




# **Pressure heterogeneity in small displacement electrohydraulic forming processes**

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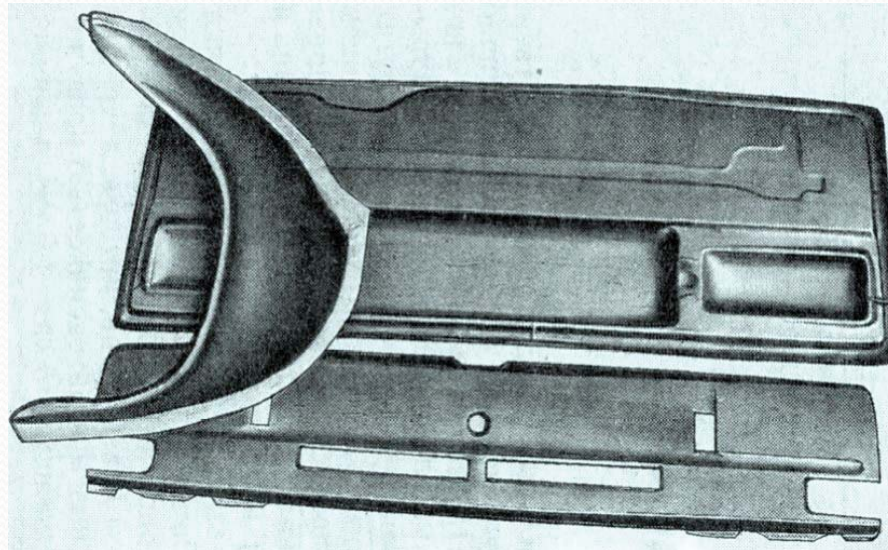
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- *Electrohydraulic (submerged arc discharge) forming of sheet metal parts has been used as a specialized high speed forming method since the 1960's.*
  - *Parts formed generally had a major dimension in the 5 to 25 cm range and required gross metal 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.

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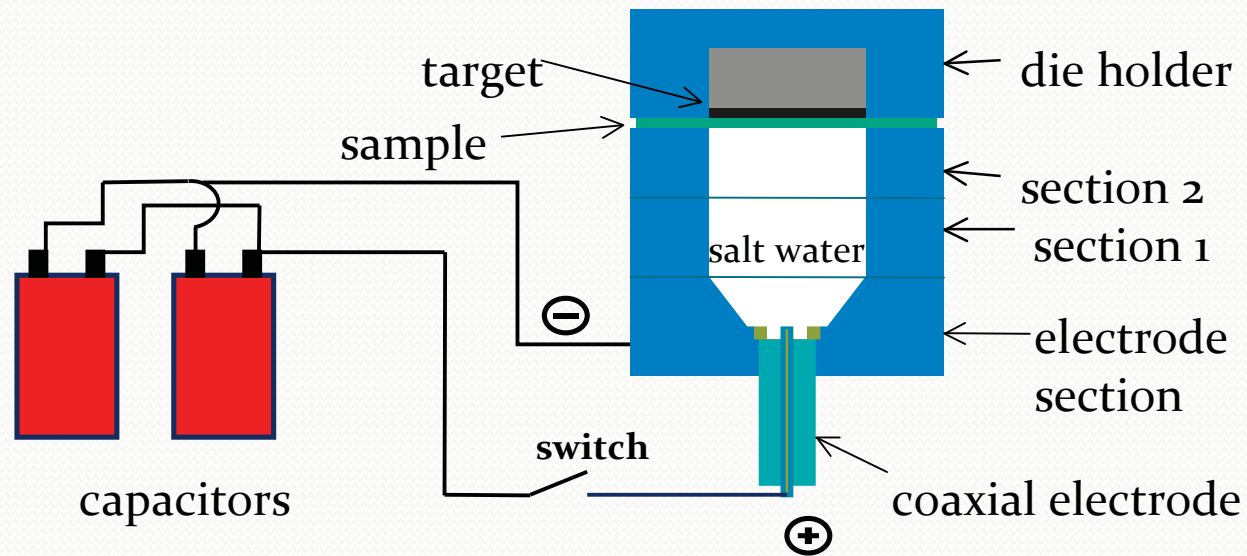
## Recent application of electrohydraulic forming of a medical component from titanium sheet

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

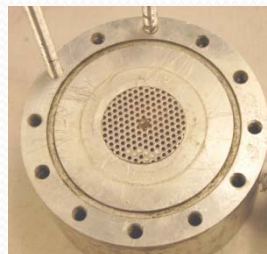
No explicit explanation found in available literature

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

## Electrohydraulic pressure heterogeneity test system



Chamber

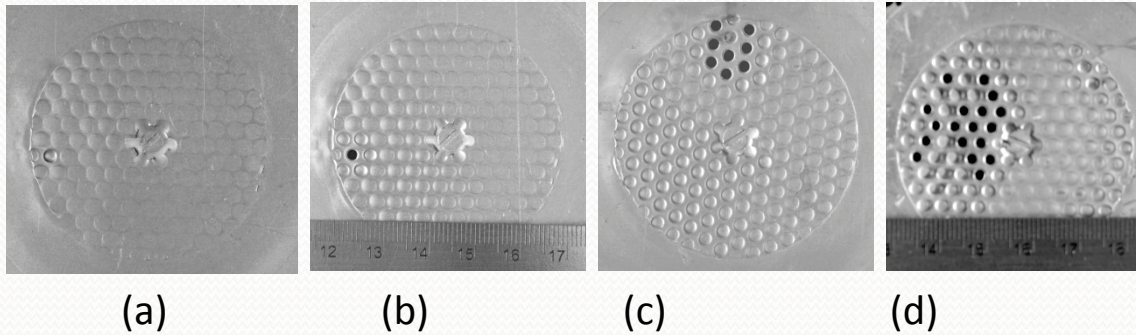


target section



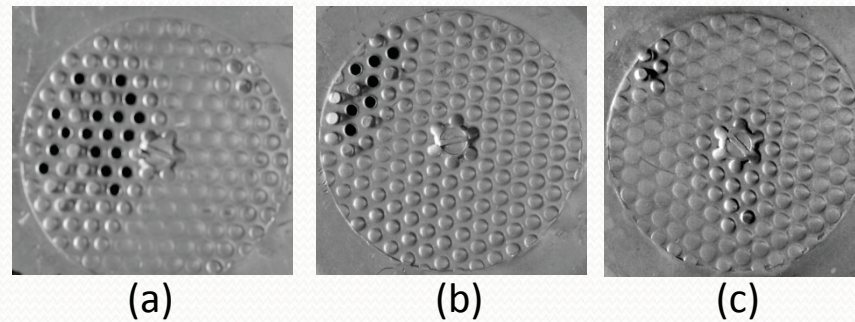
coaxial electrode

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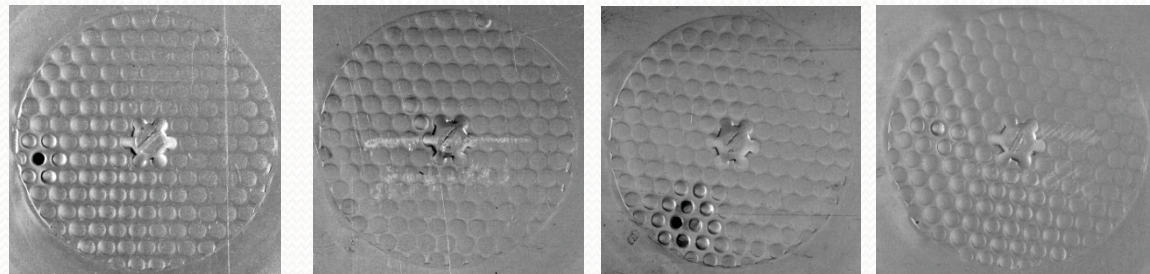
Effect at different energy levels

a) 1.5 KJ(@120  $\mu$ F), b) 3 KJ(@120  $\mu$ F), c) 4.5 KJ(@120  $\mu$ F), d) 6 KJ(@240  $\mu$ F)

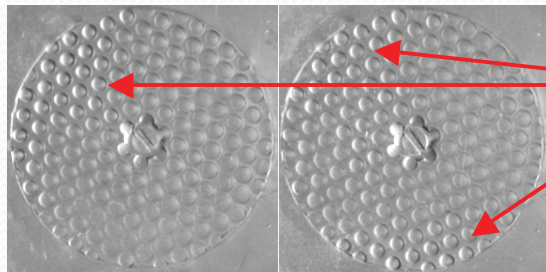


Effect of chamber geometry change at constant 6KJ (@240  $\mu$ F) discharge;  
 a) one spacer, b) two spacers, c) two spacers and electrode section cone insert.

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Four experiments using 3 KJ (@120  $\mu$ F) discharge energy in the two section chamber



higher pressure areas

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

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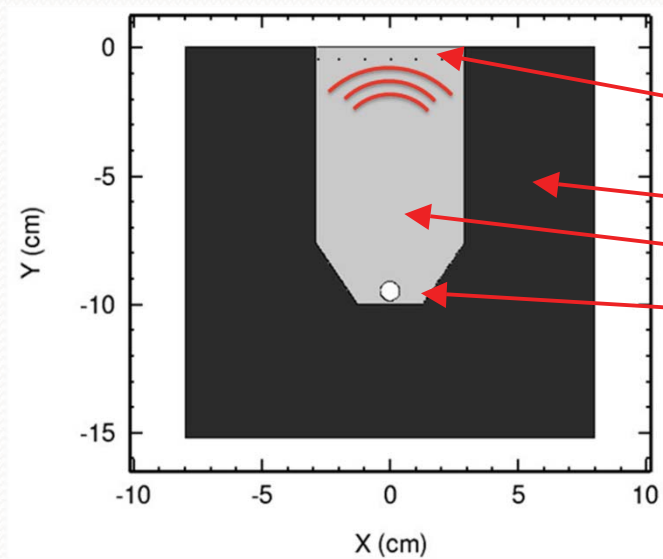


## **Numeric model of the experimental system**

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

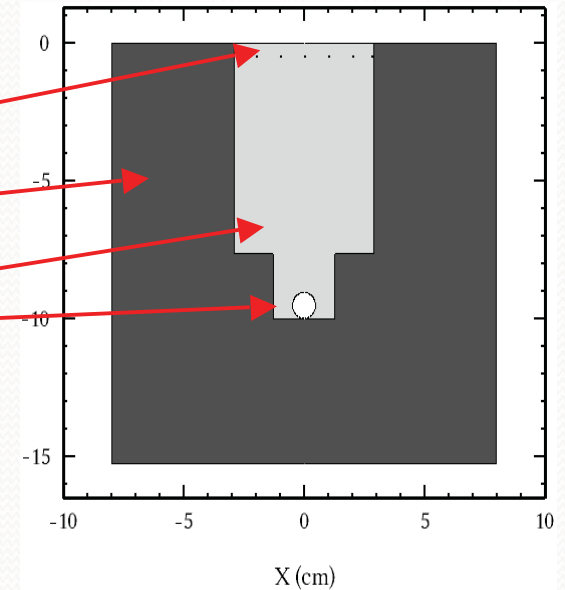
- CTH has models for multiphase, elastic-viscoplastic, porous, and explosive materials.
- CTH numerically solves the partial differential equations describing the conservation of mass, momentum, and energy. It does this in a structured Eulerian mesh fixed in space and uses equations of state (EOS) to 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

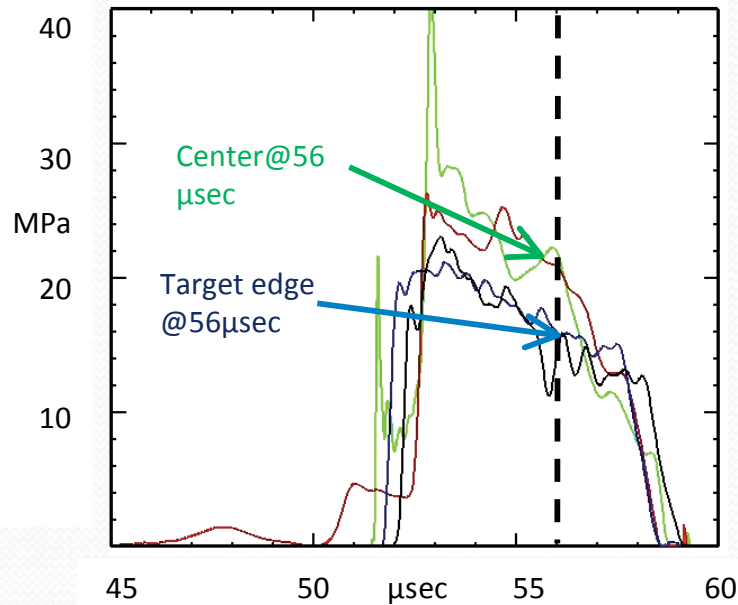
Sample target area with  
pressure nodes  
Container (steel)  
Transfer medium (water)  
Energy source(TNT)



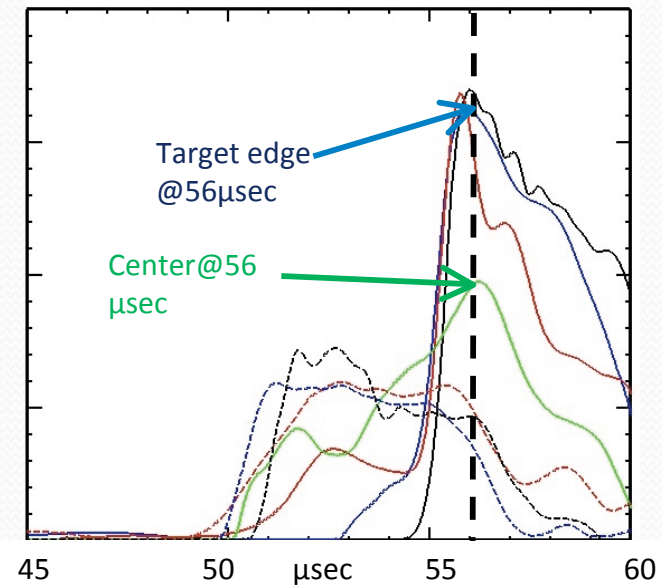
(b)  
with electrode section insert

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## Pressure-time histories at the model tracer nodes;



*symmetric case,*

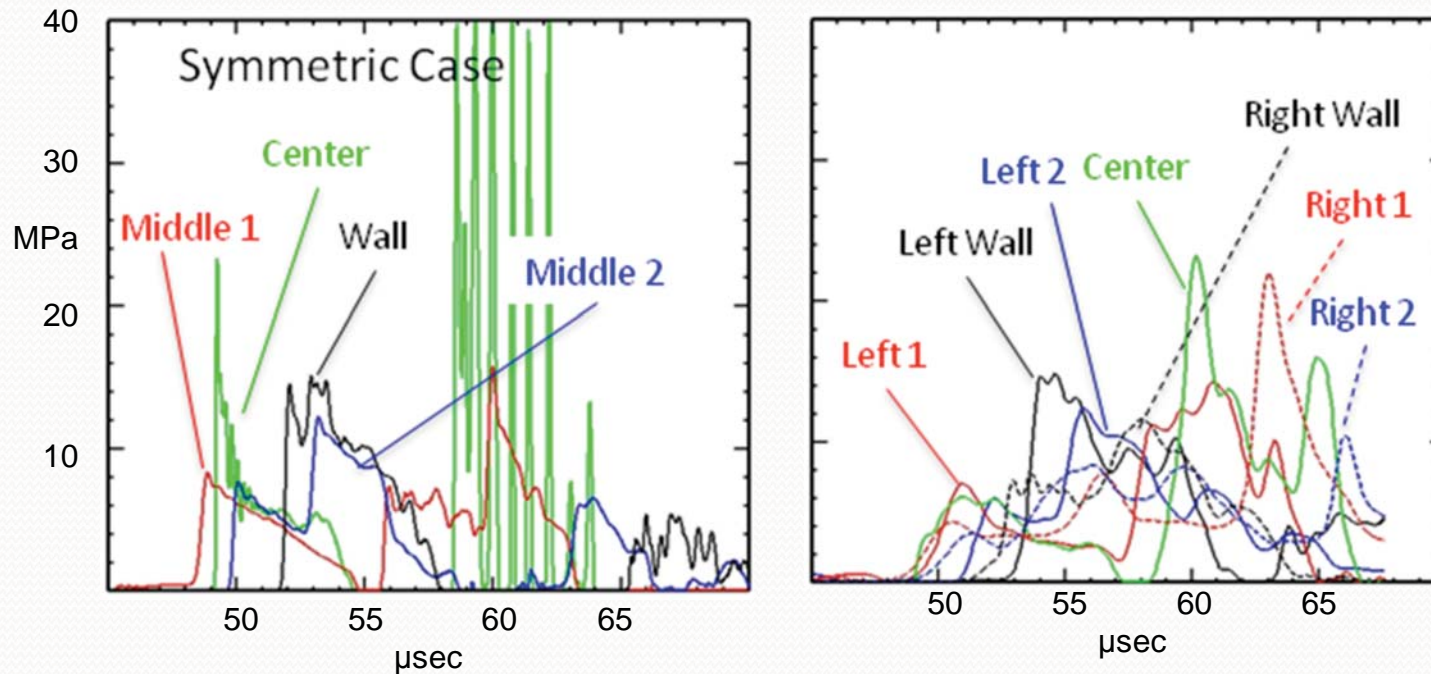


*asymmetric case*

## Original geometry (a)

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## Pressure-time histories at the model tracer nodes;



Symmetric discharge

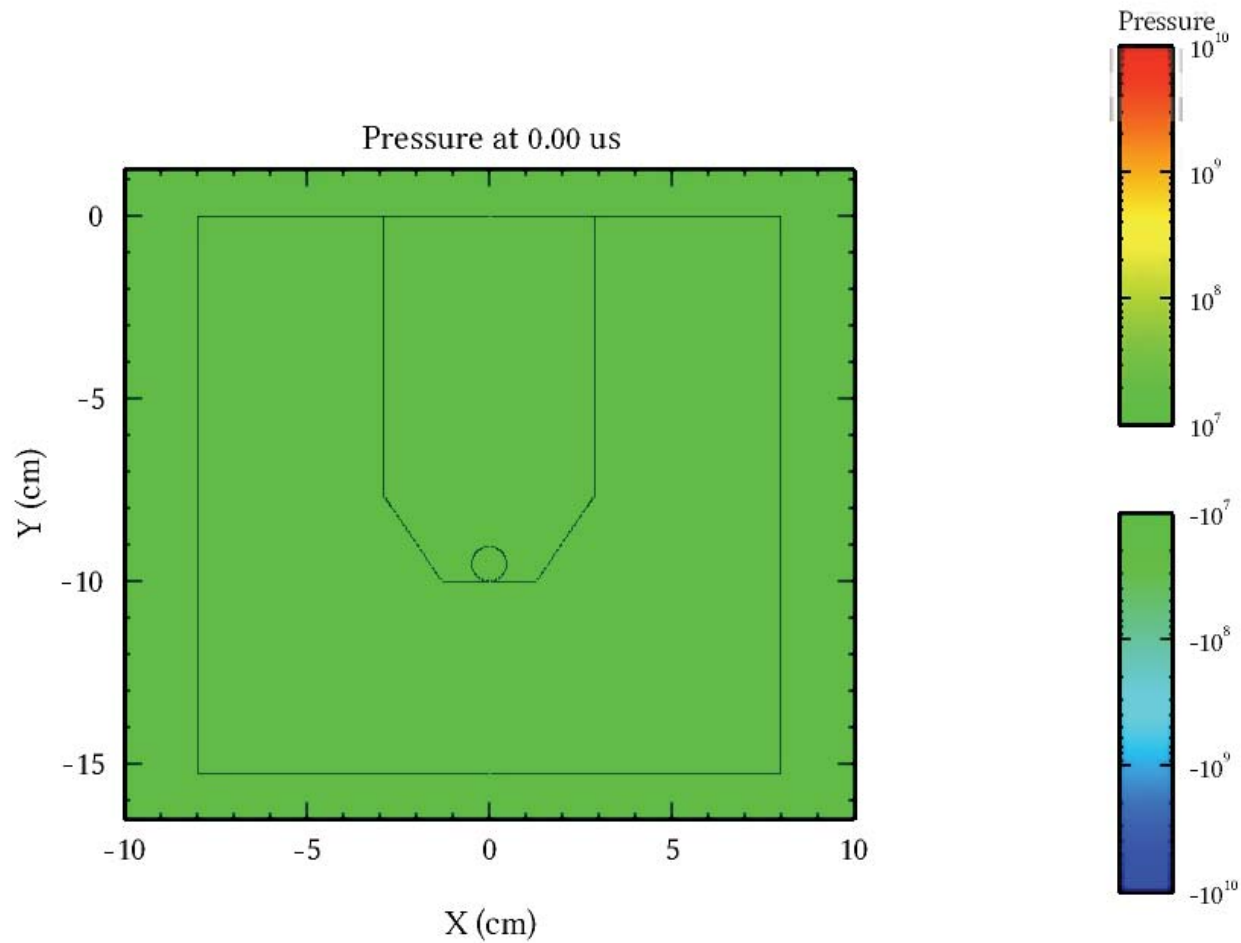
Asymmetric discharge

With electrode section insert; geometry (b)

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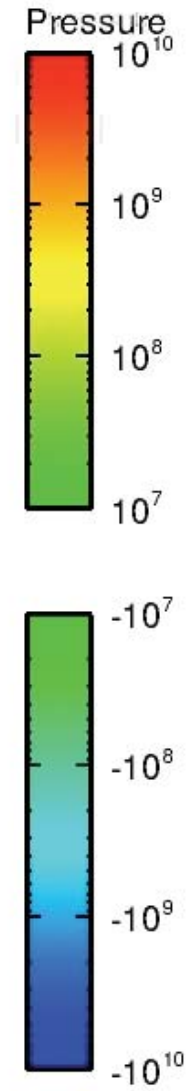
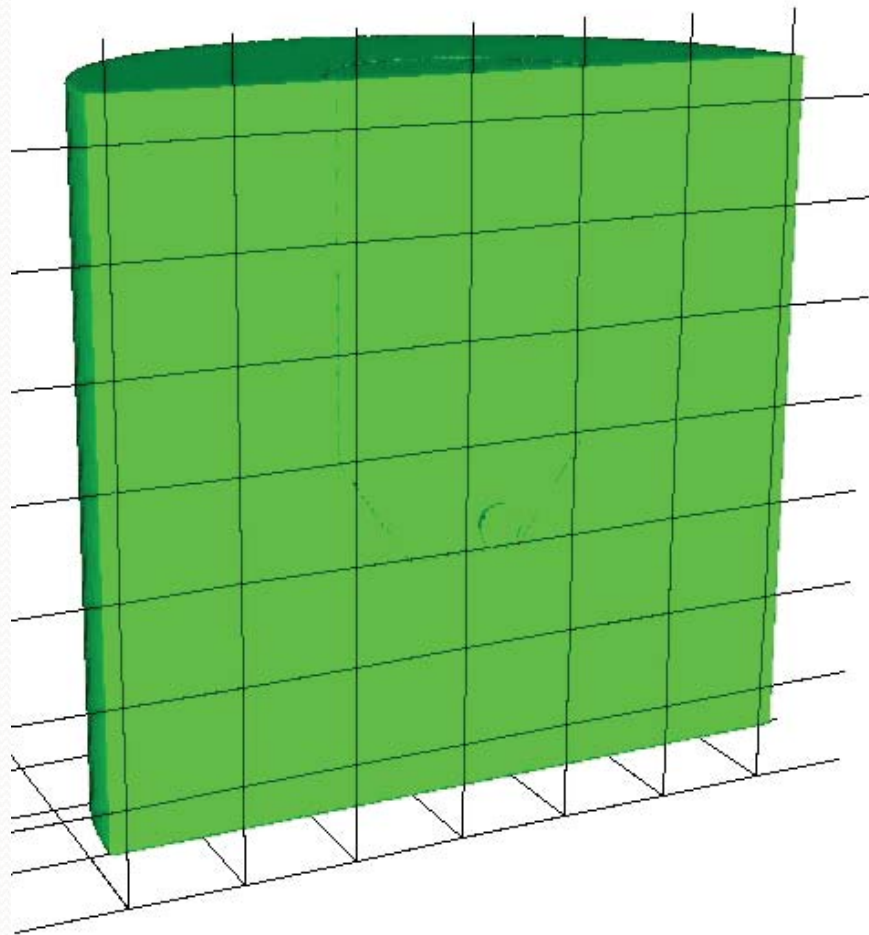
## Simulation symmetric 2D case



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# Simulation asymmetric case

Pressure at 0.00 us.





## 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*

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