Pressure heterogeneity in small displacement electrohydraulic forming processes

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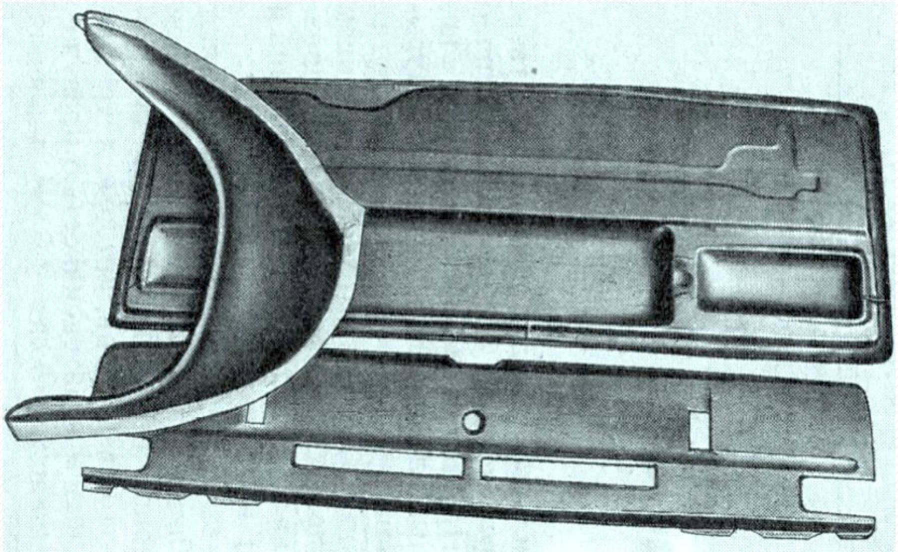
- *Electrohydraulic (submerged arc discharge) forming of sheet metal parts has been used as a specialized high speed forming method since the 1960's.*

- *Parts formed generally had a major dimension in the 5 to 25 cm range and required gross metal expansion in the centimeter range.*

- *In the literature, the pressure front emanating from the initial plasma bubble generated by the arc is assumed to be uniformly spherical*

Electrohydraulic forming ;

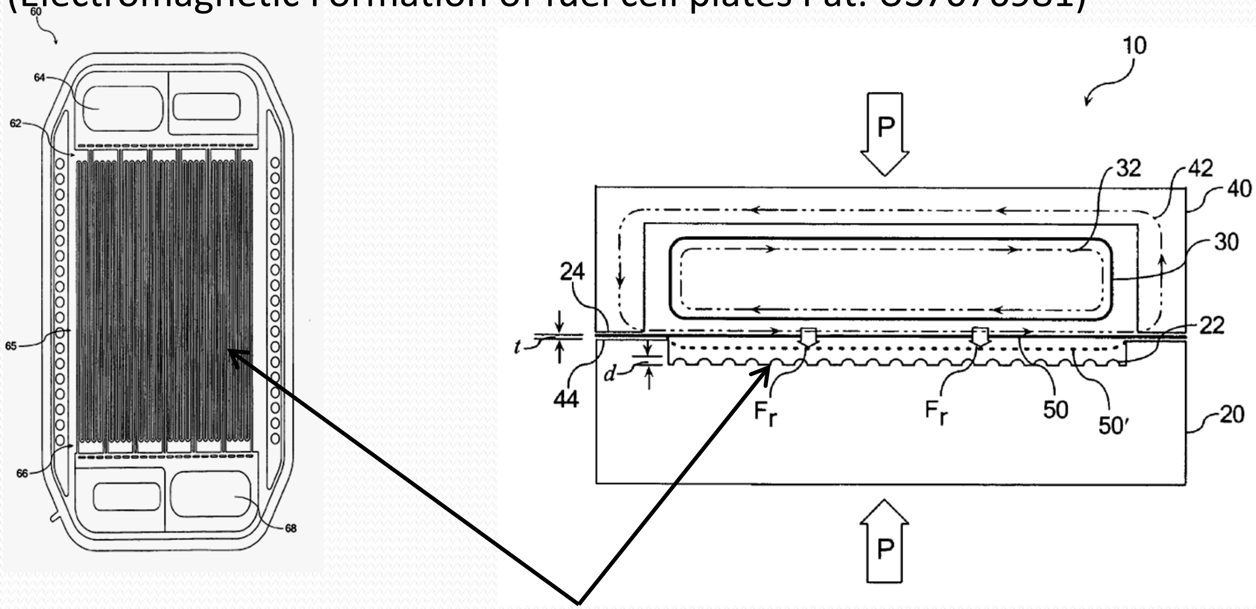
- historically applied to parts requiring significant plastic deformation
- evidence of initial pressure heterogeneity washed out by plastic strains ?



Examples of panels for Russian Lada automobiles formed using multiple discharge electrohydraulic forming performed at Kharkiv Aviation Institute, Ukraine
ASM Handbook, Volume 14B, 2006, ASM International,pp. 405-418.

Example small part with low gross deformation and fine features; Fuel Cell plates
Application for uniform pressure electromagnetics <u>if</u> material has adequate conductivity

(Electromagnetic Formation of fuel cell plates Pat. US7076981)



Fuel cell plate flow passages ~ 1-3 mm depth (3x metal thickness)

Electrohydraulic process not dependent on workpiece conductivity

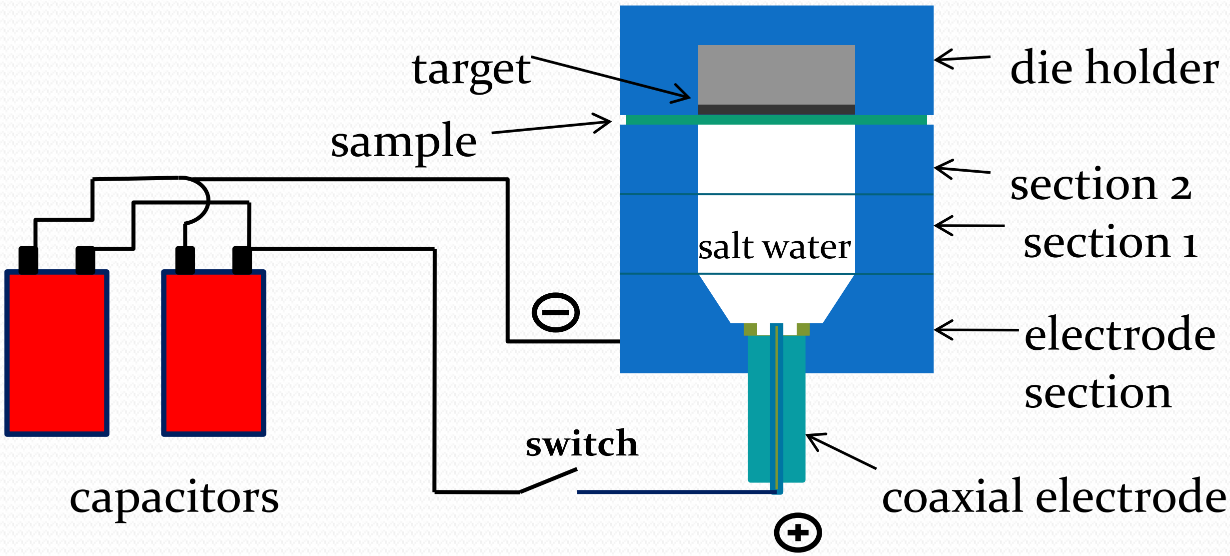
Recent application of electrohydraulic forming of a medical component from titanium sheet

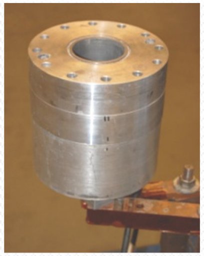
- Part characteristics very similar to fuel cell plates
- Exhibited unacceptable geometry and surface detail variations due to obvious pressure heterogeneity

No explicit explanation found in available literature

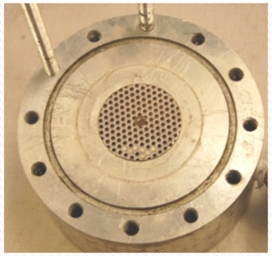
Small scale investigation aimed at replicating and illuminating phenomena conducted August 2009 at OSU

Electrohydraulic pressure heterogeneity test system





Chamber



target section

coaxial electrode

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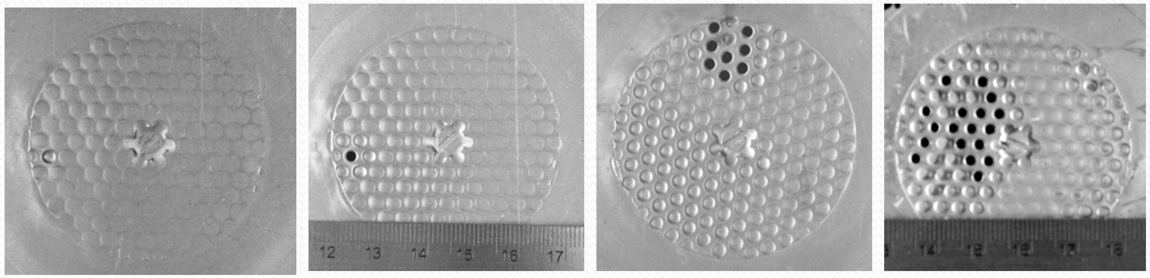
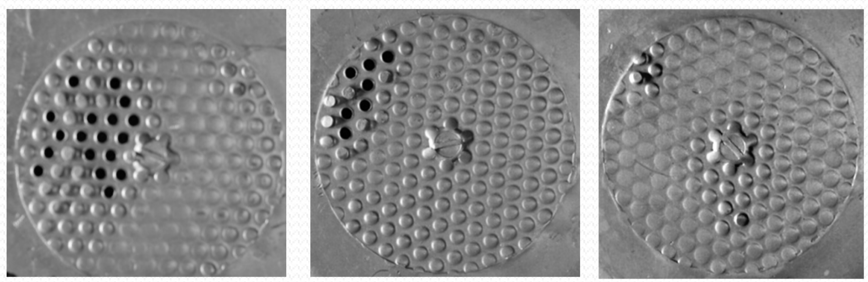


(a) (b) (c) (d)

Effect at different energy levels

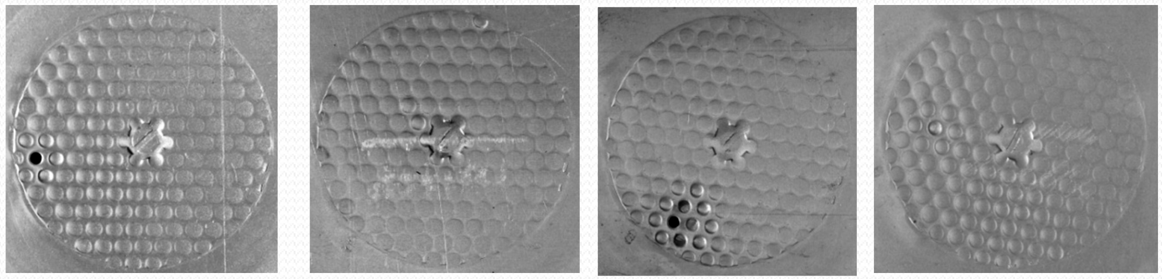
a)1.5 KJ(@120 μF), b) 3 KJ(@120 μF), c) 4.5 KJ(@120 μF), d) 6 KJ(@240 μF)



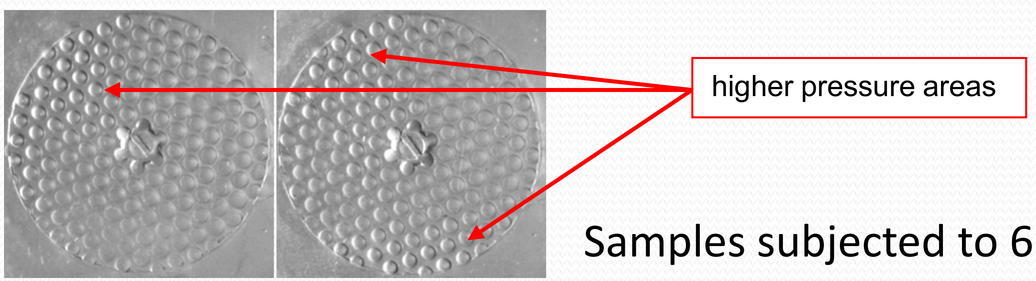
(a) (b) (c)

Effect of chamber geometry change at constant 6KJ (@240 μF) discharge;

a) one spacer, b) two spacers, c) two spacers and electrode section cone insert.



Four experiments using 3 KJ (@120 µF) discharge energy in the two section chamber



Samples subjected to 6 KJ(@240 µF) discharge
with an intervening 25 mm thick natural rubber pad.

Numeric model of the experimental system

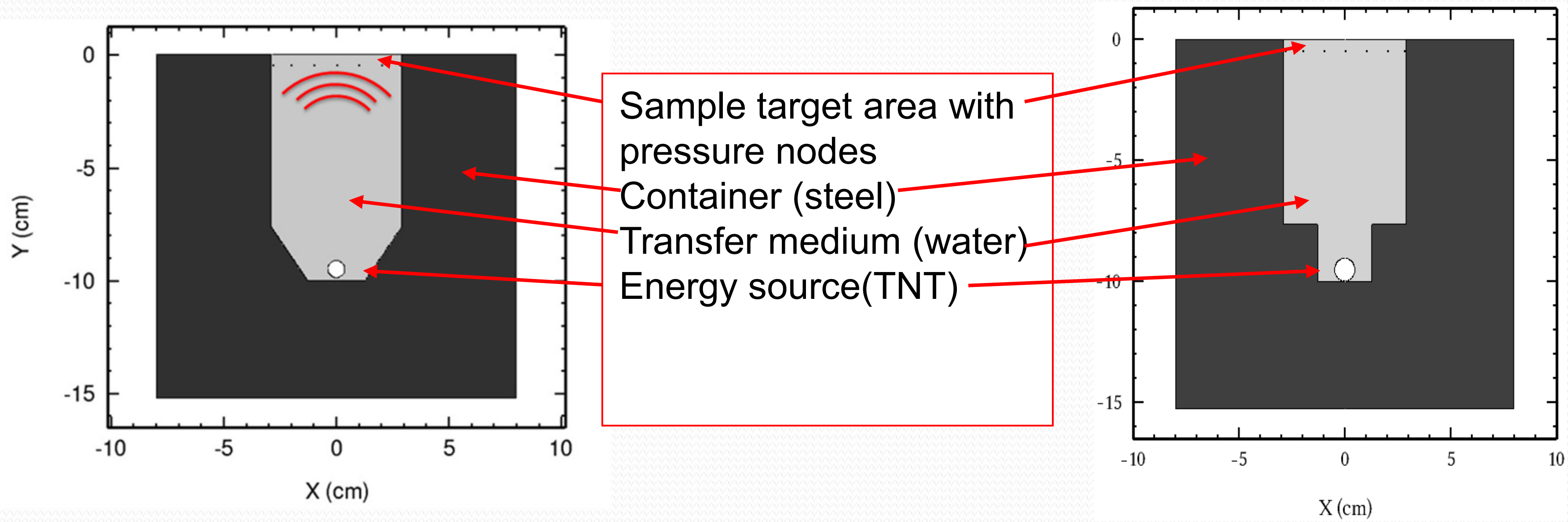
The model employed CTH, a multi-material, large deformation, strong shock wave, solid mechanics code developed at Sandia National Laboratories.

•CTH has models for multiphase, elastic-viscoplastic, porous, and explosive materials.

•CTH numerically solves the partial differential equations describing the conservation of mass, momentum, and energy. It does this in a structured Eulerian mesh fixed in space and uses equations of state (EOS) to close the coupled system of equations.

•CTH is capable of predicting cavitation in fluids as the result of events such as the submerged arc discharges of the experiments presented

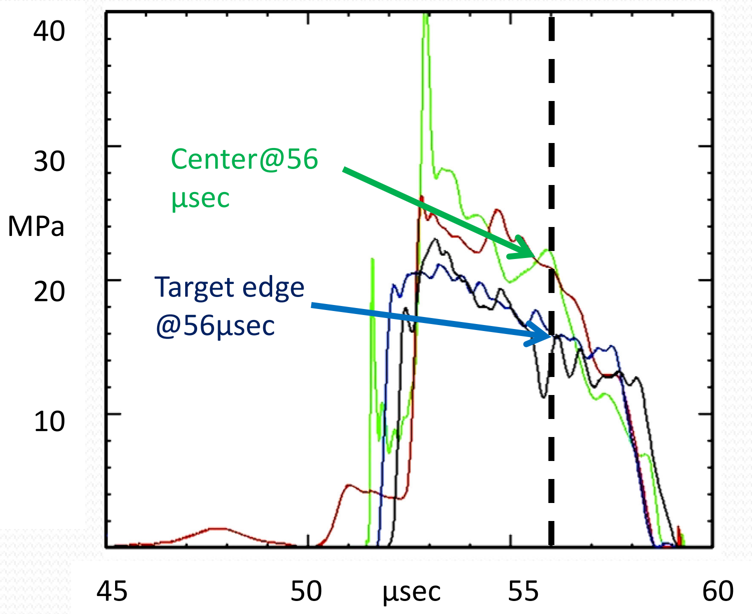
Schematic of the CTH model geometries and component materials

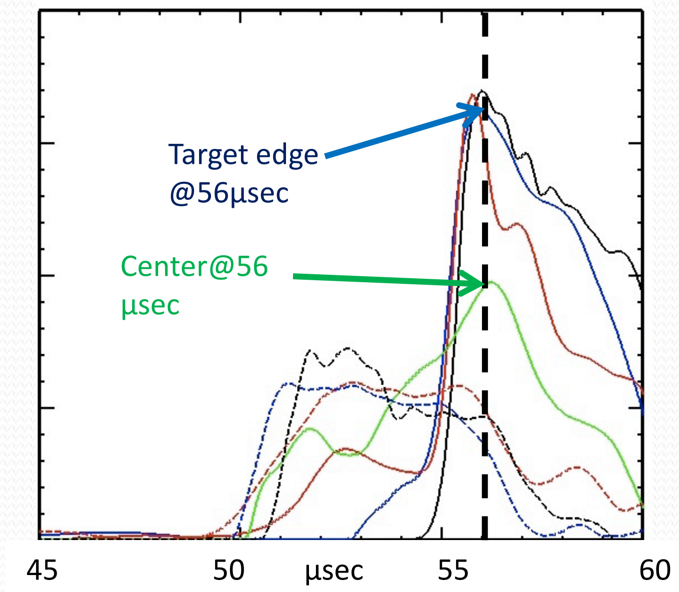


(a) original

(b) with electrode section insert

Pressure-time histories at the model tracer nodes;



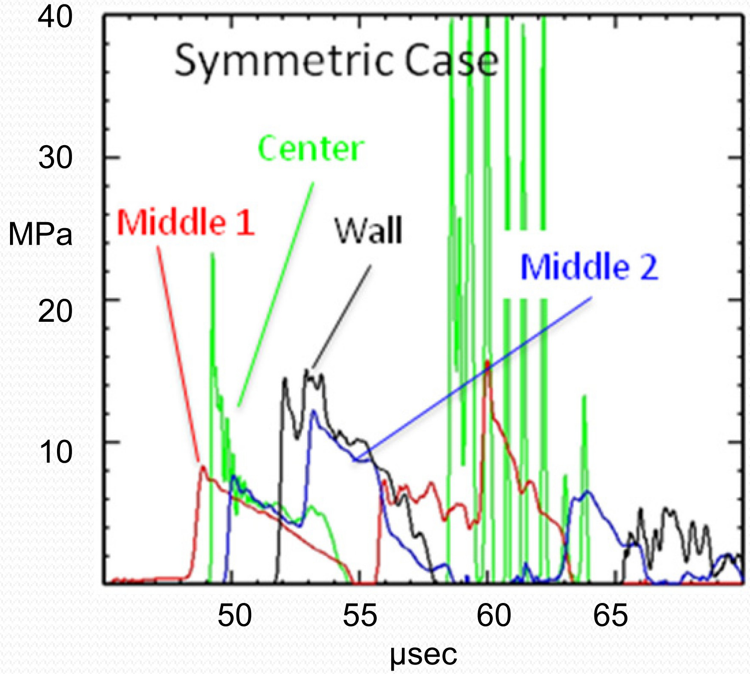


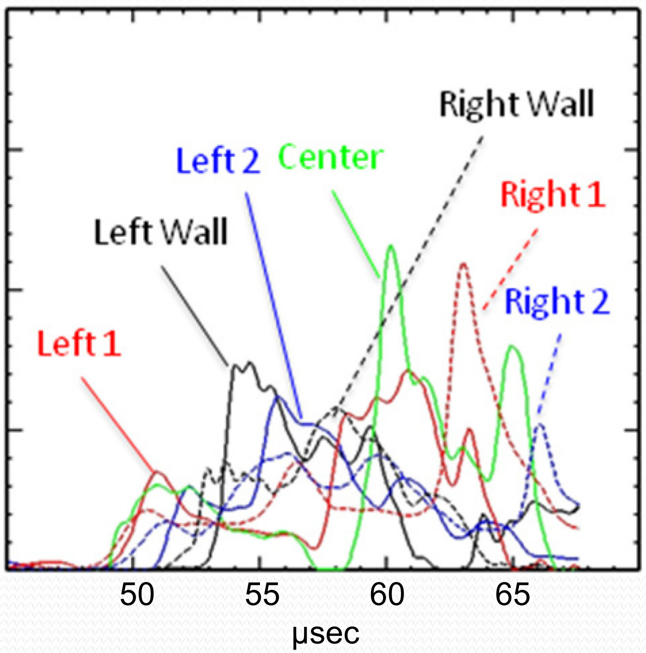
symmetric case,

asymmetric case

Original geometry (a)

Pressure-time histories at the model tracer nodes;



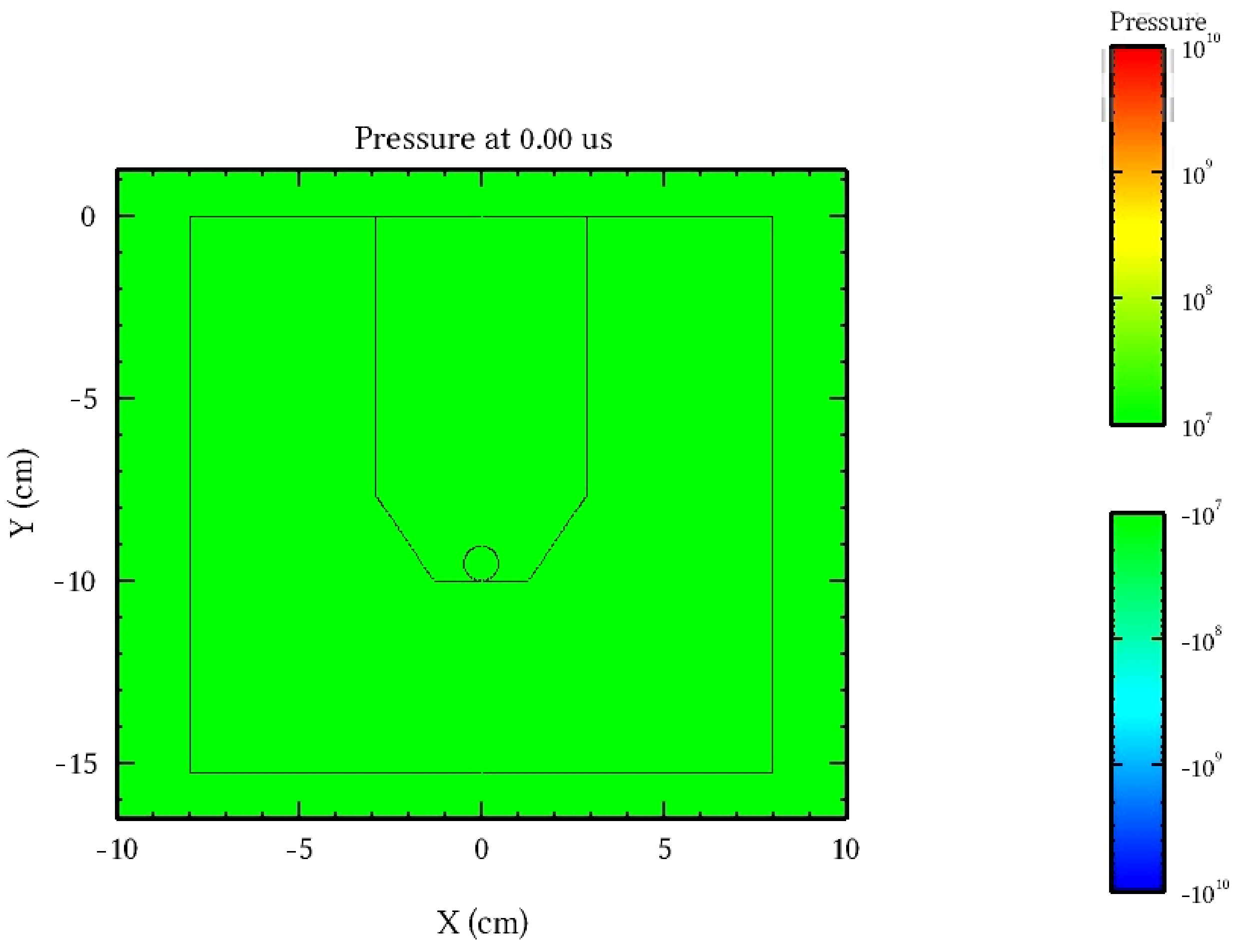


Symmetric discharge

Asymmetric discharge

With electrode section insert; geometry (b)

Simulation symmetric 2D case



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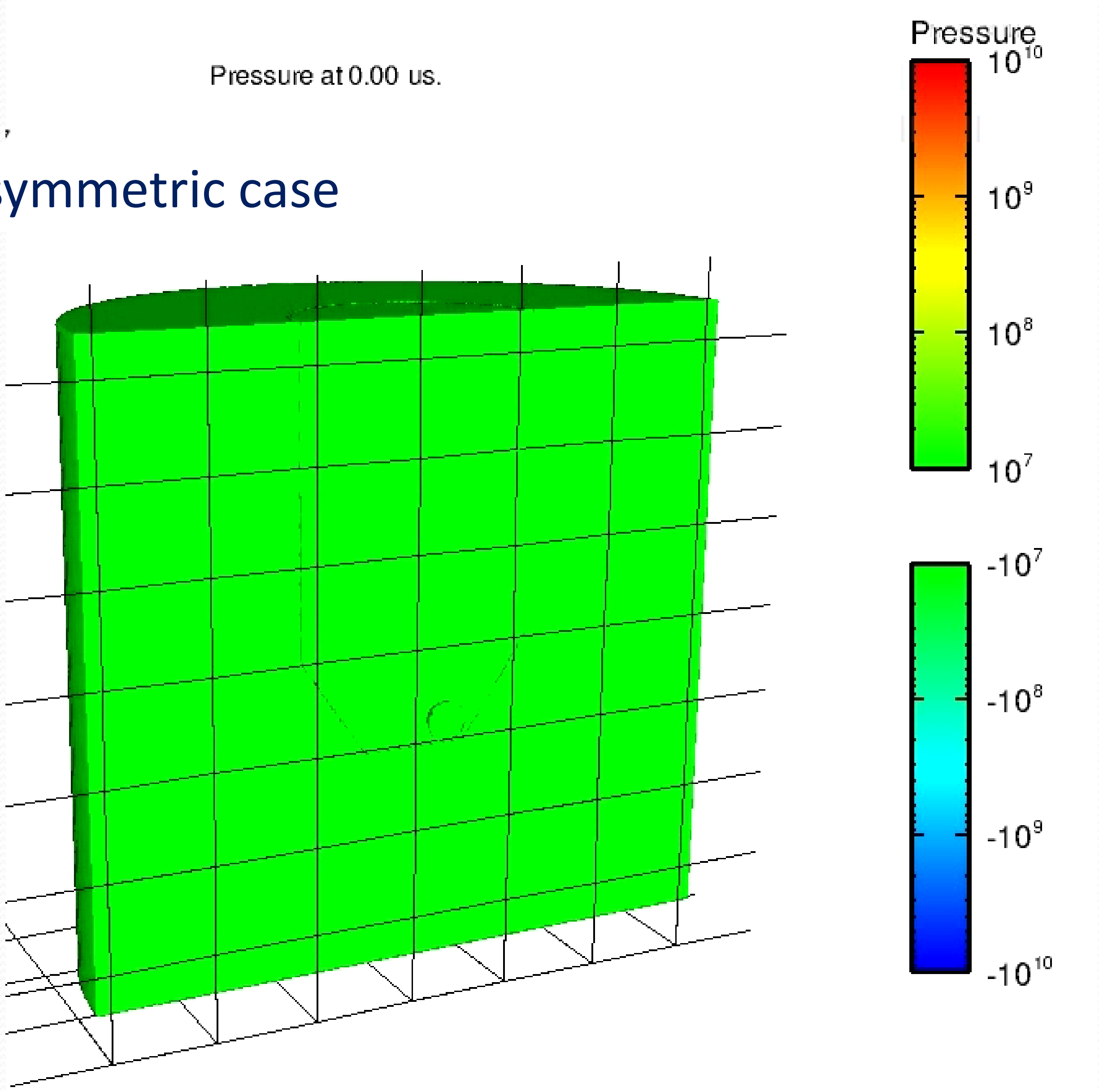
Simulation asymmetric case



Summary and conclusions

•Electrohydraulic forming has the potential advantages of insensitivity to work piece conductivity relative low cost, compactness and shared capital equipment with electromagnetic methods.

•Observed extreme pressure heterogeneity needs to be controlled or eliminated before method can be productively applied to high definition, low gross deformation parts of low electrical conductivity.

•Results reported not explicitly available in the previous literature on high speed, electrohydraulic forming attributed to the fact that large plastic deformation was the goal of the early work.

•Large deformation would tend to obliterate any initial pressure heterogeneity especial after die contact.

Thank You for Your Attention