ICHSF2012 INTERNATIONAL CONFERENCE ON HIGH SPEED FORMING

A Study on Contour of Workpiece According to the Shape of Forming Coil in EMF Process

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2012.04.25

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- Electromagnetic forming system
- Setup and procedure
- Results and discussion

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- Results and discussion

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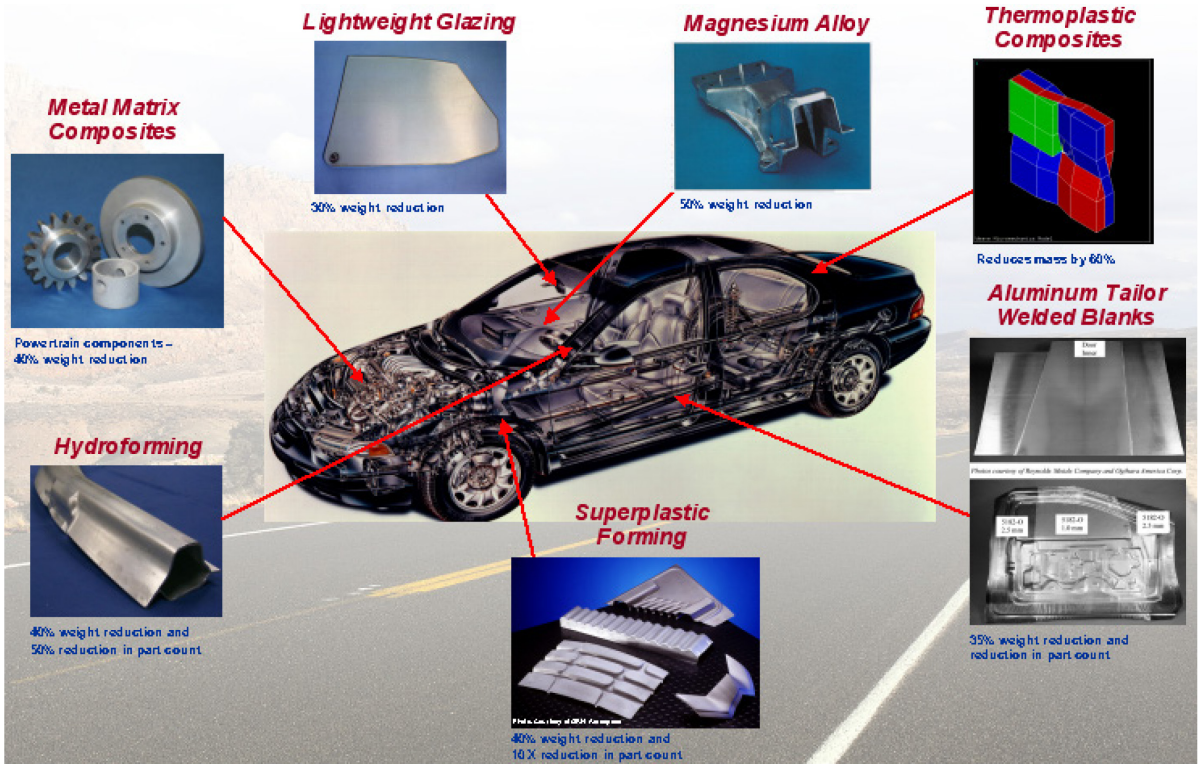
Introduction – Motivation

- Lightweight cars for energy efficiency

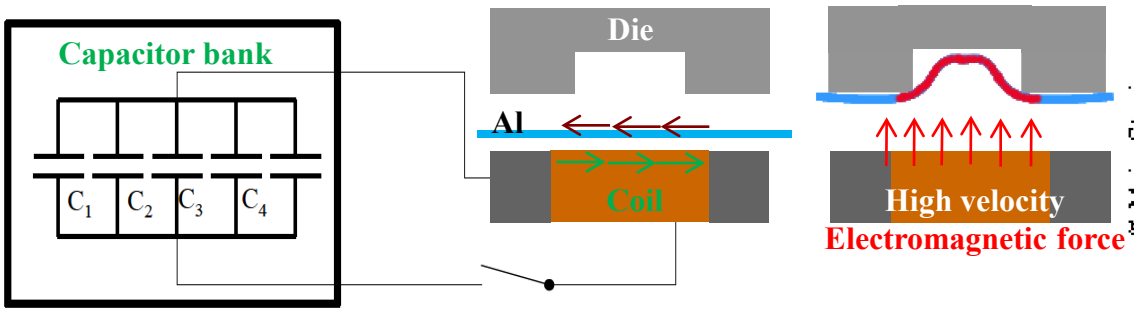
- Light weight materials for automotive application such as aluminum body frame



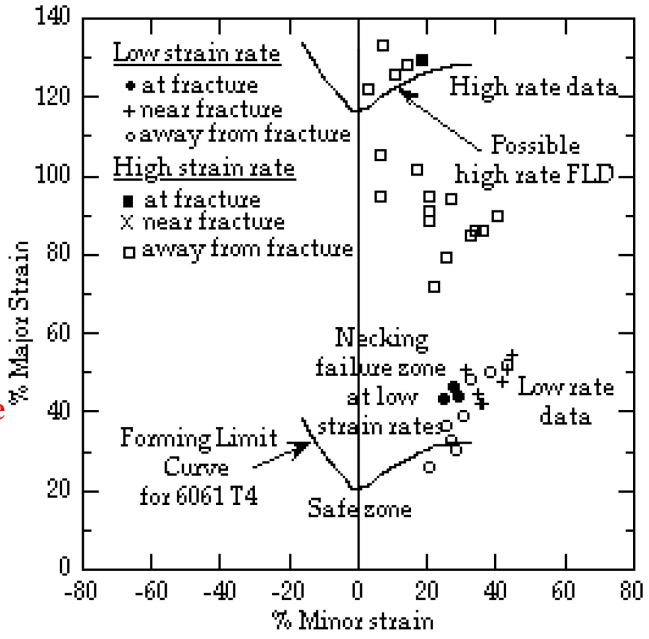
* Pacific Northwest National Laboratory, USA

Introduction – Motivation

EMF process



- **Fast forming process (≥100us)**
- **One side die**
- **Environmentally friendly forming process**



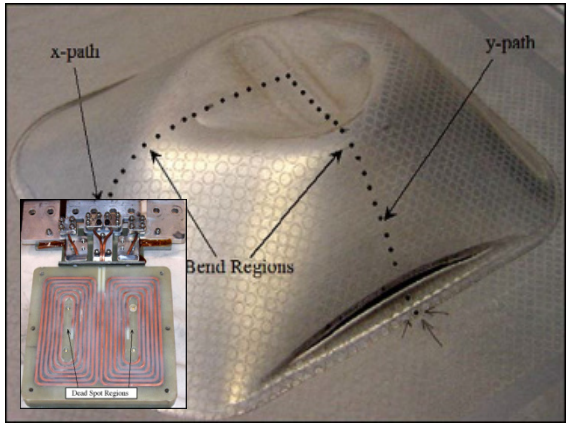
Forming limit diagram Al6064-T4

* G. S. Daehn et al.,Improved Formability with Electromagnetic Forming: Fundamentals and a Practical Example (1998)

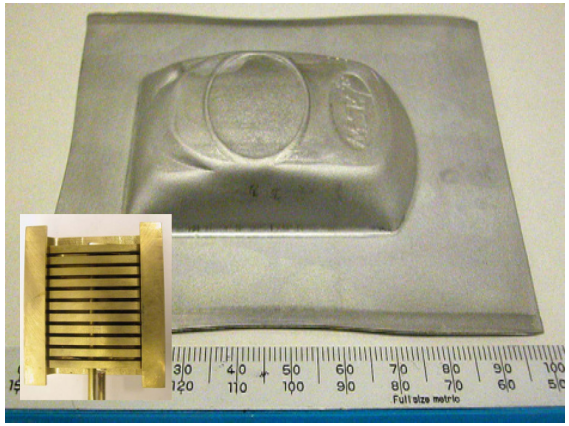
Introduction – Related research

- G. S. Daehn et al. : High velocity metal forming mechanisms analysis(OSU)
- Oliveria et al. : Aluminum sheet forming using double spiral coil (Univ. of Waterloo)
- M. Kamal et al. : Development of cell phone case by two-step EMF (OSU)

G. S. Daehn et. al



D. A. Oliveira et al.

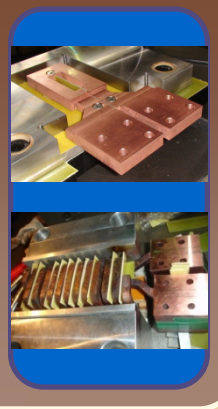


M. Kamal et al.

Introduction – Objectives

Experimental work

- 0.5mmt Al5052 sheet
- Bar-type, helical-type forming coil
- Effect of charging voltage
- Measurement of contour on workpiece



Numerical analysis

- Distribution of electromagnetic force

Analysis of contour on workpiece with various shape forming coil in EMF process

Experimental works

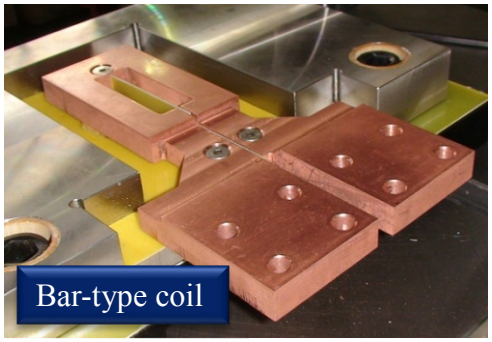
Electromagnetic forming system

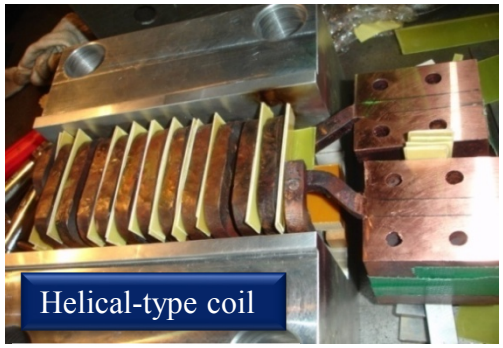
System capacitance		480uF
Charge voltages		1-10kV
Inductance	Bar-type	0.4μH
	Heliacal-type	2μH
Energy levels		2.4-24kJ

Experimental works

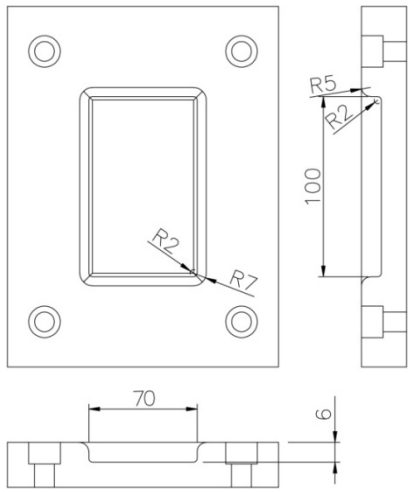
Setup and procedure

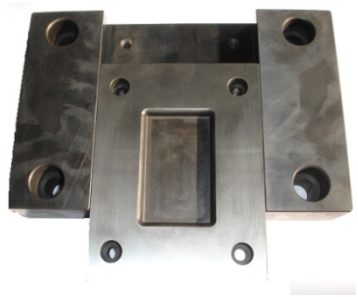
- **Bar-type, helical-type forming coil**


Bar-type coil


Helical-type coil

- **0.5mmt Al5052 sheet**
- **Charging voltages : 4, 5, 6kV**
- **Analyze the contour on workpiece using 3D scanning**



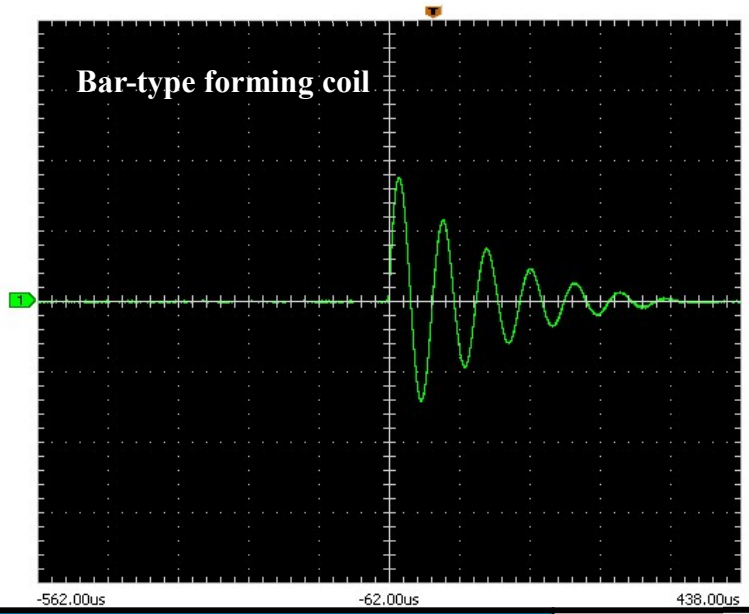


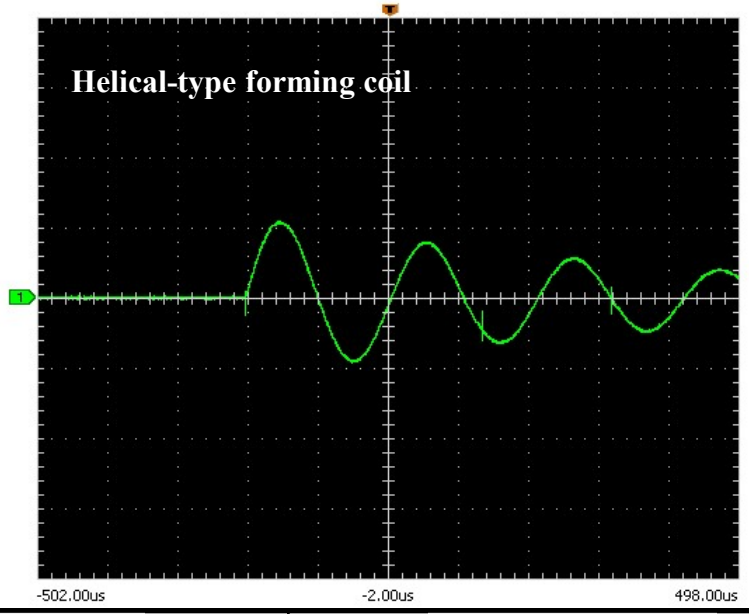
Rectangular box forming

Experimental works

Results and discussion

- **Primary current**



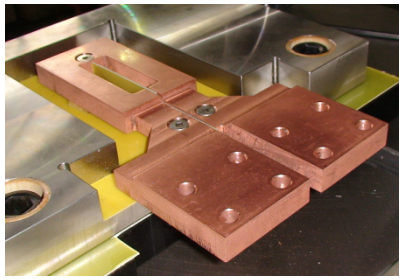


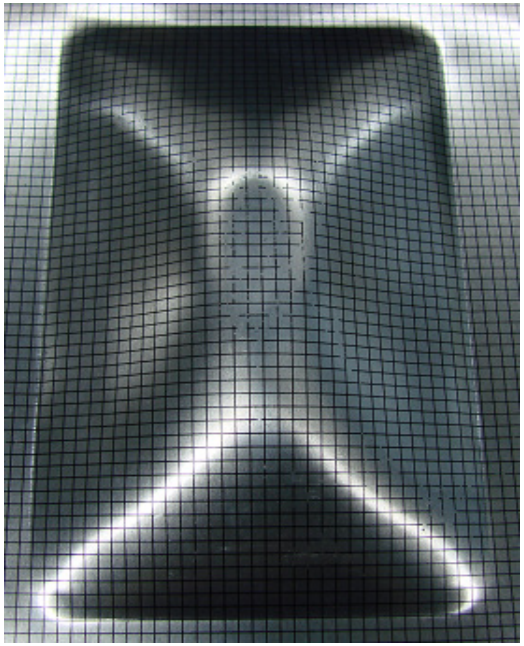
	Bar-type	Helical-type
Charged voltage (kV)	5	5
Peak current (kA)	126	55
Rise time (μs)	20	50

* Rise time : time to peak current

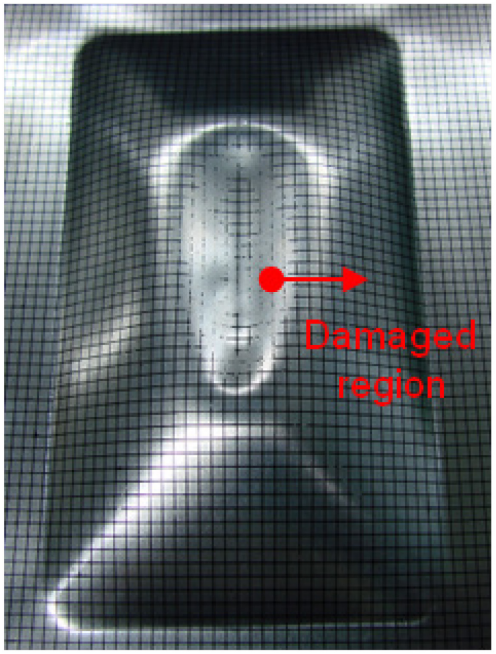
Experimental works

- **Contour on workpiece with bar –type forming coil**

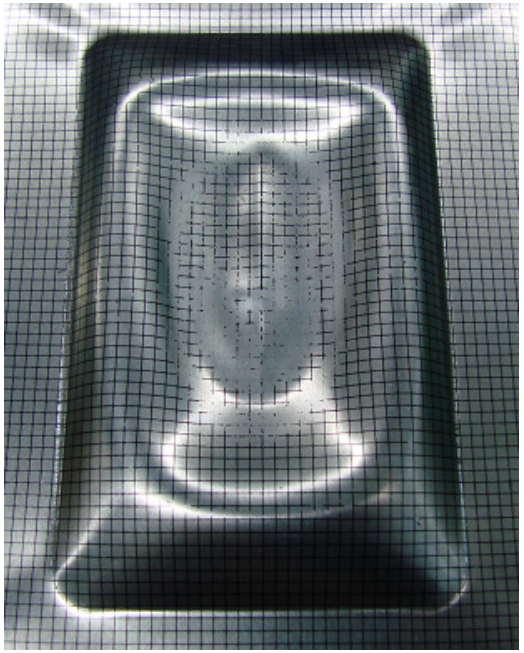




4kV



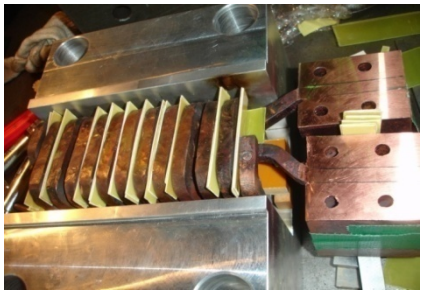
5kV

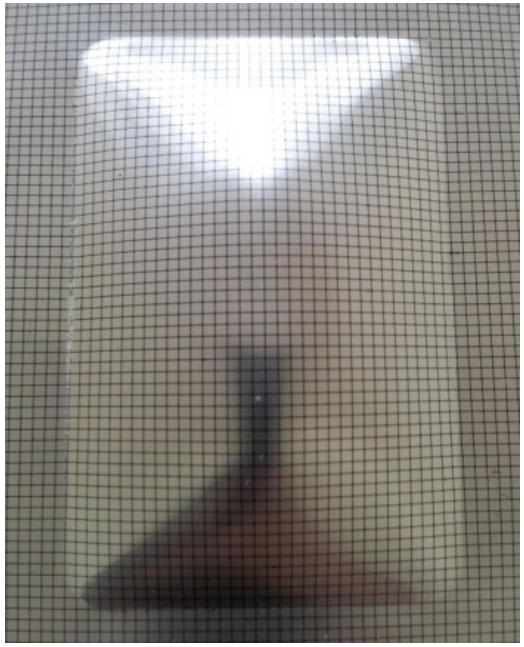


6kV

Experimental works

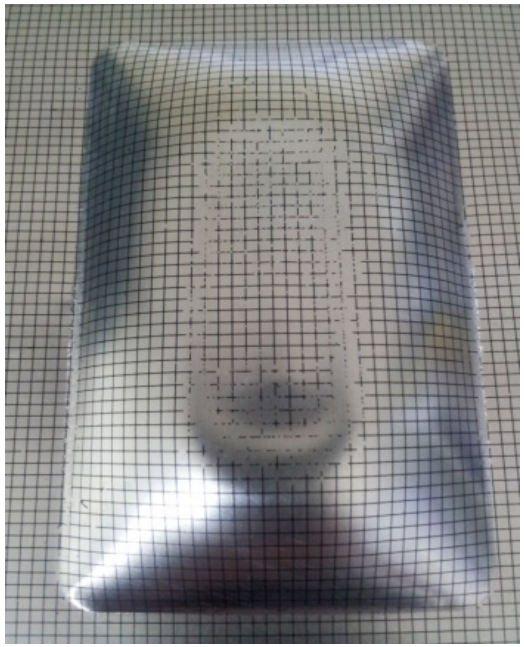
- **Contour on workpiece with helical-type forming coil**





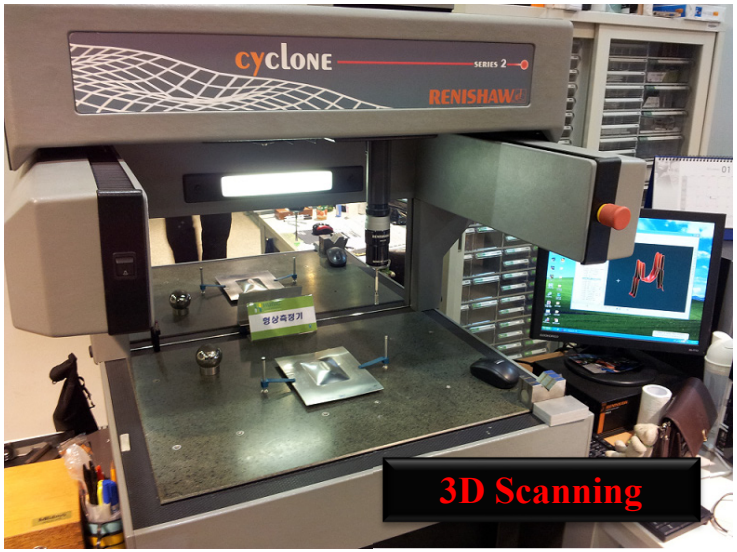
4kV

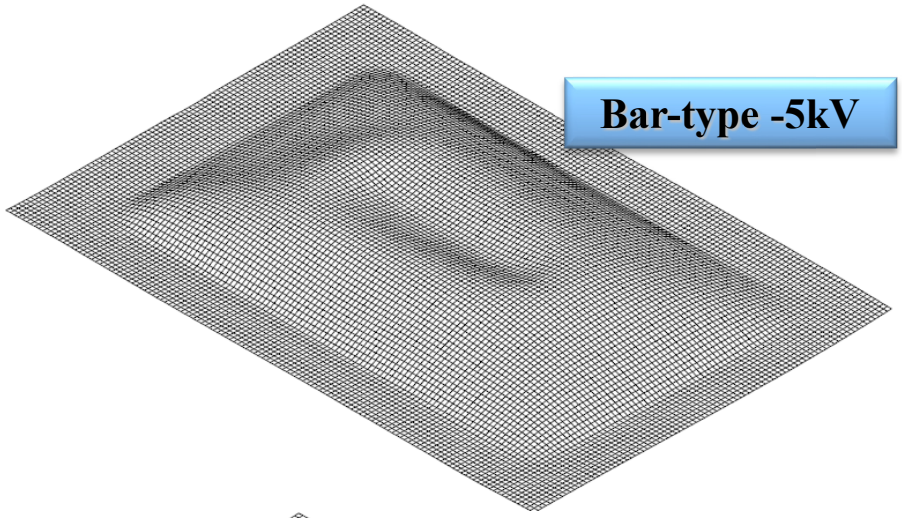
5kV

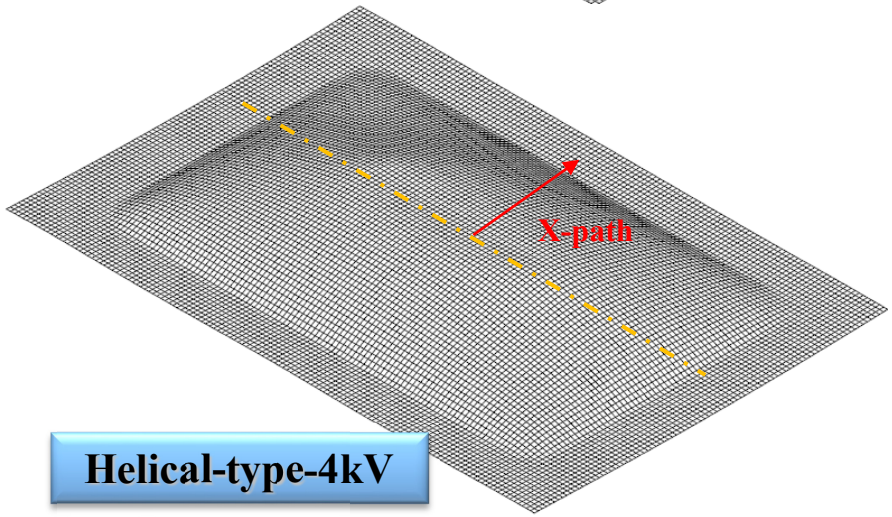


6kV

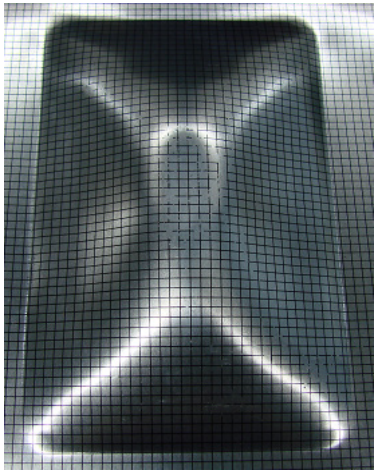
Experimental works



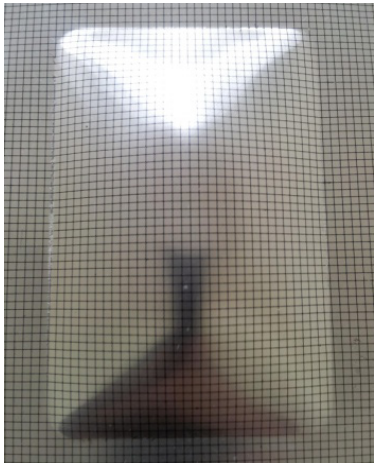




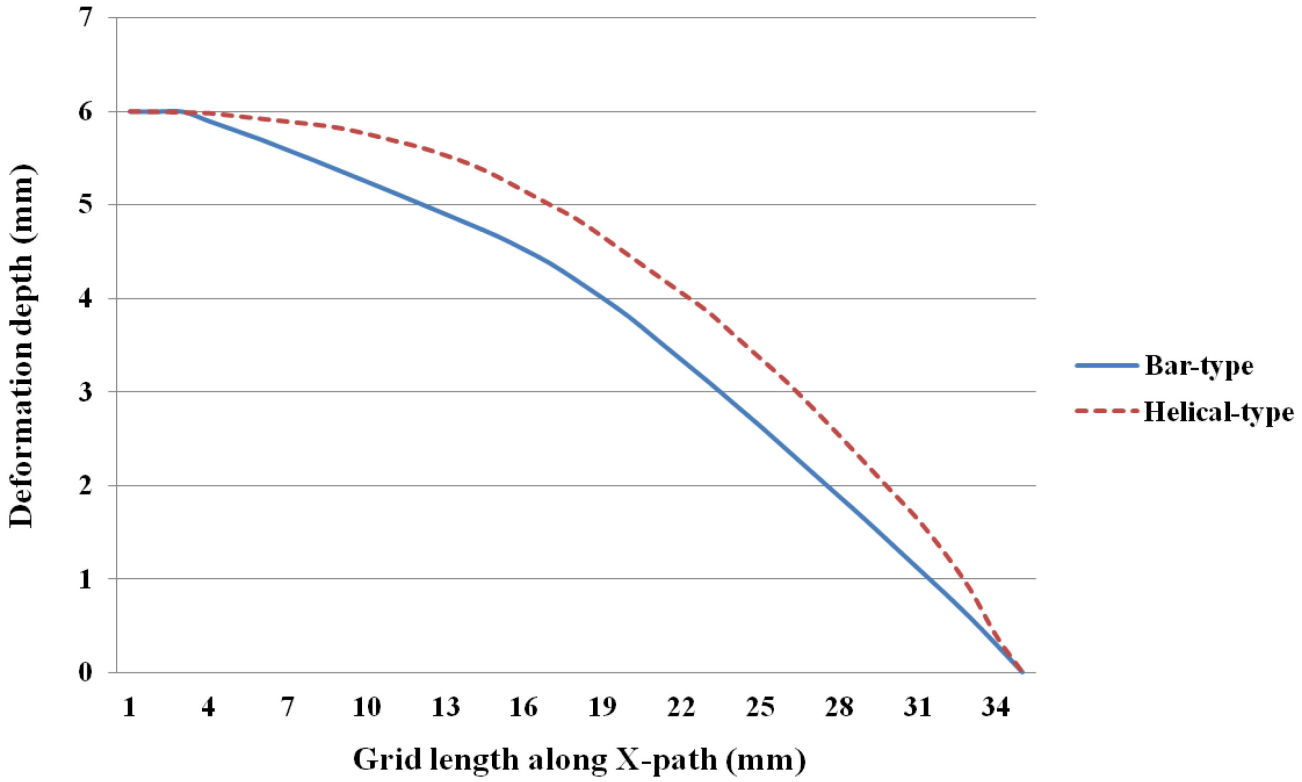
Experimental works



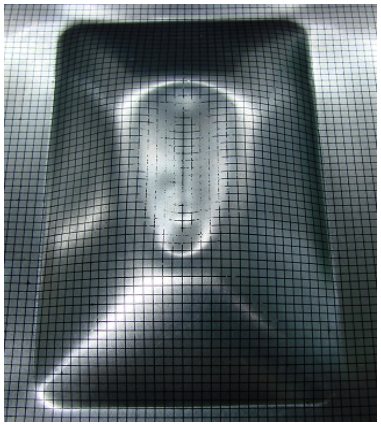
4kV(Bar-type)



4kV(Helical-type)

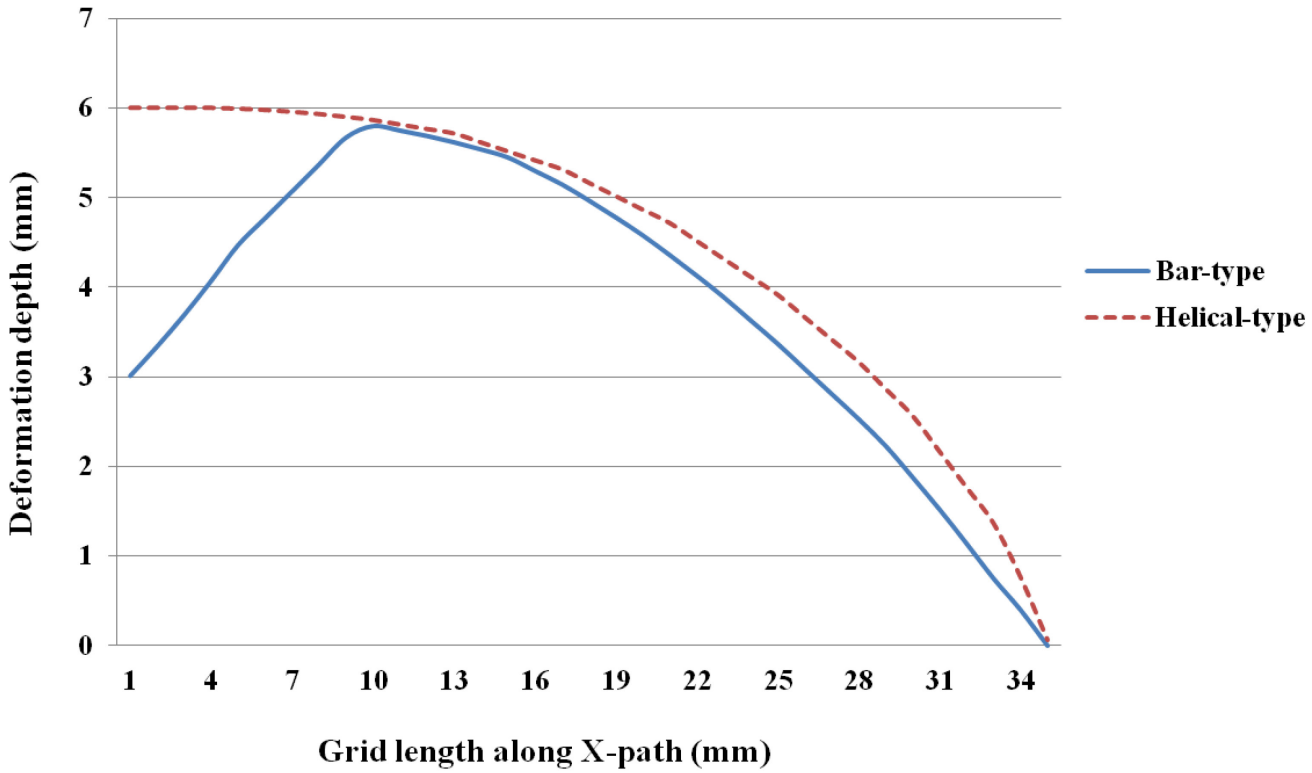


Experimental works



5kV(Bar-type)

5kV(Helical-type)



Numerical analysis

Electromagnetic FE-model

- Electromagnetic modeling using ANSYS/EMAG
- Primary current input

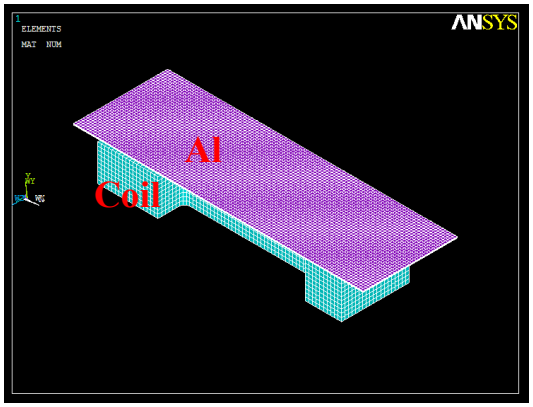
  * Bar-type : 126kA

  * Helical-type : 55kA

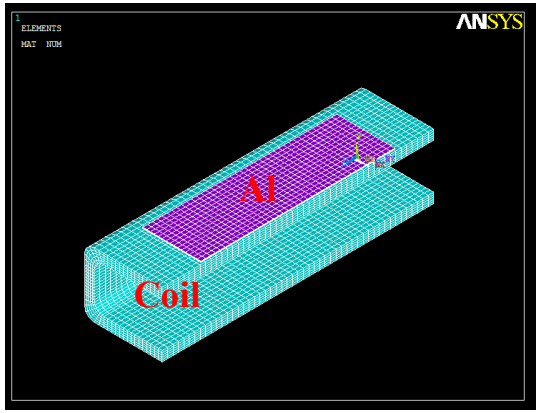
- Material property

Material	Electrical resistivity ($\mu\Omega - cm$)	Permeability
Coil	1.67	1
Al	2.90	1
Air	-	1

- Eight-node quadrilateral element of mapped mesh



Bar-type forming coil

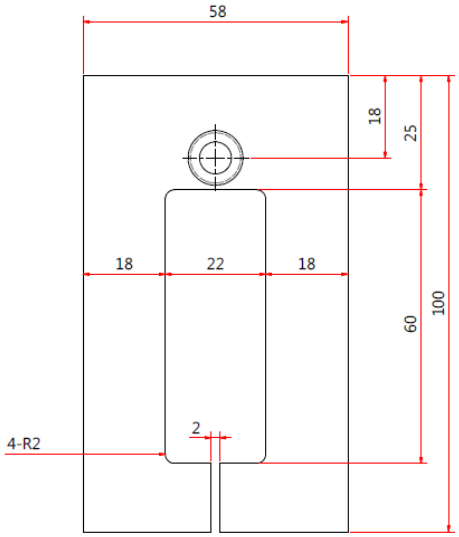


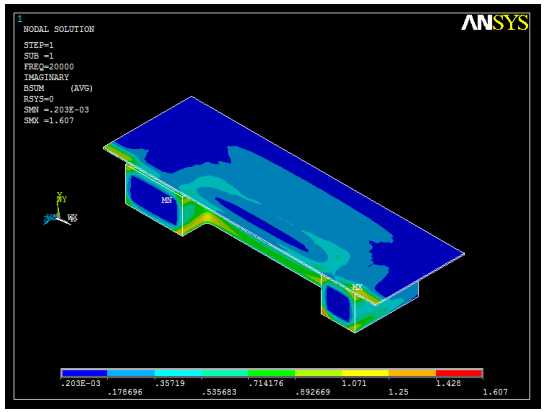
Helical-type forming coil

Numerical analysis

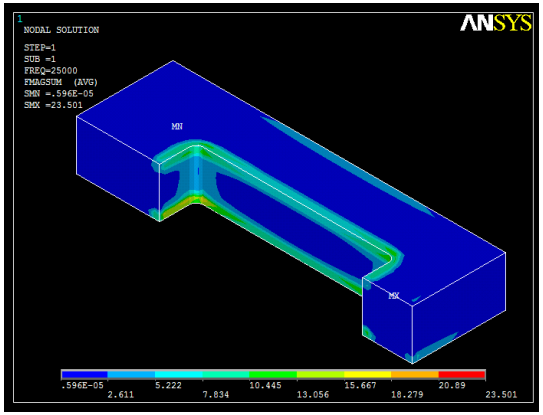
Results and discussion

- **Bar –type forming coil**

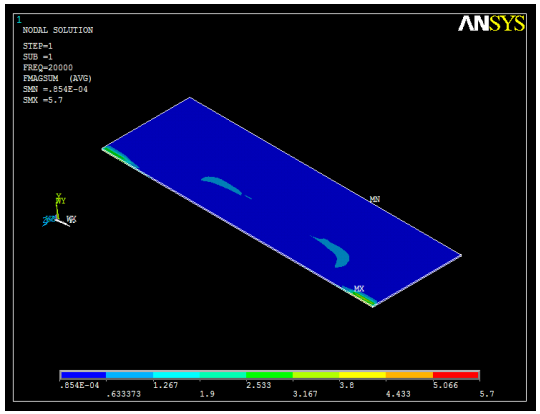




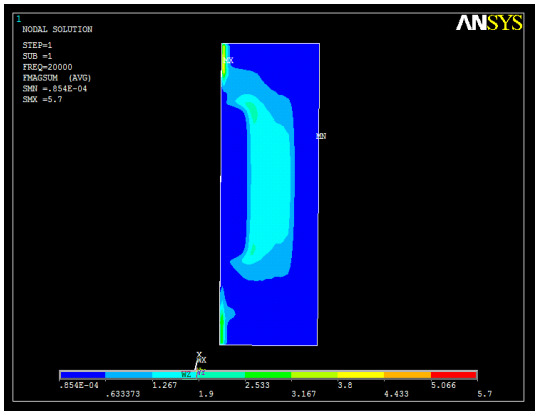
Flux density



Magnetic force (coil)



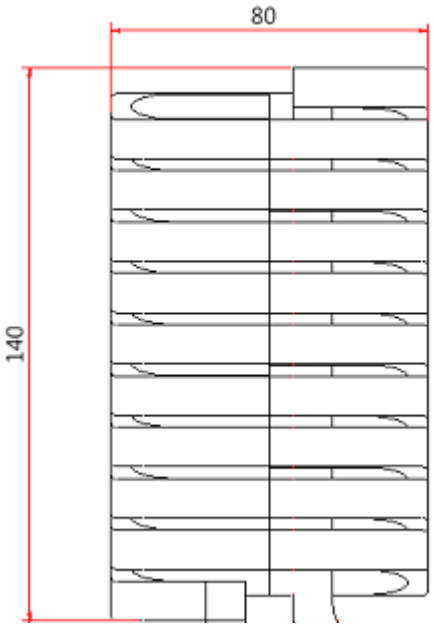
Magnetic force (Al-Top view)

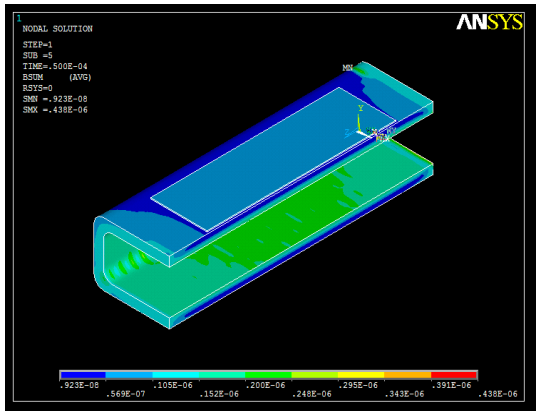


Magnetic force (Al-Bottom view)

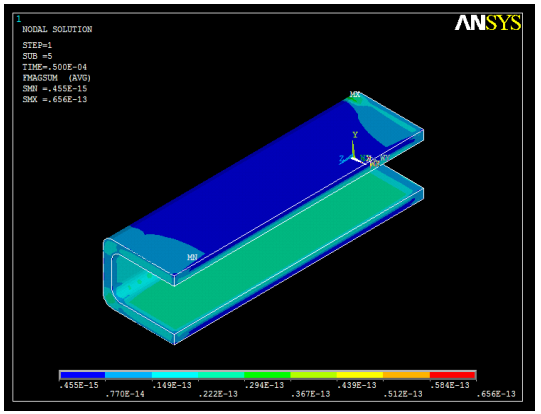
Numerical analysis

- **Helical-type forming coil**

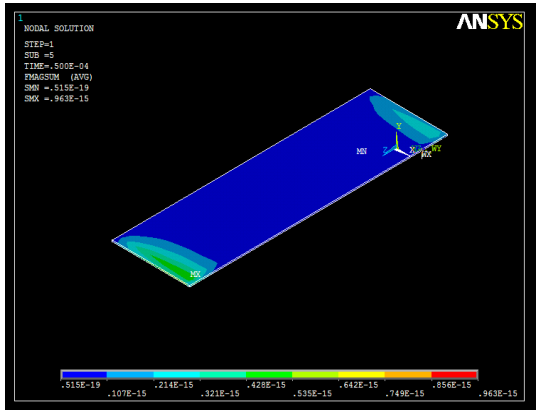




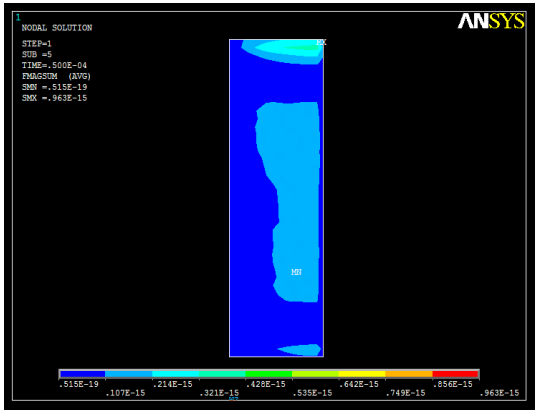
Flux density



Magnetic force (Coil)



Magnetic force (Al-Top view)

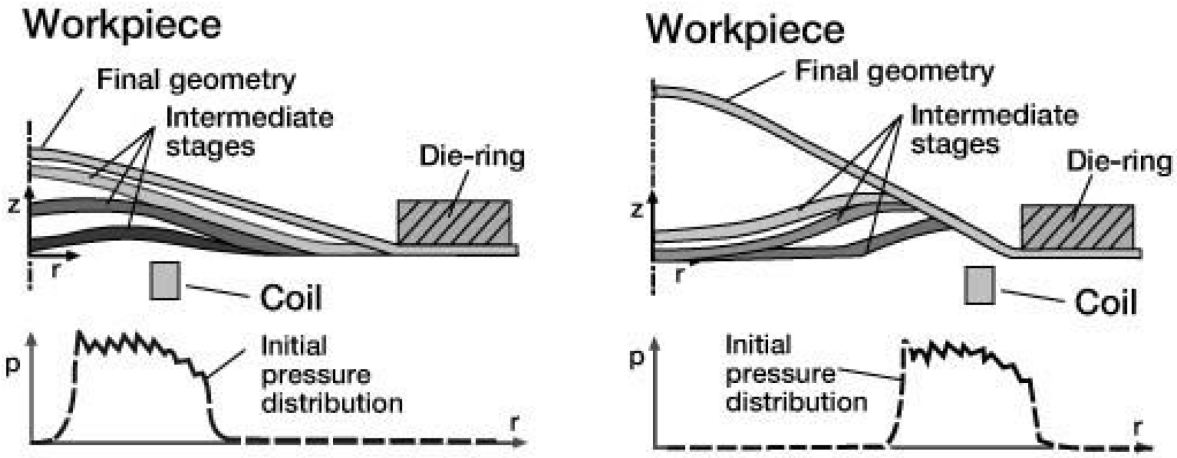


Magnetic force (Al-Bottom view)

Conclusion

- **Surface damage from the rebound after the collision was observed on workpiece in EMF with bar-type forming coil, especially the number of rebound was increased as charged voltage increases.**
- **According to the shape of forming coil, distributions of electromagnetic force on workpiece have been changed and non-uniform of distributions of electromagnetic force was lead to non-uniform forming.**
- **To achieve successful forming for rectangular box product, helical-type forming coil is more effective than bar-type forming coil in EMF process.**
- **As a next step, electromagnetic-mechanical coupled model will be developed for predictions of deformation on workpiece**

Thanks for your attention



* Beerwald et al.,"Fundamentals for process dimensioning and design of electromagnetic forming" (2004)