AN INNOVATIVE SHEARING PROCESS FOR AHSS EDGE STRETCHABILITY IMPROVEMENTS

Mike Shih
United States Steel Corporation
AHSS Edge Fracture

Cause:
- Material Property
- Die Condition
- Poor Sheared Edge Condition

- AHSS Edge Fracture
- Conventional FLD fail to predict
Outline

- Introduction
- Optimized Bevel Shear Hole Piercing
  - Hole Expansion Test
  - Evaluation of the Sheared Edge
- Developmental Straight Edge Shearing
  - Adjustable Shearing Device
  - Sheared Edge Tension Test
  - Sheared Edge Dome Test
  - Sheared Edge Limit Strain
- Conclusions
Introduction

Shearing Processes

Hole Punching (Hole piercing die)

- Blank Holder
- Punch
- Sheet Metal
- Die
- Clearance

Bevel Shear

- Blank Holder
- Punch
- Sheet Metal
- Die
- Clearance

Straight Edge Shearing (Blanking die, Trimming die)

- Blank Holder
- Upper Blade
- Lower Blade
- Sheet Metal
- Back Cut Angle (clearance angle)
- Blade Rake Angle $\Theta_2$
- Shear Rake angle $\Theta_3$
- Front View
Optimized Bevel Shear Hole Piercing

Specimen holding fixture

Blank Holder

Punch

Clearance

θ

6 degrees

Die spring

Punch

Die

Sheet Steel

Holder

Pd

Dd
Punch Load vs. Die Clearance
(DP980 1.2 mm, Longitudinal and Transverse)

Over 50% load drop

Peak Load (Lbf)

Die Clearance

8% 13% 17% 21%
Hole Expansion Test

DP780 1mm

Hole Expansion Ratio

Die Clearance

0% 10% 20% 30% 40% 50% 60%

10% 15% 20%

flat 3-L 3-T 6-L
6-T 9-L 9-T

Hole Expansion Test
Hole Expansion Test - DP980

- Best Shearing Condition
  6 degrees Bevel Shear

- DP980 1.2 mm
- DP980 2 mm
Optimized Shearing Condition
- 6 Degrees, 15% DC, Longitudinal Shearing

Test Material

Hole Expansion Ratio

50XK 1.4mm

DP600 2mm

DP780 (1mm)

Trip780 (1.6mm)

DP980 2mm
Concept Punch

Optimized : 6L
Concept 1 : 6-6
Concept 2 : 6C
Concept 2 : 9C

Hole Expansion Ratio

Punch Condition

50XK

DP600 1mm
DP600 1.6 mm
DP600 2 mm

www.autosteel.org
Evaluation of the Sheared Edge

Bevel Shear

<table>
<thead>
<tr>
<th>Side</th>
<th>Rollover (%)</th>
<th>Burnish (%)</th>
<th>Fracture (%)</th>
<th>HER (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side 1</td>
<td>12</td>
<td>21</td>
<td>68</td>
<td>53</td>
</tr>
<tr>
<td>Side 2</td>
<td>13</td>
<td>13</td>
<td>74</td>
<td></td>
</tr>
</tbody>
</table>

Flat Head Punch

<table>
<thead>
<tr>
<th>Side</th>
<th>Rollover (%)</th>
<th>Burnish (%)</th>
<th>Fracture (%)</th>
<th>HER (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side 1</td>
<td>16</td>
<td>21</td>
<td>63</td>
<td>32</td>
</tr>
<tr>
<td>Side 2</td>
<td>16</td>
<td>21</td>
<td>63</td>
<td></td>
</tr>
</tbody>
</table>

Microhardness profile of test DP780, Chiriac, C. et al. 2011, MS&T 2011
Developmental Straight Edge Shearing

- **Back Cut Angle** (clearance angle)
- **Holding Pad**
- **Lower Blade Rake Angle θ1**
- **Lower Blade**
- **Die Clearance**
- **Upper Blade Rake Angle θ2**
- **Upper Blade**
- **Sheet Metal**
- **Shear Rake Angle θ3**
Adjustable Straight Edge Shearing Device

Shear Rake Angle $\Theta 3$

Upper Blade

Lower Blade
Effect of the Shear Rake Angle

DP600, 1 mm

$\Theta 3 \leq 3$ degrees

$\Theta 3 = 1$ degree

$\Theta 3 = 2$ degrees

$\Theta 3 = 3$ degrees

$\Theta 3 = 4$ degrees

$\Theta 3 = 5$ degrees

Rolling

Curve
Shear Load Between Different Shear Rake Angles $\Theta 3$

Shear Load (KN) vs. Displacement (mm)

- 1 degree: 22% energy drop, 67% load drop
- 3 degrees: 78% load drop, 19% energy drop
- 4 degrees: Graph showing load and displacement changes

Legend:
- 001
- 002
- 003
- 004

Shear Rake Angles:
- 1 degree
- 2 degrees
- 3 degrees
- 4 degrees

www.autosteel.org
Specimen Shearing Direction

Longitudinal Shearing

Transverse Shearing

Sheet Metal

Material Orientation

Sheet Metal

Material Orientation
Comparison of the Shear Load

\[(\theta_1, \theta_2, \theta_3) \rightarrow \theta_1: \text{Lower Blade Rake Angle} \quad \theta_2: \text{Upper Blade Rake Angle} \quad \theta_3: \text{Shear Rake Angle}\]

Different Die Clearance

- 363-10%
- 363-15%
- 363-20%

- 15.8% energy drop
- 26.5% energy drop

Different Shearing Direction

- 363-L
- 363-T

- 5.2% energy drop
Sheared Edge Tension (SET) Test

Milled Edge

Sheared Edge
Total Elongation (TE) Between Different Shearing Conditions

Shearing Condition

Conventional Shearing

JSTM Milled

8% improvement
Different Failure Modes in the SET test

Type (4)  
Localized Necking  
Fracture initiation

Type (3)  
Tensile failure + Localized Necking

Type (2)  
Edge crack + Tensile failure

Type (1)  
Tensile failure
Effects of Die Clearance

DP600, 1mm

Shearing Conditions

TE (%) - 10%, 15%, 20%
Comparison of the Dome Height

Dome Height (mm)

Shearing Condition

333 363 393 633 663 693 933 963 993

10% 15% 20%
Comparison of the Strain at Failure

Shearing Condition

Fracture Strain

Shearing Condition

Comparison of the Strain at Failure
Sheared Edge Limit Strain (SELS)

Best Shearing Conditions: 363, (333 or 663) with 15% die clearance

Criteria:
- The first through-thickness crack at the edge
- The onset of local necking

\[ q = \frac{A_o - A_f}{A_o} \]

\[ SELS = \frac{q}{1 - q} \times 100 \]

(Methodology: Wang, J. et al. 2008, International Conference on New Developments in Advanced High-Strength Sheet Steels)
Conclusions

- The experiments confirmed that the use of the optimal hole shearing condition can result in significantly better edge stretchability for all AHSS.
- A computer controlled adjustable straight edge shearing device was successfully developed based on the findings from the beveled shear hole piercing process.
- The maximum shearing force and applied energy can be significantly reduced when proper shear variables are used during shearing.
- The shearing force also depends upon the die clearance, and the larger die clearance tends to decrease the shear force.
- The sheared edge tension test and dome test confirmed that the optimal setup of the rake angles in the straight edge shearing process would result in a significant improvement of edge stretchability for test AHSS.
- The optimal shearing condition for AHSS is using the rake angle setup (3,6,3) with 15% die clearance.
Thank you
Great Designs in Steel is Sponsored by:

AK Steel
ArcelorMittal Dofasco Hamilton
ArcelorMittal
Severstal
NUCOR
ThyssenKrupp
USS

Steel Market Development Institute

www.autosteel.org