Research in Blanking, Hole Flanging and Edge Cracking

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Introduction

- Blanking is an integral part of sheet forming operations.
- Important issues that require attention in blanking are
  1. Achieving ‘good’ part edge quality
  2. Reverse loading during blanking of high strength materials
  3. Tool failure
  4. Blanking using servo-presses
Introduction

Schematic of the blanking process

\[ v_p = \text{punch velocity} \]
\[ f_b = \text{blankholder force (bhf)} \]
\[ d_p = \text{punch diameter} \]
\[ d_d = \text{die diameter} \]
\[ t = \text{sheet thickness} \]
\[ r_d = \text{die radius} \]
\[ r_p = \text{punch radius} \]
\[ d_b = \text{diameter of blankholder} \]
\[ h = \text{distance between sheet and blankholder} \]

Fracture zone (\( Z_f \))

Burr zone (\( Z_b \))

Roll over zone (\( Z_r \))

Shear zone (\( Z_s \))

Blanked edge (obtained from simulations)
1. Edge quality

- Hole flanging / edge cracking of advanced high strength steels (AHSS) is challenging because of the low formability of the material.
- Edge formability / hole flangeability can be improved by improving the blanked / pierced edge quality.
- Higher flangeability requires lower hardness (lower strain) on the blanked / pierced edge.
- The optimum blanking parameters to obtain lowest hardness (and strain) on the blanked edge have to be determined for AHSS.

Factors influencing edge quality:

(i) punch-die clearance and concentricity
(ii) blank holder pressure
(iii) punch tip geometry
(iv) punch velocity
(v) tool wear/radius
(vi) sheet material/thickness
1. Edge quality

- Several researchers have noted that the quality of the sheared edge zone affects the flangeability and HER of the sheet.
- The quality of the sheared edge can be quantitatively expressed in terms of hardness at the sheared edge.
- A better edge has lower hardness at the sheared edge.
- Many applications demand a certain shear zone and fracture zone limit in the hole/blank for good fitment/alignment.
Factors influencing the Hole Expansion Ratio (HER):

- Edge quality of the hole
- The method used to finish the hole (e.g. blanking, reaming etc.)
- Punch/die clearance used in blanking
- Positioning of burr with respect to punch
- Sheet material / thickness

Formed specimen - hole expansion test with conical punch [Sadagopan et al., 2003]
1. Edge quality

FE Simulation of Blanking
Influence of temperature on FE simulation of blanking

(a) Experimental sheared edge geometry from blanking DP 590, using 13.5% punch/die clearance [Konieczny, 2007], and (b) sheared edge from the FE simulation, with temperature distribution

Load vs. stroke curve from FE simulations of blanking of 1 mm thick DP 590 with 1.1% punch/die clearance, considering isothermal and non-isothermal conditions.
1. Edge quality

Distributions of damage values (DV) at the sheared edge explain the effect of punch geometry. Spherical punch yields more uniform distribution of DVs along the sheared edges and thus the influence of burr orientation on expansion ratio is less significant for this punch geometry.
1. Edge quality

Different ways to improve edge quality: Punch geometry

- Gradually contacting punch for improving stretch flangability [Mori et. al., 2013]
- Humped bottom punch to improve HER [Takahashi et. al., 2013]
Overall Objectives

The overall objectives of the study are to:

a) **Understand the factors that affect the quality of pierced/blanked edge** as well as Hole Expansion Ratio (HER) and edge cracking.

b) **Develop guidelines for optimum blanking conditions** for given sheet material, thickness and hole diameter (or curvature).

The important parameters that can affect the blanked edge quality and the hole expansion ratio, flangeability are

(i) punch-die clearance
(ii) blank holder pressure
(iii) punch tip geometry
(iv) punch velocity
(v) hardness of blanked/pierced edge
(vi) surface quality of the blanked/pierced edge.
Simulation study – Punch shapes used

Punch Shapes Used in Simulations
Note: Simulations were conducted with true stress-true strain data independent of temperature and strain rate. However, temperature due to deformation were estimated.

Flat Bottom Punch
Dimensions from [Takahashi et al., 2013] (Geometry-1)

Humped Bottom Punch
Dimensions from [Takahashi et al., 2013] (Geometry-2)

Conical punch-flat (For comparison) (Geometry-3)

Conical punch - pointed (For comparison) (Geometry-4)

A corner radius of 0.1 mm was used at all sharp edges.
Simulations – Conducted by CPF

Experiments – Conducted by [Takahashi et al., 2013]
Note: Type 1 denotes flat punch and type 2 denotes humped bottom punch
Simulation study - Results

Conical-flat punch gives the least average strain at the edge as well as the least maximum strain at the edge.

<table>
<thead>
<tr>
<th>Punch geometry</th>
<th>Average effective strain</th>
<th>Avg maximum strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat (1.2)</td>
<td>1.23</td>
<td>1.99</td>
</tr>
<tr>
<td>Humped (2.2)</td>
<td>1.06</td>
<td>1.57</td>
</tr>
<tr>
<td>Conical punch – Flat (3.3)</td>
<td>0.85</td>
<td>1.1</td>
</tr>
<tr>
<td>Conical punch – Pointed (4.1)</td>
<td>1.08</td>
<td>2</td>
</tr>
</tbody>
</table>
Reverse tonnage occurs when the material “snaps through” during a blanking operation. If this unchecked reverse tonnage exceeds the press capacity, it leads to excessive tool wear, unscheduled maintenances and catastrophic failure.
The reverse loads depends on:
• Total tonnage
• A very small tool in the center of a very large bed will actually produce more reverse tonnage than if the same tool is run on a press bed that closely matches the tool’s size.

Avoiding it:
• Tonnage should be monitored using a tonnage monitor.
• Tool size and press bed size should be matched.
• Staggering tools
• Shock dampers and other components to absorb reverse tonnage.
• Servo press
3. Tool life in blanking

- Common issue in blanking of advanced / ultra high strength steel (AHSS / UHSS) or high volume blanking of thin sheets (~ 0.2mm).
- Various parameters like sheet material and thickness, punch material and coating, punch-die clearance and punch velocity, punch/die corner corner radii influence punch life.
- Newer and better punch materials and coatings may help in extending punch life.
- Punch/die geometry can also be modified to improve punch life without much sacrifice in blanked edge quality.
3. Tool life in blanking

Experiments by [Högman 2004]

- Sheet material - Docol800 DP, 1mm thick.
- Punch material – Vanadis 4, 60 HRC
- Punch wear from experiments correlate with punch stress from FEA.

(a) Uniform clearance (10%)
(b) Larger clearance (27%)

Chipped after 40,000 strokes
No chipping after 200,000 strokes

Maximum Punch Stress (Simulations at ERC/NSM)
2010 MPa
2270 MPa

3. Tool life in blanking

Conclusions

• Optimize the punch-die clearance for the blanking operation.
• A punch-die clearance that is variable at the contour of a part gives a more uniform punch stress. This results in more uniform punch wear, thereby improving punch life considerably.
• FEM simulations conducted at CPF matched experimental results from [Högman 2004]
4. Blanking using servo press

The flexibility of slide motion in servo drive (or free motion) presses. [Miyoshi, 2004]
4. Blanking using servo press

Slide motion used for partial and finish blanking [Miyoshi, 2004 / Komatsu]

Precision Formed Part a) partially blanked, b) finished blanked [Miyoshi, 2004 / Komatsu]
Questions/Comments

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