FEA FORMING SIMULATION VALIDATION OF ADVANCED SHEET METALS

Dr C. Q. Hu,

WMG, the University of Warwick

Outlines

- Background
- Review on some commonly used plastic yielding criteria
- Experimental setup
- FEA model setup
- Correlation results
- Conclusions

Background (1/2)

- **FEA stamping CAE has become an essential tool in automotive industry:**
  - ✓ **Increased applications of advanced materials such as (HSS, AHSS, Al alloys) and complex components**
  - ✓ **Reduced the time cycle for a new model development**
- **Simulation has been carried out for direct recommendations in all stages of stamping engineering**
  - ✓ **Feasible study**
  - ✓ **Tool design**
  - ✓ **Tool try-out**
  - ✓ **Production line**

Background (2/2)

- **Build up confidence when advanced sheet metals are utilised**
- **Demand for high-quality prediction, i.e. Evolution from qualitative prediction to quantitative detail prediction.**
  - ✓ **Strain distribution**
  - ✓ **Thinning**
  - ✓ **Wrinkle tendency**
  - ✓ **Springback (or Dimension control)**
  - ✓ **Surface defects**

- **Example**

Review on some commonly used yielding criteria

- **Hill 48**

$$\sigma_y = \left[\frac{1+r_0}{2r_0}\sigma_{11}{}^2 - \sigma_{11}\sigma_{22} + \frac{1+r_{90}}{2r_{90}}\sigma_{22}{}^2 + (1+2r_{45})\frac{r_0+r_{90}}{2r_0 r_{90}}\sigma_{12}{}^2 \right]^{1/2}$$

- **Hill 90**

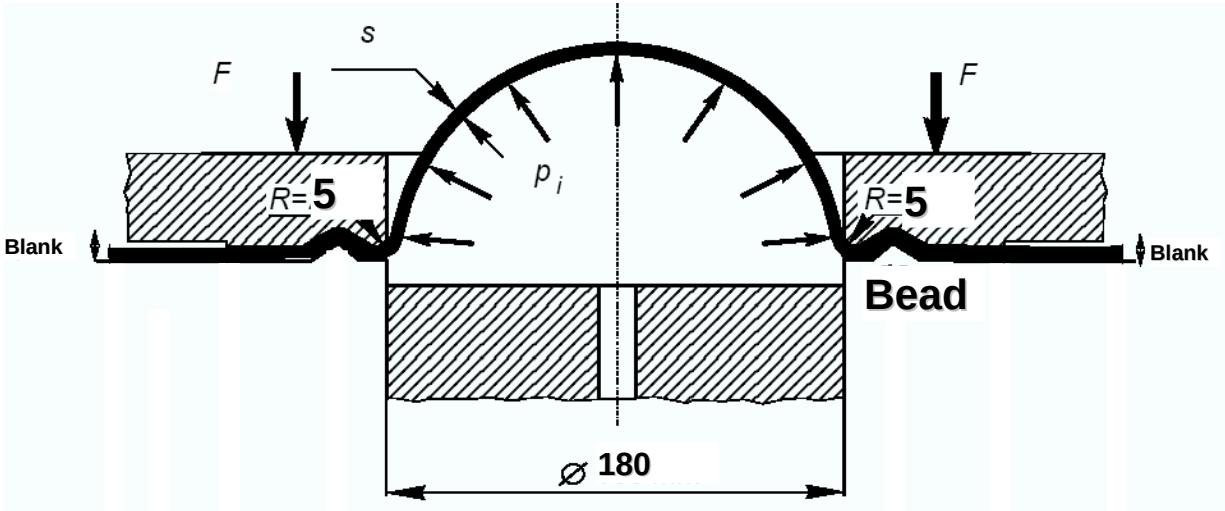
$$\begin{aligned} &|\sigma_{11}+\sigma_{22}|^m + \alpha^m\left[(\sigma_{11}-\sigma_{22})^2 + 4\sigma_{12}{}^2\right]^{\frac{m}{2}} + \left(\sigma_{11}{}^2+\sigma_{22}{}^2+2\sigma_{12}{}^2\right)^{\frac{m}{2}-1}\left[\beta\left(\sigma_{11}{}^2-\sigma_{22}{}^2\right)+\gamma\left(\sigma_{11}{}^2-\sigma_{22}{}^2\right)\right] \\ &=\left(1+\alpha^m+\beta+\gamma\right)\sigma_{22}{}^m \\ &=\left(2\sigma_y{}^b\right)^m \end{aligned}$$

- **Barlat 89**

$$\phi\left(K_\alpha\left(\sigma_{ij}\right)\right) = a\left|K_1+K_2\right|^m + \left|K_1-K_2\right|^m + c\left|2K_2\right|^m = 2\sigma_Y{}^m$$

Experimental setup

- **Materials: DP600 1.0mm & AA6111 0.9mm**
- **Bulge tests**
- **Measurement equipment: GOM Argus® and Aramis® LVDT, and hydraulic pressure sensor**

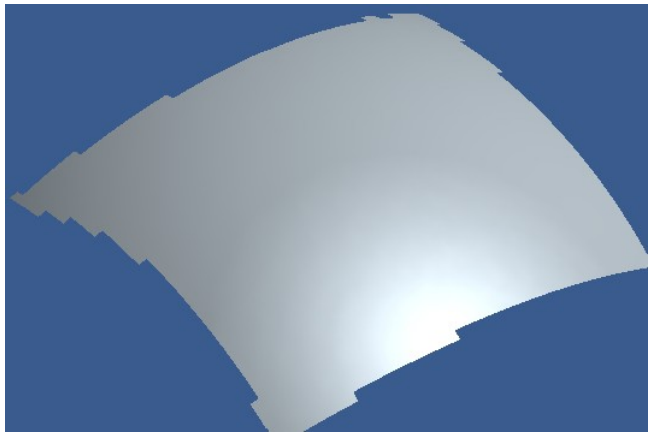


FEA model setup

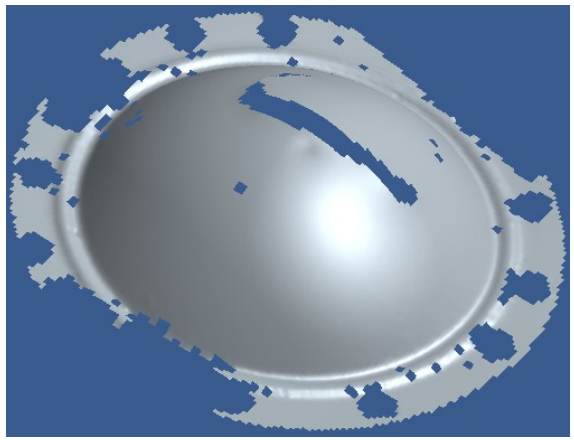
- **The incremental solver of AutoForm V4.05 used**
- **Element:** triangle shell element according to Mindlin theory for non-linear plastic material behavior
- **Plastic yielding criteria: Hill 48, Hill 90 and Barlat 89**
- **Hardening: Isotropic**
- **Material flow:** extrapolating the uni-axial tensile test curves based on combinations of Swift and Hockett-Sherby equations
- **Experimental FLC:** used for cracking criteria
- **Coefficient of friction:** 0.1
- **The advanced adaptive space discretization to modify the element size**

Correlation results (CR) (1/6)

Aramis ® results

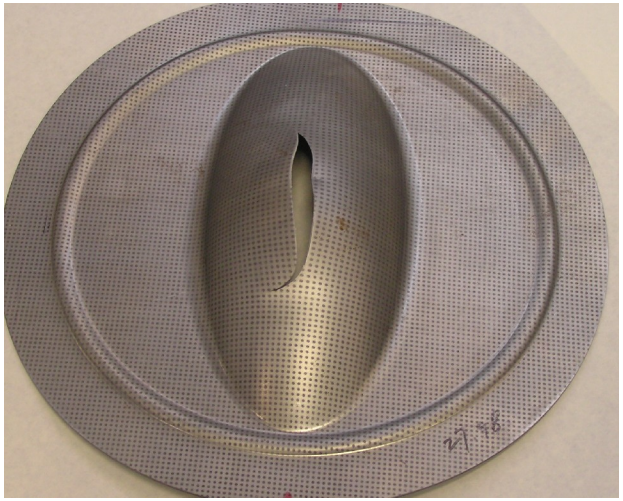


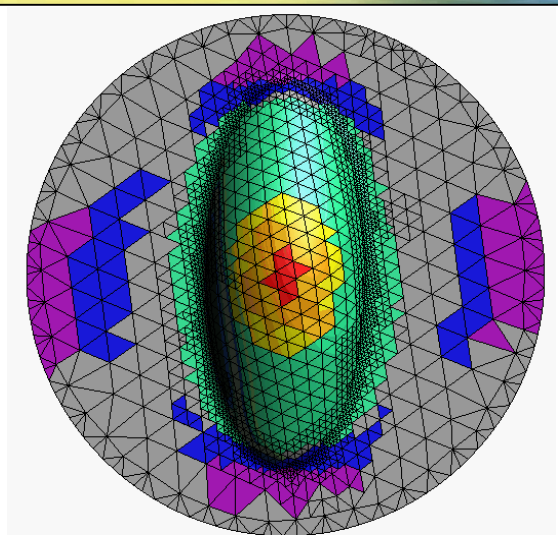
Argus® results



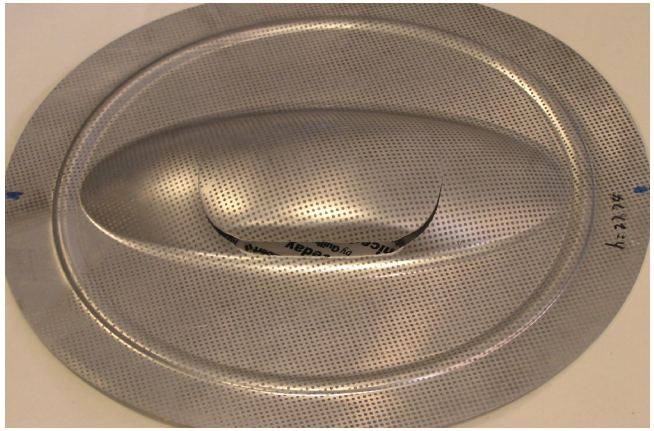
CR(2/6): Failure mode predictions

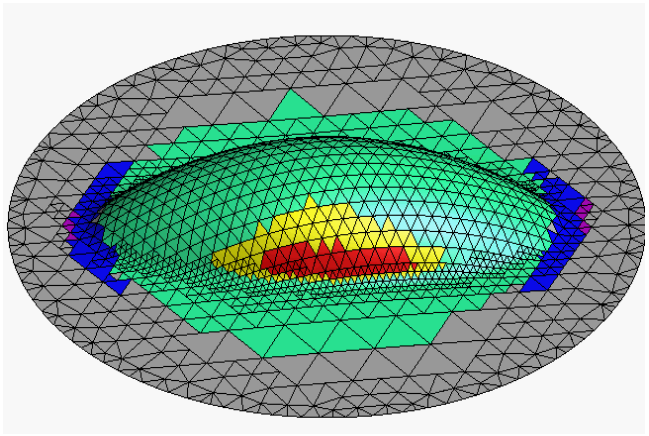
Pole failure





Rim failure

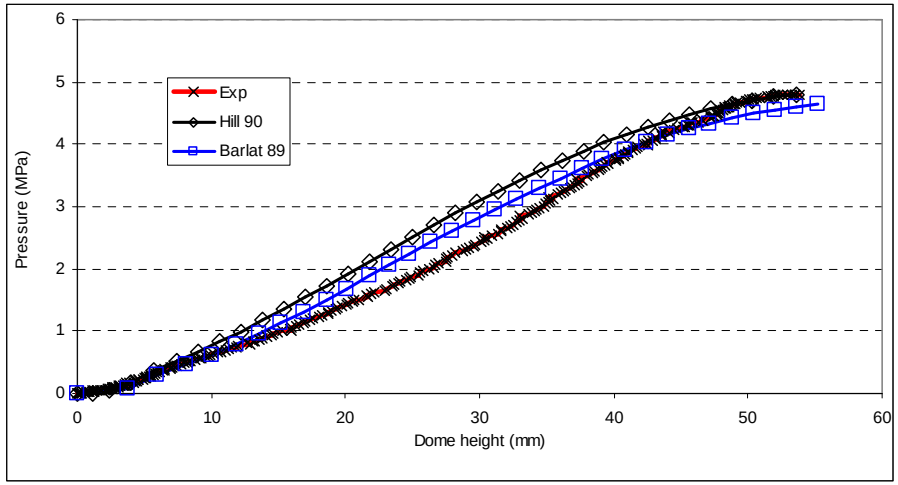




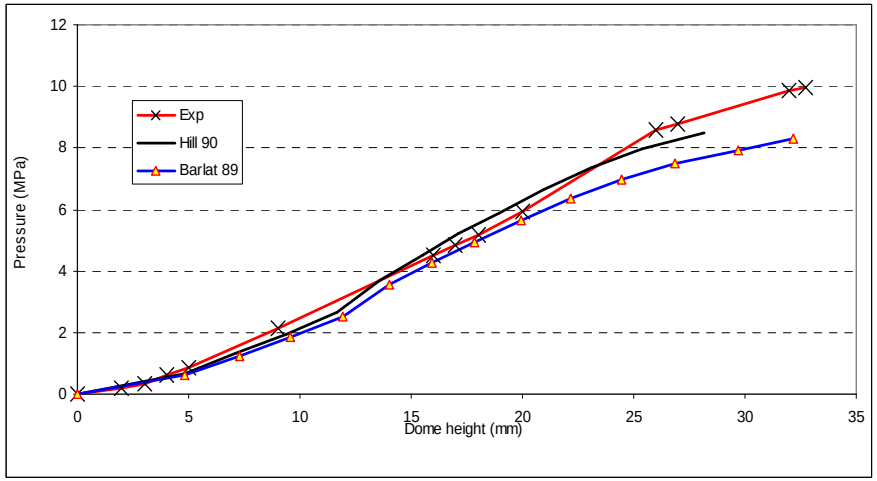
CR(3/6): Pressure vs dole displacement

AA6111 0.9mm

Using the circular die



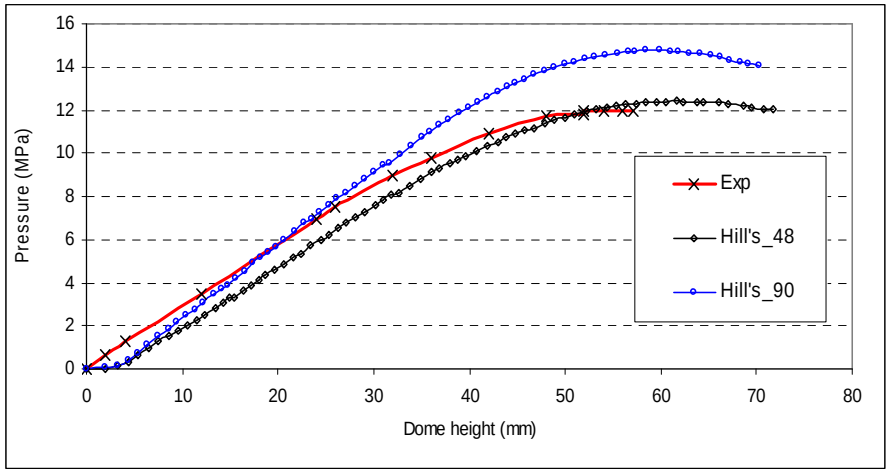
Using the elliptical die



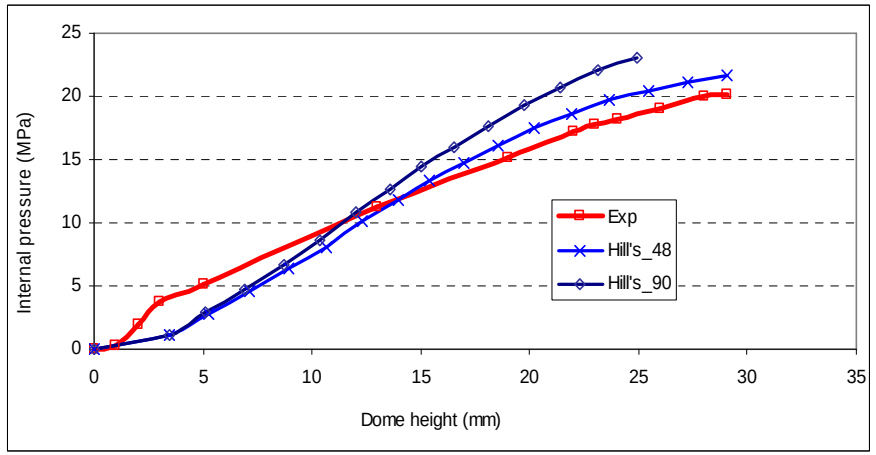
CR(4/6): Pressure vs dole displacement

DP600 0.9mm

Using the circular die



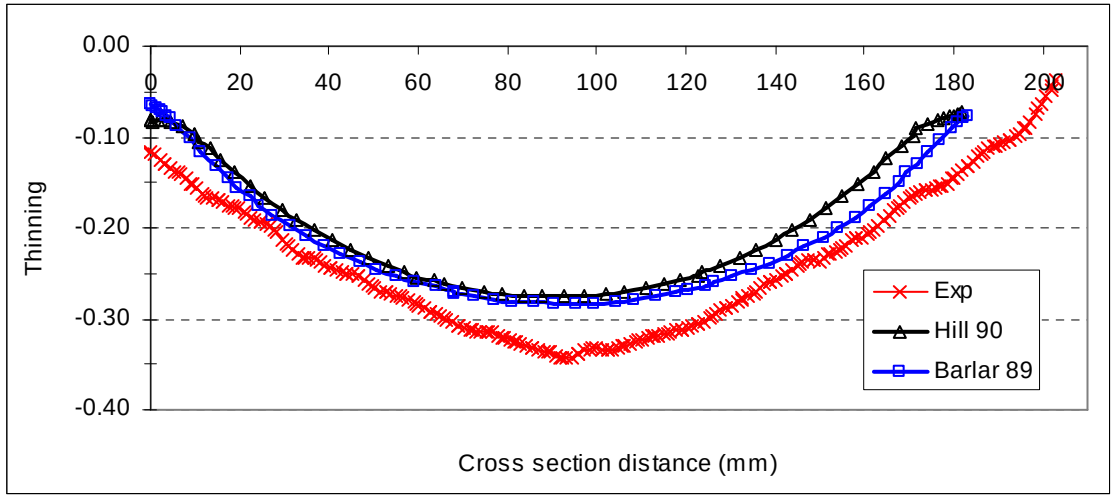
Using the elliptical die



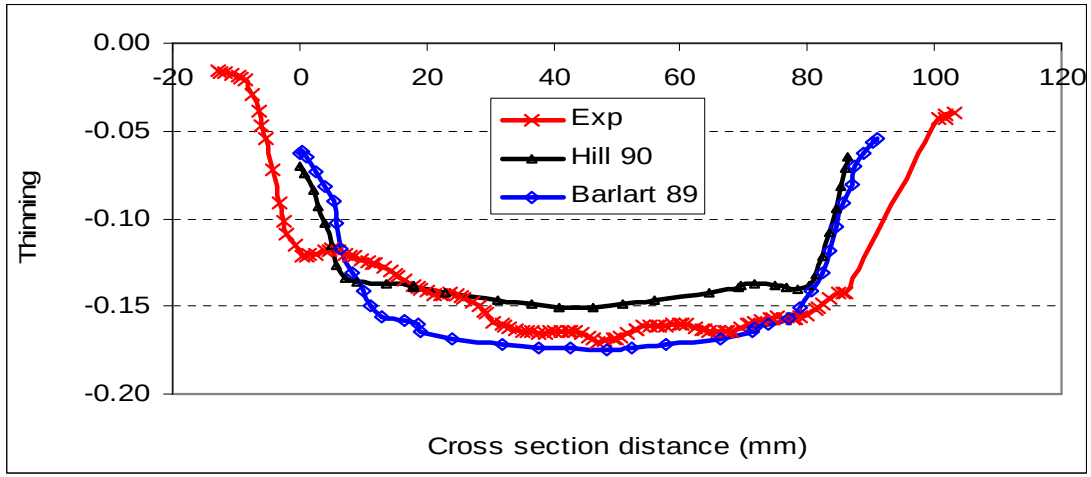
CR(5/6): Thinning

AA6111 1.0

Using the circular die



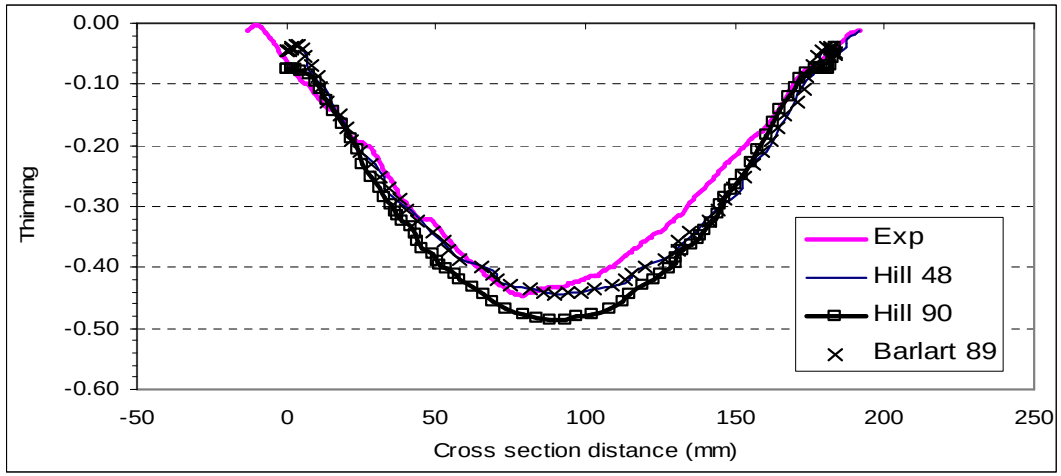
Using the elliptical die



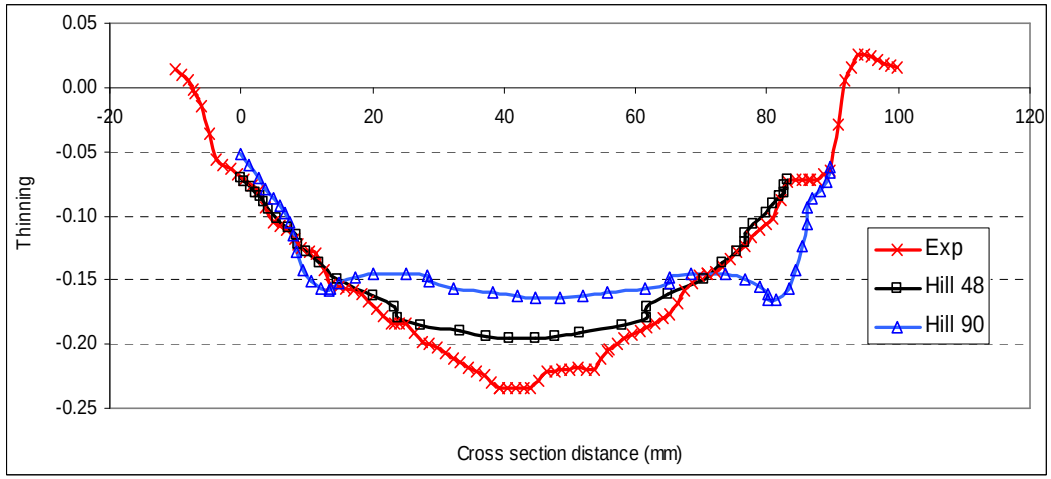
CR(6/6): Thinning

DP600 1.0mm

Using the circular die



Using the elliptical die



Conclusions

- **Bulge test, which introduces stretching deformation and minimise contact influence, can be an efficient benchmark test for FEA correlation**
- **For the AA611, FEA predictions are consistent with the experimental results**
- **For the DP600, reasonable correlations have been observed, while Hill 48 yielding criterion comparatively played better than Hill 90. Further confirmation investigation is needed**

Thank you for your attention