OPTIMAL PRODUCTION TRIMMING PROCESS FOR AHSS EDGE STRETCHABILITY IMPROVEMENT

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Outline

• Introduction
  – Edge Fracture
  – Flat Trim vs. Shear Trim

• Cutting Test

• Edge Stretchability
  – Trimmed Edge Tension Test
  – Half Specimen Dome Test

• Trimmed Edge Characterization

• Summary
Edge Fracture

- FLD failed to predict
- May be due to poor trimmed edge condition
Introduction – Flat Trim

Shear Rake Angle = 0

Front View

Upper Blade

Holding Pad

Side View

Sheet Metal

Lower Blade

Die Clearance
Introduction – Flat Trim

- **Quality**
  - *Poor Trimmed Edge Stretchability*

- **Cost**
  - *Split Parts*
  - *Tool Wear/Damage*
  - *Energy Consumption*
  - *Down Time*
Introduction – Shear Trim

Shear Trim

Shearing Parameters (θ1, θ2, θ3)

Shear Rake Angle θ3

Upper Blade Rake Angle θ2

Back Cut Angle (clearance angle)

Holding Pad

Upper Blade

Sheet Metal

Lower Blade

Lower Blade Rake Angle θ1

Die Clearance

Front View
Introduction – Shear Trim

• Quality
  − Better Trimmed Edge Stretchability

• Cost
  − Less Split Parts
  − Less Tool Wear/Damage
  − Reduce Energy Consumption
  − Reduce Down Time
## Test Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness (mm)</th>
<th>Yield Strength (MPa)</th>
<th>Tensile Strength (MPa)</th>
<th>Total Elong. (%)</th>
<th>n Value</th>
<th>R Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP600 - L</td>
<td>1.0</td>
<td>391</td>
<td>645</td>
<td>26.4</td>
<td>0.16</td>
<td>0.86</td>
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<tr>
<td>DP600 - T</td>
<td>1.0</td>
<td>411</td>
<td>659</td>
<td>26.7</td>
<td>0.15</td>
<td>1.03</td>
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<tr>
<td>DP980 - L</td>
<td>1.2</td>
<td>677</td>
<td>994</td>
<td>14.0</td>
<td>0.14</td>
<td>0.73</td>
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<tr>
<td>DP980 - T</td>
<td>1.2</td>
<td>660</td>
<td>992</td>
<td>14.1</td>
<td>0.14</td>
<td>1.05</td>
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</tbody>
</table>
Cutting Conditions

Flat Trim

Shear Trim

Shear Trim

Shear Trim OT

0 degree

1 degree

2 degree

3 degree

Optimized (6,6,3)
Cutting Force

**Peak Load (kN)**

- **Flat Trim**
- **Shear Trim**

**Shear Rake Angle (Degree)**

- DP600
- DP980

**Reduction Ratio (%)**

- DP600
- DP980

Shear Rake Angle (Degree) vs. Peak Load (kN)

Shear Rake Angle (Degree) vs. Reduction Ratio (%)
Cutting Force Estimation

Flat Trim

\[ F = C_1 \times T \times L \times UTS \]

Material Constant

\( C_1 = 0.77, \) DP600
\( C_1 = 0.68, \) DP980

Shear Trim

\[ F = C_{\text{Shear}} \times T^2 \times \frac{UTS}{2} \times \tan \theta \]

Material Constant

\( C_{\text{Shear}} = 1.00, \) DP600
\( C_{\text{Shear}} = 0.86, \) DP980
Edge Stretchability

Trimmed Edge Tension Test

Milled Edge

As-Trimmed Edge
Edge Stretchability – Tension Test

DP600

<table>
<thead>
<tr>
<th>Cutting Condition</th>
<th>Total Elongation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Trim-T</td>
<td>16</td>
</tr>
<tr>
<td>Flat Trim-L</td>
<td>18</td>
</tr>
<tr>
<td>Shear Trim 1-T</td>
<td>20</td>
</tr>
<tr>
<td>Shear Trim 1-L</td>
<td>22</td>
</tr>
<tr>
<td>Shear Trim 2-T</td>
<td>24</td>
</tr>
<tr>
<td>Shear Trim 2-L</td>
<td>26</td>
</tr>
<tr>
<td>Shear Trim 3-T</td>
<td>28</td>
</tr>
<tr>
<td>Shear Trim 3-L</td>
<td></td>
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<tr>
<td>Shear Trim OT-T</td>
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<tr>
<td>Shear Trim OT-L</td>
<td></td>
</tr>
</tbody>
</table>
Edge Stretchability – Tension Test

**DP600**

- Flat Trim
- Shear Trim 1
- Shear Trim 2
- Shear Trim 3
- Shear Trim OT
- Milling
- Laser
- Water

**DP980**

- Flat Trim
- Shear Trim 1
- Shear Trim 2
- Shear Trim 3
- Shear Trim OT
- Milling
- Laser
- Water

**Total Elongation %**
Edge Stretchability

Half Specimen Dome Test

3D Stretching

Edge Fracture
Edge Stretchability – Dome Test

### DP600

<table>
<thead>
<tr>
<th>Cutting Condition</th>
<th>Strain at Failure (%)</th>
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</thead>
<tbody>
<tr>
<td>Water</td>
<td>36 ± 2</td>
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<tr>
<td>Laser</td>
<td>32 ± 2</td>
</tr>
<tr>
<td>Milling</td>
<td>30 ± 2</td>
</tr>
<tr>
<td>Shear Trim OT</td>
<td>28 ± 2</td>
</tr>
<tr>
<td>Shear Trim 3</td>
<td>26 ± 2</td>
</tr>
<tr>
<td>Shear Trim 2</td>
<td>24 ± 2</td>
</tr>
<tr>
<td>Shear Trim 1</td>
<td>22 ± 2</td>
</tr>
<tr>
<td>Flat Trim</td>
<td>20 ± 2</td>
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</tbody>
</table>

### DP980

<table>
<thead>
<tr>
<th>Cutting Condition</th>
<th>Strain at Failure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>34 ± 2</td>
</tr>
<tr>
<td>Laser</td>
<td>30 ± 2</td>
</tr>
<tr>
<td>Shear Trim OT</td>
<td>28 ± 2</td>
</tr>
<tr>
<td>Shear Trim 3</td>
<td>26 ± 2</td>
</tr>
<tr>
<td>Shear Trim 2</td>
<td>24 ± 2</td>
</tr>
<tr>
<td>Shear Trim 1</td>
<td>22 ± 2</td>
</tr>
<tr>
<td>Flat Trim</td>
<td>20 ± 2</td>
</tr>
</tbody>
</table>
Trimmed Edge Characterization

Macrographs of Cutting Edge

- Flat Trim
- Shear Trim OT
- Laser
- Water Jet

Formation
Striations
Smooth
Trimmed Edge Characterization - Microhardness

Distance from the Trimmed Edge (µm)

HV

Flat Trim-1
Flat Trim-2

Laser-1
Laser-2

Water-1
Water-2

Shear Trim OT-1
Shear Trim OT-2
Trimmed Edge Characterization - Microhardness

Distance from the Trimmed Edge (μm)

HV

SAZ

Flat Trim
Shear Trim 1 degree
Shear Trim OT
Laser
Water
The Improvement of the Mechanical Trimming Process

Strain at Failure (%)

- Flat Trim
- Shear Trim 1 -Dull
- Shear Trim 1 -Sharp
- Shear Trim OT
- Flat Trim-Polish
- Laser
- Water

Conventional Shear
Summary

- The traditional trim condition with zero-degree angles has the lowest trimmed edge stretchability, while water jet cutting has the highest.

- The developed optimal mechanical trimming process (OT) can improve the cutting condition more than 60% total elongation when compared to the traditional trimming process.

- The laser cutting and water jet cutting has better trimmed edge stretchability than mechanical cutting. However, the water jet cutting edge rusted more easily and should be avoided in production.

- The post polishing process can be used as an alternative way to improve the mechanical trimmed edge stretchability.

- A shear trim with 15% die clearance is recommended in the production trimming set up for AHSS.