Ballistic Performance of Steels and Aluminums in FE Firing Simulations

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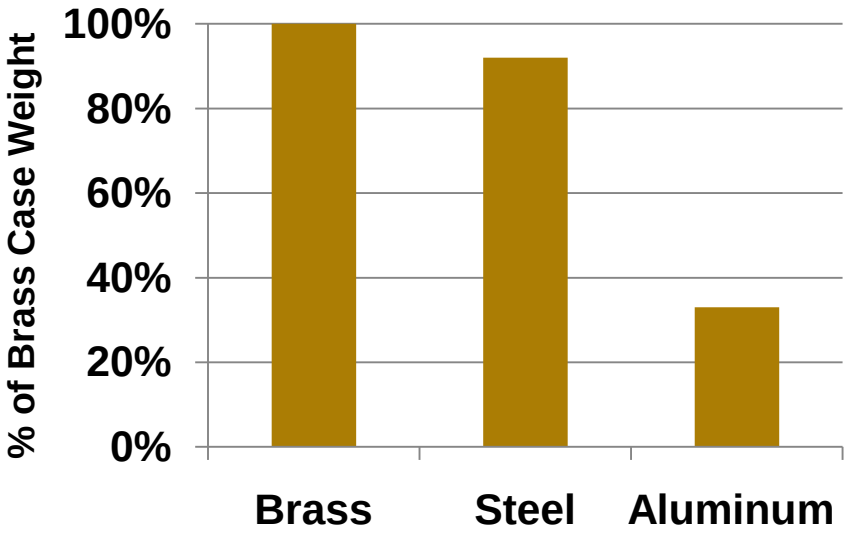
Alternative materials reduce case weight

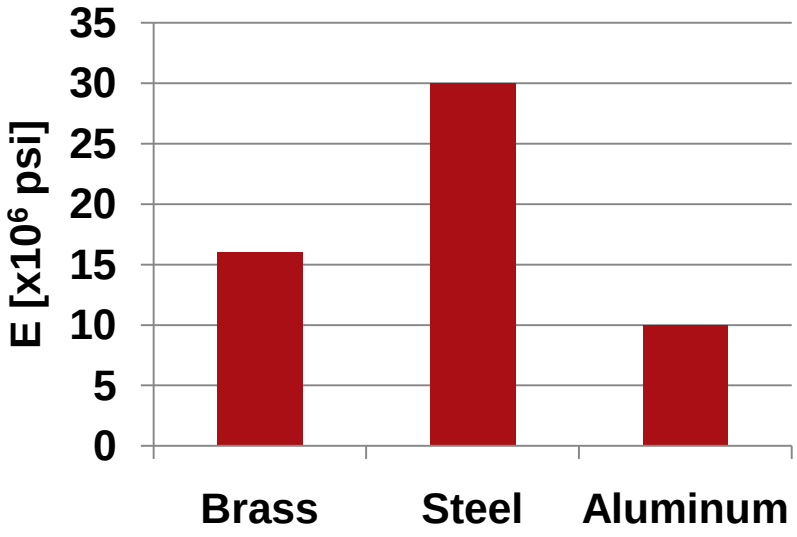
Why steel and aluminum alloys as alternative cartridge case materials?

- Reduced case weight
  - 8% density reduction for steel
  - 67% density reduction for aluminum
- Material cost



General mechanical property differences

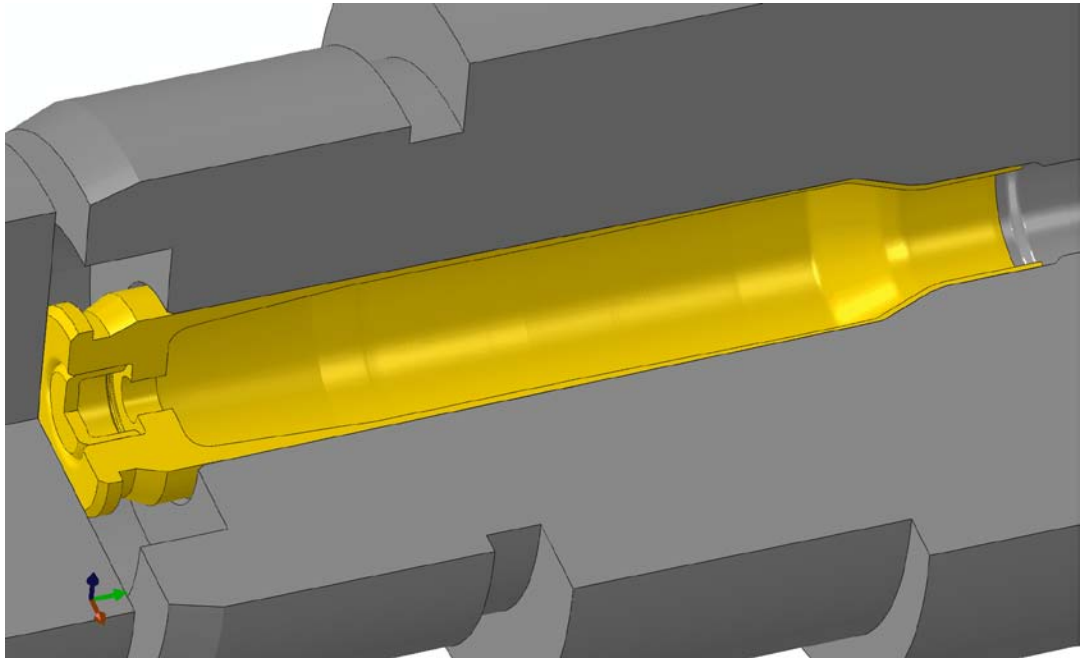
- Stiffness
- Strength



Finite element modeling

Firing simulation

- Axi-symmetric, transient dynamic simulation of firing (case pressurization) event
- Solver – Abaqus/Explicit (v6.9-EF1)
- Nominal chamber, case and bolt face geometry represented in all models
- Primer cup geometry is included in Aluminum 5.56 mm case models



Brass case (baseline) model setup

Geometry

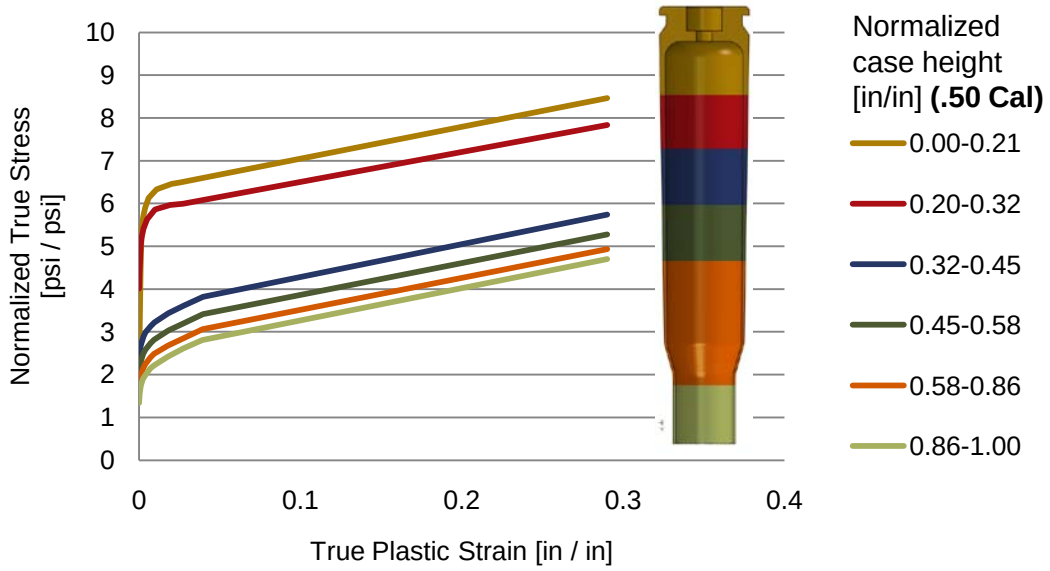
- Nominal case geometry for .50 Cal. and 5.56 mm brass cartridge cases

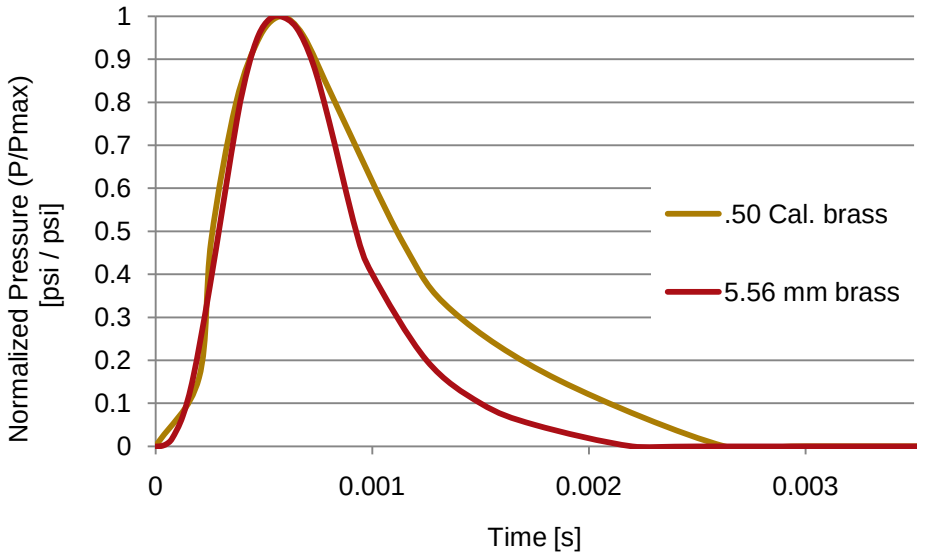
Material model

- Based on an extensive material evaluation of Lake City 5.56 mm cartridge cases (Tew, 2003)

Loading

- No explicit modeling of energetic material − uniform pressure history is applied
- .50 Cal. – calculated
- 5.56 mm – measured mid-case pressure





Steel .50 Cal. case model setup

Geometry

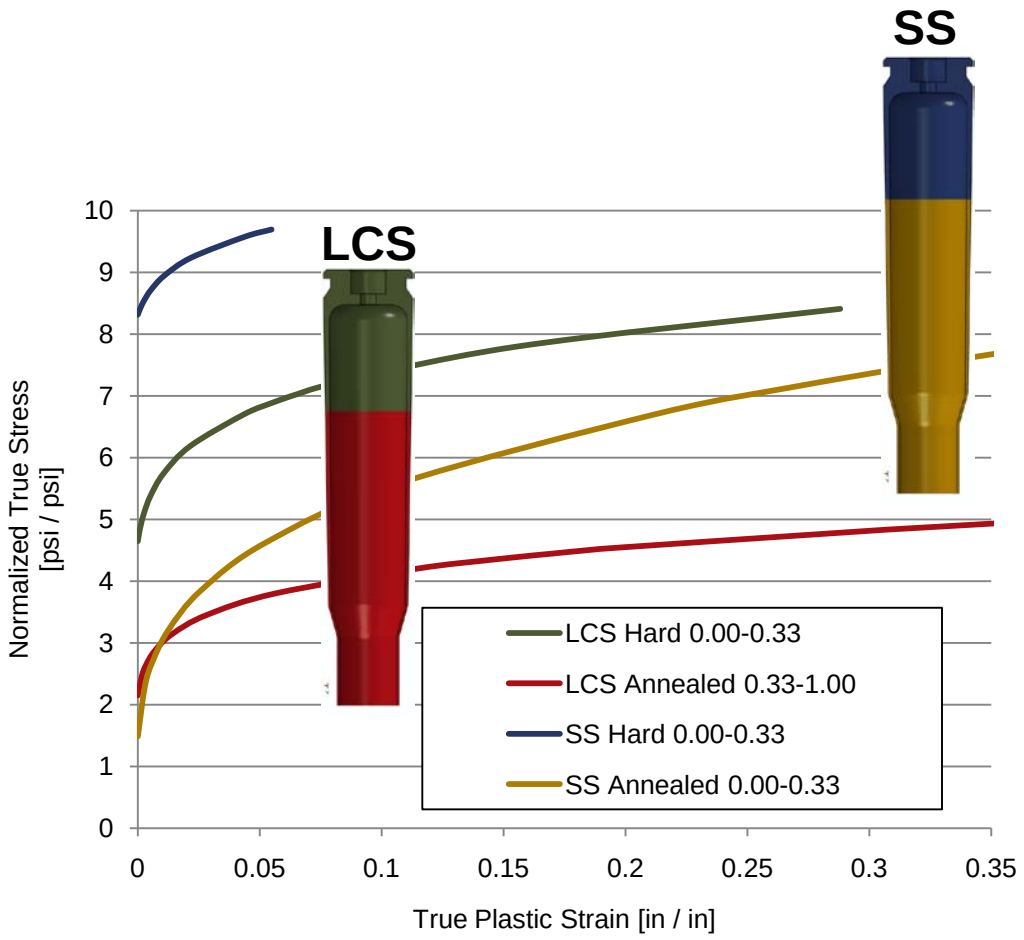
- .50 Cal. steel case geometry is unaltered from brass case

Material model

- Two candidate steels:
  - **LCS** – a low-carbon steel
  - **SS** – a stainless steel
- Case is divided into two sections, representative of the division in brass flow stress curves

Loading – peak pressure

- 65 ksi
- 85 ksi



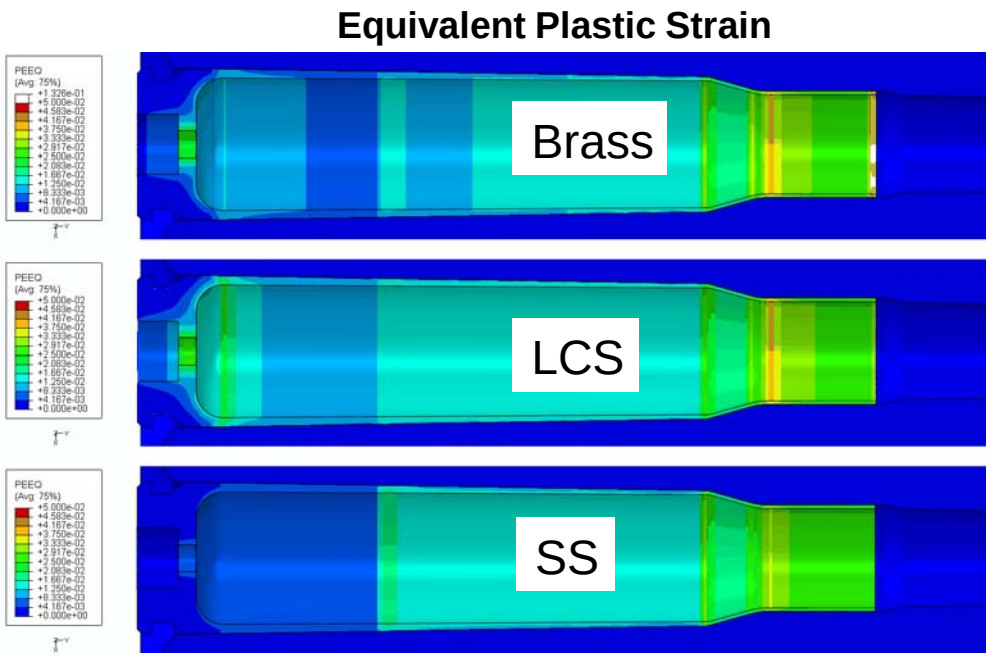
Acceptable deformation with increased residual force

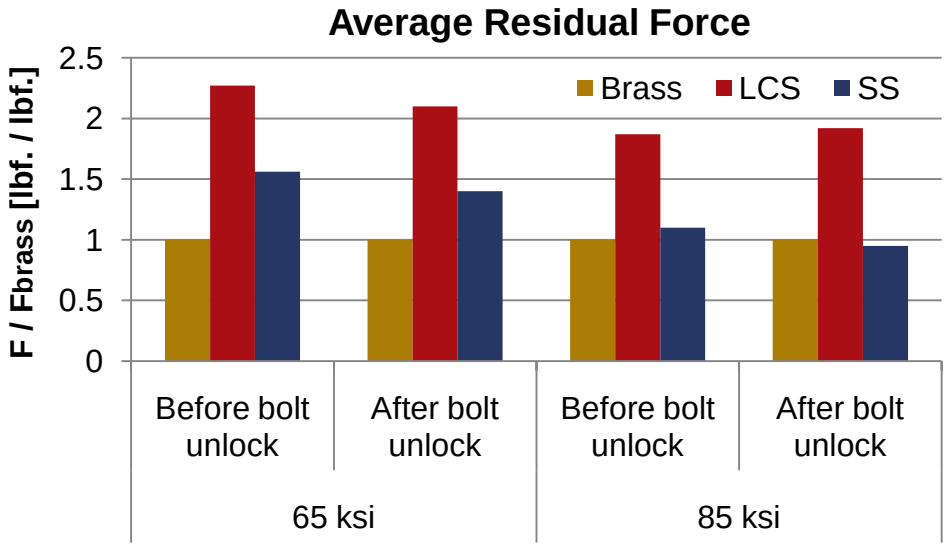
Plastic strain

- Overall deformation similar for brass and LCS cases
- SS shows clear advantage for resisting deformation in case head

Average residual force

- Low-carbon steel
  - 2x brass force at 65 and 85 ksi
- Stainless steel
  - 1.5x brass force at 65 ksi
  - Similar to brass force at 85 ksi

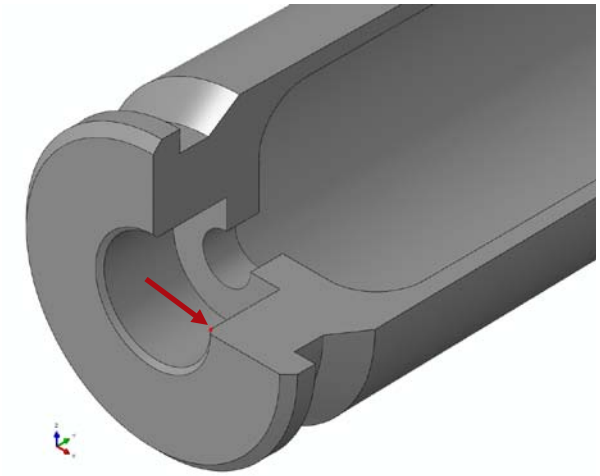


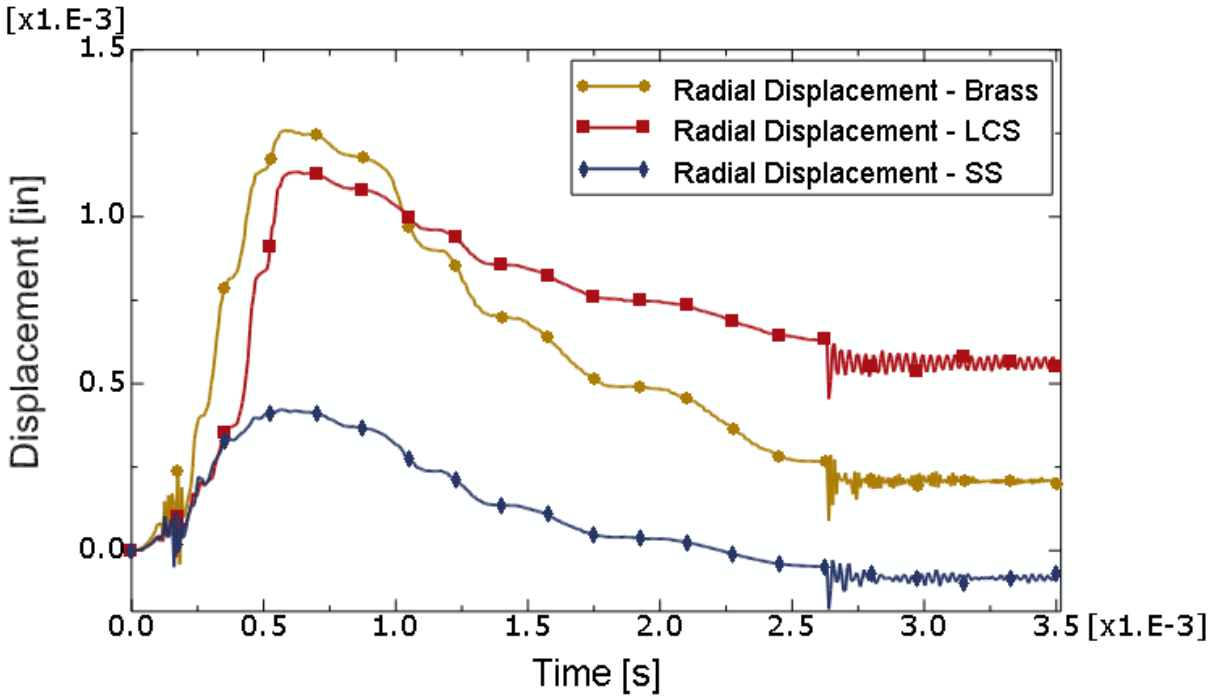


Less pocket deformation with reduced spring-back

Radial displacement of primer pocket (65 ksi)

- Peak – LCS similar to brass – SS much less than brass
- Residual - LCS 2x brass deformation – SS much less than brass





Steel can replace brass, reduce weight and cost

Residual force

- LCS – 2x residual force of brass case at 65 and 85 ksi
- SS – 1.5x residual force of brass case at 65 ksi

Deformation

- LCS – similar to brass case performance
- SS – clear advantage over brass and LCS cases in unsupported (case head) region

Geometry

- LCS – Not likely that further weight reduction is attainable in current material state
- SS – Likely candidate for further weight reduction

Material cost

- Low-carbon steel < Stainless steel < Cartridge brass
- LCS requires coating for corrosion resistance
- Coating may also benefit extraction for LCS and SS

Aluminum 5.56 mm case model setup

Geometry

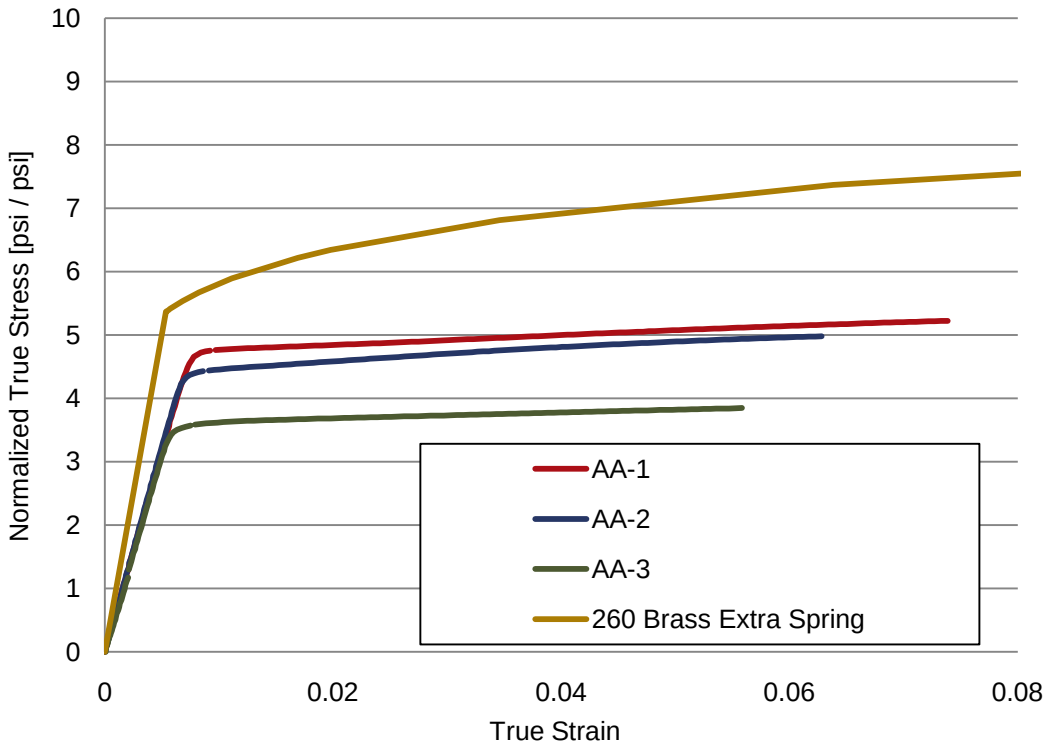
- 5.56 mm aluminum case geometry is altered from brass case to accommodate lower strength materials

Material model

- Three candidate aluminum alloys: **AA-1, AA-2, AA-3**
- Entire case is in hardened condition necessary for adequate performance

Loading – peak pressure

- 65 ksi

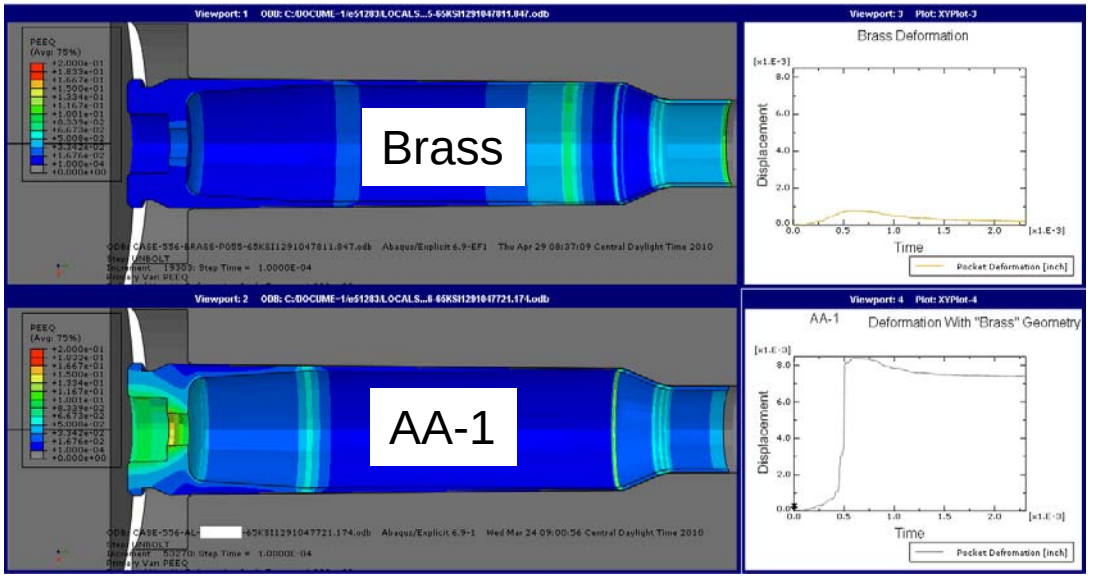


Aluminum 5.56 mm case design

Deformation with brass geometry

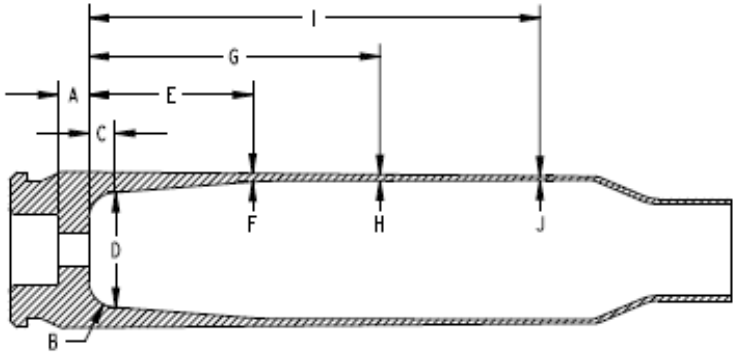
- Aluminum case (AA-1) radial primer pocket deformation is approximately 8 times that of brass case

Equivalent Plastic Strain



Modified geometry

- Dimensions changed that do not affect case/bullet or case/weapon interface

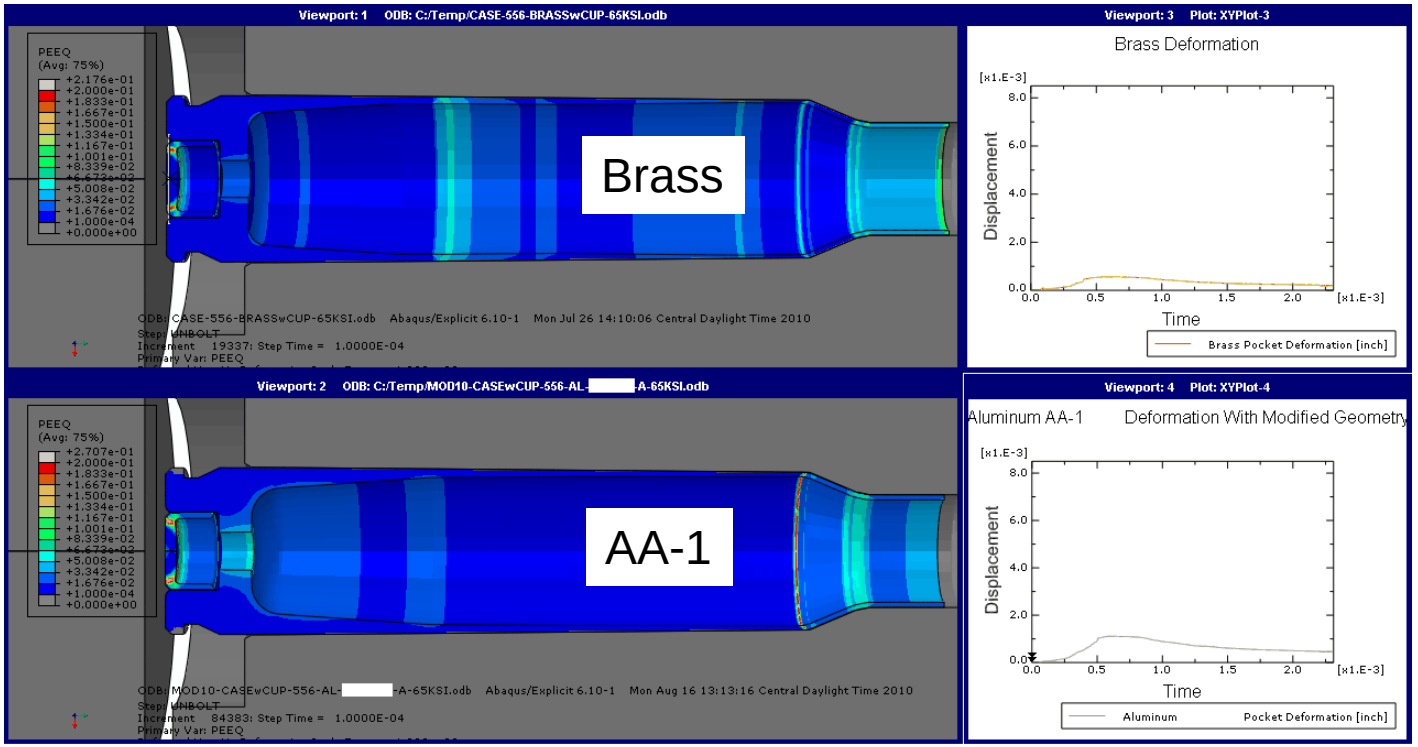


Plastic strain compares favorably with brass

Deformation with modified geometry

- Overall deformation
- Radial primer pocket deformation

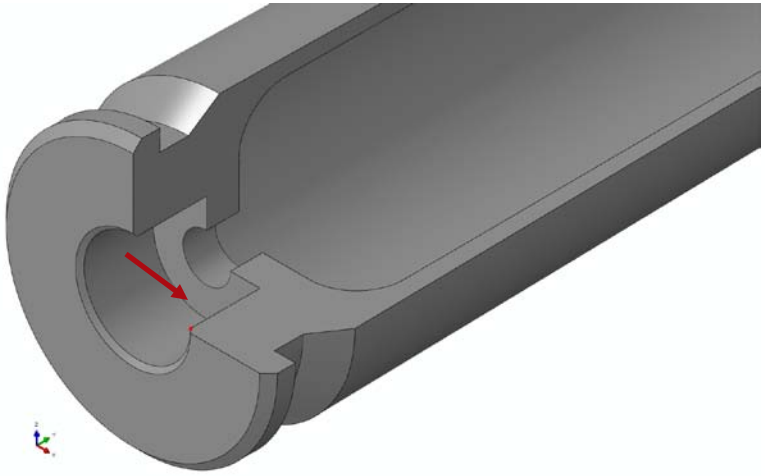
Equivalent Plastic Strain

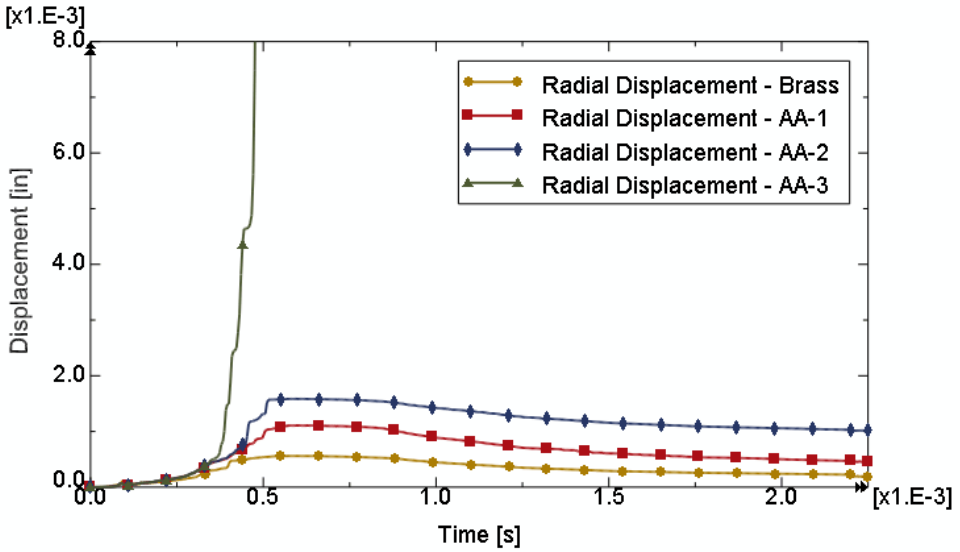


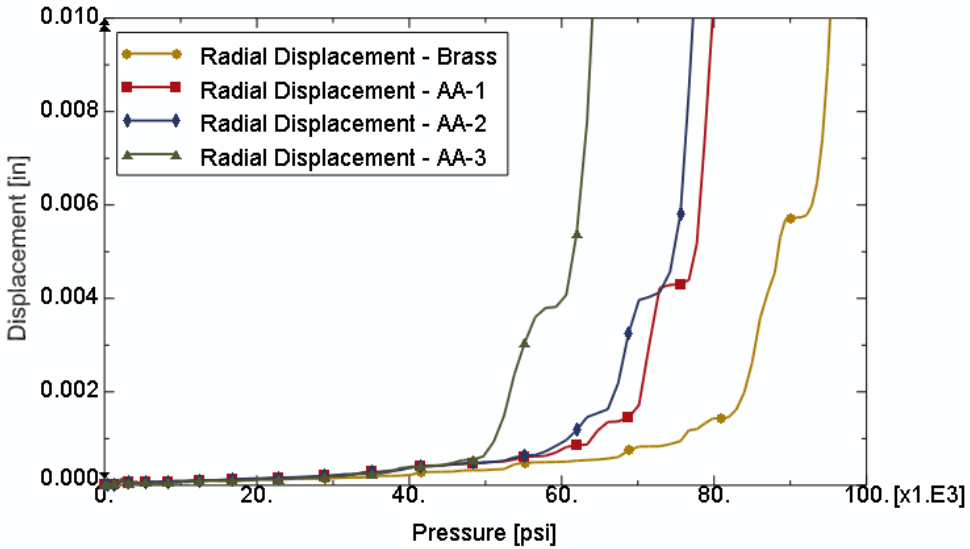
Primer pocket deformation compares favorably with brass

Radial deformation of primer pocket

- AA-1 and AA-2 compare favorably with the brass case
- AA-3 is unstable prior to reaching design pressure
- All alloys' performance is limited to design pressures less than brass case



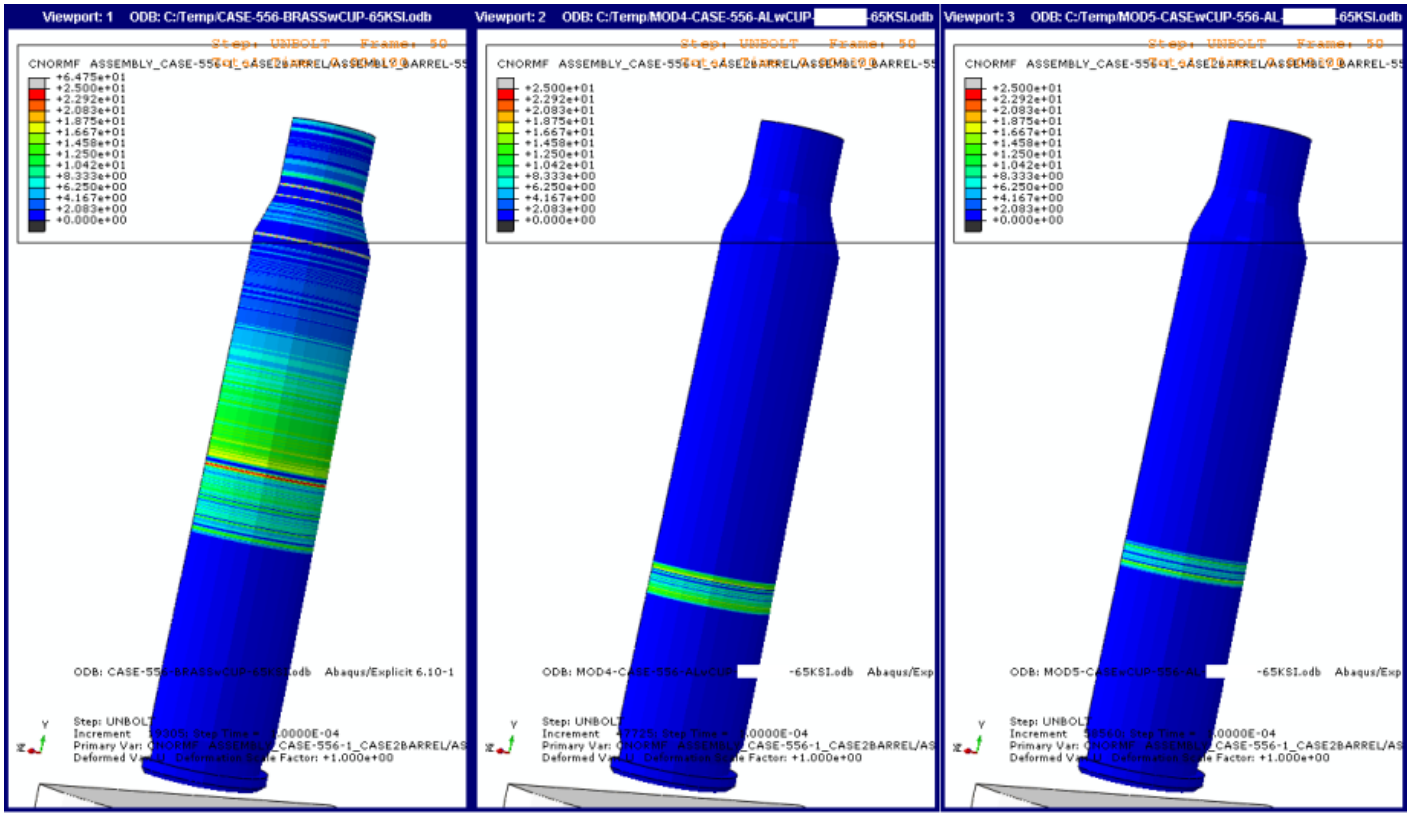




Aluminum alloys better for extraction

Residual force

- Reduced residual contact force between case and chamber
- Potential benefit for weapon extraction



Brass AA-1 (mod4) AA-1 (mod5)

Aluminum 5.56 mm Results

Case design

- AA-1 – 8x deformation of brass case with same geometry
- Dimensional changes made to increase AA case performance
  - No effect on case/bullet or case/weapon interface
  - Tradeoff with internal case volume

Performance

- AA-1 – Best candidate
- AA-2 – Has potential to work well
- AA-3 – Not likely to work for the estimated material state

References

- *Abaqus v6.9-EF1*. Simulia – Dassault Systemes.
- Tew, B. W. 2003. "Material and Structural Evaluation of Lake City 5.56 Cartridge Case," ATK Lake City Small Caliber Ammunition.