



# **Effects of Force Distribution and Rebound on Electromagnetically Formed Sheet Metal**

by

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# Outline

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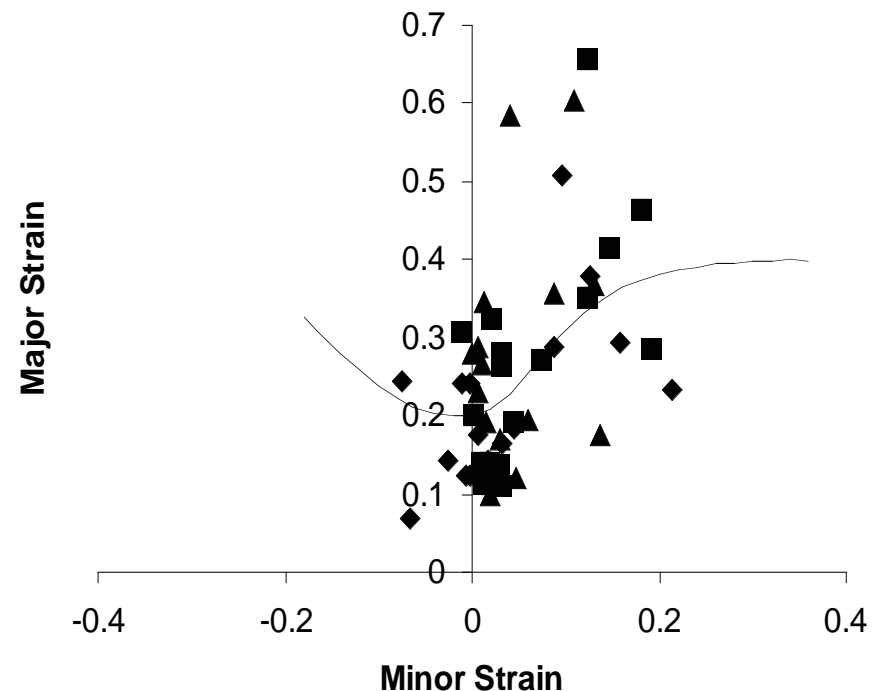


- Introduction to Electromagnetic Forming (EMF)
- Description of Present Work
- Experimental/Numerical Results
- Conclusions

# Electromagnetic Forming

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- High speed forming process first developed during the space race to form hard to form parts (Wagner and Boulger, 1960)
- Results in increased formability for Al alloys ( Daehn *et al.*, 1994-2007, Golovashchenko, 1999, Imbert *et al.*, 2005 and Imbert, 2005)

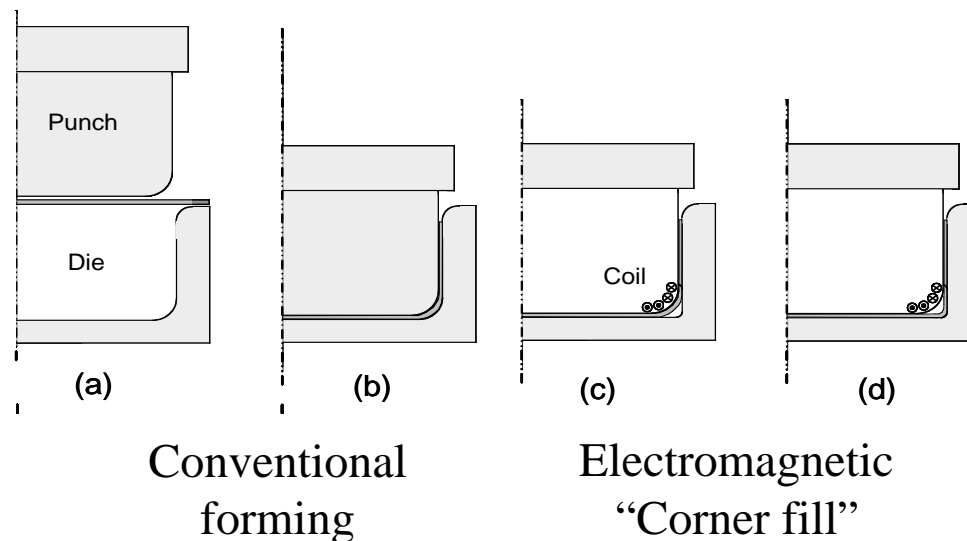


Formability data for three different AA 5754 samples (Imbert, 2005)

# Present Work

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- The present work is part of ongoing research into EM corner fill
- An experimental and numerical study was undertaken to study the effect of the induced force distribution and the rebound of the sheet



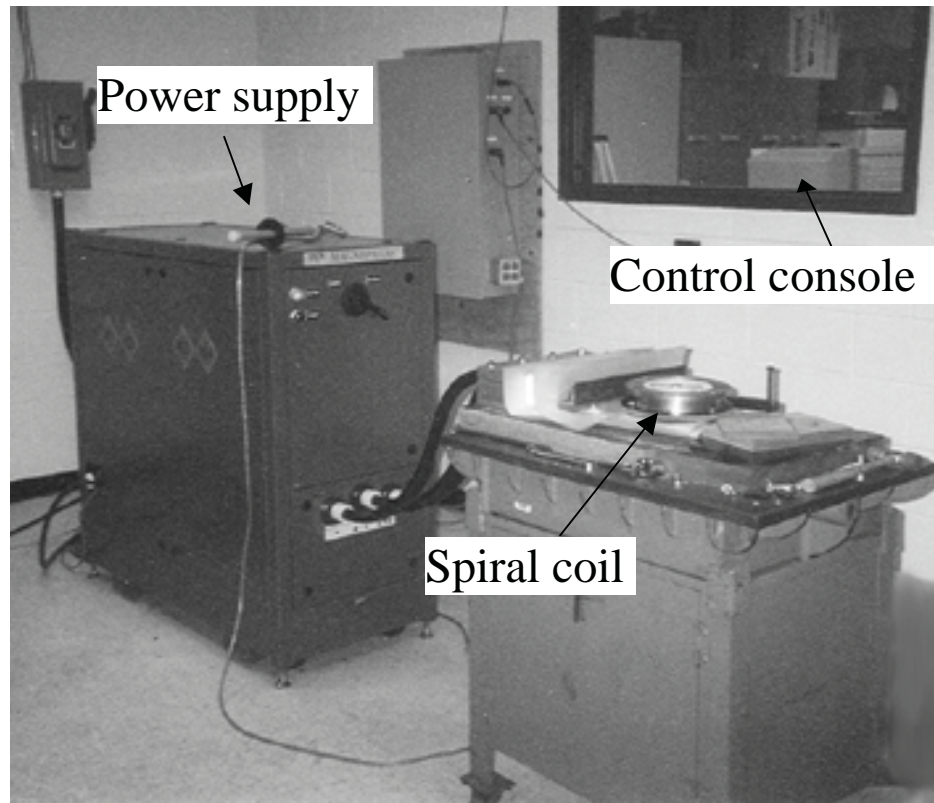
# “Single Step” Corner fill

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- Baseline for subsequent tests
- Form flat sheet into a conical and v-channel die using a single discharge
- Significant insight was gained on the behaviour of sheet metal in EMF
- Conical and v-channel samples used

# Apparatus used for Conical Samples

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IAP Magnapress 22.5 kJ, 15 kV Pulse Generator

Ford EMF laboratory

# University of Waterloo EMF Lab

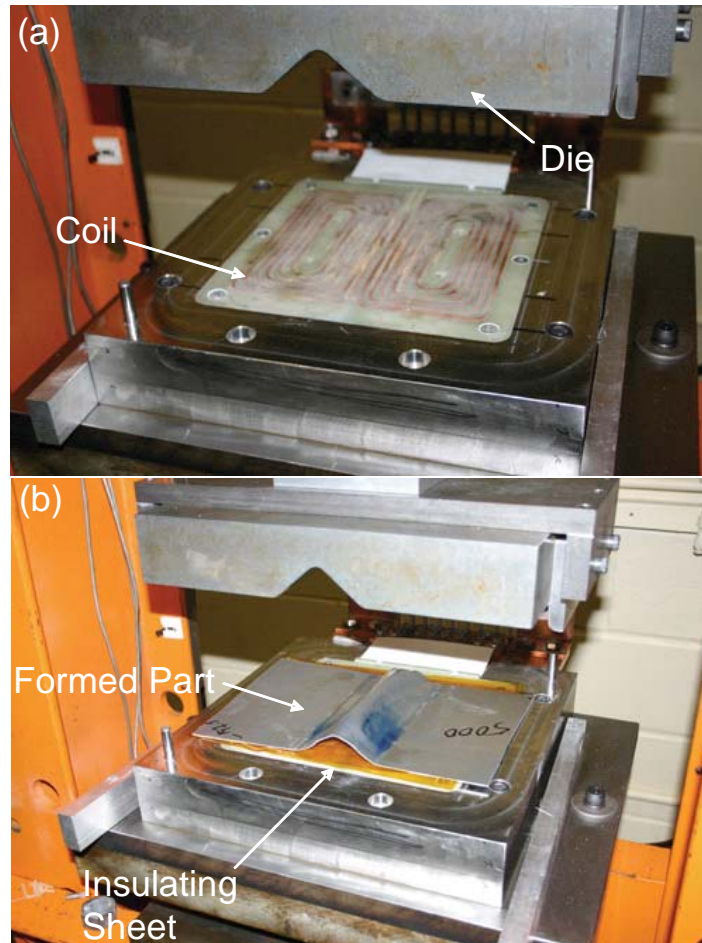
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Pulsar Research Edition 20kJ, 9 kV Pulse Generator

# EMF of V-Channel

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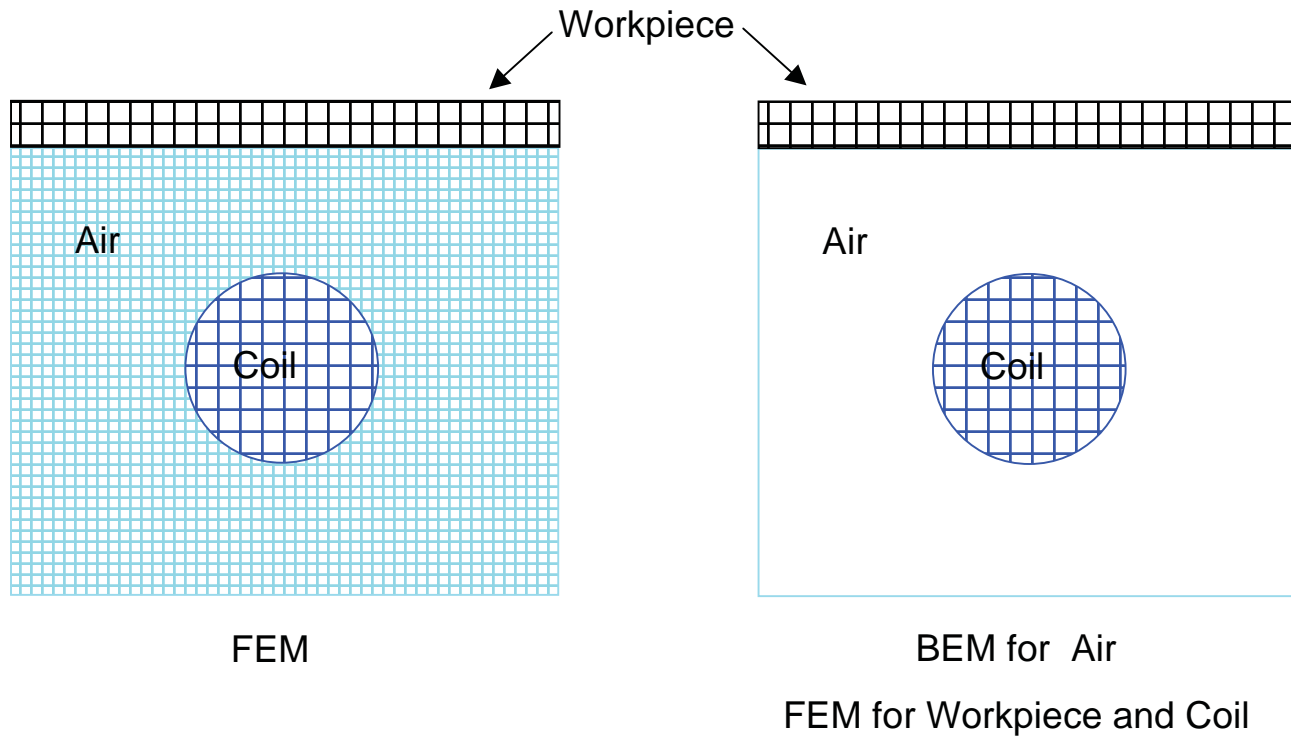
# Numerical Method

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- Used version of LSTC LS-Dyna capable of performing EM simulations.
- The EM solver combines Finite Element Analysis (FEA) with the Boundary Element Method (BEM) to perform the electromagnetic analysis by solving Maxwell's equations in the eddy-current approximation
- Software provides for a coupled solution of the structural and EM problems
- A cluster with two Opteron 270 dual core 64-bit 2 GHz processors with 2 Mbytes of L2 Cache. The machine was equipped with 16 Gbytes of RAM, eight of which were used for some models.
- Pulse generators modeled as an RLC circuit
- Simulation times ranging from 3 – 7 days.

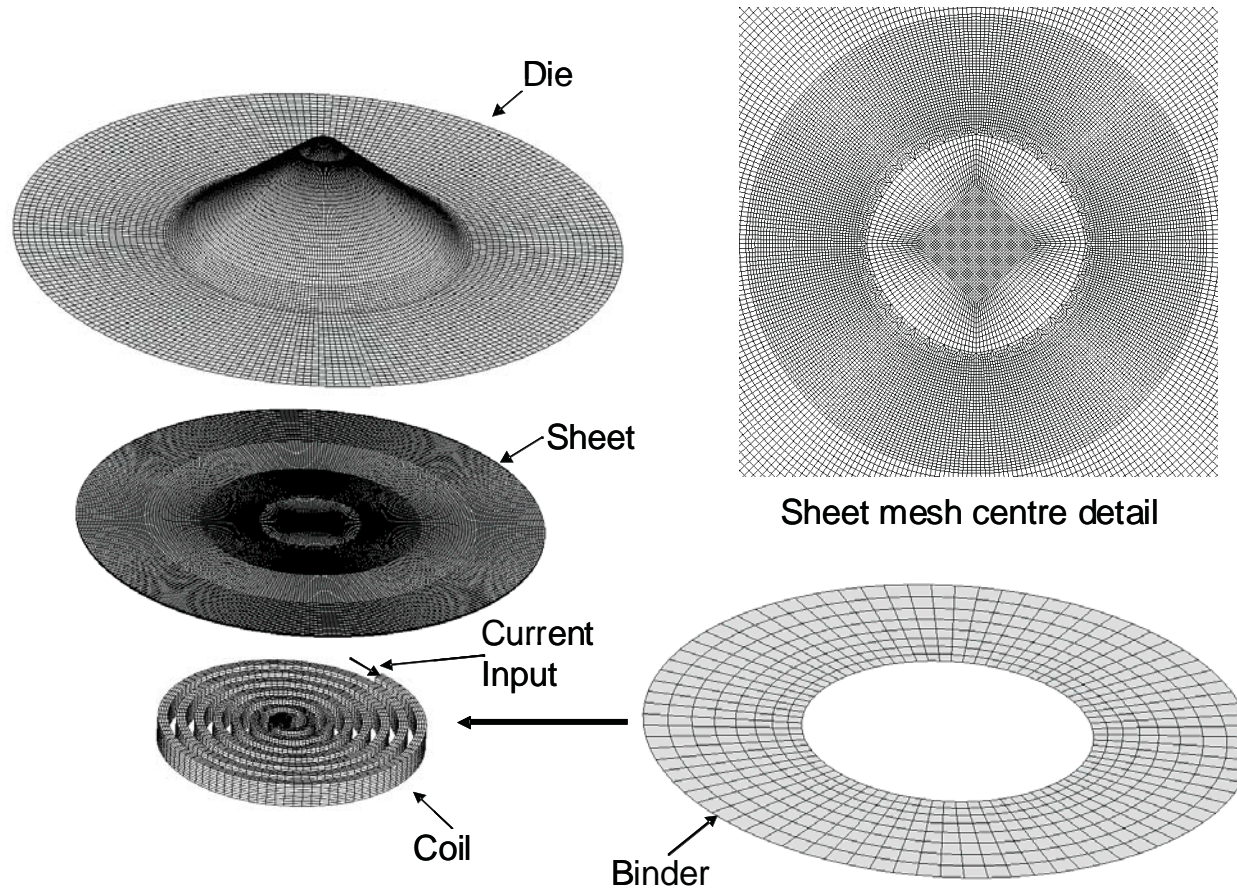
# FEA vs. BEM/FEA

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# Conical Part Mesh

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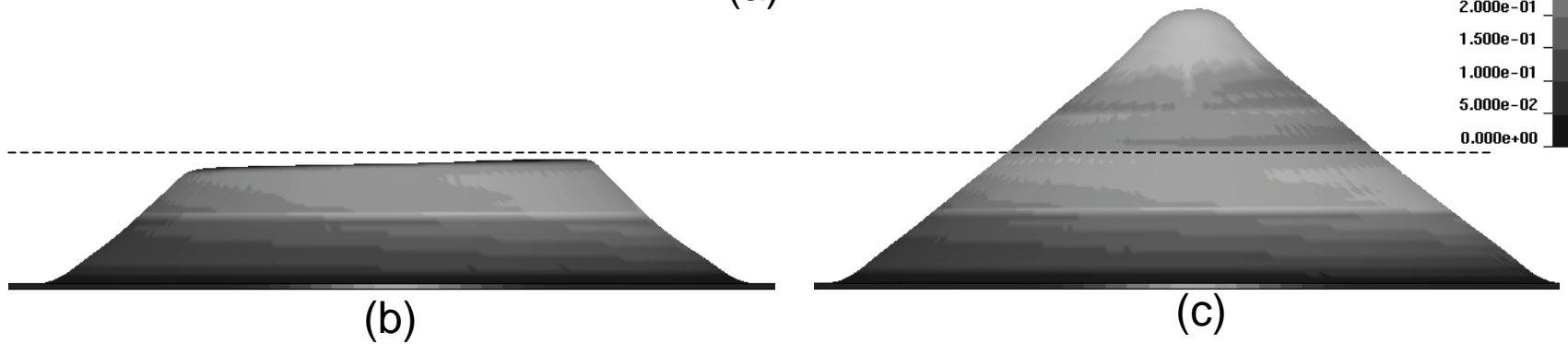
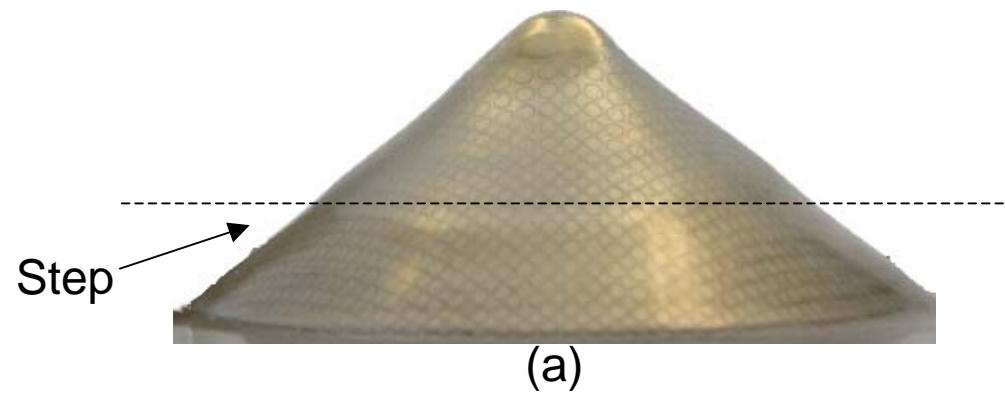


Coil and Sheet: 8 node hexahedral “brick” elements  
(sheet=258,560 and coil 20,772)

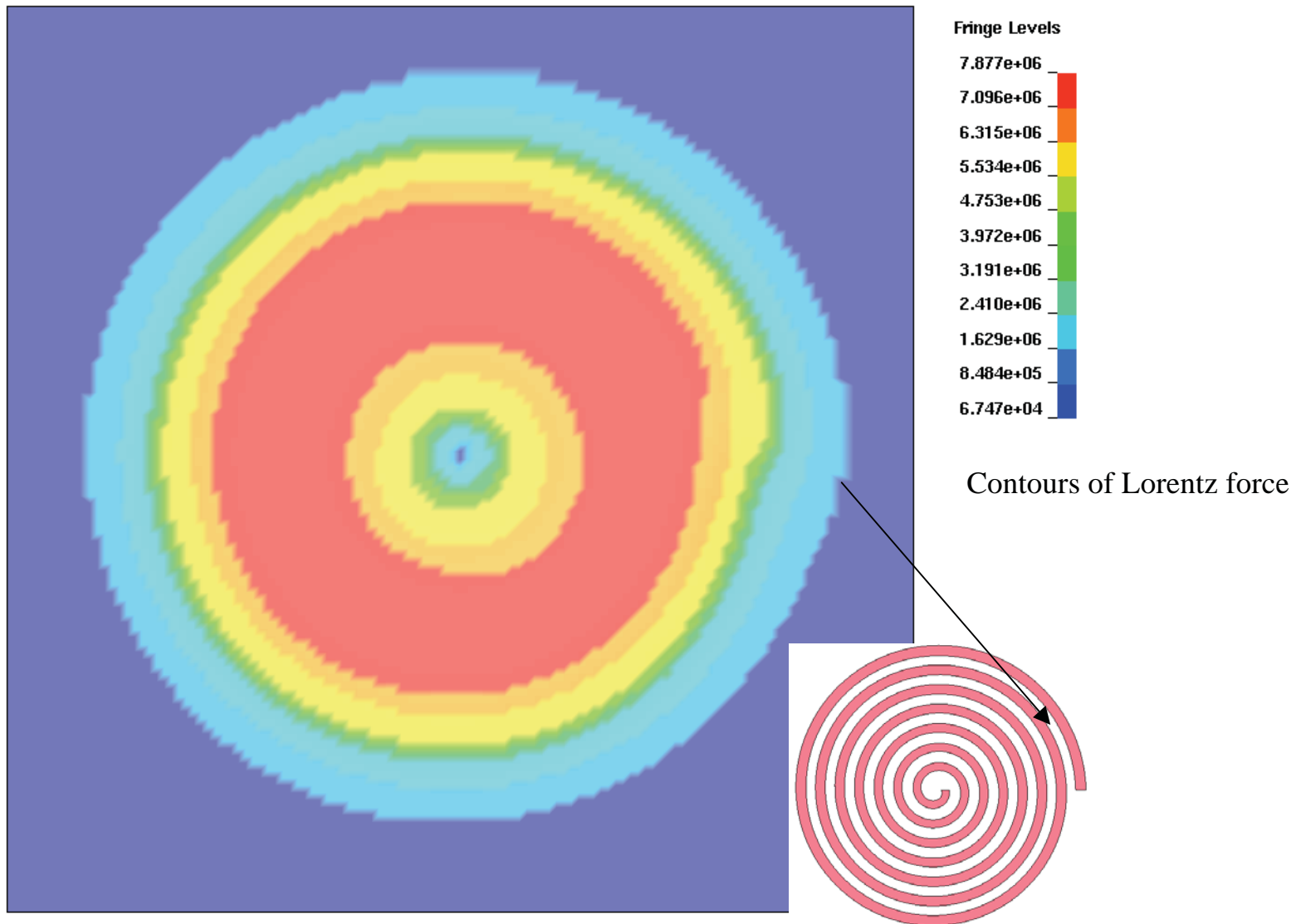
Binder and Die: 4 node shell elements

# Experimental/Numerical Cones

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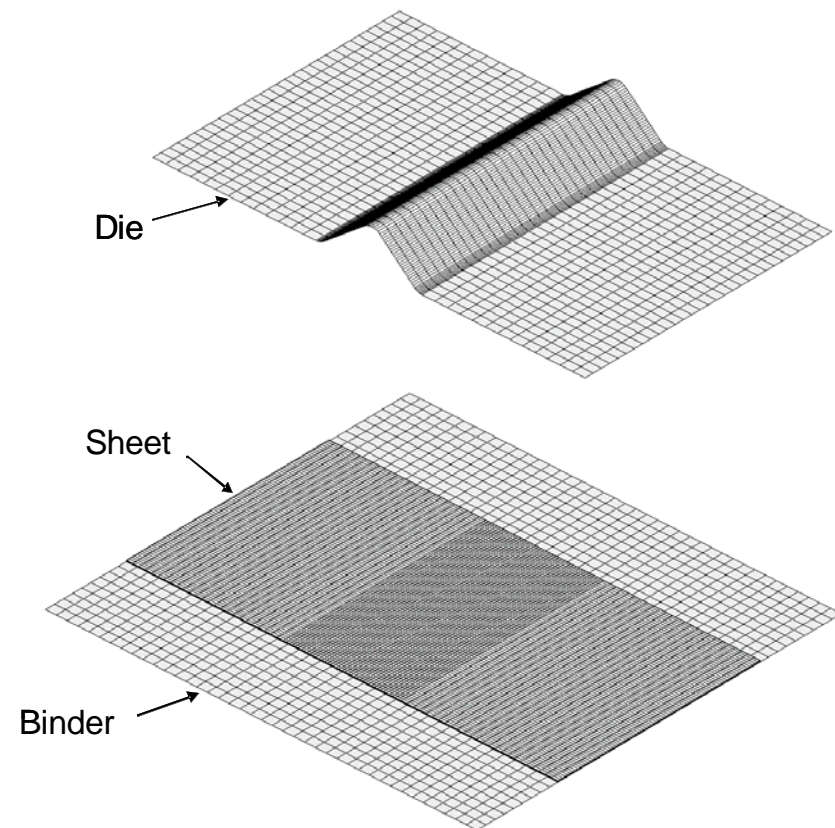
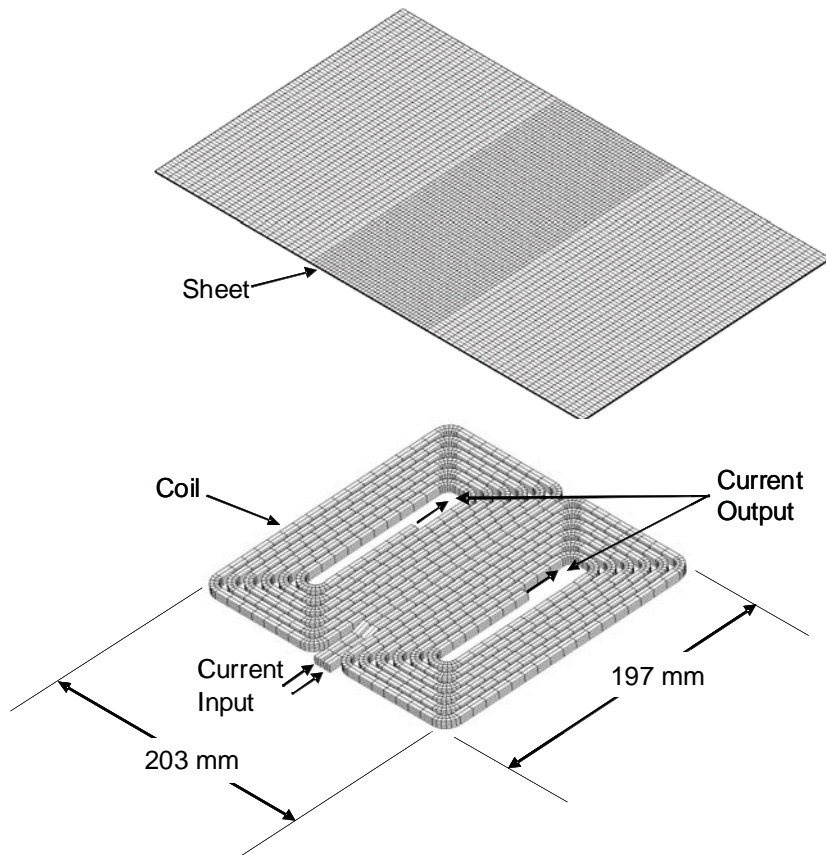


# Predicted Lorentz Forces from Spiral Coil



# V-Channel Mesh

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Coil and Sheet: 8 node hexahedral “brick” elements  
(sheet=28,800 and coil = 5,952)

Binder and Die: 4 node shell elements

# No Contact-Force Distribution Effects

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(a)



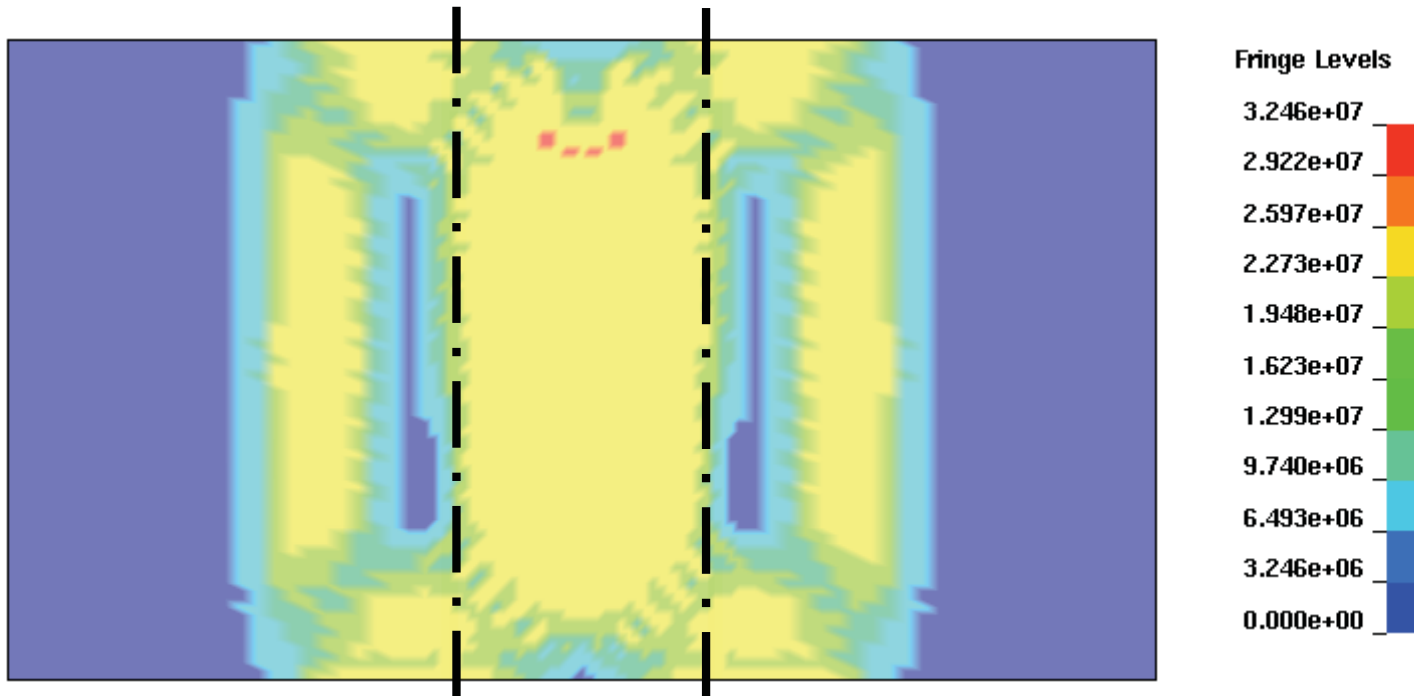
(b)



(c)

# V-Channel Simulation

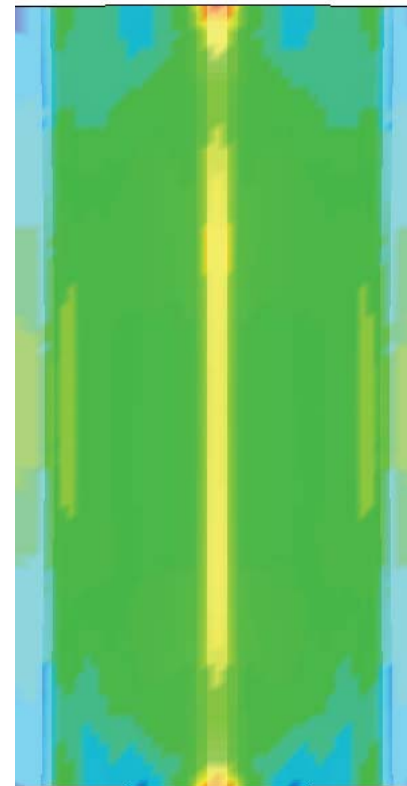
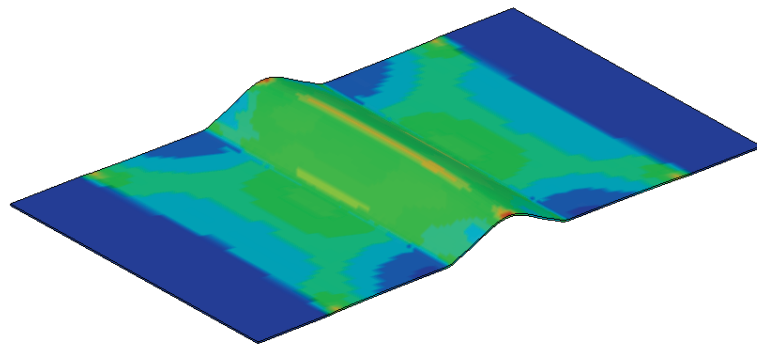
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Contours of Lorentz force

Side of the sheet  
exposed to the coils

# V-Channel Formed With 3000 V



Fringe Levels

1.096e-01

9.867e-02

8.771e-02

7.674e-02

6.578e-02

5.482e-02

4.385e-02

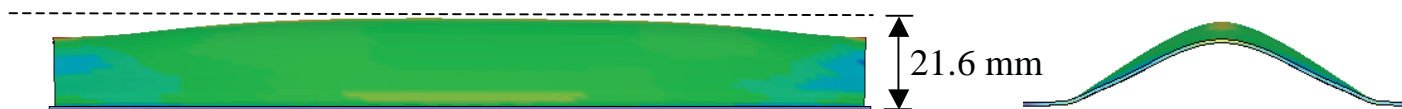
3.289e-02

2.193e-02

1.096e-02

0.000e+00

Effective  
plastic strain



# Contact-Force Distribution and Rebound

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(a)

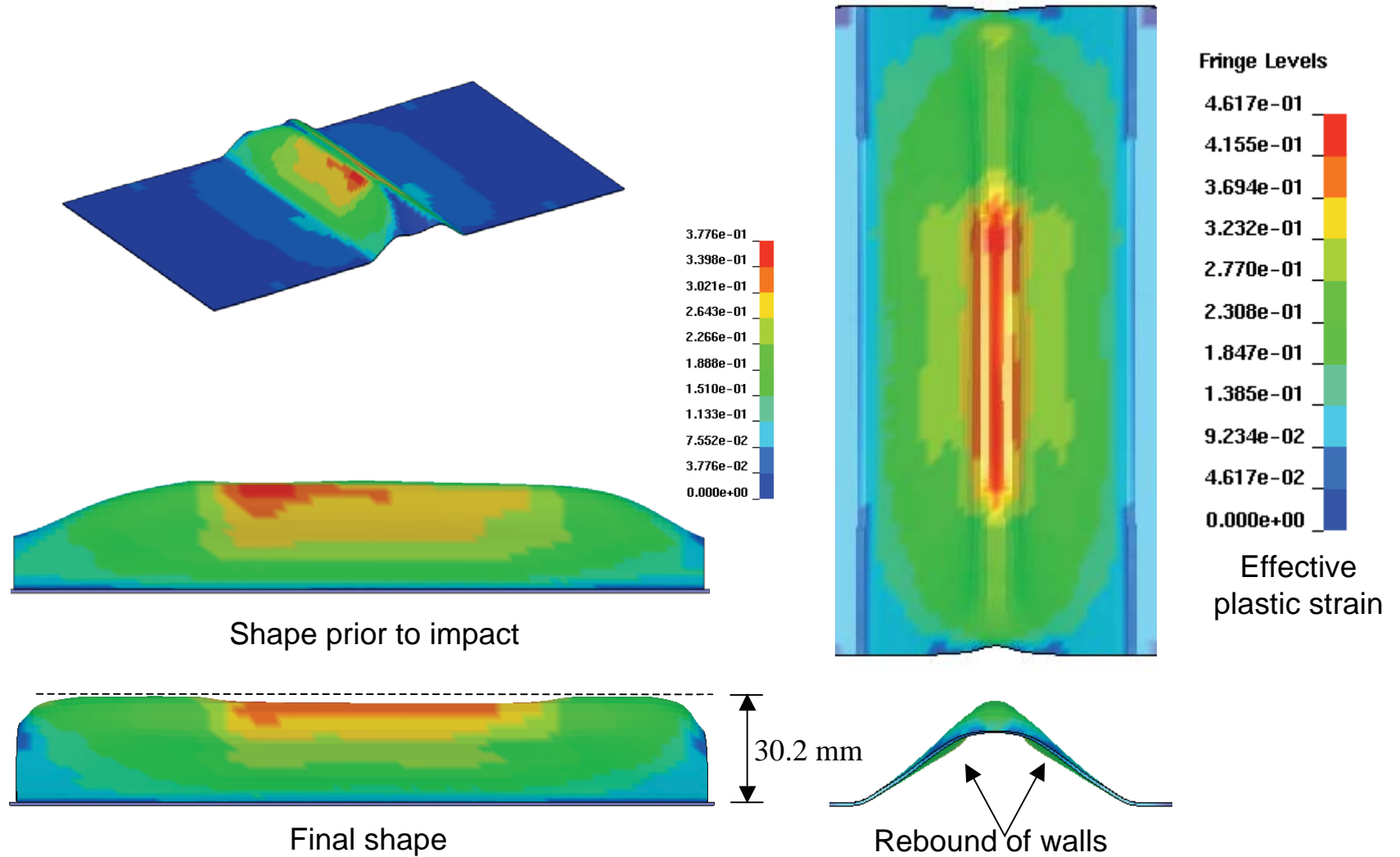


(b)



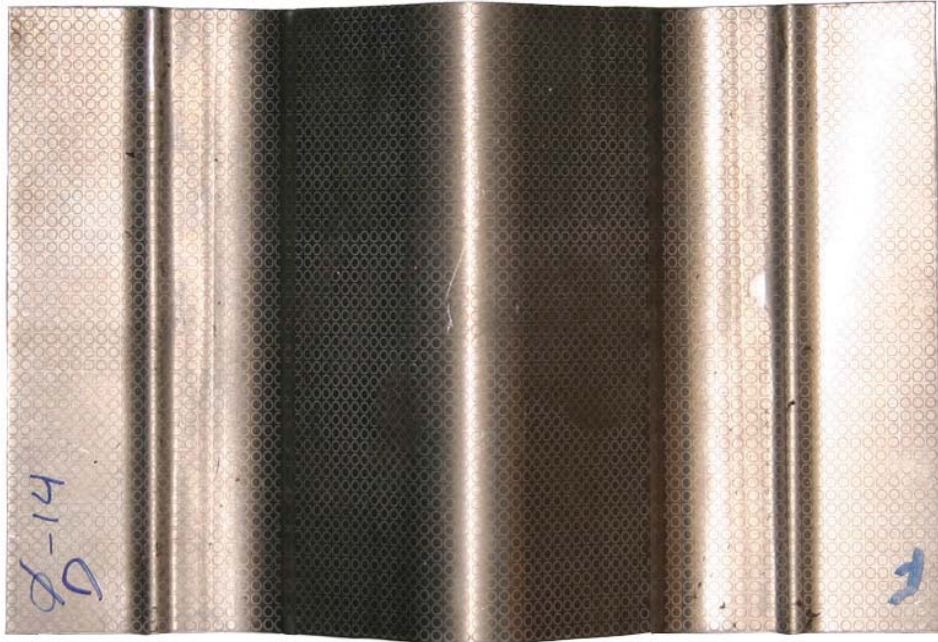
(c)

# V-Channel 5000 V



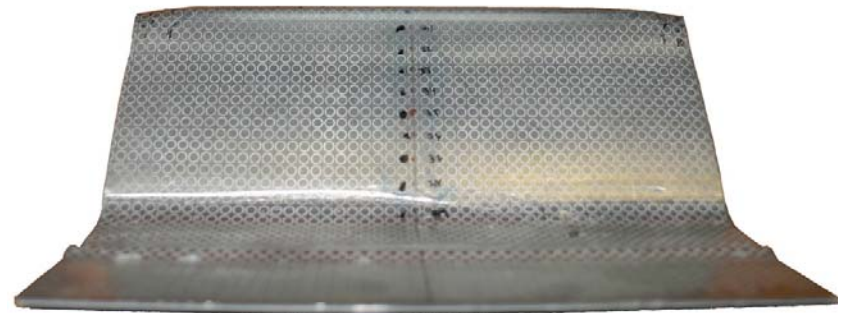
# Two Step Corner Fill-Conventional Step

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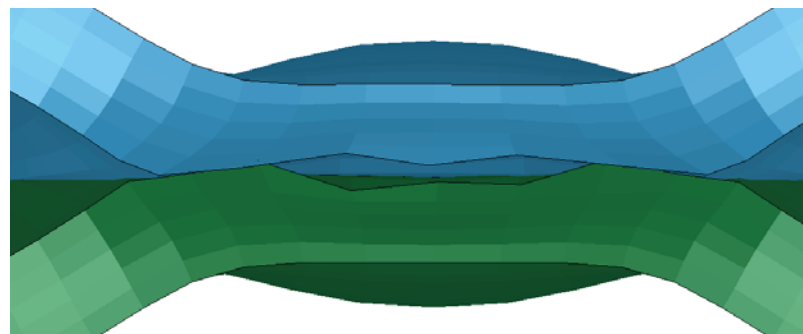
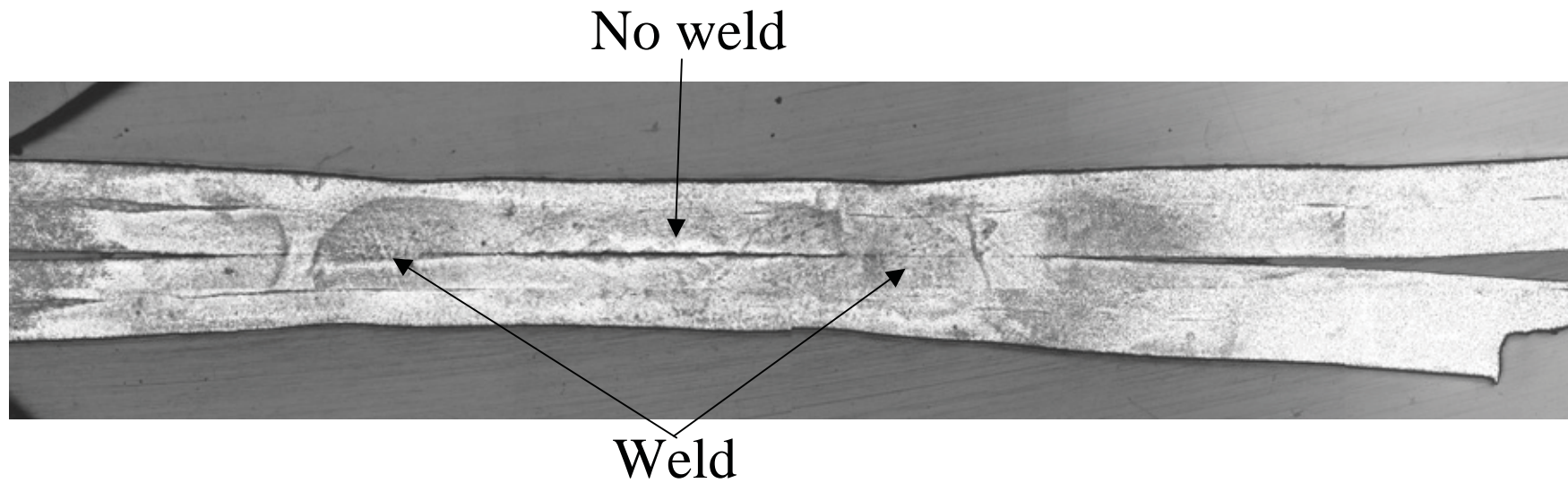
# Two Step Corner Fill-EM Step

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# Rebound in Sheet Welding (Al-Al)

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# Conclusions

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- The effect of the force distribution and rebound can be significant and must be taken into account

# QUESTIONS?