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Analysis of Defective Socket Head Bolts at High Strain Rates

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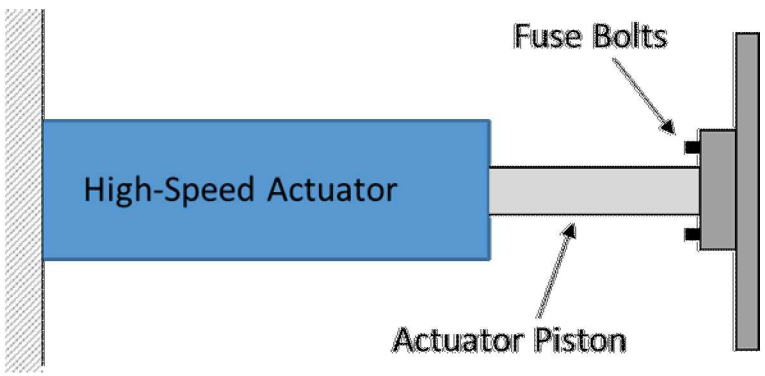
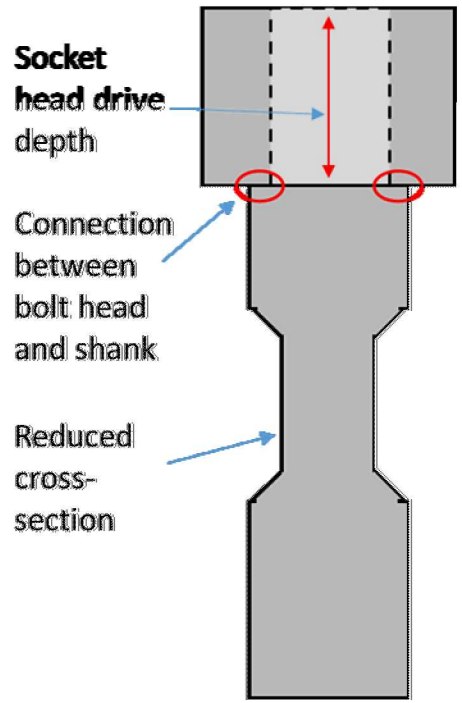
Introduction and Motivation

- Fuse bolts are used to protect high-speed actuator piston from bending during dynamic experiments
- A 3/8” fuse bolt fractured unexpectedly due to a manufacturing defect in the connection between the bolt head and shank
- Need to better understand how the defect caused fracture and the overall behavior of socket head fuse bolts at high strain rates





Model Inputs and Problem Approach

SIERRA SM explicit dynamics FEM software

Material model: Johnson-Cook plasticity

- High strain rates and finite strains
- Rate and temperature-dependent hardening function
- Damage is defined as cumulative effective plastic strain

Problem approach:

1. Evaluate effect of socket head drive depth with a simplified geometry
2. Model full bolt geometry to evaluate behavior of fuse geometry

ASTM A574 steel material properties	
Youngs Modulus, psi	2.80E+07
Poisson's Ratio	0.33
Yield Stress, psi	130000
Shear Modulus, psi	2.49E+05
Hardening Constant	5.00E+09
Hardening Exponent	2.28E-01

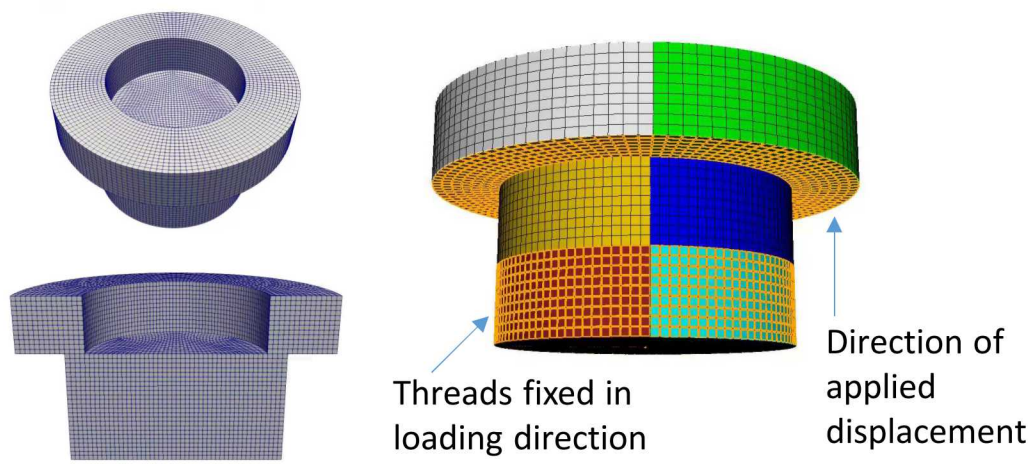
Mesh and Boundary Conditions

Improvements on initial geometry:

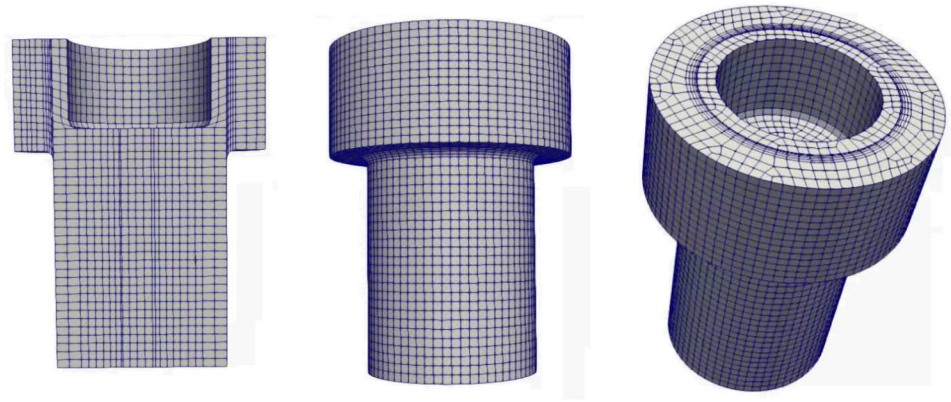
- Smooth corners between bolt head and shank to avoid stress singularity
- Model full socket head length

Boundary conditions for simplified geometry:

- 200 in/sec displacement applied to bearing surface of bolt head
- Threaded section fixed in loading direction
- Center node at bottom of bolt shaft is fixed in all directions to prevent rigid body motion



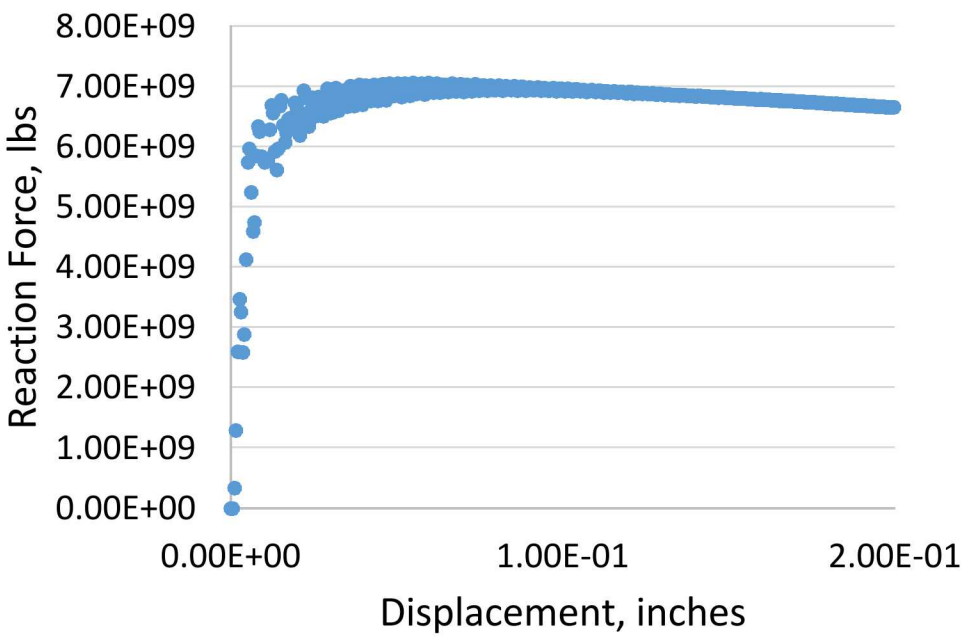
Original Mesh

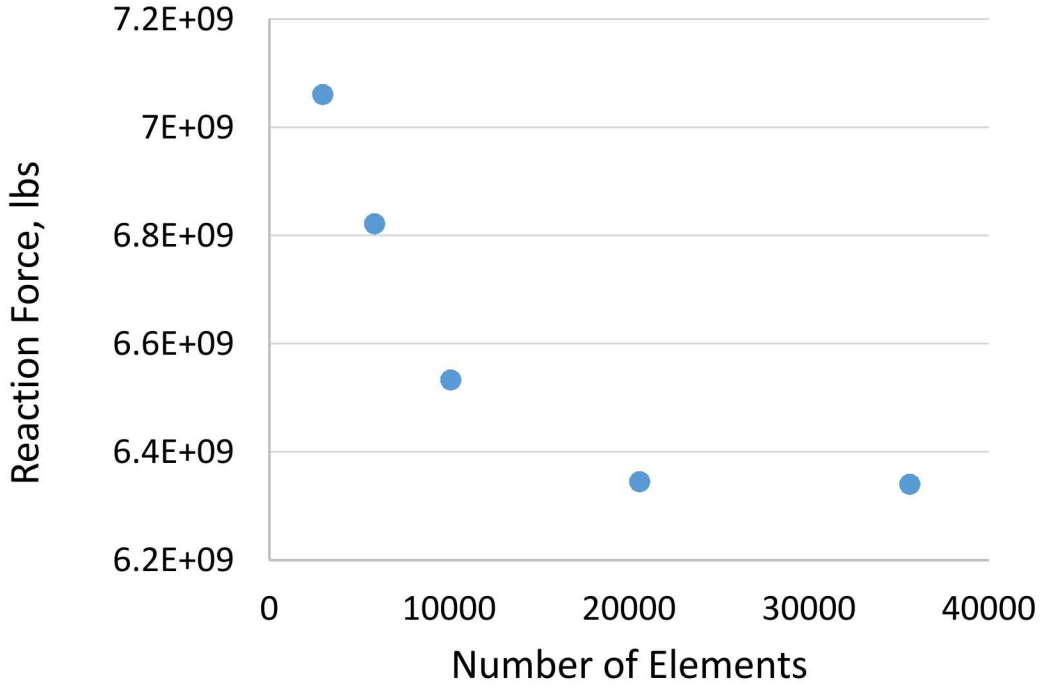


Improved Mesh

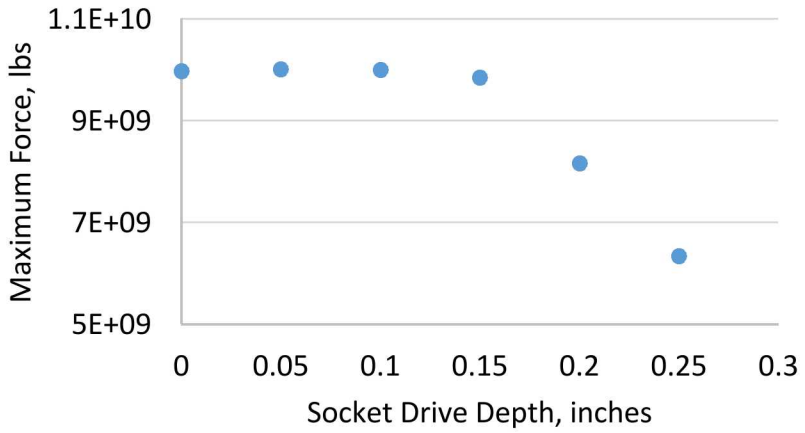
Mesh Refinement

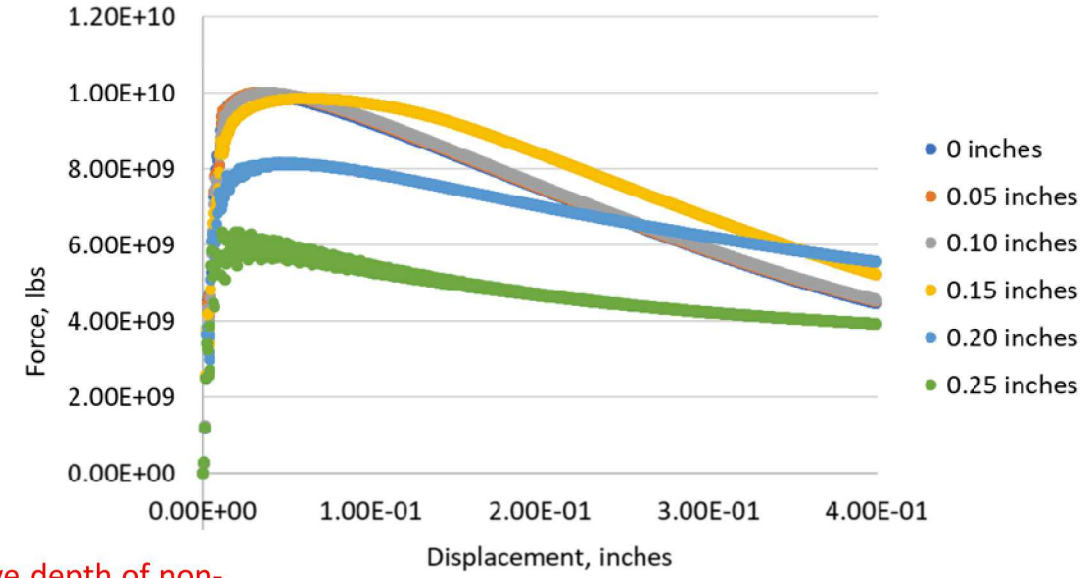
- Model converges with average element size of 0.05 cm



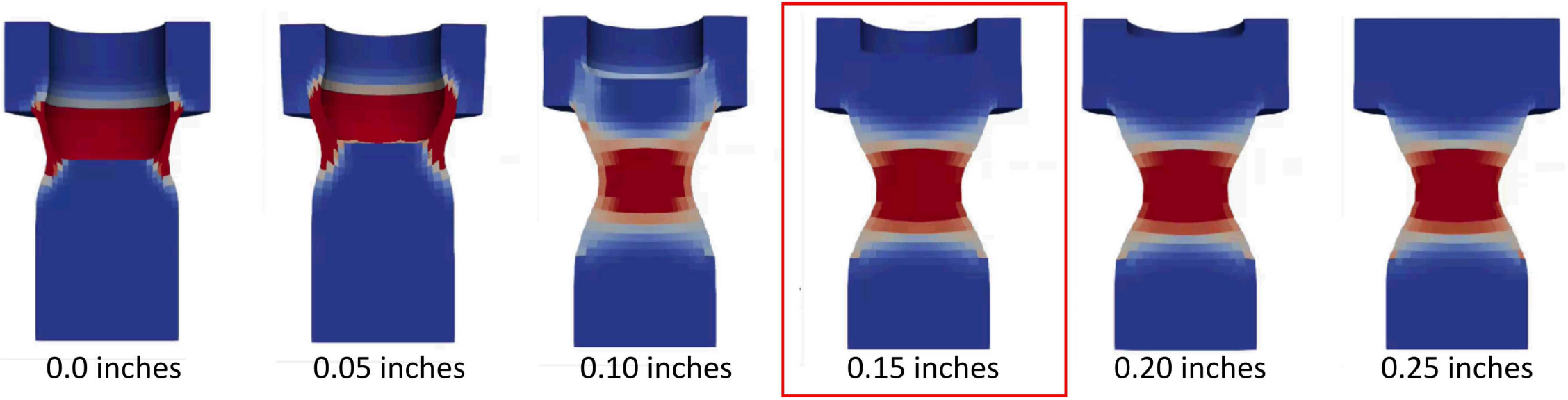


Effect of Socket Head Drive Depth



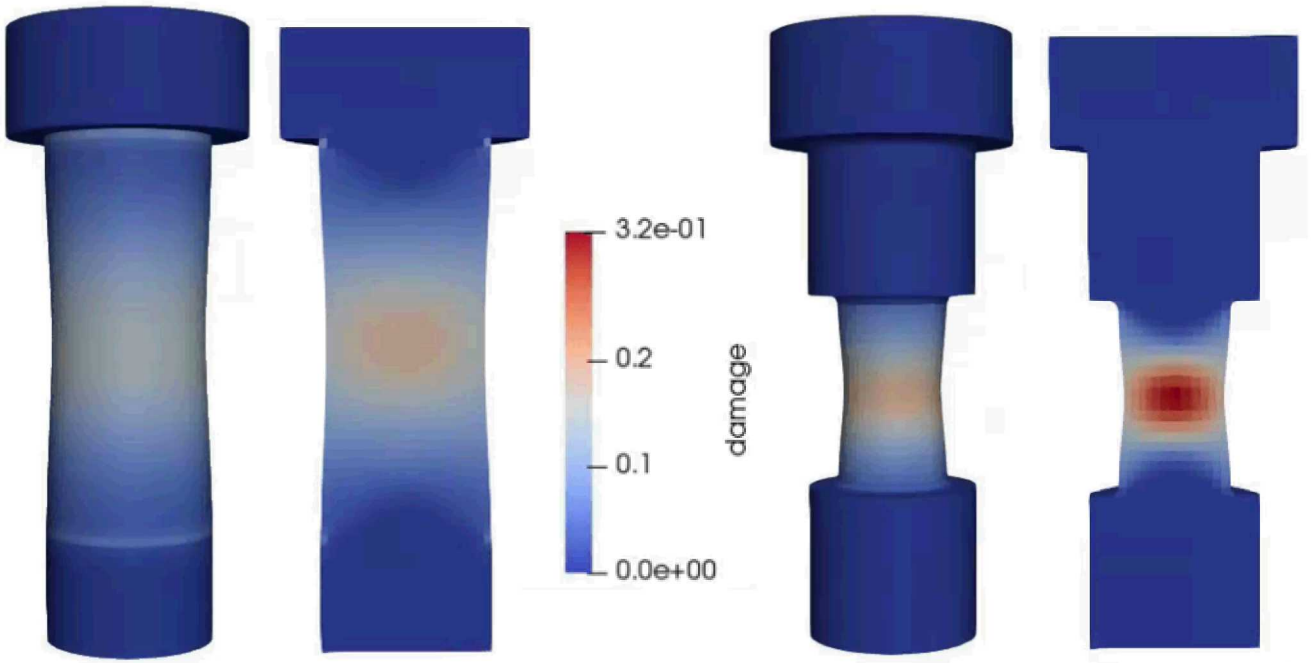


Standard drive depth of non-defective socket bolts



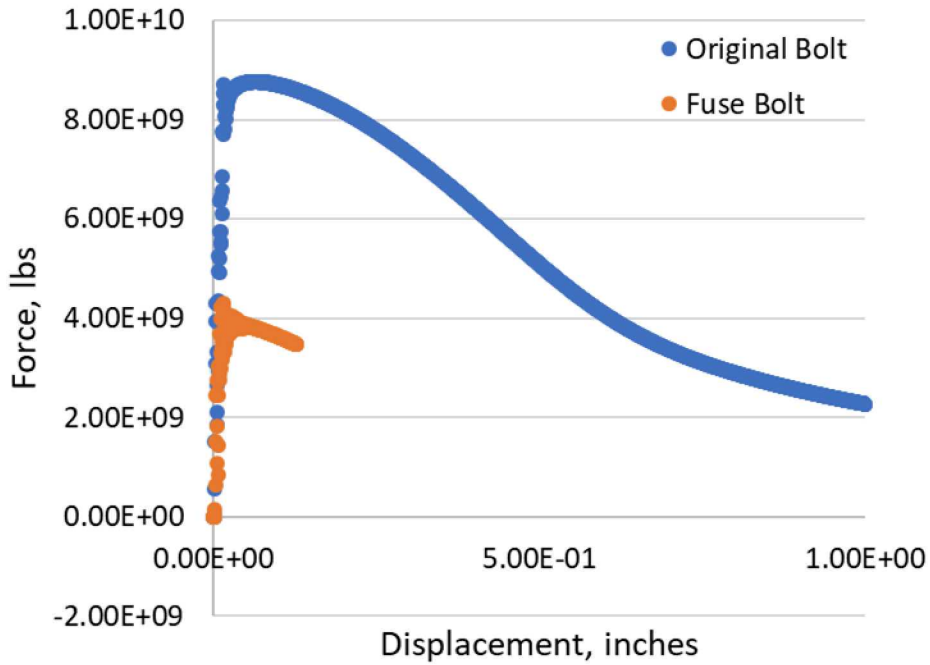
0.0 inches | 0.05 inches | 0.10 inches | 0.15 inches | 0.20 inches | 0.25 inches

Behavior of Fuse Bolt



Original Bolt

Fuse Bolt



Conclusions

- The cause of failure in the dynamic experiment is a result of the manufacturing defect
- Socket head drive depth must be at least 0.15 inches to ensure that failure occurs in the bolt shank
- Non-defective fuse bolts are suitable for continued use in dynamic experiments