GROWTH IN AUTOMOTIVE APPLICATIONS AND ASSOCIATED MANUFACTURING AND MANUFACTURING TOOLING CHALLENGES

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Auto/Steel Partnership
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Introduction

- Currently the Executive Director of the Auto/Steel Partnership
- Over 38 years in automotive steel industry
- 17+ years with General Motors – Global Lead; innovation, body and chassis structures
- Prior experience in project execution, management, coordination and technical leadership
- Education: Bachelor of Science – Mechanical and Production Automotive from Bolton Technical College
Agenda

• Drivers for growth of Advanced High-Strength Steel (AHSS)
• AHSS defined
• Impact on Progressive Die Tooling
• AHSS Hole Punch Force and Edge Cracking Study
• Conclusion
Fuel Economy Regulations History

Miles per gallon equivalent

Model year

Passenger Cars

Light Trucks

Obama Administration Standards

54.5 mpg fleetwide average in 2025

MY1978-2011 figures are NHTSA Corporate Average Fuel Economy (CAFE) standards in miles per gallon. Standards for MY2012-2025 are EPA greenhouse gas emission standards in miles per gallon equivalent, incorporating air conditioning improvements. Dashed lines denote that standards for MY2017-2025 reflect percentage increases in Notice of Intent.
Overview – U.S. Crash Regulations

**FRONT**
- FMVSS 208: Rigid barrier
- FMVSS 208: 60 mph
- FMVSS 208: 25 mph
- IHTSA-Oblique: Deformable barrier
- IHS: Deformable barrier

**ROOF**
- FMVSS 210a: Rigid barrier
- FMVSS 208: Rollover
- FMVSS 301: Roof Crush
- IHS: - Roof Crush
- US NCAP: - SSIF

**SIDE**
- FMVSS 201: Rigid barrier
- FMVSS 214: Deformable barrier
- FMVSS 214: Deformable barrier
- US NCAP: Rigid barrier
- US NCAP: 15 mph

**FMVSS 305**
- 100% Offset
- Electric vehicles
- 45 km/h
- Rigid barrier (0°-30°)

**FMVSS 581**
- Pendulum test
- 2.5 km/h / 4 km/h

**IHS**
- IIHS RCAR Bumper Test
- 10 km/h / 5 km/h
- Rigid barrier

- IIHS RCAR Structure Test
- 15 km/h
- Rigid barrier
Automotive Steel Grade Innovation

1970

Number of Unique Steel Specifications

Elongation (%)

Tensile Strength (MPa)
Automotive Steel Grade Innovation

1980

Number of Unique Steel Specifications

Elongation (%)

Tensile Strength (MPa)

200 500 800 1100 1400 1700 2000

Mild
HSLA, FB
Automotive Steel Grade Innovation

1990
Automotive Steel Grade Innovation
Automotive Steel Grade Innovation
Automotive Steel Grade Innovation

TODAY

Aluminum Alloys
Yield Strength vs. Elongation %

CONVENTIONAL STEELS
IF
IF-HS
Mild
TRIP
HSLA, FB
DP, CP
3rd GEN AHSS
AHSS GRADES

Tensile Strength (MPa)

Number of Unique Steel Specifications

Elongation (%)

0 10 20 30 40 50 60 70 80

0 40 80 120 160 200
AHSS Growth Exceeds Forecast

AHSS continues its growth trajectory with approximately 254 pounds per vehicle in 2014, surpassing our estimates in 2010 for 2014 by over 20 pounds per vehicle (prior 2014 estimate was 232 pounds).

AHSS Pounds per Vehicle 2010 Study vs. 2013/2014 Study
Auto/Steel Partnership (A/SP)

- Collaborative organization
- Founded in 1987

- Members include:
Evaluation of Progressive Die Wear Properties of Bare DP1180

• Study die wear durability of various tooling materials and coatings for flanging operations on bare DP1180 steel

• Update OEM tooling standards based on the test results
Experimental Material – Bare DP1180

Engineering Stress-Strain Curves for Bare DP1180 (1.2 mm Thickness)

<table>
<thead>
<tr>
<th>Sample Orientation</th>
<th>Specimen Gauge (mm)</th>
<th>Yield Strength (MPa)</th>
<th>Ultimate Tensile Strength (MPa)</th>
<th>Total Elongation (%)</th>
<th>Uniform Elongation (%)</th>
<th>Yield Point Elongation (%)</th>
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<tbody>
<tr>
<td>L</td>
<td>1.23</td>
<td>919</td>
<td>1182</td>
<td>10.6</td>
<td>5.6</td>
<td>0.0</td>
</tr>
<tr>
<td>T</td>
<td>1.24</td>
<td>926</td>
<td>1212</td>
<td>8.8</td>
<td>5.1</td>
<td>0.0</td>
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<tr>
<td>D</td>
<td>1.22</td>
<td>909</td>
<td>1198</td>
<td>10.4</td>
<td>5.4</td>
<td>0.0</td>
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</table>
The volume fraction of martensite was calculated using Image Pro Plus software.

The volume fraction of martensite was found to be approximately 70.2% in the longitudinal section, and 71.1% in the transverse section.
Progressive Die Setup
Progressive Die Setup
Die Wear Experiment in Production Environment

- Over 100k hits; 33 die inserts; Combination of 10 die materials and 9 coatings; 42 ton testing materials
- Preserve one panel every 500 hits
Forming Simulation for Progressive Die Wear Experiment

- **Sliding Energy Density Comparison**
- **Thinning Strain Comparison**
- **Effective Strain Comparison**
2015/2016 Progressive Die Wear Experiment Stamping
No. 1, 2, 8, 10, 11, and 12 were replaced by new inserts after 15,000 hits.

The combinations of 8 die materials and 7 coatings were evaluated up to 20k hits.
2015 Progressive Die Wear Experiment Results
2015 Progressive Die Wear Experiment Results

A1 = 56.46 mm²
A2 = 14.02 mm²
# Die Wear Ranking for 2015 Project

<table>
<thead>
<tr>
<th>Die ID</th>
<th>Die Material</th>
<th>Hardness (Rc)</th>
<th>Coating</th>
<th>SEM Worn Area (mm²)</th>
<th>Visual ranking</th>
<th>Hits to “RR” Both Die Marks are Rough</th>
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<tbody>
<tr>
<td>1</td>
<td>D6510</td>
<td>54-58</td>
<td>PVD Duplex CrN</td>
<td>247</td>
<td>11 (most wear)</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>CC1</td>
<td>38-42</td>
<td>PVD Duplex CrN</td>
<td>286</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>T44</td>
<td>41-47</td>
<td>PVD Duplex CrN</td>
<td>62</td>
<td>4</td>
<td>700</td>
</tr>
<tr>
<td>4</td>
<td>TD2</td>
<td>55-58</td>
<td>PVD Duplex CrN</td>
<td>70</td>
<td>2</td>
<td>5000</td>
</tr>
<tr>
<td>5</td>
<td>TD2</td>
<td>55-57</td>
<td>PVD Duplex CrN</td>
<td>91</td>
<td>5</td>
<td>5000</td>
</tr>
<tr>
<td>6</td>
<td>DC53</td>
<td>55-60</td>
<td>PVD Duplex CrN</td>
<td>46</td>
<td>6</td>
<td>1400</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>TD2</td>
<td>55-60</td>
<td>Concept</td>
<td>87</td>
<td>7</td>
<td>300</td>
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<tr>
<td>9</td>
<td>S2333</td>
<td>40-45</td>
<td>PVD Duplex CrN</td>
<td>71</td>
<td>1 (least wear)</td>
<td>1200</td>
</tr>
<tr>
<td>10</td>
<td>S0050A</td>
<td>54-58</td>
<td>Cr Plate</td>
<td>109</td>
<td>8</td>
<td>35</td>
</tr>
<tr>
<td>11</td>
<td>S0050A</td>
<td>38-42</td>
<td>Cr Plate over Ion Nitride</td>
<td>103</td>
<td>3</td>
<td>35</td>
</tr>
</tbody>
</table>
No. 8 was replaced by No. 14 after 4,000 hits

No. 3 was replaced by No. 13;
No. 5 was replaced by No. 15;
No. 14 was replaced by No. 16;
After 70,000 hits

The combinations of 6 die materials and 6 coatings were evaluated up to 80k hits
2016 Progressive Die Wear Experiment Results
Die Wear Ranking for 2016 Project
Conclusions – Progressive Die Wear Properties on Bare DP1180

• The die wear was evaluated by various combinations of die materials and coatings in 2015 and 2016, up to 100,800 hits for bare DP1180 steel

• The inserts #7 (TD2, Cool Sheet), 9 (Cast Caldie, Concept+Most), 10 (DC53, Concept+Most), and 11 (TD2, Duplex+Variantic) are the potential candidates for stamping 1180 grades steel in mass production
AHSS Hole Punch Force and Edge Cracking

Goals:

- Understand the impact of punch size, shape, clearance tolerances and surface roughness on the punch force and edge cutting quality.
- After samples are collected, edge stretchability and failure criteria will be investigated for FEA relating to cut quality.

Images of punch presses with different hole sizes (10mm, 30mm, 60mm) are shown.
AHSS Hole Punch Force and Edge Cracking

Approach:
1. Hole punch force measurements with the following variables:
   - punch size (10, 30, 60mm)
   - punch shape (flat, conical)
   - clearance tolerances (6, 12, 25%)
   - surface finish (rough, smooth)
2. HER tests will be run using DIC with multiple steels:
   - DQ
   - HSLA
   - AHSS 980
AHSS Hole Punch Force and Edge Cracking

Deliverables:
1. Punch design for making the best quality cut edge
2. Evaluation of edge stretchability and its controlling factors

Status:
1. Hole piercing dies are ready, awaiting 980 and 1180 steel material
2. HER die design complete and currently being built
3. FEA has been performed on HER test

Formability

10 mm diameter (draw 17mm)  30 mm diameter (draw 13mm)  60 mm diameter (draw 15mm)

Thinning
Conclusions

• The automotive industry will continue to be challenged to meet more stringent fuel efficiency and safety regulation
• AHSS offer performance, value and sustainable solutions to meet these challenges
• A/SP stamping tooling optimization team provided tooling material/coating solutions to stamp steels of over 1000 MPa
• A/SP will continue to study other challenges such as Hole Punch Force and Edge Cracking for AHSS
Thank You

Visit: www.a-sp.org

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