Tool and Die Design for Deep Drawing AHSS

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Dipl.-Ing. M. Vulcan
High Strength Steel Sheets
Stretch Drawing of Flat Parts
Controllable Draw Beads
Cushion Systems and Die Design
Summary
Development of High Strength Steels

- **Multiphase Steel**: Increase of strength by microstructural change
- **Isotropic Steel**: Concerted control of grain refining by adding Titanium
- **Higher-Strength IF-Steel**: Solid solution hardening
- **Bake Hardening Steel**: Diffusion of interstitial N and C to increase the yield strength
- **Dual Phase Steel**: Embedding hard martensite parts in ferritic matrix
- **Phosphorus-Alloyed Steel**: Solid solution hardening by adding phosphorus
- **Micro-Alloyed Steel**: Hardening by carbides of micro alloy elements Ti, Nb, V

Source: Thyssen
Comparison of Different Steel Grades
Flow Curves of Actual Sheet Metals
## High Strength Bake-Hardening Steels

<table>
<thead>
<tr>
<th>Steel Type</th>
<th>Yield Strength in MPa</th>
<th>UTS in MPa</th>
<th>Elong. at Fracture $A_{80}$ in %</th>
<th>R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>min</td>
<td>max</td>
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<tr>
<td>HSLA 180 BH</td>
<td>180</td>
<td>240</td>
<td>300</td>
<td>380</td>
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<tr>
<td>HSLA 220 BH</td>
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<td>280</td>
<td>320</td>
<td>400</td>
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<tr>
<td>HSLA 260 BH</td>
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<td>320</td>
<td>360</td>
<td>440</td>
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<tr>
<td>HSLA 300 BH</td>
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<td>360</td>
<td>400</td>
<td>480</td>
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</tbody>
</table>

## High and Advanced High Strength Steels

<table>
<thead>
<tr>
<th>Steel Type</th>
<th>Yield Strength in MPa</th>
<th>UTS in MPa</th>
<th>Elong. at Fracture $A_{80}$ in %</th>
<th>R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
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<td>min</td>
<td>max</td>
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<tr>
<td>DP 600</td>
<td>381</td>
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<td>574</td>
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<tr>
<td>DP 700</td>
<td>583</td>
<td></td>
<td>735</td>
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<tr>
<td>DP 800</td>
<td>567</td>
<td></td>
<td>869</td>
<td></td>
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<tr>
<td>TRIP 700</td>
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<td>680</td>
<td>850</td>
<td>20-30</td>
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<tr>
<td>CP 800</td>
<td>793</td>
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<td>903</td>
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<td>MS 1200</td>
<td>1150</td>
<td></td>
<td>1350</td>
<td></td>
</tr>
</tbody>
</table>

Source: Birzer
- High Strength Steel Sheets
- Stretch Drawing of Flat Parts
- Controllable Draw Beads
- Cushion Systems and Die Design
- Summary
Test Equipment for Stretch Drawing followed by Deep Drawing

Source: T. Krockenberger, IFU
Test Equipment for Stretch Drawing followed by Deep Drawing, Installed in Single Acting Hydraulic Press at IFU

Source: T. Krockenberger, IFU
First Stage: Clamping the Sheet

Source: D. Vlahovic, IFU
Second Stage: Predefined Stretching of the Sheet

Source: D. Vlahovic, IFU
Third Stage: Tool Closing
Last Stage: Deep Drawing of the Sun Roof Panel

Source: D. Vlahovic, IFU
Principal Strain after Deep Drawing

Principal Strain after Pre-Stretching

Source: D. Vlahovic, IFU

Results FEM Process Simulation
- High Strength Steel Sheets
- Stretch Drawing of Flat Parts
- Controllable Draw Beads
- Cushion Systems and Die Design
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Springback Reduction:

Increased Wall Stresses in the Straight Sides by Driving the Active Drawbeads Upwards.

Guideline: $\sigma_{\text{Wall}} < 0.8 \sigma_{\text{Fracture}}$

Desired Wall Stress Distribution

Source: S. Beck, IFU
Intention: Improved Wall Quality by Introducing Additional Forces

Additional Force by Increased Blankholder Force and/or Increased Drawbead Height

Desired Punch Force Trajectory

Source: S. Beck, IFU
Elastic Hinge

Vertical Force

Horizontal Force in the Sheet (Restraining Force)

Load Cell

Force in the Sheet

Side Wall Stress Sensor

Punch

Source: S. Beck, IFU
Position of the Wall Stress Sensors and Position of the Drawbeads

Source: S. Beck, IFU
Stress at Fracture

Side Wall Stress vs. Stroke for Constant Draw Bead Heights

Quelle: S. Beck, IFU
Curvature of the Side Wall for Variable Draw Bead Heights vs. Stroke

Source: S. Beck, IFU
Springback Phenomena when Drawing U-Profiles

Source: M. Beth
Sidewall of the Part, drawn without Drawbeads

Sidewall of the Part, drawn with Controllable Drawbeads

Source: S. Beck, IFU

Surface Quality with and without Controllable Drawbeads
(Measured with the System Diffracto)
High Strength Steel Sheets
Stretch Drawing of Flat Parts
Controllable Draw Beads
Cushion Systems and Die Design
Summary
Design of Conventional Draw Dies

Source: M. Häussermann, IFU
Blankholder Pressure: 4 ... 0 N/mm²

Source: M. Häussermann, IFU

Blankholder Pressure by the Box-Profile
Principle of the Segment-Elastic Blankholder

Locally increased Blankholder Pressure

Source: M. Häussermann, IFU
Draw Die with Segment-Elastic Blankholder, Prismatic Designed Draw Ring and 10-Point Cushion System Integrated into the Die

Prismatic Designed Draw Ring

Segment-Elastic Blankholder

Return Stroke Cylinders

Stroke Measurement

Hydraulic Cylinders

Source: M. Häussermann, IFU
Hydraulic Multipoint Cushion System in the Die

Source: M. Häussermann, IFU
Normal Pressure: 4,5 ... ... 0 N/mm²

Equal Pin Forces

Increase of 100% in the Middle Area

Source: M. Häussermann, IFU
Optimization of the Cushion Pin Forces

Total Blankholder Force  530kN

Good Part with 68 mm Draw Depth

Source: M. Häussermann, IFU
Die for the Deep Drawing of Longitudinal Beams with Cushion System integrated into the Die

Source: D. Haller, IFU
Die for the Deep Drawing of Longitudinal Beams with Cushion System integrated into the Die

Source: D. Haller, IFU
Experimental Die

Source: J. Hengelhaupt, IFU
Stuttgart University
Institute for Metal Forming Technology

Hydraulic HMI
Main Mobile Hydraulic Unit
Press HMI
10 Point Flexible Binder Die
20,000 kN Hydraulic Press at the IFU
IFU HMI
MOOG Controller Units
HYDAC Power Unit
Cooling System
2 x Return Tank Units
2 x Bladder Accumulators Station (each 1 x 60 bar and 2 x 10 bar)

Source: IFU
Control system with Touch Screen to Adjust the Blankholder Pressure Area by Area
Design of Closed Loop Control of the BHF

<table>
<thead>
<tr>
<th>Nominal Value</th>
<th>Friction Force versus the Stroke</th>
<th>Max. Wrinkle Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>Actual Values</td>
<td></td>
</tr>
<tr>
<td>Controller</td>
<td>Measuring Friction Force and Wrinkle Height</td>
<td></td>
</tr>
<tr>
<td>Ram</td>
<td>Upper Binder</td>
<td>Segment-elastic Blankholder</td>
</tr>
<tr>
<td></td>
<td>Cushion System integrated into the Die</td>
<td></td>
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</table>

Source: IFU
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Stuttgart University
Institute for Metal Forming Technology