University of Waterloo

Effects of Force Distribution and Rebound on Electromagnetically Formed Sheet Metal

by

José Imbert*, Michael Worswick* and Pierre L'eplattenier**

***University of Waterloo, Waterloo, Ontario, Canada**

****LSTC, Livermore, California**

10th International Conference on High Speed Forming

March 9-10th, 2010, Columbus, OH

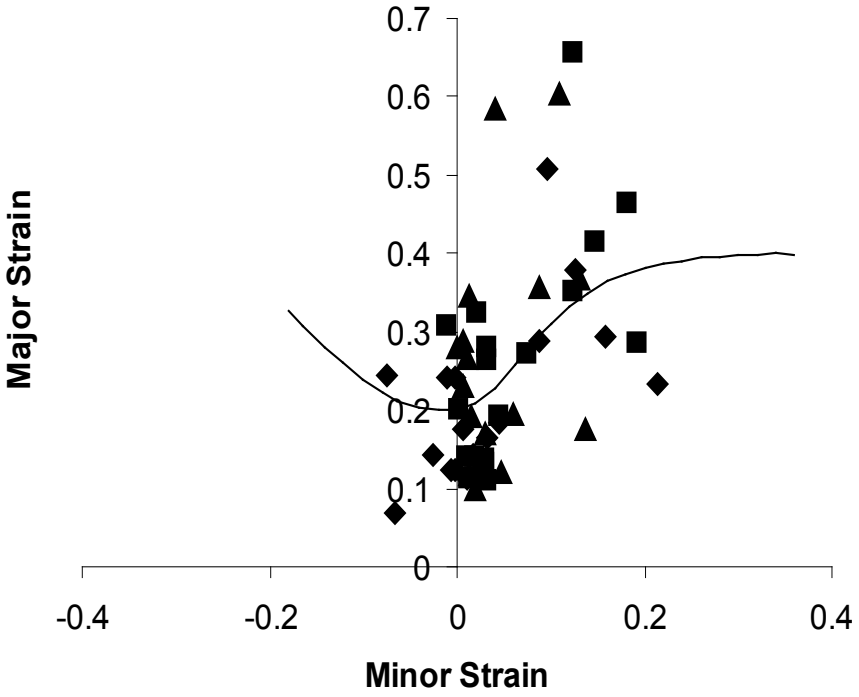
Outline

University of Waterloo

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

Electromagnetic Forming

- 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, Golovashchenco, 1999, Imbert *et al., 2005* and Imbert, 2005)

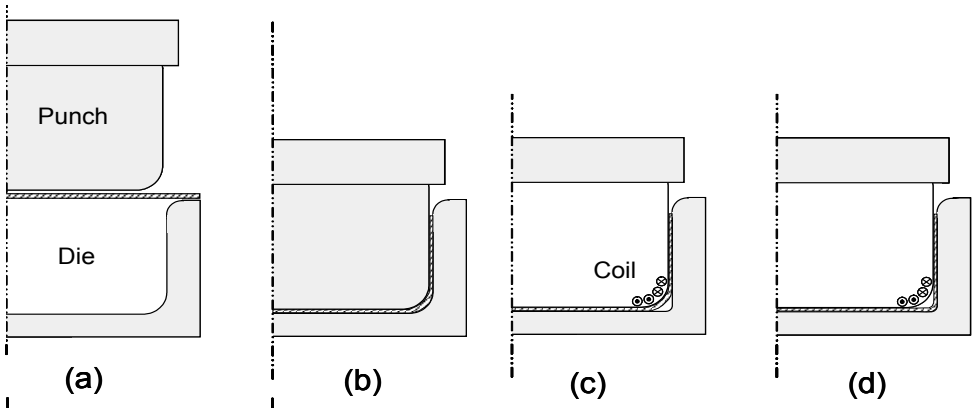


Formability data for three different AA 5754 samples (Imbert, 2005)

Present Work

University of Waterloo

- 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



Conventional forming

Electromagnetic "Corner fill"

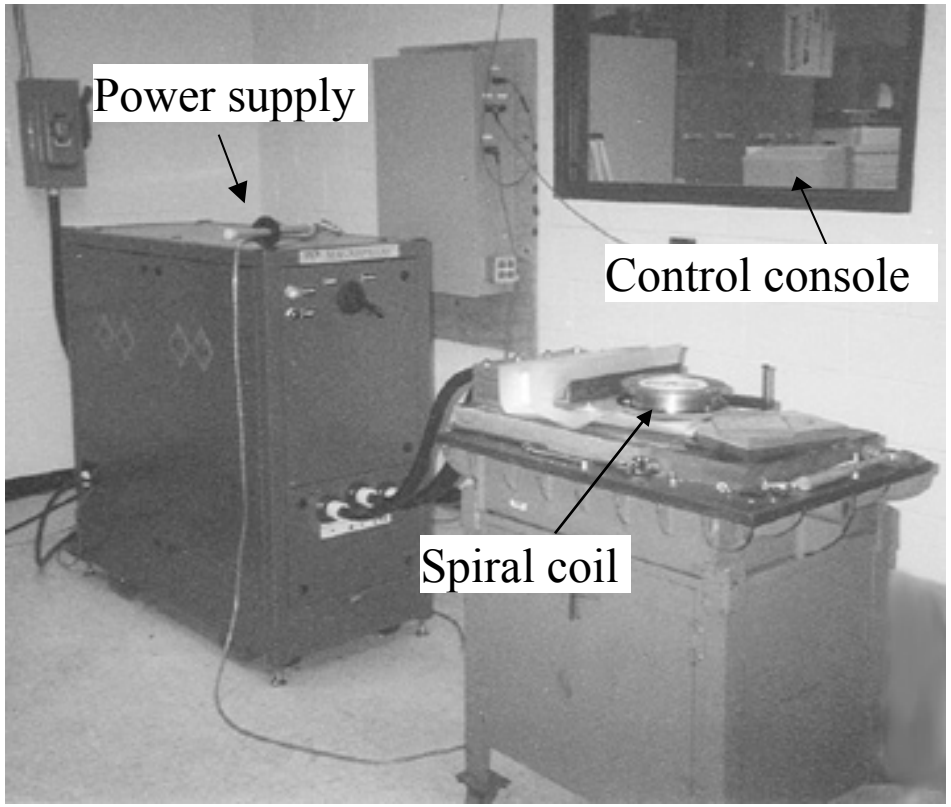
“Single Step” Corner fill

University of Waterloo

- 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

University of Waterloo

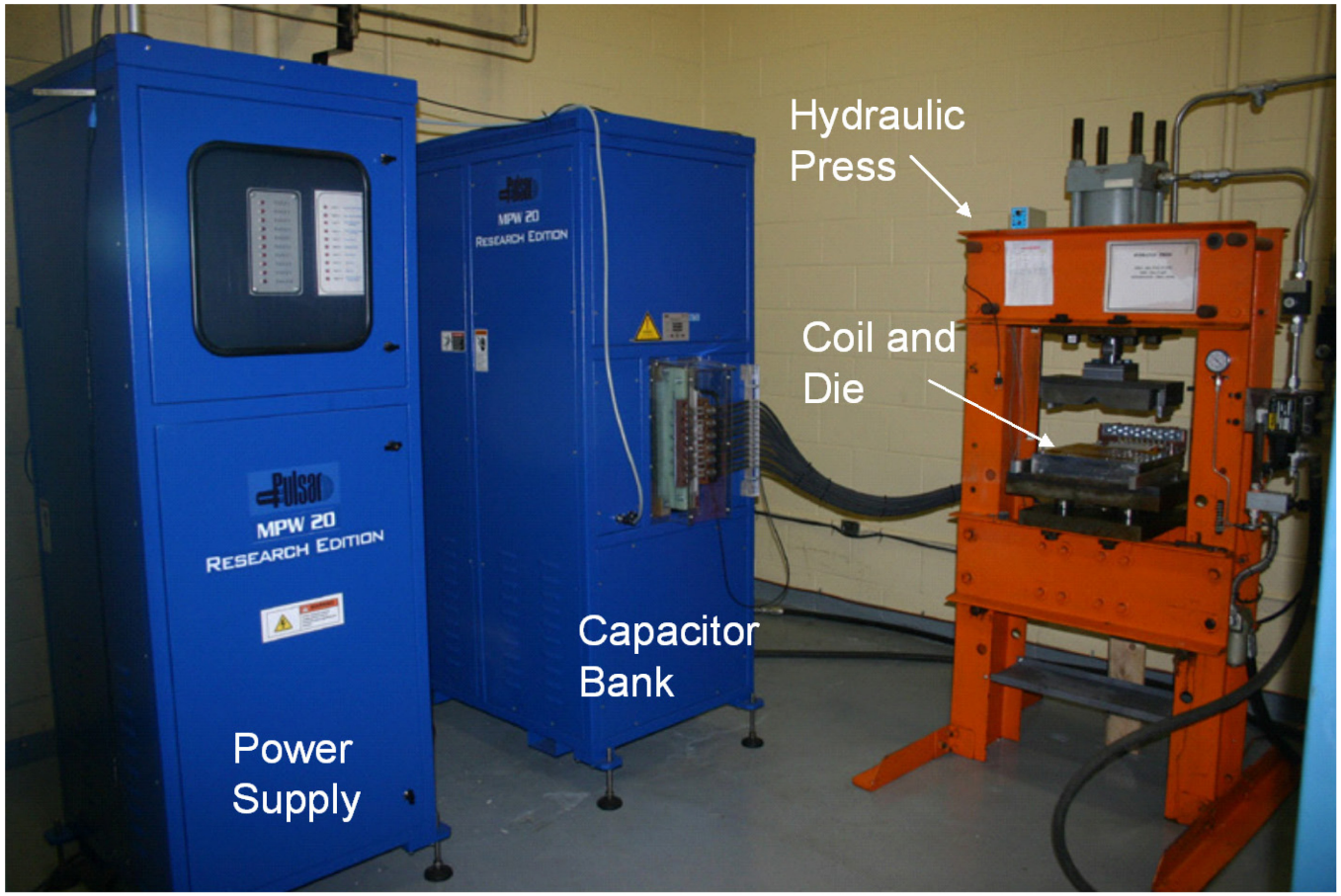


IAP Magnapress 22.5 kJ, 15 kV Pulse Generator

Ford EMF laboratory

University of Waterloo EMF Lab

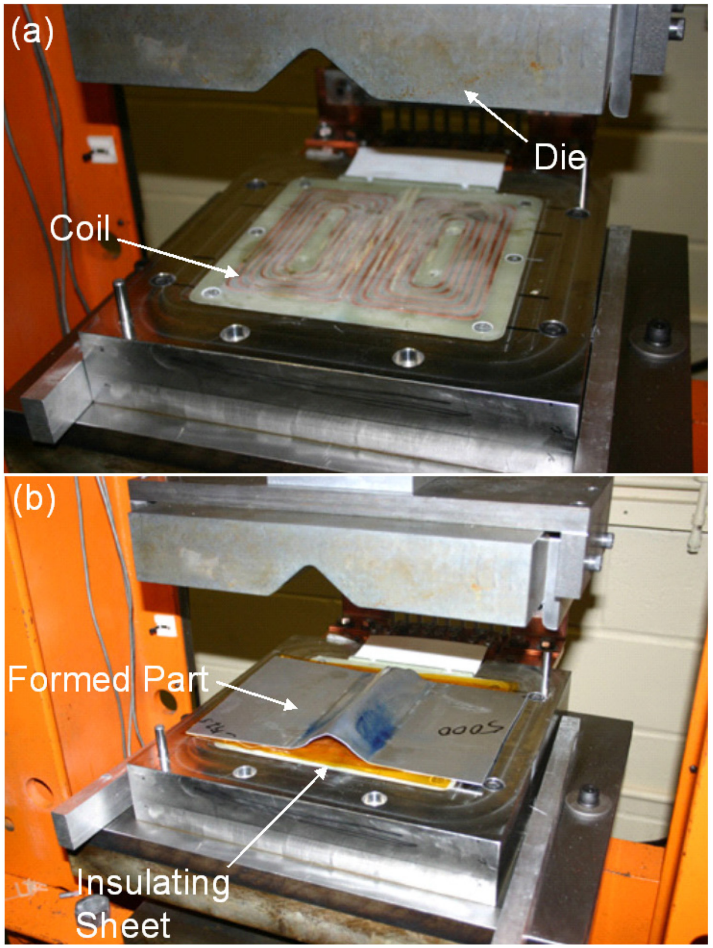
University of Waterloo



Pulsar Research Edition 20kJ, 9 kV Pulse Generator

EMF of V-Channel

University of Waterloo

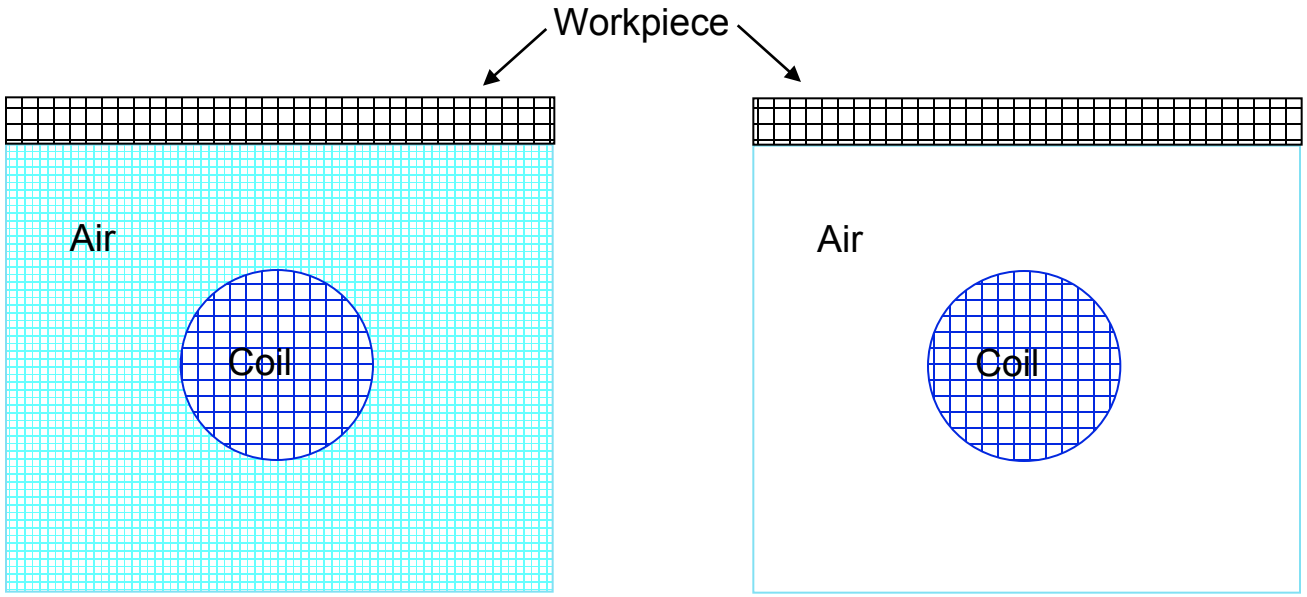


Numerical Method

University of Waterloo

- 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

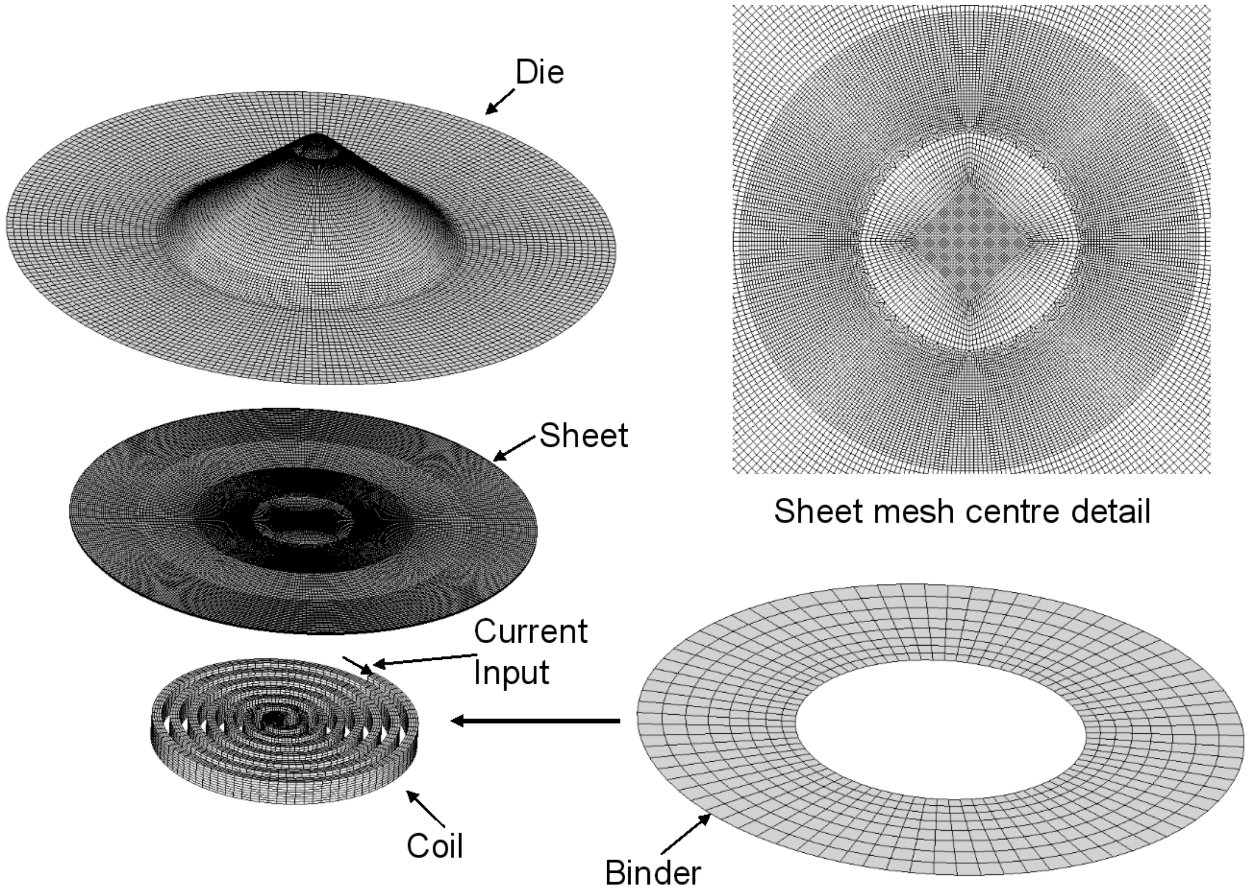


FEM

BEM for Air

FEM for Workpiece and Coil

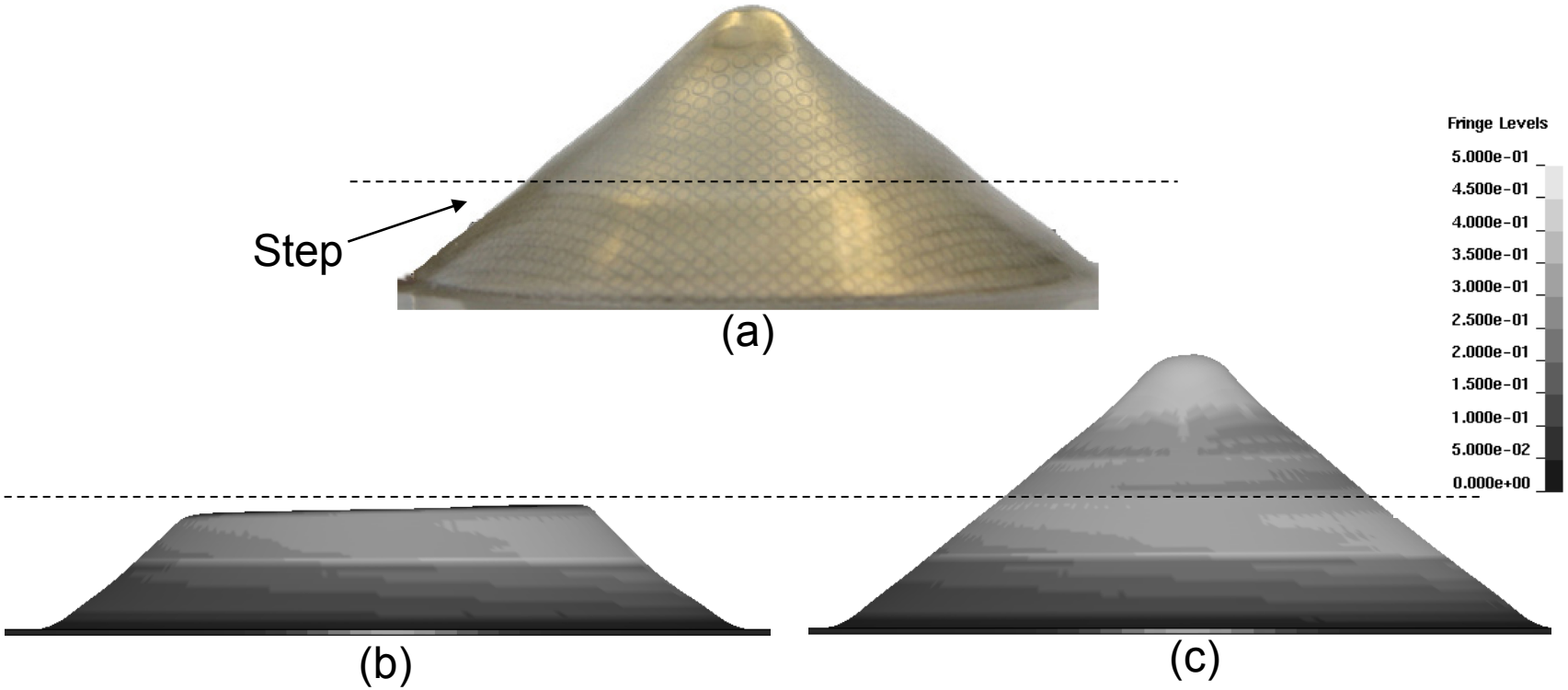
Conical Part Mesh



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

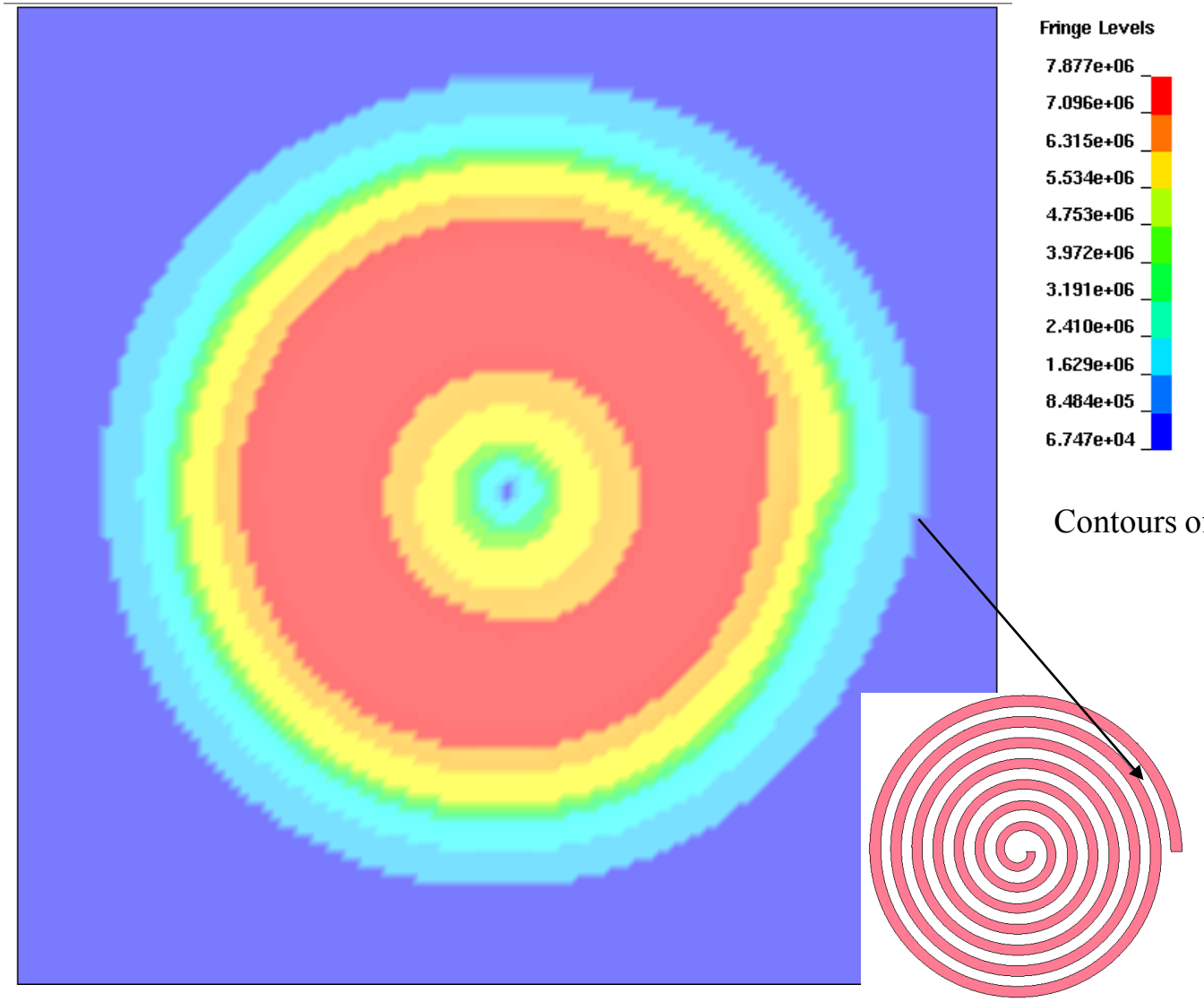
Binder and Die: 4 node shell elements

Experimental/Numerical Cones



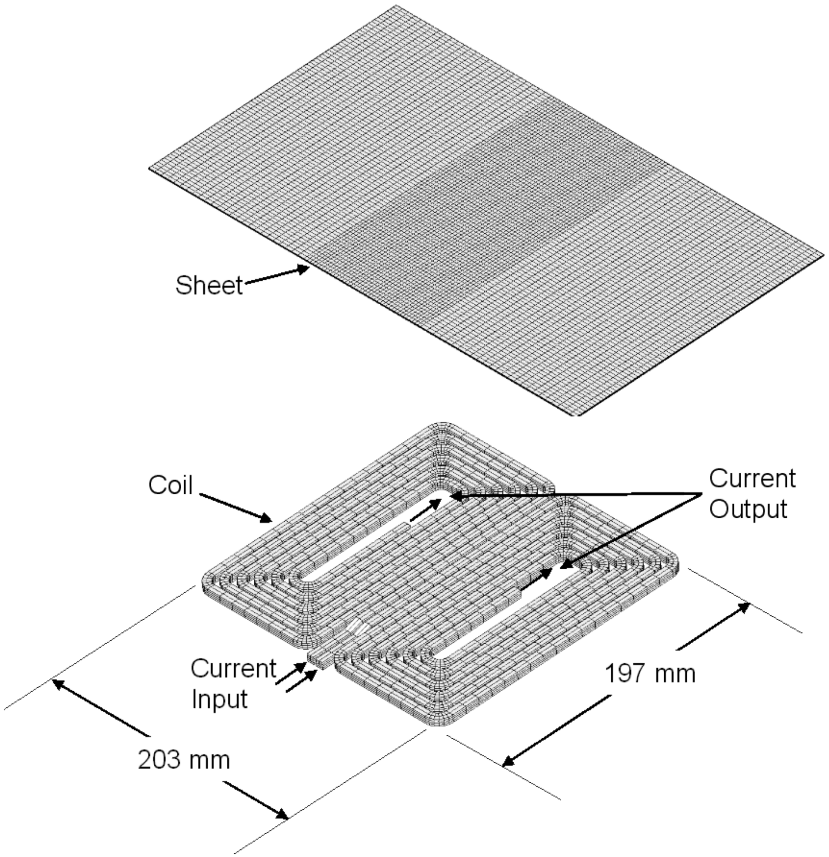
University of Waterloo

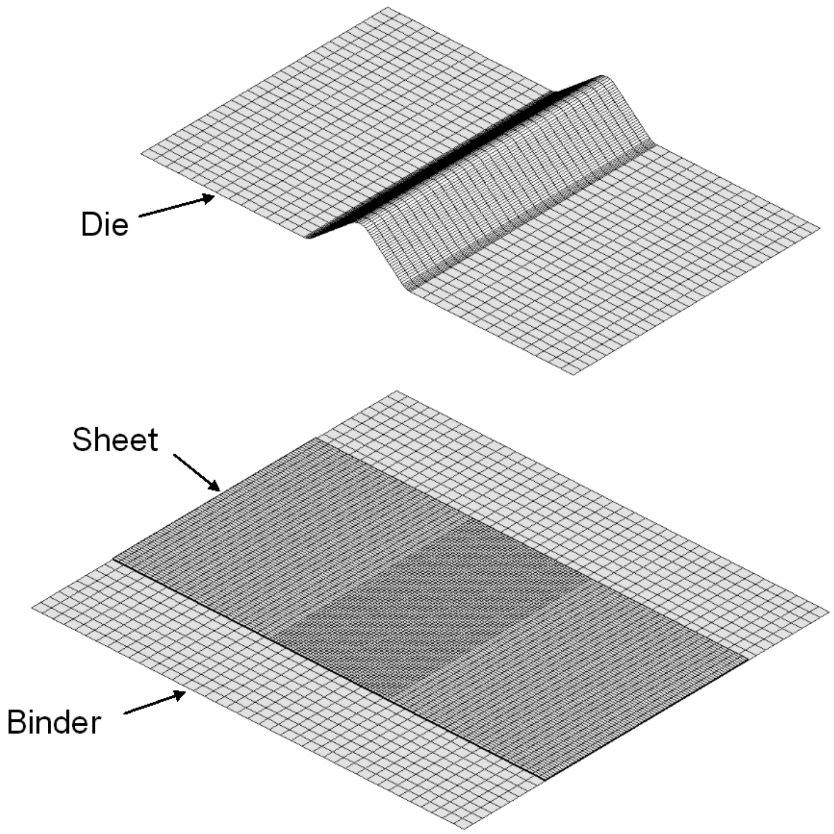
Predicted Lorentz Forces from Spiral Coil



Contours of Lorentz force

V-Channel Mesh



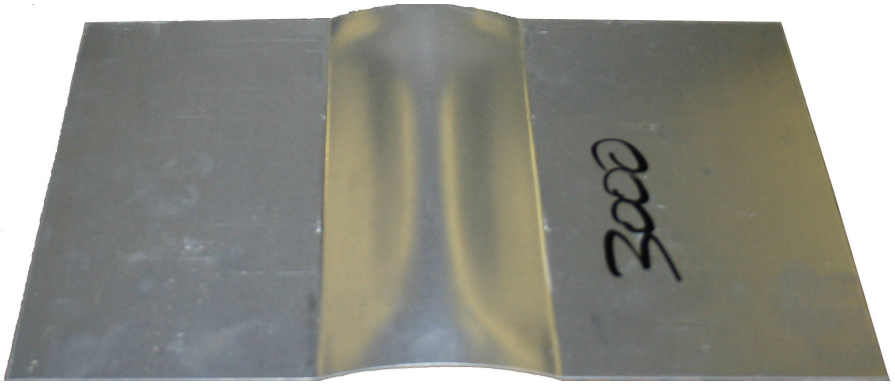


Coil and Sheet: 8 node hexahedral "brick" elements (sheet=28,800 and coil = 5,952)

Binder and Die: 4 node shell elements

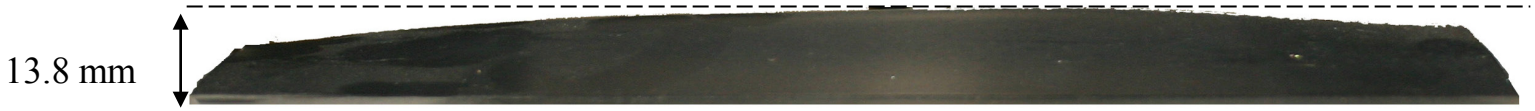
No Contact-Force Distribution Effects

University of Waterloo



(a)

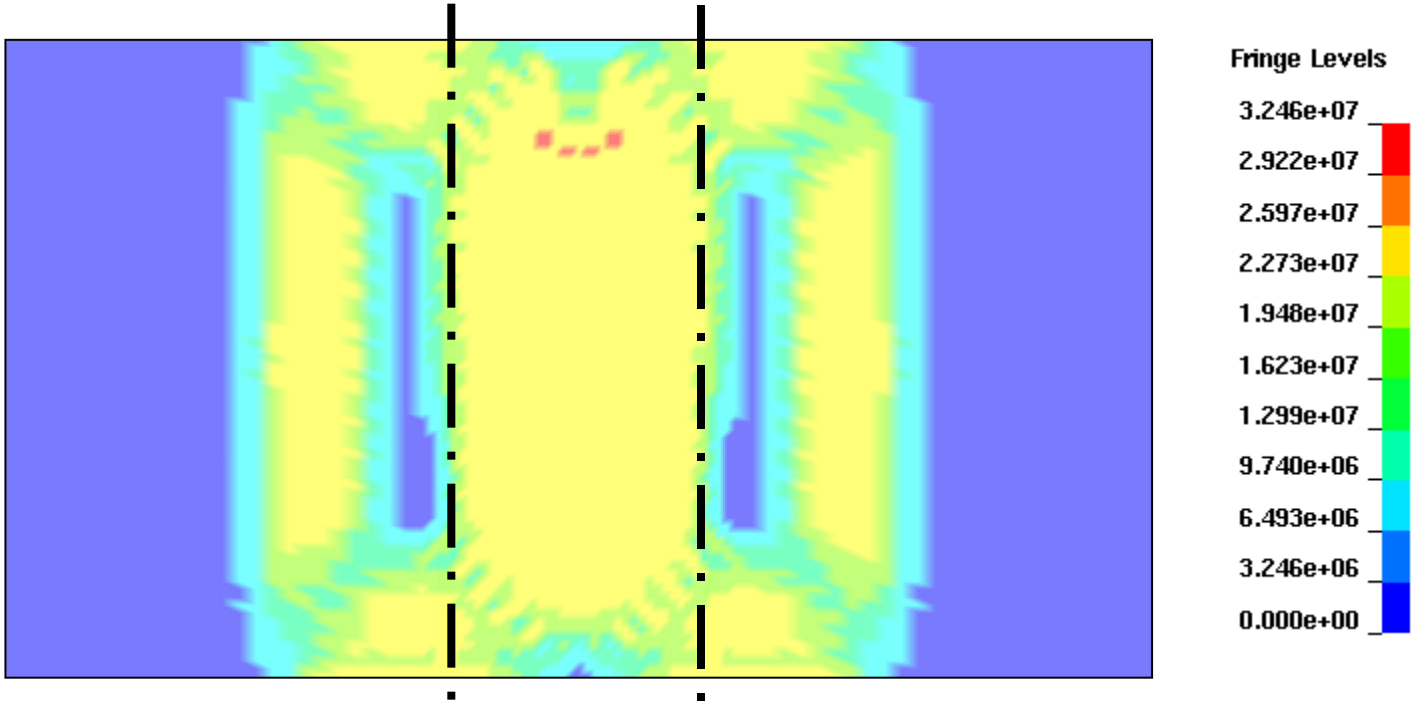
(b)



(c)

V-Channel Simulation

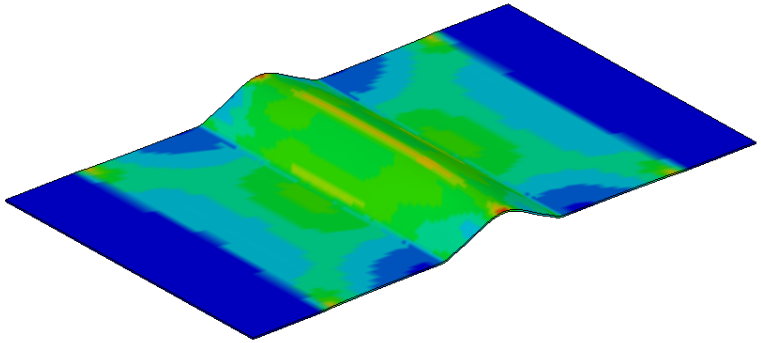
University of Waterloo

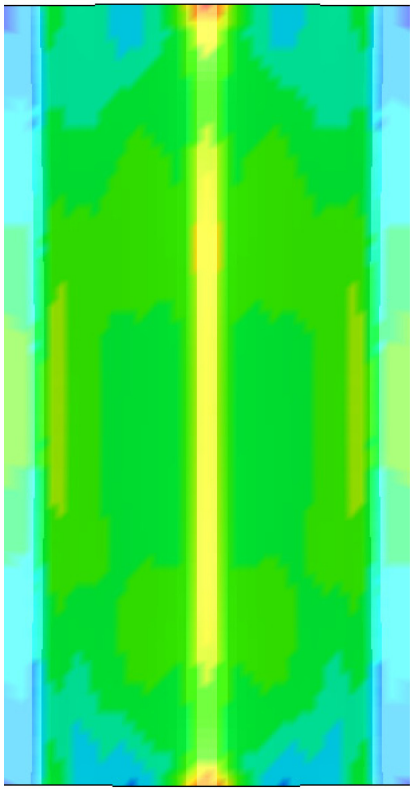


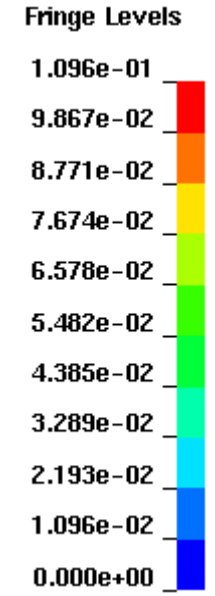
Contours of Lorentz force

Side of the sheet
exposed to the coils

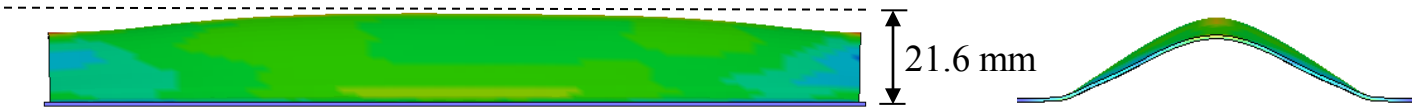
V-Channel Formed With 3000 V





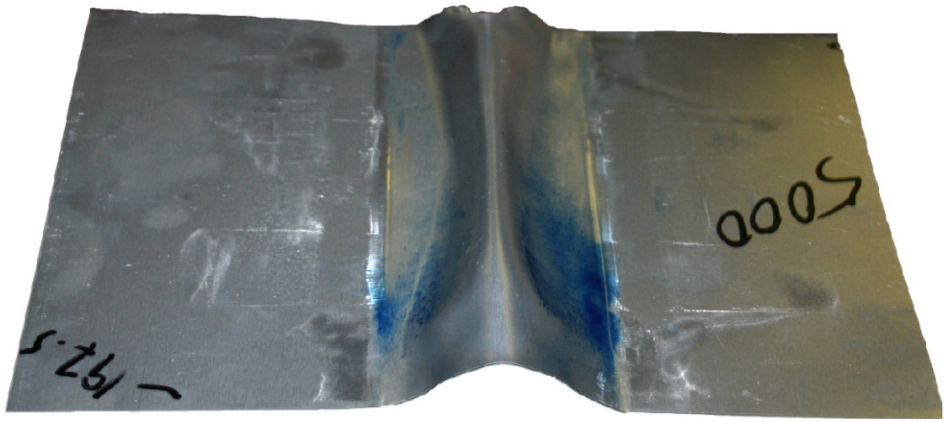


Effective plastic strain



Contact-Force Distribution and Rebound

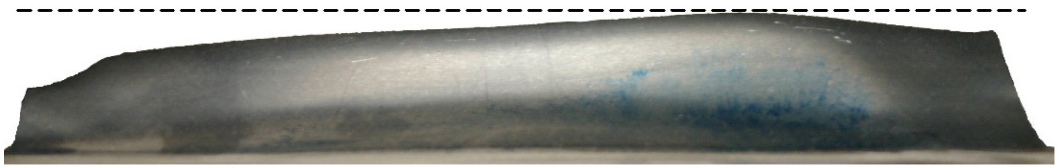
University of Waterloo



(a)

(b)

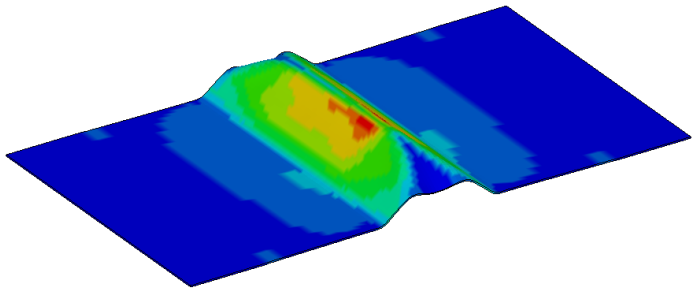
24.3 mm

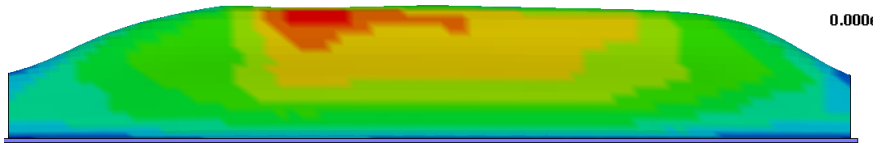


(c)

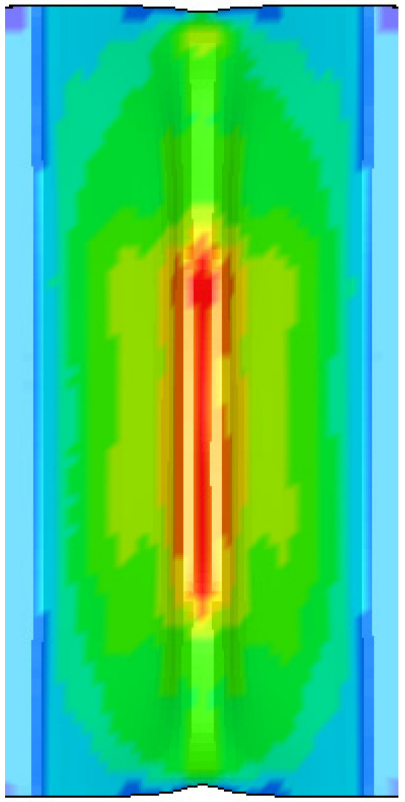
V-Channel 5000 V

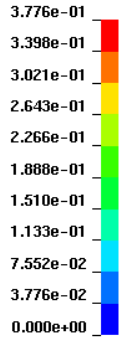
University of Waterloo

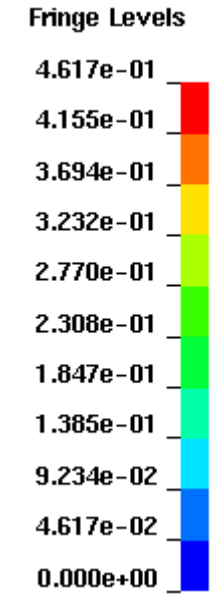




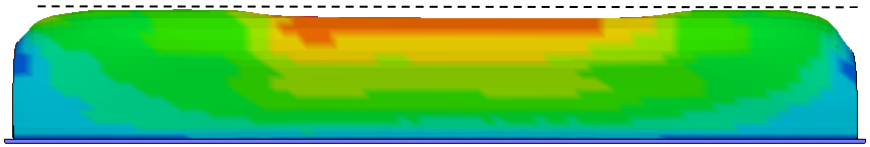
Shape prior to impact





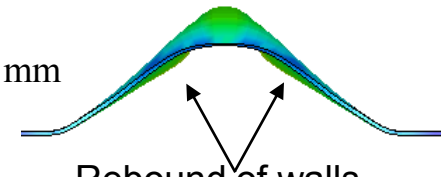


Effective plastic strain



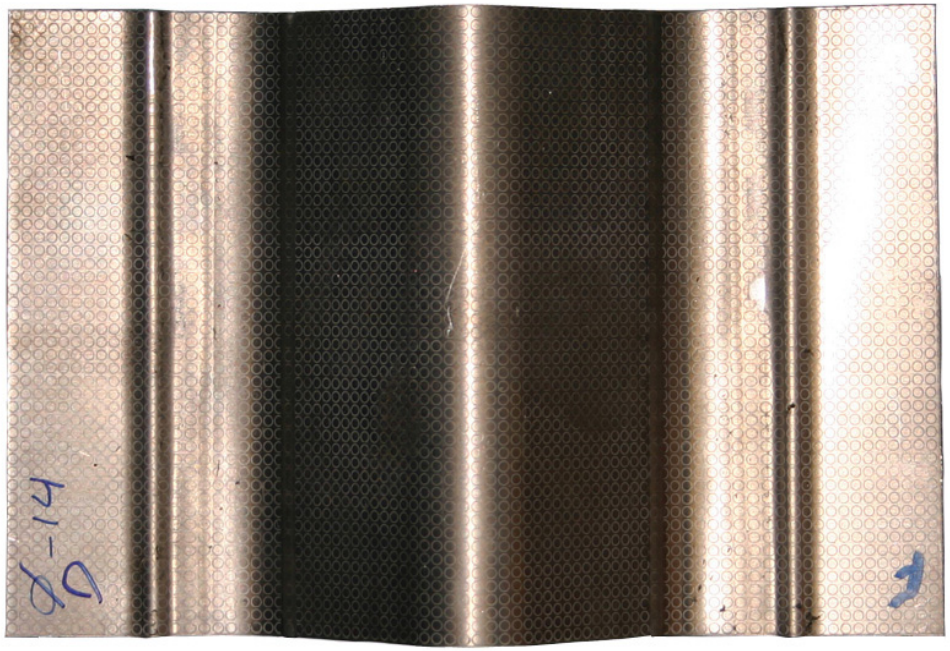
30.2 mm

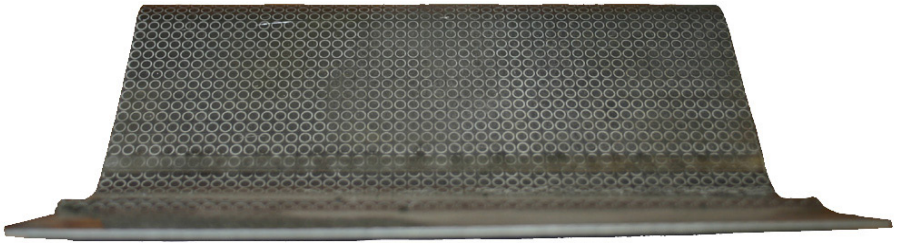
Final shape



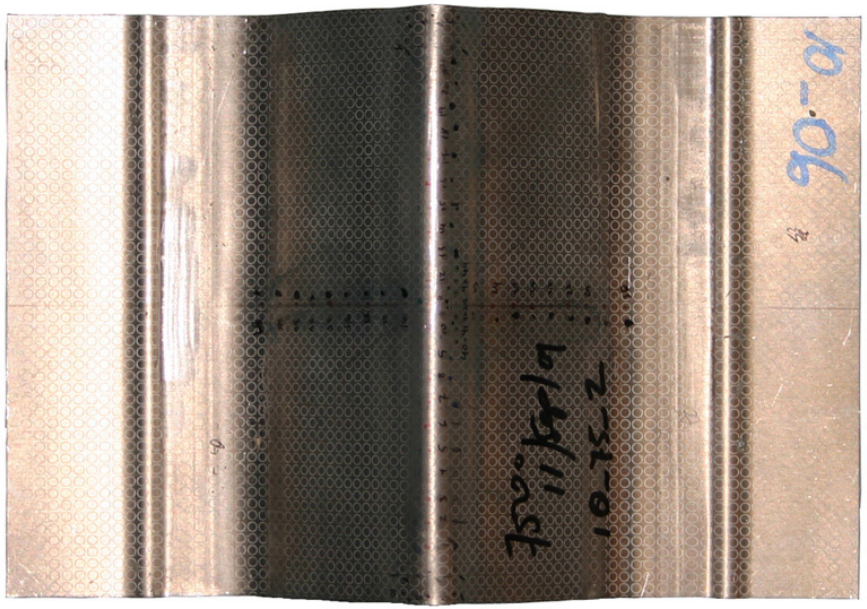
Rebound of walls

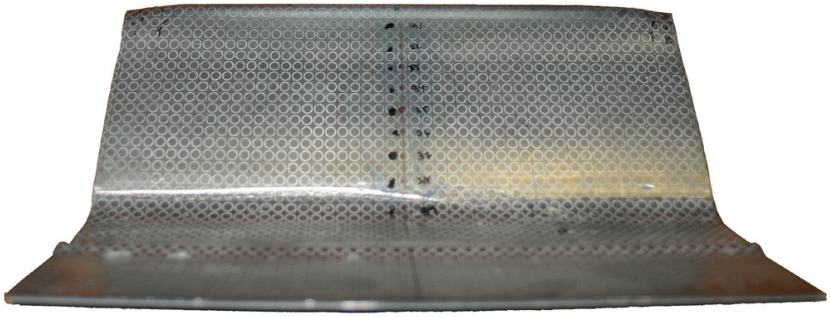
Two Step Corner Fill-Conventional Step



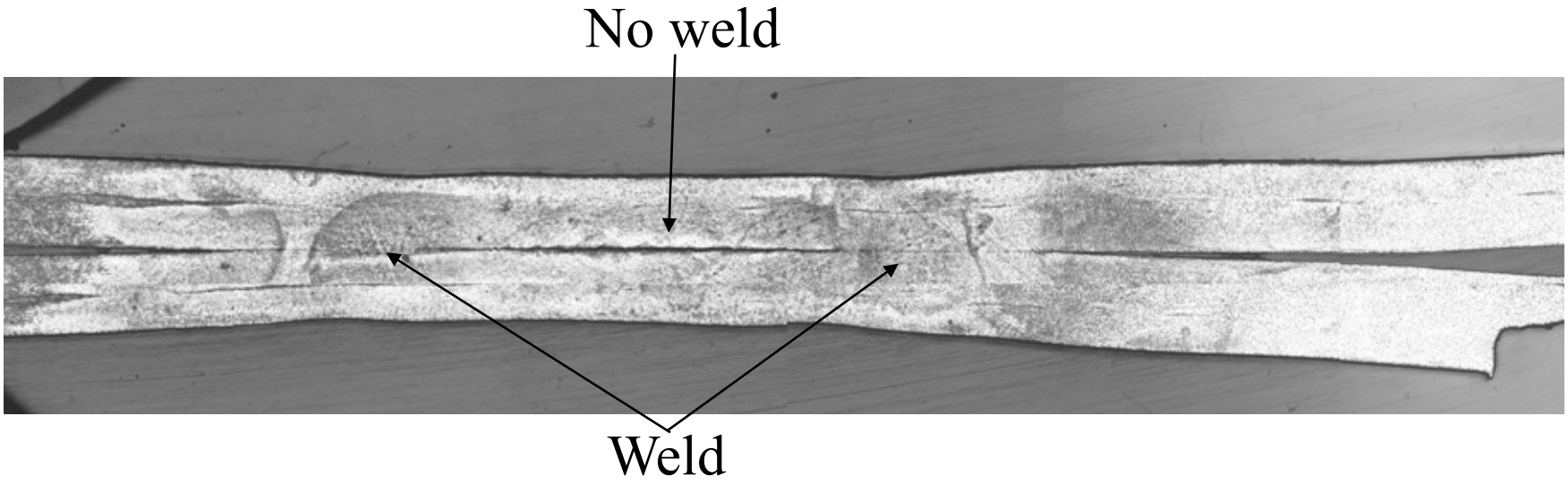


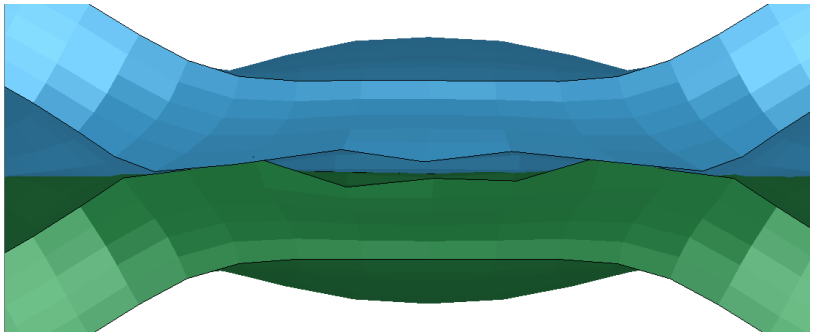
Two Step Corner Fill-EM Step





Rebound in Sheet Welding (Al-Al)





Conclusions

University of Waterloo

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

University of Waterloo

QUESTIONS?