Dimensional Control and Formability in Impact Forming

A simulation perspective

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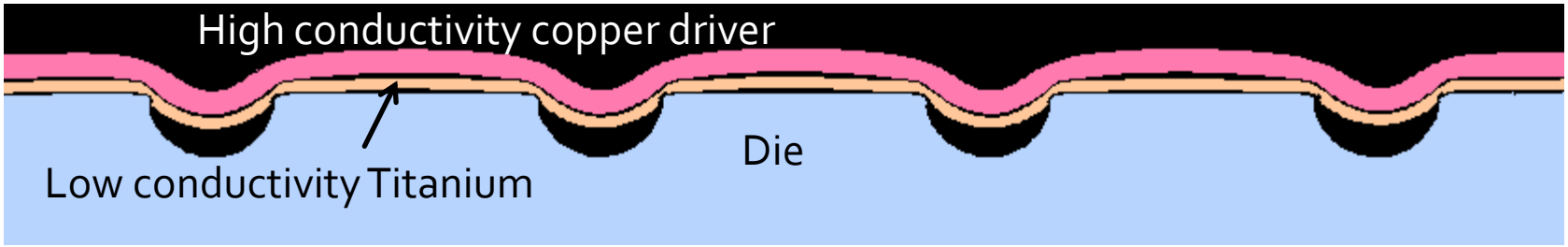
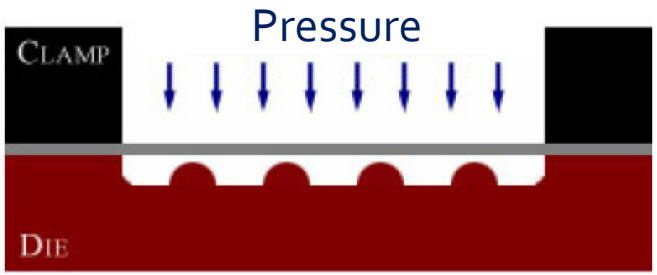
Motivation

- Dynamics of impact
- Shape fidelity & frictional effects
- Rebound characteristics (Magnetic pressure effect)
- Constitutive and failure laws



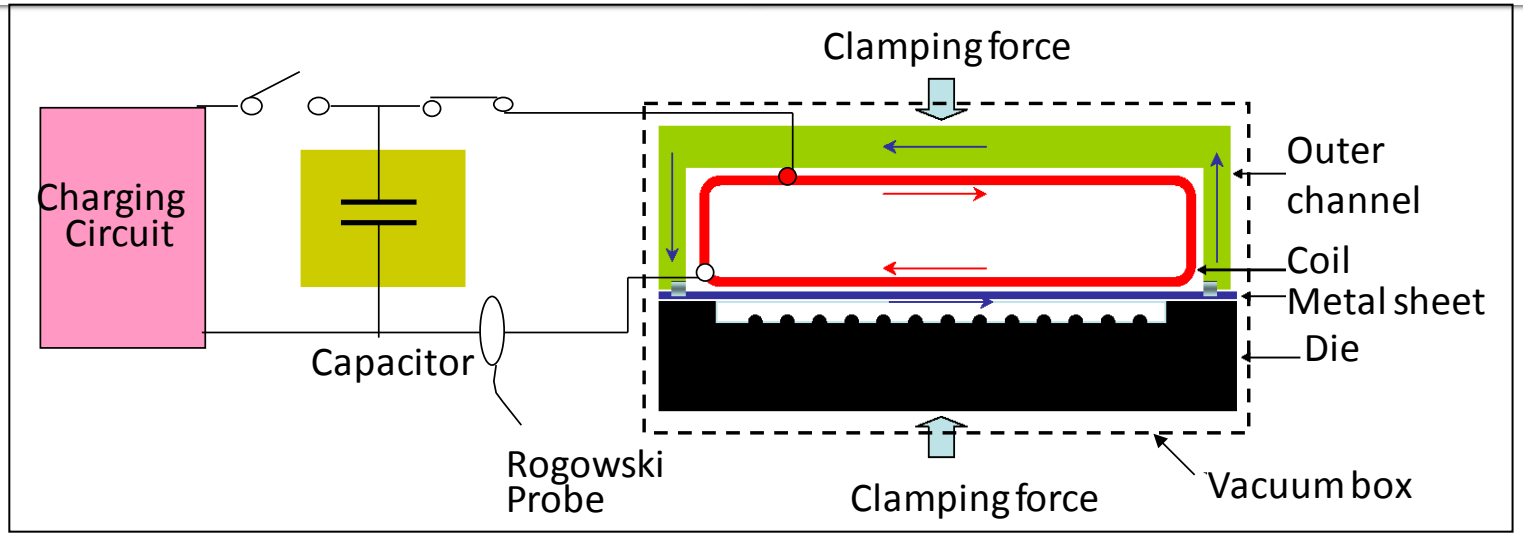
Boundary conditions

- Uniform pressure applied on copper driver section
- Velocity from model compared against experimental velocity (PDV)
- Mechanical deformation only
- Computationally efficient – electro-magnetics decoupled from solver



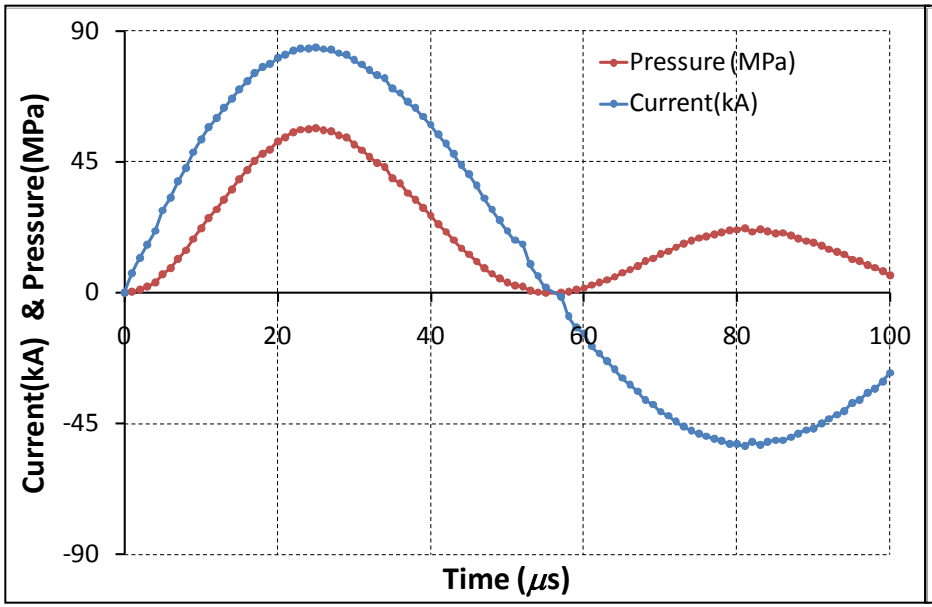
Schematic

Experiments

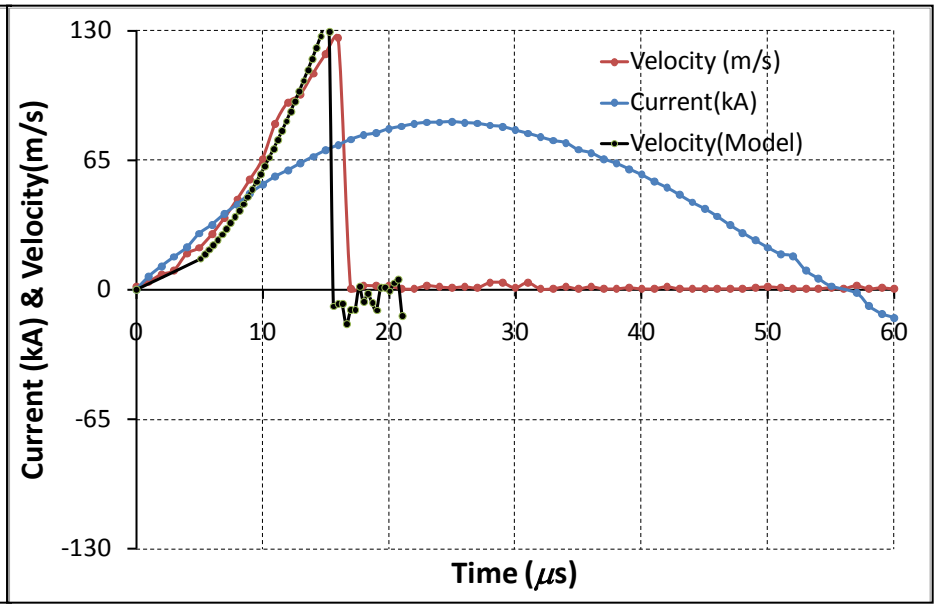


- Titanium sheet is formed using copper as driver
- Velocity of flyer is measured using Photon Doppler Velocimeter system
- Energy range - 1.6 to 6.4 kJ, Vacuum 100 Torr Standoff 2 mm, Peak velocity range 100-300 m/s

Model variables@ 3.2 kJ



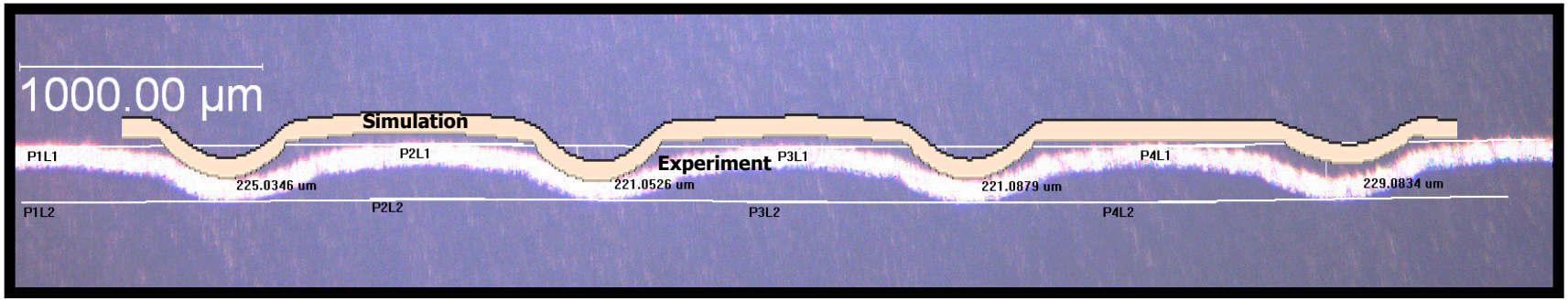
Input current



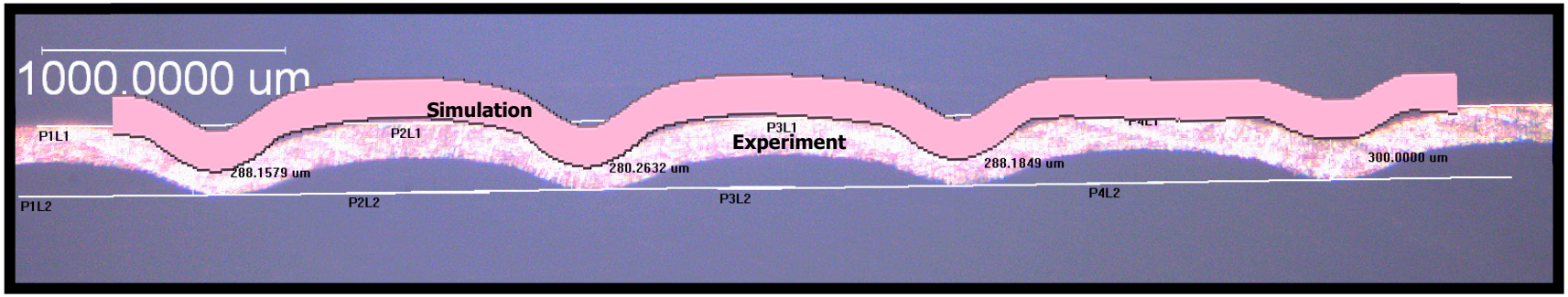
Output velocity

Strains @ 3.2 kJ

Model validation



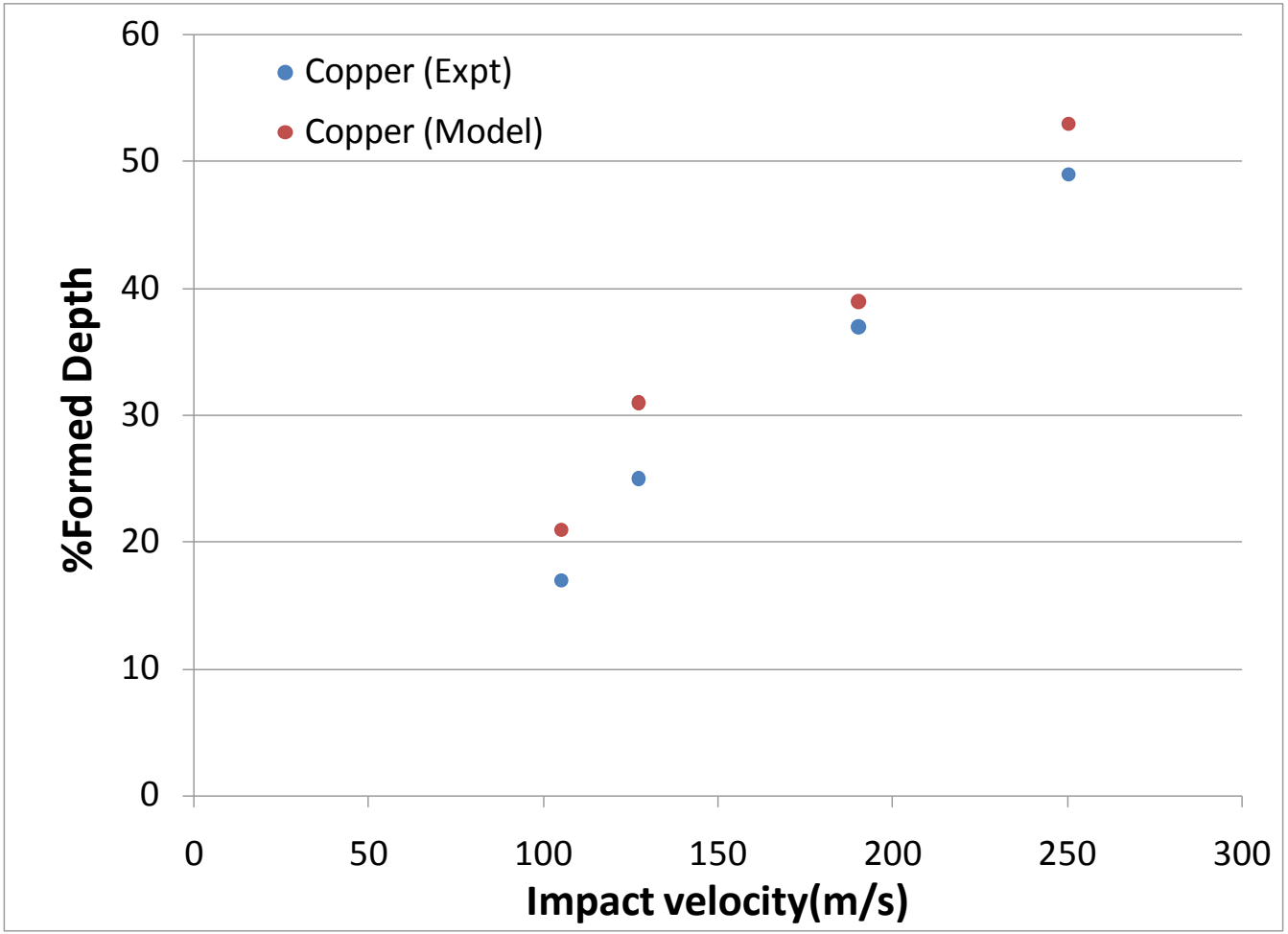
Titanium after impact @ 3.2 kJ



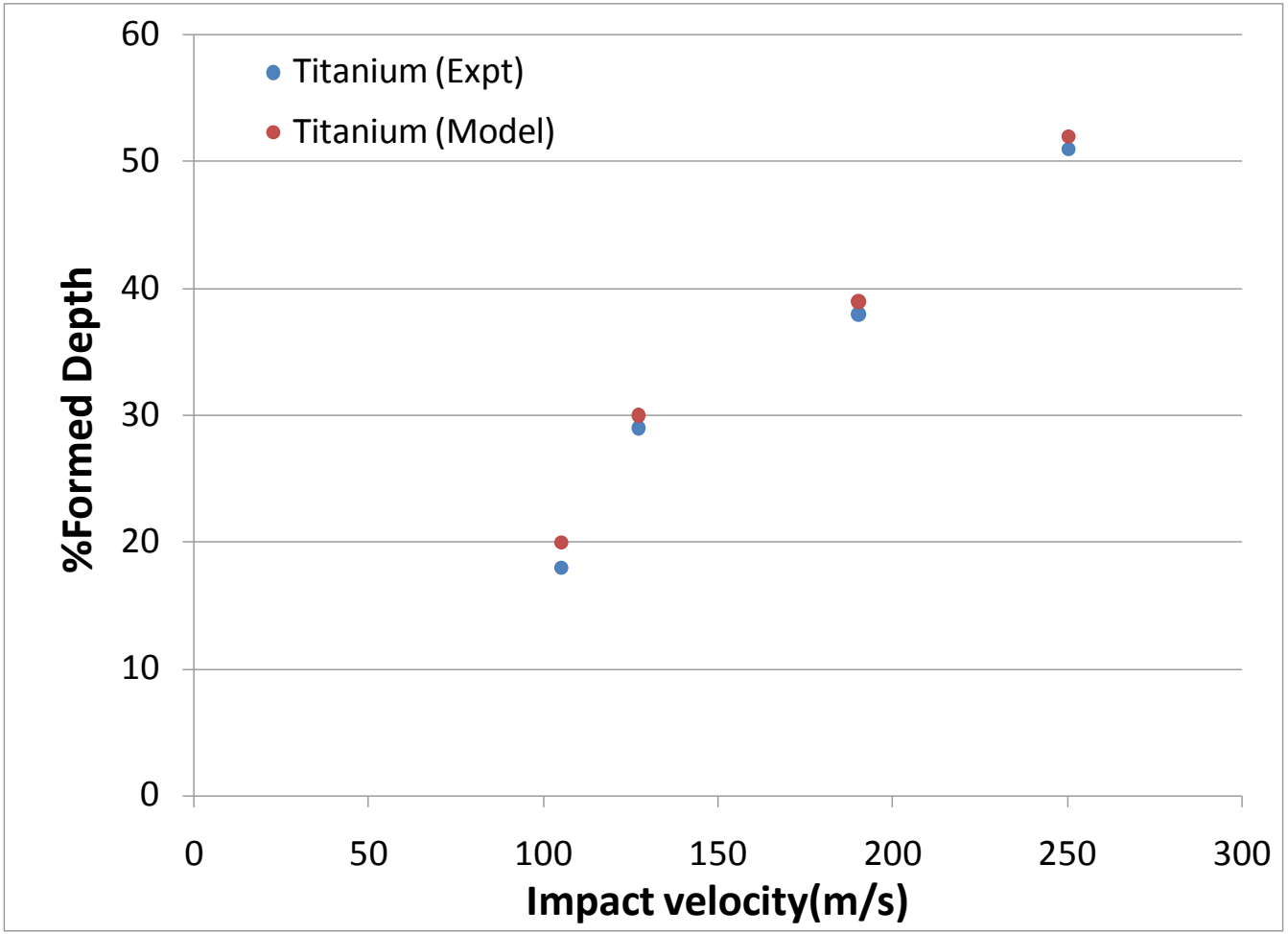
Copper Driver after impact @ 3.2 kJ

*Courtesy: Huimin Wang, EMF group

Form depth (Copper)



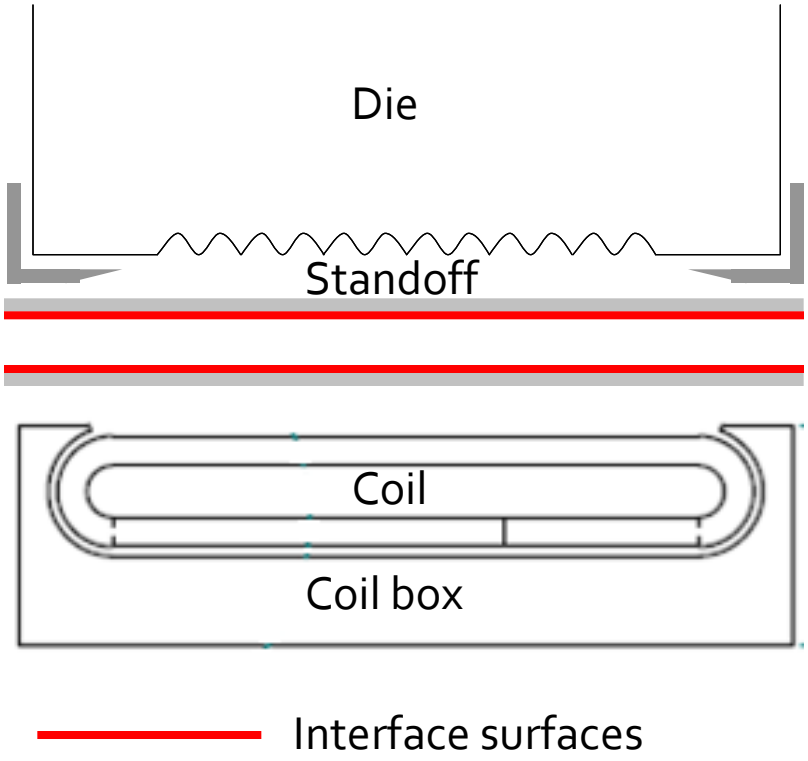
Form depth (Titanium)



Interface Effects

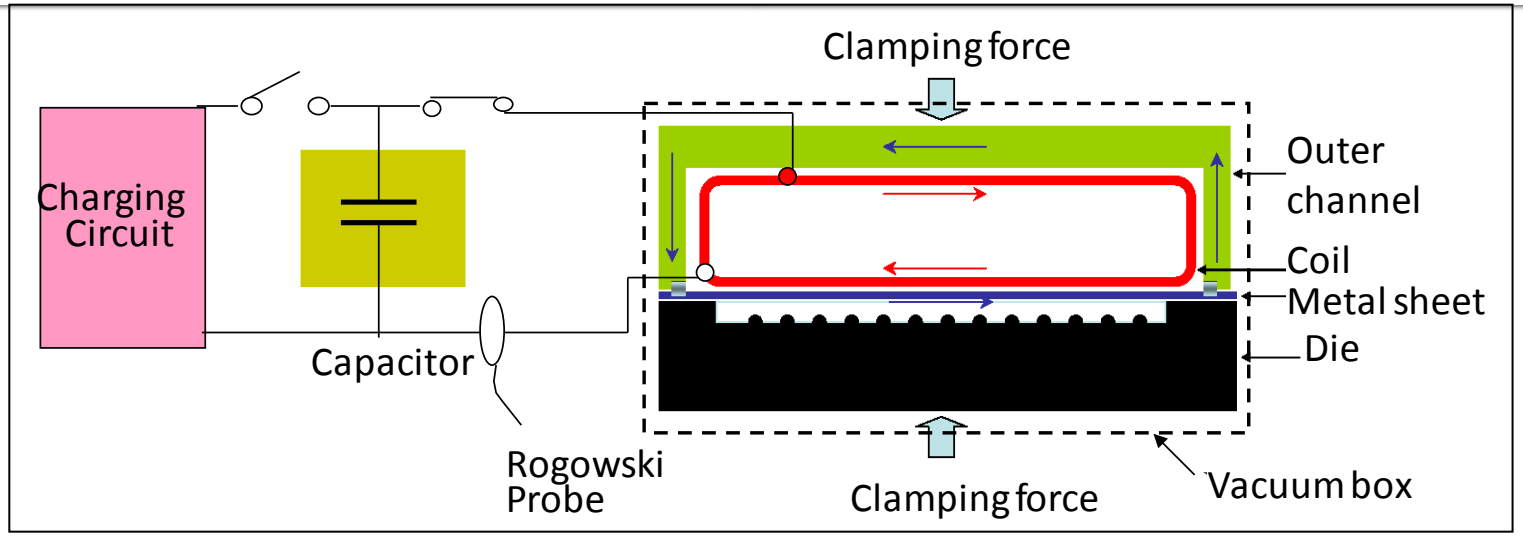
Interface = Mating sides between driver and forming material

- "Sticking" at interface between driver and work piece
- To avoid sticking placed different media in interface
- Media included paper, carbon copy paper, and vacuum grease
- Sticking eliminated, however shearing resulted



*Courtesy: Kristin Banik, 2008

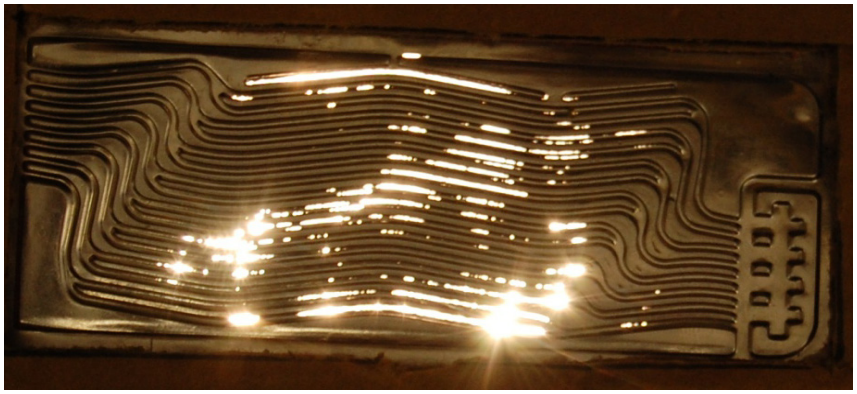
Experiments



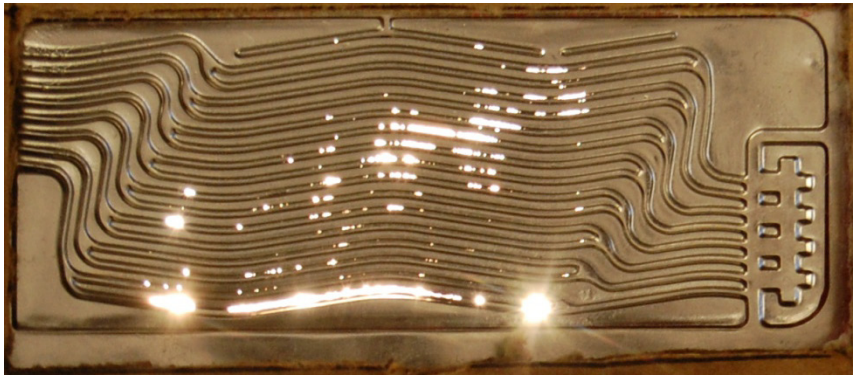
- 304 Steel sheet is formed using copper as driver
- Interface of study is the mating surface between driver sheet and workpiece
- Energy 4 kJ, Vacuum 90 Torr , Peak velocity 205 m/s Standoff distance 3mm

Results

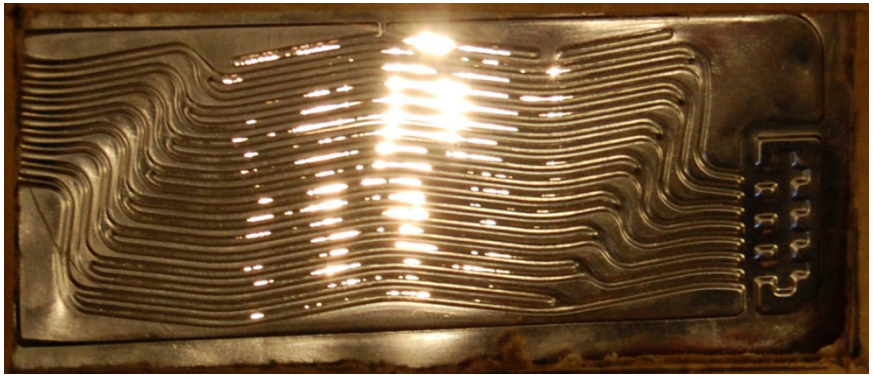
No interface material



Carbon Paper



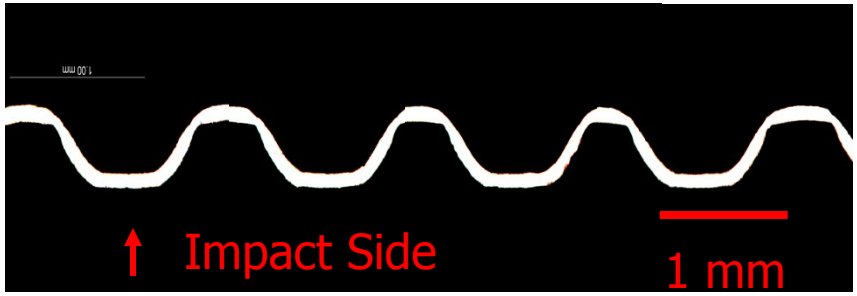
Paper



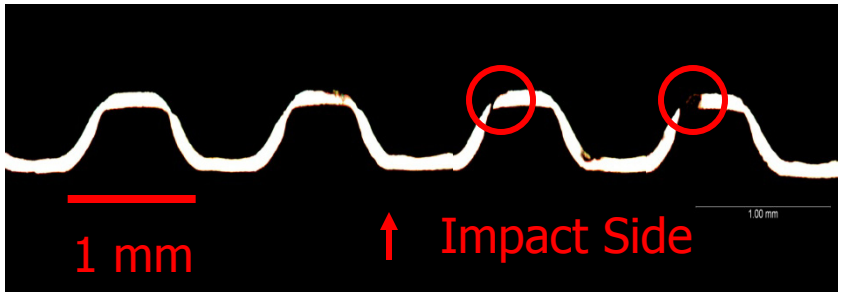
Vacuum Grease

Samples are illuminated from behind

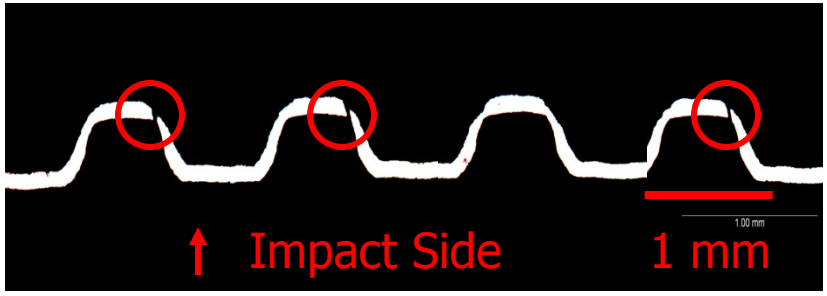
EMF Plate Cross Sections



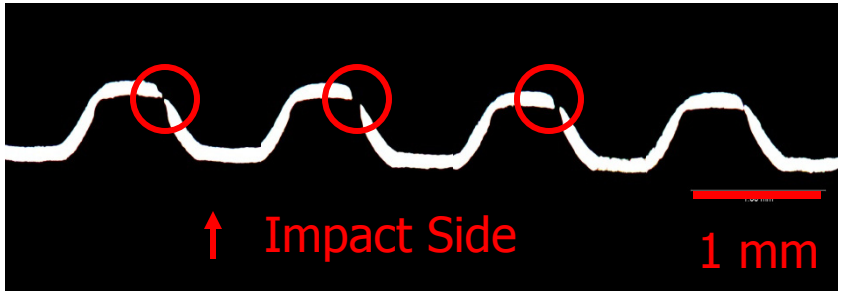
No interface material



Carbon Paper



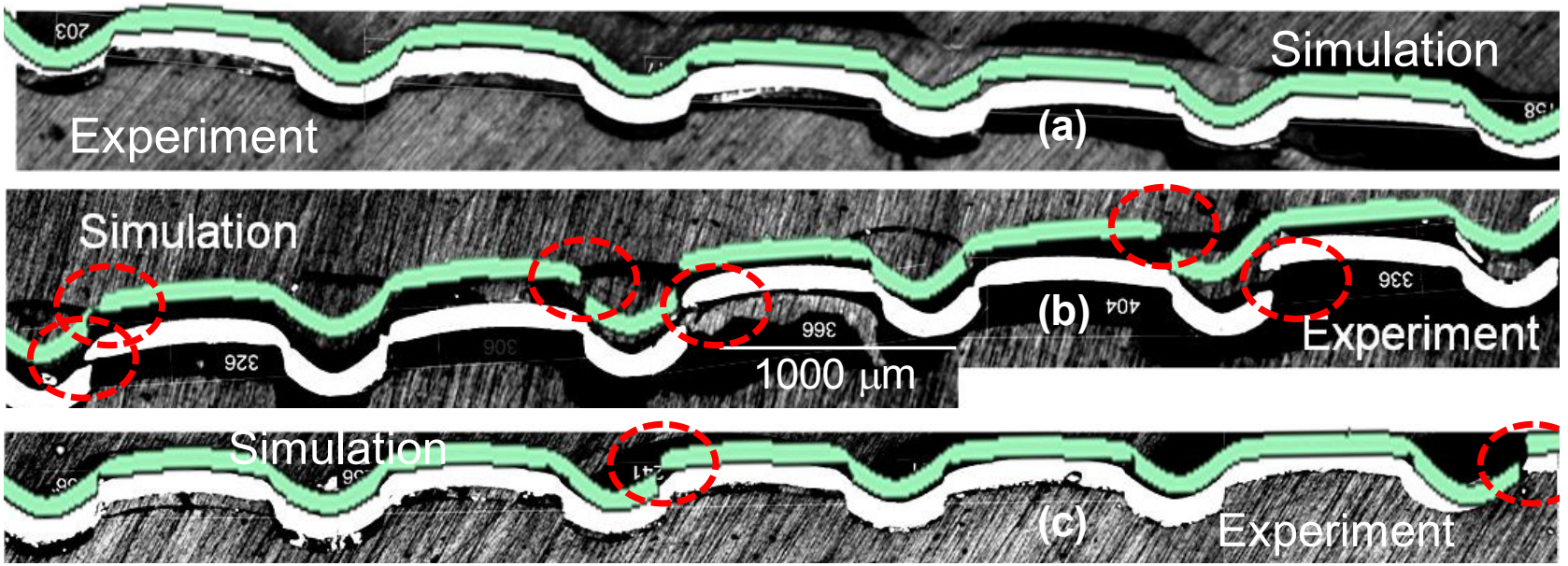
Paper



Vacuum Grease

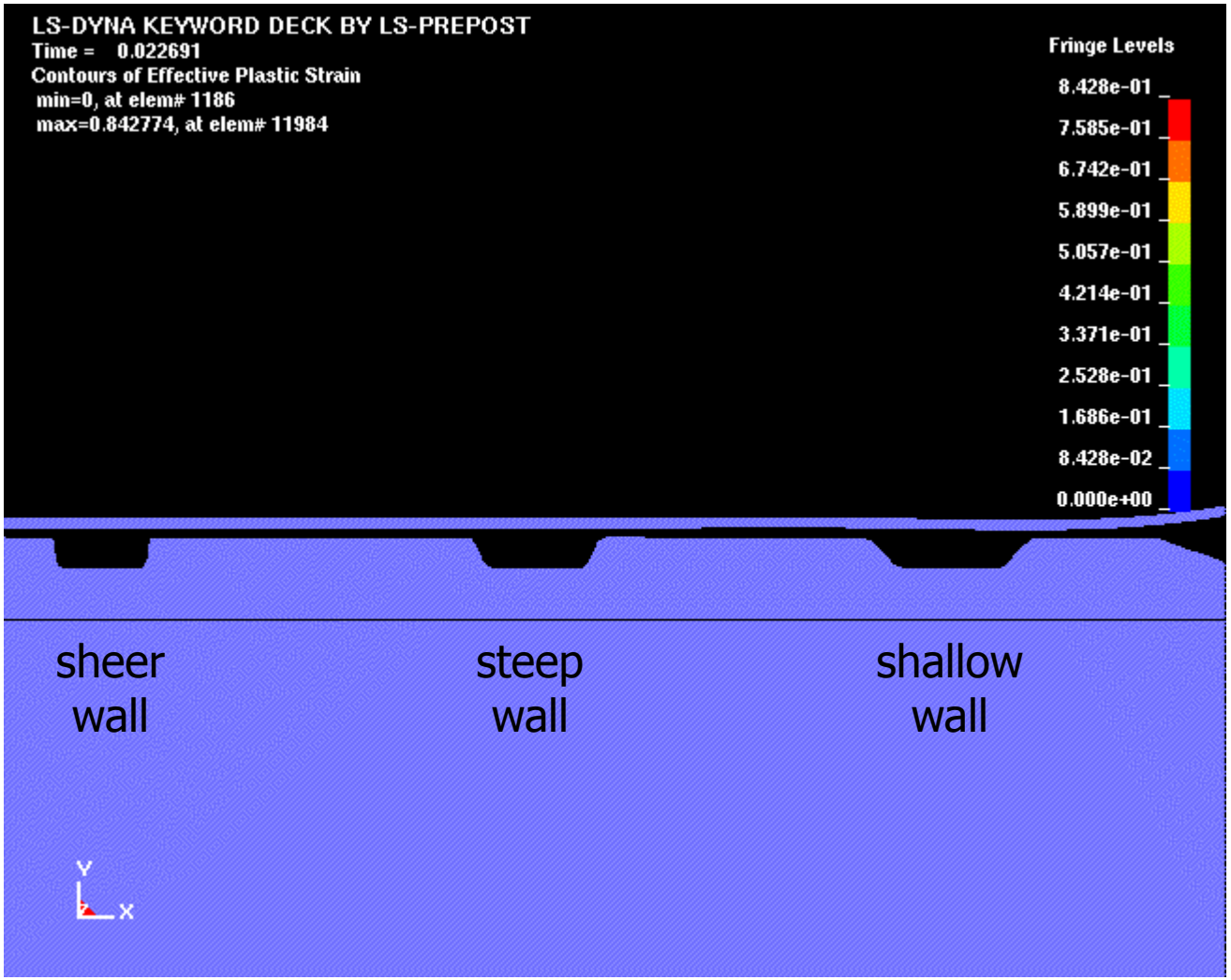
Peak Velocity 205 m/s

Friction calibration



- (a)No lubrication (μ=0.5)
- (b)Lubrication between Copper and SS201 (austenitic steel) (μ=0.5 / μ=0.05)
- (c)Lubrication between all interfaces (μ=0.05)

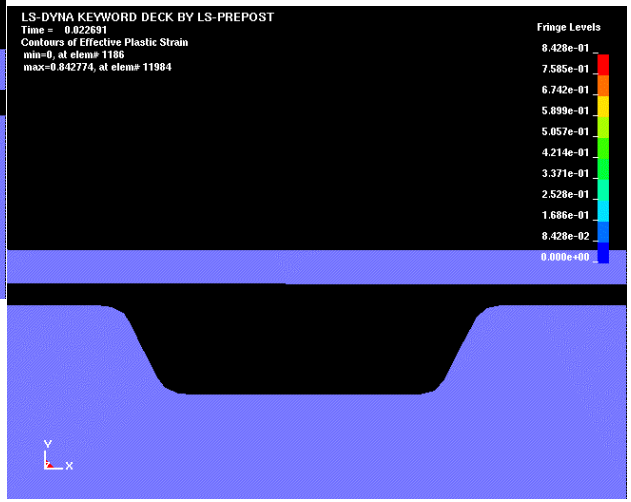
No Lubrication (μ=0.5)



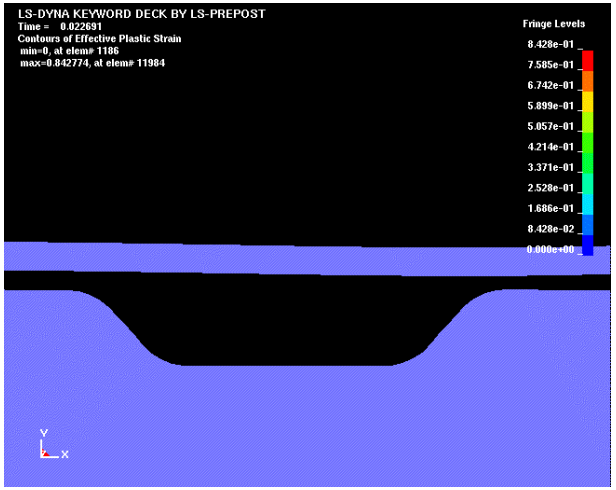
Lubrication (μ=0.05)

Entry angle (Friction 0.5)

Channel 1 (θ_1)



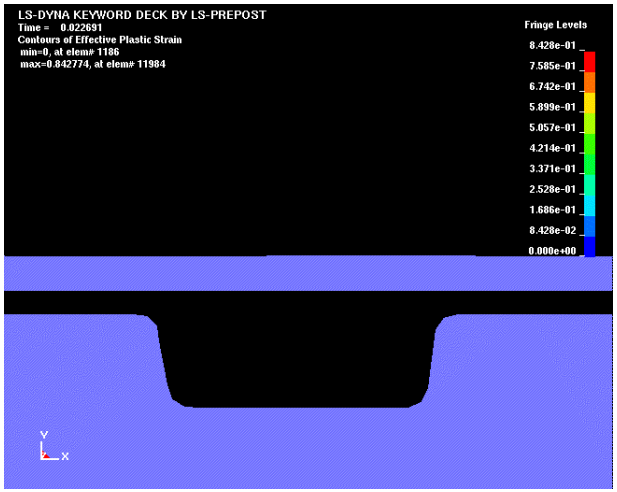
Channel 2 (θ_2)



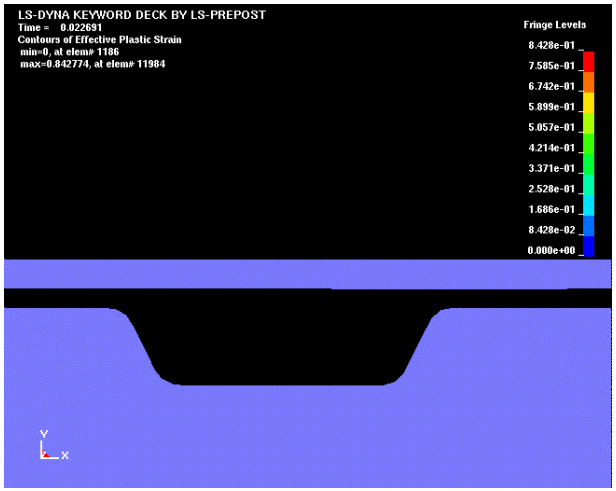
Channel 3 (θ_3)

$$\theta_1 > \theta_2 > \theta_3$$

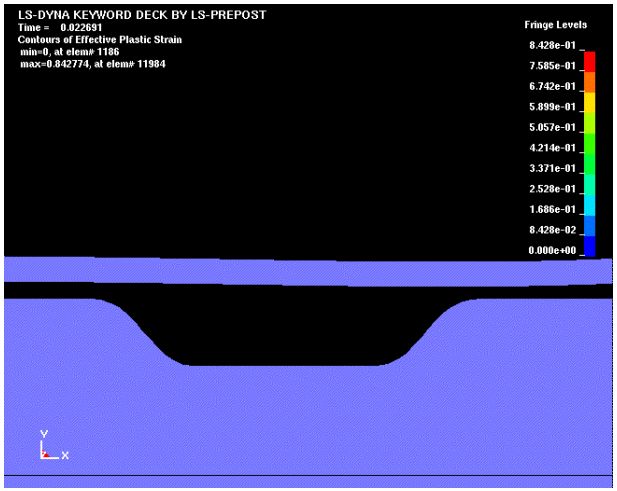
Entry angle (Friction 0.05)



Channel 1 (θ_1)



Channel 2 (θ_2)

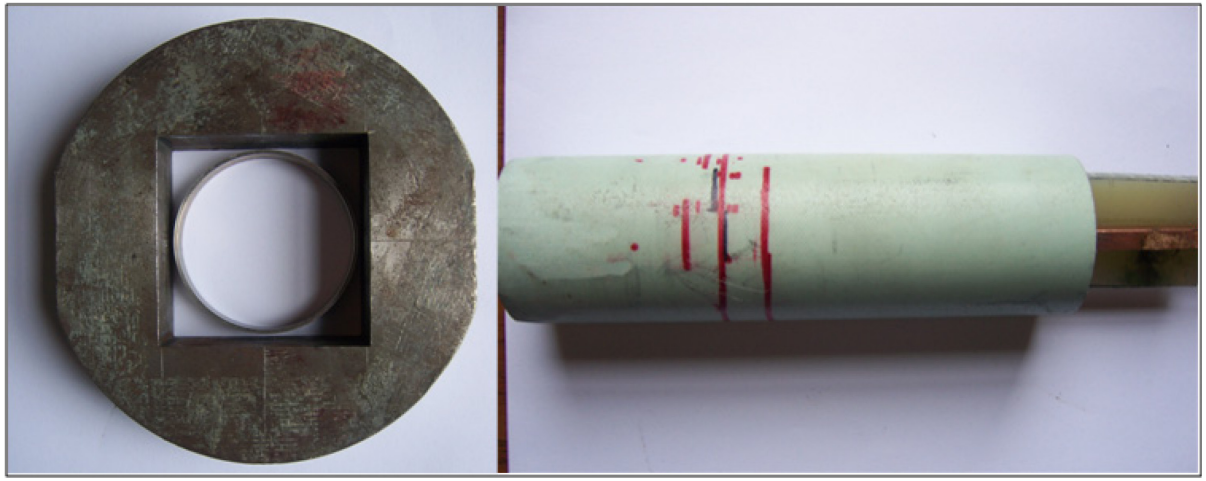


Channel 3 (θ_3)

$\theta_1 > \theta_2 > \theta_3$

Shape fidelity

Experiments

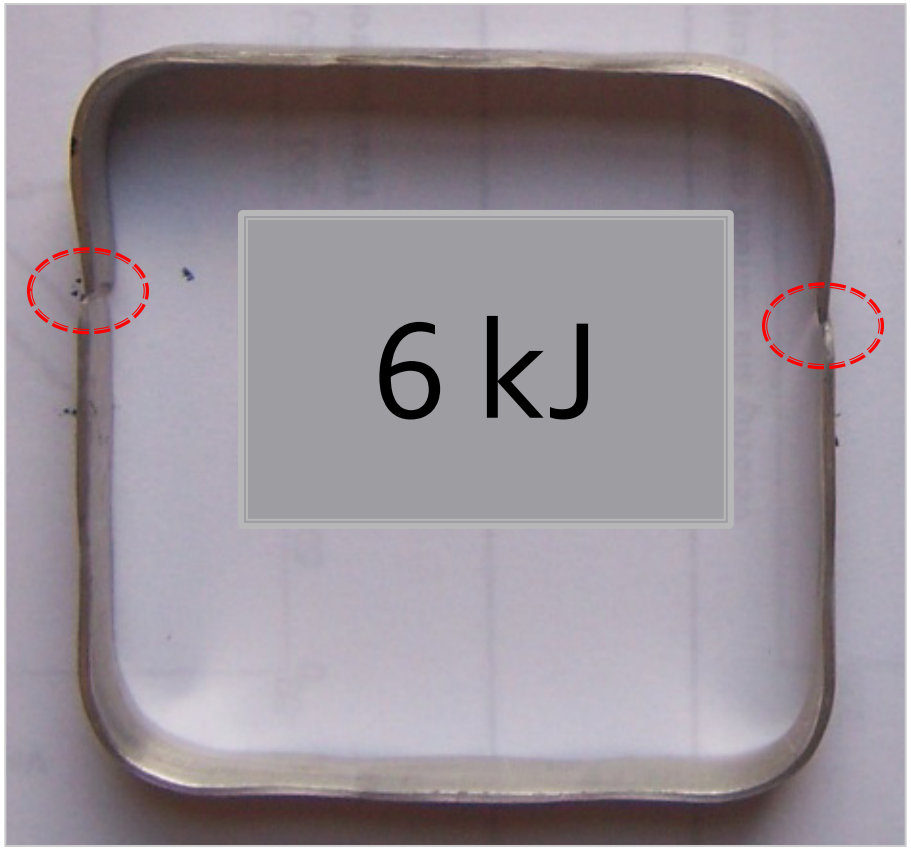


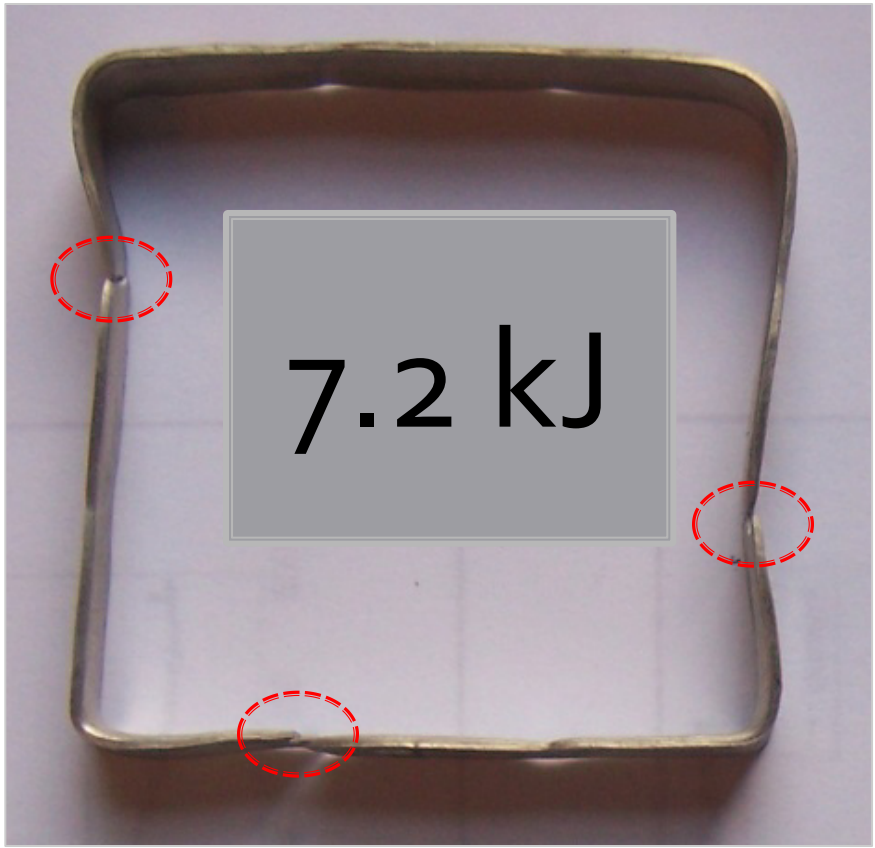
Ring constrained in square

Cylindrical coil

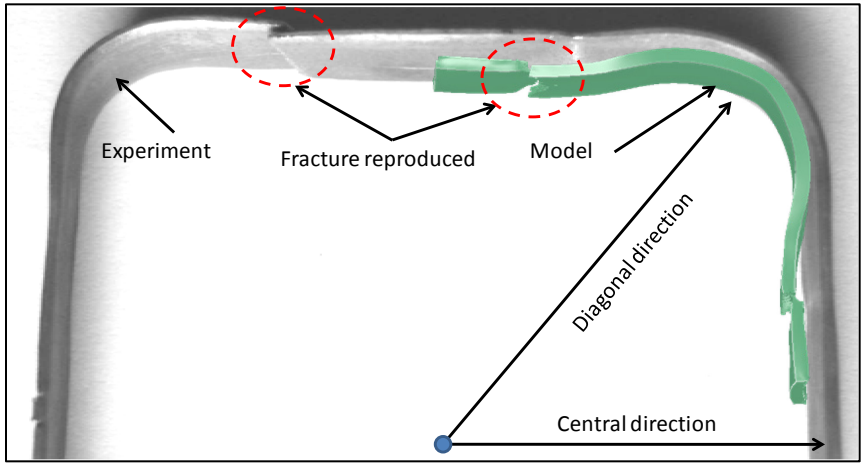
- Aluminum rings are formed without any driver
- Velocity of flyer is measured using Photon Doppler Velocimeter system
- Energy range - 6 to 8 kJ, Standoff 2 mm, Peak velocity range 100-200 m/s

Ring specimens after impact

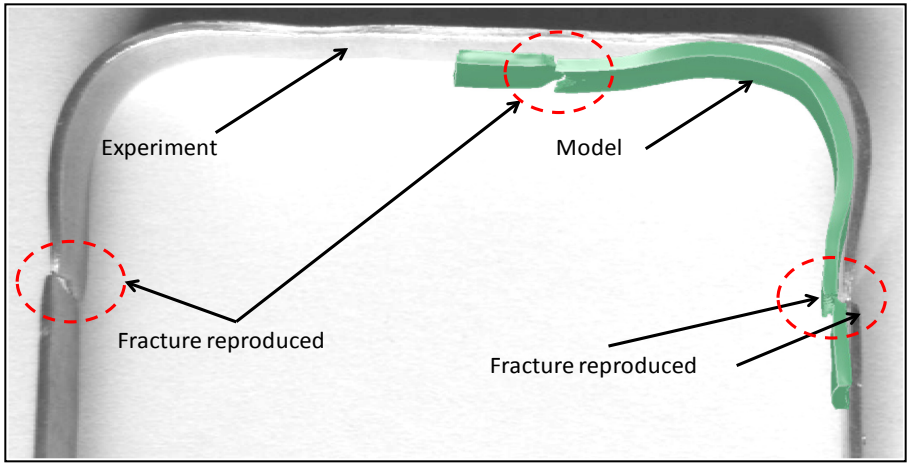




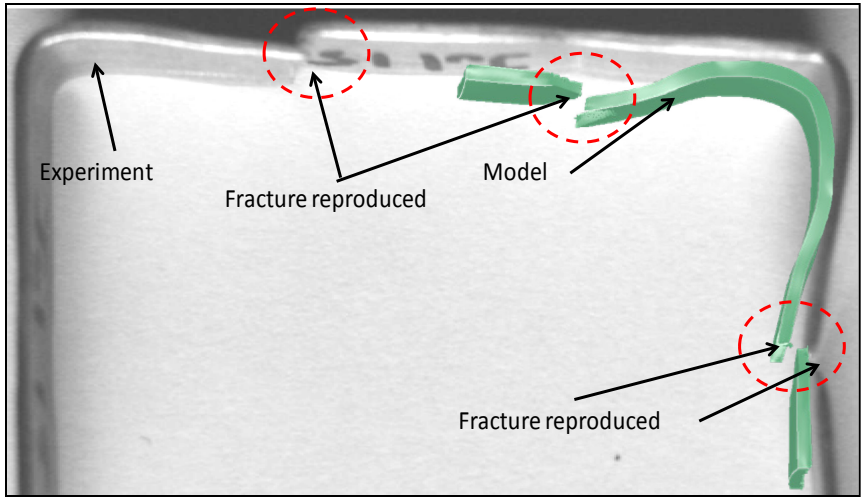
Model vs. Experiment



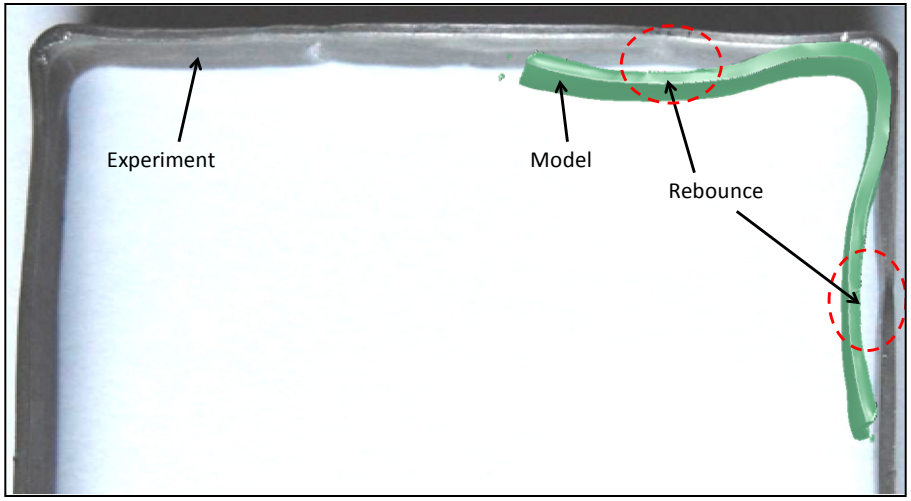
Energy 5.6 kJ



Energy 6 kJ

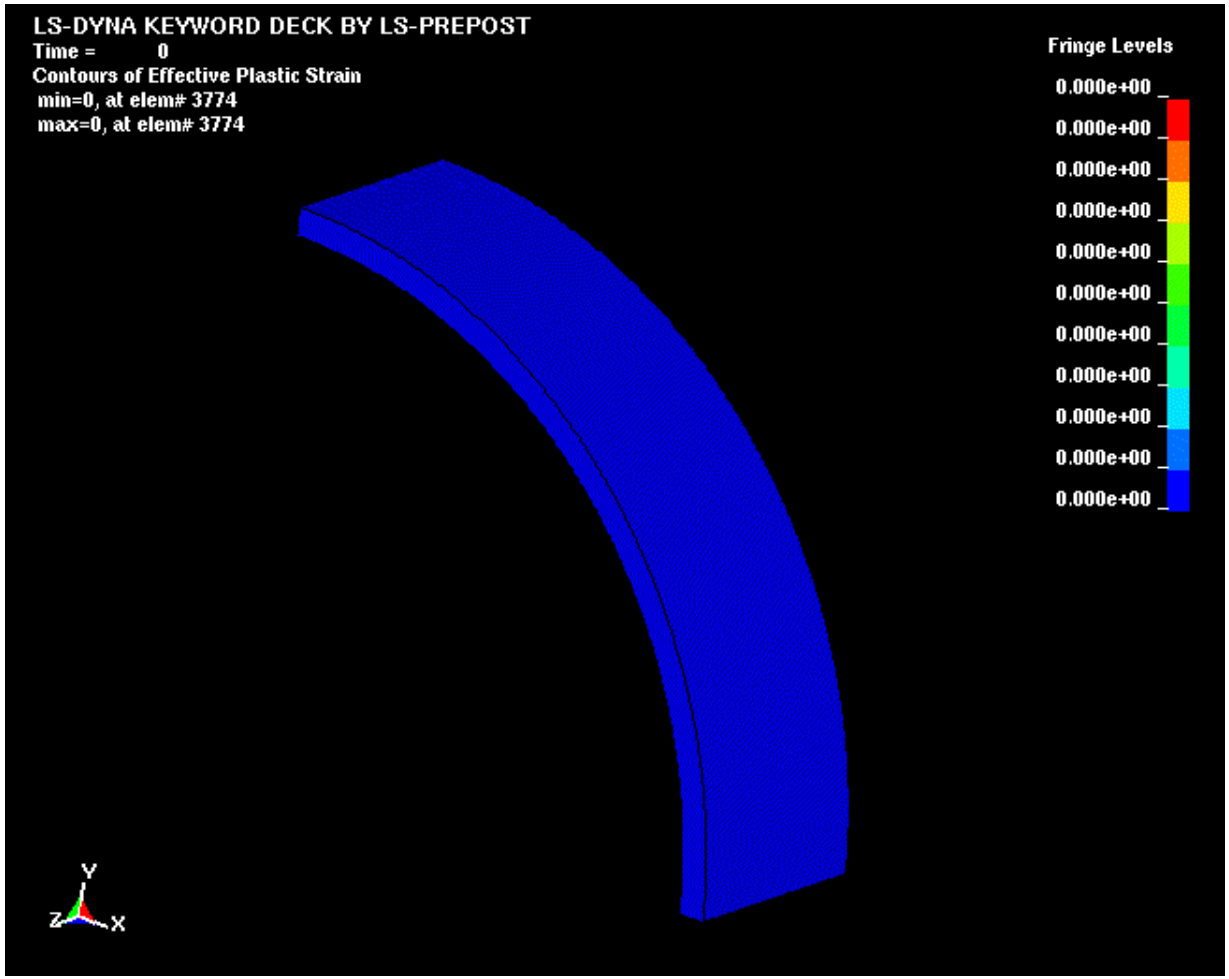


Energy 6.72 kJ



Energy 7.2 kJ

@ 6 kJ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Contours of Effective Plastic Strain
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max=0, at elem# 3774
Fringe Levels
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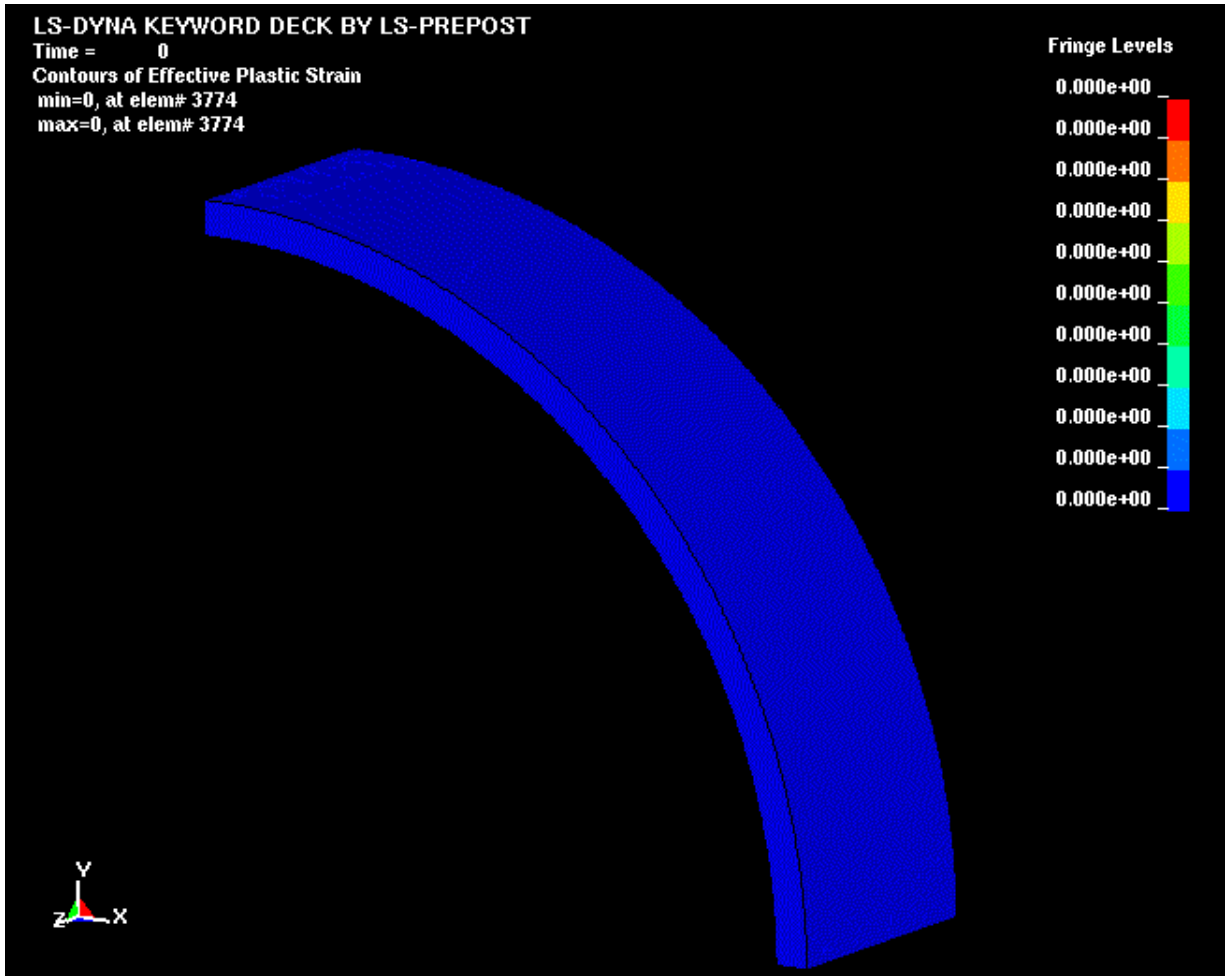
0.000e+00
0.000e+00
0.000e+00
0.000e+00
0.000e+00
0.000e+00
0.000e+00
0.000e+00
0.000e+00
Y
Z
X

@ 7.2 kJ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Contours of Effective Plastic Strain
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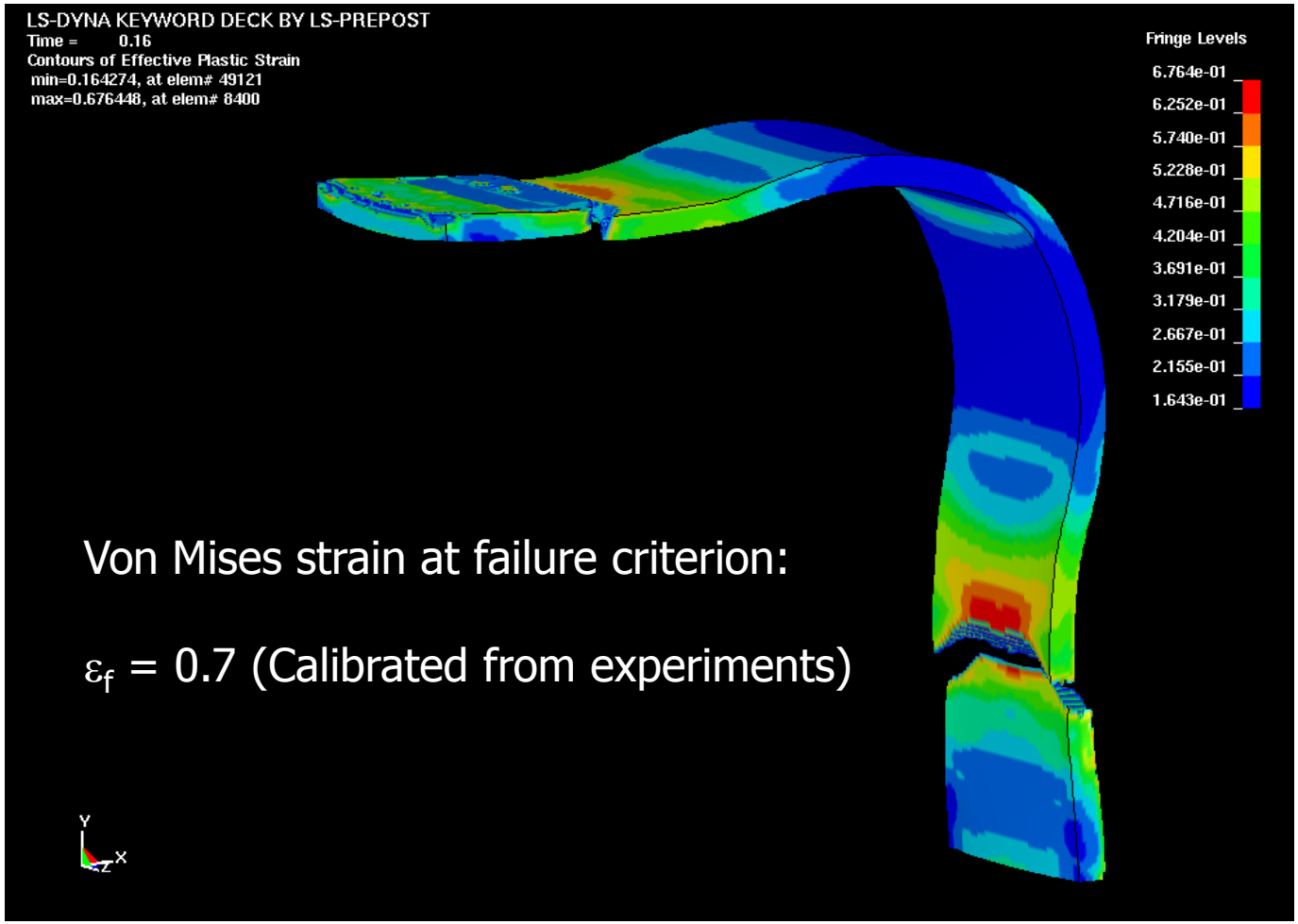
0.000e+00
0.000e+00
Y
Z
X

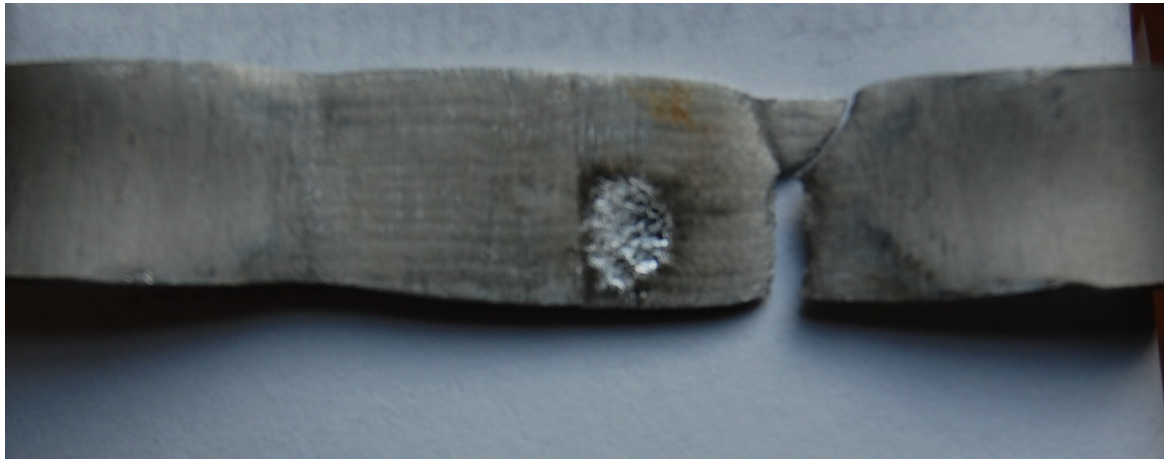
Failure laws

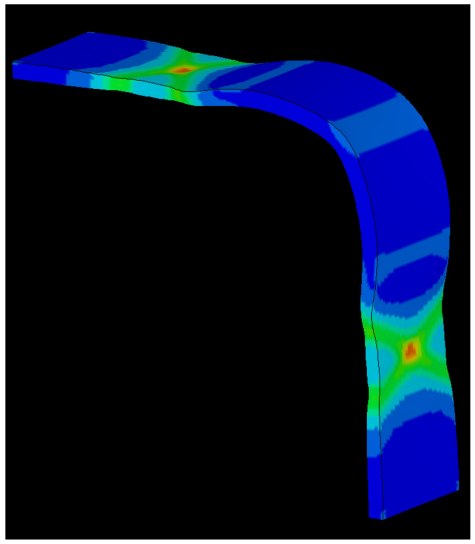


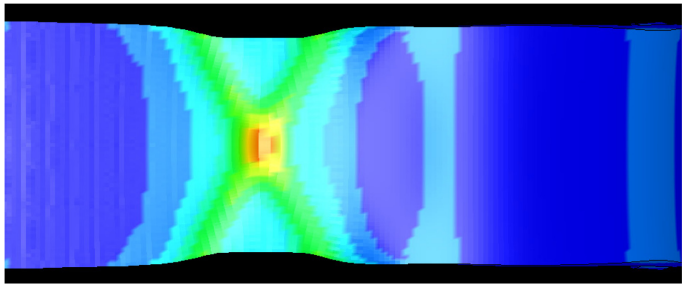
Von Mises strain at failure criterion:

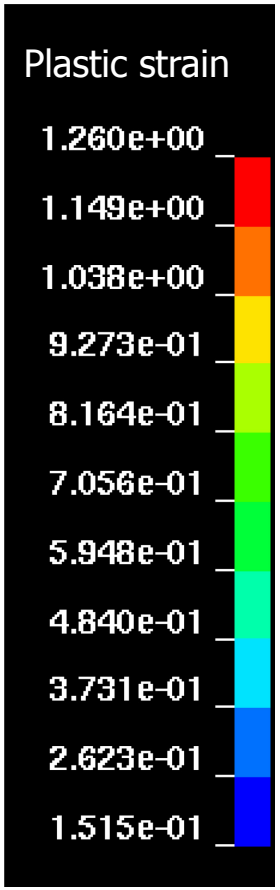
ε_f = 0.7 (Calibrated from experiments)

Fracture mode

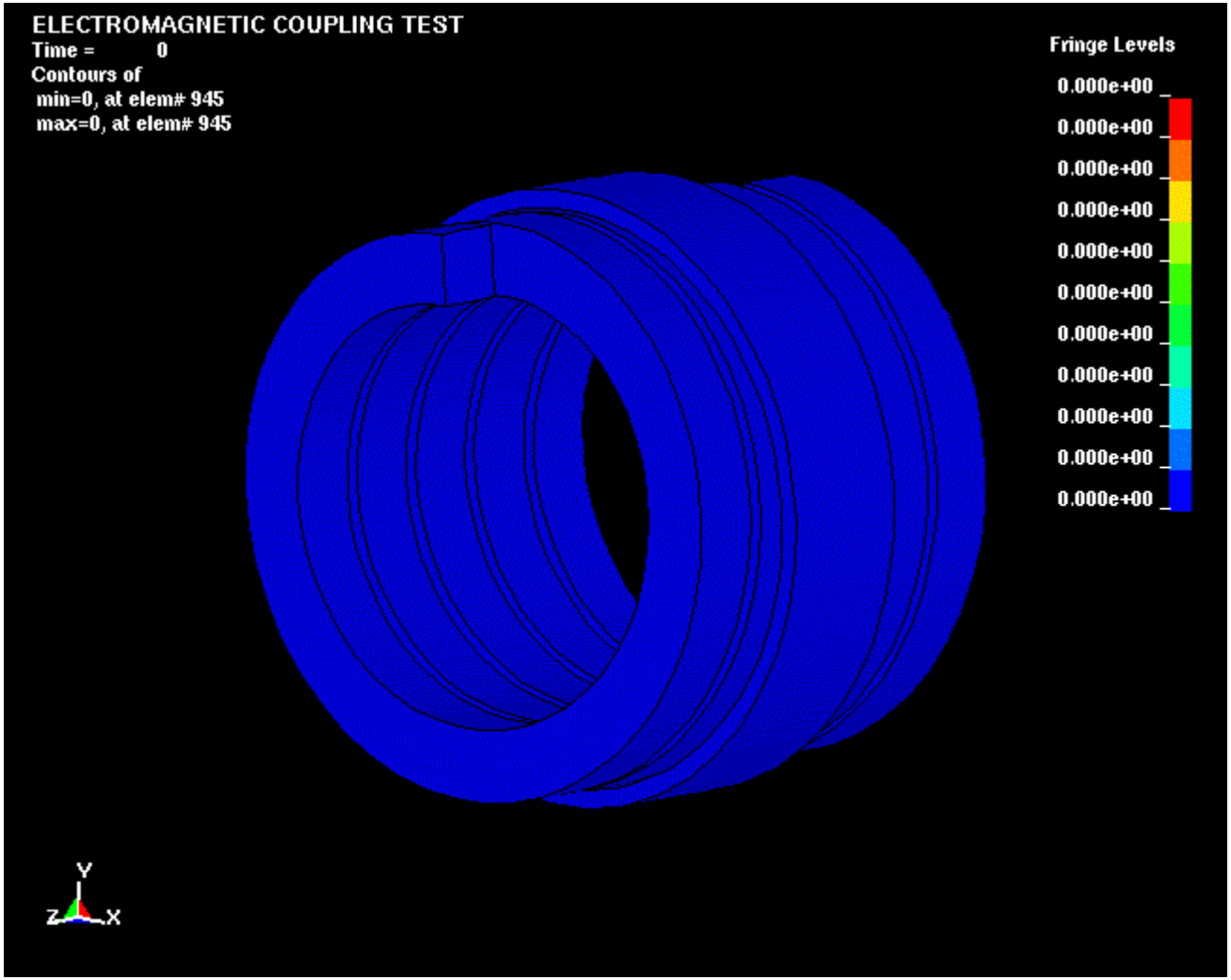








Effect of magnetic pressure



Note: Magnetic pressure restores shape

Conclusions

- Friction plays a critical role in influencing formed product quality
- Mechanical simulation shows exaggerated rebound. Electromagnetic simulation shows realistic rebound
- Magnetic pressure wave stabilizes the ring into the square cavity minimizing rebound
- Higher velocities diffuse plastic strains through the entire sample thus preventing necking
- Channel entry angle influences formability and welding

Acknowledgements

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- Steve Hatkevich, American Trim