Effects of Force Distribution and Rebound on Electromagnetically Formed Sheet Metal

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Outline

• 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 (Daeihn 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

- 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

- 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

IAP Magnapress 22.5 kJ, 15 kV Pulse Generator
Ford EMF laboratory
Pulsar Research Edition 20kJ, 9 kV Pulse Generator
EMF of V-Channel
Numerical Method

• 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

Workpiece

FEM for Workpiece and Coil

BEM for Air

FEM for Air

Coil

Air

Coil

Air
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
Predicted Lorentz Forces from Spiral Coil

Contours of Lorentz force

Fringe Levels
7.877e+06
7.096e+06
6.315e+06
5.534e+06
4.753e+06
3.972e+06
3.191e+06
2.410e+06
1.629e+06
6.484e+05
6.747e+04
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

(a)

13.8 mm

(b)

(c)
V-Channel Simulation

Side of the sheet exposed to the coils

Contours of Lorentz force

Fringe Levels

3.246e+07
2.922e+07
2.597e+07
2.273e+07
1.948e+07
1.623e+07
1.299e+07
9.740e+06
6.493e+06
3.246e+06
0.000e+00
V-Channel Formed With 3000 V

Effective plastic strain
Contact-Force Distribution and Rebound

24.3 mm
V-Channel 5000 V

Shape prior to impact

Final shape

Rebound of walls

Effective plastic strain

Fringe Levels

30.2 mm
Two Step Corner Fill-Conventional Step
Two Step Corner Fill-EM Step
Rebound in Sheet Welding (Al-Al)
Conclusions

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