Agile Production of Sheet Metal Aviation Components Using Disposable Electromagnetic Actuators

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4th International Conference on High Speed Forming – 2010

Basics of Electromagnetics

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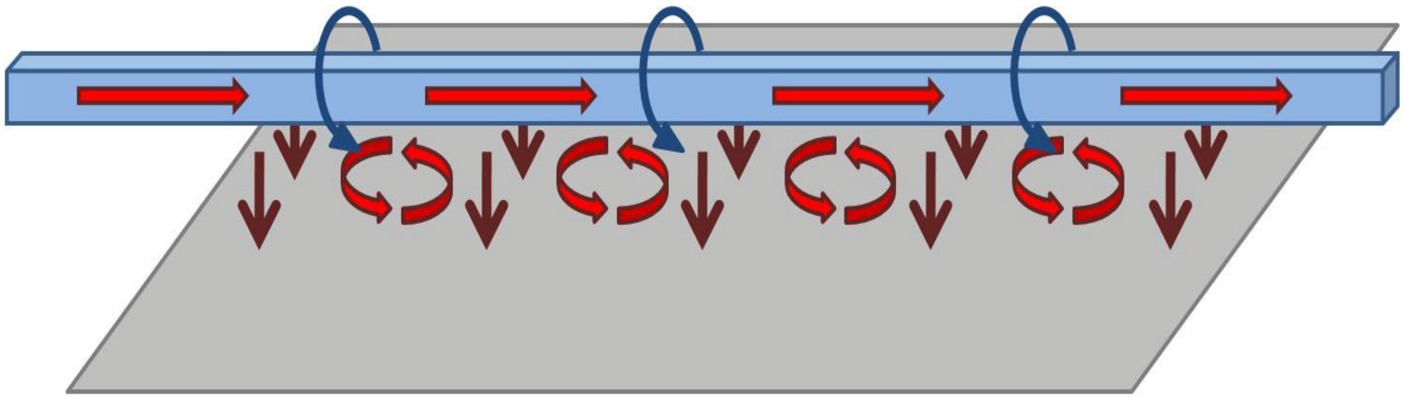
- Induction
  - Current creates a magnetic field → "Induces" current in adjacent metal
- Magnetism
  - Current in opposite directions → Repulsion



- These principles are the basis of electromagnetic forming

Electromagnetic Forming

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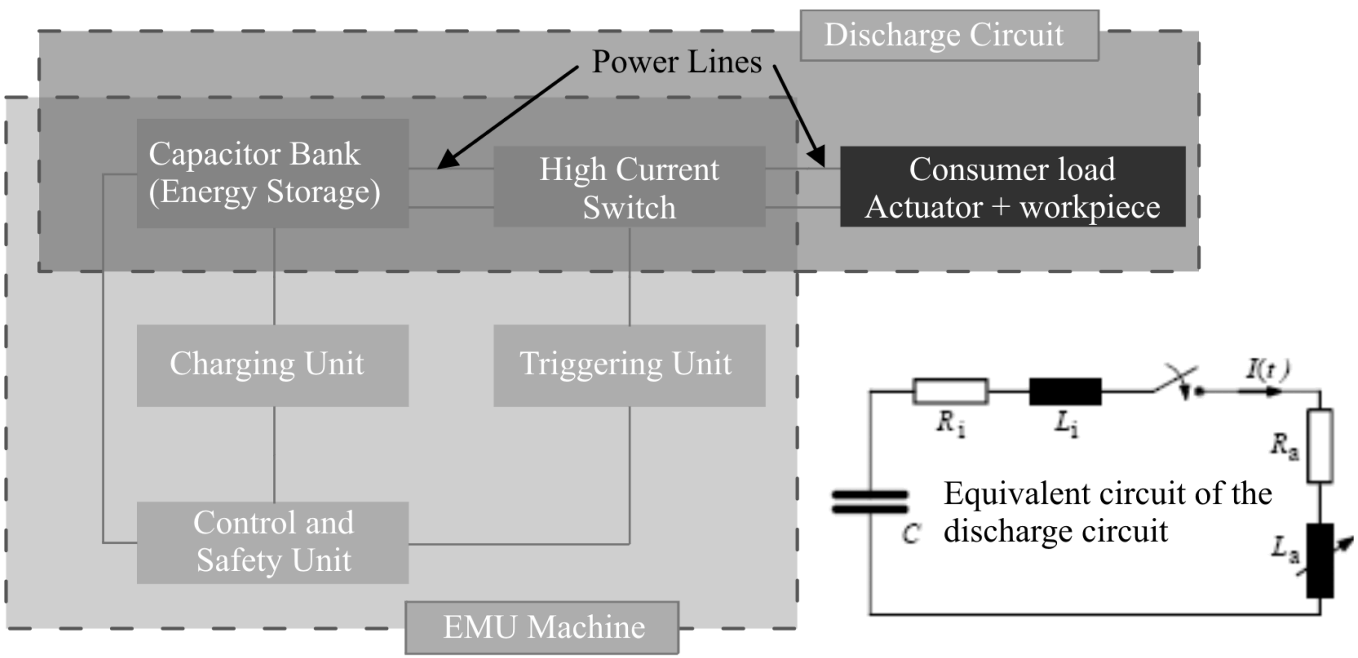
- Capacitor bank stores electrical energy
- Energy supplied to actuator through high current switch
- Induces a current in workpiece→Strong repulsive force



Electromagnetic Forming Benefits

- Agile
  - Only significant capital cost is capacitor bank
  - Single-sided tools
  - Flanging, drawing, shearing, embossing, ring expansion/shrinking
    - Requires only new coil, die

- Increased formability
  - High Strain Rate Forming
  - Formation of more complex part designs
  - Can often form in T6 (full-hard) condition
- Hybrid Forming (Traditional + Electromagnetic)

Introduction to Components

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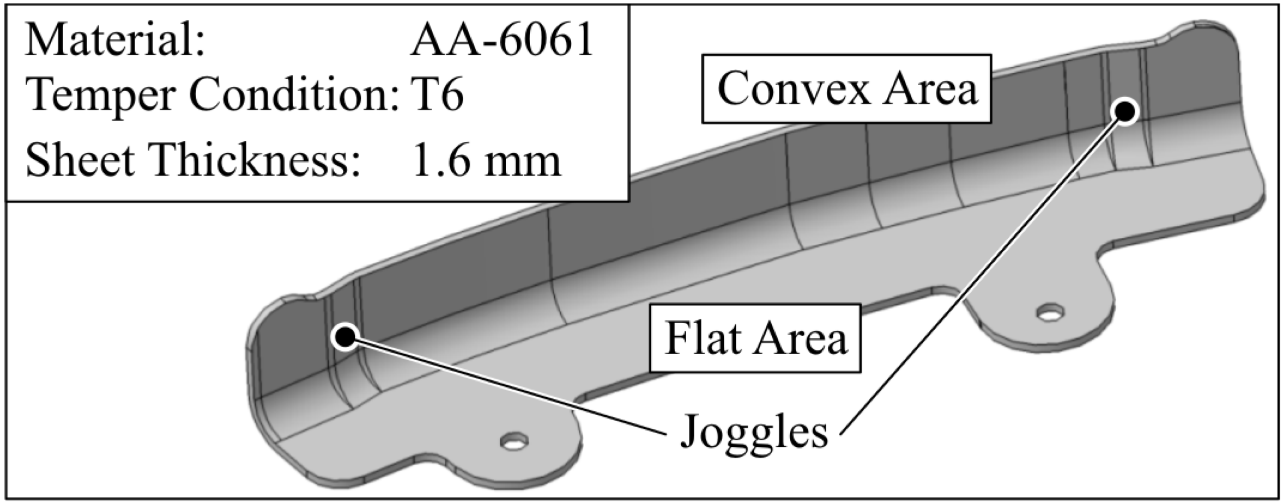
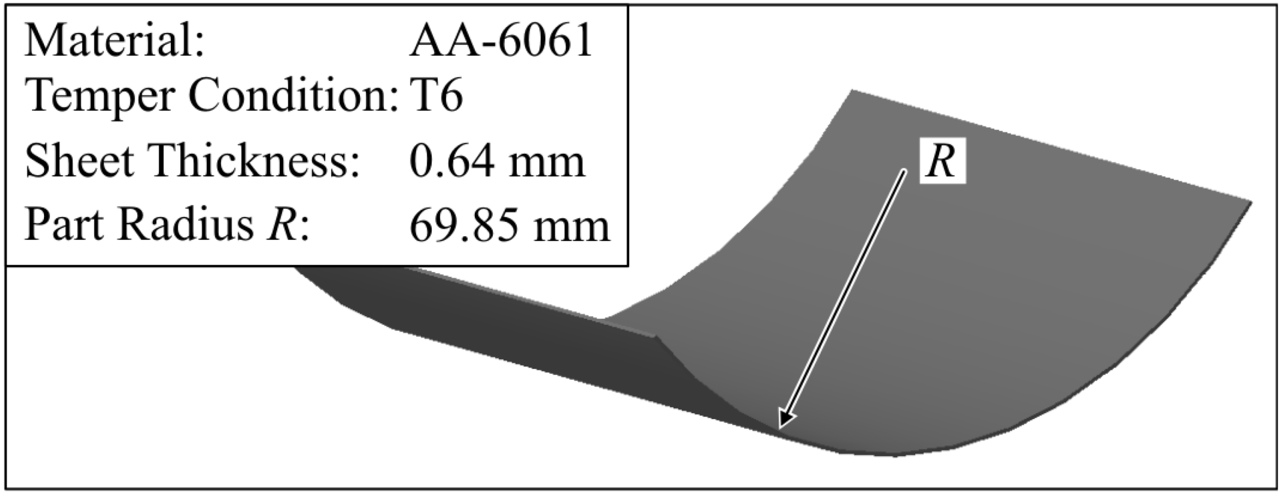
- "Flanged"



- "Curved"



Curved Component Setup

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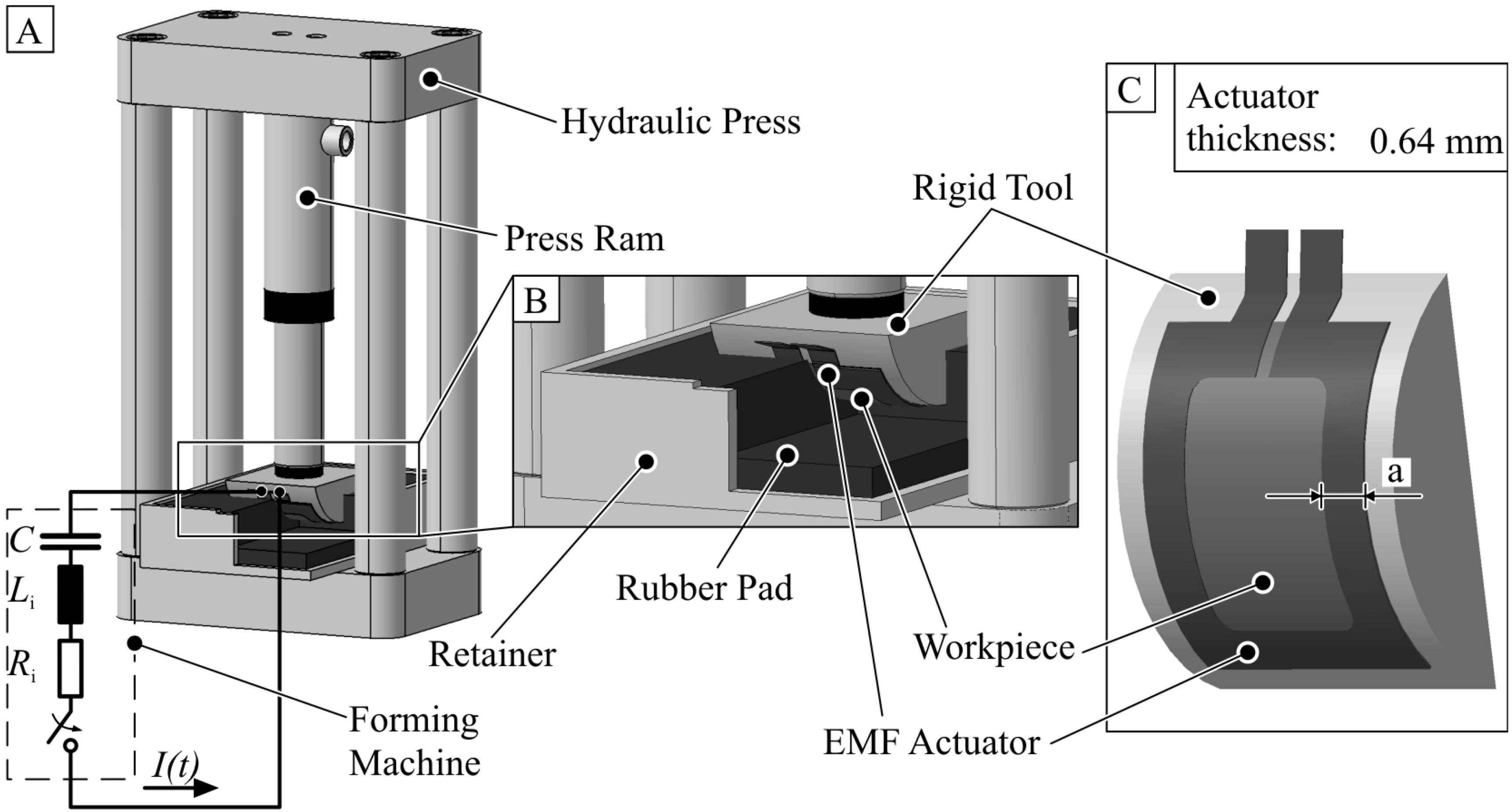

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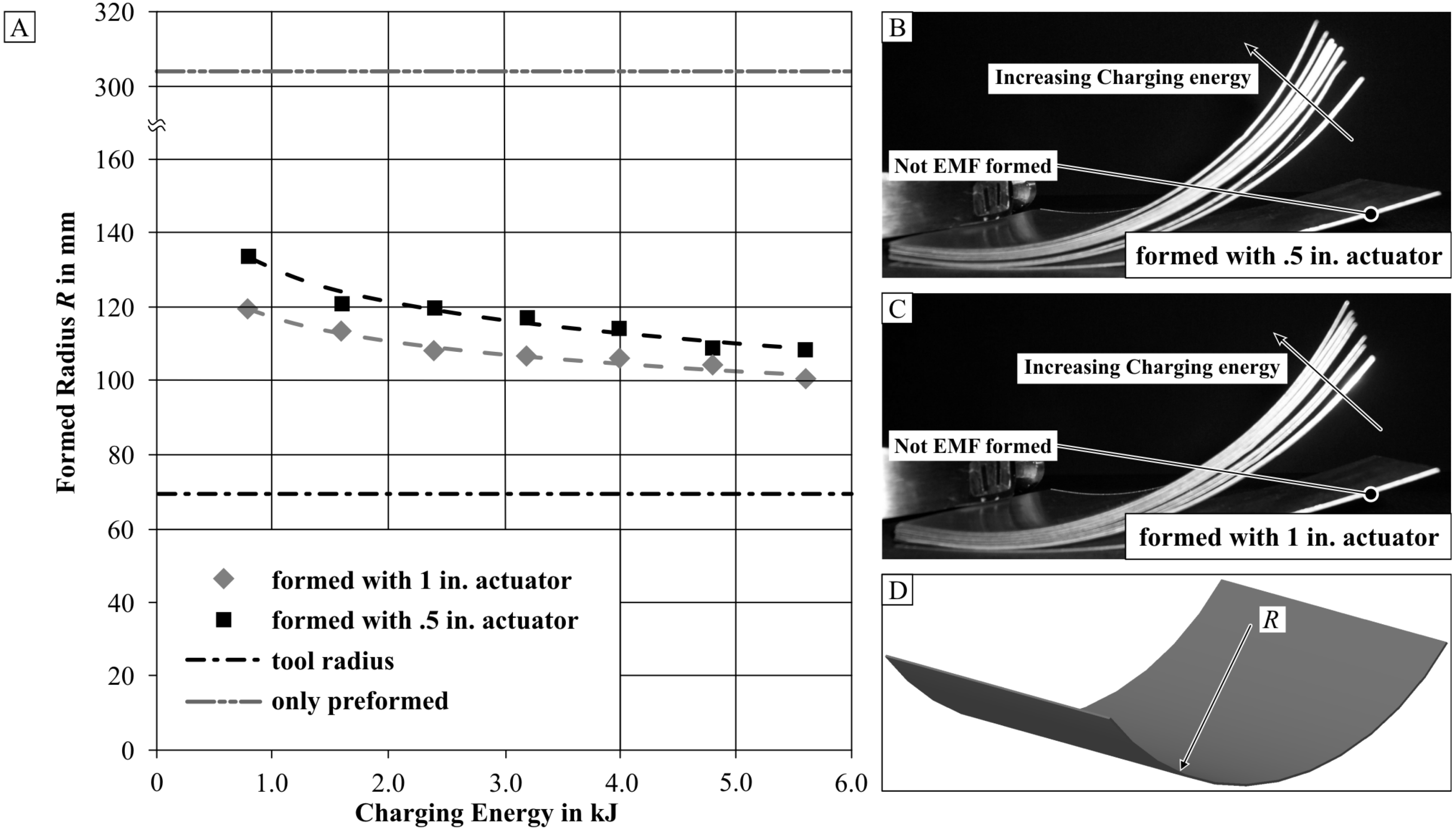
Effects of Experiment Variables



Conclusions – Curved Component

- Up to 87% of springback in the part was eliminated
  - Target radius – 70 mm
  - In experiments, radius reduced from 310 mm to 101 mm
- Narrow coils lead to greater maximum forming, wide coils lead to more consistent and controllable results
- Target radius was not achieved
  - More robust coils for higher forming energy
  - Coil designs that form the part in the middle as well as edges

Introduction – Flanged Component

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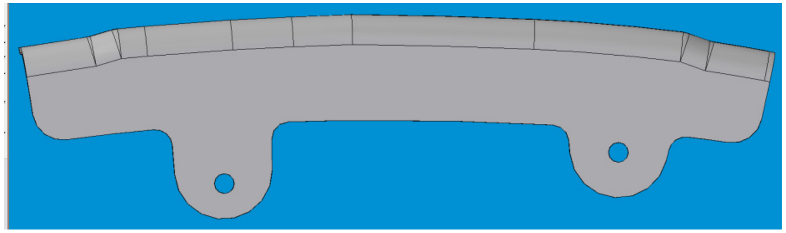
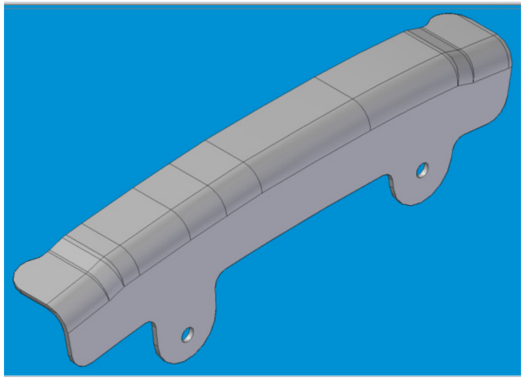
1. Optimization of the current production process for the example part
   - Decreasing the production costs
   - Reducing lead time
   - Eliminating manufacturer reliance on external certified vendors (i.e. heat treatment)
2. Development of a production method for parts with similar geometric properties to the example part
   - *Easily adaptable to similar shapes (Agile Hybrid Metal Forming)*





Current Production Process

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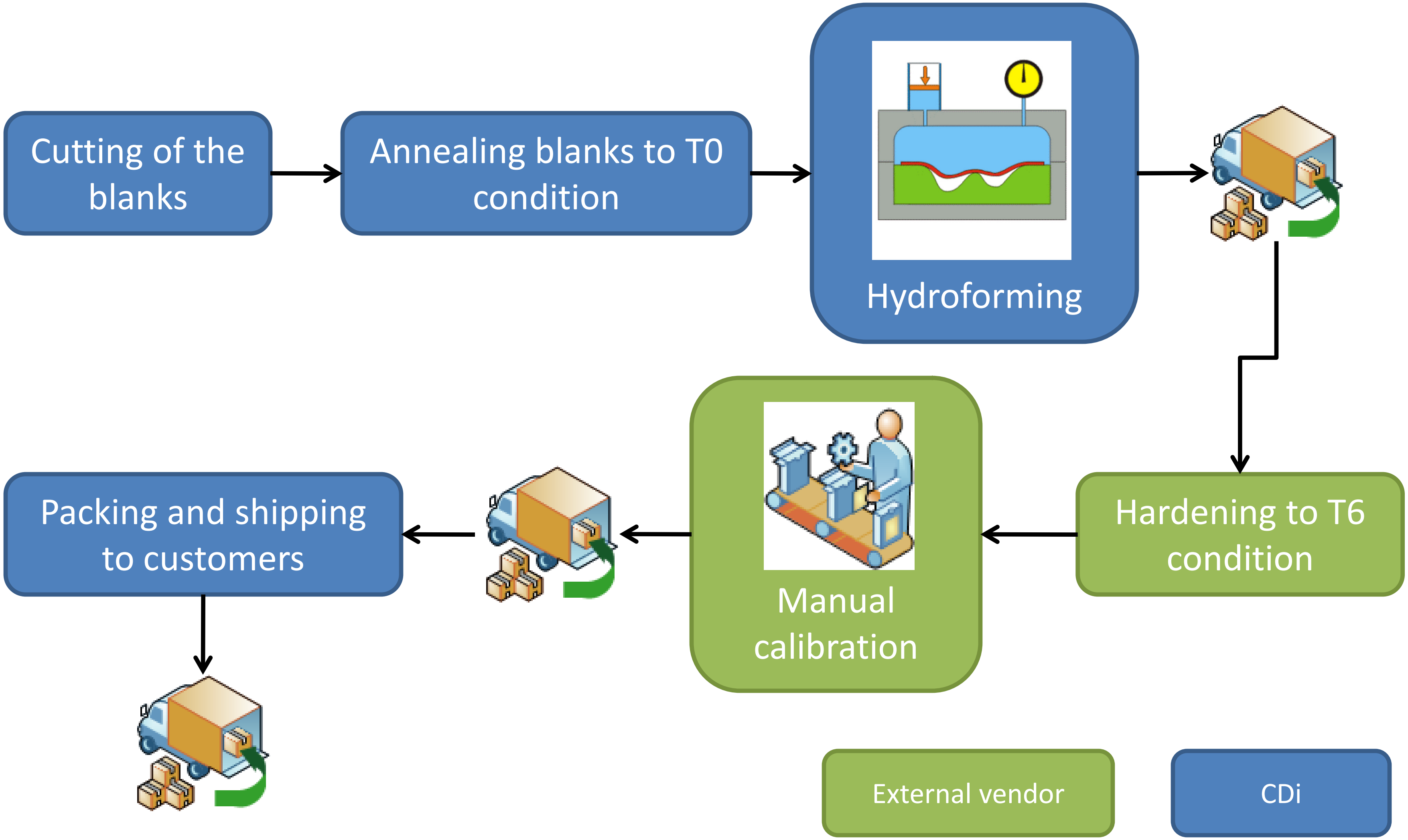
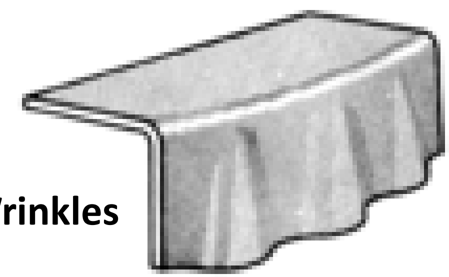


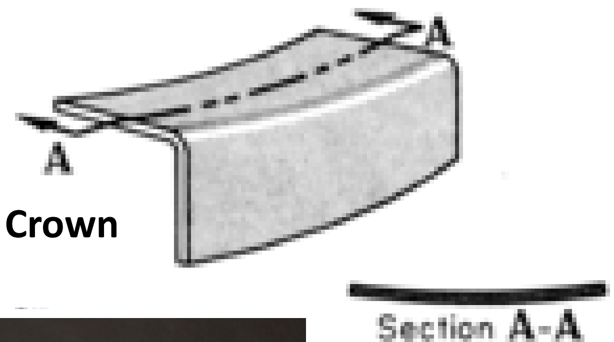
The Problems

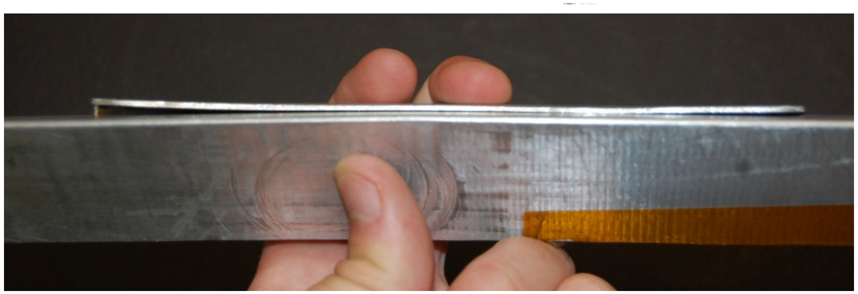
- Eliminating the two heat treatment steps (forming at a T6 condition)
  - Problem: crown, wrinkles and springback

Wrinkles



Crown





  - Solution: electromagnetic calibration after hydroforming

The Coil

Single shot coil

Material:

AA6061 covered with Kapton tape

Thickness: 0.02 inch

Advantages and disadvantages:

- Cheaper than copper
- Lower tooling costs (possible to laser cut)
- Lower conductance than copper

Flanged Component Setup

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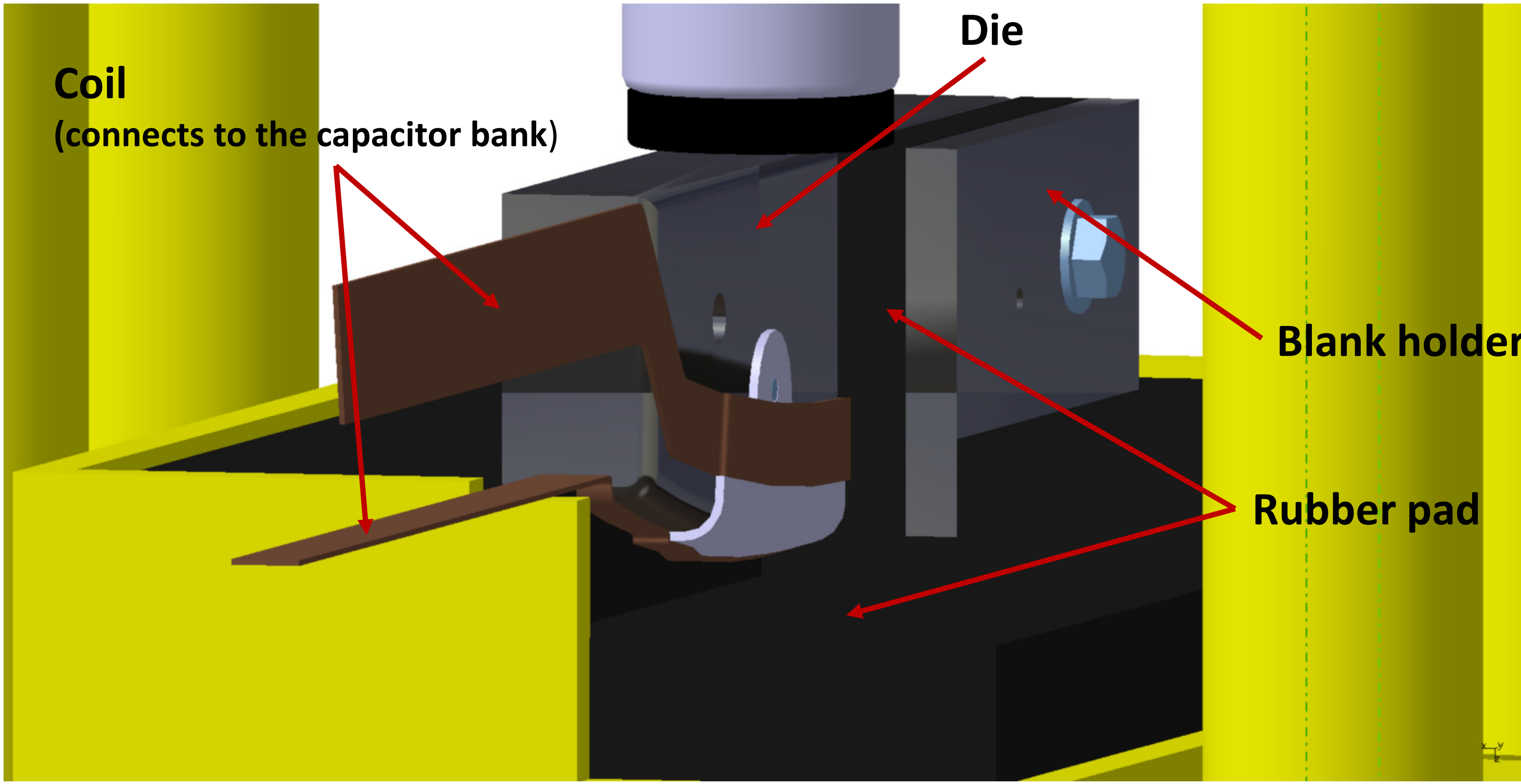

Flanged Component Results

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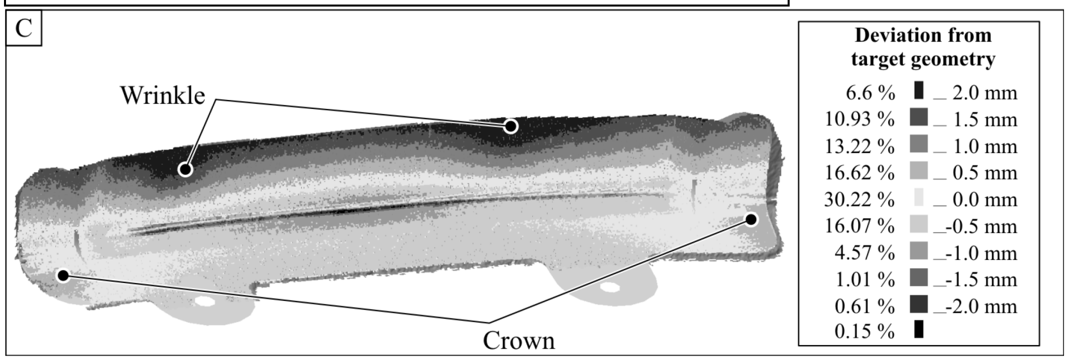
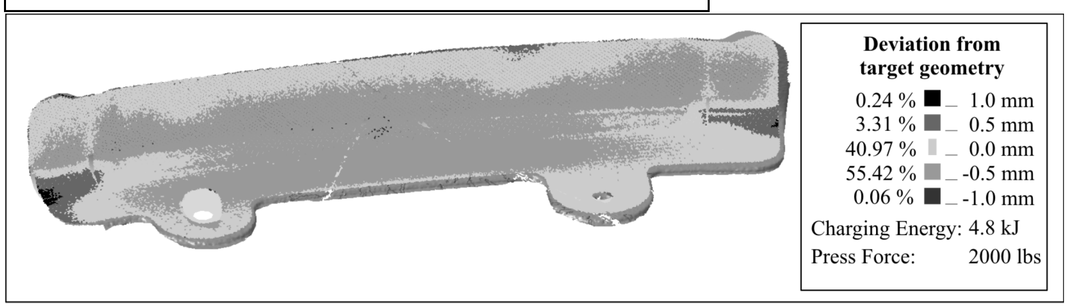
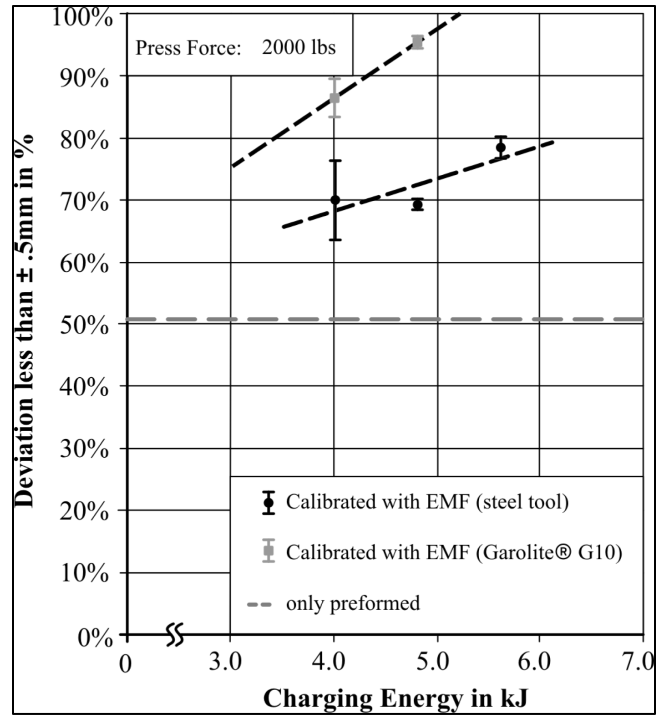
Before EMF Calibration:



After EMF Calibration:



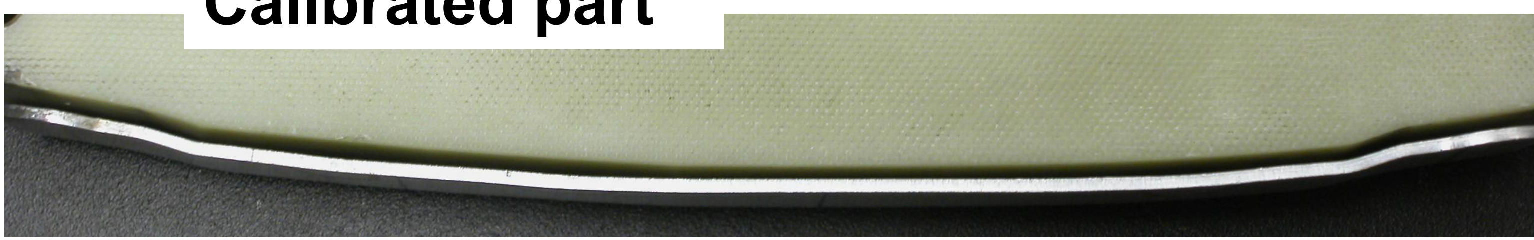
Effect of Charging Energy and Tool Material



Visual Comparison

Hydroformed part

Calibrated part

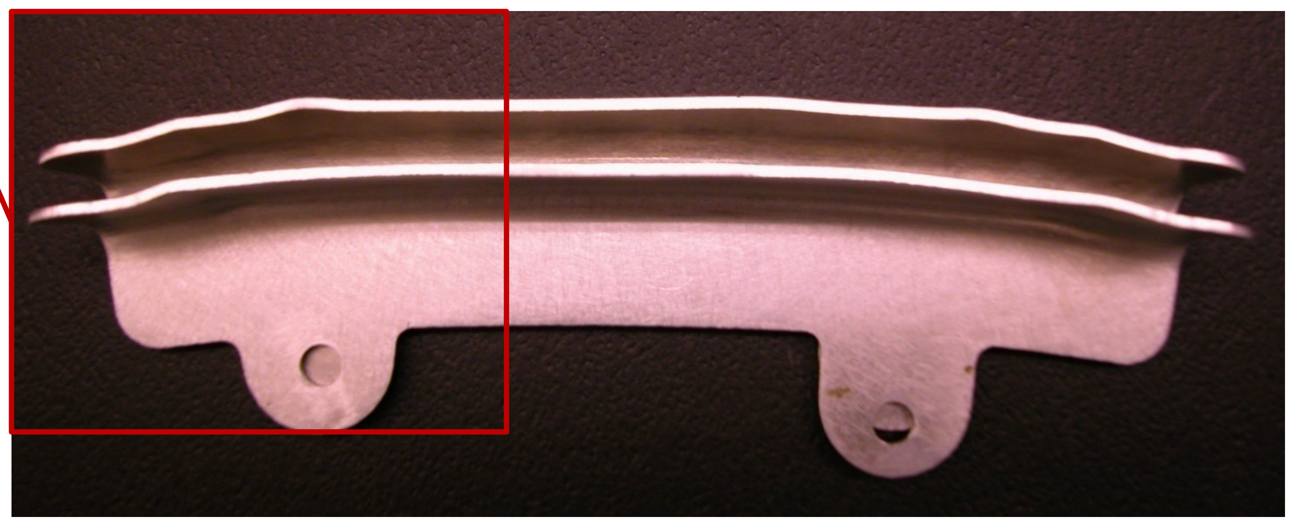


Visual Comparison

Part Accuracy Increases with:

- Increasing charging energy
- Softer tool material (Garolite G-10)

- Press force had little effect on final shape



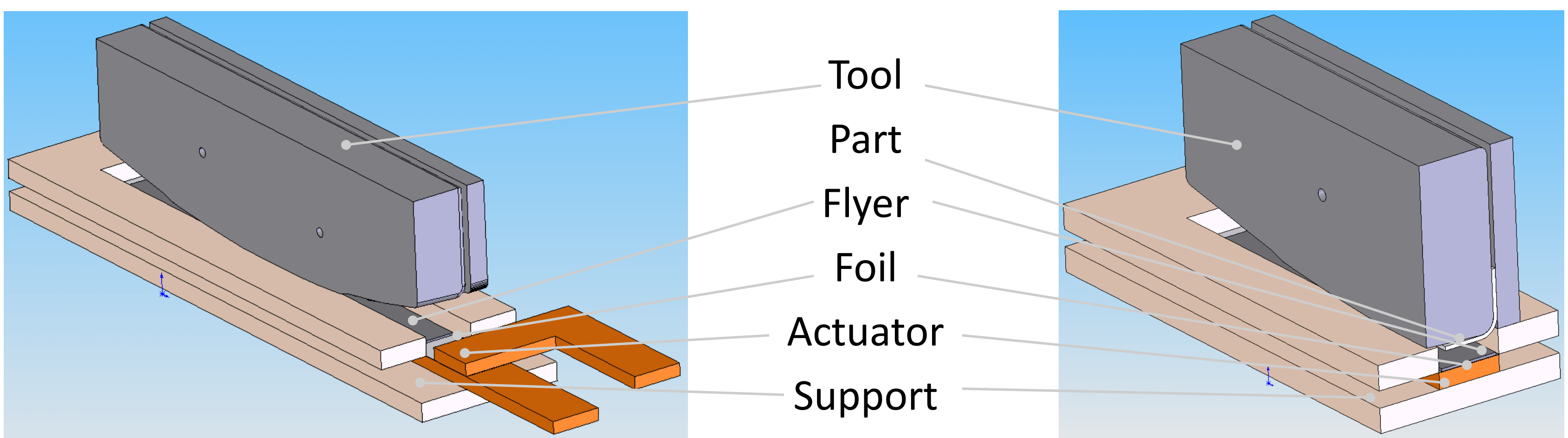
Conclusions – Flanged Component

- Reduced springback
- No wrinkles
- Shape nearly within specifications (including joggles)
- Average part angle at the flange – 90.3 (Target was 90)

- Crown not completely eliminated, but within specifications

New Method – Exploding Foil Forming

- Capacitor bank discharges large current into actuator
- Actuator transfers current to metal foil
- Foil explodes due to large current, creating a high-pressure wave
- Pressure wave pushes flyer into part at high velocity



Results – Exploding Foil Forming

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Part is completely within dimensional tolerances

- Part remains in T6 temper condition throughout entire process – no heat treatment required
- Exploding foil process shows significant improvements over hydroforming or electromagnetic forming

- Hydroforming only:

- Hydroforming then explosive foil calibration:

Conclusions

- Electromagnetic calibration using disposable actuators is a feasible approach
- There is clear room for improvement relative to current production processes
- The use of electromagnetic forming or explosive forming techniques allow complex parts to be formed in the T6 (full-hard) condition

Thanks to Cutting Dynamics, Inc. for providing financial support, materials, and tooling for this study