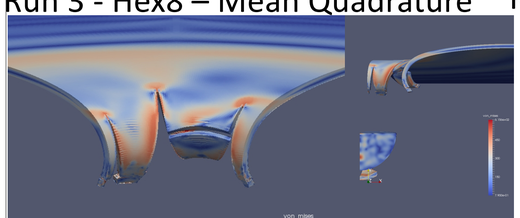
Run 2 - Tet10 – Fully Integrated



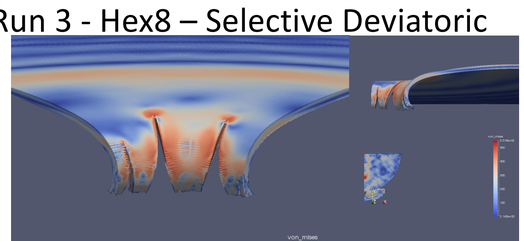
Run 2 - Tet10 – Composite



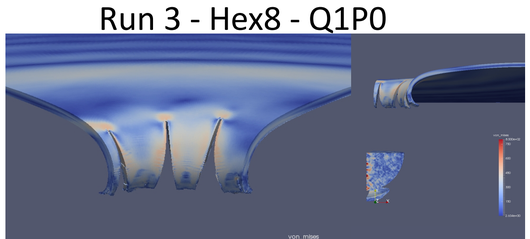
Run 3 - Hex8 – Mean Quadrature



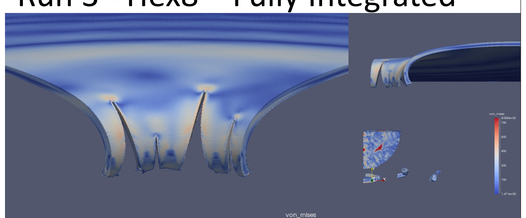
Run 3 - Hex8 – Selective Deviatoric



Run 3 - Hex8 - Q1P0



Run 3 - Hex8 – Fully Integrated



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