Tooling Solutions and Processing Parameters Designed for Stamping and Forming Advanced High-Strength Steels

Thomas Hillskog, Senior Technical Advisor, Uddeholms AB
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• Tooling requirements
  − Tool steel substrate
  − Tooling surface

• Results
  − Based on laboratory testing
  − Based on actual production tools

• Summary and conclusions
Introduction

• Sheet metal grades
• Trends in automotive sector
• Influences of sheet material strength
• Failure mechanisms
Sheet Metal Grades

Tensile Strength (MPa) vs. Elongation (%)

- Conventional Steels
  - IF
  - IF+HS
  - BH
  - CMn +
- Austenitic Stainless (Annealed)
- AHSS Grades
  - TWIP
  - TRIP
  - HSLA, FB
  - DP, CP
  - MS
  - MnB+ HF
  - Current 3rd GEN AHSS
  - 3rd GEN AHSS

Source: WorldAutoSteel
Trends

1. HSS, aluminum, magnesium, plastics, carbon fiber
2. **High strength steel (>550 MPa ; 80,000 psi)**
3. Mainly other metals, glass, fluids, interior parts

Influence of Sheet Material Strength

Sheet thickness: 1 mm (0.039”)

- High force
- Shock wave during breakthrough

Force, N

Time, s

Punch diameter: Ø 4.80 mm (0.19”)

Die clearance: 10%

- 1400 MPa
- 800 MPa
- 500 MPa
- 280 MPa
## Influence of Sheet Material Strength

<table>
<thead>
<tr>
<th>Type of sheet</th>
<th>Strength $R_m$ (MPa)</th>
<th>Blanking</th>
<th>Forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft-mild</td>
<td>&lt; 330</td>
<td>• Increased wear</td>
<td>• Increased wear</td>
</tr>
<tr>
<td>Medium strength</td>
<td>330-550</td>
<td>• Increased wear</td>
<td>• Increased wear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased chipping-cracking</td>
<td>• Increased galling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increased plastic deformation</td>
<td>• Increased spring back</td>
</tr>
<tr>
<td>High strength</td>
<td>550-800</td>
<td></td>
<td>• Increased plastic deformation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Increased wrinkling problems</td>
</tr>
<tr>
<td>Ultra high strength</td>
<td>&gt; 800</td>
<td>• Shock waves</td>
<td>• Reduced formability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Increased increased spring back</td>
</tr>
</tbody>
</table>

- Increased wear
- Increased galling
- Reduced formability
## Influence of Sheet Material Strength

<table>
<thead>
<tr>
<th>Type of sheet</th>
<th>Tensile strength $R_m$ (psi)</th>
<th>Blanking</th>
<th>Forming</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tool failure</td>
<td>Note</td>
</tr>
<tr>
<td>Soft -mild</td>
<td>&lt; 48,000</td>
<td>• Increased wear</td>
<td>• Changed die clearance</td>
</tr>
<tr>
<td>Medium strength</td>
<td>48,000 to 80,000</td>
<td>• Increased chipping-cracking</td>
<td>• Reduced burr formation</td>
</tr>
<tr>
<td>High strength</td>
<td>80,000 - 116,000</td>
<td>• Increased plastic deformation</td>
<td></td>
</tr>
<tr>
<td>Ultra high strength</td>
<td>&gt; 116,000</td>
<td>• Shock waves</td>
<td></td>
</tr>
</tbody>
</table>
The Cold Work Failure Mechanisms

- Wear
- Plastic deformation
- Chipping
- Cracking
- Galling

- Sliding contact
- Contact pressure
- Fatigue
- Fatigue
- Sliding contact
Requirements on the Tool Steel

The most commonly used tool steels for blanking, trim, forming and calibration dies:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Steel Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>12% Cr-steel</td>
<td>AISI D2</td>
<td>W.-Nr. 1.2379</td>
</tr>
<tr>
<td>5% Cr-steel</td>
<td>AISI A2</td>
<td>W.-Nr. 1.2363</td>
</tr>
</tbody>
</table>

These grades are not always suitable for demanding presswork applications like those involving AHSS. They do not have sufficient chipping/cracking resistance.
New Tooling Requirements for Blanking AHSS

- Tool steel with the correct balance of properties
- Sufficient compressive strength (working hardness >60 HRC)
- Tool steel with high chipping/cracking resistance
- Excellent tool making characteristics
- Very good surface finish on tooling – a poor surface finish will significantly reduce chipping/cracking resistance
  - A good surface finish is particularly important here
Influence of Tool Steel Type and Surface Finish

- Tool material with carbide stringers
- Time for crack initiation
- Tool lifetime
- Tool with poor surface finish
- Tool with EDM-surface layer
- Time for crack propagation

- Tool with poor surface finish
- Tool with EDM-surface layer
**Influence of Tool Steel Type and Surface Finish**

**Initial status:**
Stamped material – S700 MC

Material used for punching:
PM M4 (HSS), 60 - 62 HRC.

PVD coated

Wearing off (chipping) after 10,000 hits

**Current status:**
Upgrade: Vanadis 4 Extra at 60 - 62 HRC.

Result: Increase in service life; over 90,000 hits (still stamping).
Modern steels with improved chipping resistance

- Caldie - ESR matrix steel
- Vanadis 4 Extra - PM steel - modified carbides
- Sleipner - modified carbides
- O1, A2, D2, ~ D6

Wear resistance

Chipping resistance
### Results from Lab Tests

**Blanking of AHSS, t=1.8 mm (0.071”)**

**Edge appearance after 50,000 hits**

#### Limiting tool steel failure mechanisms

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Abrasive wear</th>
<th>Adhesive wear/galling</th>
<th>Chipping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arne (AISI O1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rigor (AISI A2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleipner</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sverker 21 (AISI D2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sverker 3 (AISI D6/D3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caldie</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vanadis 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vanadis 4 Extra</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vanadis 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vanadis 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vanadis 23</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Steel Matters**

Demand Nothing Less

www.autosteel.org
Die Clearance for Blanking of AHSS Sheets

1 mm (0.039”) thick material
200,000 hits
Vanadis 4 Extra, punch hardness at 60 HRC

Graph showing punch wear (μm^2) vs. die clearance (%) for Docol 1400 M and Docol 800 DP.

- Galling
- Chipping / cracking

Image of galling and chipping/cracking on steel surfaces.
Results from Lab Tests – Coatings

**Docol DP800**
- Uncoated: 200,000 hits
- Coated TiAlN: 100,000 hits

**Docol MS1400**
- Uncoated
Results from Production Tools

Ford’s New DP 600 Die Standards

Six months prior to launch of the 2005-model-year Ford Freestyle and 500 vehicles, both laden with DP 600 steel, Ford Motor Co. asks its engineers to prepare new die standards for trimming and drawing the advanced high-strength alloy.

BY BRAD KUHN, EDITOR

Increased vehicle safety requirements and strict crash requirements drive increased application of advanced high-strength steels (AHSS) for parts surrounding the driver compartment. Forming these stronger parts increases contact pressures at the surfaces of stamping dies, which accelerates all of the common tooling-failure modes. Failure to account for these increased contact pressures places stamping at risk—exactly what Ford Motor Co. faced early in 2004 as it prepared to launch its new Ford 500 and Freestyle vehicles. Both incorporate a fair share of AHSS parts—DP (dual-phase) 600, for example, represents 15 percent of the steel by mass, on the Ford 500 body.

A Caldie trim post—strap chutes folded with cam slides mounted for horizontal piercing—units ready for press installation. It’s used to trim 1.8-mm DP 600 steel for production of four side inners at Ford’s Chicago, IL, stamping plant. The bronze color is a PVD TiCN coating on the tool.

8 Trim dies in Caldie
PVD TiCN coated

DP 600 sheet;
1.8 mm (0.071”) thick

Production since 2005:

800,000 parts/die with no downtime

In total, over 2.5 millions parts have been produced.
Results from Production Tools

Caldie – trimming of hot stamped AHSS

Product: Structural pieces for automotive (B-pillar)
Sheet material: PHS 1500 Alu; pre-coated; 1500 MPa (217,000 psi)
Thickness: 2.2 mm (0.087”)

<table>
<thead>
<tr>
<th></th>
<th>PM HSS</th>
<th>8 % Cr</th>
<th>Caldie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (HRC)</td>
<td>57 / 59 HRC</td>
<td>59 / 61 HRC</td>
<td>60 / 62 HRC</td>
</tr>
<tr>
<td>Heat treatment</td>
<td></td>
<td></td>
<td>1870°F 970°F, 2x2h</td>
</tr>
<tr>
<td>Production before</td>
<td>Very short before</td>
<td>5,000 before welding</td>
<td>26,000</td>
</tr>
<tr>
<td>maintenance</td>
<td>welding repair</td>
<td>welding repair</td>
<td></td>
</tr>
<tr>
<td>Failure</td>
<td>Chipping</td>
<td>Chipping</td>
<td>Chipping</td>
</tr>
<tr>
<td>Comments</td>
<td>Too brittle</td>
<td>Too brittle</td>
<td>The best result</td>
</tr>
</tbody>
</table>
Results from Production Tools

Door Beam

Sheet material: MS 1200; 1.5 mm (0.059”)

Forming die: Sleipner + TD; 61 HRC

Trimming die: Caldie; 61 HRC

Annual volume: over 200,000
Results from Production Tools

Control arm

Sheet material: DP 800; 2.9 mm (0.114”)

Forming die: Vanadis 4 Extra + CVD TiCN; 60 HRC

Trim die: Vanadis 4 Extra; 60 HRC

Volume: over 300,000 / year
Summary and Conclusions

• Influence of new AHSS materials
• How it affects the failure types
  – Increased chipping / wear
  – Increased galling
• New requirements
  – On tool steels
  – Tool making – surface finish, die clearance, etc.
  – Use of coatings
• Cases with new, more suitable tool steels
Tooling Solutions for AHSS

• Cooperation between AHSS manufacturers and tool steel manufacturers is essential

• Uddeholm has focused for many years on developing tool steel grades that can meet the new requirements