THE EFFECTS OF AHSS SHEAR EDGE CONDITION ON EDGE FRACTURE

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Edge Fracture

Poor Shearing Edge Condition?

- Edge Fracture in Stamping
- Conventional FLD fails to predict
Outline

• Background
• Laboratory Shearing Test
  – Computer Control Hole Punch/Shear Process
• Evaluation of Punch/Shear Force
• Validation Edge Fracture Test
  – Hole Expansion Test
• Evaluation of Shear Edge Condition
• Conclusions
Background

**Straight Edge Shearing** (Blanking die, Trimming die)

- **Back Cut angle** $\Theta_2$ (clearance angle)
- **Blade Rake angle** $\Theta_1$
- **Shear Rake angle** $\Theta_3$

**Hole Punching** (Hole piercing die)

- **Blank Holder**
- **Punch**
- **Sheet Metal**
- **Die**

**Bevel Shear**

- **Blank Holder**
- **Punch**
- **Sheet Metal**
- **Die**

$\Theta_1 = \Theta_3$
Laboratory Shearing Test
Computer control hole punch/shear process

- Computer control
- Bevel angle
- Die clearance
- Shear speed
- Shear load
Schematic of Bevel Shear

\[ H = Pd \times \tan \Theta \]

\[ F \sim X \sim \frac{1}{\tan \Theta} \]

Shearing Test Conditions:

- Bevel Shear Angle: 0, 3, 6, 9, 12, 18, 24 degrees
- Die Clearance: 5, 10, 15, 20, 25, 30 % of test steel thickness
- Low speed
### MECHANICAL PROPERTIES OF TESTED STEELS

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness (mm)</th>
<th>Yield Strength (MPa)</th>
<th>Tensile Strength (MPa)</th>
<th>Total Elong. (%)</th>
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## Hole Punch/Shear Conditions

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<tr>
<th>Grade</th>
<th>Thickness [mm]</th>
<th>Punch diameter [mm]</th>
<th>Die diameter [mm]</th>
<th>Clearance [%]</th>
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<td>10.5</td>
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</table>

\[
D_{\text{die}} = 2Cl \times t / 100 + D_{\text{punch}}
\]
Hole Shearing Orientations

Transverse Shearing

Longitudinal Shearing

Material Rolling Direction

www.autosteel.org
Evaluation of Punch / Shear Force

Conventional Empirical formula:
\[ F = 0.7 \times \text{UTS} \times T \times L \]

Punch Load vs. Shear Angle
(DP780 1mm, transverse, die clearance 5%)

Over 55% load reduction
Ratio = 1/ tan \( \Theta \)

Peak Load (lbf)

Peak 1
Peak 2
Ratio

Shear Angle (degree)

Die Spring Force

Peak 1
Peak 2
Increase Shear Angle From 9 to 24 degree

Reduce Peak 1

Increase Die Clearance

Inc. Peak 1

Reduce Peak 2

ΔT increase
Comparison of Punch Penetration at Load Peak 1 and Peak 2

- Y1
- Y2
- H

Penetration (mm)

Shear Angle (Degree)

Group 1

Group 2

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Photograph of Punch/Shear Samples

Top View
- 3 degrees Peak 1
- 6 degrees Peak 1
- 18 degrees Peak 2

Curvature

Bottom View
- Faster shearing
  - 3 degrees Peak 1
  - 6 degrees Peak 1

Slower shearing
  - 18 degrees Peak 2

Large Rollover

Group 1
Group 2
Punch Load vs. Die Clearance
( DP780 1 mm, Transverse Shearing Direction )

Over 50% load reduction
Effects of Hole Shearing Orientations

Difference is larger at 3 degrees
Punch Load vs. Die Clearance
(DP980 1.2 mm, Longitudinal and Transverse)
Validation Edge Fracture Test
Hole Expansion Test

- Hole expansion test
- Specimen orientation: Burr Up
- Conical punch
- 1 inch/min

Tinus-Olsen formability machine
Effects of Bevel Shear Angle and Die clearance

DP780, 1mm, Transverse

Over 51% improvement

3 or 9 degrees?

Die Clearance

Hole Expansion Ratio

Die Clearance

Die Clearance
Effects of Material Shearing Orientations

![Graph showing the effects of material shearing orientations with different die clearances and hole expansion ratios.]

- **Dp780, 1mm**
  - 3 or 6 degrees
  - 15% < CL < 20%

- **Graph Key:**
  - flat
  - 3 degree-L
  - 3 degree-T
  - 6 degree-L
  - 6 degree-T
  - 9 degree-L
  - 9 degree-T

- **Die Clearance:**
  - 10%
  - 15%
  - 20%
Effects of Material Shearing Orientations

DP980, 1.2 mm

Over 60 % improvement

3, 6 and 9
Evaluation of Shear Edge Condition

- Rollover depth
- Penetration depth
- Fracture angle
- Burnish surface
- Rough fracture surface
- Burr height
- Fracture depth
No Visible Burr

Die Clearance $\leq 20\%$

~ 0.006 mm

With Visible Burr

Die Clearance $\geq 25\%$

~ 0.138 mm
HET Fracture Locations / Surface

Transverse Shearing

Longitudinal Shearing

Material Rolling Direction

HET fracture locations along rolling direction
Longitudinal Shearing (9 degrees, 10% CL)

- **Location 1**: No Fracture
- **Location 2**: Fracture with Shear direction and 3D Formation
- **Location 3**: No Fracture with Large Plastic Deformation and Shear direction
Transverse Shearing
(12 degrees, 15% CL)

3D Formation

Fracture location
at 1 or 3

Location 1

Fracture

Large Rollover
On trailing edge of the bevel shear punch
(Bevel Shear Angle > 9 degrees)

Tensile mixed type failure

Location 3
12 degree, 15% clearance - Loc. 3
Large rollover
Cause for relative larger load peak 2 - tensile/shear mixed type failure
Location 3

18 degree, 15% clearance - Loc. 1
Back Cut
Negative rollover
Burnish Depth vs. Die clearance
(Dp780, Location 1, Transverse)
Rollover Depth vs. Die Clearance
(DP780, Location 1, Transverse)

Rollover Depth (% of Thickness)

Die Clearance (%)
Conclusions

- Beveling shearing/piercing process has been developed at a lab base hydraulic press and has been successfully used for piercing holes for AHSS.

- The maximum shearing force can be significantly reduced more than 50% when a beveling angle is used during shearing. The shearing force depends also upon the die clearance during shearing.

- The optimal shearing condition results in more than 60% improvement in the hole expansion ratio when compared to conventional flat head punching process.

- The optimized shearing condition for piercing and shearing AHSS is the combination of a beveling angle between 3 and 6 degrees and a 17% die clearance and the shearing direction parallel to the material rolling direction.
Thank you